HYDROGEOLOGIC RECONNAISSANCE OF THE STRATIFIED-DRIFT AQUIFERS NEAR SIMSBURY, CONNECTICUT

By James W. Bingham

U.S. GEOLOGICAL SURVEY

Water Resources Investigations Report 83-4145

Prepared in cooperation with the

TOWN OF SIMSBURY, CONNECTICUT

Hartford, Connecticut

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information, write to:

Chief, Connecticut Office
U.S. Geological Survey, WRD
450 Main Street, Room 525
Hartford, Connecticut 06103

Copies of this report can be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225
(Telephone: (303) 234-5888)

CONTENTS

FIGURE

PLATES

(Plates are in pocket)

FACTORS FOR CONVERTING INCH-POUND UNITS
TO INTERNATIONAL SYSTEM OF UNITS (SI)

Multiply inch-pound unit	By	To obtain SI unit
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
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)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
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]	0.01691	cubic meter per second per square kilometer [(m^3/s)/km^2]

HYDROGEOLOGIC RECONNAISSANCE OF THE STRATIFIED-DRIFT AQUIFERS NEAR SIMSBURY, CONNECTICUT

By James W. Bingham

ABSTRACT

The Simsbury area contains extensive stratified-drift deposits that have large potential for development of ground water. Hydrogeologic information on the water-yielding characteristics and boundaries of stratified-drift aquifers and sources of recharge is essential for anticipating the effects of developing these ground-water resources. This report, an assessment of hydrogeologic conditions based on existing data, is intended to guide future studies by identifying potentially favorable areas for development and the additional data needed for water-resources planning and management.

Stratified-drift deposits with suitable characteristics for large-scale development are known to underlie part of Stratton Brook valley and the west side of the Farmington River valley near the community of Hoskins. These deposits are presently tapped by the Village Water Company for public supply. Buried coarse-grained stratified drift also underlies the Farmington River valley below Horseshoe Cove. In many other areas where coarse-grained stratified drift is present, the saturated thickness is either inadequate for installing large-capacity wells, or is undefined. The areas most in need of additional study to define aquifer characteristics and potential for ground-water development include the main Farmington River valley between Tariffville and Avon, Stratton Brook valley upstream of Stratton Brook State Park, and Bissell Brook valley along the northern margin of Simsbury.

INTRODUCTION

Purpose and Scope

The purpose of this report is to summarize the existing hydrogeologic information on stratified-drift aquifers near Simsbury, Connecticut (fig. 1) in map format and delineate the areas where data are insufficient for quantitative appraisal of aquifer yields and response to pumping. Additionally, the report outlines a program for collection of hydrogeologic data in the data-deficient areas and discusses possible uses of such data. This study is the first phase of a cooperative program between the U.S. Geological Survey and the Town of Simsbury to fully evaluate ground-water availability from the stratified-drift aquifer in the area.

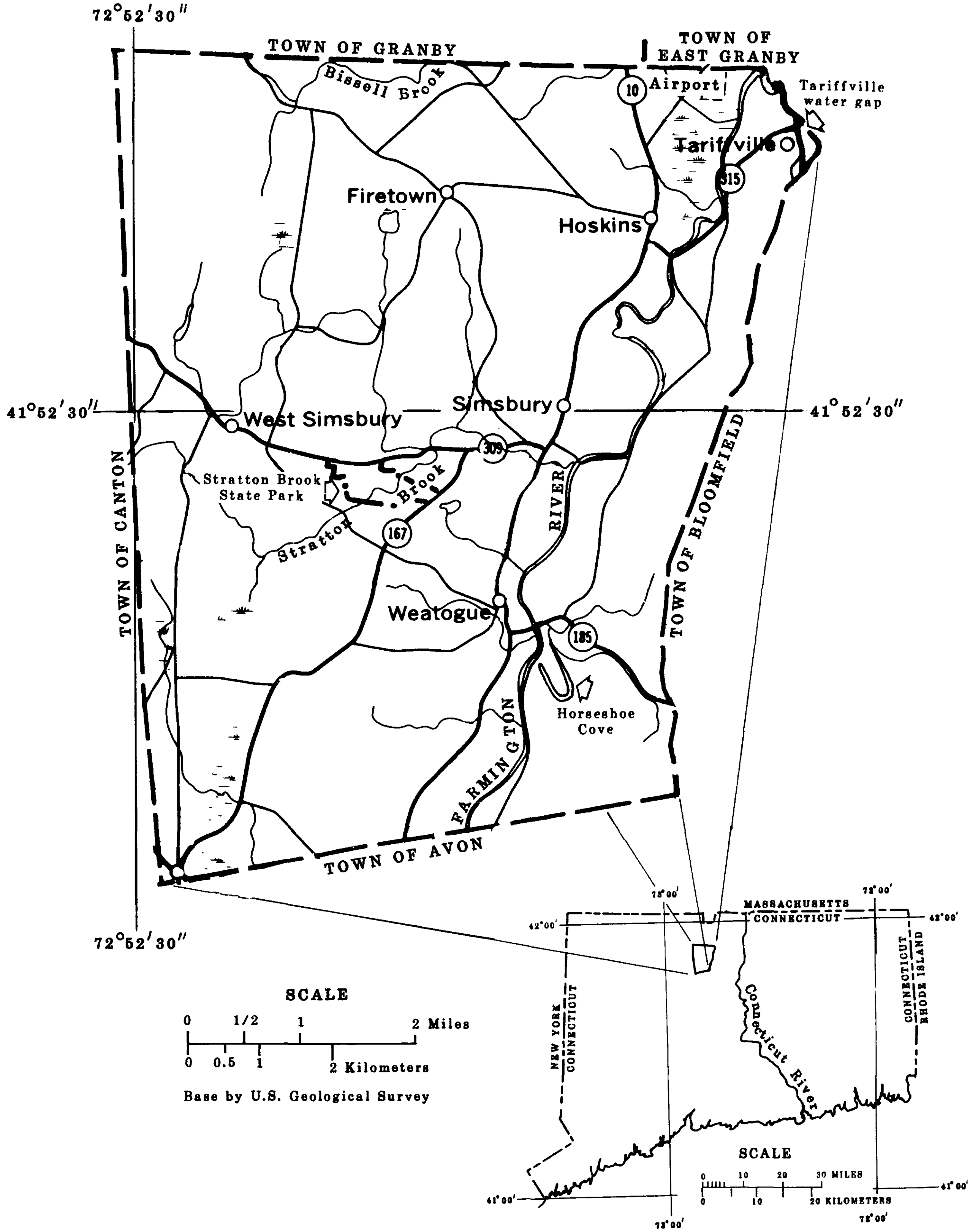

Figure 1.--Map showing location of study area.

The scope of this report is limited to evaluation of available data for the stratified drift which is the only aquifer capable of sustaining large withdrawals for public or industrial supply. The aquifer is composed of interbedded layers of saturated gravel, sand, silt, and clay deposited by glacial meltwaters. The data are used to delineate the extent, saturated thickness, and average grain size of the stratified drift in order to determine the most favorable areas for ground-water development.

The data used in preparing this report were compiled from U.S. Geological Survey reports and files, Village Water Co. and Town of Simsbury files, and drillers' well completion reports obtained from the Connecticut Department of Environmental Protection. The included maps (plates 1, 2, 3, and 4) delineate the areal extent of stratified drift and till, show the configuration of the bedrock surface beneath the stratified drift, and show the saturated thickness and average grain size of the stratified drift based on existing data. These maps are an interpretation of newly collected data, together with all previous data resulting in greater detail than in any prior reports.

Previous investigations

The Town of Simsbury is partly or wholly included in several earlier ground-water and geologic investigations. The earliest (Gregory, 1909) described the occurrence of ground water in all the major aquifers in Connecticut but contained little specific data about Simsbury. A later report (Palmer, 1921), dealt in greater detail with the occurrence, quantity, and quality of ground water in the area from Southington to Granby. The report described 61 wells in Simsbury and the occurrence of ground water in the various aquifers. Randall, (1964a) described the geology and ground-water resources in a six-town area between Farmington and Granby, that includes Simsbury. That report provides information on the occurrence, development, and chemical quality of ground water in both unconsolidated and bedrock aquifers. A companion basic data report (Randall, 1964b) contains the records of wells and springs and chemical analyses of ground-water samples.

In the early 1970's, the U.S. Geological Survey, in cooperation with the Connecticut Department of Environmental Protection, collected water-resources data in the Farmington and upper Connecticut River basins. The Farmington River basin study includes all stratified-drift areas in Simsbury; the hydrogeologic data were published by Hopkins and Handman (1975) and by the U.S. Geological Survey (1970, 1971, 1972), but did not provide sufficient information for quantifying aquifer yields or predicting the effects of ground-water development on the hydrologic system in the Simsbury area.

In addition to the cited water-resources investigations, the U.S. Geological Survey, during the 1960's, mapped the surficial and bedrock geology of the Avon and Tariffville quadrangles in cooperation with the State of Connecticut. The Town of Simsbury is located in the Avon and Tariffville quadrangles and the geologic maps by Randall (1970), Schnabel (1960), Schnabel (1962), and Schnabel and Eric (1965) provide a detailed geologic framework for water-resources investigations. Other maps containing useful information have been published by the U.S. Geological Survey as part of the "Connecticut Valley Urban Area Study" (Handman and Ryder, 1973; Handman and Schnabel, 1973; Handman, 1974; Pessl, 1973a; Radway and Schnabel, 1976).

Several site-specific investigations that contain valuable hydrogeologic data have been conducted by consultants for the town, utilities, and industries. Consultants' reports used in this study include those by Fuss and O'Neill (1979, 1981), and Griswold and Fuss (1976).

All of the hydrogeologic data used in this report are on file at the offices of the U.S. Geological Survey or the Natural Resources Center, Connecticut Department of Environmental Protection, both of which are located in Hartford, Connecticut.

HYDROGEOLOGIC FRAMEWORK

Subsurface Units

Management of ground-water resources requires an understanding of the hydrogeologic system. The essential system elements are the three-dimensional boundaries and hydraulic characteristics of the water-bearing units, the sources and amounts of recharge, the circulation pattern, and the locations and amounts of ground-water discharge.

Simsbury is underlain by three water-bearing units -- stratified drift, till, and bedrock. Stratified drift, the major aquifer, occurs principally in the Farmington River valley and along Stratton Brook and Bissell Brook. This unit is bounded laterally by the adjacent valley walls made up of till and bedrock and vertically by the contact with till and bedrock that underlie the valley at depth. The water-yielding characteristics of stratified drift vary considerably, principally because of differences in grain-size, saturated thickness, and available recharge. Till, commonly termed "hardpan," is a poor aquifer because the compactness and wide range of grain sizes cause the permeability to be very low. Yields from wells tapping till are generally inadequate to supply the water requirements of a modern household. Bedrock, principally of the sedimentary and igneous type, underlies the entire town and is discontinuously mantled by unconsolidated deposits of stratified drift and till. Bedrock is capable of yielding enough water to individual wells for domestic supply. In some places, bedrock well yields are high enough to meet commercial and industrial requirements of up to approximately 150,000 gal/d (gallons per day) or about 100 gal/min (gallons per minute).

Ground-Water Circulation

Below the water table, open spaces between individual grains of stratified drift and till and open fractures in the bedrock are completely filled with water that constantly moves from areas of inflow (or recharge) to areas of outflow (or discharge).

A quantitative expression of ground-water circulation into, through, and out of an aquifer is given by the following equation (Schicht and Walton, 1961) and may be simply stated as "inflow equals outflow plus or minus changes in storage":

$$GW_r = (GW_{ro} + GW_{et} + U) \pm \Delta S$$

Where:

GW_r = Ground-water inflow or recharge

$$\left.\begin{array}{l} GW_{ro} = \text{Ground-water runoff} \\ GW_{et} = \text{Ground-water evapotranspiration} \\ U = \text{Underflow} \end{array}\right\} \text{ground-water outflow or discharge}$$

ΔS = Change in ground-water storage

This equation represents natural conditions where there is no discharge from pumpage. The terms are defined in the glossary.

All the factors in the expression vary with time and vary in amount from place to place. Under natural conditions, recharge to the stratified-drift aquifer in Simsbury is derived mainly from direct percolation of precipitation to the water table and partly from lateral inflow of ground water from adjacent till and bedrock. Another source of ground-water inflow is induced recharge due to pumping withdrawals. High-capacity wells near streams or ponds lower the water table, reversing the natural hydraulic gradient and causing surface water to flow into the aquifer. Several high-capacity wells near Stratton Brook derive much of their total pumpage from induced recharge.

Ground-water outflow from stratified drift, under natural conditions, consists mainly of ground-water runoff to streams that are hydraulically connected to this aquifer. Ground-water discharge contributes to the streamflow most of the year and sustains the streamflow during periods of dry weather. Additional natural discharge of ground water occurs by evaporation and by transpiration of plants (evapotranspiration), particularly in swampy areas and where the water table is normally less than five feet below land surface, such as in much of the Farmington River valley.

Underflow occurs as down-valley movement of ground water mostly through the stratified drift. Generally, when the various components of recharge and discharge are estimated for a basin above a specific stream-gaging station, underflow is the ground water moving downgradient beneath the gaging site and is not measured as part of the streamflow leaving the basin. In some geologic settings, underflow can be a signficant factor. However, very little underflow leaves Simsbury through the Tariffville water gap because of the relative impermeability of the bedrock and absence of stratified drift.

The quantitative expression for ground-water circulation allows a qualitative prediction of the hydrologic effects that will result from a change in one or more parameters in the preceding equation. For example, if recharge is reduced, equilibrium will be maintained by a reduction in discharge, a reduction in ground-water storage, or both.

Water-Yielding Characteristics of Stratified Drift

Previous studies have shown that stratified drift in the Simsbury area is capable of sustaining large ground-water withdrawals for municipal or industrial supply under the following conditions:

1) The saturated thickness is equal to or greater than 40 feet.

2) The drift consists of substantial amounts of well-sorted sand and gravel, preferably with the sand and gravel making up the entire saturated section, or at least the lower part.

3) The drift is of large areal extent or is hydraulically connected to a perennial stream that has a low flow (90-percent flow duration) of at least 1 Mgal/d (million gallons per day).

The long-term sustained yield from a stratified-drift aquifer and the potential yields of individual wells tapping it can be determined where adequate hydrogeologic data are available. Data requirements for determining overall aquifer yield include the hydraulic properties of the aquifer -- specifically, storage coefficient and transmissivity; location and nature of the hydraulic boundaries that limit the continuity of the aquifer; the quantity and variability of natural recharge and discharge; and the quantity of water that can be induced to infiltrate from adjacent streams or lakes.

Existing hydrogeologic information is inadequate for quantitative determination of the long-term yield of the stratified-drift aquifer or the yields of wells tapping it. The hydraulic properties, in particular, are poorly defined. Although saturated thickness is mapped for most of the stratified drift (plate 2), estimates of transmissivity are possible in only a few areas because hydraulic conductivities are poorly known. Grain-size distribution provides a basis for estimation of average hydraulic conductivity (Mazzaferro and others, 1978, p. 39-42), however, much of the stratified drift lacks suitable grain-size data for determining transmissivity on the basis of this relationship (see plate 3).

The position and configuration of some of the hydraulic boundaries that enclose the stratified-drift aquifer can only be approximated. The adjacent valley walls, consisting of till and bedrock, have relatively low transmissivity and constitute one type of hydraulic boundary, termed "impermeable-barrier boundary." Major perennial streams that may recharge the aquifer under conditions of ground-water development constitute the other type, termed "line-source boundary." However, in most cases, the position of the hydraulic boundaries are not exactly coincident with these physical features. Hydraulic boundaries and their effects are discussed in detail by Ferris and others (1962). A more accurate determination of the effective location of the hydraulic boundaries of the stratified-drift aquifer will require a substantial amount of additional data.

Natural recharge has not been measured for any of the stratified-drift aquifers in the study area or elsewhere in Connecticut. It is variable in both time and space and difficult to measure directly. Conservative estimates of the recharge from precipitation that falls on stratified drift and recharge from ground water flowing into the stratified drift from adjacent till-bedrock areas can be made with methods developed in other Connecticut studies and outlined in Mazzaferro and others (1978). The methods are based on the equation discussed in the section on "Ground-Water Circulation". With this equation, the average annual ground-water recharge to a basin is conservatively estimated to equal the average annual ground-water discharge, assuming that ground-water evapotranspiration and storage changes are negligible. In areas entirely underlain by stratified drift, ground-water discharge (ground-water runoff and underflow) is estimated to be about 95 percent of the total runoff. As a statewide average, total runoff for the period 1931-60 equals 1.16 (Mgal/d)/mi^2 (million gallons per day per square mile) and estimated ground-water discharge is therefore about 1 (Mgal/d)/mi^2. Long-term average ground-water recharge from precipitation falling on the stratified drift is conservatively estimated to also be about 1 (Mgal/d)/mi^2.

Average annual recharge to till and bedrock from precipitation is estimated to be about 0.4 (Mgal/d)/mi^2 with this method. To date, information is not available to characterize recharge rates during extremely wet or dry years.

The amount of water in a stream, together with other factors such as streambed thickness and permeability, and hydraulic gradient between stream and aquifer, control the induced recharge resulting from pumping of wells. It is not possible at this time to reliably estimate the quantity of water that could be induced to infiltrate from streams adjacent to the stratified-drift aquifers in Simsbury. The amount would vary depending upon the stream, the location along a stream reach, and with time. A large quantity of streamflow, however, is a favorable factor for induced recharge. For example, there is significantly more streamflow in the Farmington River than in Stratton Brook, although the aquifer characteristics are more favorable near Stratton Brook.

AVAILABILITY OF WATER FROM STRATIFIED DRIFT

Relative ground-water availability in areas of stratified drift can be estimated from information on grain-size distribution and saturated thickness that are shown on plates 2 and 3. Potential yields from properly constructed wells are estimated on the basis of these factors and included in the explanation on plate 3. The estimates were modified from Randall (1964a), but also are based on data collected for this report.

The distribution of the coarse- and fine-grained stratified drift on plate 3 is based on available well and test-hole data. Areas of unknown grain size are also shown on this plate.

Some of the important hydrogeologic information shown on plates 2 and 3 may be summarized and interpreted as follows:

1) Stratified-drift deposits with potential for large-scale water development underlie much of Stratton Brook and the west side of the Farmington Valley in the vicinity of Hoskins where it is coarse-grained and the saturated thickness is greater than 40 feet.

2) Dominantly fine-grained stratified-drift deposits underlie a large part of the Farmington River valley. Potential for large-scale ground-water development is limited in this area unless some coarse-grained material is present in the deep bedrock valley. A few logs of wells and test holes show that discontinuous beds of coarse material occur below the thick deposits of fine-grained material, but the water-yielding potential of wells tapping the buried coarse sand or gravel cannot be determined from available data. Also, some potential for development may exist where the upper 30 to 60 feet of this unit are saturated and are composed of fine sand or coarser material. Potential well yields as high as 250 gal/min may be possible.

3) The water-yielding characteristics of stratified-drift deposits underlying many parts of Simsbury are unknown, owing to the lack of information on grain-size distribution and saturated thickness.

SUGGESTIONS FOR FUTURE STUDIES

The information in this report can be used to:

- Identify areas underlain by saturated coarse-grained stratified drift capable of providing large quantities of water for future public, industrial, or commercial supply.

- Develop the ability to accurately predict consequences of various natural or man-made stresses on the hydrologic system. Such predictive capability requires coordinated effort on a regional level. The hydrologic system extends beyond the boundaries of the Town of Simsbury and is, therefore, subject to the effects of water- or land-use activities in adjacent towns.

- Integrate hydrologic considerations into the development of land-use regulations to help ensure that the quality and quantity of ground water are not adversely affected.

As noted, hydrogeologic data in many parts of the study area is sparse or incomplete. In such areas, the information is inadequate for the intended uses. A program to provide the minimum hydrogeologic data required might include the following:

1) Collection of subsurface information in those areas where the water-bearing characteristics of stratified-drift deposits are largely unknown. Detailed plans for a carefully designed and flexible test-drilling program are a necessary part of the total program. Based on previous studies in Connecticut, an average density of approximately 10 test holes per square mile is adequate to provide the needed subsurface information. It is neither practical nor necessary, however, to drill holes at this density throughout the entire area. For example, areas with less than 10 feet of saturated thickness of stratified drift can be eliminated because they are generally considered inadequate for development of public- or industrial-supply wells. If a few test holes along the Farmington River valley between Avon and Tariffville fail to show that buried coarse-grained deposits are present, then the density of subsurface data needed to define the water-yielding capabilities of the aquifer could be significantly reduced.

Based on the present level of knowledge, future studies of the stratified drift could be concentrated in the following areas for the stated reasons:

- The stratified drift in the Farmington River valley between Avon and Tariffville, including the area in the vicinity of the Simsbury airport because of its large saturated thickness, proximity to the Farmington River, and its relatively undeveloped condition.

- The partially developed area west of the Farmington River near Hoskins because of the known saturated thickness of coarse-grained material.

- Stratton Brook valley, mostly upstream from the present Village Water Company well field, because of the potential for more than 40 feet of saturated coarse-grained material near the brook.

- Bissell Brook valley, north of Firetown Road, along the northern town line, because of the presence of coarse-grained material, a potential saturated thickness of more than 40 feet, and proximity to the brook that could be a source of induced recharge.

The following steps would provide the essential information and also reduce the costs of further evaluation of these areas: (1) obtain estimates of total footage from the bedrock contour map (plate 1) and confirm these estimates by seismic refraction profiling prior to any drilling; (2) drill holes to penetrate the entire section of unconsolidated material to bedrock and carefully collect samples of the subsurface materials; (3) analyze the grain-size distribution of the subsurface samples for estimation of the water-yielding properties of the stratified-drift aquifer; and (4) conduct short-term pumping tests and collect ground-water quality samples from selected wells installed during the test-drilling program.

2) Periodic monitoring of surface-water quality and collection of data on streamflow, stream-channel morphology, and streambed sediments.--Surface-water-quality data for streams such as Stratton and Bissell Brooks may be necessary because the stratified-drift aquifer is hydraulically connected to streams. Chemical, physical, and bacteriological analyses of samples from the streams taken under various flow conditions will indicate the quality of water available for induced recharge and perhaps the changes in ground-water quality. Streamflow and stage measurements, particularly during low-flow periods and data on stream-channel morphology and thickness, and grain-size composition of streambed sediments, can be used to make preliminary estimates of the degree of interconnection of the stream-aquifer system and the potential for induced recharge.

3) Development of a program for submission and storage of hydrogeologic data.--Hydrogeologic data that would contribute substantially to the Town's water-resources and land-use objectives include reliable well and test hole logs, samples of material from wells and test borings, pumping-test data, and information on water use, water quality, and waste disposal. Submission of logs and samples from test borings presently is not required by State or municipal agencies. Consequently, the available records are incomplete, and scattered among several agencies or individuals.

A systematic program to collect these data would help in assessing the water resources of the area. The more important hydrogeologic data requiring systematic collection are:

- Logs and samples of earth materials from all wells and test borings in areas of stratified drift with accurate locations of wells or test borings.

- Records of pumping tests on public-supply and industrial wells tapping stratified drift.

- Records of pumpage and water-level measurements in areas of large-scale ground-water withdrawal.

- Seismic-refraction profiles that produce useful hydrogeologic information, such as depth to the water table and depth to bedrock. In some cases, the extent of contamination plumes can be mapped by resistivity or electromagnetic geophysical techniques.

- Chemical, physical, and bacteriological analyses of ground and surface water.

- Location and description of sites in or adjacent to areas of stratified drift where liquid or solid wastes have been or are being disposed, including road-salt storage facilities. (Much of this information presently is collected by the Connecticut Department of Environmental Protection.)

4. Water-level measurements in observation wells.--Continuous or periodic water-level measurements in observation wells to determine head distribution in the aquifer and variation with time. The area within which ground water would move toward proposed centers of pumping and the direction and rates of ground-water movement could be estimated using these data and information on the transmissivity and hydraulic boundaries of the aquifer. Available information for the promising area near Hoskins and existing pumping centers would be enhanced by additional water-level data obtained from observation wells. The well-network could also be used to monitor changes in ground-water quality to help assure protection of the resource from contamination.

5. Collection and analysis of ground-water samples.--Available information is not adequate for determining areal and time variations in the quality of water in stratified-drift aquifers. This information could be developed by collecting and analyzing water samples from domestic and public-supply wells and from observation wells installed where conditions are favorable for future development. Analyses of water from observation wells may also aid in identifying areas where deterioration of water quality is attributable to disposal of wastes or other practices, such as highway deicing.

Predicting the Hydrologic Effects of Ground-water Development

The ability to predict the effects of stresses, such as pumping or prolonged drought, on a hydrogeologic system is a valuable aid to water-resources planning and management. Predicting the response of various elements of a hydrologic system to stresses often can be accomplished by developing a mathematical model of the aquifer. The conditions to be evaluated may be simulated in the model and a response observed. Digital computers are commonly utilized in simulation modeling and are capable of rapidly solving the flow equations that govern the behavior of the hydrologic system. The reliability of a model is determined by its ability to reproduce observed conditions; once calibrated and verified, it may be used to predict the hydrologic consequences of alternative management plans. The available data and the proposed data-collection program outlined in this report would provide most of the information required for constructing predictive models of the major stratified-drift areas in Simsbury. The models can be refined as additional data becomes available.

SUMMARY

Available hydrogeologic information is inadequate for quantitative determination of the long-term yield of the stratified-drift aquifer or the hydrologic effects of future development on streamflow and water levels. The potential yields of individual wells tapping this aquifer can be estimated at a few locations where transmissivity and saturated thickness are known or may be computed from existing subsurface data.

Data on the quality of water from the stratified drift is sparse and was not evaluated. It is probable that ground water can be used for most purposes, with only minor treatment. Complete chemical, physical, and biological analyses of samples from a larger number of sites would be required to fully assess the ground-water quality in the stratified drift.

The evaluation of hydrogeologic conditions, summarized on plates 2 and 3, indicates that stratified-drift deposits in Stratton Brook valley and the Farmington River valley near the community of Hoskins have the potential for large-scale development. These areas, as well as stratified-drift deposits in Bissell Brook valley and the Farmington River valley between Avon and Tarrifville, appear to warrant further study.

Additional hydrogeologic data will be required to: (1) fully identify the areas where the stratified-drift aquifer is capable of providing large quantities of water for future public or industrial supply, (2) identify areas where quality of ground water may be impaired by man's activities, and (3) predict the consequences of alternative water-development and management plans on the hydrologic system.

A suggested data-collection program is outlined, but development of a detailed program will depend on the amount of hydrologic information needed. Construction of a digital simulation model of the hydrogeologic system as a water-management tool is possible at any stage of data collection for some or all favorable areas. However, any model will be subject to the constraints of the data collected at the time.

SELECTED REFERENCES

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geological Survey Water-Supply Paper 1536-E, p. 69-174.

Fuss and O'Neill, 1979, Hydrogeologic basic data report, Power Forest area, Simsbury, Connecticut: Fuss and O'Neill Consulting Engineers, Manchester, Connecticut, duplicated report, 5 p., 2 plates.

____1981, Environmental and engineering report for inland wetlands and watercourses permit, The Hartford Life Insurance satellite data center facility , Exhibit B, Simsbury, Connecticut: Fuss and O'Neill Consulting Engineers, Manchester, Connecticut, duplicated report, 6 p., 55 boring log sheets.

Gregory, H. E., 1909, Underground water resources of Connecticut: U.S. Geological Survey Water-Supply Paper 232, 200 p.

Griswold and Fuss, Inc., 1976, Sanitary landfill feasibility study for Town of Simsbury, Connecticut: Griswold and Fuss Consulting Engineers and Surveyors, Manchester, Connecticut, duplicated report, 53 p., 11 plates, 8 appendices.

Handman, E. H., 1974, Contour map of the bedrock surface, Tariffville Quadrangle, Connecticut-Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF-512C.

Handman, E. H., and Ryder, R. B., 1973, Contour map of the bedrock surface, Avon Quadrangle, Connecticut: U.S. Geological Survey Miscellaneous Field Studies Map MF-514A.

Handman, E. H., and Schnabel, R. W., 1973, Depth to bedrock, Avon Quadrangle, Connecticut: U.S. Geological Survey Miscellaneous Field Studies Map MF-514B.

Hopkins, H. J., and Handman, E. H., 1975, Hydrogeologic data for the Farmington River basin: Connecticut Water Resources Bulletin No. 28, 49 p.

Mazzaferro, D. L., Handman, E. H., and Thomas, M. P., 1978, Water resources inventory of Connecticut, part 8, Quinnipiac River basin: Connecticut Water Resources Bulletin No. 27, 88 p.

Palmer, H. S., 1921, Ground water in the Southington-Granby area, Connecticut: U.S. Geological Survey Water-Supply Paper 466, 219 p.

Pessl, Fred, Jr., 1973a, Unconsolidated materials, Tariffville Quadrangle, Connecticut: U.S. Geological Survey Miscellaneous Field Studies Map MF-512A.

_____1973b, Resources of coarse aggregrate, Tariffville Quadrangle, Connecticut: U.S. Geological Survey Miscellaneous Field Studies Map MF-512B.

Radway, J. A., and Schnabel, R. W., 1976, Unconsolidated materials, Avon Quadrangle, Connecticut: U.S. Geological Survey Miscellaneous Field Studies Map MF-514C.

Randall, A. D., 1964a, Geology and ground water in the Farmington-Granby area, Connecticut: U.S. Geological Survey Water-Supply Paper 1661, 130 p.

_____1964b, Records and logs of selected wells and test borings, records of springs, and chemical analyses of water in the Farmington-Granby area, Connecticut: Connecticut Water Resources Bulletin No. 3, 25 p.

_____1970, Surficial geology of the Tariffville Quadrangle, Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ-798.

Ryder, R. B., Thomas, M. P., and Weiss, L. A., 1981, Water resources inventory of Connecticut, part 7, upper Connecticut River basin: Connecticut Water Resources Bulletin No. 24, 78 p.

Schicht, R. J., and Walton, W. C., 1961, Hydrogeologic budgets for three small watersheds in Illinois: Illinois State Water Survey Report of Investigations 40, 40 p.

Schnabel, R. W., 1960, Bedrock geology of the Avon Quadrangle, Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ-134.

_____1962, Surficial geology of the Avon Quadrangle, Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ-147.

Schnabel, R. W., and Eric, J. H., 1965, Bedrock geologic map of the Tariffville Quadrangle, Hartford County, Connecticut and Hampden County, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ-370.

Thomas, M. P., and Adams, P. A., 1977, Map showing drainage areas, Tariffville Quadrangle, Connecticut: U.S. Geological Survey Miscellaneous Field Studies Map MF-512D.

Thomas, M. P., and Melvin, R. L., 1977, Map showing drainage areas, Avon Quadrangle, Connecticut: U.S. Geological Survey Miscellaneous Field Studies Map MF-514D.

U.S. Geological Survey, 1970, Water resources data for Connecticut, Part 1-3: U.S. Geological Survey, 206 p.

_____1971, Water resources data for Connecticut, Part 1-3: U.S. Geological Survey, 273 p.

_____1972, Water resources data for Connecticut, Part 1-3: U.S. Geological Survey, 266 p.

Bedrock: Solid rock, commonly called "ledge," that is locally exposed at the land surface but more commonly is buried beneath a few inches to as much as 400 feet of unconsolidated deposits.

Flow duration, of a stream: The percentage of time during which specified daily discharges were equaled or exceeded in a given period. Based on daily flows ordered by magnitude not chronologic.

Ground water: Water in the saturated zone from which wells, springs, and ground-water runoff are supplied.

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

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

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

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

Ground-water recharge: The amount of water that reaches the saturated zone.

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

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 common types of boundaries are termed impermeable-barrier boundaries and line-source boundaries.

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

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

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

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. The significant hydraulic feature is that ideally no ground water flows across this boundary.

Induced infiltration: The process by which water moves into an aquifer from an adjacent surface-water body in response to the decline in head under the stream due to pumping.

Induced recharge: The 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 that is hydraulically connected to an adjacent aquifer. Ideally there is no drawdown along such a boundary.

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

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

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

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

Stratified drift: A dominantly sorted sediment laid down by or in melt-water from a glacier; includes sand, gravel, silt, and clay, arranged in layers.

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

Transmissivity: The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient. Equal to the average hydraulic conductivity times the saturated thickness. Expressed in units of square feet per day.

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

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

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

Water table: The upper limit of the saturated zone.