Streamflow Augmentation at Fosters Brook, Long Island, New York— A Hydraulic Feasibility Study

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Prepared in cooperation with the Nassau County Department of Public Works and the Suffolk County Department of Health Services

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By KEITH R. PRINCE

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Streamflow Augmentation at Fosters Brook, Long Island, New York— A Hydraulic Feasibility Study

By Keith R. Prince

Abstract

A 27-day streamflow augmentation test was conducted in December 1979 at Fosters Brook, near the south shore of Long Island, to investigate the hydraulic feasibility of pumping ground water to supply flow to an ephemeral stream during dry periods.

Measurements of soil moisture in the unsaturated zone beneath the streambed indicate that infiltration rate and soil-moisture content are interrelated. Initial infiltration was measured with a neutron logger; the wetting front traversed the unsaturated zone at an average of 11.2 inches per hour and reached the water table in 5.5 hours. Soil moisture in the unsaturated zone ranged from 20 percent at the start of the test to nearly 41 percent, nearly the saturation point, 20 days later.

Stream discharge was measured at four sites along the stream channel, and the augmentation rate was monitored continuously at the starting point. Infiltration rates increased steadily in all reaches during the first 12 days of the test, but from the 12th to the 20th day, when discharge was increased by 50 percent, infiltration rates decreased along the two upstream reaches but continued to increase along the three downstream reaches. Infiltration rates remained constant from days 20 through 26.

During the first 24 hours of the test, the stream reached a maximum length of 2,050 feet, but after 13 days, it had shortened to 1,300 feet as a result of seepage losses. The relationship between discharge and stream length was linear within the range of discharge investigated (0.54–1.63 cubic feet per second).

Ground-water levels rose in response to flow augmentation and reached a maximum rise of about 6.5 feet in a well situated 14 feet from the center of the streambed and 225 feet downstream from the start of the flow. Measured water-level response was compared to levels predicted by a one-dimensional analytical model and a three-dimensional mathematical model; results indicate that ground-water response is determined principally by streambed characteristics and soil-moisture content in the unsaturated zone.

Variations in water temperature and in streambed composition had significant effects upon infiltration rates. Changes in water temperature, amount of vegetation, soil-moisture content, and stream stage, combined with local variations in streambed permeability and aquifer conductivity, make accurate prediction of seepage rates virtually impossible at present. Data from this study suggest that site-specific investigations are necessary wherever streamflow augmentation is planned.

INTRODUCTION

The continued rapid population growth on Long Island since the end of World War II has caused concern among the island's planners and water managers over the continued availability of an adequate supply of potable water. Because all freshwater for domestic and industrial use in the central and eastern part of the island (Nassau and Suffolk Counties) (fig. 1) is obtained from the ground-water reservoir, the purity of this resource should be safeguarded. In an effort to minimize contamination of ground water by septic waste, sanitary-sewer systems have been constructed in parts of both counties and are planned for most of the remaining areas.

Before construction of sanitary sewers, wastewater was returned to the shallow aquifer through cesspools and septic tanks and thereby caused little net draft on the ground-water system. However, the large-scale implementation of sewers that carry many millions of gallons of wastewater per day to treatment plants and the ocean has caused a significant loss of recharge to the aquifer system. In southwestern Nassau County, where sewers began operation in 1952 and became fully operational by 1964, water levels and streamflow have declined markedly (Franke, 1968; Garber and Sulam, 1976; Pluhowski and Spinello, 1978). An analog model used by the U.S. Geological Survey to simulate the long-term local and regional effects of sewerage indicates that, after 20 years of sewer operation, the water table may decline as much as 20 ft in east-central Nassau County and that streamflow on

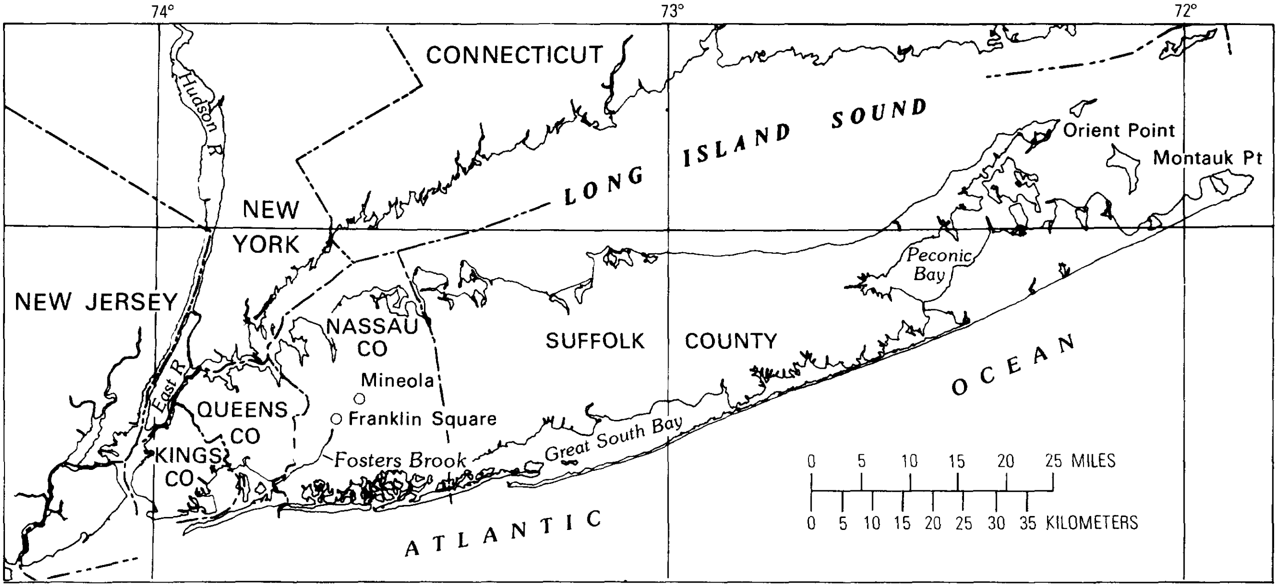

Figure 1. Location of Fosters Brook, Nassau County, N.Y.

southern Long Island will be reduced, on the average, to approximately 40 percent of its 1975 volume (Kimmel and others, 1977).

Decreased water levels and reductions in streamflow will reduce the amount of freshwater discharged through streams to the south-shore bays, which in turn could cause an increase in bay salinity and reduce the productivity of Long Island's large shellfish industry. Furthermore, the likelihood that the upper reaches of some streams may become permanently dry will have detrimental effects on the aesthetic and recreational value of some of the island's wetlands and parks and on its wildlife. These issues have created a need to investigate means to offset the undesirable effects of a lowered water table. One of several methods that have been proposed is streamflow augmentation with pumped ground water or highly treated wastewater.

Purpose and Scope

The effects of sanitary sewers on Long Island's hydrologic environment have been well documented. Several approaches to minimize these effects have been suggested, one of which is streamflow augmentation, whereby water pumped from the ground-water reservoir or, if available, highly treated wastewater (reclaimed water) is discharged into a dry-stream reach to provide streamflow.

The purpose of this report is to describe a study of the hydrologic feasibility of using pumped ground water to augment streamflow in a Nassau County stream that has become dry as a result of lowered ground-water levels. The report investigates the relationship between induced flow and (1) stream length, (2) infiltration rates, (3) ground-water levels, (4) soil moisture in the unsaturated zone during recharge, and (5) grain-size distribution of streambed sediment. In addition, results of analytical computations and computer simulation are compared with field observations to reveal the major factors that control infiltration rate and to help delineate their complex relationship. The testing period covered 27 days from November 30 to December 26, 1979. Augmentation was conducted at three different rates to investigate the hydrologic processes under a variety of stress conditions. Water was provided at a constant rate of 1.00 ft^3/s during the first 13 days, 1.64 ft^3/s during the next 8 days, and 0.54 ft^3/s during the last 6 days.

Acknowledgments

The author is indebted to Michael Pender and his staff at the Nassau County Department of Public Works for assistance in site selection and operations, to the Franklin Square Water District for supplying water during a part of the flow augmentation test, and to R. E. Wright Associates for support in field operations.

LOCATION AND DESCRIPTION OF AREA STUDIED

The streamflow augmentation test was conducted at Fosters Brook, an ephemeral stream near Franklin Square, southwest Nassau County (fig. 2). The area is suburban and surrounded by moderately to densely grouped single-family houses.

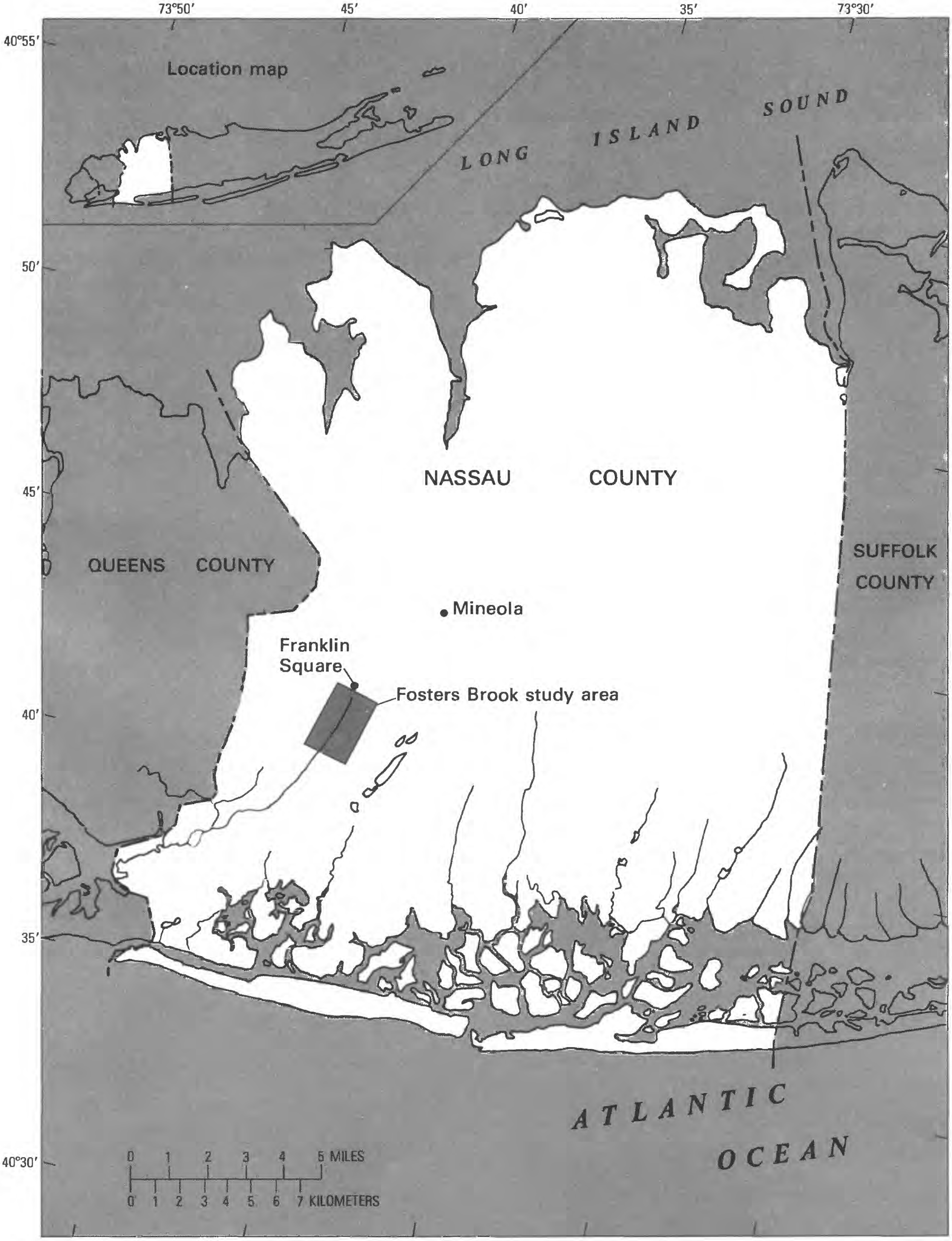

Figure 2. Location of reach studied on Fosters Brook.

Franklin Square and nearby communities have had sanitary sewers since the early 1960's so that the local hydrologic regime exemplifies conditions that could prevail elsewhere after sewers have been in operation for several years. Fosters Brook was a perennial stream before the installation of sanitary sewers in the area but has since become dry over most of its length as a consequence of the lowered ground-water levels. Only during storms does the stream flow, and this flow consists almost entirely of direct runoff that enters the stream channel through storm drains from paved areas such as streets and parking lots.

The hydrogeology of Long Island has been described in several reports such as those by Cohen and others (1968) and McClymonds and Franke (1972); a detailed description of southwest Nassau County is given in Perlmutter and Geraghty (1963).

The lithology and water-bearing characteristics of the major hydrologic units beneath southwestern Nassau County are listed in table 1. The hydrologic system of the area can be characterized as an unconsolidated, southward-dipping, wedge-shaped unit containing three major aquifers and several confining units, as shown in figure 3. The deepest unit is crystalline bedrock, which yields insignificant amounts of water and is therefore regarded as the bottom of the ground-water reservoir. Overlying the bedrock is the Lloyd aquifer, a secondary source of public-supply water. Above the Lloyd aquifer is the Raritan clay, a confining unit that separates the Lloyd from the primary source of water, the Magothy aquifer. The Magothy aquifer, which includes scattered clay lenses that create local semiconfining units, is the major source of public-supply water on the island. Overlying the Magothy aquifer is the upper glacial (water-table) aquifer composed of glacial outwash. As the uppermost water-bearing unit, it is the aquifer of concern in this study.

In southwest Nassau County, the upper glacial aquifer consists mainly of highly permeable outwash deposits and contains large quantities of water. Porosity of the deposits typically ranges from 30 to 40 percent, and individual wells have been reported to have a specific capacity as high as 109 gal/min/ft (Perlmutter and Geraghty, 1963).

TEST DESIGN AND PROCEDURES

To determine the effectiveness of supplementing streamflow with pumped ground water, a detailed data-collection system was devised to provide records on surface-water discharge, ground-water levels, soil moisture,

Table 1. Characteristics of major hydrogeologic units of the ground-water reservoir underlying Long Island, N.Y.
[Modified from Cohen and others, 1968]

Unit	Geologic name	Approximate maximum thickness (ft)	Water-bearing character
Upper glacial aquifer	Upper Pleistocene deposits	400	Mainly sand and gravel of moderate to high permeability; also includes clayey till of low permeability.[1]
Gardiners Clay	Gardiners Clay	150	Clay, silty clay, and some fine sand of low to very low permeability.
Jameco aquifer	Jameco Gravel	200	Mainly medium to coarse sand of moderate to high permeability.
Magothy aquifer	Magothy (?) Formation	1000	Coarse to fine sand of moderate permeability; locally contains gravel of high permeability and abundant silt and clay of low to very low permeability.
Raritan clay	Clay member of the Raritan Formation	300	Clay of very low permeability; some silt and fine sand of low permeability.
Lloyd aquifer	Lloyd Sand Member of the Raritan Formation	300	Sand and gravel of moderate permeability; some clayey material of low permeability.

[1]Permeability denotes how readily water can move through porous material.

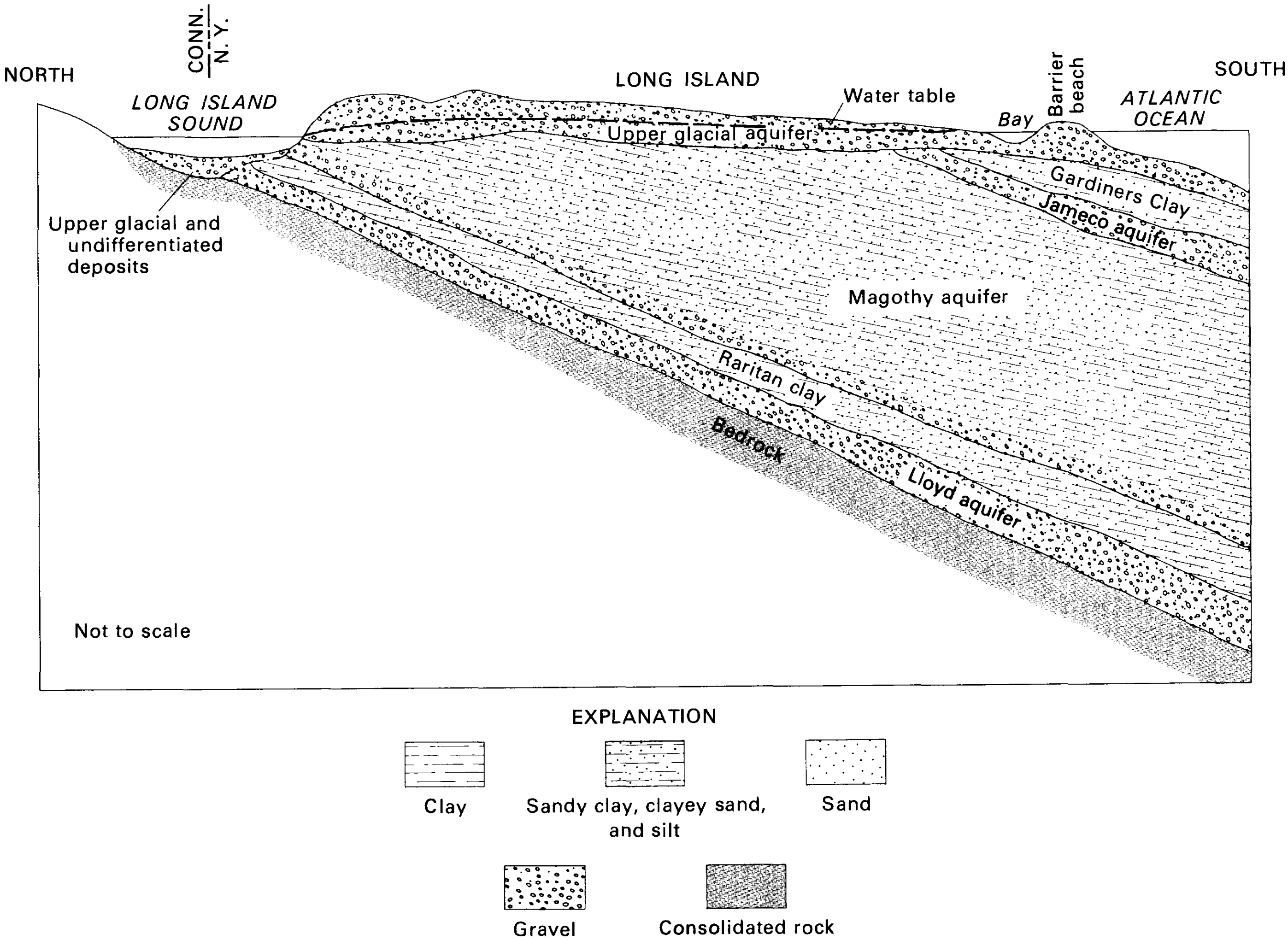

Figure 3. Generalized geologic cross section of Long Island (from McClymonds and Franke, 1972, p. 54).

water quality, and streambed composition. Streamflow was measured periodically throughout the test at four sites, and water-level measurements were made concurrently to determine the relationship between streamflow and ground water.

Surface Water

Most of the water for stream augmentation was pumped from a shallow well tapping the upper glacial aquifer about 2,000 ft north of the study site, far enough to avoid significant influence on ground-water movement near the stream. The supply well was screened from 55 to 73 ft below land surface. Additional water was obtained from Franklin Square Water District near the pump site. The water was transmitted through underground storm drains into Fosters Brook. Discharge was measured both at the pump site and at the storm-drain discharge; comparison of values indicated no measurable loss of water through pipe leakage.

Three rates of streamflow augmentation were scheduled to be used during the test: 0.50, 1.00, and 1.50 ft^3/s. Because of difficulty in regulating the pumping well, the actual values of augmentation were 0.54, 1.00, and 1.63 ft^3/s. Furthermore, because the capacity of the supply well was approximately 1.00 ft^3/s, an additional 0.64 ft^3/s was obtained from the fire hydrant near the pump site. As the water for augmentation exited the storm drain, it flowed through a 9-in wide by 15-in high Parshall flume. This, combined with an analog stage recorder, enabled continuous monitoring of the rate of augmentation. From there the water flowed over a 50-ft concrete apron and into the Fosters Brook stream channel (fig. 4).

During the test, streamflow and stage were measured at regular intervals at four additional sites spaced 300, 678, 1,159, and 1,929 ft from the start of flow (fig. 4). Stage was measured with a staff gage; discharge was measured with current meters and wading rods. At the site farthest downstream (which varied, depending on length of stream at the time of measurement), discharge was measured with a portable 3-in wide Parshall flume

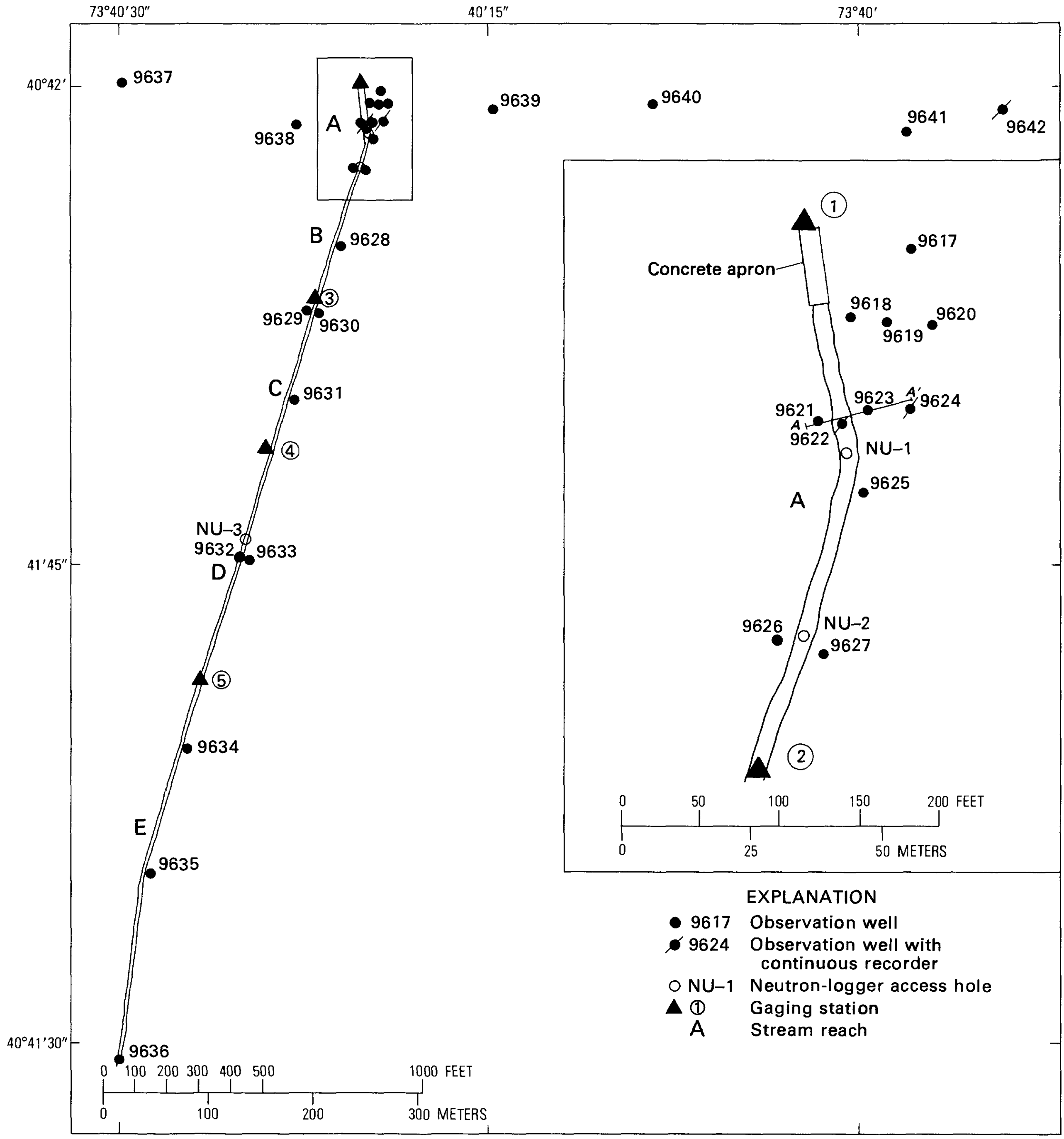

Figure 4. Location of observation wells, discharge-measurement sites, neutron-logger access holes, and water-quality sampling sites. (The location of area is shown in fig. 2.)

whenever flow was low enough to avoid creating an artifically high stage. (If stage were raised by the flume, infiltration rates in the area would be altered by the higher hydraulic head.)

Because the length of a wetted channel of constant width is proportional to the average rate of infiltration of stream water into the aquifer, the length of wetted channel was measured at least once a day during the test and more often when the channel length was changing rapidly.

Flow in the Unsaturated Zone

When flow augmentation was begun, the water table was between 5 and 10 ft beneath the streambed throughout the area. As water seeps through a streambed and moves downward to the water table, it flows through a zone of unsaturated material that to some extent determines the rate of seepage through the streambed. (The relative position of the streambed, the unsaturated zone, and the water tables is depicted in fig. 5.) Analysis of flow through the unsaturated zone indicates that both moisture content and hydraulic conductivity of the material are functions of pressure head. (Soil moisture is held between the soil grains by surface tension; higher moisture content causes lower surface tension and less negative pressure head, so the reduced tension allows water to move between the soil grains more freely. Thus the greater the pressure head, the faster will be the infiltration through the unsaturated zone.)

Because soil-moisture content plays an important role in the rate of infiltration through the unsaturated zone, a soil-moisture measurement system was incorporated into the data-collection network. Soil moisture was measured directly beneath the streambed at sites 210, 325, and 1,465 ft downstream from the start of flow (fig. 4) with a neutron logger that provided a graph of soil moisture with depth. (Neutron loggers measure soil moisture with a probe containing a radiation source that produces fast neutrons and detectors that are sensitive to slow neutrons. As the fast neutrons from the probe radiate out into the soil and become scattered and slowed, some are reflected back to the detectors. Because the quantity of neutrons that become slowed depends primarily upon the moisture content of the soil, the rate at which "slow neutrons" reach the detectors can be interpreted as the concentration of soil moisture. Examples of soil-moisture logs are given in fig. 9 and are discussed in the "Soil Moisture" section.)

Ground Water

Streamflow augmentation where the water table is below streambed altitude is "strip recharge," which in time produces a rise in ground-water level beneath the streambed. This rise, or mound, will increase in height until a new equilibrium is reached at which the rate of ground-water movement away from the mound is equal to the rate of recharge to the mound. The height and areal extent of ground-water mounding was important to this study for two main reasons: (1) If the mound were to rise high enough it could cause local flooding in adjacent low-lying areas and in basements of buildings constructed since the stream originally went dry, and (2) the data provided a basis for use in analytical and mathematical models to predict the effects of a variety of stresses on infiltration rates.

The ground-water data-collection network consisted of 26 wells screened between 5 and 10 ft below the regional water table. (Locations are shown in fig. 4.) Three wells (N 9622, N 9632, and N 9636) were drilled in the

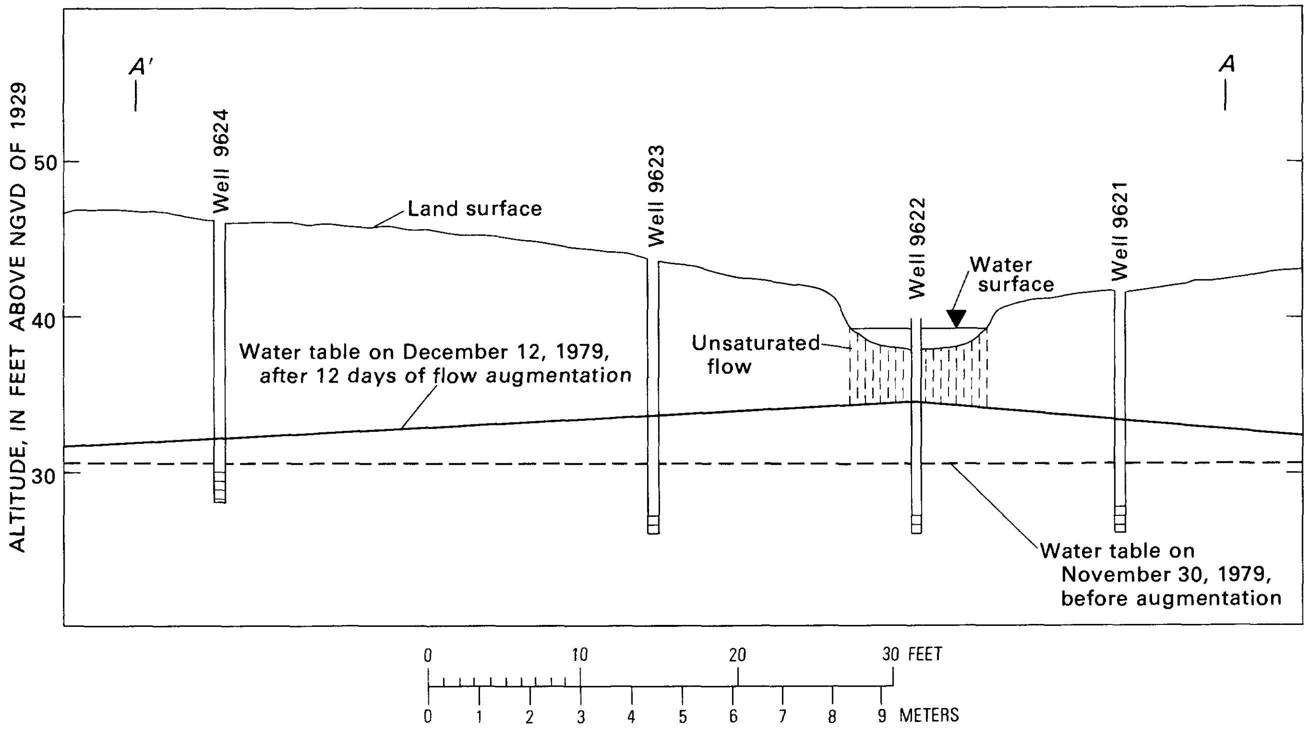

Figure 5. Relative position of the streambed, the unsaturated zone, the observation-well screens, and the water-table altitude on November 30, 1979, just before streamflow augmentation, and on December 12, 1979, after 13 days of flow at 1.00 ft^3/s. (The location of section is shown in fig. 4.)

center of the stream channel to monitor the water table beneath the infiltration area and to determine whether the water table would rise and intersect the stream channel during the test.

All wells were measured by the wetted tape method at regular intervals concurrently with stream-discharge measurements. In addition, three wells (N 9622, at the streambed; N 9624, 45 ft east of N 9622; and N 9642, 2,000 ft east of the start of flow) were equipped with continuous recorders to allow continuous monitoring of water levels. Well N 9642 was used to monitor regional trends beyond the affected areas and to provide a baseline for data analysis.

RESULTS OF STREAMFLOW AUGMENTATION

Surface-Water Response

Stream-discharge measurements were obtained to determine surface-water losses between gaging stations so that the areal and temporal variation in infiltration rates could be estimated, and linear regression analyses of the discharge measurements were done to determine trends. (Discharge values are listed in table 2.) Figure 6 depicts linear regression plots of discharge at each measurement site during augmentation rates of 1.00 and 1.63 ft^3/s. Regression analysis was not necessary for the 0.54 ft^3/s rate because flow was measurable only at site 1, where the Parshall flume provided high accuracy and resulted in relatively little scatter in the data.

During the first 13 days of the test, when augmentation rate was constant at 1.0 ft^3/s, stream discharge at each site decreased through time, as was evidenced by the downward slope of the regression line in figure 6*A*. This indicates that infiltration rates were increasing with time and that discharge was decreasing by a corresponding amount in each successive reach. The initial rapid increase in infiltration rates resulted partly from the increase in soil-moisture content and the corresponding increase in hydraulic conductivity in the unsaturated zone. The channel at site 5, the farthest downstream, became dry during the second day of the test as a consequence of increased seepage loss.

Water Temperature

During the second part of the test, December 13–20, in which the augmentation rate was constant at 1.63 ft^3/s, a greater percentage of the flow reached sites 2 and 3 than during the first part of the test (fig. 6*B*). The discharge regression lines for sites 2 and 3 have a positive slope; that is, discharge was increasing with time, which indicates a reduction of infiltration rate into the streambed. In contrast, the regression lines for sites 4 and 5 have a small negative slope, which indicates that discharge was still decreasing and that infiltration rates were increasing.

These trends could be real or may merely reflect the large variation inherent in current-meter measurements. If the trends are real, the increase in discharge at sites 2 and 3 could have been caused by a decrease in water temperature, which would retard infiltration rate. Water that was used to supplement flow in the second part of the test was obtained from Franklin Square Water District and is assumed to have been colder because it was transmitted

Table 2. Stream discharge at four sites at Fosters Brook, November 30–December 24, 1979
[All values are in cubic feet per second]

Date	Time	Measurement site[1] 2	3	4	5
Nov. 30	1600	0.84	0.75	0	0
	1800	0.87	0.79	0	0
	2100	1.0	0.69	0.39	0.02
	2300	0.94	0.70	0.38	0.10
Dec. 1	0200	0.94	0.72	0.36	0.11
	0500	0.94	0.75	0.40	0.10
	0700	0.90	0.71	0.39	0.09
	1000	0.95	0.81	0.49	0.05
	1300	0.99	0.84	0.49	0.01
	1600	0.93	0.75	0.36	0
	1900	0.94	0.79	0.47	0
	2100	0.93	0.67	0.38	0
Dec. 2	0030	0.88	0.67	0.40	0
	0400	0.92	0.68	0.40	0
	0700	0.91	0.65	0.39	0
	1000	0.92	0.73	0.52	0
	1300	0.92	0.66	0.41	0
	1600	0.93	0.68	0.44	0
	1900	0.90	0.68	0.28	0
	2100	0.84	0.67		0
Dec. 3	0030	0.87	0.65	0.34	0
	0400	0.84	0.66	0.31	0
	0700	0.88	0.53	0.31	0
	0900	0.93	0.73	0.29	0
	1400	0.89	0.76	0.27	0
	1800	0.81	0.73	0.39	0
	2100	0.83	0.76	0.32	0
Dec. 4	0100	0.83	0.67	0.30	0
	0500		0.68	0.30	0
	0900	0.82	0.68	0.26	0
	1300	0.80	0.63	0.26	0
	1700	0.81	0.62	0.30	0
	2100	0.80	0.53	0.28	0

Table 2. Stream discharge at four sites at Fosters Brook, November 30–December 24, 1979—Continued

Date	Time	Measurement site[1]			
		2	3	4	5
Dec. 5	0100	0.83	0.43	0.28	0
	0500	0.78	0.49	0.25	0
	0900	0.79	0.53	0.23	0
	1400	0.70	0.54	0.24	0
	1700	0.80	0.52	0.29	0
	2100	0.80	0.60	0.27	0
Dec. 6	0100	0.81	0.54	0.24	0
	0500	0.76	0.55	0.24	0
	0900	0.78	0.57	0.23	0
	1300	0.74	0.53	0.21	0
	1600	0.77	0.59	0.26	0
Dec. 7	0500	0.76	0.55	0.34	0
	0900	0.79	0.56	0.27	0
	1300	0.78	0.57	0.22	0
	1700	0.81	0.56	0.22	0
	2000	0.77	0.56	0.20	0
Dec. 8	0100	0.76	0.56	0.21	0
	0600	0.74	0.53	0.21	0
	0900	0.70	0.57	0.21	0
	1300	0.72	0.49	0.21	0
	1600	0.70	0.47	0.25	0
	2100	0.72	0.42	0.21	0
Dec. 9	0100	0.71	0.45	0.18	0
	0500	0.68	0.39	0.18	0
	0900	0.72	0.42	0.19	0
	1300	0.67	0.40	0.17	0
	1700	0.71	0.33	0.21	0
	2100	0.69	0.32	0.18	0
Dec. 10	0100	0.67	0.37	0.17	0
	0600	0.64	0.41	0.17	0
	0900	0.70	0.50	0.17	0
	1300	0.74	0.52	0.18	0
	1700	0.70	0.52	0.17	0
	2100	0.73	0.51	0.16	0
Dec. 11	0100	0.74	0.53	0.16	0
	0500	0.78	0.51	0.15	0
	0900	0.70	0.48	0.15	0
	1300	0.68	0.49	0.15	0
	1700	0.72	0.49	0.15	0
	2100	0.72	0.51	0.15	0
Dec. 12	0030	0.72	0.47	0.15	0
	0500	0.72	0.49	0.15	0
	0900	0.74	0.50	0.14	0
	1600	1.4	1.2	0.78	0.23
	1900	1.4	1.1	0.80	0.27
	2100	1.4	1.1	0.80	0.22

Table 2. Stream discharge at four sites at Fosters Brook, November 30–December 24, 1979—Continued

Date	Time	Measurement site[1]			
		2	3	4	5
Dec. 13	0030	1.4	1.1	0.75	
	0900	1.6	1.3	0.94	0.26
	2300	1.4	1.2	0.77	0.23
Dec. 14	0200	1.4	1.2	0.80	0
	0600	1.4	1.2	0.74	0
	1000	1.4	1.2	0.80	0.22
	1400	1.5	1.2	0.78	0.21
	1700	1.3	1.2	0.77	
	2100	1.4	1.2	0.72	0.21
Dec. 15	0030	1.4	1.2	0.80	0.21
	0500	1.5	1.3	0.63	0.19
	0900	1.7	1.4	0.89	0.18
	1300	1.4	1.4	0.88	0.18
	1700	1.6	1.4	0.81	0.18
	2100	1.4	1.3	0.75	0.18
	2330	1.3	1.2	0.80	0.18
Dec. 16	0600	1.4	1.4	0.73	0.18
	0900	1.5	1.3	0.92	
	1300	1.5	1.4	0.81	
	1700	1.5	1.2	0.79	
Dec. 17	1000	1.5	1.3	0.74	0.19
	1300	1.5	1.2	0.78	0.18
	1700	1.6	1.2	0.71	0.18
	2300	1.6	1.3	0.68	0.21
Dec. 18	0600	1.6	1.2	0.70	0.20
	0900	1.5	1.4	0.77	0.18
	1300	1.5	1.3	0.76	0.18
	1800	1.5	1.3	0.69	0.18
Dec. 19	0900	1.5	1.3	1.0	0.18
	1300	1.5	1.3	0.75	0.18
	1700	1.5	1.3	0.74	0.18
Dec. 20	1010	1.4	1.3	0.79	
Dec. 21	0850	0.10	0	0	0
Dec. 22	1025	0.22	0	0	0
Dec. 23	0100	0.20	0	0	0
	0800	0.20	0	0	0
Dec. 24	0035	0.20	0	0	0
	1230	0.29	0	0	0
	1851	0.30	0	0	0

[1]Site locations are shown in figure 4.

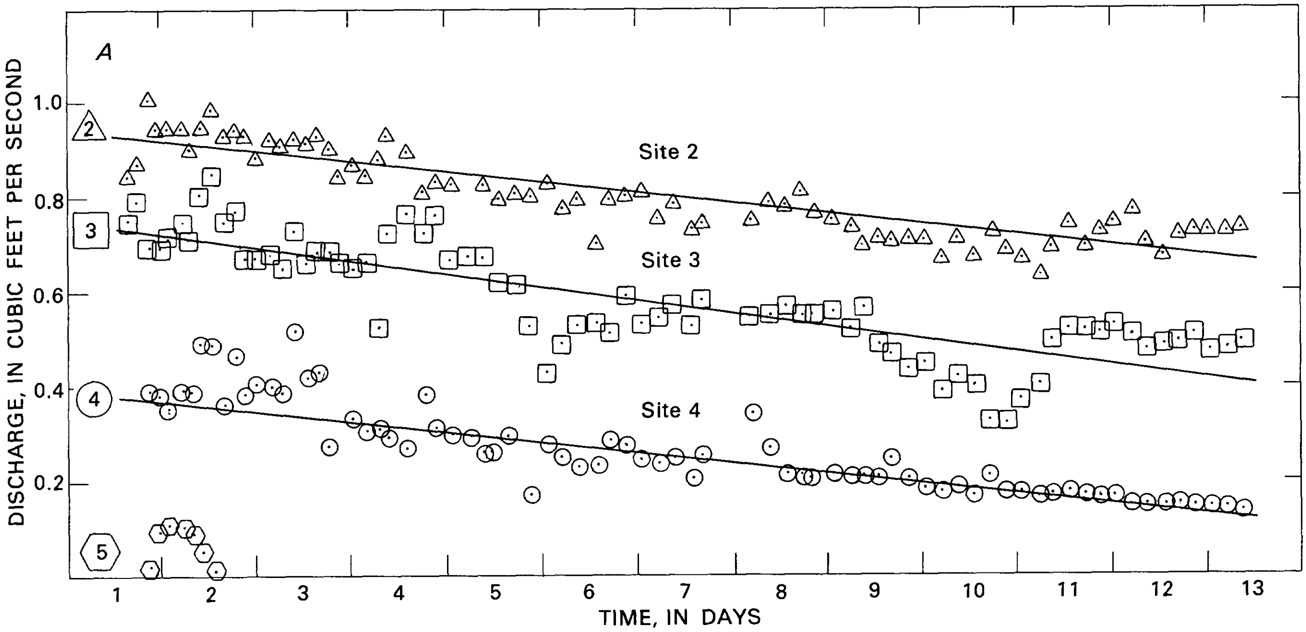

Figure 6. Linear regression of stream discharge *(A)* at three sites during flow augmentation at 1.00 ft³/s, November 30–December 12, 1979 and *(B)* at four sites during flow augmentation at 1.63 ft³/s, December 12–20, 1979. (Site locations are shown in fig. 4.)

through pipes lying near land surface, probably within 10 ft, where it would have been cooled by the winter air temperature. In contrast, water pumped from the well installed for this study would have been warmer because the local water table was approximately 25 ft below land surface and was less susceptible to winter cooling. (Effects of water temperature are covered in detail in a later section, "Temperature.")

If the water mixed from two sources were indeed cooler during the second part of the test than during the first, infiltration rates would decrease as a result of the greater viscosity of the water and streamflow would decrease less rapidly. Moreover, because the water was warmer than the winter air, it would be cooled as it moved downstream and would produce still lower infiltration rates in the downstream reaches--a pattern not fully supported by the data. Table 3 gives data on average infiltration rates for all reaches during each test period and average infiltration rates for the entire test. Infiltration rates in each reach were calcuated as follows. First, linear regression analyses of the discharge data for each reach and each augmentation rate were done to obtain a discharge value for the middle day of each test period and each reach. Seepage losses for each reach were then calculated for each augmentation rate by determining the difference in stream discharge at successive downstream sites. The seepage-loss values of each reach were then divided by the approximate area of wetted channel to yield an average infiltration rate per unit area. Comparison of infiltration rates (table 3) reveals that they differed widely from reach to reach, with no consistent trend toward higher infiltration rates in the upper reaches. For example, the infiltration rate on December 16 in reach A was 4.43 ft/d and in reach C it was 8.81 ft/d, 99 percent higher. Infiltration rates in reach C also clearly reflected the change in augmentation rate; for example, the infiltration rate on December 6 (discharge 1.00 ft³/s) was 5.56 ft/d and on December 16 (discharge 1.64 ft³/s) it was 8.81 ft/d (table 3), an increase of 58 percent.

These examples are extreme but are cited to indicate the variability of infiltration rates during the test and also the potential for error in interpreting discharge data. Infiltration rates may vary along the stream for a number of other reasons; for example, pools and riffles having large differences in stream stage would produce local areas of high and low infiltration rate, and local variations in streambed composition would also cause local differences in infiltration rate. Thus, water temperature alone was probably not a major cause of spatial or temporal variation in the infiltration rate at Fosters Brook; this variation probably resulted from a combination of several factors, of which temperature was only one component.

Wetted Channel Length

A further indicator of average infiltration rates over the entire stream is total length of wetted channel. Stream length (distance from augmentation site to beginning of dry channel) was measured daily during the test period and is plotted in figure 7. Thirteen hours after augmentation began on November 30 (1.00 ft³/s), stream length had

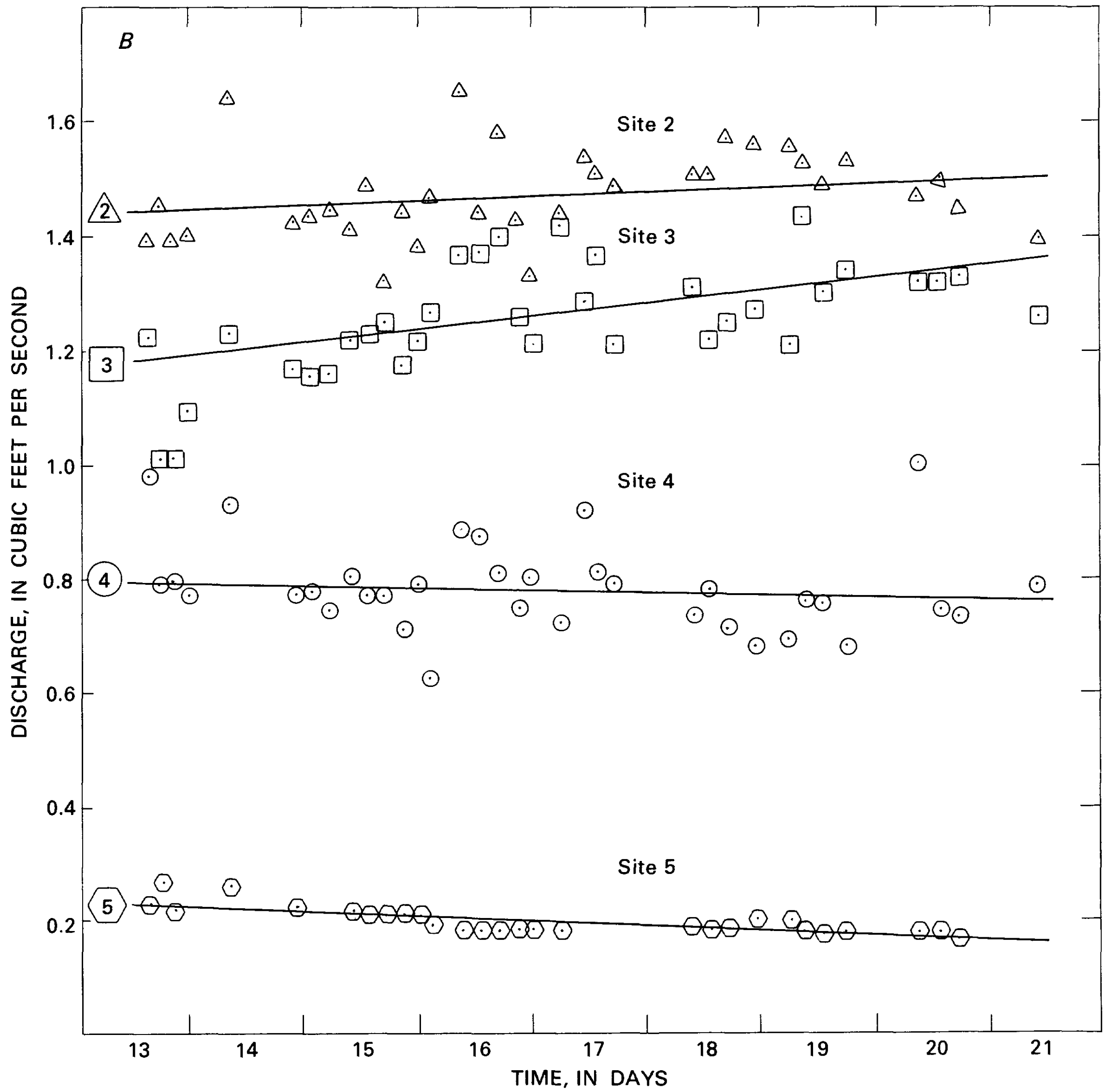

Figure 6. Linear regression of stream discharge —Continued

reached 2,050 ft. Thereafter it gradually shortened and by December 12 was only 1,300 ft, a 36-percent decrease as a result of increasing infiltration rate. Similarly, when the augmentation rate was increased to 1.63 ft^3/s on December 12, the stream extended to 2,719 ft, but by December 20, it had decreased to 2,154 ft. On December 20, augmentation rate was reduced to 0.54 ft^3/s, and that day the stream shortened to 815 ft and remained at that length until the test ended on December 26.

Duration of Wetting

The distribution of data points for the first two periods of the test (fig. 7) indicates two distinctly different hydrologic regimes. When the channel was initially wetted, infiltration rates, as indicated by stream length, increased in response to increasing soil-moisture levels, less entrapped air in the unsaturated zone, and surface wetting. As a result, stream length shortened quickly. After a few days, however, the stream length began to stabilize as the factors controlling infiltration rates approached equilibrium. The similarity of regression slope for days 1–6 with that for days 15–17 reflects this tendency, and the same is true of the curves for days 6–13 and days 17–20. The number of days from the time augmentation began (or was increased) until the break in slope was about 5 days in both tests; the break in slope reflects the stabilization of some major factor(s) controlling seepage rates from the stream, most notably soil moisture in the unsaturated zone.

As was stated previously, stream length during the first two periods of the test (1.00 and 1.63 ft^3/s) decreased rapidly then more gradually, but during the last part of the test remained constant. The major controlling factor would seem to be the wetting and saturation of the streambed and

Table 3. Infiltration rates calculated from linear regression for five stream reaches at Fosters Brook in December 1979
[Location of reaches and sites is shown in fig. 4]

Date (discharge, ft³/s)	Infiltration rate (ft/d) Reach A	Reach B	Reach C	Reach D	Reach E	Average of all reaches (ft/d)
Dec. 6---- (1.00)	5.62	5.04	5.56	5.77	Dry	5.50
Dec. 16--- (1.63)	4.43	4.77	8.81	6.54	4.46	5.80
Dec. 23--- (0.54)	5.64	5.77	Dry	Dry	Dry	5.70
Average --	5.23	5.19	7.18	6.16	4.46	5.67

material beneath it. At the beginning of the test and at the start of the second test period, a long channel length (greater than 1,000 ft) was being wetted for the first time in several days, whereas during the last test period, the channel had been under water for 21 consecutive days. This suggests that 21 days would have been enough time for stream length at the higher augmentation rates to have stabilized also. A graph of discharge in relation to stream length as it approached stabilization is given in figure 8.

Although the three data points in figure 8 are grouped closely about the line, implying close linear relationship between stream length and discharge, three points and zero discharge at zero flow are not enough to provide confidence in the relationship. Great caution must be exercised in the adoption of this simplified model because any bias in measurements of stream length or discharge would result in a biased regression coefficient. Although the relationship between stream length and discharge may genuinely pass through the origin, it may not

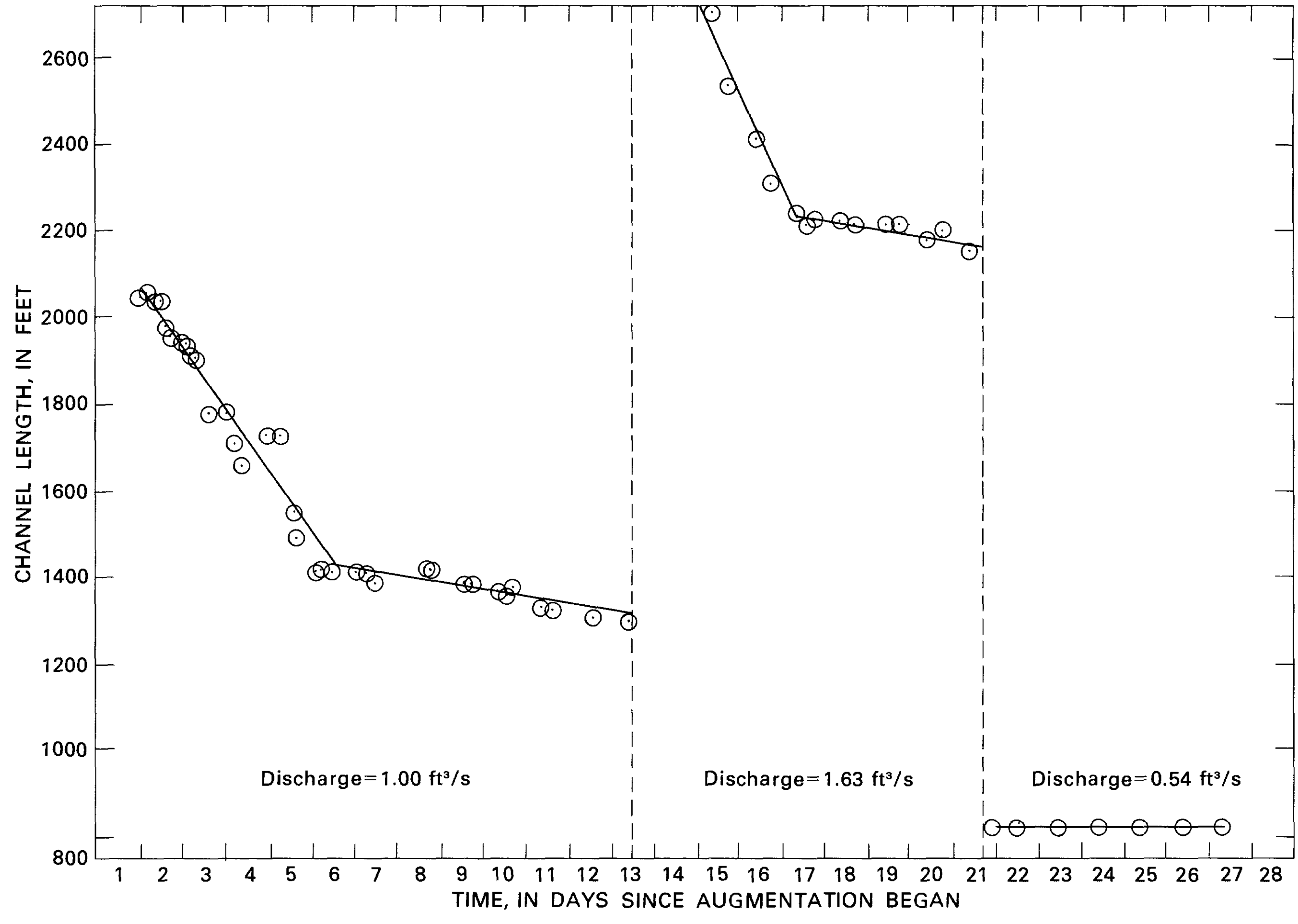

Figure 7. Wetted stream length in relation to the augmentation rate and lines of best fit as calculated by least-squares regression, November 30–December 26, 1979.

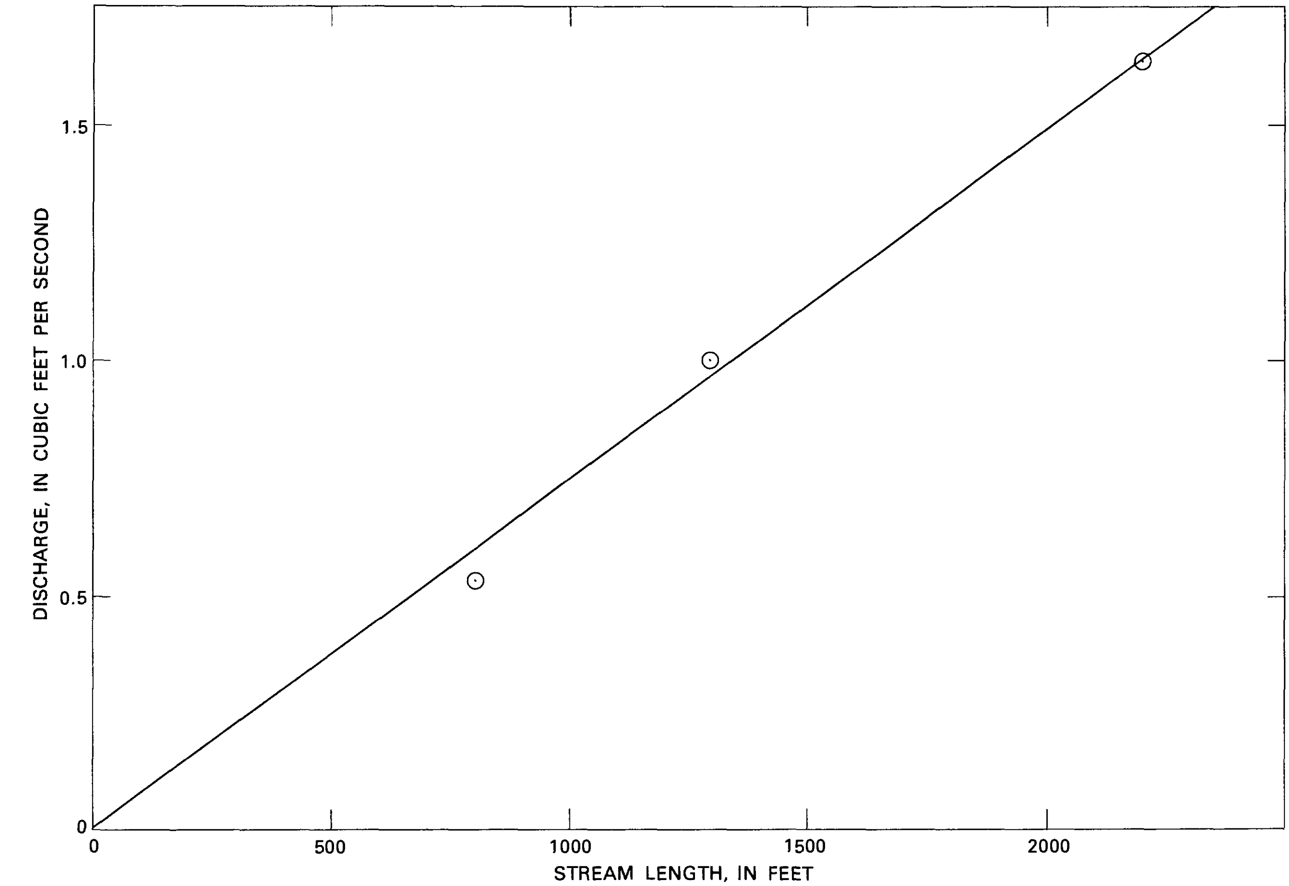

Figure 8. Relationship between stream length and discharge after stabilization, December 1979.

be linear over the whole range of discharge values. Extrapolation of the regression line to higher flow values, for example, to 10 ft^3/s, would be even less certain because larger discharges would increase stream stage and hydraulic head, thus altering the relationship. The data in figure 8 indicate that infiltration rates at low discharge (less than 2 ft^3/s) are not sensitive to small changes in stage; rather, the major controlling factor seems to be the numerous pools and riffles along the stream channel. The stream stage in various pools is controlled by the outlet elevations from those pools and not by the discharge rate at low levels of streamflow. At higher discharges, the pools and riffles would no longer be significant, stream stage would be the dominant factor. Furthermore, at low stages the pools provide greater wetting and the riffles less wetting, which causes the local variations in infiltration rate.

Relationship of Soil Moisture to Infiltration Rate

After precipitation or some other form of surface recharge, the amount of water held in the interstices of the soil in the unsaturated zone gradually decreases as a result of draining and evapotranspiration. Because the rate of infiltration through the unsaturated zone is partly dependent on soil moisture, prediction of infiltration rate requires knowledge of the degree of saturation before infiltration begins. As soil moisture increases in response to recharge, the rate of infiltration through the unsaturated zone increases until saturation occurs, at which time the rate remains constant.

Soil moisture was measured at three sites before the start of the test. Soil-moisture content in the unsaturated zone ranged from 16 to 25 percent at access holes 1 and 2 (fig. 9*A* and *B*); at hole 3, it ranged from 19 to 32 percent (fig. 9*C*). This difference is attributed to differences in soil composition because access hole 3 seemed to be in slightly finer grained material, which would have a higher negative soil pressure head and therefore higher moisture levels.

In the logs for all three access holes, moisture levels peak at about 42 percent within the capillary fringe (just above the water table), where the sediment is fully saturated. At this depth the water has filled all available pore space, and the moisture content is equal to the effective porosity of the aquifer material.

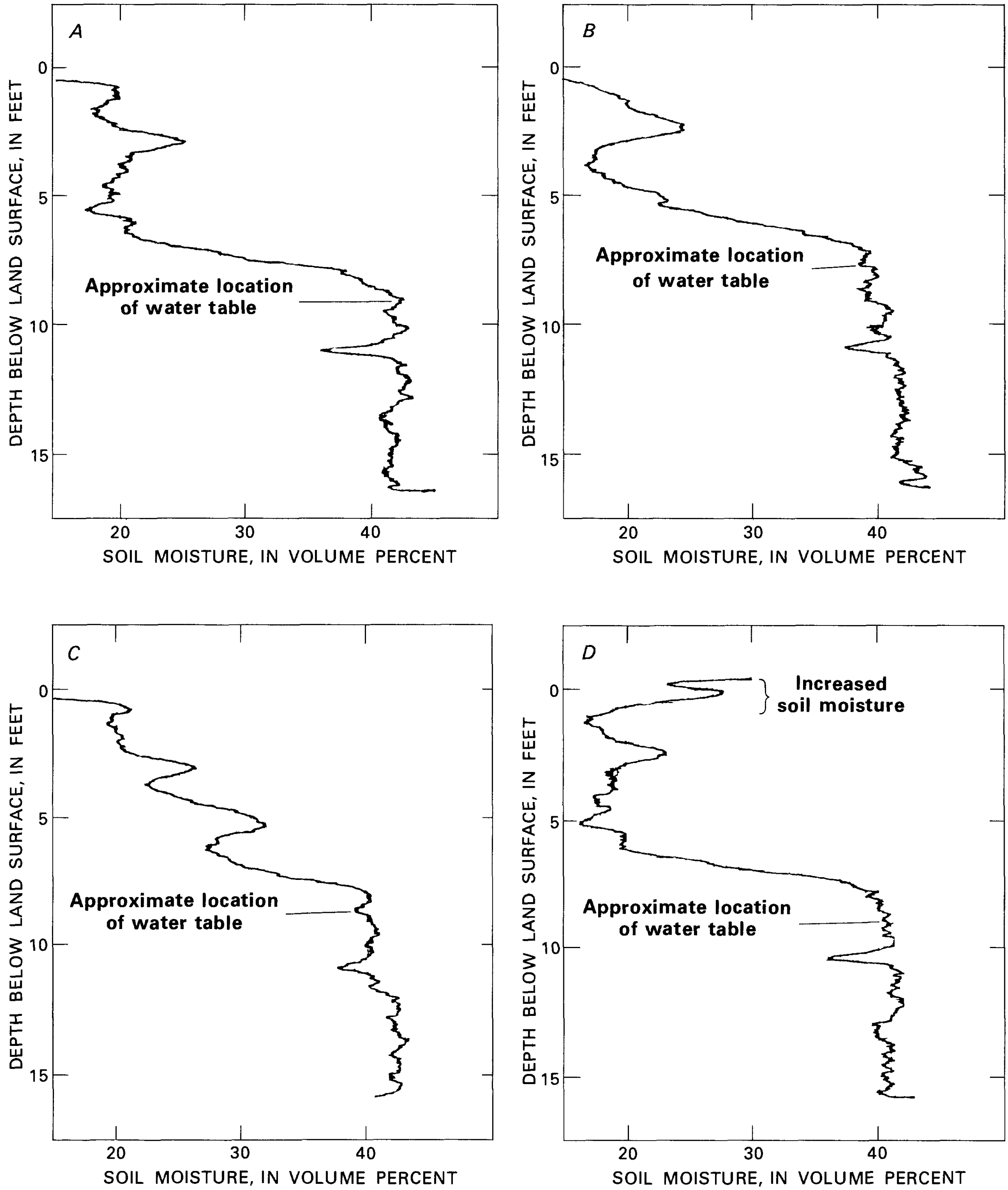

Figure 9. Soil-moisture logs showing moisture content of unsaturated zone beneath stream channel. *A,* Access hole 1 before the start of the test; *B,* access hole 2 before the start of the test; *C,* access hole 3 before the start of the test; *D,* access hole 1 as the wetting front moved downward at the start of the test. (The location of access holes is shown in fig. 4.)

As soon as streamflow was induced, water began to infiltrate the streambed and move toward the water table. (As water moves through the unsaturated zone, some is held in place by tension forces, and as the amount held in place increases, the tension forces decrease, allowing the water to move more quickly.) To document this process in detail, soil-moisture logs were run at access hole 1 several times during the test. The initial soil-moisture level beneath the streambed before the test averaged 20 percent. After 6 hours of flow it had risen to 30 percent, but after 4 days it had risen only an additional 2 percent, to 32 percent. After 20 days of flow, soil moisture had risen to 41 percent, almost the saturation level of 42 percent, but the area beneath the stream never became totally saturated.

Water in transit to the water table through the unsaturated zone causes the water table to rise rapidly beneath the recharge area because of a greatly reduced effective specific yield. The effective specific yield is equal to the specific yield minus the soil-moisture level. In other words, if the saturated level is 42 percent and the soil-moisture level is 41 percent, the effective specific yield (volume of pore space yet to be filled with water) is only 1 percent. Thus, a very small increase in soil moisture results in saturated flow.

A soil-moisture log run on December 23, after 24 days of testing and 3 days after the flow had been reduced from 1.63 ft^3/s to 0.54 ft^3/s, showed that moisture levels had decreased to about 30 percent, the same level recorded in the first few days of the test. Evidently, the decreased flow produced slower infiltration rates, probably because of lower water stage in the stream. Because the high soil-moisture levels could no longer be maintained, some of the stored moisture drained to the water table, reducing the infiltration rate.

Additional soil-moisture logs were run after the end of the test to obtain data on the subsequent decline in moisture level. Streamflow was stopped on December 26, and by December 31, the moisture level had decreased to 22 percent, just 2 percent above the initial level.

When the flow was begun, nine soil-moisture logs were run at irregular intervals over a 6-hour period at site 1 to determine the rate of movement of the wetting front through the unsaturated zone. (In figure 9*D*, the wetting front is evident as a sharp increase in soil moisture at a depth between 6 and 7 ft). During this period, the wetting front traversed the unsaturated zone in about 5.5 hours at a rate of 11.2 in/h.

The rate of advance of the wetting front through the unsaturated zone at Fosters Brook was much lower than rates calculated for three recharge basins on Long Island. Seaburn and Aronson (1974) calculated rates that range from 18 to 74 in/h, and the average for all storms studied at the basins was 40 in/h. Because these storms occurred from November through March, the extreme difference between infiltration rates at the basins and at Fosters Brook is not attributable to temperature but to geohydrologic differences. For example, the larger amounts of fine-grained sands or clay beneath Fosters Brook would produce significantly lower infiltration rates. (Grain-size distribution is discussed in the "Streambed Composition" section.) Also, the depositional environment in the stream is considerably different from that in a recharge basin inasmuch as stream deposition occurs in moving water, whereas deposition in the recharge basin occurs in standing water. This would affect the orientation of the sediment as it settles out. Furthermore, recharge basins are located in areas favorable to infiltration of water and are scoured and cleaned routinely to maintain high infiltration rates.

Ground-Water Response

Ground-water levels near Fosters Brook began to rise as soon as the wetting front reached the water table, as evidenced by measurements at well N 9622, in reach A at the center of the streambed (fig. 4). During the first 12 days, water levels rose sharply, but thereafter they rose more slowly and at some wells eventually declined. The maximum rise was 6.47 ft in well N 9627, located 14 ft east of the stream and 225 ft downstream from the start of flow, on December 13. Although the range of water-level change at N 9627 was greater than it was in most other wells in which maximum change was generally less than 3 ft, the overall trend at all wells was similar, as was indicated by a hydrograph of wells N 9624, N 9622, and N 9642 (fig. 10).

The influence of recharge can be readily seen as a rise in water levels along the entire stream length. For example, water levels in reach E (wells N 9634, N 9635, and N 9639) rose in response to the arrival of streamflow and decreased rapidly when stream length receded. (Well records are given in the appendix, at the end of the report.)

The areal extent of ground-water mounding could not be closely defined because the wells were insufficient in number and distribution. (The density of housing precluded installing wells where they might have helped to define the ground-water mound; drilling operations were thus confined to the narrow right-of-way along Fosters Brook and outlying streets where a drill rig could be maneuvered.) However, the data indicate that the mound was of relatively limited width and that it dissipated quickly with distance from the stream. The hydrographs in figure 10 indicate that well N 9624, 45 ft from the stream, rose a maximum of 1.75 ft and that well N 9622, directly in the streambed, rose 3.91 ft. Beyond 45 ft, net change in water levels decreased even more rapidly with distance; for example, none of the nearby houses (within a few hundred feet) were affected by the ground-water mound,

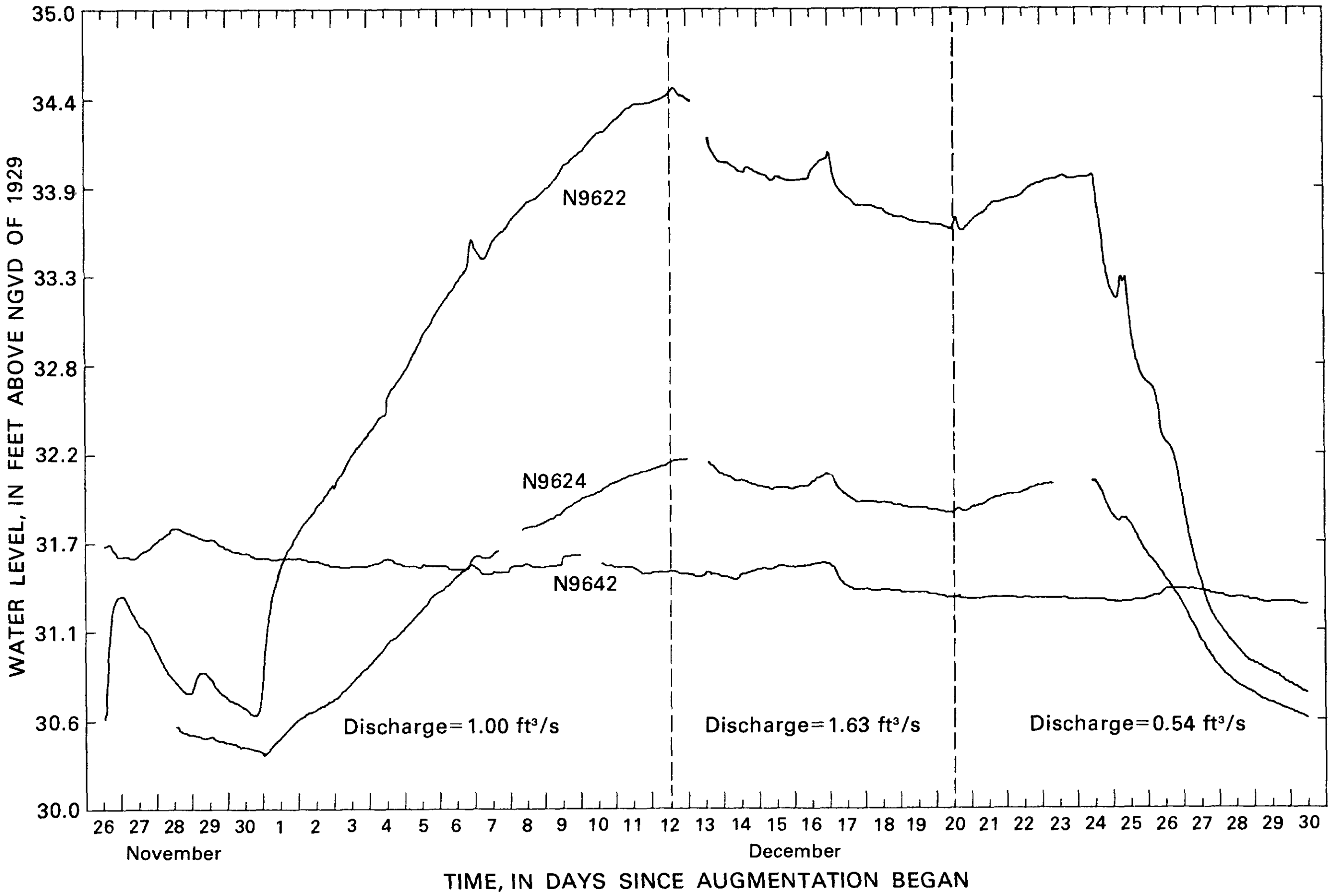

Figure 10. Water-level measurements obtained in three wells with continuous recorders during a streamflow augmentation test, November 30–December 26, 1979. Well N 9622 is in reach A at the center of the stream, N 9624 is 45 ft east of the stream, and N 9642 is 2,000 ft east of the stream. (Locations are shown in fig. 4.)

and at well N 9642, 2,000 ft from the stream, no response to augmentation was discernible.

At three sites along Fosters Brook, a pair of wells was drilled equidistant from the stream center. These were wells N 9621 and N 9623 in reach A, wells N 9626 and N 9627 in reach A, and wells N 9629 and N 9630 in reach C (fig. 4). Comparison of water levels on either side of the stream (Appendix) indicates that the ground-water mound was not symmetrical in relation to the center of the stream channel nor was the amount of ground-water mounding uniform along the channel length. For example, the difference between net water-level increase at the two wells of each group from November 30 to December 12 was as follows:

reach A (N 9621 and N 9623): 0.40 ft
reach A (N 9626 and N 9627): 0.90 ft
reach C (N 9629 and N 9630): 1.29 ft

In addition, water levels were consistently higher on the east side of the stream than on the west. This discrepancy is attributed to variation in streambed composition and to the bend in stream channel just north of well N 9625 (fig. 4). In addition, the wells were not drilled to exactly the same depth below the water table. (Because a ground-water mound had formed, flow was three dimensional, that is, radial and downward away from the center of the mound, so that wells screened at different depths would indicate different pressure heads.) Thus, the ground-water mound could be expected to be symmetrical only under ideal conditions, that is, with uniform areal recharge from the stream and an isotropic, homogeneous porous medium. At Fosters Brook, recharge was not uniform along the length of the stream, as exhibited by the variation in infiltration rates (table 3) both longitudinally and transversely, and in addition, the aquifer material was neither isotropic nor homogeneous. Thus, a certain degree of asymmetry is to be expected.

FACTORS AFFECTING SEEPAGE RATES

Much of the information presented thus far demonstrates the variability of rate at which water will seep from the stream channel into the aquifer. As was explained earlier, several factors influence these seepage rates, some of which are (1) composition of the streambed and aquifer, (2) soil-moisture conditions, (3) water temperature, (4) stream stage, and (5) clogging of streambed. An understanding of the relationship among these factors is necessary to evaluate the feasibility of streamflow augmentation at any given site.

Streambed Composition

Composition of the streambed and surrounding aquifer determines the basic characteristics of seepage from the stream. Variations in composition will produce local differences in seepage rate from the stream; for example, seepage will be much slower where sediments consist of silt and clay than in areas of coarse sand and gravel.

Samples of streambed sediment were collected at 11 sites along Fosters Brook for grain-size distribution analyses to be related to seepage rates in this study and to provide data for studies on other streams.

Streambed samples were taken at 250-ft intervals along the stream channel. At each site one sample was collected at the center of the stream with a small hand shovel from a depth less than 2 in., and another was collected in the same manner from the 6- to 8-in. depth interval. At a site 500 ft downstream from the point of flow augmentation, an additional sample was collected from the 3- to 5-in. depth interval because the sediment there seemed to differ considerably from that in the rest of the reach. Results of the grain-size analyses are listed in table 4; a graph (fig. 11) depicts results of the grain-size analyses as average percentages for all samples in the given grain-size ranges. The unshaded area above and below an individual bar represents the range from the highest to lowest percentage encountered in each grain-size group. For example, in the column representing the grain-size range from 8 to 4 mm, the highest percentage of grains of that size among all samples was 74 percent and the lowest was 1.02 percent. The average of all samples in the 8- to 4-mm range was 32.46 percent by weight, as indicated by the bar.

The largest range in percentage of total sample weight was in the 8- to 4-mm size group (1–75 percent) followed by the 0.5- to 0.25-mm group (7.5–46.5 percent). In addition, the average percentage in these two groups (32.5 and 20.5, respectively) are the highest of all size fractions examined (fig. 11), which indicates that gravel and sand form the largest percentage of streambed sediment. The smallest range in percentage of total sample weight was in the 0.125- to 0.063-mm and the < 0.063-mm groups (the silts and clays), both from 0 to 4 percent. These groups also form the smallest average percentage of total weight in the samples (1 percent and 0.8 percent, respectively).

The small range in amount of silt and clay contained in samples (<0.125 mm) may be misleading in relation to their influence on infiltration rate. In poorly sorted aquifer material, the permeability is generally controlled by the amount of clay because the fine particles occupy the interstices between larger particles and inhibit the flow of water. Even small amounts of silt and clay can retard this flow, therefore, small differences in silt and clay content can produce large differences in permeability. However, the permeability of the streambed depends also upon shape, size, compaction, and distribution of the silts and clays; therefore, grain-size analysis alone is not sufficient to determine permeability of the source material.

Comparison of grain-size data from Fosters Brook with data from another stream to predict results of streamflow augmentation could be of questionable value owing to differences in depositional environment and the source of material available to the streams. Fosters Brook is no longer a natural stream channel such as is found elsewhere on Long Island because flow occurs only during storms, and this flow as well as most of the sediment is derived from local surface runoff instead of the natural stream deposits. The washed-in sediment is coarser and of a different color than that typical of perennial Long Island streams; also, the streambed contains broken glass and trash to depths as great as 6 in. The washed-in material may have significant bearing upon seepage rates; however, this was not investigated.

Soil Moisture

As was discussed earlier, both soil-moisture content and hydraulic conductivity are functions of pressure head, and as soil moisture increases, hydraulic conductivity also increases. This is described by Darcy's Law for one-dimensional flow in an unsaturated isotropic soil:

$$Q = -K(\Psi)\frac{\partial h}{\partial x} \qquad (1)$$

where

Q is flow through an unsaturated medium,
K is hydraulic conductivity,
Ψ is pressure head, and
$\frac{\partial h}{\partial x}$ is gradient.

This relationship implies that, given a constant gradient, flow rate increases as soil moisture (and consequently pressure head) increases.

Table 4. Grain-size distribution analysis of streambed sam

[Weight columns indicate absolute weight held by each sieve, in gr

Sample source		Grain-size range, in millimeters							
		8 - 4		4 - 2.8		2.8 - 2		2 - 1	
Distance from start of flow (ft)	Depth interval (in.)	Weight	Percent	Weight	Percent	Weight	Percent	Weight	Perce
0	0 - 2	22.62	17.96	4.75	3.77	7.11	5.65	18.58	14.75
	6 - 8	47.93	26.19	7.72	4.22	15.01	8.20	42.64	23.30
250	0 - 2	57.65	39.45	11.67	7.99	14.10	9.65	26.72	18.29
	6 - 8	76.52	41.70	15.93	8.68	14.75	8.04	26.02	14.18
500	0 - 2	74.66	36.32	25.18	12.25	20.34	9.89	30.16	14.67
	3 - 5	9.54	8.79	3.11	2.87	2.91	2.68	12.30	11.34
	6 - 8	31.71	20.85	5.01	3.29	6.20	4.08	15.45	10.16
750	0 - 2	26.15	16.02	8.42	5.16	9.47	5.80	18.57	11.37
	6 - 8	60.13	30.56	9.96	5.06	10.47	5.32	22.84	11.61
1000	0 - 2	81.11	49.30	11.90	7.23	10.42	6.33	19.42	11.80
	6 - 8	25.19	16.82	5.02	3.35	4.25	2.84	6.71	4.48
1250	0 - 2	105.00	50.84	13.92	6.74	11.03	5.34	18.08	8.75
	6 - 8	84.99	52.06	9.50	5.82	8.06	4.94	13.35	8.18
1500	0 - 2	104.95	48.78	13.97	6.49	13.66	6.35	24.78	11.52
	6 - 8	147.92	74.00	4.41	2.21	3.06	1.53	6.01	3.01
1750	0 - 2	90.61	47.22	12.42	6.47	9.64	5.02	18.57	9.68
	6 - 8	1.19	1.02	1.32	1.13	2.02	1.73	6.82	5.85
2000	0 - 2	55.51	28.75	13.44	6.96	14.16	7.33	31.70	16.42
	6 - 8	27.13	14.69	11.12	6.02	13.17	7.13	26.74	14.47
2250	0 - 2	62.96	33.74	6.54	3.50	5.95	3.19	11.79	6.32
	6 - 8	6.76	3.96	4.31	2.52	7.61	4.45	23.85	13.95
2500	0 - 2	104.15	51.81	11.78	5.86	8.43	4.19	15.97	7.94
	6 - 8	60.89	35.67	10.80	6.33	10.51	6.16	18.07	10.58

osters Brook, Nassau County, N.Y., December 1979
nt columns indicate percentage of composite sample weight]

Grain-size range, in millimeters									
1 - 0.5		0.5 - 0.25		0.25 - 0.125		0.125 - 0.063		< 0.063	
ight	Percent	Weight	Percent	Weight	Percent	Weight	Percent	Weight	Percent
27.59	21.91	32.31	25.66	11.78	9.35	0.94	0.75	0.25	0.20
42.66	23.32	24.73	13.52	1.71	0.93	0.38	0.21	0.19	0.10
21.88	14.97	9.98	6.83	2.51	1.72	1.11	0.76	0.50	0.34
2.04	17.46	16.26	8.86	1.44	0.78	0.33	0.18	0.19	0.10
5.99	17.51	16.93	8.24	1.76	0.86	0.36	0.18	0.16	0.08
29.06	26.78	33.43	30.81	11.04	10.17	4.21	3.88	2.91	2.68
25.22	16.58	47.24	31.06	15.42	10.14	2.78	1.83	3.08	2.02
40.99	25.11	52.70	32.28	5.66	3.47	0.65	0.39	0.65	0.39
2.08	26.47	37.88	19.25	2.52	1.28	0.49	0.25	0.36	0.18
23.51	14.29	14.80	8.99	2.20	1.34	0.59	0.36	0.56	0.34
6.43	10.97	52.06	34.76	34.42	22.98	4.55	3.04	1.13	0.75
28.21	13.66	25.41	12.30	3.04	1.47	0.90	0.44	0.95	0.46
4.41	8.83	21.52	13.18	9.31	5.70	1.38	0.85	0.72	0.44
34.00	15.80	21.75	10.11	1.36	0.63	0.32	0.15	0.34	0.16
4.39	7.19	19.59	9.80	3.08	1.54	0.86	0.43	0.56	0.28
28.47	14.84	29.02	15.12	2.31	1.20	0.42	0.22	0.41	0.21
25.44	21.83	54.14	46.46	16.49	14.15	4.46	3.83	4.65	3.99
50.56	26.18	26.36	13.65	0.78	0.40	0.25	0.13	0.35	0.18
49.82	26.97	50.83	27.52	5.01	2.71	0.54	0.29	0.34	0.18
31.40	16.83	59.81	32.05	6.80	3.64	0.66	0.35	0.71	0.38
47.39	27.73	61.51	35.99	13.38	7.83	3.12	1.83	2.98	1.74
33.27	16.55	26.13	12.99	0.93	0.46	0.15	0.07	0.21	0.10
25.47	14.92	31.62	18.52	8.97	5.25	2.25	1.32	2.14	1.25

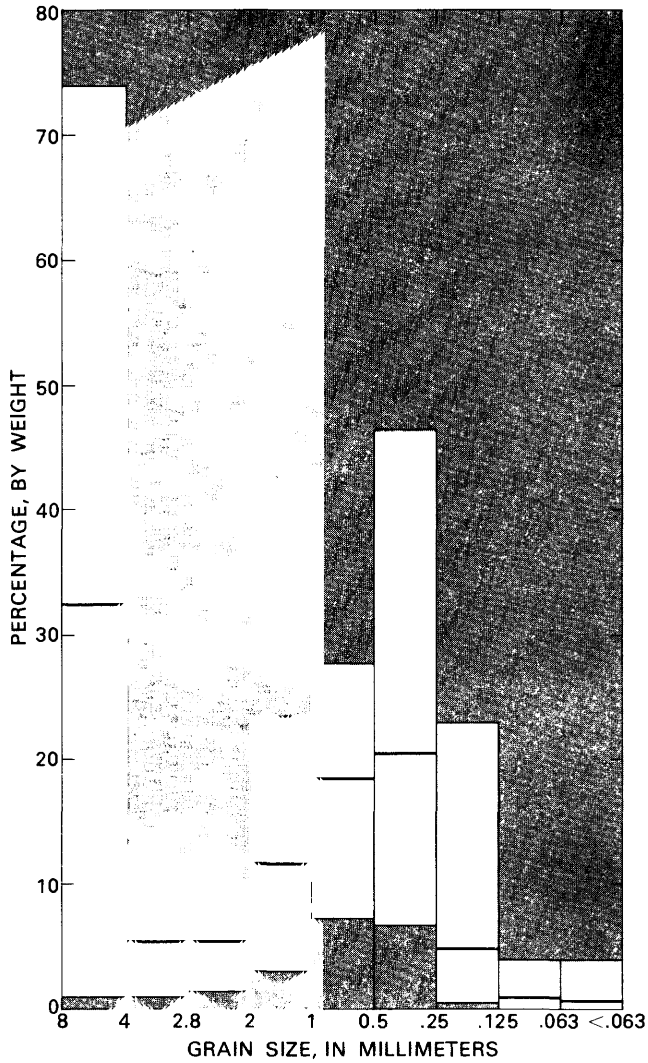

Figure 11. Grain-size distribution of streambed sediment in Fosters Brook. A bar indicates the average grain-size fraction among all samples. The unshaded area represents the range of values in a grain-size fraction among all samples.

Within a limited range of recharge (infiltration) rates, soil moisture varies in response to recharge. The change in soil-moisture content at neutron-logger access hole 1 during and shortly after the augmentation test is depicted in figure 12. On the first day of the test, soil moisture increased abruptly from approximately 20 percent to approximately 30 percent (see also fig. 5), and from days 2 to 15 it continued to increase because seepage from the stream was faster than flow through the unsaturated zone. By the 15th day (December 14), soil moisture had reached a peak of about 41 percent, which represents saturated flow under negative pressure head or unsaturated flow very close to the effective porosity of the aquifer. After day 21, soil moisture decreased in response to the abrupt decrease in augmentation rate. At the lower augmentation rate (0.54 ft^3/s), stream stage declined, and seepage through the streambed decreased as a result of the lower pressure head. This lower seepage rate was not sufficient to maintain the nearly saturated flow conditions above the water table, and soil moisture decreased accordingly. In time, a new soil-moisture equilibrium for this new recharge rate would have been reached.

The decrease in soil moisture after the streamflow rate was reduced indicates that the soil-moisture level was controlled by the rate of seepage from the stream and that seepage rate was more dependent on pressure head at the streambed than on soil-moisture content in the unsaturated zone, although the reverse may be true at certain times, such as during the initial wetting phase at the start of augmentation.

Temperature

Changes in water temperature alter the viscosity of water and thus affect the rate of flow through an aquifer. Hydraulic conductivity of an aquifer can be expressed as

$$K = k\frac{\varrho g}{\mu} \qquad (2)$$

where

K is hydraulic conductivity,
k is intrinsic permeability,
ϱ is density of water,
g is gravitational constant,
μ is kinematic viscosity of water

and density (ρ) and kinematic viscosity (μ) are temperature dependent.

Although the changes in density and viscosity of water resulting from seasonal extremes in air temperature are not great, they can have a significant effect on the rate of infiltration. During the initial phase of flow augmentation, when water was derived solely from the nearby well, the stream temperature was 14°C. If this were to decrease by 2°C, hydraulic conductivity would decrease by approximately 5–6 percent (from eq. 2).

During the second phase of the test (days 13–21), when additional water was supplied by Franklin Square Water District to increase the flow, the added water was presumably colder than the well water so that when the two were mixed the temperature would have dropped about 2°C. The hydrograph of well N 9622 (fig. 10) substantiates this assumption because when the additional

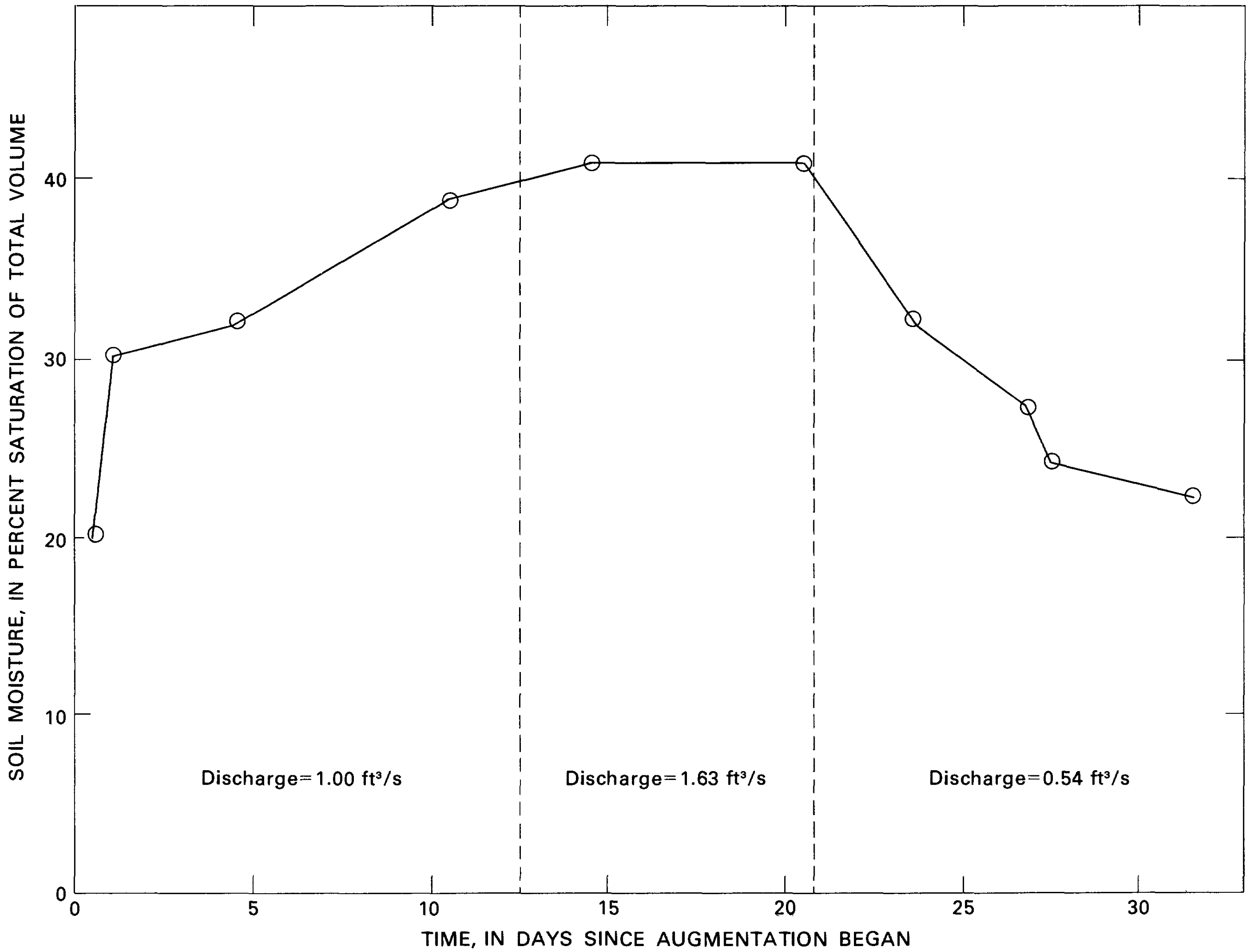

Figure 12. Average soil moisture beneath streambed at neutron-logger access hole 1, November 30–December 31, 1979. (The location is shown in fig. 4.)

water was added to the stream on day 13, the water level in the well began to decline, and on day 21, when the additional water was shut off, the water level rose. This water-level response reflects changes in infiltration rates that are inconsistent with a stream stage (discharge)/infiltration rate relationship until the effects of temperature are considered.

Temperature of stream water will also fluctuate daily and seasonally in response to air temperature. Despite wide variations in air temperature from day to day, an overall trend was determined from a 5-day moving average by the following procedure. First, the mean daily values for the first 5-day series were averaged, and that value was assigned to the last day of the 5-day period. The next 5-day series began with day 2 of the first group and ended with day 6 of the test, and the mean daily values for that group were averaged. The process was continued until the period of interest had been covered. Mean daily temperatures were obtained from the weather station, which is maintained by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, at Mineola, N.Y. (fig. 1); the record derived by this method is shown as a graph in figure 13. The trend of mean daily air temperature (fig. 13) shows a general similarity to the hydrograph of well N 9622 (fig. 10). Even though air temperature is only partly responsible for the changes in infiltration rates and water levels, a correlation seems evident.

The effect of ambient temperature on stream water is also evidenced by a change in seepage rates from the stream during several periods of rainfall. Rain fell on December 6–7, 13, 16–17,19, and 24–25, and each storm was intense enough to generate overland runoff and to increase flow through the stream channel. Early in each storm, ground-water levels within 50 ft of the stream rose sharply but peaked and began falling before the storm had

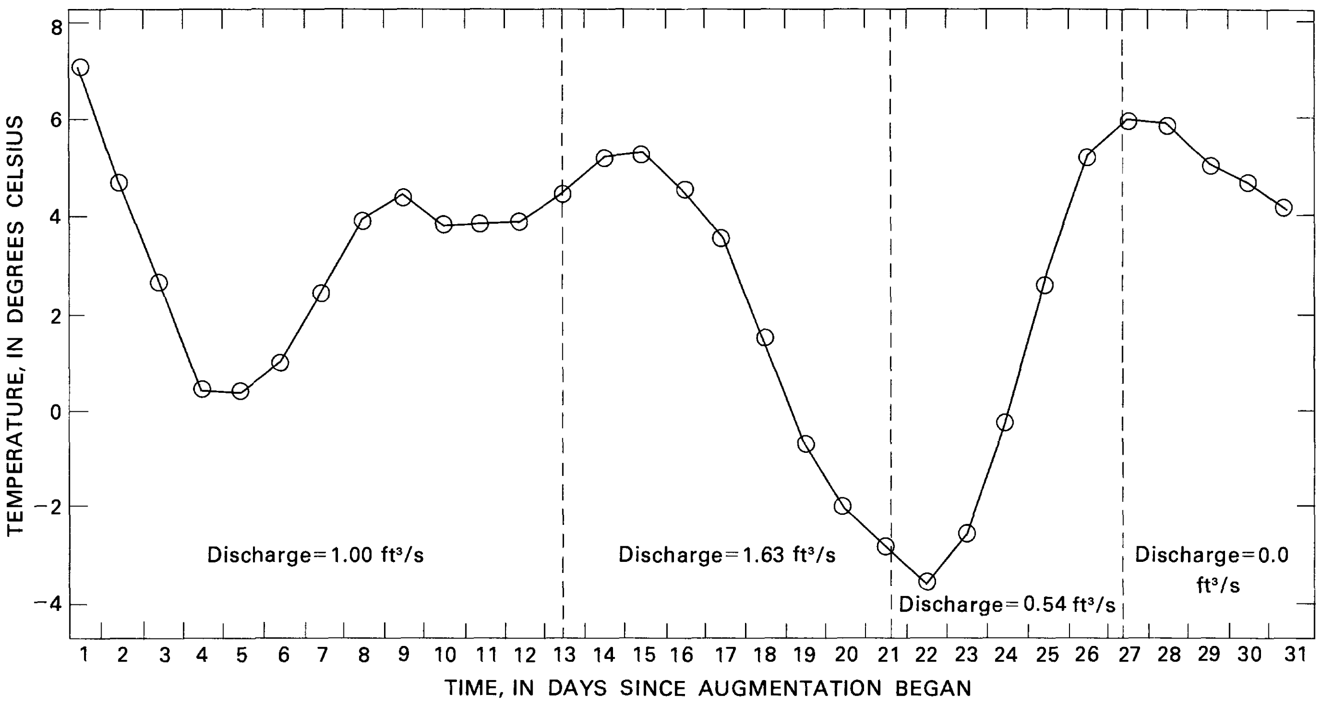

Figure 13. Five-day moving average of mean daily air temperature at Mineola, N.Y., November 30–December 30, 1979. Data are from U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

ended, and shortly after the end of each storm, water levels resumed the trend they had exhibited beforehand. The temporary decline in water levels during each rainstorm (fig. 10, well N 9622) is attributed to a decrease in seepage rates during the storm in spite of the elevated stream stage. These decreases were probably caused by a lowering of water temperature by the addition of winter runoff, which was substantially colder than the ground water being pumped for the test.

The above example implies a strong correlation between infiltration rate and water temperature. The relationship between temperature and water density and viscosity is not linear, and as the temperature approaches freezing, the viscosity and density increase faster. During the storms mentioned above, the water falling as precipitation was just above 0°C, the range in which temperature changes would have the greatest effect.

Other Factors

Algae

A moderate growth of algae developed on the streambed during the stream-augmentation test. In warm weather the algae might eventually become thick enough to reduce seepage rates from the streambed, but because the test was relatively short and the season not conducive to algal growth, its effect on seepage rates could not be determined. However, it may be advisable to study the effect of algal growth on seepage rates before major decisions concerning streamflow augmentation are made.

Chemical Reactions

To determine chemical interactions between the water and the streambed sediments that might affect seepage rates or the quality of stream water, water samples were taken at three sites. Results of these analyses are listed in table 5.

The change in chemical character of the water as it moved downstream was relatively small. Some constituents showed no change at all, and among those that showed a change, the differences were probably within the range of laboratory precision or where zero is the reported value, the actual value is below detection limits. The only changes of any significance were in dissolved iron, manganese, and pH. Dissolved iron was 20 μg/L at the upstream site and was below detection limit at the two downstream sites. Manganese was 210 μg/L at the upstream site and had decreased to 160 μg/L at the downstream site, and pH decreased from 6.5 to 6.0 between the upstream and downstream sites. Even though these

Table 5. Chemical quality of water in Fosters Brook, Nassau County, N.Y. during flow augmentation, December 19, 1979
[Site locations are shown in fig. 4]

Constituent or characteristic	Unit of measure	Concentration or value		
		Site 1	Site 3	Site 5
Alkalinity, total ($CaCO_3$)	mg/L	33	32	31
Calcium (Ca)	mg/L	16	17	17
Chloride (Cl)	mg/L	20	20	19
Fluoride (F)	mg/L	0	0	0
Hardness, noncarbonate	mg/L	21	24	25
Hardness, total	mg/L	54	56	56
Iron, Dissolved (Fe)	μg/L	20	0	0
Iron, Suspended (Fe)	μg/L	40	40	40
Magnesium, dissolved (Mn)	mg/L	3.3	3.3	3.3
Maganese, total (Mg)	μg/L	210	200	160
Nitrite NO_2 (as N, total)	mg/L	0.01	0.01	0.01
Nitrate NO_3 (as N, total)	mg/L	4.5	5.1	5.0
Nitrogen NH_4 (as N, total)	mg/L	0	0	0
Nitrogen NO_2 (as N, dissolved)	mg/L	0.01	0.01	0.01
Nitrogen NO_3 (as N, dissolved)	mg/L	4.0	5.3	4.1
Nitrogen, total (as N)	mg/L	4.7	5.5	5.2
Nitrogen, total organic (as N)	mg/L	0.21	0.39	0.18
Nitrogen (as NH_4, total)	mg/L	0.0	0.0	0.0
pH		6.5	6.3	6.0
Phosphate, total (as P)	mg/L	0.01	0.01	0.01
Phosphorus, total (as P)	mg/L	0	0	0.01
Phosphorus, total (as PO_4)	mg/L	0	0	0.03
Potassium, dissolved (K)	mg/L	2.0	2.0	2.1
Silica, dissolved (Si)	mg/L	12	12	12
Sodium adsorption ratio		1.1	1.0	0.9
Sodium, dissolved (Na)	mg/L	18	17	16
Specific conductance	μmho/cm @25 °C	215	210	225
Sulfate, dissolved (SO_4)	mg/L	28	27	27

changes are minor, they could affect the streambed sediments and in turn alter seepage rates from the stream channel, possibly through clogging of the streambed by precipitate.

Impoundments

Artificial impoundments may locally increase seepage rates from the stream by raising the stream stage and therefore the hydraulic head driving the water into the aquifer. Fosters Brook contains several artificial impoundments that have been created behind cement spillways where storm drains emptied into the stream. The normal depth of the stream during augmentation was usually less than 0.5 ft, but behind the spillways it reaches 1 or 2 ft during periods of runoff. However, determination of the effect of impoundments on local seepage rates was beyond the scope of this study.

ANALYSIS

The hydrologic mechanisms involved in stream augmentation are highly variable and interact in a complex manner that is as yet poorly understood. To assess the workings of these factors during flow augmentation and to evaluate their effects individually and collectively, field data were compared with solutions from both analytical and numerical models.

Analytical Solution

Analytical expressions to determine the growth of water-table mounds beneath recharge sites have been presented by Bittinger and Trelease (1965), Hantush (1967), and Marino (1974). The expression selected for this analysis, presented by Glover (1966), is an adaptation of

Darcy's Law, the basic ground-water flow equation, and is written as

$$h=\frac{q_1 x}{2\pi KD}\sqrt{\pi}\int_{\frac{x}{\sqrt{4\alpha t}}}^{\infty}\frac{e^{-u^2}}{u^2}\,du \qquad (3)$$

where

- h is change in head (ft),
- q_1 is rate of recharge (ft^3/s),
- x is distance from center of stream (ft),
- K is aquifer hydraulic conductivity (ft/d),
- D is aquifer thickness (ft),
- KD is aquifer transmissivity (ft^2/s),
- α is KD/V where V is the specific yield (ft^2/s), and
- t is time since recharge began (s).

This solution assumes an isotropic, homogeneous aquifer and uniform seepage rate from a straight channel of infinite length. Percolation beneath the recharge site (streambed) is vertically downward to the water table, and the space which can be filled is a constant equal to the drainable porosity. The analysis of flow in this case examines only one-dimensional flow beneath the water table.

Glover's solution (1966) was applied to a hypothetical well 45 ft from the center of the stream channel, similar to well N 9624 in reach A (fig. 4). This distance was chosen to avoid the following problems in mathematical representation of the system: (1) changes that develop in pore space which can be filled beneath the recharge area during infiltration, (2) flow in more than one dimension near the recharge mound, and (3) anisotropy of streambed and unsaturated zone and aquifer.

Analysis of ground-water mounding at adequate distance from the recharge strip (streambed) minimizes the disparity between the fillable pore space and the drainable porosity of the aquifer. For example, when the unsaturated zone is under conditions similar to those beneath the streambed, recharge causes soil moisture to increase and fillable porosity to decrease as a result of in-transit water, but the potentially drainable porosity remains the same. Thus, if soil moisture in the unsaturated zone were to rise to 30 percent through recharge and the total drainable porosity were 35 percent, the fillable pore space beneath the recharge area would be only 5 percent. The effect of this decrease in the pore space yet to be filled would be that the ground-water mound would rise more rapidly than was predicted by analytical solutions that do not consider this phenomenon. In addition, flow in two or three dimensions instead of one, as assumed by Glover's solution, would also cause a more rapid rise in the ground-water mound than was predicted, as evidenced by water levels observed in well N 9622 (fig. 10), which rose much more quickly than was predicted by Glover's solution.

A comparison of Glover's solution with measured water-level change at well N 9624 is given in figure 14. Aquifer characteristics used in this analysis were hydraulic conductivity of 200 ft/d, specific yield of 0.35, and aquifer thickness of 70 ft.

Initial calculations used an average recharge rate that had been determined from seepage rates calculated from the regression analysis of streamflow measurements (fig. 6); the resulting analytical solutions showed the ground-water mound to be rising more rapidly than the field data indicated. A different approach was then used, whereby a recharge rate was calculated for each day, again from the regression analysis; this method more accurately simulated the water-table rise observed through the first 12 days of the test.

When the augmentation rate was increased from 1.00 to 1.63 ft^3/s on day 13, ground-water levels began to decline partly as a result of slower infiltration rates (fig. 9) caused by the lowered water temperature. In the analytical solution for days 13–20, infiltration rate was reduced by 30 percent, considerably more than the calculated 5-percent reduction, in an attempt to represent the assumed real-world conditions; but still the predicted water-level decline was smaller than the observed decline at well N 9624. In fact, the predicted water level declined for only 1 day and then began to rise again. The analytical procedure was not extended to the third period of testing because water levels and overall trends were not being simulated, and the results would therefore have been meaningless.

The analytical solution can accurately predict changes in water level only if the values used for aquifer characteristics and seepage rates are correct. Because the change in water levels during the second phase of the test was not accurately predicted (the decrease in infiltration rate as a result of lower water temperature was not sufficient to account for the decline in water levels), some additional factor governing infiltration--possibly hydraulic characteristics of the streambed combined with the behavior of flow in the unsaturated zone--is indicated.

Numerical Model

Computer simulation was done with a three-dimensional numerical model presented by Trescott (1975) which represents flow at or beneath the water table but not in the unsaturated zone. Even so, the model provides a more useful representation of the flow system than the analytical solution because it simulates flow in three dimensions and can also represent a finite stream channel.

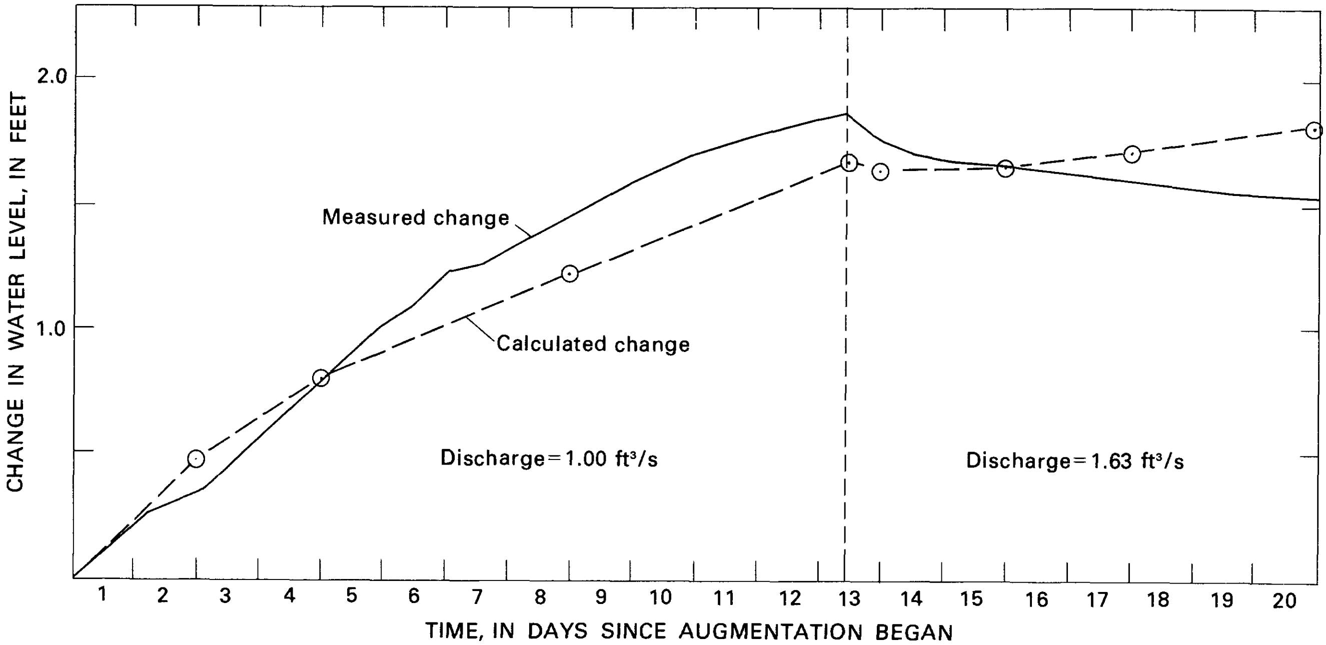

Figure 14. Observed water-level change in well N 9624, 45 ft from the center of the stream, in comparison with change predicted by Glover's solution for a hypothetical well similarly located.

Model water levels were set at zero elevation at the start of simulation, and all changes calculated by the model represent net change in water-table elevation. The simulation represented only one side of Fosters Brook because ground-water flow was assumed to move symmetrically away from the center of the recharge strip (streambed).

The numerical model uses a variable grid spacing, as depicted in figure 15. The area modeled is surrounded by constant-head boundaries on three sides, and the center of the stream is represented by an impermeable boundary. The aquifer system is represented as six layers: layer 1 (bottom layer) represents the Magothy aquifer, 700 ft thick; layer 2 represents a Pleistocene clay, 10 ft thick, of limited areal extent but continuous throughout the modeled area; and layers 3–6 represent the saturated thickness of the upper glacial aquifer with thicknesses of 20, 20, 15, and 10 ft, respectively. (The Raritan clay is considered a no-flow boundary because flow through it is minimial.)

The water-transmitting properties of the aquifers in the modeled area were assumed to be areally uniform. Hydraulic conductivity and storage coefficients for the Magothy aquifer were obtained from Franke and Cohen (1972); hydraulic conductivity and storage coefficients for the clay layer were assumed to be similar to those of the Gardiners clay, an extensive Pleistocene unit described also in Franke and Cohen (1972). Values of hydraulic conductivity and specific yield for the upper glacial aquifer were those used in the analytical solution previously discussed.

As was discussed earlier, water in transit through the unsaturated zone reduced effective specific yield because it occupies part of the drainable pore space. The model accounts for this phenomenon by reducing the specific yield in the streambed nodes to 0.2 times the value used elsewhere in that layer.

Seepage from the stream channel into the aquifer could not be simulated directly by the numerical model and was therefore represented as wells injecting water into the uppermost layer of the model. The stream was simulated by two nodes in each row acting as injection wells; these nodes are identified in figure 15 as stream channel. Injection rates were based on stream-length data (fig. 7) and stream-discharge measurements (table 2). Simulation of the augmentation test was divided into three pumping periods that correspond to the three different rates of stream augmentation. Average seepage rate for each of the five reaches was calculated as follows: (1) linear regression analysis was done on discharge data obtained by streamflow measurements given in table 2, (2) discharge values for the middle day of each of the three pumping periods was calculated by the linear regression equations, (3) seepage loss per stream reach was calculated as the difference between discharge values measured at the upper

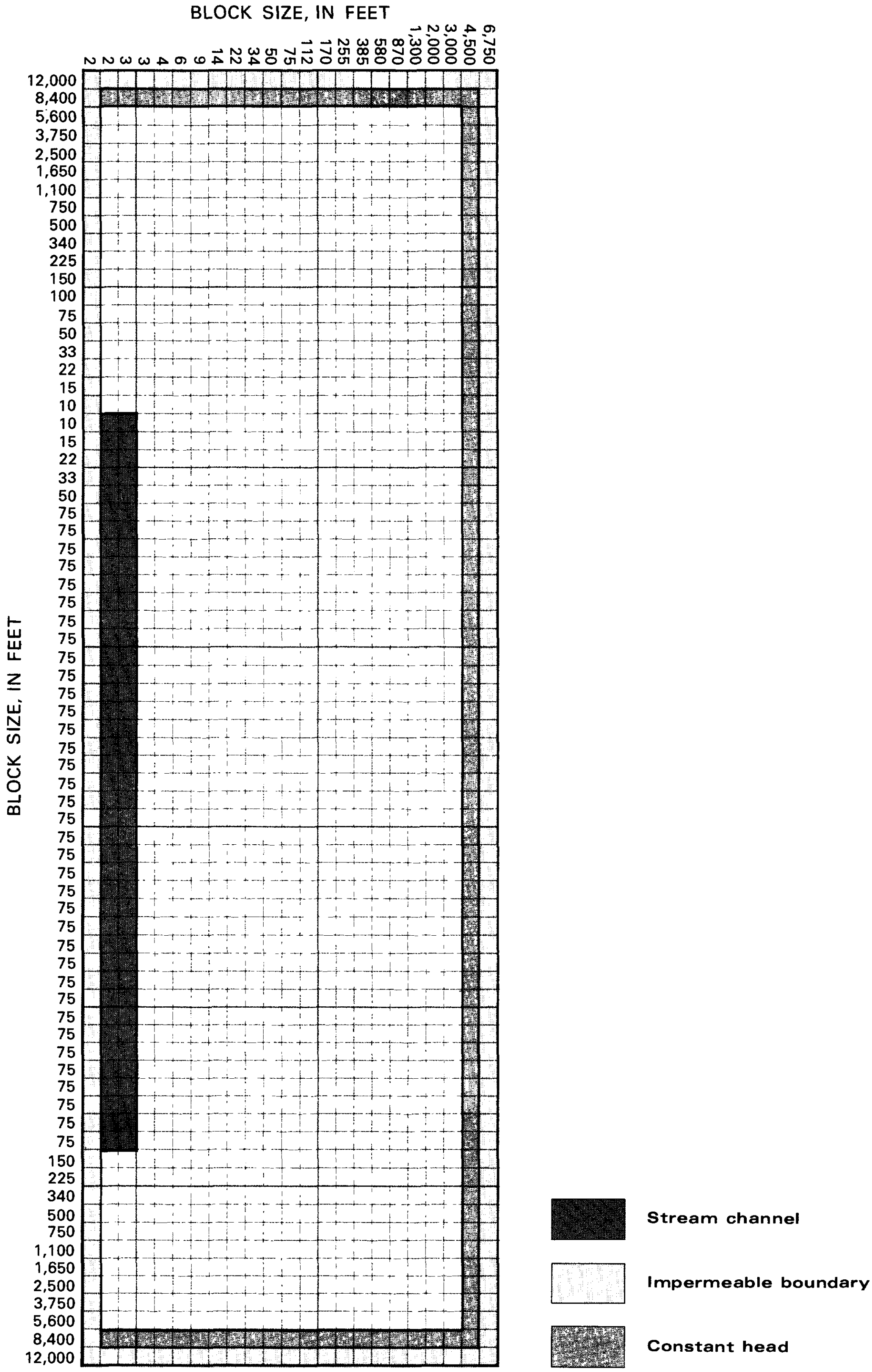

Figure 15. Fosters Brook model grid (areal view). Blocks that simulate injection (seepage) are depicted as stream channel. Impermeable (no-flow) boundary is at center of streambed. Hachures indicate constant-head boundary. Block dimensions are in feet.

and lower end of each reach, (4) seepage rate per unit area of stream channel was calculated by dividing seepage loss for each reach by the area of the reach, and (5) the appropriate injection rate for each node was calculated from the area represented by each individual block. The total stabilized stream length for each pumping period was approximated as closely as the model grid would allow.

As was stated previously, the principal goal of the model simulation was not to obtain a precise prediction of water levels but to compare simulated trends and responses with observed data to observe and assess the dynamics of factors governing the ground-water response to flow augmentation.

Simulated water levels were within an order of magnitude of observed values, and ground-water trends observed in two of the three test periods were successfully duplicated by the three-dimensional model. Figure 16 compares water levels at well N 9624 (fig. 4) with simulated water levels in a hypothetical well similarly located. The simulated water levels rise more sharply than the observed levels over the first 4 days of the test, but from days 4 through 12, the observed levels rise more sharply than the simulated levels. This discrepancy is attributed to use of an average infiltration rate for the entire 12-day period when in fact that rate of infiltration was increasing, as is indicated by trends depicted in figure 6.

Simulated water levels from days 20 to 26 also follow the general observed water-level trends, rising at the beginning of the new pumping period and falling after the first few days; total simulated change in water levels during this 6-day period is also fairly close to the observed change. Simulated water levels from days 12 to 20 do not follow the observed trend; the simulated levels drop slightly on day 13 but slowly rise over the next 7 days, whereas observed water levels fell steadily from beginning to end. This discrepancy is similar to that produced by the analytical equation (fig. 14); in both cases the error is attributed to exclusion of factors affecting infiltration at the streambed and in the unsaturated zone.

Alternatively, the infiltration (recharge) rates used in the numerical model, which were obtained from the linear regression of discharge measurements (fig. 6), may be in error because of the inherent variability of streamflow measurements. However, when the recharge rate in the analytical solution discussed previously was changed to account for the decrease in water temperature, the result was similar to that produced by the three-dimensional model.

When the entire 27-day test period was simulated, water level at the hypothetical well on the last day was close to the observed level at well N 9624, with a difference of less than 0.3 ft. However, simulated and observed water levels near the start of flow differ significantly, as indicated by the water-level net change contours in figure 17. The observed water-level changes are asymmetrical about the center of the stream channel, especially at wells N 9626 and N 9627, near the lower end of reach A (fig. 4), where the water-level increases were 1.7 and 6.2 ft. This asymmetry reflects the heterogeneity of streambed sediments and the corresponding variation in hydraulic conductivity; under ideal conditions the ground-water mound beneath the stream would develop symmetrically around the center of the streambed. Thus, it is probable that the source of error in the model representations is local variation in hydraulic conductivity of streambed and aquifer.

In an idealized flow system, the area of greatest water-level rise would be beneath the stream channel

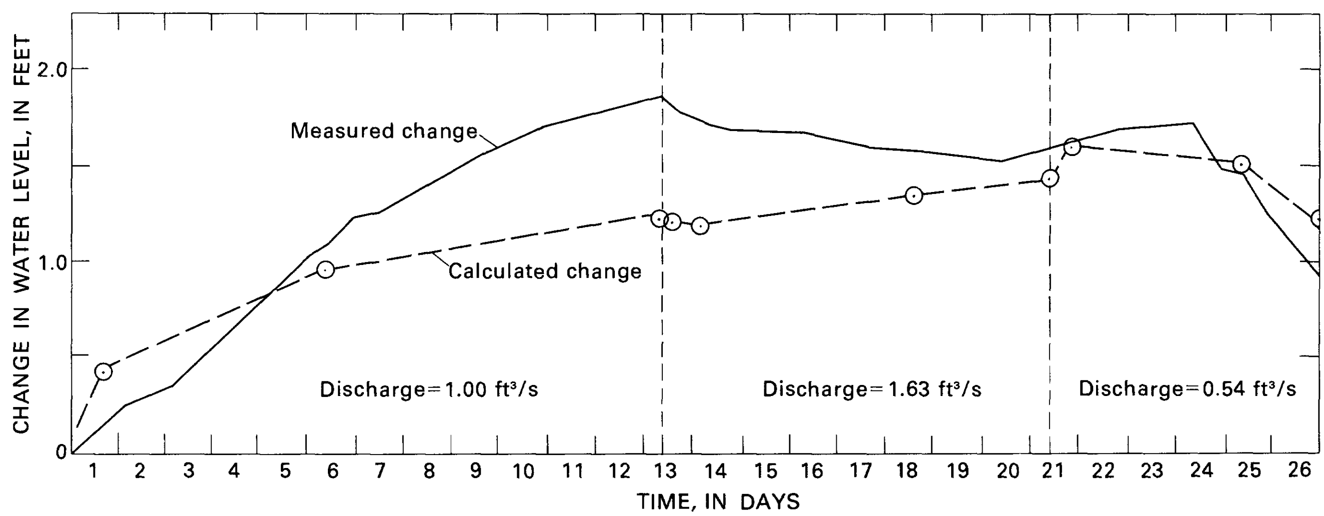

Figure 16. Comparison of the observed water-level change in well N 9624, 45 ft from the center of the stream, with change simulated by a three-dimensional numerical model for a well similarly located.

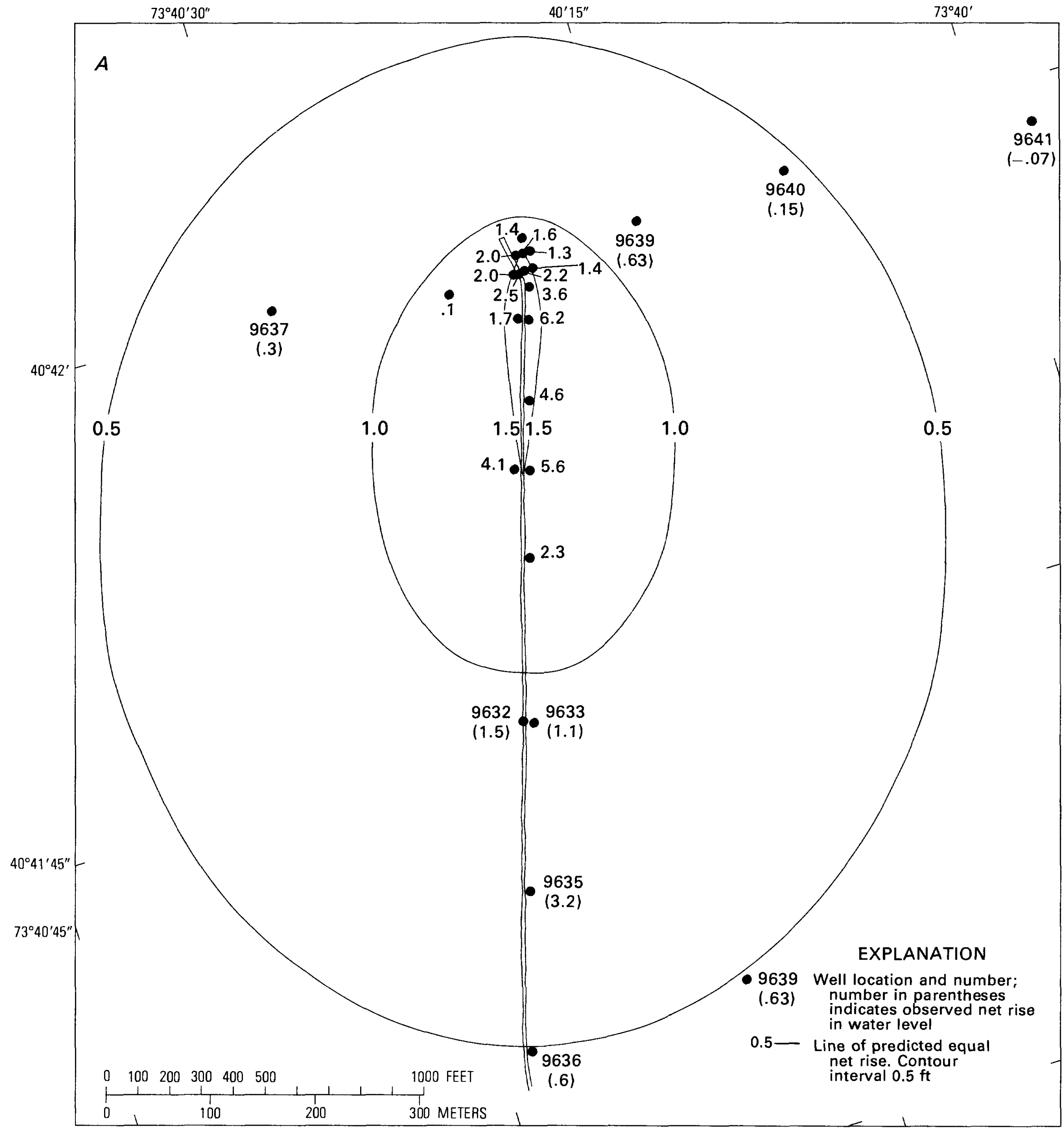

Figure 17. Net increase in ground-water levels near Fosters Brook after 27 days of streamflow augmentation, as simulated by a three-dimensional numerical model. *A,* general view. *B,* detail of upper reaches.

about 400 ft downstream of the point of flow augmentation. However, model response does not conform to observed data, as evidenced by wells in the center of the stream channel (N 9622 and N 9632 in reaches A and D, respectively) which had a net change of less an 2.5 ft, whereas wells in the streambank at other locations indicated more than twice this increase. Furthermore, the point of maximum ground-water buildup along the stream channel was much further downstream (about 700 ft at well N 9627) than was indicated by model analysis.

From wells N 9629 and N 9630 in reach C (fig. 17*A*) to N 9635 in reach E (fig. 17*B*), net change would be expected to diminish gradually, as shown by the water-level contours. However, the field data indicate areas of small net increase (N 9632) surrounded by areas of greater net increase (N 9631 and N 9634), which implies a sub-

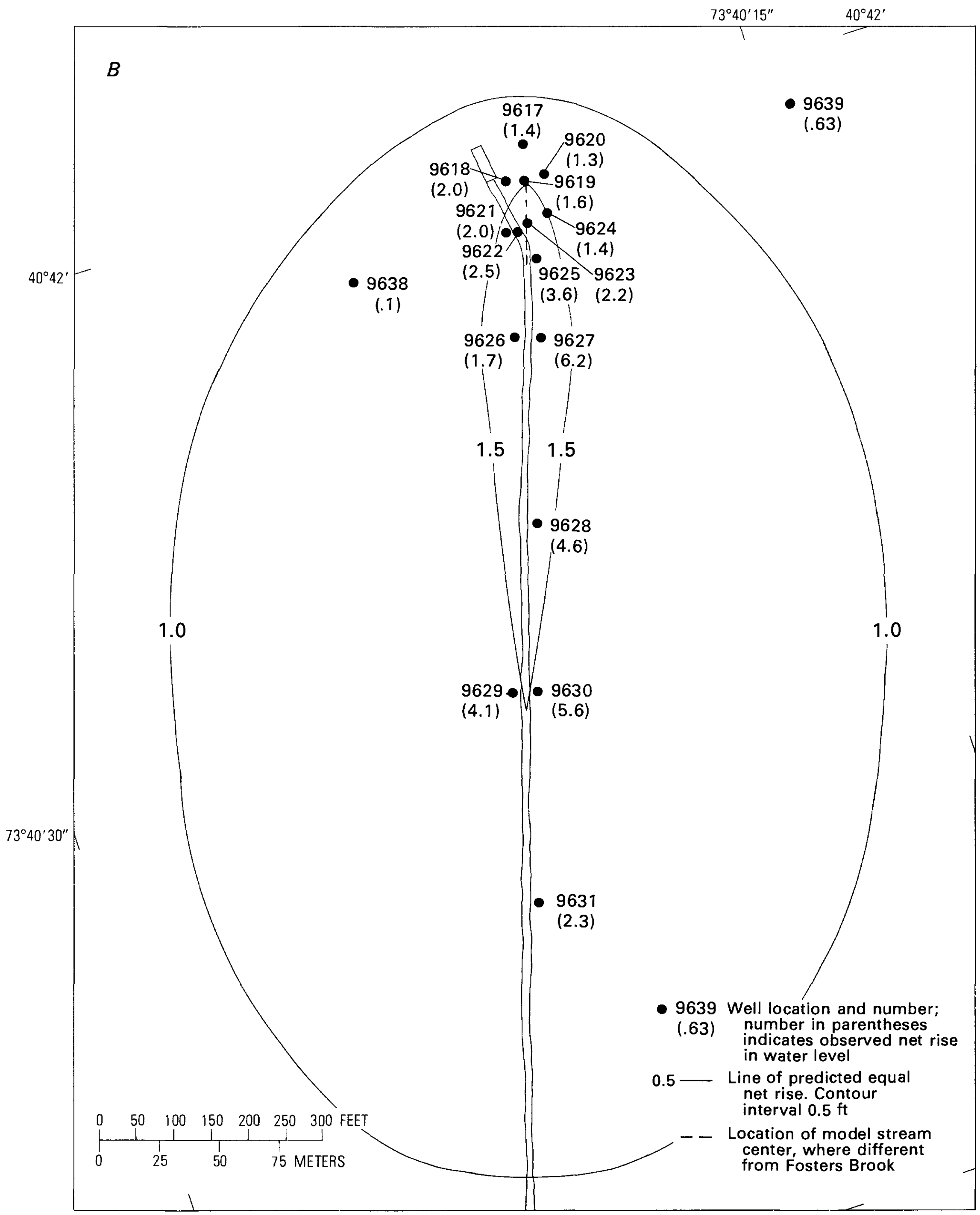

Figure 17. Net increase in ground-water levels near Fosters Brook after 27 days of streamflow augmentation—Continued.

stantial variability of infiltration rates along the stream channel.

Results of the three-dimensional simulation indicate specific aspects in which the errors may have occurred. Of all factors in the stream-augmentation process, flow in the unsaturated zone is the least understood, and the mathematical model does not account for it. Infiltration rates vary not only along the length of stream channel but also across it, but studies to obtain sufficient data on the minute variations in composition and hydrologic characteristics of the aquifer and streambed would not be economically feasible.

As was stated previously, the simulated infiltration rates did not duplicate field conditions exactly; the disparity is attributed mainly to inherent error in the discharge measurements from which infiltration rates were calculated. Division of the stream into small reaches to provide more precise delineations of infiltration rates did not yield substantial improvement because, again, measurements are too imprecise for this purpose. Changes in water-level trends after the augmentation rate was increased on day 12 of the test are assumed to have been related to this increase; however, simulation with analytical and mathematical models indicated that neither temperature change nor local variations in aquifer hydraulic conductivity alone could produce changes as great as those observed.

Thus, infiltration rate varies locally within the stream channel and is affected by external forces such as temperature, evapotranspiration, and clogging. The major factor seems to be hydraulic conductivity of the streambed, but transient changes within the unsaturated zone during infiltration may offset the general trends, making precise calculation difficult or impossible.

SUMMARY AND CONCLUSIONS

Large-scale construction of sanitary sewers in Nassau and Suffolk Counties has caused ground-water levels to decline and streamflow to decrease in many areas, and expansion of sewerage in the future is expected to cause similar effects in other areas. A 27-day streamflow augmentation test was made at Fosters Brook in December 1979 to determine the hydraulic feasibility of pumping ground water into the stream channel to restore streamflow in the dry upper reaches.

Stream discharge, flow in the unsaturated zone, ground-water levels, and water quality were monitored at several points to determine the hydrologic effects of flow augmentation. During the first 12 days, water was provided at 1.00 ft^3/s, from day 13 to day 21 at 1.63 ft3/s, and from day 22 to day 27 at 0.54 ft^3/s. Stream length was monitored regularly.

Soil-moisture measurements were made beneath the stream channel at seven locations throughout the test. Background soil-moisture levels were about 20 percent, but after 20 days of streamflow they had increased to 41 percent, almost saturation level. Soil-moisture logs indicate that the initial wetting front moved through the unsaturated zone at an average rate of 11.2 in/h.

Stream discharge was measured periodically at four sites along the reach and continuously at the point where augmentation was begun. During the first 12 days of the test, discharge decreased with distance from the source, but during the next 6 days it increased within the first 1,500 ft but decreased downstream. Infiltration rates varied greatly from reach to reach.

Stream length, an indicator of average infiltration rates, was monitored throughout the test and indicated that infiltration rates were constantly changing. The stream attained a maximum length of 2,719 ft at a discharge of 1.63 ft^3/s but shortened to 2,154 ft over the next 8 days even though discharge remained the same. Minimum stream length was 815 ft after day 21 at a discharge of 0.54 ft^3/s. The data suggest two distinct infiltration regimes at any given discharge. When the channel is initially wetted, the stream attains maximum length and then shortens quickly because infiltration rates increase rapidly. After a few days, however, when the soil-moisture content approaches saturation, stream length decreases at a distinctly slower rate. Analysis of stream length and augmentation rate indicate a linear relationship within the discharge range studied. However, this relationship was not projected to significantly greater discharge and may become invalid as stream discharge and stage increase beyond values investigated in this study.

Infiltration rates from the stream were affected by several factors including streambed composition (grain size and clay content), water temperature, stream stage, presence of algae, and soil-moisture content. These factors are interdependent, but their relationships are so complex as to make quantified assessments of each nearly impossible.

Ground-water response to flow augmentation was measured at 26 shallow wells along the stream; three were equipped with continuous stage recorders. Response varied areally; the maximum net increase of 6.47 ft occurred about 700 ft below the start of flow during a discharge of 1.63 ft^3/s, while water levels at outlying wells merely reflected the regional decline that occurred during the period studied.

The observed response was compared with results from an analytical and a numerical model to determine and evaluate the hydrologic mechanisms involved. Both analyses indicated that changes in infiltration rate and the resultant water levels in wells could not have been caused solely by temperature changes in the water.

The three-dimensional numerical model simulated the recharge mound as being symmetric about the center of the stream channel with maximum head changes near the point of flow augmentation. The comparison of model results with field data shows that recharge rate varied considerably along the stream and that net change as measured in wells was not symmetrical with respect to the center of the stream. This discrepancy is attributed to variations in infiltration through the streambed as a result of streambed composition and stream-channel alinement. The three-dimensional model successfully duplicated the general trend in water levels during the first and last parts of the test but not the decline in the second test period. Again, this difference is attributed to imprecise measurement of stream discharge and the resulting error in calculated seepage rates.

The test at Fosters Brook demonstrated that flow augmentation in a dry stream channel is hydrologically feasible on Long Island. Small quantities of water (less than 2

ft^3/s) introduced into the dry stream channel flowed over a channel length ranging from 1,000 to 2,000 ft.

If augmentation of a stream similar to Fosters Brook were desired and the initial augmentation rate were less than 2 ft^3/s, water would need to be added downstream to offset seepage losses. If a minimum flow of 0.5 ft^3/s were desired, additional augmentation would be required every 1,000 or 2,000 ft.

The feasibility of augmenting streams at rates exceeding 5 ft^3/s was not tested; this would produce greater velocities and higher stream stages than were considered in this study. Because higher stage would increase infiltration rates, the linear relationship between stream length and augmentation rate would probably not apply.

Before streamflow augmentation is considered as a valid method of replenishing dried-up stream reaches, site-specific studies should be done to evaluate potential hazards. For example, the Fosters Brook study was done where the water table was at sufficient depth that recharge would not raise it to streambed level; in areas where the water table is at lesser depth, flooding could result. Also, even though this investigation was conducted during December, when air temperature was frequently below freezing, algal growth on the streambed was sufficient to decrease infiltration through the stream channel. It is likely that algal growth and other aquatic vegetation during warm seasons would be far greater.

The Fosters Brook test demonstrated that the interrelated factors involved in flow augmentation are complex and difficult to assess. The variability of hydrologic characteristics along any stream may be so great as to make prediction of response almost impossible and to make it likely that the responses observed at Fosters Brook differ from those at other Long Island streams.

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Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979

N-9617

Latitude: 40°42' Longitude: 73°40'19"

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 6	1030	31.51	Dec. 2	1007	30.90	Dec. 6	130	31.51	Dec. 10	549	31.88	Dec. 14	1305	32.06	Dec. 19	1630	32.00
Nov. 16	1015	30.89		1313	30.93		500	31.54		902	31.92		1702	32.05	20	900	31.97
23	1045	30.90		1610	30.94		914	31.57		1311	31.95		2147	32.05		1612	31.99
26	1035	30.69		1905	30.94		1309	31.58		1650	31.99	15	45	32.05	21	35	32.00
27	1226	30.77		2100	30.98		1632	31.60		2260	32.02		607	32.03		823	31.98
30	840	30.66	3	1	30.98		2300	31.67	11	59	32.02		946	32.01		1606	32.01
	1520	30.66		400	31.02	7	515	31.69		559	32.02		1406	32.05	22	31	32.04
	1710	30.64		700	31.02		904	31.67		900	32.04		1720	32.04		825	31.98
	1910	30.62		1025	31.05		1301	31.69		1301	32.06		2001	32.03		1638	32.03
	2100	30.63		1425	31.07		1707	31.70		1702	32.06		2330	32.05	23	10	32.08
	2300	30.64		1729	31.08		2100	31.71		2156	32.07	16	613	32.05		854	32.08
Dec. 1	200	30.65		2000	31.16	8	138	31.71	12	115	32.07		980	32.07		1553	32.10
	500	30.70	4	100	31.18		510	31.71		610	32.07		1400	32.10	24	3	32.12
	700	30.70		500	31.22		910	31.80		900	32.08		1653	32.11		1234	32.16
	920	30.72		920	31.24		1300	31.81		1305	32.10	17	900	32.11		1853	32.12
	1119	30.74		1325	31.23		1720	31.80		1804	32.14		1300	32.07	25	1119	32.03
	1318	30.77		1705	31.31		2148	32.00		2220	32.15		1713	32.00		1936	31.95
	1522	30.80		2125	31.35	9	45	31.83	13	129	32.15	18	26	32.00	26	956	31.80
	1750	30.78	5	100	31.34		612	31.80		910	32.13		627	32.02		1635	31.78
	1906	30.78		503	31.38		905	31.83		1644	32.13		908	32.01	27	1020	31.51
	2100	30.75		902	31.39		1335	31.87		2203	32.10		1421	32.01	28	1132	31.22
2	1	30.88		1304	31.43		1730	31.88	14	111	32.10		1759	32.01	31	945	30.87
	400	30.90		1705	31.46		2212	31.87		609	32.09	19	950	32.02			
	700	30.92		2110	31.50	10	56	31.87		900	32.06		1300	32.02			

N-9618

Latitude: 40°42' Longitude: 73°40'19" Sequence No.: 2

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 6	945	31.58	Dec. 2	1010	31.39	Dec. 6	125	32.32	Dec. 10	547	32.79	Dec. 14	1306	32.80	Dec. 19	1633	32.77
Nov. 16	1030	31.00		1315	31.44		506	32.39		904	32.78		1704	32.80	20	901	32.71
23	1040	31.46		1612	31.47		916	32.38		1313	32.78		2145	32.78		1614	32.68
26	1040	30.62		1907	31.51		1311	32.41		1652	32.78	15	43	32.78	21	53	32.72
27	1234	30.82		2102	31.57		1636	32.44		2159	32.84		603	32.77		830	32.76
30	840	30.68	3	1	31.61		2303	32.57	11	56	32.86		945	32.78		1610	32.77
	1531	30.59		410	31.64	7	519	32.47		615	32.90		1406	32.80	22	27	32.82
	1712	30.56		701	31.67		906	32.43		902	32.89		1718	32.80		827	32.82
	1912	30.58		1025	31.71		1303	32.46		1303	32.91		2002	32.79		1640	32.81
	2105	30.63		1425	31.70		1708	32.49		1705	32.91		2339	32.80	23	20	32.85
	2301	30.72		1733	31.77		2102	32.88		2154	32.94	16	615	32.79		855	32.86
Dec. 1	202	30.85		2010	31.84	8	140	32.89	12	112	32.94		930	32.83		1555	32.88
	503	30.97	4	103	31.88		512	32.57		608	32.95		1400	32.87	24	6	32.90
	701	31.03		503	31.93		912	32.62		903	32.96		1655	32.88		1232	32.90
	925	31.07		922	31.94		1301	32.64		1307	32.98	17	903	32.89		1852	32.81
	1121	31.15		1327	31.94		1730	32.66		1808	32.97		1303	32.78	25	1116	32.59
	1320	31.17		1707	32.06		2142	32.64		2219	33.00		1716	32.74		1934	32.43
	1523	31.19		2128	32.07	9	40	32.64	13	128	32.98	18	22	32.74	26	958	32.21
	1721	31.21	5	103	32.12		609	32.64		902	32.99		623	32.75		1640	32.17
	1909	31.23		506	32.16		907	32.69		1647	32.93		911	32.73	27	1021	31.42
	2102	31.28		1020	32.19		1335	32.72		2159	32.97		1420	32.74	28	1134	31.31
2	2	31.36		1305	32.22		1730	32.73	14	109	32.92		1758	32.73	31	947	30.67
	402	31.39		1708	32.25		2205	32.77		606	32.83	19	903	32.73	Jan. 2	1022	30.56
	702	31.42		2118	32.28	10	48	32.77		902	32.78		1303	32.74	4	1200	30.41

N-9619

Latitude: 40°42' Longitude: 73°40'19" Sequence No.: 3

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 6	1000	31.45	Dec. 2	1012	31.05	Dec. 6	128	31.82	Dec. 10	545	32.31	Dec. 14	1307	32.31	Dec. 19	1636	32.24
Nov. 16	1035	30.94		1317	31.07		545	31.87		906	32.27		1706	32.31	20	904	32.22
23	1050	30.76		1612	31.08		917	31.88		1315	32.27		2143	32.32		1615	32.22
26	1041	30.58		1911	31.11		1312	31.91		1654	32.28	15	40	32.38	21	51	32.22
27	1238	30.77		2100	31.16		1637	31.93		2158	32.34		601	32.45		831	32.26
30	845	30.61	3	10	31.16		2305	31.97	11	54	32.36		941	32.29		1612	32.27
	1530	30.57		412	31.21	7	523	32.00		612	32.38		1405	32.31	22	26	32.34
	1715	30.56		705	31.23		907	31.97		903	32.38		1717	32.31		830	32.32
	1915	30.57		1028	31.26		1304	32.01		1304	32.39		2003	32.30		1643	32.34
	2107	30.57		1427	31.27		1711	32.02		1706	32.41		2340	32.31	23	23	32.37
	2303	30.58		1736	31.33		2107	32.48		2152	32.44	16	616	32.31		856	32.37
Dec. 1	109	30.67		2005	31.39	8	43	32.06	12	109	32.46		925	32.34		1536	32.38
	505	30.73	4	110	31.44		523	32.07		607	32.46		1358	32.37	24	10	32.40
	705	30.74		507	31.48		915	32.12		905	32.46		1700	32.38		1230	32.42
	930	30.77		925	31.46		1302	32.14		1308	32.48	17	906	32.34		1851	32.32
	1122	30.82		1330	31.49		1730	32.12		1808	32.48		1308	32.33	25	1114	32.16
	1323	30.84		1709	31.58		2145	32.14		2217	32.49		1718	32.26		1933	32.07
	1525	30.87		2130	31.60	9	38	32.14	13	126	32.42	18	19	32.27	26	1000	31.87
	1723	30.90	5	106	31.63		605	32.14		903	32.44		619	32.27		1643	31.77
	1912	30.90		509	31.67		908	32.18		1648	32.42		912	32.27	27	1023	31.36
	2103	30.97		911	31.69		1330	32.20		2154	32.42		1428	32.26	28	1136	31.02
2	4	31.00		1307	31.73		1725	32.24	14	105	32.38		1757	32.24	31	949	30.69
	403	31.04		1709	31.76		2209	32.25		604	32.35	19	906	32.25	Jan. 2	1024	30.56
	703	31.05		2120	31.78	10	52	32.27		903	32.32		1306	32.26	4	1203	30.41

N-9620

Latitude: 40°42' Longitude: 73°40'19" Sequence No.: 4

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 6	915	31.59	Dec. 2	1015	30.84	Dec. 6	110	31.50	Dec. 10	1422	31.82	Dec. 14	2141	31.99	Dec. 20	906	31.92
Nov. 16	1040	30.81		1319	30.87		539	31.54		1656	31.90	15	38	31.99		1616	31.92
23	1100	30.49		1615	30.89		918	31.53		2154	31.96		559	31.99	21	49	31.91
26	1043	30.64		1913	30.89		1314	31.56	11	51	32.03		945	31.98		834	31.95
27	1244	30.74		2110	30.95		1639	31.56		608	32.08		1405	31.99		1614	31.96
30	850	30.64	3	15	30.96		2307	31.63		905	32.00		1715	31.99	22	24	31.99
	1525	30.61		411	30.98	7	525	31.64		1306	32.01		2004	31.99		832	31.97
	1720	30.60		707	31.00		909	31.62		1707	31.99		2341	31.99		1644	32.03
	1918	30.59		1030	31.04		1306	31.66		2150	32.05	16	617	32.00	23	24	32.08
	2110	30.58		1427	31.02		1713	31.66	12	108	32.05		925	32.03		857	32.03
	2310	30.58		1738	31.09		2110	31.70		606	32.05		1338	32.05		1557	32.04
Dec. 1	112	30.63		2010	31.15	8	45	31.71		910	32.05		1700	32.05	24	12	32.07
	508	30.65	4	117	31.18		520	31.72		1310	32.07	17	909	32.01		1228	32.09
	706	30.65		515	31.21		918	31.75		1810	32.09		1315	32.00		1848	32.15
	940	30.65		927	31.18		1303	31.77		2216	32.11		1718	31.95	25	1112	31.92
	1125	30.71		1332	31.19		1736	31.79	13	124	32.09	18	13	31.99		1931	31.86
	1325	30.75		1711	31.27		2149	31.89		904	32.11		613	32.01	26	1002	31.69
	1527	30.76		2133	31.36	9	36	32.09		1650	32.10		914	31.94		1645	31.62
	1722	30.75	5	109	31.32		601	32.29		2150	32.08		1417	31.97	27	1024	31.36
	1912	30.79		511	31.34		901	31.81	14	103	32.04		1755	31.95	28	1138	31.08
	2105	30.81		914	31.36		1330	31.84		601	32.03	19	910	31.96	31	951	30.76
Dec. 2	4	30.85		1309	31.40		1728	31.85		904	31.98		1310	31.96	Jan. 2	1026	30.64
	405	30.87		1711	31.43		2210	31.92		1308	31.94		1639	31.97	4	1158	30.50
	707	30.88		2122	31.47	10	49	31.93		1708	31.97						

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9621

Latitude: 40°42' Longitude: 73°40'21" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Sept. 19	1300	31.31	Dec. 2	1032	31.24	Dec. 6	113	32.17	Dec 10	539	32.88	Dec. 14	1315	32.85	Dec. 19	1650	32.68
Nov. 16	1045	30.93		1336	31.28		543	32.30		912	32.84		1716	32.83	20	918	32.64
23	1120	30.81		1641	31.31		924	32.26		1320	32.85		2135	32.85		1626	32.66
26	1045	30.60		1936	31.33		1319	32.29		1704	32.87	15	36	32.85	21	43	32.68
27	1248	30.81		2132	31.38		1643	32.27		2139	32.92		552	32.83		836	32.71
30	905	30.62	3	40	31.40		2310	32.46	11	49	32.96		938	32.80		1628	32.76
	1550	30.48		435	31.46	7	537	32.39		602	33.02		1400	32.81	22	20	32.85
	1737	30.46		730	31.47		915	32.37		909	33.01		1700	32.81		834	32.78
	1932	30.52		1050	31.54		1312	32.40		1309	33.04		2005	32.79		1647	32.84
	2129	30.58		1521	31.53		1719	32.42		1714	33.03		2343	32.80	23	30	32.85
	2324	30.59		1832	31.56		2132	32.47		2140	33.07	16	619	32.81		907	32.87
Dec. 1	225	30.78		2015	31.66	8	40	32.46	12	104	33.07		915	32.82		1602	32.90
	525	30.86	4	120	31.70		518	32.46		555	33.09		1349	32.88	24	16	32.90
	715	30.91		520	31.75		935	32.59		912	33.08		1700	32.90		1223	32.95
	945	30.95		945	31.73		1315	32.63		1312	33.10	17	912	32.80		1846	32.75
	1145	31.01		1343	31.77		1747	32.64		1820	33.10		1315	32.75	25	1106	32.46
	1342	31.03		1716	31.89		2146	32.65		2206	33.12		1725	32.72		1929	32.21
	1544	31.06		2137	31.88	9	33	32.68	13	112	33.07		2355	32.71	26	1008	31.97
	1736	31.06	5	111	31.92		559	32.70		907	33.07	18	609	32.72		1147	31.88
	1935	31.10		517	31.96		920	32.72		1640	32.96		922	32.70	27	1025	31.35
	2125	31.15		924	32.00		1315	32.76		2149	32.97		1408	32.70	28	1140	30.99
2	40	31.20		1314	32.06		1720	32.80	14	100	32.90		1751	32.67	31	1001	30.60
	430	31.22		1717	32.09		2155	32.89		559	32.86	19	913	32.67	Jan. 2	1028	20.48
	730	31.25		2136	32.15	10	41	32.89		912	32.85		1313	32.68		1155	30.29

N-9623

Latitude: 40°42' Longitude: 73°40'19" Sequence No.: 5

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 6	1046	31.43	Dec. 2	1321	31.34	Dec. 6	520	32.51	Dec. 10	908	33.24	Dec. 14	1710	33.16	Dec. 20	910	32.96
Nov. 16	1050	30.72		1621	31.38		920	32.53		1316	33.25		2138	33.21		1618	32.89
23	1115	30.59		1916	31.39		1315	32.58		1658	33.28	15	35	33.17	21	46	33.01
26	1050	30.49		2112	31.26		1641	32.59		2149	33.51		557	33.08		840	33.06
27	1255	30.72	3	18	31.51		2313	32.80	11	45	33.51		930	33.13		1616	33.00
30	852	30.71		414	31.54	7	520	32.68		559	33.41		1400	33.16	22	21	33.14
	1535	30.47		710	31.57		911	32.68		906	33.41		1715	33.13		835	33.20
	1722	30.47		1034	31.64		1307	32.73		1307	33.44		2006	33.12		1649	33.07
	1914	30.47		1429	31.66		1715	32.75		1710	33.44		2344	33.11	23	33	33.13
	2310	30.50		1742	31.69		2135	32.81		2146	33.47	16	619	33.12		900	33.15
Dec. 1	213	30.61		2020	31.80	8	49	32.81	12	100	33.47		920	33.13		1558	33.21
	510	30.74	4	123	31.84		530	32.86		601	33.47		1350	33.19	24	14	33.18
	708	30.81		525	31.90		922	32.91		915	33.49		1702	33.21		1226	33.16
	940	30.87		929	31.91		1305	32.96		1315	33.51	17	915	33.11		1844	32.96
	1127	30.93		1335	31.94		1735	32.97		1812	33.58		1320	33.08	25	1109	32.65
	1325	30.98		1712	32.06		2137	32.98		2212	33.51		1722	33.00		1927	32.36
	1528	31.05		2136	32.09	9	30	33.00	13	118	33.48	18	11	33.00	26	1004	31.99
	1723	31.07	5	115	32.14		555	33.04		905	33.46		608	33.08		1645	31.91
	1917	31.09		515	32.20		911	33.09		1638	33.42		916	32.98	27	1028	31.37
	2106	31.13		917	32.23		1320	33.13		2126	33.26		1413	32.96	28	1142	30.97
2	15	31.21		1311	32.28		1715	33.21	14	58	33.25		1754	32.94	31	1003	30.65
	407	31.25		1713	32.36		2152	33.22		555	33.27	19	915	32.93	Jan. 2	1030	30.51
	711	31.29		2127	32.42	10	39	33.24		906	33.18		1315	32.94	4	1152	30.35
	1017	31.28	6	120	32.46		537	33.24		1410	33.16		1642	32.94			

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9625

Latitude: 40°41'59" Longitude: 73°40'20" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 6	1128	31.73	Dec. 2	1019	32.18	Dec. 6	110	34.07	Dec. 10	533	35.52	Dec. 14	1316	35.39	Dec. 1	1645	35.40
Nov. 16	1105	30.99		1322	32.24		523	34.16		914	35.52		1717	35.30	20	912	34.50
23	1140	30.90		1623	32.30		925	34.25		1345	35.54		2133	35.19		1622	34.70
26	1055	32.63		1928	32.34		1319	34.33		1708	35.57	15	33	35.12	21	37	34.85
27	1300	31.00		2117	32.41		1645	34.36		2141	35.63		555	35.08		845	34.94
30	915	30.78	3	25	32.44		2321	34.70	11	32	35.67		930	35.09		1618	35.06
	1540	30.50		420	32.52	7	545	34.54		610	35.73		1402	35.02	22	13	35.08
	1730	30.48		716	32.57		916	34.56		910	35.75		1700	34.99		844	35.12
	1928	30.65		1040	32.64		1314	34.65		1310	35.79		2009	34.99		1655	35.23
	2121	30.87		1430	32.67		1721	34.63		1717	35.81		2348	34.98	23	35	35.31
	2315	31.11		1745	32.64		2119	34.74		2143	35.82	16	622	34.95		903	35.35
Dec. 1	215	31.36		2035	32.85	8	200	34.73	12	58	35.82		920	34.98		1600	35.38
	515	31.55	4	127	32.94		559	34.73		558	35.82		1350	35.16	24	18	35.40
	710	31.62		528	33.04		925	34.98		920	35.84		1701	35.22		1220	35.38
	952	31.70		938	33.11		1310	35.04		1318	35.87	17	915	34.80		1813	34.79
	1130	31.76		1338	33.19		1740	35.07		1817	35.91		1321	34.74	25	1101	34.07
	1330	31.84		1714	33.32		2134	35.08		2210	35.92		1723	34.67		1925	35.51
	1531	31.88		2145	33.42	9	38	35.08	13	115	35.85		2359	34.68	26	1006	32.89
	1727	31.96	5	119	33.51		609	35.09		908	35.84	18	602	34.69		1647	32.63
	1921	31.94		523	33.61		912	35.28		1635	35.71		918	34.64	27	1032	31.95
	2110	32.01		921	33.69		1318	35.35		2143	35.57		1411	34.58	28	1147	31.46
2	20	32.07		1319	33.78		1715	35.38	14	52	35.57		1753	34.63	31	1020	30.90
	415	32.14		1719	33.87		2156	35.44		552	35.53	19	918	34.54	Jan. 2	1040	30.69
	715	32.18		2123	33.99	10	46	35.48		913	35.46		1318	34.54	4	1143	30.48

N-9626

Latitude: 40°41'58" Longitude: 73°40'21" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Sept. 19	1400	32.17	Dec. 2	1030	30.60	Dec. 6	118	31.46	Dec. 10	530	31.95	Dec. 14	1318	32.04	Dec. 19	1648	32.03
Nov. 16	1110	30.49		1333	30.63		538	31.49		917	31.92		1720	32.03	20	916	32.00
23	1145	30.31		1634	30.65		928	31.53		1348	31.92		2131	32.02		1622	31.99
26	1100	30.26		1934	30.67		1323	31.54		1712	31.93	15	32	32.02	21	36	31.94
27	1305	30.42		2129	30.82		1649	31.56		2139	31.96		550	32.04		847	32.03
30	910	30.29	3	25	30.75		2326	31.69	11	30	32.00		935	32.02		1624	32.02
	1545	30.24		430	30.80	7	550	31.67		558	32.04		1400	32.03	22	16	32.11
	1735	30.25		735	30.80		920	31.71		913	32.02		1700	32.04		847	32.03
	1935	30.25		1047	30.88		1317	31.69		1315	32.01		2011	32.03		1657	32.04
	2127	30.22		1520	30.89		1725	31.66		1720	32.01		2352	32.03	23	47	32.06
	2320	30.25		1828	30.92		2129	31.70		2139	32.06	16	627	32.02		905	32.07
Dec. 1	220	30.30		2045	31.02	8	203	31.66	12	56	32.06		915	32.07		1601	32.08
	520	30.33	4	130	31.06		601	31.67		553	32.05		1347	32.09	24	24	32.08
	712	30.38		534	31.11		932	31.80		922	32.04		1715	32.11		1220	32.12
	948	30.39		940	31.09		1314	31.91		1320	32.07	17	918	32.07		1830	32.07
	1142	30.42		1340	31.10		1745	31.82		1818	32.09		1325	32.04	25	1103	31.97
	1340	30.46		1718	31.22		2132	31.82		2204	32.13		1726	32.02		1923	31.89
	1542	30.47		2154	31.22	9	36	31.82	13	109	32.09		2351	32.04	26	1010	31.61
	1735	30.48	5	122	31.25		607	31.82		911	32.12	18	559	32.04		1650	31.54
	1931	30.50		528	31.30		919	31.87		1632	32.12		919	32.02	27	1033	31.19
	2120	30.55		931	31.31		1510	31.90		2142	32.14		1410	32.02	28	1150	30.92
2	25	30.59		1323	31.34		1712	31.91	14	53	32.21		1749	32.02	31	1022	30.54
	426	30.61		1724	31.39		2150	31.91		549	32.25	19	920	32.02	Jan. 2	1044	30.39
	725	30.62		2130	31.44	10	41	31.92		916	32.09		1320	32.02	4	1141	30.19

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9627

Latitude: 40°41'58" Longitude: 73°40'21" Sequence No.: 2

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 6	1145	32.61	Dec. 2	1023	32.69	Dec. 6	100	35.87	Dec. 10	915	36.77	Dec. 14	1719	36.89	Dec. 20	922	36.86
Nov. 16	1115	31.11		1325	32.81		534	35.95		1346	36.78		2129	36.89		1628	36.94
23	1155	31.22		1627	32.93		926	36.05		1710	36.80	15	30	36.88	21	34	36.85
26	1105	30.66		1929	33.07		1321	36.12		2136	36.84		548	36.88		850	36.89
27	1310	31.13		2120	33.19		1647	36.14	11	28	36.87		925	36.89		1620	36.91
30	910	31.10	3	28	33.29	7	553	36.35		552	36.89		1356	36.91	22	11	36.93
	1500	30.61		422	33.49		918	36.33		913	36.89		1658	36.92		849	36.93
	1751	30.63		713	33.60		1316	36.39		1312	36.91		2010	36.92		1700	36.96
	1901	30.61		1042	33.77		1723	36.41		1718	36.92		2350	36.93	23	45	37.02
	2100	30.60		1433	33.88		2138	36.43		2136	36.96	16	626	36.93		908	36.93
	2300	30.64		1750	34.03	8	206	36.48	12	52	36.96		910	36.94		1604	36.96
Dec. 1	200	30.84		2050	34.24		608	36.45		550	36.96		1345	36.97	24	21	37.00
	500	31.14	4	135	34.40		930	36.56		925	36.95		1705	36.98		1218	37.04
	700	31.35		538	34.59		1312	36.59		1320	36.98	17	918	36.91		1833	36.90
	1001	31.58		948	34.75		1741	36.60		1822	37.00		1330	36.89	25	1058	36.78
	1134	31.71		1350	34.93		2130	36.63		2202	37.01		1730	36.86		1921	36.72
	1333	31.83		1718	35.07	9	34	36.63	13	100	37.05		2349	36.91	26	1012	35.63
	1534	31.90		2148	35.13		603	36.70		910	37.03	18	554	36.90		1652	35.42
	1724	32.00	5	125	35.32		916	36.68		1630	37.07		923	36.88	27	1035	34.09
	1923	32.09		525	35.44		1310	36.73		2139	37.01		1405	36.88	28	1018	33.15
	2115	32.21		927	35.53		1710	36.73	14	50	36.97		1748	36.86	31	1024	31.93
2	25	32.35		1321	35.62		2148	36.76		546	36.92	19	922	36.86	Jan. 2	1040	31.37
	418	32.51		1721	35.73	10	39	36.77		915	36.89		1322	36.86	4	1138	31.09
	720	32.61		2132	35.81		527	36.79		1317	36.91		1654	36.87			

N-9628

Latitude: 40°41'56" Longitude: 73°40'21" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 7	1124	33.67	Dec. 2	1026	34.23	Dec. 6	52	35.08	Dec. 10	524	35.52	Dec. 14	1320	36.16	Dec. 19	1657	36.43
Sept. 10	1130	32.98		1327	34.27		538	35.11		921	35.72		1723	36.18	20	926	36.44
Nov. 16	1120	32.55		1630	34.31		930	35.13		1350	35.74		2127	36.19		1618	36.35
23	1200	32.71		1930	34.37		1325	35.16		1705	35.75	15	28	36.19	21	31	36.34
26	1110	32.75		2124	34.41		1652	35.19		2135	35.80		540	36.22		856	36.34
27	1315	32.99	3	30	34.44		2333	35.34	11	26	35.83		925	36.20		1600	36.37
30	920	32.99		425	34.49	7	556	35.35		549	35.87		1356	36.22	22	9	36.40
	1505	31.87		718	34.52		922	35.31		917	35.89		1655	36.25		855	36.40
	1712	31.86		1044	34.56		1319	35.36		1316	35.89		2012	36.26		1704	36.45
	1905	32.34		1435	34.54		1727	35.37		1722	35.89		2356	36.26	23	50	36.46
	2105	32.79		1752	34.60		2124	35.38		2134	35.89	16	629	36.27		912	36.44
	2305	33.09		2055	34.67	8	208	35.38	12	48	35.90		910	36.27		1607	36.46
Dec. 1	205	33.38	4	137	34.70		603	35.43		547	35.92		1340	36.31	24	30	36.18
	500	33.56		541	34.74		939	35.50		906	35.96		1710	36.44		1212	36.53
	705	33.66		951	34.74		1317	35.51		1320	36.00	17	920	36.37		1832	36.47
	1008	33.74		1352	34.74		1715	35.52		1824	36.03		1332	36.37	25	1056	36.46
	1137	33.79		1721	34.79		2129	35.56		2159	36.29		1732	36.32		1917	36.51
	1336	33.85		2153	34.84	9	30	35.57	13	106	36.07		2344	36.35	26	1014	36.19
	1538	33.88	5	128	34.87		600	35.57		914	36.11	18	549	36.37		1654	36.16
	1732	33.92		531	34.91		925	35.62		1627	36.13		925	36.37	27	1037	35.12
	1926	33.94		934	34.93		1306	35.64		2135	36.16		1403	36.38	28	1155	34.46
	2118	34.00		1326	34.94		1707	35.66	14	47	36.14		1746	36.38	31	1030	33.44
2	30	34.10		1727	34.97		2145	35.74		542	36.14	19	925	35.40	Jan. 2	1046	32.84
	422	34.15		2130	35.02	10	35	35.54		918	36.14		1325	36.40	4	1135	32.29

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9629

Latitude: 40°41'54" Longitude: 73°40'21" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Sept. 10	1200	32.14	Dec. 2	1008	32.46	Dec. 6	10	33.94	Dec. 10	539	34.24	Dec. 14	1324	34.36	Dec. 19	1700	34.48
Oct. 18	947	29.54		1316	32.62		510	33.95		925	34.18		1728	34.34	20	928	34.46
Nov. 16	1125	30.84		1620	32.72		934	33.95		1354	34.22		2124	34.37		1626	34.54
23	1300	30.72		1915	32.79		1329	33.95		1720	34.20	15	27	34.35	21	28	34.42
27	1321	30.71		2100	32.84		1657	33.97		2131	34.25		544	34.35		900	34.40
30	925	30.72		2350	32.92		2300	33.99	11	24	34.26		921	34.36		1604	34.29
	1510	30.11	3	412	33.05	7	503	34.05		547	34.28		1348	34.44	22	7	34.29
	1716	30.05		710	33.10		927	33.97		922	34.29		1650	34.45		858	34.22
	1912	30.06		1030	33.14		1323	34.01		1320	34.33		2020	34.43		1707	34.16
	2115	30.29		1439	33.25		1732	34.01		1727	34.36		2359	34.44	23	56	34.14
	2310	30.49		1754	33.30		2122	34.01		2131	34.32	16	633	34.42		914	34.08
Dec. 1	210	30.76		2105	33.44	8	248	34.01		45	34.32		905	34.48		1608	34.08
	505	31.03	4	140	33.50		600	34.02		543	34.33		1335	34.52	24	27	34.05
	710	31.17		538	33.56		945	34.08		909	34.34		1650	34.52		1208	34.06
	940	31.32		1000	33.53		1318	34.09		1325	34.37	17	923	34.41		1828	34.10
	1115	31.48		1358	33.58		1705	34.04		1827	34.35		1330	34.42	25	1054	34.22
	1320	31.61		1724	33.64		2123	34.09		2155	34.38		1736	34.37		1915	34.09
	1520	31.76		2216	33.71	9	27	34.07	13	104	34.34		2340	34.48	26	1016	33.60
	1805	31.95	5	106	33.74		557	34.06		919	34.40	18	548	34.47		1656	33.41
	1906	31.95		510	33.75		938	34.14		1625	34.43		927	34.45	27	1038	32.26
	2100	32.02		943	33.73		1305	34.23		2132	34.37		1402	34.49	28	1159	31.79
2	5	32.15		1336	33.80		1705	34.24	14	44	34.34		1744	34.44	31	1032	30.85
	412	32.33		1732	33.83		2140	34.22		539	34.33	19	927	34.48	Jan. 2	1048	30.42
	715	32.38		2110	33.80	10	31	34.24		923	34.32		1327	34.47	4	1132	30.22

N-9630

Latitude: 40°41'54" Longitude: 73°40'21" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 7	1110	32.13	Dec. 2	1014	33.79	Dec. 6	5	35.21	Dec. 10	531	35.49	Dec. 14	1322	35.67	Dec. 19	1702	35.77
Sept. 10	1120	31.81		1320	33.94		505	35.24		923	35.49		1725	35.65	20	930	35.77
Nov. 16	1130	30.78		1622	34.03		932	35.24		1352	35.50		2122	35.67		1630	35.77
23	1255	30.13		1915	34.13		1328	35.25		1717	35.50	15	26	35.68	21	27	35.78
26	1115	30.22		2105	34.17		1654	35.25		2129	35.63		542	35.70		903	35.56
27	1325	30.82		2355	34.25		2303	35.26	11	23	35.62		920	35.67		1605	35.56
30	927	30.32	3	415	34.35	7	507	35.32		545	35.60		1348	35.70	22	5	35.57
	1515	29.96		715	34.43		925	35.37		920	35.57		1650	35.70		859	35.55
	1719	29.95		1025	34.47		1322	35.34		1319	35.61		2017	35.69		1709	35.56
	1908	30.23		1438	34.55		1729	35.33		1725	35.59		2357	35.69	23	59	35.54
	2110	30.76		1753	34.61		2218	35.33		2128	35.59	16	631	35.71		917	35.50
	2310	31.19		2115	34.72	8	231	35.13	12	40	35.61		905	35.73		1610	35.52
Dec. 1	210	31.63	4	145	34.78		558	34.41		539	35.63		1335	35.73	24	35	35.50
	510	31.97		540	34.83		947	35.39		911	35.61		1650	35.75		1207	35.56
	710	32.14		958	34.83		1322	35.42		1327	35.67	17	926	35.76		1825	35.53
	945	32.36		1359	34.90		1701	35.42		1837	35.68		1335	35.75	25	1052	35.56
	1117	32.51		1725	34.95		2121	35.42		2153	35.69		1737	35.71		1912	35.47
	1322	32.69		2117	34.98	9	24	35.42	13	101	35.70		2336	35.76	26	1018	34.62
	1525	32.83	5	105	34.99		552	35.42		916	35.73	18	545	35.79		1659	34.49
	1802	32.99		515	35.03		935	35.46		1624	35.68		928	35.74	27	1039	33.13
	1907	33.03		940	35.06		1302	35.48		2129	35.69		1400	35.75	28	1201	32.14
	2105	33.18		1334	35.10		1705	35.49	14	41	35.67		1742	35.73	31	1034	30.88
2	10	33.35		1730	35.12		2136	35.51		536	35.63	19	929	35.77	Jan. 2	1050	30.48
	415	33.55		2105	35.19	10	31	35.48		921	35.66		1330	35.78	4	1129	30.15
	708	33.67															

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9631

Latitude: 40°41'51" Longitude: 73°40'23" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 7	1105	29.92	Dec. 2	720	30.59	Dec. 5	2145	31.33	Dec. 10	28	31.69	Dec. 14	926	32.07	Dec. 19	1704	32.41
Sept. 10	1230	30.86		1017	30.64	6	15	31.35		527	31.69		1326	32.10	20	934	32.42
Nov. 16	1135	29.58		1322	30.69		515	31.37		928	31.70		1730	32.10		1635	32.32
23	1305	29.11		1625	30.70		936	31.37		1356	31.72		2120	32.11	21	22	31.85
26	1120	29.30		1920	30.74		1331	31.38		1723	31.75	15	24	32.12		907	31.45
27	1331	29.76		2110	30.72		1659	31.39		2126	31.78		540	32.14		1608	31.22
30	930	29.54	3	1	30.79		2310	31.41	11	21	31.88		916	32.14	22	3	31.05
	1525	29.03		420	30.85	7	511	31.45		540	32.18		1340	32.17		905	30.82
	1722	29.03		720	30.85		924	31.48		927	31.88		1645	32.18		1712	30.71
	1915	29.27		1034	30.87		1336	31.50		1323	31.83		2025	32.19	23	105	30.44
	2120	29.64		1443	30.78		1734	31.53		1729	31.82	16	1	32.20		919	30.45
	2320	29.84		1755	30.95		2115	31.54		2126	31.83		603	32.23		1612	30.38
Dec. 1	215	30.00		2125	31.01	8	220	31.51	12	36	31.83		902	32.25	24	40	30.32
	515	30.09	4	130	31.05		552	31.53		535	31.86		1332	32.28		1204	30.24
	715	30.14		545	31.08		952	31.60		913	31.86		1640	32.30		1823	30.75
	950	30.19		1003	31.07		1325	31.61		1330	31.88	17	930	32.30	25	1050	31.35
	1120	30.27		1402	31.09		1705	31.57		1838	31.92		1338	32.31		1409	31.32
	1325	30.31		1727	31.15		2119	31.59		2151	31.95		1740	32.30	26	1020	31.00
	1527	30.35		2119	31.18	9	20	31.59	13	59	31.98		2334	32.36		1700	30.81
	1800	30.39	5	108	31.21		549	31.61		921	32.00	18	542	32.35	27	1040	30.42
	1911	30.43		520	31.23		930	31.65		1719	32.06		930	32.37	28	1205	30.04
	2110	30.46		945	31.22		1300	31.68		2124	32.15		1358	32.36	31	1036	29.44
2	15	30.51		1339	31.26		1700	31.70	14	38	32.11	19	930	32.40	Jan. 2	1054	29.25
	420	30.57		1735	31.27		2132	31.74		533	32.08		1332	32.40	4	1126	29.05

N-9632

Latitude: 40°41'46" Longitude: 73°40'25" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Oct. 18	1000	28.01	Dec. 2	2120	29.66	Dec. 6	1706	28.94	Dec. 10	1729	28.76	Dec. 14	2117	30.20	Dec. 20	940	30.97
Nov. 16	1200	28.22	3	5	29.65		2321	29.00		2121	28.79	15	21	30.25		1645	30.76
23	1350	28.16		428	29.70	7	524	29.44	11	18	28.89		531	30.30	21	13	30.36
30	1535	28.00		725	29.72		934	29.51		525	29.19		915	30.29		924	29.78
	1727	27.97		1038	29.71		1331	29.45		934	28.84		1342	30.37		1613	29.56
	2220	28.04		1448	29.61		1741	29.41		1328	28.77		1640	30.40	22	1	29.47
	2330	28.08		1800	29.63		2215	29.24		1729	28.73		2028	30.42		909	29.24
Dec. 1	220	28.33		2155	29.66	8	218	29.17		2123	28.79	16	7	30.42		1718	29.12
	520	28.63	4	200	29.69		545	29.11	12	30	28.79		555	30.38	23	112	29.05
	720	28.75		555	29.72		1000	29.13		532	28.77		900	30.52		923	28.95
	958	28.81		1012	29.67		1330	29.07		922	28.75		1330	30.60		1619	28.91
	1130	29.01		1410	29.69		1645	29.04		1334	28.78		1635	30.62	24	51	28.86
	1330	29.11		1733	29.60		2112	29.00		1847	28.79	17	940	30.68		1200	28.81
	1536	29.18		2206	29.48	9	14	28.99		2145	28.95		1340	30.72		1819	28.77
	1754	29.23	5	113	29.44		540	28.99	13	56	29.33		1745	30.71	25	1044	29.49
	1917	29.27		530	29.36		941	28.89		926	29.65		2330	30.78		1906	29.46
	2118	29.35		953	29.27		1255	28.90		1616	29.69	18	540	30.77	26	1024	29.03
2	22	29.33		1345	29.21		1650	28.87		2119	29.93		935	30.80		1705	28.90
	430	29.43		1741	29.17		2118	28.88	14	30	29.99		1354	30.82	27	1043	28.72
	735	29.44		2120	29.14	10	21	28.84		529	30.04		1735	30.83	28	1211	28.57
	1025	29.55	6	25	29.12		518	28.83		930	30.03	19	930	30.90	31	1040	28.27
	1330	29.58		530	29.07		934	28.77		1330	30.08		1335	30.92	Jan. 2	1058	28.14
	1631	29.64		941	28.97		1401	28.75		1711	30.14		1720	30.92	4	1120	27.94
	1930	29.69		1336	28.94												

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9633

Latitude: 40°41'46" Longitude: 73°41'25" Sequence No.: 2

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 7	1045	28.85	Dec. 2	723	28.99	Dec. 5	2115	28.95	Dec. 10	25	28.83	Dec. 14	531	29.57	Dec. 19	1722	30.56
Sept. 10	1345	28.69		1022	29.08	6	20	28.95		521	28.83		928	29.66	20	938	30.62
Nov. 16	1140	28.18		1326	29.14		520	28.96		932	28.78		1328	29.70		1640	30.53
23	1315	28.07		1630	29.16		940	28.91		1359	28.77		1708	29.72	21	19	30.00
26	1125	28.04		1925	29.17		1334	28.91		1727	28.75		2118	29.79		913	29.60
27	1337	28.30		2115	29.20		1703	28.90		2123	28.77	15	23	29.81		1611	29.43
30	935	28.04	3	3	29.22		2315	29.16	11	20	28.77		538	29.84	22	6	29.32
	1530	27.97		425	29.23	7	518	29.21		536	28.79		915	29.88		907	28.80
	1726	27.97		723	29.24		932	29.20		931	28.78		1345	29.96		1717	29.27
	1919	27.96		1038	29.23		1329	29.20		1326	28.77		1640	29.98	23	112	29.75
	2125	27.98		1447	29.22		1738	29.15		1733	28.74		2027	30.02		1618	28.83
	2325	28.06		1758	29.20		2210	29.08		2122	28.77	16	5	30.05	24	43	28.81
Dec. 1	220	28.20		2140	29.24	8	215	29.02	12	33	28.77		557	30.13		1201	28.73
	520	28.32	4	155	29.26		549	28.95		531	28.77		900	30.14		1820	28.75
	720	28.41		550	29.27		956	28.98		919	28.73		1330	30.15	25	1048	29.10
	955	28.53		1008	29.27		1327	28.95		1333	28.74		1615	30.19		1904	29.14
	1126	28.60		1408	29.23		1645	28.92		1842	28.76	17	933	30.33	26	1022	28.82
	1329	28.67		1731	29.25		2110	28.82		2146	28.90		1339	30.35		1704	28.75
	1535	28.76		2121	29.47	9	17	28.82	13	54	29.03		1743	30.36	27	1044	28.62
	1750	28.80	5	110	29.27		543	28.82		924	29.34		2330	30.37	28	1208	28.50
	1915	28.83		525	29.19		940	28.81		1614	29.49	18	544	30.37	31	1038	28.22
	2115	28.87		945	29.01		1256	28.85		2121	29.57		933	30.43	Jan. 2	1056	28.13
2	20	28.95		1342	28.98		1650	28.82	14	35	29.57		1336	30.47	4	1123	29.76
	425	28.98		1739	28.96		2129	28.85									

N-9634

Latitude: 40°41'41" Longitude: 73°40'27" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 7	953	30.76	Dec. 2	1032	28.41	Dec. 6	32	27.80	Dec. 10	520	28.15	Dec. 14	1333	32.29	Dec. 19	1725	35.18
Sept. 10	1400	29.94		1340	28.36		535	27.80		938	28.07		1715	32.35	20	950	33.19
Nov. 16	1210	28.32		1633	28.29		944	27.77		1403	28.05		2121	32.48		1646	33.05
23	1325	28.21		1745	28.22		1338	27.75		1733	28.05	15	19	32.50	21	12	31.86
26	1130	27.83		2125	28.22		1709	27.72		2117	28.03		528	32.58		919	30.90
27	1345	28.41	3	15	28.17		2330	27.81	11	16	28.02		910	32.61		1619	33.43
30	940	28.39		432	28.11	7	535	30.68		530	28.00		1340	32.60		2351	30.04
	1540	28.02		627	28.09		938	30.18		937	27.97		1636	32.73	22	912	29.66
	1732	27.96		1042	28.01		935	29.80		1331	27.94		2034	32.76		1724	29.48
	1925	27.89		1453	28.03		1744	29.49		1737	27.86	16	10	32.73	23	125	29.37
	2130	27.82		1805	27.94		2200	29.28		2119	27.86		540	32.72		928	29.02
	2342	27.82		2205	27.99	8	212	29.09	12	25	27.84		855	32.79		1620	28.98
Dec. 1	225	27.85	4	205	27.98		539	29.06		527	27.92		1325	32.86	24	46	28.98
	525	28.44		600	27.95		1003	28.85		925	27.83		1630	32.88		1158	28.74
	725	28.76		1018	27.89		1335	28.74		1340	27.83	17	945	33.01		1817	29.36
	1002	28.97		1415	27.85		1640	28.65		1852	27.87		1342	33.02	25	1044	31.19
	1205	28.99		1736	27.90		2107	28.54		2140	30.15		1748	33.02		1901	31.25
	1337	28.93		2153	28.06	9	11	28.46	13	50	30.09		2323	33.05	26	1026	29.77
	1543	28.85	5	117	27.89		535	28.37		929	30.13	18	538	33.07		1706	29.52
	1737	28.80		535	27.74		945	28.34		1609	31.54		928	33.09	27	1047	29.00
	1922	28.75		957	27.79		1252	28.32		2116	31.71		1351	33.11	28	1215	28.62
	2125	28.73		1349	27.82		1650	28.28	14	27	31.92		1730	33.13	31	1042	28.05
2	27	28.64		1745	27.80		2115	28.24		526	30.02	19	935	33.18	Jan. 2	1100	27.85
	435	28.54		2125	27.80	10	18	28.19		933	32.19		1340	33.20	4	1117	27.62
	740	28.44															

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9635

Latitude: 40°41'36" Longitude: 73°40'28" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Aug. 7	930	27.52	Dec. 2	1345	26.53	Dec. 6	540	26.55	Dec. 10	942	26.53	Dec. 14	1720	27.17	Dec. 20	955	26.89
Nov. 16	1220	26.80		1635	26.54		947	26.52		1405	26.53		2110	27.16		1651	26.90
23	1330	26.69		1947	26.56		1341	26.52		1737	26.52	15	17	27.19	21	5	26.91
27	1350	26.89		2135	26.55		1713	26.52		2113	26.56		526	27.16		927	26.85
30	945	26.58	3	20	26.52		2339	26.58	11	15	26.56		906	27.15		1623	26.81
	1545	26.56		435	26.53	7	542	27.01		521	26.56		1335	27.09	22	2318	26.79
	1736	26.55		730	26.54		943	27.02		940	26.52		1635	27.04		917	26.78
	1930	26.55		1045	26.49		1340	26.94		1335	26.53		2039	27.01		1730	26.74
	2140	26.55		1455	26.54		1749	26.77		1740	26.55	16	13	26.98	23	140	26.73
	2345	26.54		1808	26.49		2152	26.81		2114	26.55		536	26.96		933	23.63
Dec. 1	230	26.54		2220	26.56	8	206	26.76	12	19	26.55		850	26.96		1623	26.69
	530	26.56	4	210	26.57		541	26.76		523	26.55		1320	26.96	24	55	26.67
	730	26.54		605	26.57		1008	26.72		928	26.51		1630	26.96		1156	26.67
	1005	26.55		1022	26.52		1340	26.69		1345	26.51	17	945	27.09		1814	26.67
	1137	26.58		1420	26.51		1635	26.66		1854	26.50		1342	27.13	25	1041	27.17
	1342	26.58		1740	26.54		2100	26.62		2134	26.50		1750	27.08		1858	27.32
	1545	26.58		2141	26.55	9	7	26.58	13	47	26.52		2319	27.08	26	1028	26.99
	1732	26.55	5	120	26.56		510	26.56		933	26.62	18	534	27.09		1715	26.90
	1925	26.57		540	26.56		945	26.57		1557	26.92		941	26.98	27	1049	27.76
	2135	26.59		1000	26.52		1250	26.60		2113	27.11		1347	26.99	28	1218	26.66
	40	26.56		1353	26.54		1645	26.59	14	23	27.16		1727	26.96	31	1044	26.50
	440	26.57		1748	26.54		2110	26.60		523	27.21	19	936	26.96	Jan. 2	1102	26.46
	745	26.52		2130	26.56	10	15	26.60		936	27.19		1345	26.96	4	1114	26.34
	1036	26.56	6	39	26.56		517	26.60		1335	27.20		1730	26.92			

N-9636

Latitude: 40°41'29" Longitude: 73°40'30" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Oct. 18	1010	26.86	Dec. 2	1950	25.94	Dec. 6	1345	25.72	Dec. 10	1410	26.03	Dec. 14	2106	27.41	Dec. 20	952	26.07
Nov. 23	1405	26.82		2145	25.88		1718	25.72		1743	26.04	15	13	27.24		1656	26.06
30	1045	26.51	3	25	25.90		2342	25.78		2106	26.06		521	27.02		2358	26.04
	1550	26.12		445	25.88	7	546	28.10	11	12	26.03		900	26.91	21	933	25.96
	1740	26.07		735	25.89		947	27.67		518	26.01		1330	26.83		1630	25.95
	1935	26.07		1047	25.84		1344	27.42		944	25.93		1630	26.76		2344	25.96
	2150	26.11		1501	25.80		1754	27.21		1338	25.91		2041	26.71	22	920	25.85
	2350	26.12		1812	25.79		2146	27.06		1746	25.87	16	18	26.65		1733	25.79
1	235	26.09		2230	25.88	8	200	26.98		2110	25.89		533	26.53	23	135	25.86
	535	26.08	4	215	25.88		541	26.77	12	16	25.89		845	26.50		937	25.74
	735	26.12		610	25.88		1020	26.76		518	25.89		1318	26.46		1628	25.86
	1010	26.02		1028	25.83		1345	26.68		935	25.88		1630	26.43	24	100	25.79
	1142	26.03		1427	25.77		1630	26.62		1350	25.88	17	950	27.35		1152	25.79
	1345	26.01		1744	25.80		2055	26.48		1858	25.86		1340	27.20		1810	25.79
	1540	25.99		2149	25.84	9	2	26.46		2129	25.85		1755	26.90	25	1100	28.39
	1720	26.00	5	128	25.84		505	26.46	13	42	25.84		2313	26.94		1852	28.31
	1930	26.04		545	25.84		1000	26.34		1603	28.37	18	530	26.95	26	1032	27.29
	2140	26.03		1005	25.78		1245	26.31		2110	28.74		945	26.62		1720	26.97
2	50	26.00		1357	25.76		1640	26.28	14	19	27.90		1336	26.66	27	1053	26.70
	450	25.98		1752	25.78		2100	26.19		519	28.11		1723	26.49	28	1225	26.35
	750	25.91		2135	25.82	10	10	26.19		940	27.76	19	940	26.27	31	1050	25.89
	1043	25.92	6	47	25.80		503	26.17		1339	27.57		1350	26.18	Jan. 2	1104	25.97
	1350	25.97		550	25.97		946	26.06		1725	27.38		1733	26.36	4	1111	25.66
	1640	25.96		952	25.72												

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9637

Latitude: 40°42' Longitude: 73°40'30" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Sept. 11	1345	30.13	Dec. 1	2205	29.64	Dec. 6	2353	29.80	Dec. 11	2355	29.87	Dec. 17	1340	29.90	Dec. 24	107	29.89
19	1100	30.00		1445	29.59	7	1305	29.85	12	1330	29.84		2257	29.85		1143	29.92
16	940	29.77	2	2320	29.63	8	120	29.77	13	28	29.87	18	1310	29.88	25	1031	29.93
23	1405	29.73	3	1555	29.64		1226	29.81		1328	29.87	19	1350	29.89	26	1610	29.84
26	1005	29.77	4	255	29.69	9	214	29.87	14	12	29.89	20	1010	29.87	27	1107	29.67
27	1435	29.68		1325	29.69		1230	29.80		1409	29.86	21	945	29.88	28	1230	29.73
30	1202	29.66	5	210	29.69	10	28	29.83	15	8	29.84	22	935	29.94	31	1100	29.65
	1805	29.61		1345	29.70		1320	29.83		1305	29.85	23	205	29.89	Jan. 2	1116	29.59
Dec. 1	29	29.63	6	42	29.74	11	18	29.86		2305	29.85		1002	29.74	4	1107	29.50
	1452	29.61		1312	29.73		1355	29.83	16	1305	29.91						

N-9638

Latitude: 40°41'59" Longitude: 73°40'23" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Sept. 19	1130	30.48	Dec. 2	1435	29.77	Dec. 7	1309	30.56	Dec. 11	2359	30.82	Dec. 16	1305	30.93	Dec. 23	957	30.90
Nov. 16	950	30.17		2320	30.18	8	115	30.60	12	1333	30.85	17	1345	30.92	24	111	30.97
23	1455	30.19	3	1549	30.24		1225	30.65	13	25	30.84		2254	31.01	25	1027	30.97
26	1000	29.86	4	250	30.33	9	212	30.66		1323	30.89	18	1314	30.93	26	1620	30.81
27	1430	30.16		1328	30.31		1225	30.69	14	9	30.91	19	1315	30.95	27	1109	30.69
30	1157	30.19	5	140	30.36	10	25	30.73		1413	30.88	20	1016	30.89	28	1234	30.59
	1800	30.06		1348	30.40		1322	30.75	15	4	30.91	21	947	30.94	31	1104	30.34
Dec. 1	15	30.07	6	40	30.48	11	16	30.78		1300	30.90	22	940	30.96	Jan. 2	1118	30.22
	1450	30.11		1317	30.49		1350	30.79		2309	30.90	23	200	30.95	4	1103	30.03
	2210	30.15		2348	30.57												

N-9639

Latitude: 40°41'59" Longitude: 73°40'15" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Sept. 11	1400	31.21	Dec. 2	1432	30.70	Dec. 7	1325	31.02	Dec. 12	1335	31.17	Dec. 17	1350	31.19	Dec. 24	115	31.20
Oct. 18	850	31.11		2325	30.74	8	109	31.10	13	21	31.22		2248	31.20		1136	31.24
Nov. 16	955	30.85	3	1545	30.76	9	210	31.07		1320	31.21	18	1318	31.20	25	1024	31.25
23	1425	30.75	4	230	30.84		1221	31.07	14	8	31.18	19	1400	31.22	26	1623	31.08
26	1010	30.70		1333	30.87	10	18	31.11		1418	31.17	20	1020	31.14	27	1112	30.95
29	1152	30.67	5	145	30.89		1328	31.14	15	1	31.15	21	955	31.20	28	1239	30.87
30	1808	30.62		1452	30.93	11	15	31.15		1256	31.17	22	943	31.25	31	1105	30.73
Dec. 1	45	30.65	6	28	30.97		1348	31.15		2312	31.18	23	210	31.19	Jan. 2	1120	30.66
	1445	30.69		1320	30.99	12	2	31.18	16	1300	31.21		955	31.15	4	1058	30.54
	2214	30.72	7	1	31.04												

Appendix. Water levels in wells at Fosters Brook, Nassau County, N.Y., August-December 1979—Continued

N-9640

Latitude: 40°41'59" Longitude: 73°40'9" Sequence No.: 1

N-9640

Latitude: 40°41'59" Longitude: 73°40'9" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Sept. 11	1445	31.47	Dec. 2	1428	30.93	Dec. 7	1328	31.01	Dec. 12	1340	31.04	Dec. 17	1350	31.05	Dec. 24	121	31.04
Oct. 18	830	31.57		2330	30.95	8	101	31.01	13	17	31.07		2244	31.06		1132	31.05
Nov. 16	1000	31.17	3	1540	30.94		1215	31.04		1317	31.07	18	1322	31.03	25	1021	31.10
23	1430	31.06	4	240	30.99	9	28	31.05	14	5	31.12	19	1405	31.03	26	1630	31.02
26	1015	31.04		1326	30.99		1215	31.01		1423	31.03	20	1025	30.98	27	1114	30.95
30	1148	30.98	5	150	30.98	10	12	31.06		2358	31.02	21	957	31.02	28	1243	30.93
	1814	30.95		1355	30.99		1330	31.04	15	1253	31.02	22	946	31.00	31	1107	30.87
Dec. 1	52	31.09	6	20	31.04	11	8	31.06		2317	31.03	23	215	31.02	Jan. 2	1122	30.83
	1510	30.99		1324	31.02		1345	31.03	16	1258	31.09		953	30.96	4	1053	30.74
	2218	30.97	7	6	31.08	12	6	31.09									

N-9641

Latitude: 40°41'58" Longitude: 73°39'58" Sequence No.: 1

Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level	Date	Time	Water Level
Sept. 11	1445	31.65	Dec. 2	1423	31.11	Dec. 7	1331	31.08	Dec. 12	1342	31.06	Dec. 17	1355	30.93	Dec. 24	125	30.96
Oct. 18	820	31.56		2335	31.10	8	57	30.92	13	11	31.05		2241	30.99		1130	30.99
Nov. 16	1005	31.31	3	1537	31.08		1206	31.13		1315	31.06	18	1325	31.00	25	1018	31.06
23	1440	31.24	4	310	31.14	9	25	31.05	14	1	31.05	19	1410	31.01	26	1635	31.05
26	1020	31.22		1328	31.13		1210	31.08		1427	30.91	20	1028	30.97	27	1117	30.97
30	1142	31.22	5	155	31.09	10	10	31.08		2355	30.98	21	104	30.95	28	1245	30.96
	1817	31.13		1400	31.11		1334	31.09	15	1245	30.86		951	30.97	31	1109	30.92
Dec. 1	58	31.14	6	12	31.13	11	4	31.06		2321	30.83	22	220	30.96	Jan. 2	1124	30.89
	1435	31.13		1328	31.10		1342	31.05	16	1252	30.84	23	950	30.90	4	1049	30.85
	2221	31.16	7	12	31.13	12	9	31.06									

CONVERSION FACTORS AND ABBREVIATIONS

The following factors may be used to convert the units of measurement in this report to the International System of Units (metric system).

Inch-Pound Units

Multiply	by	To obtain
inch (in)	2.54	centimeters (cm)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.59	square kilometers (km^2)
cubic feet per second (ft^3/s)	28.32	liters per second (L/s)
	.02832	cubic meters per second (m^3/s)
gallons per minute per foot [(gal/min)/ft]	.01923	liters per second per meter [(L/s)/m]
feet per day (ft/d)	.3048	meters per day (m/d)

SI Units

millimeter (mm)	.03937	inch (in)
centimeter (cm)	.3937	inch (in)
gram (g)	.03527	ounce (oz)
degrees Celsius (°C)	(1.8 + 32)	degrees Fahrenheit (°F)

Other Abbreviations

National Geodetic Vertical Datum of 1929 (NGVD) (formerly mean sea level)

Milligrams per liter (mg/L)

Micrograms per liter (mg/L)