# HYDROGEOLOGY, GROUND-WATER AVAILABILITY, AND WATER QUALITY IN THE TITICUS RIVER VALLEY, RIDGEFIELD, CONNECTICUT

By Stephen J. Grady, Martha F. Weaver, and James W. Bingham

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## CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who prefer metric (International System) units rather than the inch-pound units used in this report, the following conversion factors may be used:

| Multiply inch-pound unit | by | To obtain metric unit |
|---|---|---|
| | Length | |
| inch (in.) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | Area | |
| square foot ($ft^2$) | 0.09290 | square meter ($m^2$) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| | Flow | |
| foot per day (ft/d) | 0.3048 | meter per day (m/d) |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second($m^3/s$) |
| gallon per minute (gal/min) | 0.06308 | liter per second (L/s) |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second ($m^3/s$) |
| million gallons per day per square mile [(Mgal/d)/$mi^2$] | 1,460 | cubic meters per day per square kilometer [($m^3$/d)$km^2$] |
| | Hydraulic Units | |
| hydraulic conductivity in foot per day (ft/d) | 0.3048 | hydraulic conductivity in meter per day (m/d) |
| transmissivity in foot squared per day ($ft^2/d$) | 0.09290 | transmissivity in meter squared per day ($m^2/d$) |
| hydraulic gradient in foot per mile (ft/mi) | 0.1894 | hydraulic gradient in meter per kilometer (m/km) |
| inch per year (in./yr) | 25.4 | millimeter per year (mm/yr) |
| | Temperature | |
| degree Fahrenheit (°F) | °C = 5/9 x (°F - 32) | degree Celsius (°C) |

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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## ABSTRACT

Projected needs for additional water supplies, coupled with limited alternative sources, have prompted an evaluation of the availability and quality of water in the stratified-drift aquifer within the Titicus River valley in Ridgefield, Connecticut. Previous studies indicated that this aquifer may be capable of yielding moderate to large quantities of water to wells. Hydrologic data from test drilling, seismic-refraction profiling, streamflow measurements, and water-quality analyses, coupled with ground-water model simulations, indicate that the aquifer is capable of yielding 1 million gallons per day of potable water.

Stratified drift underlies 1.26 square miles of the Titicus River valley, and in places is more than 90 feet thick. Although much of the stratified drift is fine grained, poorly sorted sand and gravel layers are common, and some areas within the valley have dominantly coarse-grained sediments. Transmissivity values estimated from grain-size analyses and logs of test borings range from less than 500 to more than 5,000 feet squared per day.

A mathematical model of drawdowns and yields from hypothetical wells in the most hydrologically favorable locations within the upper and lower sections of the Titicus River valley predicts maximum withdrawal rates of 0.9 and 0.4 million gallons per day, respectively. Estimates of the water available from natural and induced recharge in the upper valley area, based on empirical equations for ground-water outflow and the 30-day, 2-year low flow of streams, indicate that 0.6 million gallons per day could be sustained without causing undesirable hydrologic consequences. The total sustained long-term yield for the complete stratified-drift aquifer in the Titicus River valley is estimated to be 1.0 million gallons per day.

Water quality in the aquifer generally is suitable for human consumption and most other uses, with the exception of locally elevated levels of hardness and manganese, which may limit use. Hardness is attributed to the solution of carbonate minerals in the aquifer and underlying bedrock; manganese probably is derived from decaying vegetation in swamps. Water quality of the Titicus River is similar to that of ground water but contains elevated concentrations of bacteria that are indicative of livestock sources.

# INTRODUCTION

Population growth and industrial development are stressing water resources beyond the current capacity of some existing water-supply systems in Connecticut. This situation is particularly severe in southwestern Connecticut, where rapid population growth has resulted from the area's proximity to the New York metropolitan area, and most surface-water resources have already been developed or are committed to other uses. Additional water supplies will most likely be developed from ground-water sources, because (1) present State policy encourages ground-water development; (2) there are few areas suitable for reservoir development; and (3) reservoir construction costs are high.

Stratified-drift aquifers generally are considered as the ground-water source most capable of providing the large volumes of water needed for public and industrial supplies in Connecticut. A major component of the U.S. Geological Survey's program in the State is to investigate the quantity and quality of water in stratified-drift aquifers that may have the potential as a regional water supply. As an element of this program, information on the hydrogeology, the availability of ground water, and the quality of water in the Titicus River valley was collected and assessed by the U.S. Geological Survey in cooperation with the Town of Ridgefield, Connecticut.

## Purpose and Scope

This report presents the results of a study conducted between July 1983 and September 1985 to estimate the sustained long-term yield of the stratified-drift aquifer in the Titicus River valley and to appraise the quality of water within the aquifer and the Titicus River. This report also describes the hydrogeology of the river-aquifer system and presents estimates of the principal hydraulic properties of the aquifer that determine its water-yielding characteristics. Methods used to estimate the quantity of natural recharge to the aquifer and the potential for induced recharge from the Titicus River, and maximum pumpage from areas of high transmissivity within the aquifer are summarized. The report also includes tables listing the results of physical, chemical, and bacteriological analyses of water from wells and streams within the Titicus River valley.

## Location and Description

Ridgefield, located in southwestern Connecticut, borders New York State and is approximately equidistant from Hartford and New York City. The Titicus River drains an area of 8.6 $mi^2$ (square miles) in the western half of Ridgefield and flows westward out of Connecticut into North Salem, New York, where it is tributary to the Croton River, which is tributary to the Hudson River. The stratified-drift aquifer described in this report extends over an area of 1.26 $mi^2$ in the Titicus River valley within the town of Ridgefield (fig. 1.).

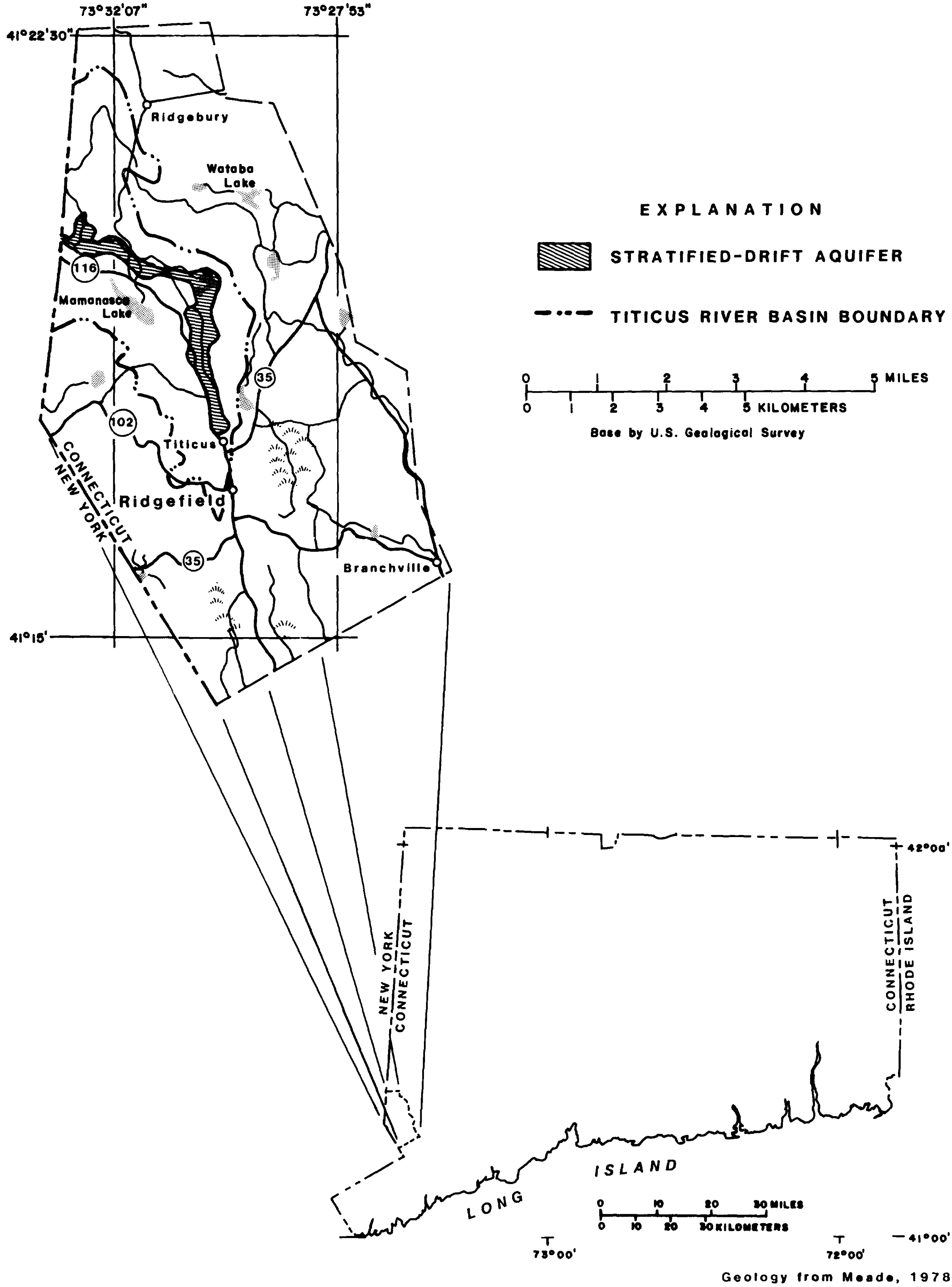


Figure 1.--Location of the Titicus River valley aquifer in Ridgefield, Connecticut.

Moderate to high topographic relief characterizes the study area. The elevation of the land surface along the center of the valley ranges from about 500 ft (feet) above sea level at the New York-Connecticut State line, to about 600 ft at the south end of the valley near the village of Titicus. The tops of hills and ridges bordering the valley are at elevations of from 800 to almost 1,000 ft. Nearly vertical cliffs rise 200 to 300 ft above the valley floor at some places.

The drainage pattern within the Titicus River valley is poorly developed; swamps and wetlands cover approximately half (0.64 $mi^2$) of the aquifer area. Numerous small ponds and flooded pits occur within the valley. Two larger surface-water bodies, 0.06 $mi^2$ Pierrepont Lake (also named Lake Naraneka) and 0.13 $mi^2$ Mamanasco Lake also drain to the Titicus River (plate A). Although Pierrepont Lake is located within the aquifer boundaries, the larger Mamanasco Lake is upstream from the area underlain by stratified drift. The principal tributary of the Titicus River within Connecticut is Mopus Brook, which joins the Titicus approximately 1,500 ft above the State line; it drains an area of 2.66 $mi^2$ in the northwestern corner of Ridgefield.

## Previous Investigations

Information on the regional characteristics of streamflow in western Connecticut, and maps showing the extent and estimated hydraulic properties of the stratified-drift aquifer within the Titicus River valley were provided by an earlier hydrologic study of the upper Housatonic River basin (Cervione and others, 1972). The hydrogeologic data collected for that study, including logs of two wells and seven test holes in the Titicus River valley, were reported by Melvin (1970). On the basis of this information, the State's ground-water availability map (Meade, 1978) indicates that parts of the stratified-drift aquifer in the Titicus River valley are coarse grained and may be capable of yielding moderate to large quantities of water to individual wells. Much of the aquifer, however, was inferred to be fine grained and capable of yielding only small quantities of water.

Although the surficial geology has not been mapped in detail, much information about the bedrock of the area has been provided by Moore (1935), Prucha and others (1968), and, most recently, by Rodgers' (1985) geologic map of Connecticut.

## Methods

The hydrologic characteristics of the stratified-drift aquifer in the Titicus River valley were estimated using: (1) low-flow discharge measurements at 5 sites on the Titicus River and its tributaries; (2) logs of materials penetrated in 7 wells and 6 test holes drilled during the study, and 3 wells and 8 test holes previously drilled; (3) grain-size analyses of 63 subsurface samples collected from 13 wells and test holes; and (4) 6 seismic-refraction profiles. Water quality was assessed from physical, chemical, and bacteriological analyses of seven ground-water and three surface-water samples. Locations of data-collection sites are shown on plate A.

The potential aquifer yield was determined by comparing the maximum estimated well yields from the aquifer with estimates of natural and induced recharge. A mathematical model was used to estimate yields from hypothetical pumping wells within the most transmissive parts of the aquifer. Recharge was estimated using empirical relations developed from other areas in Connecticut.

## Acknowledgments

This investigation was conducted by the U.S. Geological Survey in cooperation with the Town of Ridgefield. The authors appreciate the assistance and information provided by town officials, and are grateful to private citizens and public officials who allowed access to property to collect hydrogeologic data.

# HYDROGEOLOGY

Evaluation of the water resources in the study area requires an understanding of the components of the hydrogeologic system and their interactions. The components of the hydrogeologic system include the Titicus River and its tributaries, the geologic units that underlie the valley, and the water associated with them. These components are related through the hydrologic cycle--the circulation of water from the atmosphere, to the land surface, flowing across the land surface or infiltrating beneath it, and ultimately returning to the atmosphere. The quantity of water entering the subsurface, and the changes that occur in the chemical and physical properties of water as it moves through the geologic units, are of particular interest in this study.

## Description of Hydrogeologic Units

Three principal geologic units underlie the Titicus River valley and adjacent upland areas: crystalline bedrock, till, and stratified drift. The crystalline bedrock underlies the entire area, and is covered by a thin layer of till in most areas. Stratified-drift deposits, present mainly in the valley, overlie till and bedrock. The general spatial relations among these units are shown in figure 2, and their areal distribution is shown on plate A.

### Bedrock

Two types of crystalline bedrock--carbonate and noncarbonate--are found in the study area. The carbonate type is marble, composed predominantly of calcium and magnesium carbonate minerals and formed by metamorphism of carbonate-rich sedimentary rocks (limestone and dolomite). The noncarbonate bedrock is mostly schist and gneiss, composed mainly of silicate minerals and formed by metamorphism of rock types of more diverse origin. Carbonate minerals are dissolved relatively easily by circulating waters, and, consequently, marble is deeply weathered and rarely outcrops. In the Titicus River valley, the eroded marble bedrock underlies the valley floor, whereas the steep cliffs and ridges bordering the valley are formed principally by the more resistant gneiss.

The yield of wells completed in crystalline bedrock aquifers depends on the number, size, and degree of interconnection of the intercepted water-bearing fractures. In turn, the fracture pattern is related to rock type, geologic history, and topography. Regional studies in Connecticut, however, have shown little areal variation in the water-yielding characteristics of the noncarbonate crystalline bedrock aquifers (Randall and others, 1966, p. 63; Cervione and others, 1972, p. 57; Mazzaferro and others, 1979, p. 59; Weiss and others, 1982, p. 47). Wells tapping these aquifers commonly yield from 1 to 25 gal/min (gallons per minute) and primarily supply individual homes and commercial establishments in areas where public-water supplies are

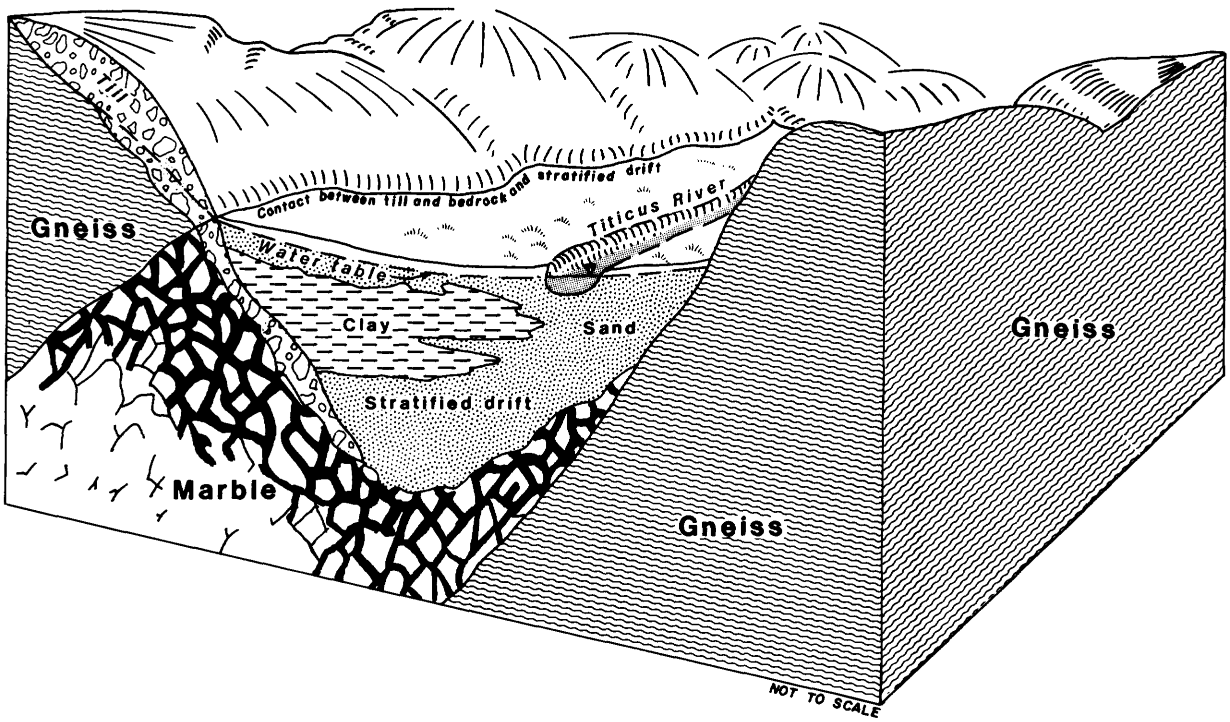


Figure 2.--Idealized spatial relations among stratified drift, till, and bedrock.

not available. Wells tapping the carbonate bedrock aquifers generally yield more water (1 to 50 gal/min) than those in the noncarbonate bedrock, because dissolution of carbonate minerals by circulating ground water enhances the permeability of the aquifer. In some places in western Connecticut, individual wells in the carbonate bedrock aquifer yield as much as 200 gal/min (Ryder and others, 1970, p. 26).

## Till

A thin and locally discontinuous layer of till mantles the bedrock in most places within Connecticut. Till is a heterogeneous, unstratified mixture of clay- to boulder-sized sediment that was deposited by one or more of the continental glaciers that covered New England during the late Pleistocene Epoch. Because it is compact, hard, and commonly contains large cobbles and boulders, till is commonly referred to as "hard pan" by well drillers. The till layer generally ranges from 5 to 25 ft in thickness; however, as much as 145 ft of till has been reported at some places in southwestern Connecticut (Ryder and others, 1970, p. 21). The hydraulic conductivity of till is low, and the saturated section in generally thin; therefore, the yields of wells in till tend to be small.

## Stratified Drift

Stratified-drift aquifers, composed of interbedded layers of sand, gravel, silt, and clay deposited during the deglaciation of southern New England, are the most productive aquifers. These deposits are principally confined to the valleys that were drainageways for the glacial meltwater streams. The coarser-grained sediments were deposited in fluvial or lacustrine environments near the active ice margin, while finer-grained sediments accumulated in more distant lakes that formed behind blocked drainageways. Stratified drift, however, is commonly highly variable in texture, both areally and with depth.

Where the stratified drift is well sorted and coarse grained, it has excellent water-yielding characteristics. Wells tapping coarse-grained stratified-drift aquifers, particularly where their saturated thickness exceeds 40 ft and they are hydraulically connected to adjacent large streams, commonly yield from 50 to 500 gal/min. These aquifers, therefore, have the greatest potential for supplying the large quantities of water required for public supply and industrial uses.

## Hydrologic Cycle

The hydrologic cycle can be described by a water budget in which the amount of water entering the basin will equal the amount leaving the basin plus or minus any changes in the amount stored over a given period of time. Precipitation is the source of all water stored in and moving through streams, lakes, and aquifers in the Titicus River basin. Nearly half of the water that enters the basin from precipitation exits as runoff in streams. Runoff includes the amount of water that flows over the land surface, as well as that which infiltrates and subsequently discharges into streams that drain the basin. Slightly more than half of the precipitation falling on the basin returns to the atmosphere by evaporation directly from surface-water bodies and from ground water where the water table is shallow (less than about 8 ft below the land surface) and through the transpiration of plants. Over long periods of time, the amount of water stored in aquifers and surface-water bodies remains substantially unchanged. Figure 3 shows the average annual amounts of water entering and leaving the Titicus River basin during the 1949-84 period.

### Precipitation and Evapotranspiration

Southwestern Connecticut lies within the northern temperate climate zone. The prevailing west-to-east movement of air transports the majority of weather systems into this part of Connecticut from the interior of the continent. The most common weather systems are cool, dry, continental air masses and migratory storms, but this area also experiences the periodic moderating effects of maritime air masses. Precipitation is evenly distributed throughout the year (fig. 4) and averages about 4 in. (inches) per month. Between 1949 and 1984, annual precipitation at the National Weather Service station at Round Pond in Ridgefield averaged 49.8 in. (fig. 5) and ranged from 32.2 in. (1965) to 73.76 in. (1984). Figure 5 also shows the cumulative departure from mean annual precipitation--that is, the cumulative excesses and deficiencies of precipitation during this period. The graph depicts the wetter-than-normal periods of 1951-55 and 1972-79, and the drier-than-normal period of 1960-71.

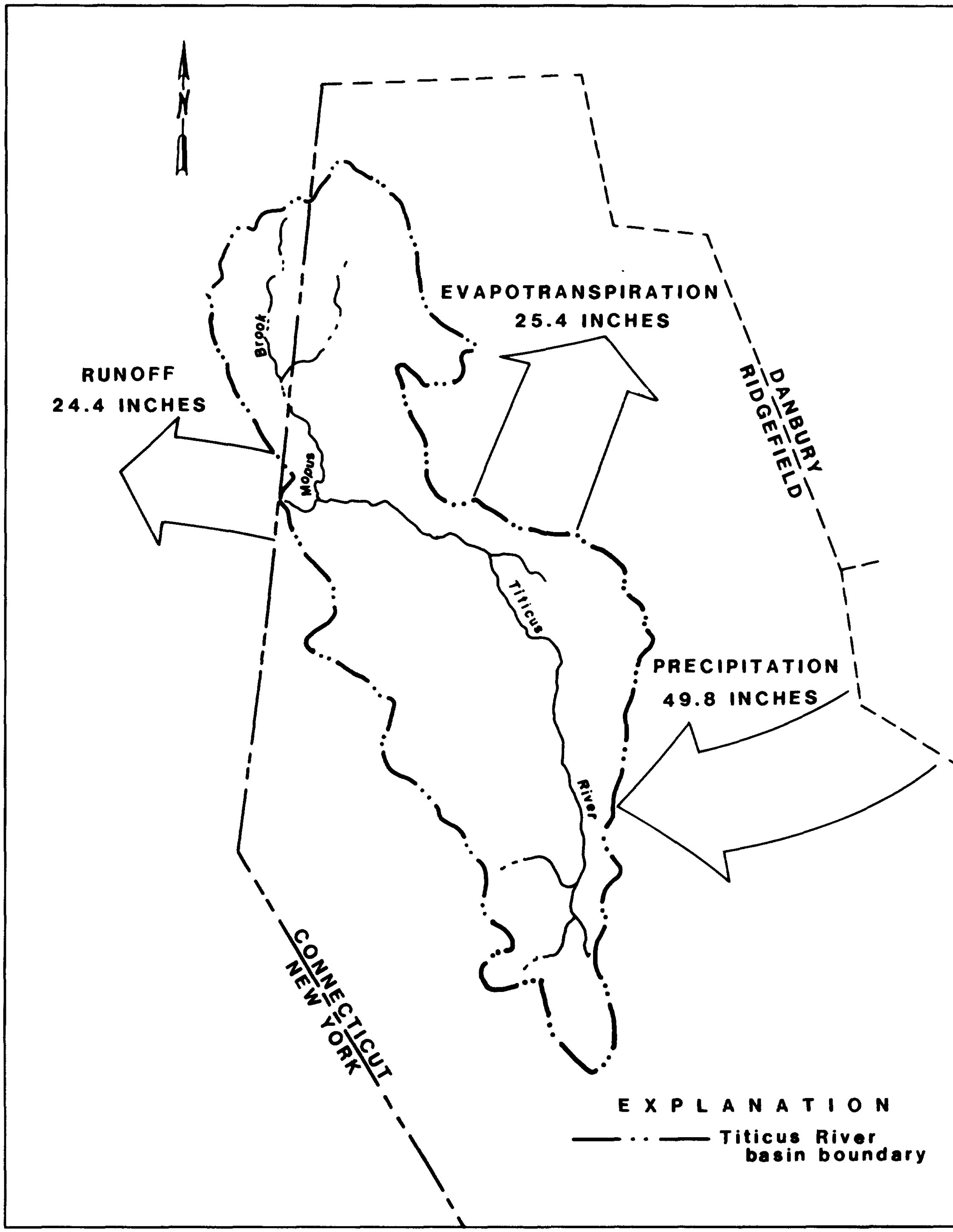


Figure 3.--Average rates of precipitation, evapotranspiration, and runoff in the Titicus River basin, 1949-84.

A large part of the water that falls on the basin returns to the atmosphere by means of (1) direct evaporation from water surfaces and moist soils, and (2) transpiration from vegetation. Evapotranspiration (the combination of both processes) occurs throughout the year but is much greater during summer months when the air temperature and duration of daylight increase (Thornthwaite, 1952, p. 382). Although difficult to measure directly, evapotranspiration can be estimated based on water-budget calculations. For the upper Housatonic River basin, Cervione and others (1972, p. 7) estimate that the average annual evapotranspiration is approximately 22 in., or nearly half of the average annual precipitation. Values ranging from 21 to 25 in. have been obtained in other studies for adjacent parts of Connecticut (Meinzer and Stearns, 1929, p. 138; Ryder and others, 1970, p. 6; Mazzaferro and others, 1979, p. 6; Mazzaferro, 1986, p. 7). For the Titicus River basin, average annual evapotranspiration is estimated to be 25.4 in., and is equal to the mean annual precipitation (49.8 in.) minus the estimated mean annual runoff (24.4 in.).

## Streamflow

Streamflow, at various times of the year, consists of surface-water runoff, ground-water runoff, or a combination of both. Surface runoff is that part of the precipitation that falls on and flows across the land surface into streams, lakes, and wetlands. During most of the year, surface runoff is the largest component of streamflow. Streamflow is sustained between storms or periods of snowmelt by ground-water runoff--water derived from precipitation that infiltrates the ground, percolates through the unsaturated zone to the water table, and subsequently discharges to streams, lakes, and wetlands.

The amount of streamflow passing any point on a stream varies continuously. For a specific place and time, the streamflow depends upon precipitation, evapotranspiration, surface-water and ground-water storage, the size, geology, and topography of the upstream drainage area, and the influence of manmade changes to the drainage basin.

Although the flow of the Titicus River has not been gaged, its average flow can be estimated from information on the areal distribution of average streamflow in the upper Housatonic River basin (Cervione and others, 1972). Based on streamflow records at gaged sites within this basin for a standard 30-year reference period (October 1, 1930 through September 30, 1960), Cervione and others (1972, p. 14) have mapped the areal distribution of mean annual streamflow. The average streamflow contours mapped by Cervione and others (1972, p. 14) express the ratio of mean annual streamflow to the approximate statewide mean of 1.16 (Mgal/d)/mi$^2$ (million gallons per day per square mile) [1.80 (ft$^3$/s)/mi$^2$ (cubic feet per second per square mile)]. Estimates of the average streamflow for any ungaged site can be obtained by locating the site on the map and interpolating between contours. Because the 1.0-(Mgal/d)/mi$^2$ contour transects the Titicus River basin, it is estimated that mean annual streamflow from the Titicus River basin approximately equals the statewide average of 1.16 (Mgal/d)/mi$^2$, which is equivalent to 24.4 in. of runoff. Average annual precipitation for the 1930-60 reference period (Cervione, 1982, p. 6) is approximately equal to the average annual precipitation for the 1949-84 period used for this study. Therefore, no adjustment to mean annual streamflow is necessary.

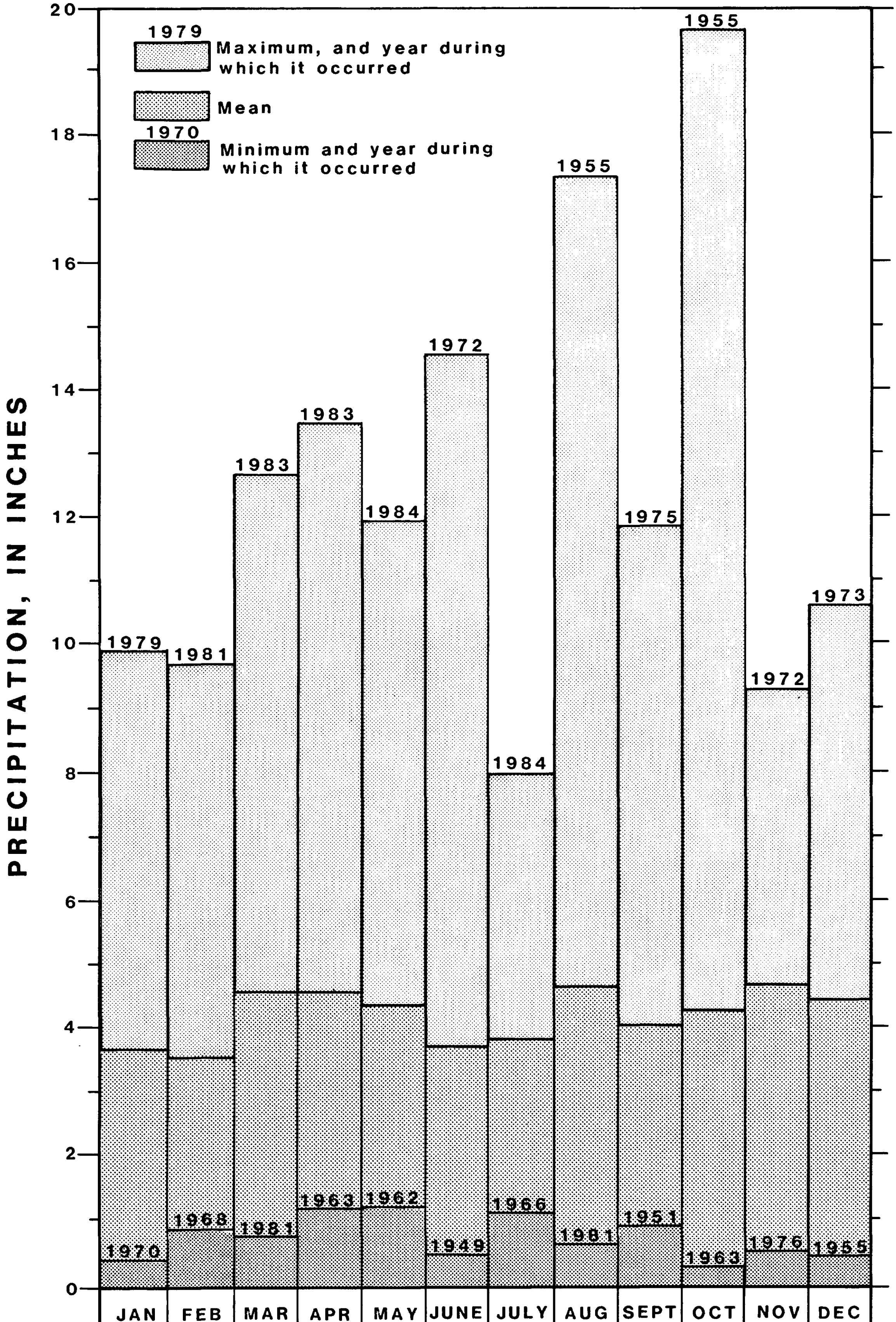


Figure 4.--Range of monthly precipitation at the National Weather Service station at Round Pond near Ridgefield, Connecticut, 1949-84.

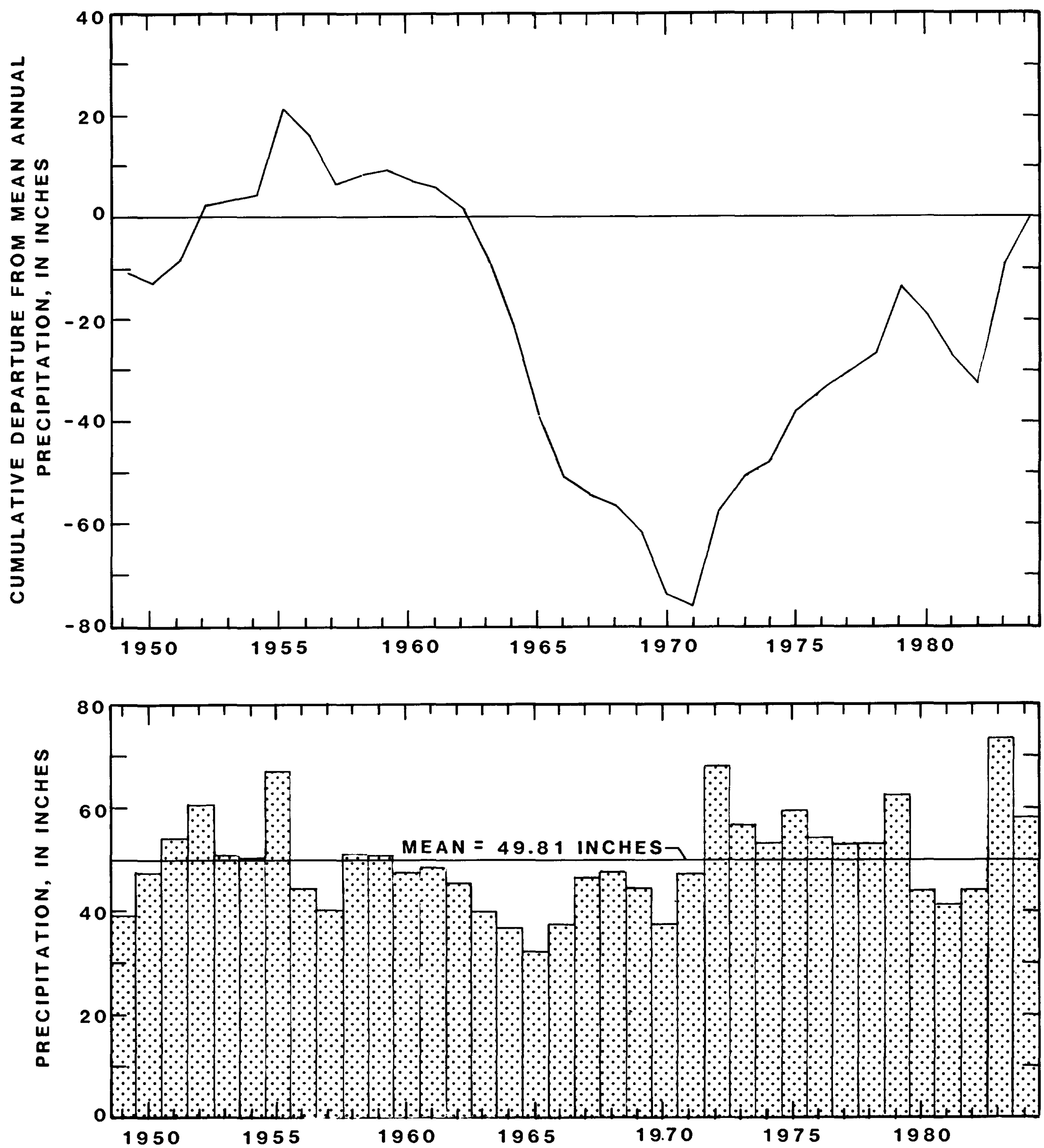


Figure 5.--Annual precipitation and cumulative departure from mean annual precipitation at the National Weather Service station at Round Pond near Ridgefield, Connecticut, 1949-84.

The average streamflow is a useful index of the quantity of runoff that can be expected to occur over the long term. For planning ground-water supplies, information also is needed on the magnitude and frequency of low flows during dry periods when streamflow is derived predominantly from ground-water runoff. Low flows at ungaged sites can be estimated from regional flow-duration curves, such as those developed by Thomas (1966).

### Flow duration

A flow-duration curve is commonly used to describe the variability of streamflow at a site. It shows the percentage of time that any given daily mean flow is equaled or exceeded. Thomas (1966) determined that the flow-duration curve for streams in Connecticut depends on the surficial geology of the drainage basin. In general, the slope of the flow-duration curves for unregulated streams draining nonurbanized basins decreases as the percentage of upstream drainage area underlain by stratified drift increases.

Regional flow-duration curves for streams in the upper Housatonic River basin have been prepared by Cervione and others (1972, p. 15) based on analysis of streamflow records, and drainage-area characteristics for gaged sites in the basin. The flow-duration curve for any unregulated stream at an ungaged site in the basin can be constructed using these regional curves once the total upstream area, the percentage of that area underlain by stratified drift, and the average streamflow have been determined.

Figure 6 shows the flow-duration curve for the Titicus River at the New York-Connecticut State line and the probable maximum and minimum limits of duration for the wettest and driest years. The area drained by the Titicus River upstream from this site is 8.6 $mi^2$, of which 1.26 $mi^2$ (14.6 percent) is underlain by stratified drift. Mean annual streamflow for this location, is interpolated from figure 17 of Connecticut Water Resources Bulletin 21 (Cervione and others, 1972, p. 14), to be 1.15 $(Mgal/d)/mi^2$. Figure 6 indicates that the estimated 90-percent duration flow of the Titicus River at this site ranged from 0.44 Mgal/d during the driest year to about 4 Mgal/d during the wettest year, and averaged 1.2 Mgal/d.

Streamflow values estimated by the regionalization techniques have large standard errors of estimate (or the standard deviation of plotted points about the regression line), particularly for small discharges. The standard error is lowest--about 6 percent--for flows equaled or exceeded 1 to 5 percent of the time, but is much larger--25 to 36 percent--for the low-flow values in the 90- to 99.9-percent duration range (Cervione and others, 1972, p. 11). The standard error of estimate for points on the flow-duration curve for the Titicus River is shown in figure 6. Discharge measurements were made near this site (station 01374770) as well as other selected sites in the Titicus River valley (shown on plate A) on August 30, 1983 to check the reliability of low-flow values obtained from the flow-duration curve (table 1). The measured discharge for the Titicus River near the New York-Connecticut State line was compared with the observed daily mean flow for a continuously gaged stream with similar hydrologic conditions--the Saugatuck River near Redding, Connecticut (station 01208990). Flows at both sites were at the 97-percent duration value, which indicates that the flow-duration curve for the Titicus River developed by regionalization methods provides fairly accurate estimates of low flows.

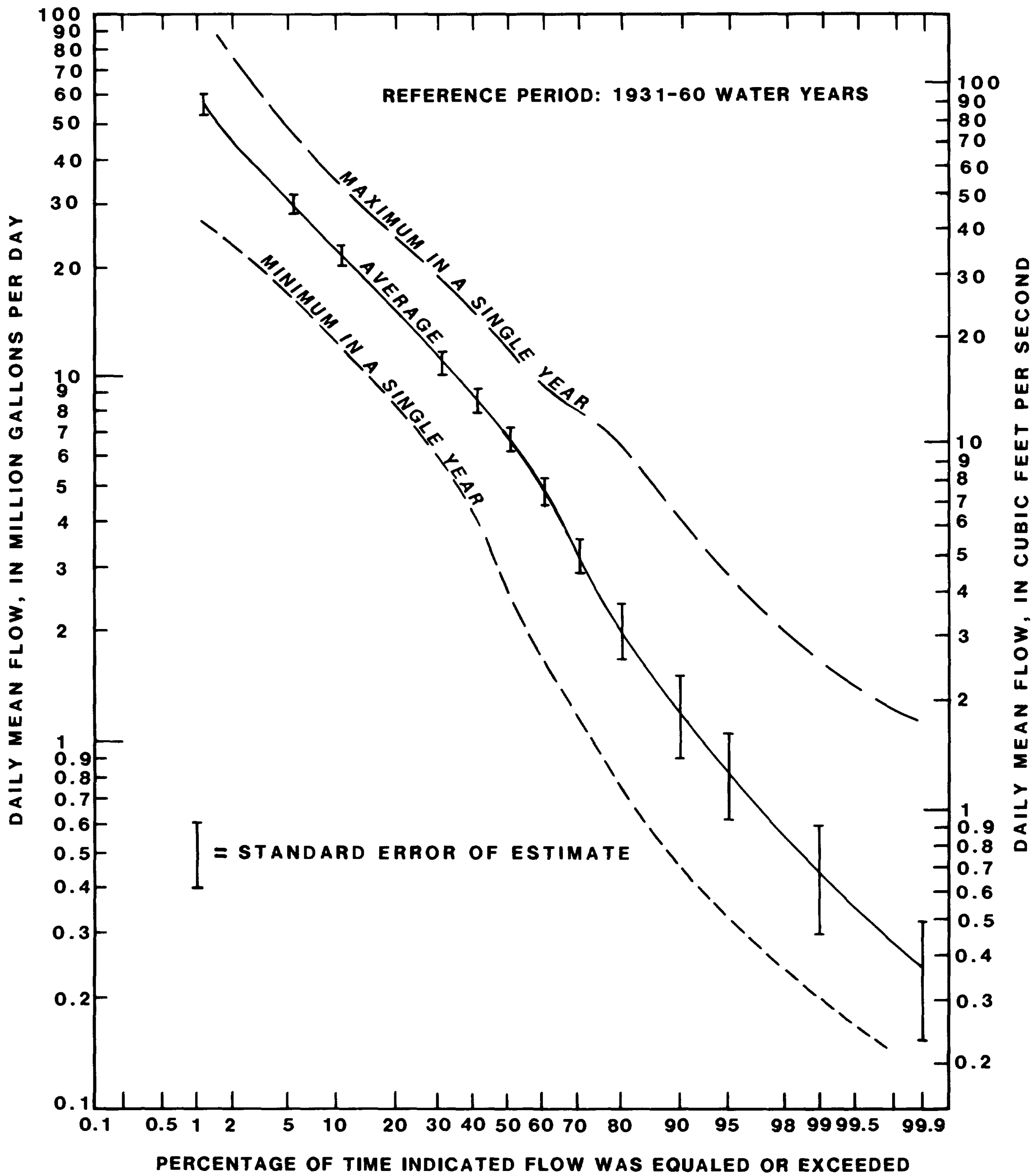


Figure 6.--Flow-duration curve for the Titicus River at the New York-Connecticut State line estimated by regionalization methods.

Table 1.--Low-flow measurements at miscellaneous sites in the Titicus River valley on August 30, 1983

| Station number (Plate A) | Discharge (cubic feet per second) | Discharge (million gallons per day) |
|---|---|---|
| 01374720 | 0.29 | 0.19 |
| 01374730 | .05 | .03 |
| 01374750 | .19 | .12 |
| 01374765 | .20 | .13 |
| 01374770 | .94 | .61 |

## Frequency of low flows

In planning the development and management of water resources, it may also be necessary to know how often specified streamflows are expected to recur and how long they are expected to last. The lower part of flow-duration curves indicate the minimum amounts of streamflow available for certain percentages of time. Therefore, once flow-duration values are determined at an ungaged site, they can be readily transformed into low-flow-frequency values.

Recurrence intervals of annual lowest mean daily flows for selected periods of consecutive days at long-term, continuous-record gaging stations in the upper Housatonic River basin have been determined by Cervione and others (1972, p. 16-17). Flows for similar consecutive-day periods and recurrence intervals for the Titicus River can be determined by comparing its flow-duration curve (fig. 6) to the values obtained for the upper Housatonic River basin. For example, Cervione and others (1972, p. 17) have found that the lowest mean daily flow for 30 consecutive days with an average recurrence interval of 2 years is equivalent to the flow equaled or exceeded 90 percent of the time. The flow equaled or exceeded 90 percent of the time for the Titicus River at the New York-Connecticut State line is 1.2 Mgal/d (fig. 6). Table 2 includes the estimated lowest mean daily flows for the Titicus River that will occur for time periods of 3 to 183 consecutive days at recurrence intervals of from 2 to 20 years.

Table 2.--Estimated lowest mean daily flows for the Titicus River at the New York-Connecticut State line

[in million gallons per day]

| Recurrence interval, in years | Lowest mean daily flow for indicated number of consecutive days: 3 | 7 | 30 | 60 | 120 | 183 |
|---|---|---|---|---|---|---|
| 2 | 0.65 | 0.83 | 1.2 | 1.6 | 2.5 | 4.0 |
| 3 | .55 | .65 | .90 | 1.2 | 1.9 | 2.8 |
| 5 | .40 | .55 | .74 | .89 | 1.4 | 2.2 |
| 10 | .30 | .40 | .55 | .74 | 1.0 | 1.6 |
| 20 | .28 | .33 | .44 | .55 | .83 | 1.3 |

## Ground-Water Movement and Storage

Movement of ground water principally depends on the number and size of open spaces or pores in the soil or rock (referred to as its porosity), the continuity of the pore spaces, and the pressure or head of water within the flow system. In stratified-drift aquifers, storage and transmissivity are largely determined by the size, shape, and degree of sorting of the sediment particles.

The head in a ground-water-flow system is a measure of the potential energy of the fluid, and ground water flows in the direction of decreasing head. In an unconfined aquifer such as the stratified-drift aquifer in the Titicus River valley, gravity is the dominant force driving the movement of ground water and head is equivalent to the altitude of the water table. Under natural conditions, ground water flows from upland areas where the altitude of the water table is high, toward lower altitudes, generally in adjacent valleys. The configuration of the water table, therefore, commonly is a subdued reflection of the topography.

The ground-water flow system under natural conditions is in a state of dynamic equilibrium, with water continuously entering and exiting the system. Water enters through natural recharge and exits by underflow, ground-water runoff to rivers, streams, lakes, ponds, and swamps, and by ground-water evapotranspiration. Changes in the amount of water stored in an unconfined aquifer, indicated by the rise and fall of the water table, are controlled by the recharge and discharge rates of the system so that the system remains in balance.

Although precipitation in the study area is generally evenly distributed throughout the year (fig. 3), recharge is greatly reduced during the growing season when higher temperatures and longer days promote plant growth and evapotranspiration is greatest. Thus, most natural recharge occurs during the nongrowing season of approximately 180 to 190 days from October through April. Because ground-water discharge occurs throughout the year, there is a cyclic pattern to the annual changes in ground-water storage. The water table falls during the growing season as ground-water discharge exceeds recharge and storage is decreased, and rises during the winter and early spring months when ground-water recharge exceeds discharge and storage is replenished. The hydrograph of a long-term observation well (NT 15) that taps a stratified-drift aquifer in nearby Newtown, Connecticut (fig. 7) illustrates this annual cycle. Variations in the amount of recharge received in drier-than-normal (1981) and wetter-than-normal (1983) years are reflected in the hydrograph by fluctuations in water levels.

Changes in the magnitude of one or more of the components of the ground-water flow system will drive the system toward a new equilibrium condition with corresponding changes in the other components. For example, a natural phenomenon, such as a prolonged drought, will reduce recharge and lead to a decrease in ground-water discharge and a decrease in storage. Human-induced stresses on the system, such as pumping, will have similar results. Aquifers that are hydraulically connected to streams and lakes have the potential for increased recharge. Pumping from wells located near surface-water bodies lowers the water table to a level below the adjacent river or lake, causing water to flow from the surface-water body into the aquifer, a process termed induced infiltration. Detrimental effects, however, may occur if large volumes of surface water are induced into the aquifer. These include degradation of the ground-water quality and decreased streamflow, which in the case of small- to moderate-sized streams, may cause sections of the stream to dry up during low-flow conditions.

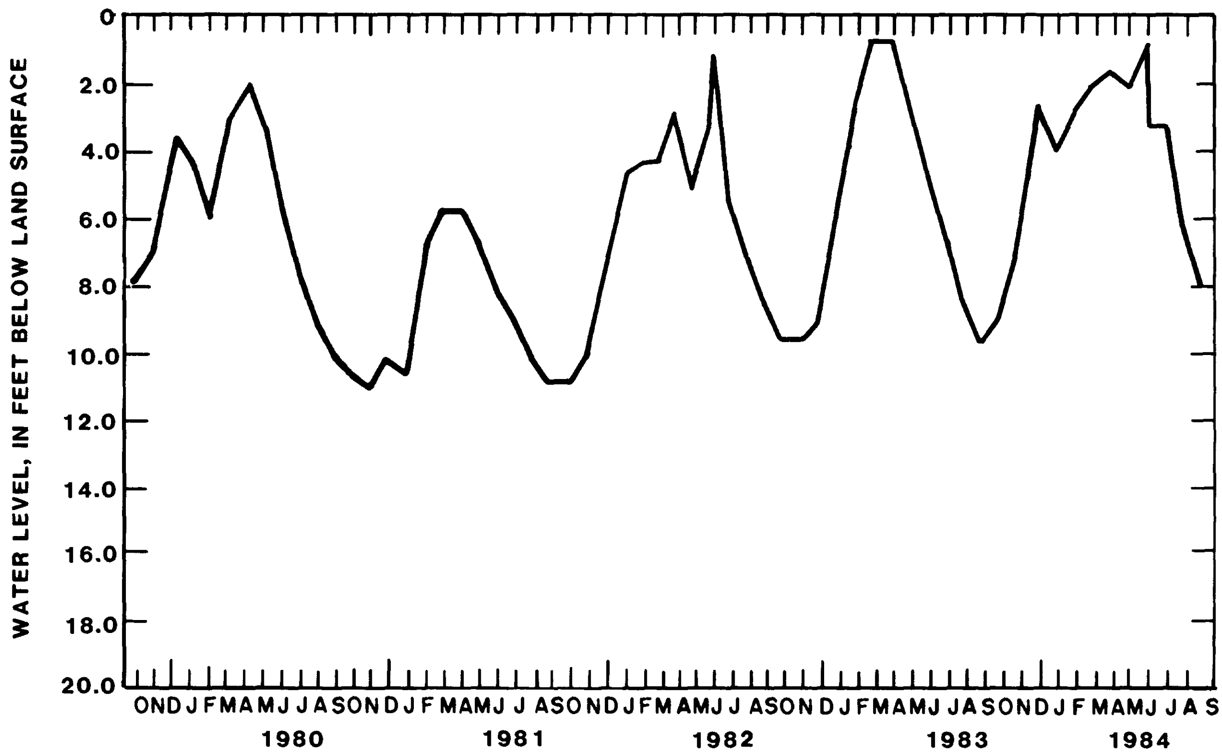


Figure 7.--Water levels at observation well NT 15.

## Aquifer Characteristics

Saturated thickness, transmissivity, and specific yield are the hydraulic properties that largely determine the ability of the stratified-drift aquifer to store and transmit water. Hydraulic boundaries limit the continuity of the aquifer, thereby affecting water-level changes in time and space that occur as a consequence of aquifer development. The quantity of water that may be withdrawn from the stratified-drift aquifer was determined in this study using estimates of these hydraulic properties and assumptions regarding the location and type of hydraulic boundaries.

### Saturated Thickness

The saturated thickness of an unconfined aquifer is the vertical distance from the water table to the base of the aquifer. It is an important characteristic in determining the amount of available drawdown and, therefore, in estimating potential well yields. Generally, a saturated thickness of 40 ft or more is needed to provide large sustained yields from conventional drilled wells, however some wells, such as Ranney collectors or large-diameter caisson wells, can provide large yields in relatively thin aquifers.

For this study, the saturated thickness was determined from the logs of wells and test holes (see table 8 at the back of this report), and from the seismic-refraction profiles shown in figure 8. Seismic-refraction surveys are an effective and widely used geophysical method to assess the hydrogeologic framework where seismic velocity discontinuities between hydrologic units are present (Haeni, 1988). Seismic-refraction profiles are interpretations of field data based on techniques described by Scott and others (1972). Haeni (1988, p. 23) reports that seismically determined depths to the water table generally agree within a few feet to depths determined by drilling.

The saturated thickness of the stratified drift in the Titicus River valley is shown on plate B. Although the stratified drift extends the entire length of the valley, it is very thin and narrow between Ridgebury Mountain and Round Mountain. For practical purposes, there is no hydraulic connection between the more extensive stratified-drift deposits in the upper part of the valley (south of Pierrepont Lake) and those in the lower part between Washington Highway and the New York-Connecticut State line. Therefore, in this report, the stratified drift is differentiated into two aquifer units, termed the upper and the lower valley aquifers.

The saturated thickness of the stratified drift exceeds 80 ft in the center of the upper valley aquifer, as shown on plate B. Seismic-refraction profile F-F' indicates that the saturated thickness is approximately 95 ft at the deepest part of the valley, and 91 ft of saturated stratified drift was penetrated at test hole R 32th (table 8). Much of the upper valley aquifer is greater than 40 ft thick, whereas only a relatively small part of the lower valley aquifer is as thick. The greatest saturated thickness observed in the lower valley is approximately 65 ft at places along seismic-refraction profile C-C' (fig. 8).

## Transmissivity

Transmissivity is the property that largely controls the rate at which water moves through the aquifer. It is defined as the volume of water at the prevailing viscosity that will flow through a unit width of the aquifer under a unit hydraulic gradient during a given time. It is equal to the average hydraulic conductivity (a measure of the rate at which water moves through a unit cross-sectional area of the aquifer) times the saturated thickness, and is expressed in $ft^2/d$ (feet squared per day). For this study, transmissivity has been estimated from the logs of wells and test holes, grain-size analyses of sediment samples, and information on the saturated thickness.

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 relation between the median grain size and the degree of 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, p. 51; Thomas, M.P. and others, 1967, p. 54; Thomas, C.E. and others, 1968, p. 50; Ryder and others, 1970, p. 20; Mazzaferro and others, 1979, p. 42). This relation between grain size and hydraulic conductivity is shown in figure 9.

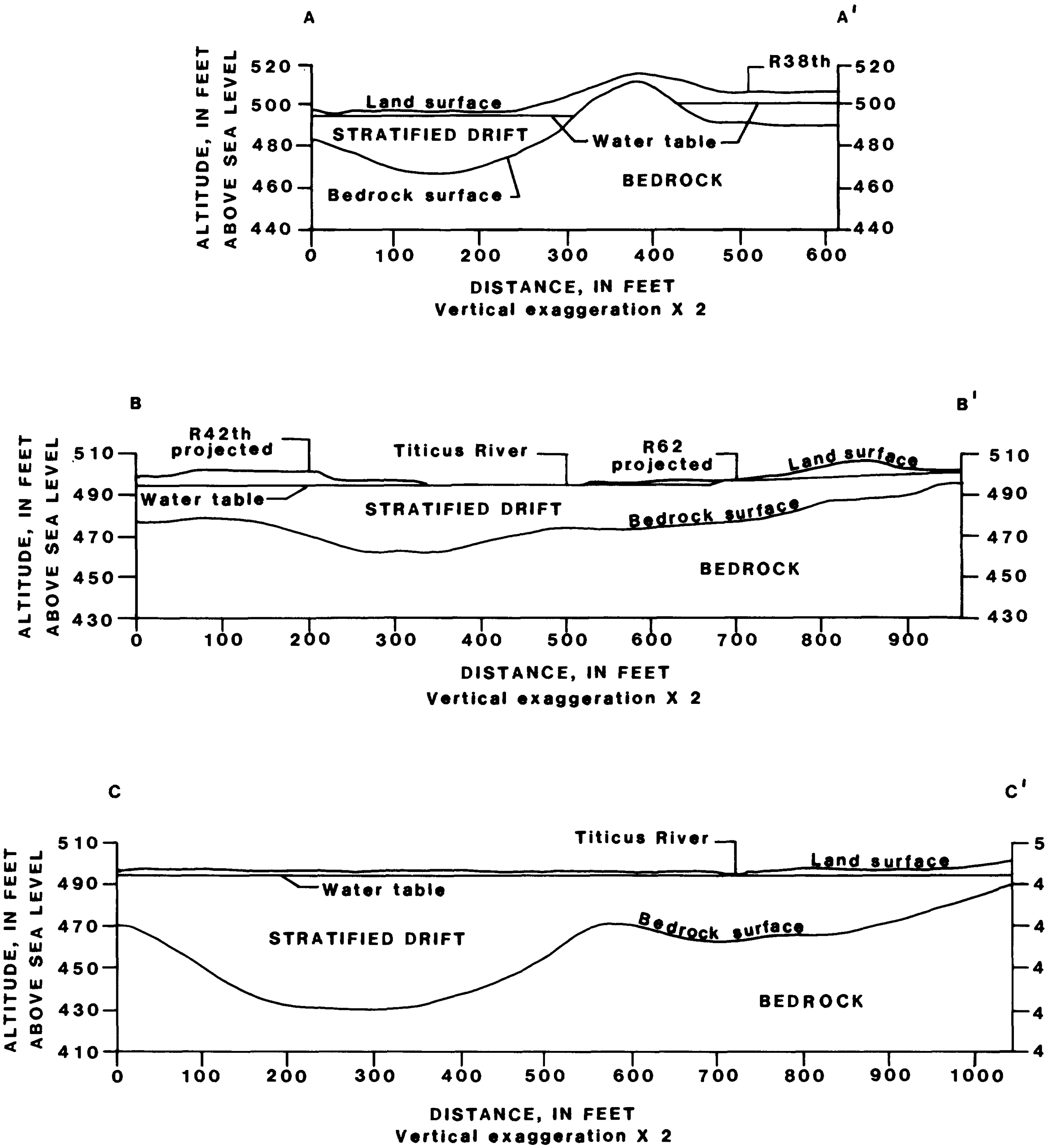


Figure 8.--Seismic-refraction profiles of the Titicus River valley. (Locations of profile lines are shown on plate A; profiles are interpretations of field data based on methods described by Scott and others, 1972.)

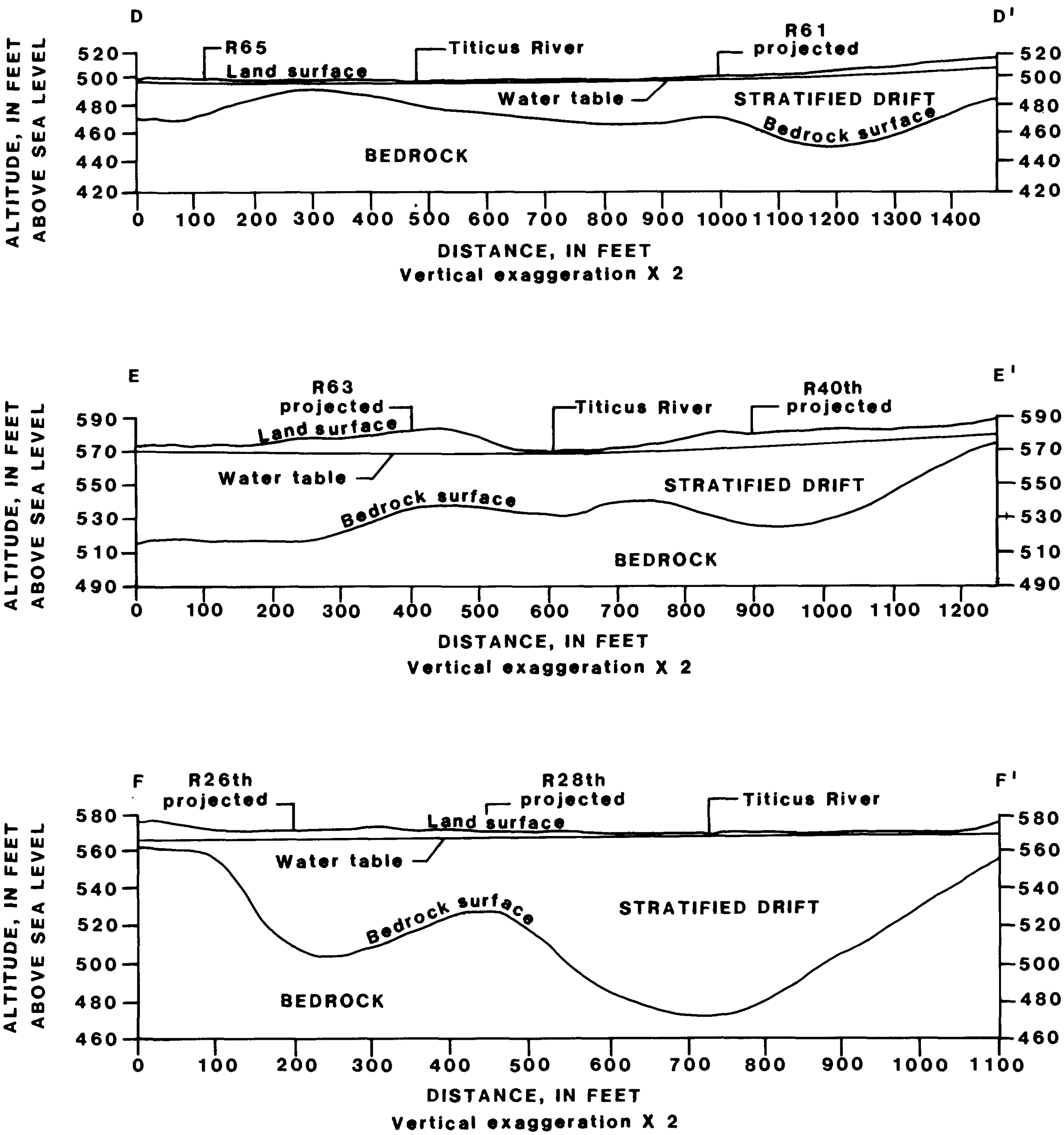


Figure 8.--Seismic-refraction profiles of the Titicus River valley--continued. (Locations of profile lines are shown on plate A; profiles are interpretations of field data based on methods described by Scott and others, 1972.)

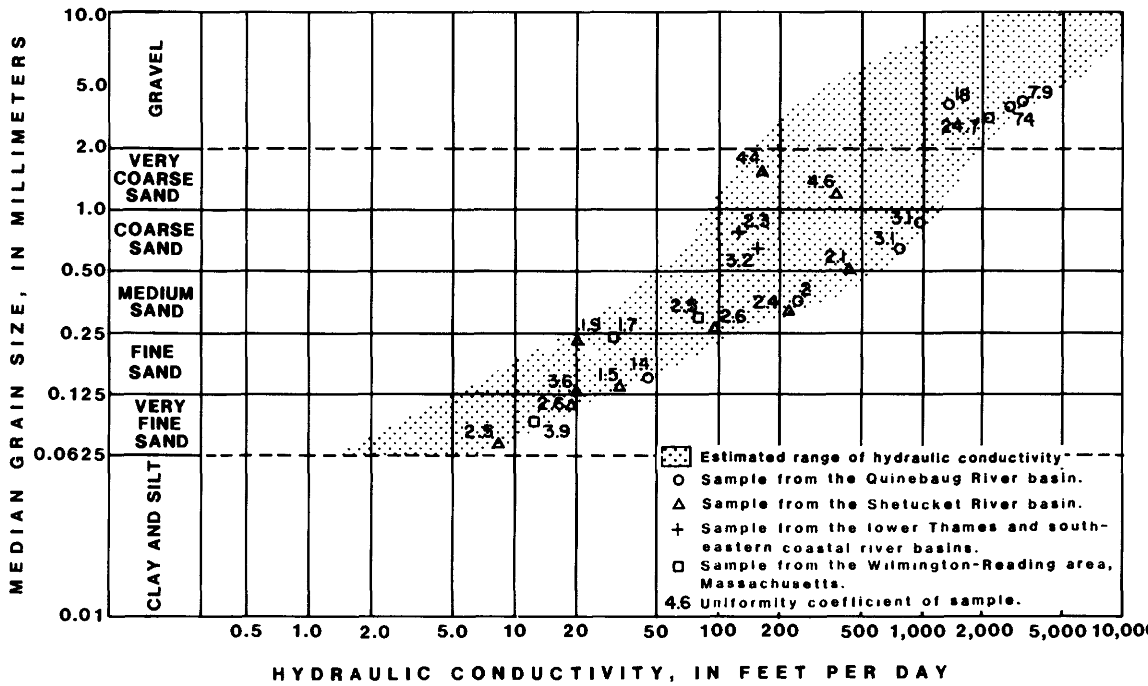


Figure 9.--Relation between hydraulic conductivity of stratified drift in southern New England and median grain size and sorting. (Fields of hydraulic conductivity shown are based on laboratory-determined hydraulic conductivities of undisturbed, horizontally oriented samples from eastern Connecticut and eastern Massachusetts. The range in hydraulic conductivity for a given median grain size results from differences in sorting, packing, and grain shape. Relation is inadequately defined for clay, silt, and gravel.) (From Mazzaferro and others, 1979, p. 42.)

Horizontal hydraulic conductivities are assigned to each lithologic unit described in the drillers' and (or) geologists' logs of wells and test holes in the study area. In most cases, the assigned hydraulic conductivities are estimated from the material's description and (or) grain-size characteristics as determined from analyses of sediment samples (see table 9 at the back of this report) using the graph in figure 9. For logs where the descriptive terms do not allow a reliable estimate of grain-size characteristics, estimates of hydraulic conductivity are based on a catalog of drillers' terms and corresponding approximate hydraulic conductivities developed in previous studies (table 3). The values estimated by these methods are subjective and their accuracy depends largely on the detail and reliability of the log. However, evaluation of estimates of hydraulic conductivity based on logs of wells and test holes from areas where hydrologic information is reliable indicates generally good agreement with values derived by more quantitative techniques (Weiss and others, 1982, p. 30-31).

A transmissivity is similarly obtained for each lithologic unit identified in the well and test-hole logs. A unit's transmissivity is equal to its horizontal hydraulic conductivity (as determined above) multiplied by its saturated thickness--the sum of the values for all units is the transmissivity of the aquifer at that site. An example of how transmissivities are estimated from the logs and grain-size information is shown in table 4. Transmissivities computed in this manner are approximate and are generally less accurate than those determined by aquifer tests. However, they provide the only source of information on the transmissivity of stratified drift in the study area.

Transmissivity of the stratified-drift aquifer in the Titicus River valley (plate C) is based on values computed for well and test-hole sites and interpolation between those sites using available information on saturated thickness. Values range from less than 500 $ft^2/d$ where the saturated stratified drift is thin and predominantly fine grained, to more than 5,000 $ft^2/d$ in thick, coarse-grained parts of the aquifer. Transmissivity exceeds 5,000 $ft^2/d$ at well R 61 that penetrates approximately 50 ft of relatively coarse-grained sediments, and at test hole R 31th that penetrates a similar coarse-grained section. Although layers of poorly sorted sand and gravel were observed in many of the test borings (see tables 8 and 9), much of the stratified drift is fine grained with appreciable quantities of silt and clay. Therefore, the transmissivity of much of the aquifer is less than 1,000 $ft^2/d$.

Table 3.--Hydraulic-conductivity values assigned to drillers' terms for stratified-drift units

[From Weiss and others, 1982, p. 33]

| Drillers' term | Hydraulic conductivity (feet per day) |
|---|---|
| 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 |

Table 4.--Example of estimating transmissivity from logs of wells and test holes, and grain-size analyses

[Well R 61. Drilled with power auger by U.S. Geological Survey, 1983; Depth to water, 5 feet below land surface; --, not applicable; ft, feet; mm, millimeters]

| Materials description | Depth below land surface (feet) | Saturated thickness (b) (feet) | Assigned hydraulic conductivity (K) (feet per day) | Estimated transmissivity [T=(K)x(b)] (feet squared per day) |
|---|---|---|---|---|
| Soil, loam | 0 - 3 | 0 | -- | -- |
| Gravel, pebble, and very fine to very coarse sand; little silt 1/ | 3 - 8 | 3 | 80 | 240 |
| Sand, fine to very coarse; clean 2/ | 8 - 16 | 8 | 40 | 320 |
| Sand, fine to very coarse; and granule gravel; trace silt to very fine sand 3/ | 16 - 21 | 5 | 80 | 400 |
| Sand, fine to coarse; little very coarse sand and granule gravel; trace silt to very fine sand 4/ | 21 - 25 | 4 | 30 | 120 |
| Sand, medium to very coarse; some granule to pebble gravel; little fine sand; trace silt to very fine sand 5/ | 25 - 36 | 11 | 80 | 880 |
| Sand, fine to very coarse; trace granule gravel; thin layers of very fine to medium sand 6/ | 36 - 47 | 11 | 50 | 550 |
| Gravel, granule to pebble; some very fine to very coarse sand; trace silt to very fine sand 7/ | 47 - 52 | 5 | 700 | 3,500 |
| Refusal (marble bedrock) | at 52 | -- | -- | -- |
| Estimated transmissivity of the saturated stratified-drift section: | | 6,010 | | |

1/ Split-spoon sample, 6-7 ft
Median grain size, 0.94 mm
Uniformity coefficient, 38.3

2/ Split-spoon sample, 12-14 ft
Median grain size, 0.43 mm
Uniformity coefficient, 4.4

3/ Split-spoon sample, 17-19 ft
Median grain size, 0.84 mm
Uniformity coefficient, 14.6

4/ Split-spoon sample, 22-23 ft
Median grain size, 0.38 mm
Uniformity coefficient, 8.1

5/ Split-spoon sample, 27-29 ft
Median grain size, 0.77 mm
Uniformity coefficient, 7.5
Split-spoon sample, 32-34 ft
Median grain size, 0.79 mm
Uniformity coefficient, 14.2

6/ Split-spoon sample, 37-39 ft
Median grain size, 0.28 mm
Uniformity coefficient, 5.1
Split-spoon sample, 42-44 ft
Median grain size, 0.69 mm
Uniformity coefficient, 16.0

7/ Split-spoon sample, 47-49 ft
Median grain size, 4.2 mm
Uniformity coefficient, 49.2

## Specific Yield

Specific yield is a measure of the ability of an unconfined aquifer to store water. It is defined as the ratio of the volume of water the saturated material will yield by gravity drainage of the interconnected pore spaces to the total volume of aquifer material. Specific yield depends on the aquifer's grain-size characteristics and the length of time it is allowed to drain (Johnson, 1967). The amount of water that can be withdrawn from an aquifer is only a fraction of the total storage. For stratified-drift aquifers in Connecticut, specific yields ranging from 0.1 to 0.4 have previously been applied (Ryder and others, 1970, p. 17; Cervione and others, 1972, p. 45-46; Mazzaferro and others, 1979, p. 40-41). For this study, a value of 0.2 was considered a reasonable specific yield.

## Boundaries

The extent of the stratified-drift aquifer in the study area is limited both horizontally and vertically by physical features that form hydraulic boundaries. Such boundaries affect the time-distance-drawdown relations that result from pumping of wells. It is necessary to define the position and nature of these boundaries to determine the response of the aquifer to withdrawals or other stresses. The two types of boundaries that affect the hydraulic continuity of the aquifer are termed line-source (or recharge) boundaries, and impermeable-barrier (or no-flow) boundaries. Perennial streams and lakes connected to an aquifer will, under certain hydraulic conditions, serve as a source of recharge to the aquifer. If the stream or lake is sufficiently large, and the nature of the streambed or lake-bed materials is such that water may pass readily into the aquifer, then pumping the aquifer on one side of the surface-water body may not produce drawdown on the other side. Under such conditions, the stream or lake is considered a line-source boundary. The contact between stratified drift and low-permeability till or bedrock is considered to be an impermeable barrier. In contrast to the stratified drift, the hydraulic conductivity of till and bedrock is generally low, and relatively little ground water is assumed to flow across the interface between these materials. In general, drawdown increases in a pumping well located near an impermeable-barrier boundary, whereas locating a well near a line-source boundary reduces drawdown. A thorough discussion of the two types of boundaries and their effects on the response of an aquifer to pumping has been provided by Ferris and others (1962) and Lohman (1972).

# GROUND-WATER AVAILABILITY

Two methods were used to evaluate the amount of ground water that could potentially be developed over the long term from the Titicus River valley aquifer: estimates of yields from hypothetical pumping wells and estimates of water available from recharge. It is necessary to compare the amount of water an aquifer can produce by pumping to the water available from recharge to determine if there is sufficient water recharging the aquifer to sustain these withdrawals over prolonged periods. The long-term yield of the aquifer was estimated to be the lower of the two values. The first method used a mathematical model based on the Theis nonequilibrium equation (Theis, 1935) and the theory of image wells (Ferris and others, 1962). The model provides an estimate of the amount of water that could be obtained from the most hydrologically favorable areas of the stratified-drift aquifer during an extended period (180 days) of no recharge. The estimated yields obtained from the model depend on (1) hydraulic properties of the aquifer (saturated thickness, average transmissivity, and specific yield); (2) characteristics of the hypothetical wells (depth, effective diameter, length of screen, and duration of pumping); (3) the effects of nearby pumping wells; and (4) the effects of aquifer boundaries. The second method estimates the water available from natural recharge to the aquifer and induced recharge from streams. This method is based on regional information on ground-water discharge and streamflow, assumptions regarding the amount of natural recharge that may be captured by pumped wells, and the amount of streamflow that may infiltrate into an adjacent aquifer.

## Estimated Well Yields

### Mathematical Model

The mathematical model for calculating maximum well yields from the stratified-drift aquifer is described in detail by Cervione and others (1972) and Mazzaferro and others (1979). The model computes drawdowns and yields for a set of hypothetical pumping wells located at a specified spacing within the modeled area. Discharging image wells located outside the modeled area are used to duplicate hydraulically the effects of impermeable-barrier boundaries on drawdown at the pumping wells (Ferris and others, 1962). This allows the use of the Theis nonequilibrium equation for radial flow to a well (Theis, 1935) by simulating an aquifer of infinite areal extent. Drawdowns at pumping wells are computed from the Theis equation (Theis, 1935, p. 20; Ferris and others, 1962, p. 92) as follows:

$$s = \frac{Q}{4\pi T}\int_{\frac{r^2 S}{4Tt}}^{\infty} \frac{e^{-u}}{u} du, \qquad (1)$$

where $u = \frac{r^2 S}{4Tt}$;

- s = 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 cubic feet per day;
- T = transmissivity, in feet squared per day;
- r = distance, in feet, from the center of the discharging well to the point of observation;
- S = specific yield; and
- t = time, in days, since pumping started.

Drawdowns computed with the Theis equation are then adjusted to account for the effects of dewatering the aquifer, partial penetration of each well, entrance loss, pumping of adjacent wells, and hydraulic boundaries.

Model application consists of four principal steps:
(1) Assign aquifer properties within the model areas and appropriate characteristics for the hypothetical wells,
(2) assign initial discharge rate at each well,
(3) compute total drawdown by summing the effects of the pumping and image wells, and
(4) adjust discharge rates at each well and repeat step 3 until an optimum rate is achieved (one that will produce drawdowns to within 1 ft of the top of the well screens).

After discharge rates are adjusted to meet the criteria of step 4, the rates of all hypothetical wells are summed to obtain the estimated maximum pumpage for the modeled area. The estimates provided by the model are considered to be reasonable approximations of the quantity of water that could potentially be developed from the aquifer, if not constrained by available recharge.

## Boundaries and Characteristics of Modeled Areas

Two areas within the Titicus River valley were identified as having favorable hydrologic characteristics for the development of large quantities of ground water. These areas correspond to the regions of greatest saturated thickness and highest transmissivity (see plates B and C) within each of the upper- and lower-valley aquifer segments. They are subsequently referred to as the upper-valley model area and the lower-valley model area, and are shown on plate D.

Each of the modeled areas is rectangular in shape. Impermeable-barrier boundaries are located on two sides of the models. They are idealized as straight, vertical planes that are approximately coincident with the contacts between the stratified drift and the relatively impermeable till or bedrock. There are no hydraulic boundaries along the remaining two sides of the models because the stratified-drift aquifer is continuous for substantial distances in both directions. The mathematical model considers the aquifer to be infinite in these directions and the extent of the model areas described on plate D is limited for convenience. Thus the sides of the model are no-flow type boundaries, whereas the up-valley and down-valley limits of the model areas are considered to be at constant head.

Streams that traverse the aquifer, including the Titicus River, are small and are unlikely to act as effective line-source boundaries. Therefore, these streams were not considered in the model. Model results are believed to be a conservative estimate of ground water available through pumping because some induced recharge is likely to occur from streams, as well as leakage across the impermeable-barrier boundaries.

The following conditions and assumptions regarding aquifer and well characteristics and period of pumping are incorporated in the model of each area.

(1) Hypothetical pumping wells are located in the thickest, most transmissive parts of the aquifer based on information shown on plates B and C.
(2) The ratio of vertical-to-horizontal hydraulic conductivity is 0.1 and the specific yield is 0.2 (Mazzaferro and others, 1979, p. 40-41; Weiss and others, 1982, p. 42).
(3) Hypothetical pumping wells are 100-percent efficient, screened in the bottom 30 percent of the aquifer, with effective diameters of 2.0 ft.
(4) Maximum available drawdown at each well is limited to 70 percent of the saturated thickness.
(5) A 180-day pumping period is used, during which little or no ground-water recharge occurs.

The locations of hypothetical pumping wells and hydraulic boundaries, and the transmissivity of the model areas are shown on plate D. The characteristics of the modeled areas and the drawdowns and discharges computed by the model are summarized in table 5.

### Results of Model Simulations

The mathematical model was used to estimate the maximum withdrawal rate (table 5) that the aquifer could sustain under constant pumping for 180 days without recharge and without lowering the pumping water level to less than 1 ft above the top of the well screens. In the upper-valley model area, where the average transmissivity is 1,300 $ft^2/d$, five hypothetical wells spaced 500 to 800 ft apart and pumped at rates of 115 to 130 gal/min yielded 0.9 Mgal/d. In the lower-valley model area, where average transmissivity is 1,400 $ft^2/d$, the four hypothetical wells spaced 400 to 800 ft apart and pumped at rates of 56 to 88 gal/min yielded 0.4 Mgal/d. Although transmissivity values are similar, the smaller areal extent and saturated thickness of the lower-valley aquifer limits the amount of water that could be withdrawn from the area to less than half of what might be developed from the upper-valley aquifer.

Aquifer yields predicted by this method are predicated on the assumed conditions used by the model. Consequently, the aquifer yields should not be viewed as exact, but as reasonable estimates of the maximum amount of water that could be developed from pumping wells with the specified locations and construction characteristics, tapping a stratified-drift aquifer with the specified hydraulic characteristics and boundaries. In addition, the maximum withdrawal rate that can be sustained over long time periods also depends on the amount of water available from natural and induced recharge. In the following section, the estimated maximum pumpage is compared to the amount of water available from recharge to provide a better estimate of the long-term yield of the aquifer.

## Estimated Recharge

Although the analytical models indicate how much water potentially may be withdrawn from the stratified-drift aquifer, it is necessary to determine if there is sufficient recharge to replenish these withdrawals over the long term. The amount of water that can be withdrawn without permanently depleting storage in the aquifer is equal to the amount of natural recharge plus the quantity of water that can be induced to infiltrate into the aquifer from surface-water sources. Although neither natural recharge nor induced infiltration have been directly measured for this study, estimates were made based on regional information about ground-water discharge and streamflow characteristics and assumptions regarding the amount of natural recharge that may be captured by pumping wells, and the amount of streamflow that may infiltrate into an adjacent aquifer.

### Natural Recharge

Natural recharge to the stratified-drift aquifer occurs from two sources: (1) precipitation that falls directly on the aquifer and percolates to the water table; and (2) water that enters the aquifer from the surrounding till and bedrock areas either by flow across the subsurface interface between these units, or by infiltration from streams that originate in the uplands and flow onto the aquifer. Ground-water outflow--the sum of ground-water runoff and underflow--has been used as a conservative estimate of natural recharge in areas with no significant pumpage and small ground-water evapotranspiration losses (Randall and others, 1966; Ryder and others, 1970; Cervione and others, 1972).

Table 5.--Summary of characteristics of modeled areas and estimated maximum pumpage

| Model area | Hypothetical pumped well number 1/ | Saturated thickness (feet) | Average transmissivity (feet squared per day) | Available drawdown 2/ (feet) | Calculated total drawdown (feet) | Calculated discharge (gallons per minute) | Estimated maximum pumpage for 180-day no-recharge period 3/ (million gallons per day) |
|---|---|---|---|---|---|---|---|
| Upper valley | 1 | 95 | 1,300 | 66.5 | 66.4 | 130 | 0.9 |
| | 2 | 95 | 1,300 | 66.5 | 66.4 | 123 | |
| | 3 | 90 | 1,300 | 63.0 | 62.9 | 118 | |
| | 4 | 85 | 1,300 | 59.5 | 58.7 | 115 | |
| | 5 | 80 | 1,300 | 56.0 | 55.1 | 116 | |
| Lower valley | 1 | 40 | 1,400 | 28.0 | 27.5 | 56 | .4 |
| | 2 | 60 | 1,400 | 42.0 | 41.3 | 88 | |
| | 3 | 60 | 1,400 | 42.0 | 41.4 | 87 | |
| | 4 | 50 | 1,400 | 35.0 | 34.4 | 73 | |

1/ See plate D for location.
2/ Equivalent to 70 percent of the saturated thickness.
3/ Combined pumpage of hypothetical wells.

Previous hydrologic studies, including those cited above, have shown that for nonurbanized areas in Connecticut, the amount of ground-water outflow is proportional to the areal extent of stratified drift that underlies a drainage basin. Cervione and others (1972, p. 48) have shown that the proportion of total runoff provided by ground-water outflow increases from about 35 to more than 90 percent with increasing percentage of drainage area underlain by stratified drift. This relation is described in Mazzaferro and others (1979, p. 45) by the equation:

$$Y = 35 + 0.6\,X \qquad (2)$$

where Y = ground-water outflow as a percentage of total runoff, and
X = percentage of total basin area underlain by stratified drift.

The water available from natural recharge on an annual basis in the model area is estimated in the following manner:

(1) Determine the total area (in square miles) that contributes recharge directly to the model area through percolation of precipitation or subsurface inflow;
(2) compute the percentage of the total area that is underlain by stratified drift (X);
(3) calculate the ground-water outflow (Y) as a percentage of mean annual runoff from equation 2;
(4) calculate the mean annual runoff for the area determined in step 1 by multiplying this area by the statewide mean annual streamflow per square mile of drainage area, 1.6 (Mgal/d)/mi$^2$, because the mean annual streamflow for the Titicus River basin approximately equals the statewide average (Cervione and others, 1972, p. 14);
(5) calculate the average annual ground-water outflow by multiplying the percentage determined in step 3 by the mean annual runoff obtained in step 4; and
(6) estimate water available from natural recharge by assuming that pumping wells in the model area could capture two-thirds (66 percent) of the average annual ground-water outflow (step 5).

Several assumptions are made when applying this process to estimate natural recharge. First, the total area determined in step 1 includes the model area as well as the adjacent areas that are not drained by streams, as shown on plate D. In the remaining adjacent areas that are drained by streams, it is assumed that all ground water would discharge to the streams above where they enter the model area, and there is no underflow to the model areas. An additional conservative bias is introduced into the estimation of water available from natural recharge by the assumption that only two-thirds of the ground-water outflow can be captured by pumping wells. This assumption is consistent with values used previously in similar studies in Connecticut (Mazzaferro, 1980, 1986; Weaver, 1987).

The amount of water available from natural recharge was estimated using the above method for the upper- and lower-valley model areas. In the upper valley where 32 percent of the total area contributing recharge is underlain by stratified drift, mean annual runoff is 1.3 Mgal/d. Ground-water outflow accounts for 55 percent of the runoff, or about 0.7 Mgal/d, of which approximately 0.5 Mgal/d could potentially be captured by wells. In the lower valley, stratified drift underlies 39 percent of the area contributing recharge to the model, and mean annual runoff is 0.6 Mgal/d. Ground-water outflow provides 58 percent of the runoff, about 0.3 Mgal/d, and approximately 0.2 Mgal/d potentially could be captured by wells.

## Induced Recharge

The Titicus River and its tributary streams that flow across the model area are hydraulically connected to the aquifer. Pumped wells located near a stream may induce water from the stream to infiltrate to the aquifer (Walton and others, 1967). Significant amounts of induced infiltration would increase the long-term yield of the aquifer.

The amount of water potentially available to the aquifer through induced recharge during dry periods is limited by the streamflow entering the model area. Low flows of streams are the best index of the potential amount of induced recharge because streamflow varies considerably during the year, whereas ground-water withdrawals are generally constant (or higher during the growing season). The 30-day, 2-year ($Q_{30,2}$) low flow at the point a stream enters the model area was used to represent the quantity of water available from induced recharge. This index of induced recharge was selected because flows of this magnitude or larger can be expected 90 percent of the time (Cervione, 1982, p. 19). Also, limitation of the induced recharge to this amount reduces the effect of pumping on streamflow, particularly during drier-than-average years.

Weiss (1983) demonstrated that the $Q_{30,2}$ low flow could be estimated at any site on an unregulated stream draining a nonurban area by the regression equation:

$$Q_{30,2} = A\,[0.0124\,(\text{percent } A_{sd} + 1) - 0.001];\quad s = \pm\,24.0 \qquad (3)$$

where: $A$ = total upstream drainage area in square miles;
percent $A_{sd}$ = percentage of total upstream drainage area (A) underlain by stratified drift; and
$s$ = observed standard error of estimate, in percent.

Equation 3 was used to estimate the amount of water potentially available from induced recharge from streams entering the model areas (see plate D). In the upper valley, the $Q_{30,2}$ low flow of the Titicus River at the point where it enters the modeled area is 0.1 Mgal/d. It is, therefore, assumed that pumpage from the upper-valley model area would induce this quantity of recharge from the streamflow entering the model area. In the lower valley, the $Q_{30,2}$ low flow is considerably greater, 0.8 Mgal/d, from the more extensive upstream drainage area. However, it is assumed that pumpage in the upper-valley model area would reduce the $Q_{30,2}$ low flow by an amount equal to the natural and induced recharge captured by the upstream development, or 0.6 Mgal/d. Therefore, a net potential induced recharge of 0.2 Mgal/d could be produced by the lower-valley model area.

## Long-Term Aquifer Yield

The final step in arriving at an estimate of the amount of water that the stratified-drift aquifer in the Titicus River valley may be capable of yielding on a sustained basis for a prolonged period is to compare the estimated maximum withdrawals to the estimate of water available from recharge. The smaller of the two estimates is considered to be the most reasonable indication of the long-term aquifer yield. Table 6 lists the computed amounts of water available from natural and induced recharge and the estimated maximum pumpage for each model area, and shows the sustained long-term yield estimated for each area and for the Titicus River valley aquifer as a whole.

In the upper valley, the combined natural plus induced recharge is 0.6 Mgal/d, which is less than the maximum pumpage of 0.9 Mgal/d computed by the mathematical model. The lower value, based on the available recharge, is considered the best estimate of the amount of ground water that can be developed from the upper valley aquifer over the long term because under existing conditions a higher rate of withdrawal cannot be sustained. In the lower valley, the total water available from natural plus induced recharge, 0.4 Mgal/d, is equal to the estimated maximum pumpage; therefore, this withdrawal rate could be sustained. Summing the estimated yields from each part of the aquifer provides a total sustained yield of the stratified drift in the Titicus River valley of 1.0 Mgal/d.

## WATER QUALITY

As water moves through the hydrologic cycle from the atmosphere, flowing above and beneath the land surface to lakes and oceans, it is affected by chemical, physical, and biological processes that modify its composition and properties. Precipitation falling as rain or snow incorporates aerosols, gases, and particulate matter from the atmosphere. At the land surface, interactions of the water with soils, rocks, and organic matter produce further changes in its quality. Infiltrating the subsurface, water enters other geochemical environments that continue to modify its composition. At any stage in the hydrologic cycle, water quality also may be affected by human activities. In highly urbanized, agricultural, or industrial areas, water quality may be adversely affected by land-use practices.

The chemical composition of water is largely controlled by the materials it contacts and the duration of that contact. Surface water is commonly less mineralized than ground water. During high flows, the chemical composition of runoff water in streams may closely resemble that of precipitation because the water has had little time to react with the earth materials. During low flows, ground-water runoff is a large component of streamflow, so that the stream's quality more closely resembles that of the ground water.

Interpretation of the quality of water in the Titicus River valley is based on analyses of samples collected at seven wells that tap stratified drift and at three surface-water sites (plate E) during July and August, 1984. The water-quality data are summarized in table 7; individual analyses are presented in tables 10 and 11 at the back of this report.

### Ground Water

The major inorganic constituents of water from the stratified-drift aquifer in the Titicus River valley are calcium, magnesium, sodium, potassium, bicarbonate, chloride, and sulfate. The concentrations of these constituents are plotted on plate E as irregular polygons to emphasize similarities and differences in water composition (Stiff, 1951). The chemical diagrams indicate that all the ground-water samples have a relatively similar composition. The size of the patterns for wells R 59 and R 60, however, indicate that concentrations are significantly higher than at other sampling sites, and may be affected by mixing with more highly mineralized ground water from the marble bedrock aquifer that underlies the valley.

Table 6.--Summary of estimated ground-water availability from recharge and pumpage for the Titicus River valley stratified-drift aquifer

| | Upper-valley model area | Lower-valley model area |
|---|---|---|
| Area contributing natural recharge to model (square miles) | 1.1 | 0.5 |
| Percent stratified drift | 32 | 39 |
| Mean annual runoff (million gallons per day) | 1.3 | .6 |
| Ground-water outflow: | | |
| 1. percentage of mean annual runoff | 55 | 58 |
| 2. million gallons per day | 0.7 | .3 |
| Water available from natural recharge (million gallons per day) | .5 | .2 |
| Total area upstream of model (square miles) | 1.7 | 5.3 |
| Percent stratified drift | 8.9 | 18 |
| Low flow ($Q_{30,2}$) of Titicus River entering model (million gallons per day) | .1 | .8 |
| Upstream withdrawals (million gallons per day) | 0 | .6 |
| Water available from induced recharge from streamflow (million gallons per day) | .1 | .2 |
| Total water available from recharge (million gallons per day) | .6 | .4 |
| Estimated maximum pumpage from model area during 180-day period (million gallons per day) | .9 | .4 |
| Sustained, long-term ground-water yield (million gallons per day) | .6 | .4 |
| Total sustained yield of the Titicus River valley stratified-drift aquifer (million gallons per day) | 1.0 | |

Table 7.--Summary of water-quality conditions in the Titicus River valley

[concentrations in milligrams per liter, except as indicated; <, less than; --, not determined]

| Constituent or property | Water source: | | | | | |
|---|---|---|---|---|---|---|
| | Ground water (seven samples) | | | Surface water (three samples) | | |
| | Maximum | Minimum | Median | Maximum | Minimum | Median |
| Calcium (Ca) | 100 | 25 | 46 | 40 | 34 | 35 |
| Magnesium (Mg) | 50 | 7.2 | 22 | 13 | 9.7 | 13 |
| Hardness, total ( as $CaCO_3$) | 425 | 92 | 210 | 154 | 125 | 133 |
| Sodium (Na) | 46 | 2.6 | 4.7 | 13 | 10 | 11 |
| Potassium (K) | 7.0 | 1.8 | 5.3 | 2.3 | 2.0 | 2.2 |
| Alkalinity, total (as $CaCO_3$) | 444 | 87 | 172 | 135 | 110 | 116 |
| Chloride (Cl) | 54 | 4.3 | 18 | 26 | 20 | 22 |
| Sulfate ($SO_4$) | 61 | 9.8 | 25 | 13 | 11 | 12 |
| Nitrogen, total ($NO_2$ + $NO_3$ as N) | 16 | .1 | 1.5 | .5 | .4 | .5 |
| Iron (Fe) | .013 | < .003 | < .003 | .092 | .070 | .086 |
| Manganese (Mn) | .630 | .001 | .051 | .021 | .008 | .011 |
| Solids, dissolved (residue on evaporation at 180° Celsius) | 653 | 129 | 265 | 243 | 203 | 203 |
| pH, units | 8.0 | 6.8 | 7.9 | 8.0 | 7.8 | 7.9 |
| Turbidity, nephelometric turbidity units | -- | -- | -- | 1.1 | .5 | 1.0 |
| Bacteria, fecal coliform, colonies per 100 milliliters | 41 | 0 | 0 | 400 | 16 | 280 |
| Bacteria, fecal streptococci, colonies per 100 milliliters | 8 | 0 | 0 | 23,500 | 216 | 264 |

The chemical composition of the ground-water samples strongly reflects the geologic materials comprising the stratified-drift aquifer and the underlying bedrock. The marble bedrock is composed predominantly of he minerals calcite ($CaCO_3$) and (or) dolomite ($MgCa(CO_3)_2$) (Prucha and others, 1968, p. 10). Ground water circulating through the marble dissolves these minerals and ionizes the Ca, Mg, and $HCO_3$ . This water may leak upward to the stratified drift. The stratified-drift deposits also are derived in part from the glacial erosion of the marble, as well as from other crystalline bedrock units, and may have significant quantities of carbonate minerals within the aquifer matrix. Consequently, the water from the stratified drift is a calcium bicarbonate type (calcium and bicarbonate ions together constituting more than half of the dissolved constituents) with magnesium comprising 14 to 22 percent of the constituents.

Hardness is a property that relates to the sudsing ability of soap and the formation of scale in water pipes; hardness is largely a function of concentrations of calcium and magnesium. Because elevated concentrations of these elements are present in water from the stratified-drift aquifer, these waters are classified as moderately to very hard under the system used by the U.S. Geological Survey (Dufor and Becker, 1964, p. 27).

| Hardness range (milligrams per liter as $CaCO_3$) | Description |
|---|---|
| 0 - 60 | Soft |
| more than 60 - 120 | Moderately hard |
| more than 120 - 180 | Hard |
| more than 180 | Very hard |

Water with more than 100 mg/L (milligrams per liter) hardness may be unsuitable for some uses--for example, such water may cause encrustations in boilers and cooking utensils. Softening treatment may be required for certain uses.

Concentrations of sodium (46 mg/L) and nitrogen (16 mg/L) in water samples from well R 60 (plate E) exceeded the State's (Connecticut General Assembly, 1975) drinking-water standard. This well is located at the edge of an athletic field complex and close to Washington Highway. The elevated levels of sodium and nitrogen in this sample, coupled with a chloride concentration of 54 mg/L, may reflect degradation by road salt, lawn fertilizers, and (or) septic systems in the surrounding areas.

Manganese concentrations exceeding the U.S. Environmental Protection Agency's recommended limit of 0.05 mg/L (U.S. Environmental Protection Agency, 1977) were found in samples from wells R 59, 60, 62, and 63. Concentrations in wells R 64 and 65 approached this limit. Manganese is thought to be leached from decaying vegetation in the organic-rich soils that are common in the swampy areas along much of the Titicus River valley. Elevated concentrations of manganese can impair the taste of drinking water and cause staining problems for industrial and domestic users.

Water samples from wells R 59, 61, 62, 63, and 64 were tested for a variety of organic constituents, including selected insecticides and herbicides, industrial chemicals, solvents, and detergents (see table 11). No organic compounds were found in these samples at concentrations exceeding State or Federal drinking-water standards. Total phenol concentrations, however, ranged from 1.0 to 6.0 $\mu$g/L (micrograms per liter). Elevated concentrations of phenolic materials in water commonly are the result of contamination by hydrocarbons, but low levels can derive from natural aquatic humic substances. If present in concentrations greater than 0.1 μg/L, phenols can impart an unpleasant taste to drinking water. The aesthetic quality of the water may be further affected by conventional water treatment that can produce chlorophenols with a more persistent disagreeable odor and taste. The source of the slightly elevated levels of phenols (5.0 and 6.0 μg/L) observed in wells R 63 and R 59 is unknown.

## Surface Water

The Titicus River was sampled at three locations (plate E) during relatively low-flow conditions. Consequently, its quality strongly reflects the composition of ground water in the stratified drift that supplies the base-flow, the principal component of the streamflow during low-flow conditions. The major inorganic constituents are present in the surface-water samples in approximately the same proportions as in the ground-water samples but in smaller concentrations (see chemical diagrams on plate E). The composition of the Titicus River water remains nearly constant throughout the valley.

Maximum levels of all inorganic constituents in the surface-water samples are either less than or approximately equal to the mean values for the ground-water samples, except for iron. Although iron was not present in concentrations at levels sufficiently large to cause problems, it was consistently higher than the levels observed in the ground water. Runoff from swampy areas where iron is released during decomposition of plant debris is the probable source of the elevated iron concentrations in the Titicus River.

The principal water-quality problem indicated by the analyses of Titicus River samples is elevated bacteria concentrations. Fecal coliform bacteria increased progressively downstream from 16 col/100 mL (colonies per 100 milliliters) at station 01374720 where the Titicus River enters the aquifer, to 400 col/100 mL at station 01374770 at the lower limit of the aquifer. Because there are no sewage effluent discharges to the Titicus River along this reach, the increase in fecal coliform indicates that the bacteria are being washed into the stream from adjacent pastureland. Conversely, fecal streptococci bacteria concentrations drop sharply from 23,500 col/100 mL at station 01374720 to 264 col/100 mL at station 01374750 at the head of the lower valley aquifer, and remain at about that level at station 01374770. This pattern, coupled with a low fecal coliform to fecal streptococci ratio (Geldreich and Kenner, 1969), indicates that the bacterial contamination is derived predominantly or entirely from nonhuman sources such as livestock or poultry wastes in the headwaters of the Titicus River.

State and Federal drinking-water standards for total coliform bacteria are expressed in terms of an average number of colonies for a specified time period or sampling frequency and degree of treatment. Therefore, it is not possible to ascertain if the Titicus River water meets these criteria based on one sampling. The river water would likely be unsuitable for consumption without treatment, considering the presence of coliform organisms in the lower reach of the stream, and may be unsuitable even with conventional treatment because of the high number of streptococcal bacteria in the upper reach. Turbidity also equaled or slightly exceeded the State and Federal drinking-water standards at two of the stations. However, bacteria and suspended particulate matter usually are filtered out when water is induced to infiltrate into an aquifer. Therefore, the water in the Titicus River may be of acceptable quality for induced recharge to the adjacent stratified-drift aquifer.

## SUMMARY AND CONCLUSIONS

The availability and quality of water in the stratified-drift aquifer within the Titicus River valley in Ridgefield, Connecticut, were evaluated to determine the potential of using the aquifer as a source of water. Hydrogeologic data collected to meet the objectives of the study include logs and grain-size analyses of materials penetrated by wells and test holes, seismic-refraction profiles, low-flow stream-discharge measurements, and water-quality analyses.

The stratified-drift aquifer occupies 1.26 $mi^2$ of the Titicus River valley. Saturated thickness increases from less than a few feet along the margins to more than 90 ft in places along the center of the valley. The stratified-drift deposits are thin and narrow in the section of the valley between Round Mountain and Ridgebury Mountain, and the deposits in the upper and lower parts of the valley form separate aquifers. Much of the stratified drift consists of fine-grained sediments (silt and clay); however, some poorly sorted sand and gravel layers were penetrated by many of the wells and test holes; in a few places, coarse-grained sediments predominate. Transmissivity values range from less than 500 $ft^2/d$ where the stratified drift is thinly saturated and predominantly fine grained, to more than 5,000 $ft^2/d$ in the thickest, more permeable sections of the aquifer.

Two methods were used to estimate the quantity of water available from the most hydrologically favorable areas of the stratified-drift aquifer. In the first method, a mathematical model, based on the Theis (1935) nonequilibrium equation and the theory of image wells (Ferris and others, 1962), was used to compute maximum withdrawals from hypothetical pumping wells located in two areas. Aquifer drawdown and yield were simulated for a 180-day period of no recharge by using estimated or assumed hydraulic characteristics of aquifer materials. Maximum withdrawals estimated by the mathematical models of the upper- and lower-valley aquifer areas were 0.9 and 0.4 Mgal/d, respectively.

An alternative method used to estimate ground-water availability was based on the assumption that the magnitude of withdrawals that could be sustained on an annual basis without permanently removing water from storage would not exceed the amount of natural recharge plus induced recharge from surface-water sources. Natural recharge was assumed to equal ground-water outflow, which was estimated by using an empirical equation. Induced recharge, which also was estimated with an empirical equation, was limited to the amount of water equal to the 30-day, 2-year low flow of streams that flowed across the modeled areas. The water available from recharge--the sum of the two components--was estimated to be 0.6 and 0.4 Mgal/d, respectively, for the upper- and lower-valley aquifer areas.

Comparison of the values provided by both methods indicates that the sustained long-term yield in the upper-valley aquifer area is limited by recharge to 0.6 Mgal/d, whereas in the lower-valley aquifer area a long-term yield of 0.4 Mgal/d could be sustained without undesirable consequences. The potential total sustained yield for the Titicus River valley aquifer, is therefore, 1.0 Mgal/d.

The quality of water in the stratified-drift aquifer is generally suitable for human consumption and most other uses. Excessive concentrations of hardness and manganese are the principal water-quality problems. Ground-water samples were classified as moderately to very hard because of elevated concentrations of dissolved calcium and magnesium that presumably are derived from weathering of carbonate minerals in the stratified-drift aquifer and from inflow from the underlying marble bedrock aquifer. Manganese exceeded Federal recommended limits for drinking water in four wells. The elevated manganese concentrations also are considered to be of natural origin, most likely from decaying vegetation in the extensive swampy areas along the floor of the Titicus River valley. Elevated concentrations of sodium, chloride, nitrogen, and phenols in a few wells may indicate degradation of ground-water quality from local human sources.

The quality of water in the Titicus River at low flow strongly reflects the composition of ground water in the stratified-drift aquifer. It is generally suitable for most uses with proper treatment to remove the principal water-quality problem, elevated bacteria concentrations. Increasing numbers of fecal coliform bacteria at downstream stations likely are derived from runoff from adjacent pasturelands. Elevated concentrations of fecal streptococcal bacteria relative to fecal coliform bacteria at the upstream station probably indicate contamination from livestock or poultry wastes in the headwaters of the Titicus River.

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## GLOSSARY

Aquifer: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable materials to yield significant quantities of water to wells and springs. In this report, the term principally refers to stratified-drift deposits known or inferred to be capable of yielding moderate to very large amounts of water to individual wells.

Carbonate bedrock: Bedrock composed primarily of calcium and magnesium carbonate minerals. In the Titicus River basin, this is marble.

Crystalline bedrock: Igneous and metamorphic bedrock; the most common types in the Titicus River basin are marble, schist, and gneiss.

Drawdown: The lowering of the water table or potentiometric surface caused by the withdrawal of water from an aquifer by pumping; equal to the difference between the static water level and the level during pumping.

Effective well diameter: The assumed diameter of a water well, used in certain hydraulic computations, that considers both the diameter of the well screen and the construction characteristics of the well. For example, a well with a 1-foot-diameter screen surrounded by a gravel pack ½-foot thick would have an effective diameter of 2 feet.

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

Flow duration: The percentage of time during which specified daily discharges have been equaled or exceeded within a given time period.

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

Ground-water outflow: The sum of ground-water runoff and underflow; it 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: The property of water generally attributable to salts of the alkaline earth elements. Hardness is a property that relates to the sudsing ability of soap and the formation of scale in water pipes, and is expressed as the concentration of calcium carbonate ($CaCO_3$) that would be 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 of an aquifer. The two types are termed impermeable-barrier boundaries and line-source boundaries.

Hydraulic conductivity: The capacity of a rock to transmit water. It is expressed as the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

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.

Image well: An imaginary well so placed with respect to a real well and hydraulic boundary such that, by discharging or recharging the aquifer, it produces a ground-water divide or condition of no drawdown along the boundary position midpoint between the real and image well.

Impermeable-barrier boundary: The contact between an aquifer and adjacent impermeable material that limits the areal extent of the aquifer--for example, 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.

Induced infiltration: The process by which water in a stream or lake moves into an aquifer after a hydraulic gradient from the surface-water body toward a pumping well or wells is established.

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

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

Long-term well yield: The yield of a well or group of wells that can be reasonably expected under conditions of continuous pumping over extended time periods. In this report, the period of continuous pumping was 180 days.

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

Natural recharge: Water that, under natural conditions, infiltrates to the saturated zone and supplies aquifers. In Connecticut, precipitation is the principal source of natural recharge.

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

Organochlorine compounds: Widely used synthetic organic compounds that are toxic and persistent in the environment; these include aldrin, chlordane, DDT, lindane, toxaphene, and others.

Partial penetration: A condition in which a well is not open to the entire saturated thickness of the aquifer.

Phenols: A class of aromatic organic compounds in which one or more hydroxyl groups are attached directly to the benzene ring. Commonly, a toxic organic compound obtained from coal tar or derivative of benzene.

Polychlorinated biphenyls (PCB), Polychlorinated napthalenes (PCN): Industrial chemicals that are mixtures of chlorinated biphenyl or napthalene compounds having various percentages of chlorine. They are similar in structure to organochlorine insecticides.

$Q_{30,2}$: The average 30-consecutive-day low flow of a stream that could be expected to recur on the average of once every 2 years. The $Q_{30,2}$ is often used by State regulatory agencies as a measure of low flow.

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.

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

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

Sorting: The degree of similarity, with respect to some grain size, of the component parts in a mass of material.

Specific yield: The ratio of the volume of water that a saturated rock or soil will yield by gravity to the total rock or soil volume.

Storage coefficient: The volume of water released from storage in a unit prism of an aquifer when the head is lowered a unit distance. In an unconfined aquifer, storage coefficient is virtually equal to the specific yield.

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

Till: Unsorted, unstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay mixed in various proportions. It is sometimes referred to by New England well drillers as "hardpan."

Transmissivity: The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient. It is equal to the average hydraulic conductivity multiplied by the saturated thickness.

Turbidity: 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): An aquifer 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 material, not firmly cemented or interlocked--for example, sand, in contrast to sandstone.

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

Uniformity coefficient: A measure of the variety in particle sizes of a sediment sample (an index of the degree of sorting). It is defined as the ratio of the sieve size through which 60 percent (by weight) of the material passes, to the sieve size that allows 10 percent of the material to pass. A material with a uniformity coefficient of 1.0 is comprised of particles that are all of the same size; the value increases with the range in grain size.

Table 8.--Logs of wells and test holes

[The logs are listed by their town well or test-hole number followed by the site location number, owner, altitude, the year drilled, source of log, and depth to water]

Well and test-hole identification and site location numbers: U.S. Geological Survey number assigned to each site. The letter prefix denotes the town in which it is located followed by a sequential number. The test holes are identified by the "th" suffix. Location number is the latitude and longitude. Number after decimal point is a sequential number used to identify closely spaced wells and test holes.

Altitude: The land surface datum (LSD) at the site, in feet above sea level, estimated from a topographic map with a contour interval of 10 feet.

Depth to water: Measurements generally made shortly after completion of well or test hole and may not represent static conditions. Expressed in feet below land surface.

Description of earth materials: The descriptive terms are those of the driller or geologist; logs by the U.S. Geological Survey are based on the corresponding grain-size classification shown in the table to the right. Terms that approximate the percentage by weight of individual components within the interval are described as follows:

| | Percent |
|---|---|
| trace: | 1 - 10 |
| little: | >10 - 20 |
| some: | >20 - 35 |
| and | >35 - 50 |

Refusal: Depth at which the drill equipment could not penetrate further.

End of hole: Depth at bottom of well or test hole in which there was no refusal.

Grain size chart

| Grain size (milli-meters) | Wentworth grade scale U.S. Geological Survey logs | Grain size (inches) |
|---|---|---|
| | Boulders (gravel) | |
| 256 | | 10.08 |
| | Cobbles (gravel) | |
| 64 | | 2.52 |
| | Pebbles (gravel) Very coarse gravel | |
| 32 | | 1.260 |
| | Pebbles (gravel) Coarse gravel | |
| 16 | | 0.630 |
| | Pebbles (gravel) Medium gravel | |
| 8 | | 0.315 |
| | Pebbles (gravel) Fine gravel | |
| 4 | | 0.157 |
| | Granules - very fine gravel | |
| 2 | | 0.079 |
| | Very coarse sand | |
| 1 | | 0.039 |
| | Coarse sand | |
| 0.5 | | 0.019 |
| | Medium sand | |
| 0.25 | | 0.0098 |
| | Fine sand | |
| 0.125 | | 0.0049 |
| | Very fine sand | |
| 0.025 | | 0.0025 |
| | Silt | |
| 0.004 | | 0.0002 |
| | Clay | |

R 26th. 4118520733037.1. Ridgefield Water Supply Co. Altitude 572 ft. Drilled 1964. Log by Test Borings, Inc. Depth to water 7 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, fine to coarse; little fine gravel; trace silt; light brown | 0 | 8.5 | 8.5 |
| Sand, very fine to fine; silt | 8.5 | 13 | 4.5 |
| Sand, fine to coarse; little fine gravel; trace silt | 13 | 26.5 | 13.5 |
| Sand, fine to medium; little silt; trace fine to medium gravel; dense | 26.5 | 30.8 | 4.3 |
| Refusal | | at 30.8 | |

R 27th. 4118560733037.1. Ridgefield Water Supply Co. Altitude 578 ft. Drilled 1964. Log by Test Borings, Inc. Depth to water 5 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, fine; little silt; gray | 0 | 4.5 | 4.5 |
| Sand, fine to medium; little fine gravel; trace silt | 4.5 | 6.5 | 2 |
| Sand, very fine to fine; some silt; trace fine gravel; brown | 6.5 | 13 | 6.5 |
| Sand, very fine to fine; little silt; medium compact to dense | 13 | 23 | 10 |
| Sand, fine to medium; trace silt; medium compact | 23 | 27 | 4 |
| Sand, fine; trace medium sand; trace medium gravel; trace silt; gray-brown | 27 | 33 | 6 |
| Sand, fine; little silt | 33 | 36 | 3 |
| Sand, fine; little silt; trace fine gravel; dark gray | 36 | 48 | 12 |
| Sand, fine; little silt | 48 | 53 | 5 |
| Sand, very fine to fine; some silt | 53 | 58 | 5 |
| End of hole | | at 58 | |

R 28th. 4118490733035.1. Ridgefield Water Supply Co. Altitude 571 ft. Drilled 1964. Log by Test Borings, Inc. Depth to water 5 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, fine to medium; trace silt; brown | 0 | 5 | 5 |
| Sand, fine to coarse; trace fine gravel; trace silt; brown | 5 | 15 | 10 |
| Sand, medium to coarse; trace fine gravel; trace silt; brown | 15 | 25 | 10 |
| Sand, fine to medium; trace fine gravel; trace silt; brown | 25 | 30 | 5 |
| Sand, fine to medium; little clay; trace silt; gray | 30 | 35 | 5 |
| Clay, sandy, gray | 35 | 62.5 | 27.5 |
| Refusal | | at 62.5 | |

R 29th. 4118520733017.1. Ridgefield Water Supply Co. Altitude 582 ft. Drilled 1964. Log by Test Borings, Inc. Depth to water 3.5 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, fine to coarse; trace silt; gray | 0 | 5 | 5 |
| Sand, fine to medium; some silt; gray | 5 | 15 | 10 |
| Sand, fine; little clay; gray | 15 | 20 | 5 |
| Clay, silty; trace of fine sand; gray | 20 | 40 | 20 |
| Clay, silty, gray | 40 | 65 | 25 |
| Clay, silty; trace gravel; gray | 65 | 72 | 7 |
| Refusal | | at 72 | |

R 30th. 4118530733041.1. Ridgefield Water Supply Co. Altitude 581 ft. Drilled 1964. Log by Test Borings, Inc. Depth to water 15 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, and gravel | 0 | 21 | 21 |
| Refusal | | at 21 | |

R 31th. 4118330733031.1. Ridgefield Water Supply Co. Altitude 575 ft. Drilled 1964. Log by Test Borings, Inc. Depth to water 3 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, fine to coarse; some fine gravel; gray | 0 | 9 | 9 |
| Sand, fine to medium; trace fine gravel; trace silt; gray | 9 | 23 | 14 |
| Sand, medium to coarse; trace fine gravel; gray | 23 | 28 | 5 |
| Gravel, coarse; little coarse sand; gray | 28 | 33 | 5 |
| Sand, coarse, and medium to coarse gravel; trace silt; gray | 33 | 43 | 10 |
| Gravel, coarse; some coarse sand; gray | 43 | 49 | 6 |
| Refusal | | at 49 | |

R 32th. 4118320733029.1. Ridgefield Water Supply Co. Altitude 573 ft. Drilled 1964. Log by Test Borings, Inc. Depth to water 6.5 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, fine; little silt; gray | 0 | 7 | 7 |
| Silt, clayey; gray | 7 | 13 | 6 |
| Silt, sandy; gray | 13 | 19 | 6 |
| Silt; little fine sand; gray | 19 | 23 | 4 |
| Sand, fine to medium; little fine to medium gravel | 23 | 28 | 5 |
| Gravel, coarse; some coarse sand | 28 | 33 | 5 |
| Sand, fine to medium; trace fine gravel; trace silt; gray | 33 | 38 | 5 |
| Sand, fine to coarse, and coarse gravel; trace silt; gray | 38 | 43 | 5 |
| Sand, fine; trace fine gravel; trace silt | 43 | 50 | 7 |
| Sand, fine to medium; trace silt | 50 | 54 | 4 |
| Sand, fine; some silt | 54 | 59 | 5 |
| Sand, fine to medium | 59 | 64 | 5 |
| Sand, very fine to fine; some silt | 64 | 76 | 12 |
| Sand, very fine, and silt; trace clay | 76 | 79 | 3 |
| Sand, fine to coarse, and gravel; some silt | 79 | 90 | 11 |
| Sand, coarse, and coarse gravel; gray | 90 | 98 | 8 |
| Refusal | | at 98 | |

R 33th. 4117570733013.1. Ridgefield Water Supply Co. Altitude 581 ft. Drilled 1967. Log by Water Exploration and Development Corp. Depth to water 2.7 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Topsoil; sand, very fine; trace clay | 0 | 15 | 15 |
| Sand, very fine to fine; some biotite flakes | 15 | 30 | 15 |
| Sand, very fine; light gray | 30 | 35 | 5 |
| Sand, very fine to fine; trace medium-sized reddish quartz grains | 35 | 45 | 10 |
| Sand, very fine to fine; light gray | 45 | 50 | 5 |
| Sand, fine; tan | 50 | 64 | 14 |
| Refusal | | at 64 | |

R 37th. 4119450733143.1 Town of Ridgefield, Board of Education. Altitude 509 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 10 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Loam, black | 0 | 3 | 3 |
| Silt, micaceous; brown | 3 | 4 | 1 |
| Sand, very fine to medium; little coarse sand; little silt; trace very coarse sand | 4 | 10 | 6 |
| Refusal | | at 10 | |

R 38th. 4120010733234.1. Paul Hampden. Altitude 503 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 13 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Loam, sandy, brown | 0 | 3 | 3 |
| Gravel, granule to pebble, and very fine to very coarse sand; trace silt to very fine sand | 3 | 17 | 14 |
| Gravel, sandy, silty | 17 | 19 | 2 |
| Refusal | | at 19 | |

R 39th. 4119590733229.1. Paul Hampden. Altitude 499 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 3 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Loam, sandy | 0 | 4 | 4 |
| Sand, very fine to medium; some pebble gravel; little silt; trace coarse to very coarse sand | 4 | 10.5 | 6.5 |
| Refusal | | at 10.5 | |

R 40th. 4119060733031.1 Francis Cashman. Altitude 575 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 5 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Loam, silty | 0 | 2 | 2 |
| Silt, and very fine sand; brown | 2 | 8 | 6 |
| Silt, and very fine sand; trace fine to coarse sand; interbedded hard and soft layers | 8 | 31 | 23 |
| Silt, and very fine sand; little fine sand; trace medium to coarse sand; layered | 31 | 55 | 24 |
| Till, clayey, silty; gray | 55 | 58 | 3 |
| End of hole | | at 58 | |

R 41th. 4119380733132.1. Town of Ridgefield, Conservation Commission. Altitude 504 ft. Drilled 1984. Log by U.S. Geological Survey. Depth to water 1 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Soil, clayey, and peat; black | 0 | 4 | 4 |
| Sand, fine to medium, and pebble gravel; trace coarse to very coarse sand; trace silt to very fine sand; gray | 4 | 18 | 14 |
| Silt, and clay, layered | 18 | 35 | 17 |
| Silt, and very fine sand; little fine sand; trace medium to very coarse sand; layered | 35 | 46 | 11 |
| Rock, decomposed | 46 | 46.2 | 0.2 |
| Refusal | | at 46.2 | |

R 42th. 4119510733224.1. Gavin Donnelly. Altitude 496 ft. Drilled 1984. Log by U.S. Geological Survey. Depth to water 1 ft.

| Materials | Depth below LSD, in feet From | To | Thickness (feet) |
|---|---|---|---|
| Soil, loam | 0 | 2 | 2 |
| Sand, very fine; some silt; trace medium to very coarse sand; layered; gray | 2 | 12 | 10 |
| Silt, and very fine to coarse sand; trace very coarse sand; layered with thin clay varves; brown | 12 | 17 | 5 |
| Sand, very fine, and silt; trace fine to coarse sand; layered | 17 | 23 | 6 |
| Sand, fine to medium, and pebble gravel; silty; gray | 23 | 28 | 5 |
| Refusal | | at 28 | |

R 52. 4118270733034.1. Wallace Reid. Altitude 590 ft. Drilled 1966. Log by Noris J. Stone and Sons. Depth to water 22 ft.

| Materials | Depth below LSD, in feet From | To | Thickness (feet) |
|---|---|---|---|
| Sand | 0 | 65 | 65 |
| Limestone | 65 | 140 | 75 |
| Rock; gray | 140 | 200 | 60 |
| End of hole | | at 200 | |

R 53. 4117570733013.2 Ridgefield Water Supply Co. Altitude 578 ft. Log by Boyd Brothers. Depth to water 20 ft.

| Materials | Depth below LSD, in feet From | To | Thickness (feet) |
|---|---|---|---|
| Sand, and silt | 0 | 63 | 63 |
| Gravel, and sand | 63 | 78 | 15 |
| Rock | 78 | 220 | 142 |
| Rock, Large pieces of asbestos | 220 | 230 | 10 |
| Rock, medium hard, (intermittent fracture zones) | 230 | 378 | 148 |
| End of hole | | at 378 | |

R 59. 4119470733148.1 Town of Ridgefield, Board of Education. Altitude 503 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 8 ft.

| Materials | Depth below LSD, in feet From | To | Thickness (feet) |
|---|---|---|---|
| Fill | 0 | 5 | 5 |
| Silt, black | 5 | 7 | 2 |
| Sand, very fine to medium; little silt; trace coarse to very coarse sand, and pebble gravel | 7 | 13 | 6 |
| Silt and clay; very little fine sand; varved; gray | 13 | 28 | 15 |
| Sand, very fine to coarse, and granule to pebble gravel; trace very coarse sand.. | 28 | 34 | 6 |
| Refusal (bedrock) | | at 34 | |

R 60. 4119420733142.1 Town of Ridgefield, Board of Education. Altitude 510 ft. Drilled in 1983. Log by U.S. Geological Survey. Depth to water 8 ft.

| Materials | Depth below LSD, in feet From | To | Thickness (feet) |
|---|---|---|---|
| Fill (loam) | 0 | 4 | 4 |
| Sand, very fine to medium; some silt; trace coarse to very coarse sand | 4 | 8 | 4 |
| Silt, and very fine sand; trace fine to medium sand; clean | 8 | 13 | 5 |
| Sand, medium to coarse; little fine sand; trace silt to very fine sand; trace very coarse sand and pebble gravel | 13 | 18 | 5 |
| Sand, very fine to very coarse, and granule to pebble gravel; little silt | 18 | 24 | 6 |
| Refusal | | at 24 | |

R 61. 4119580733159.1. Juliana Justin. Altitude 502 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 5 ft.

| Materials | Depth below LSD, in feet From | To | Thickness (feet) |
|---|---|---|---|
| Soil, loam, black | 0 | 3 | 3 |
| Gravel, pebble, and very fine to very coarse sand; little silt; dark brown | 3 | 8 | 5 |
| Sand, fine to very coarse; trace silt to very fine sand; trace pebble gravel; clean | 8 | 16 | 8 |
| Sand, fine to very coarse, and granule gravel; trace silt to very fine sand | 16 | 21 | 5 |
| Sand, fine to coarse; little very coarse sand and granule gravel; trace silt to very find sand | 21 | 25 | 4 |
| Sand, medium to very coarse, some granule to pebble gravel; little fine sand; trace silt to very fine sand | 25 | 36 | 11 |
| Sand, fine to very coarse; trace granule gravel; thin layers of very fine to medium sand | 36 | 47 | 11 |
| Gravel, granule to pebble; some fine to very coarse sand; trace silt to very fine sand | 47 | 52 | 5 |
| Refusal (marble bedrock) | | at 52 | |

R 62. 4119570733223.1. Juliana Justin. Altitude 496 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 4 ft.

| Materials | Depth below LSD, in feet From | To | Thickness (feet) |
|---|---|---|---|
| Loam; black to brown | 0 | 4 | 4 |
| Sand, very fine to medium, and silt; trace coarse to very coarse sand; gray | 4 | 8 | 4 |
| Sand, very fine, and silt; little fine to very coarse sand; trace pebble gravel | 8 | 10 | 2 |
| Sand, very fine, and silt | 10 | 13 | 3 |
| Sand, very fine to very coarse, and granule to pebble gravel; little silt; firm | 13 | 22 | 9 |
| Sand, very fine to medium; some granule to pebble gravel; some silt; very firm (till?) | 22 | 24 | 2 |
| Refusal (bedrock) | | at 24 | |

R 63. 4119020733036.1. Mary Gelfman. Altitude 575 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 3 ft.

| Materials | Depth below LSD, in feet From | To | Thickness (feet) |
|---|---|---|---|
| Loam | 0 | 2 | 2 |
| Sand, very fine to medium; little silt; trace coarse to very coarse sand; trace pebble gravel | 2 | 22 | 20 |
| Silt, and very fine to medium sand; gray; layered | 22 | 25 | 3 |
| Gravel, pebble, and fine to very coarse sand; trace silt to very fine sand | 25 | 28 | 3 |
| Sand, very fine to medium; some silt; some pebble gravel; trace coarse to very coarse sand; poorly sorted, firm. Interbedded with layers of clean, fine to coarse sand with trace of pebble gravel | 28 | 46 | 18 |
| Sand, very fine to fine, and silt; trace medium sand to pebble gravel; layered | 46 | 55 | 9 |
| Clay; yellow; with weathered granules (rock fragments) | 55 | 59 | 4 |
| Sand, very fine to medium; silty; gray | 59 | 62 | 3 |
| Rock, weathered, yellow; contains clay and grains of weathered rock fragments | 62 | 63 | 1 |
| End of hole | | at 63 | |

R 64. 4118350733040.1. Douglas Main. Altitude 578 ft. Drilled 1983. Log by U.S. Geological Survey. Depth to water 5 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, very fine to medium; little silt, trace coarse sand to pebble gravel; clean | 0 | 20 | 20 |
| Silt, and clay; layered; gray | 20 | 26 | 6 |
| Sand, very fine to medium; trace silt; clean | 26 | 30 | 4 |
| Silt, and very fine sand; Interbedded with clean very fine to coarse sand | 30 | 36 | 6 |
| Silt, and very fine sand; layered | 36 | 47 | 11 |
| Sand, very fine to fine; trace medium to coarse sand; interbedded with thin silt layers | 47 | 57 | 10 |
| Sand, very fine to coarse; trace very coarse sand to pebble gravel; trace silt | 57 | 61 | 4 |
| Silt, and very fine to very coarse sand; layered | 61 | 62 | 1 |
| Sand, very fine to coarse; little silt; trace very coarse sand and gravel | 62 | 68 | 6 |
| Till, silty, sandy; gray | 68 | 76 | 8 |
| Rock, weathered | 76 | 77 | 1 |
| Refusal | | at 77 | |

R 65. 4119510733152.1. Gavin Donnelly. Altitude 498 ft. Drilled 1984. Log by U.S. Geological Survey. Depth to water 1 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Soil, peat and very fine to fine sand; black | 0 | 4 | 4 |
| Sand, fine to very coarse, and granule gravel; trace silt to very fine sand; gray | 4 | 11.5 | 7.5 |
| Silt and varved clay; with thin interbeds of very fine sand | 11.5 | 29.5 | 18 |
| Sand, very fine to fine, and granule to pebble gravel; trace medium to very coarse sand; trace silt; gray | 29.5 | 31 | 1.5 |
| Rock, weathered; silty, gravelly (pebbles of white marble); yellow | 31 | 31.5 | 0.5 |
| Refusal | | at 31.5 | |

R 66. 4119470733146.1. Town of Ridgefield. Altitude 504 ft. Drilled 1984. Log by Sima Drilling Co. Depth to water 6 ft.

| Materials | Depth below LSD, in feet From | To | Thick-ness (feet) |
|---|---|---|---|
| Sand, and hard pan (till) | 0 | 18 | 18 |
| Limestone (Inwood Marble) (Fractures at 98, 130-135, 140-145, 315, and 335 feet) | 18 | 504 | 486 |
| End of hole | | at 504 | |

Table 9.-- Grain-size analyses of stratified-drift samples

[All samples were disturbed but uncontaminated. They were collected by driving a split-spoon sampler vertically through the depth interval indicated, in test holes and wells shown on plate A; logs are in table 8. All analyses were made by the U.S. Geological Survey. Units are millimeters, mm.

Well or test hole number: For explanation see headnotes to table 8.

Location number: For explanation see headnotes to table 8.

Particle-size distribution: Percent of total weight of samples retained within each sieve size interval (size intervals are those of the Wentworth grade scale shown in headnotes to table 8).

Median grain size: A measure of average particle size; it is equal to the particle size corresponding to the mid-point (50 percentile) of the cumulative particle-size distribution curve.

Uniformity coefficient: A measure of the variety in particle sizes in a sediment sample. It is defined as the ratio of the sieve size through which 60 percent (by weight) of the material passes to the sieve size that allows 10 percent of the material to pass. A material with a uniformity coefficient of 1.0 is comprised of particles that are all of the same size; the value increases with variety of grain size.

| Well or test-hole number | Location number | Depth interval sampled (feet below land surface) | Particle-size distribution (percent by weight): Clay and silt (less than 0.0625mm) | Very fine sand (0.0625-.125mm) | Fine sand (0.125-.25mm) | Medium sand (0.25-.5mm) | Coarse sand (0.5-1.0mm) | Very coarse sand (1.0-2.0mm) | Gravel (greater than 2.0mm) | Median grain size (mm) | Uniformity coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R 37th | 4119450733143.1 | 4 - 6 | 16 | 21 | 28 | 21 | 11 | 3 | 0 | 0.17 | 9.9 |
| R 38th | 4120010733234.1 | 14 - 16 | 8 | 5 | 10 | 10 | 11 | 10 | 46 | 1.5 | 41 |
| R 39th | 4119590733229.1 | 6 - 10 | 18 | 16 | 19 | 12 | 8 | 6 | 21 | .22 | 20 |
| R 40th | 4119060733031.1 | 10 - 11 | 63 | 34 | 3 | 0 | 0 | 0 | 0 | .04 | 8.9 |
| | | 21 - 22 | 65 | 32 | 2 | 1 | 0 | 0 | 0 | .03 | 8.3 |
| | | 22 - 23 | 93 | 4 | 3 | 0 | 0 | 0 | 0 | .02 | 4.4 |
| | | 26 - 27 | 56 | 36 | 6 | 1 | 1 | 0 | 0 | .05 | 10 |
| | | 31 - 33 | 77 | 16 | 3 | 1 | 2 | 1 | 0 | .02 | 6.0 |
| | | 36 - 38 | 51 | 35 | 12 | 1 | 1 | 0 | 0 | .05 | 11 |
| | | 41 - 43 | 54 | 37 | 8 | 1 | 0 | 0 | 0 | .05 | 10 |
| | | 51 - 53 | 55 | 30 | 13 | 1 | 1 | 0 | 0 | .05 | 11 |
| R 41th | 4119380733132.1 | 5 - 6.5 | 11 | 10 | 19 | 15 | 9 | 6 | 30 | .40 | 15 |
| | | 10 - 11.5 | 8 | 7 | 11 | 12 | 10 | 7 | 45 | 1.2 | 43 |
| | | 25 - 26.5 | 59 | 9 | 7 | 8 | 10 | 5 | 2 | .04 | 11 |
| | | 35 - 36.5 | 70 | 23 | 7 | 0 | 0 | 0 | 0 | .03 | 7.1 |
| | | 45 - 46 | 45 | 32 | 16 | 3 | 1 | 1 | 2 | .07 | 12 |
| | | 46 - 46.2 | 22 | 12 | 7 | 4 | 5 | 6 | 44 | 1.0 | 190 |
| R 42th | 4119510733224.1 | 5 - 6.5 | 26 | 30 | 24 | 9 | 10 | 1 | 0 | .11 | 12 |
| | | 10 - 11.5 | 28 | 55 | 14 | 1 | 1 | 1 | 0 | .08 | 8.8 |
| | | 15 - 16.5 | 45 | 11 | 10 | 13 | 17 | 4 | 0 | .09 | 22 |
| | | 20 - 20.5 | 41 | 46 | 7 | 4 | 1 | 0 | 1 | .07 | 11 |
| R 59 | 4119740733148.1 | 7 - 8 | 12 | 19 | 33 | 18 | 8 | 3 | 7 | .19 | 5.8 |
| | | 8 - 10 | 13 | 14 | 29 | 19 | 10 | 5 | 10 | .22 | 8.7 |
| | | 21 - 23 | 81 | 16 | 2 | 0 | 1 | 0 | 0 | .02 | 5.5 |
| | | 31 - 33 | 11 | 12 | 16 | 15 | 11 | 8 | 27 | .42 | 15 |
| R 60 | 4119420733142.1 | 6 - 8 | 26 | 26 | 26 | 16 | 5 | 1 | 0 | .12 | 13 |
| | | 8 - 11 | 47 | 47 | 5 | 1 | 0 | 0 | 0 | .06 | 11 |
| | | 16 - 18 | 2 | 4 | 12 | 45 | 25 | 7 | 5 | .41 | 3.0 |
| | | 21 - 22 | 13 | 9 | 12 | 12 | 11 | 10 | 33 | .64 | 37 |
| R 61 | 4119580733159.1 | 6 - 7 | 11 | 7 | 10 | 12 | 11 | 10 | 39 | .94 | 38 |
| | | 12 - 14 | 3 | 7 | 17 | 29 | 27 | 13 | 4 | .43 | 4.4 |
| | | 17 - 19 | 5 | 6 | 14 | 16 | 12 | 10 | 37 | .84 | 15 |
| | | 22 - 23 | 8 | 10 | 21 | 18 | 14 | 11 | 18 | .38 | 8.1 |
| | | 27 - 29 | 4 | 4 | 9 | 20 | 21 | 15 | 27 | .77 | 7.5 |
| | | 32 - 34 | 6 | 6 | 14 | 16 | 12 | 12 | 34 | .79 | 14 |
| | | 37 - 39 | 6 | 13 | 28 | 20 | 11 | 4 | 18 | .28 | 5.1 |
| | | 42 - 44 | 9 | 7 | 12 | 15 | 15 | 14 | 28 | .69 | 16 |
| | | 47 - 49 | 4 | 5 | 6 | 8 | 8 | 8 | 61 | 4.2 | 49 |
| R 62 | 4119570733223.1 | 5 - 6 | 46 | 22 | 14 | 11 | 6 | 1 | 0 | .07 | 13 |
| | | 16 - 18 | 15 | 10 | 11 | 11 | 9 | 10 | 34 | .63 | 53 |
| | | 21 - 22 | 35 | 8 | 13 | 14 | 11 | 8 | 11 | .18 | 35 |
| | | 22 - 23 | 21 | 14 | 13 | 10 | 8 | 7 | 27 | .29 | 40 |
| R 63 | 4119020733036.1 | 4 - 6 | 14 | 25 | 36 | 17 | 6 | 1 | 1 | .15 | 6.6 |
| | | 9 - 11 | 15 | 26 | 32 | 16 | 8 | 2 | 1 | .15 | 7.6 |
| | | 13 - 16 | 9 | 21 | 37 | 22 | 8 | 2 | 1 | .18 | 3.4 |
| | | 21 - 22 | 15 | 20 | 26 | 21 | 12 | 5 | 1 | .19 | 9.7 |
| | | 26 - 28 | 8 | 7 | 12 | 13 | 9 | 8 | 43 | 1.1 | 32 |
| | | 36 - 38 | 17 | 14 | 21 | 17 | 9 | 4 | 18 | .23 | 17 |
| | | 41 - 43 | 24 | 18 | 18 | 11 | 8 | 7 | 14 | .17 | 20 |
| | | 51 - 52 | 41 | 23 | 16 | 6 | 4 | 2 | 8 | .08 | 14 |
| R 64 | 4118350733004.1 | 11 - 13 | 8 | 19 | 38 | 23 | 7 | 3 | 2 | .19 | 3.4 |
| | | 16 - 18 | 22 | 25 | 29 | 18 | 5 | 0 | 1 | .13 | 12 |
| | | 26 - 28 | 6 | 19 | 55 | 20 | 0 | 0 | 0 | .17 | 2.7 |
| | | 31 - 33 | 17 | 27 | 24 | 18 | 10 | 3 | 1 | .15 | 9.9 |
| | | 36 - 38 | 52 | 42 | 6 | 0 | 0 | 0 | 0 | .06 | 10 |
| | | 41 - 43 | 56 | 35 | 7 | 0 | 0 | 0 | 2 | .05 | 10 |
| | | 47 - 48 | 21 | 46 | 24 | 6 | 2 | 0 | 1 | .10 | 7.6 |
| | | 57 - 58 | 8 | 13 | 31 | 26 | 12 | 6 | 4 | .24 | 4.4 |
| | | 62 - 63 | 11 | 15 | 24 | 22 | 11 | 6 | 11 | .25 | 7.0 |
| R 65 | 4119510733512.1 | 4.5 - 6 | 7 | 7 | 14 | 16 | 12 | 11 | 33 | .71 | 15 |
| | | 10.0 - 11.5 | 9 | 6 | 8 | 10 | 10 | 8 | 49 | 1.8 | 53 |
| | | 24.5 - 26 | 64 | 27 | 6 | 0 | 1 | 0 | 2 | .03 | 8.6 |
| | | 29.5 - 31 | 9 | 16 | 22 | 6 | 2 | 3 | 42 | .35 | 37 |

Table 10.--Physical, inorganic chemical, and bacteriological analyses of water from selected wells and surface-water sites in the Titicus River valley

[Chemical constituents dissolved except as indicated; concentrations in milligrams per liter, except as indicated;

< = less than; -- = not determined]

| Constituent or property | Well and date sampled (month, day, and year) | | | | | | | Surface-water station number and date sampled (month, day, and year) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R 59 7-31-84 | R 60 8-2-84 | R 61 8-1-84 | R 62 8-1-84 | R 63 7-30-84 | R 64 8-1-84 | R 65 8-2-84 | 01374720 7-31-84 | 01374750 7-31-84 | 01374770 7-31-84 | Water-quality criteria | Criteria source |
| Alkalinity, total, as $CaCO_3$ | 444 | 382 | 90 | 172 | 202 | 87 | 93 | 110 | 135 | 116 | -- | -- |
| Arsenic, (As) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.001 | <0.001 | 0.001 | <0.001 | 0.05 | A,B |
| Bacteria, fecal coliform in colonies/100 mL | 0 | 0 | 5 | 41 | 0 | 0 | 0 | 16 | 280 | 400 | -- | -- |
| Bacteria, fecal streptococci in colonies/100 mL | 0 | 7 | 0 | 0 | 8 | 0 | 0 | 23,500 | 264 | 216 | -- | -- |
| Barium (Ba) | .079 | .081 | .055 | .052 | .072 | .020 | .034 | .042 | .037 | .034 | 1.0 | A,B |
| Beryllium (Be) | <.001 | <.0005 | <.0005 | .001 | <.001 | <.001 | <.0005 | .001 | <.001 | <.001 | -- | -- |
| Cadmium (Cd) | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | .010 | A,B |
| Calcium (Ca) | 88 | 100 | 31 | 53 | 46 | 25 | 33 | 34 | 40 | 35 | -- | -- |
| Chloride (Cl) | 18 | 54 | 32 | 36 | 5.8 | 4.3 | 17 | 20 | 26 | 22 | 250 | A,C |
| Chromium (Cr) | <.01 | .010 | <.01 | <.01 | <.01 | <.01 | <.01 | <.01 | .010 | <.01 | .050 | A,B |
| Color, platinum-cobalt units | -- | -- | <1 | -- | -- | -- | -- | -- | -- | -- | 15 | C |
| Copper (Cu) | <.001 | .008 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | .002 | .001 | 1.0 | A,C |
| Cyanide (CN) | <.01 | <.01 | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- | -- | .01 | A |
| Dissolved solids, residue on evaporation at 180° Celsius | 556 | 653 | 265 | 371 | 255 | 129 | 220 | 203 | 243 | 203 | 500 | C |
| Fluoride (F) | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | <.1 | 2.0 | A,B |
| Iron (Fe) | .013 | .008 | .003 | <.003 | <.003 | <.003 | <.003 | .086 | .092 | .070 | .3 | C |
| Lead (Pb) | <.001 | <.001 | <.001 | <.001 | .001 | <.001 | <.001 | <.001 | .001 | <.001 | .050 | A,B |
| Magnesium (Mg) | 50 | 36 | 16 | 22 | 23 | 7.2 | 11 | 9.7 | 13 | 11 | -- | -- |
| Manganese (Mn) | .630 | .490 | .001 | .051 | .230 | .045 | .046 | .011 | .008 | .021 | .050 | C |
| Mercury (Hg) | .0001 | .0002 | .0001 | <.0001 | .0002 | <.0001 | <.0001 | .0001 | .0002 | .0002 | .002 | A,B |
| Nitrogen, total nitrite ($NO_2$) as N | .14 | .03 | <.01 | .04 | .01 | .01 | <.01 | .01 | <.01 | <.01 | 1.0 | A |
| Nitrogen, total nitrite ($NO_2$) plus nitrate ($NO_3$) as N | 1.7 | 16 | 5.4 | 1.5 | .6 | .1 | 1.1 | .4 | .5 | .5 | 10 | A,B |
| pH, units | 7.3 | 7.0 | 6.8 | 7.9 | 7.9 | 8.0 | 7.9 | 7.9 | 8.0 | 7.8 | 6.4-8.5 | A,B |
| Phosphorous, total (P) | <.01 | <.01 | <.01 | <.01 | <.01 | <.01 | .01 | <.01 | <.01 | <.01 | -- | -- |
| Potassium (K) | 7.0 | 6.1 | 1.8 | 6.2 | 5.3 | 2.7 | 4.4 | 2.2 | 2.3 | 2.0 | -- | -- |
| Selenium (Se) | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | .010 | A,B |
| Silica ($SiO_2$) | 15 | 13 | 11 | 11 | 11 | 11 | 13 | 9.5 | 11 | 11 | -- | -- |
| Silver (Ag) | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | .050 | A,B |
| Sodium (Na) | 4.7 | 46 | 15 | 9.0 | 2.8 | 2.6 | 4.2 | 10 | 13 | 11 | 20 | A |
| Specific conductance, in microsiemens/cm at 25° Celsius | 800 | 930 | 380 | 500 | 430 | 200 | 305 | 300 | 360 | 315 | -- | -- |
| Strontium (Sr) | .091 | .150 | .097 | .067 | .093 | .047 | .067 | .069 | .073 | .071 | -- | -- |
| Sulfate ($SO_4$) | 61 | 27 | 25 | 24 | 13 | 9.8 | 25 | 12 | 13 | 11 | 250 | C |
| Turbity, nephelometric turbity units | -- | -- | -- | -- | -- | -- | -- | .5 | 1.0 | 1.1 | 1.0 | A |
| Water temperature, ° Celsius | 12 | 12 | 12.5 | 14 | 12.5 | 12.5 | 11 | 21 | 19 | 19.5 | -- | -- |
| Zinc (Zn) | .010 | .024 | .016 | .005 | .004 | .006 | .010 | <.003 | .004 | .010 | 5 | C |

1/ Most stringent criterion based on:
A. Maximum permissible level for drinking water in Connecticut Public Health Regulation 19-13-B102 (Connecticut General Assembly, 1975).
B. Maximum contaminant level established by National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1975).
C. Maximum level recommended by National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977).

Table 11.-- Organic chemical analyses of water from selected wells

[Chemical constituents dissolved, except as indicated: concentrations in micrograms per liter (μg/L) except as indicated; < = less than]

| Constituent | Well number and date sampled (month, day, year) R 59 7-31-84 | R 61 8-1-84 | R 62 8-1-84 | R 63 7-30-84 | R 64 8-1-84 | Criteria source | Water-quality criteria |
|---|---|---|---|---|---|---|---|
| Chlorophenoxy acid herbicides: | | | | | | | |
| 2,4-D | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 100 | A,B |
| 2,4-DP | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| 2,4,5-T | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| Silvex | <.01 | <.01 | <.01 | <.01 | <.01 | 10 | A,B |
| Methylene blue active substance, (MBAS) total, mg/L[2/] | .02 | .06 | <.01 | .03 | .41 | 0.5 | A,C |
| Organochlorine compounds: | | | | | | | |
| Gross polychlorinated biphenyls (PCB) | <.1 | <.1 | <.1 | <.1 | <.1 | -- | -- |
| Gross polychlorinated napthalenes (PCN) | <.1 | <.1 | <.1 | <.1 | <.1 | -- | -- |
| Organochlorine insecticides: | | | | | | | |
| Aldrin | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| Chlordane | <.1 | <.1 | <.1 | <.1 | <.1 | -- | -- |
| DDD | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| DDE | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| DDT | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| Dieldrin | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| Edosulfan | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| Endrin | <.01 | <.01 | <.01 | <.01 | <.01 | 0.2 | A,B |
| Heptachlor | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| Heptachlor epoxide | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| Lindane | <.01 | <.01 | <.01 | <.01 | <.01 | 4.0 | A,B |
| Methoxychlor | <.01 | <.01 | <.01 | <.01 | <.01 | 100 | A,B |
| Mirex | <.01 | <.01 | <.01 | <.01 | <.01 | -- | -- |
| Perthane | <.1 | <.1 | <.1 | <.1 | <.1 | -- | -- |
| Toxaphene | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | 5 | A,B |
| Phenols, total[2/] | 6.0 | 1.0 | <1.0 | 5.0 | 1.0 | -- | -- |
| Volatile organic compounds, (totals): | | | | | | | |
| Benzene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Bromoform | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Carbon tetrachloride | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Chlorobenzene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Chlorodibromomethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Chloroethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 2-Chloroethyl vinyl ether | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Chloroform | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Dichlorobromomethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Dichlorodifluoromethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,1-Dichloroethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,2-Dichloroethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,1-Dichloroethylene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,2-Trans-Dichloroethylene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,2-Trans-Dichloropropane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,3-Dichloropropene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Ethylbenzene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Methylbromide | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Methylene chloride | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,1,2,2-Tetrachlorolethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Tetrachloroethylene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Toluene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,1,1-Trichloroethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| 1,1,2-Trichloroethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Trichloroethylene | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Trichlorofluoromethane | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |
| Vinyl chloride | <3.0 | <3.0 | <3.0 | <3.0 | <3.0 | -- | -- |

1/ Most stringent criterion based on:

A. Maximum permissible level for drinking water in Connecticut Public Health Regulation 19-13-B102 (Connecticut General Assembly, 1975).

B. Maximum contaminant level established by National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1975).

C. Maximum level recommended by National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977).

2/ Additional data include the following analyses for methylene blue active substance (in milligrams per liter, mg/L) and total phenols (μg/L) in samples from two wells collected on August 2, 1984, and from three surface-water stations collected on July 31, 1984:

| Site | MBAS | Phenols |
|---|---|---|
| R 60 | <0.01 | 1.0 |
| R 65 | < .01 | 5.0 |
| 01374720 | < .01 | 2.0 |
| 01374750 | < .01 | 1.0 |
| 01374770 | .09 | 19.0 |



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