GROUND-WATER APPRAISAL FOR THE COMMUNITY OF KIRYAS JOEL, ORANGE COUNTY, NEW YORK

U.S. GEOLOGICAL SURVEY

Open-File Report 79-401

Prepared in cooperation with the
Community of Kiryas Joel and the
U.S. Department of Commerce,
Office of Minority Business Enterprise

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GEOLOGICAL SURVEY

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By Roger M. Waller

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Albany, New York

1979

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CONVERSION FACTORS AND ABBREVIATIONS

The following factors may be used to convert inch-pound units of measurement in this report to the International System of Units (SI).

Multiply	by	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785×10^{-3}	liter (L)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
degree Fahrenheit (°F)	5/9(°F-32)	degree Celsius (°C)
gallon per minute per foot [(gal/min)/ft]	0.207	liter per second per meter [(L/s)/m]
gallon per day per square mile [(gal/d)/mi^2]	1.46×10^{-3}	cubic meter per day per square kilometer [(m^3/d)/km^2]

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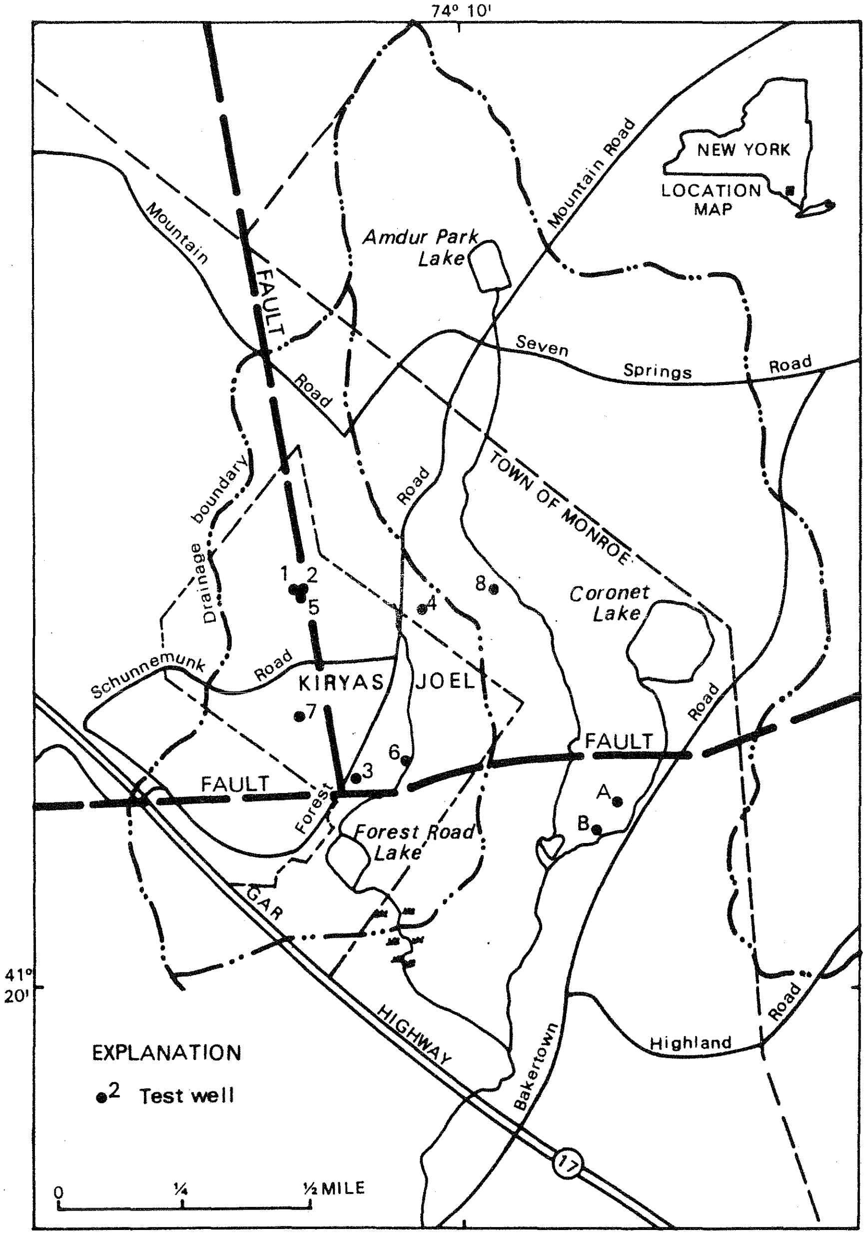
ABSTRACT

A major fracture system in indurated sedimentary rocks forms a moderately extensive aquifer yielding 100-300 gallons per minute to wells 160 to 420 feet deep. Pumping-test data show that the fracture system is interconnected to distances more than 1,000 feet from the wells. Recharge occurs through overlying clayey till, and continuous pumping may induce recharge from surface-water sources. Partial chemical analyses indicate no water-quality problems. Systematic collection of data on pumpage, water level, and chemical quality could help to determine the long-term adequacy of the aquifer system.



Base from U.S. Geological Survey
Monroe, N.Y., 1:24,000, 1957

Figure 1.--Location of major geographic features, wells, and fault traces in Kiryas Joel area.

INTRODUCTION

The newly incorporated community of Kiryas Joel, in Orange County, N.Y., is expanding rapidly and is dependent upon a ground-water supply for about 100,000 gallons per month (gal/mo). Several wells have been drilled to replace or augment the present supply well. In 1977, the U.S. Geological Survey, in cooperation with the U.S. Department of Commerce, Office of Minority Business Enterprise, and the community of Kiryas Joel, began an investigation to evaluate the adequacy of the community's aquifer system to meet the increasing demand for ground water. Pumping tests were conducted on three test wells, and the results were evaluated in terms of long-term yield of the aquifer system and the potential need for additional wells to supply more than 400,000 gal/mo.

SITE DESCRIPTION

The community of Kiryas Joel is just northwest of Monroe, N.Y., off U.S. Highway 17, in the Town of Monroe (fig. 1). The community covers less than 1 square mile in the rolling, lake-dotted area just south of the prominent Schunnemunk Mountain. The area is drained by a system of small streams that flow southward to the Ramapo River.

GEOLOGY

Near and within Kiryas Joel, bedrock is mantled by a layer of a bouldery clay (till derived from glaciation) that ranges in thickness from a few feet on the hilltops to several tens of feet in the valley bottoms. Small stream-gravel and swamp deposits occur at land surface in the valley bottoms.

Although no bedrock exposures were noted within the community, the area is underlain by sandstone, siltstone, conglomerate, and shale that have undergone high compression and temperature (Frimpter, 1972; Jaffe and Jaffe, 1973). Nearby outcrops show nearly vertical slaty beds, fractures, and evidence of faulting. (Faults are fractures along which the masses of rock have been displaced.) Frimpter (1972, pl. 1) and Jaffe and Jaffe (1973, pl. 1) have mapped the bedrock geology and conclude that steep or near-vertical fault zones are present in this area. Some of the fault zones in Orange County are highly permeable and have provided significant water yields to wells and tunnels intersecting the faults (Frimpter, 1972, p. 54). Jaffe and Jaffe (1973, pl. 1) postulate an intersection of two faults at right angles in the vicinity of the community, as depicted in figure 1.

GROUND-WATER SUPPLY

Frimpter compiled well data (1970, pl. 1) that included two wells east of the community (wells A and B, fig. 1). These wells are reported to be less than 200 ft deep and to yield less than 10 gal/min from sandstone. However, these wells were drilled for domestic use only, so it is not known whether their potential yield is greater than 10 gal/min.

Seven wells or test holes were drilled between 1974 and 1978 in an attempt to provide the community with an independent water source. The locations of these wells (nos. 1-8) are shown on figure 1; the drillers' logs are presented in table 1. Altitudes of the well sites were determined by leveling by a consulting engineering firm.

Wells 1 and 2, with 8-in. casings and placed 10 ft apart, provided the initial water supply. Only one well was pumped at a time. Recent pumping rates have reportedly averaged 100 gal/min; the rated capacity of well 1 was 125 gal/min (Kartiganer Engineers, 1969). This well system barely met the water demands (including much line flushing during construction) during the 1976 summer, which was not unusually dry.

A 6-in. test hole (no. 3), drilled in May 1974 northeast of the sewage-treatment plant, was being considered for public-supply use but was abandoned because a house was built too close for the well to meet Health Department regulations. An 8-in. well (no. 4), drilled on the hilltop off Forest Road (fig. 1) in August 1974 reportedly had a fair potential and was later deepened in a successful attempt to increase the possible yield. Another 8-in. well (no. 5), drilled near wells 1 and 2 in August 1975, was completed as a new production well and was put into service in late 1977. At that time, well 1 was left as a standby, and well 2 was abandoned. Well 6, also with 8-in. casing, was drilled in February 1976 at the south end of the Synagogue for Synagogue use only. Well 7 was drilled in April 1977 downvalley from wells 1, 2, and 5 and obtained a good water supply. Its location was selected on the basis of pumping-test results from well 6. Another test well (no. 8) was drilled in spring 1978 but was unsuccessful in obtaining a good water supply (John Koar, Modern Drilling, Inc., written commun., June 1978).

AQUIFER SYSTEM

Water enters the bedrock primarily by percolation of precipitation through the overlying till which contains the water table (the top of the zone of saturation). Because fractures in the underlying bedrock are open to the till, water from the zone of saturation can move downward into the bedrock fractures.

Analyses of the geologic and well data from Kiryas Joel indicate that the bedrock contains a fault system (an extensive zone of closely spaced fractures) that transmits water more readily than most other bedrock in the region. The lateral extent of the fault system is not known, however. On the basis of data on more than 700 wells (Frimpter, 1972, p. 56), average productivity of wells in the four principal types of bedrock in Orange and Ulster Counties ranges from 0.12 to 0.18 (gal/min)/ft of bedrock penetrated. Wells at Kiryas Joel have produced from 0.32 to 0.98 (gal/min)/ft of bedrock penetrated, which is two to six times greater than the countywide averages.

Kiryas Joel officials need to know whether the aquifer system can yield several hundred gallons per minute from widely spaced wells within the community boundary. Frimpter (1972, p. 55) indicates that "the fault zones [in Orange County] are narrow, tabular zones of fractured rock that are nearly vertical in attitude" and cautions that even widely separated wells tapping the same fault zone may interfere with each other.

Pumping tests conducted on wells 1 and 5 prior to this investigation indicate the wells to be capable of yielding over 100 gal/min. However, unsteady pumping rates, and the intermittent pumping of well 1 during testing of well 5, resulted in an uncertain appraisal of the aquifer yield. Therefore, steady-rate pumping tests were planned in 1977 to determine the water-bearing characteristics of the rock. Results of these tests are described in the following section.

A pumping test to evaluate an aquifer requires one or more observation wells to determine the water-level change in the aquifer while the test well is being pumped. Observations at each well also provide data on yield and drawdown that can be used to determine the most appropriate type of pump and the approximate pumping costs.

AQUIFER TESTS

Pumping test on well 5

Well 5 was tested in 1975 by Central Water Systems Installations, Inc. Most of the test was conducted at about 170 gal/min. The water level was still declining at the end of the test, after 24 hours of pumping. A safe rate of 125 gal/min was reportedly recommended.

Pumping test on well 6

Well 6 was selected for a pumping test in March 1977 because of its reported high yield. In addition, nearby wells 3 and 4 (fig. 1) could be used as observation wells to evaluate the response of the aquifer system to large pumping. A pumping rate of 250 gal/min was selected, and the pump intake was placed to provide a maximum of 224 ft of drawdown.

Table 1.--Drillers' logs of wells at Kiryas Joel, Orange County, New York

WELL 1. Drilled May 1967. Total depth 187 ft. Cased with 8-in. casing to unreported depth. Yield 125 gal/min. Altitude 713 ft.

Driller's log

Material	Thickness (ft)	Depth (ft)
Sand and gravel with bluestone boulders, silt, and small amount clay.............	30	30
Shale, blue, soft but stable (20 gal/min water at 40 ft).........................	30	60
Unreported.................................	127	187

WELL 2. No data. Drilled after January 1969. Probably similar to well 1. Altitude 713 ft.

WELL 3. Drilled May 1974 by Modern Drilling, Inc. Total depth 160 ft. Cased with 6-in. casing to 42 ft. Yield 50 gal/min. Altitude 655 ft.

Driller's log

Material	Thickness (ft)	Depth (ft)
Boulders and gravel, hardpan................	32	32
Slate and shale (water in fractures at 118 ft--4 gal/min; 125 ft--3 gal/min; 148 ft--20 gal/min; 115 ft--22 gal/min......	128	160

WELL 4. Drilled Aug. 1974 and Feb. 1976 by Modern Drilling, Inc. Total depth 400 ft. Cased with 8-in. casing to 84 ft. Yield 100 gal/min. Altitude 762 ft.

Driller's log

Material	Thickness (ft)	Depth (ft)
Topsoil..................................	2	2
Gravel and hardpan.........................	72	74
Bedrock (water at 160 ft--5 gal/min; 198 ft--55 gal/min)		
Drilling stopped. Resumed in 1976......	136	210
Bedrock (water, 40 gal/min).................	190	400

Table 1.--Drillers' logs of wells at Kiryas Joel, Orange County, New York (Continued)

WELL 5. Drilled August 1975 by Modern Drilling, Inc. Total depth 370 ft. Cased with 8-in. casing to 40 ft. Yield 125 gal/min. Altitude 705 ft.

Driller's log

Material	Thickness (ft)	Depth (ft)
Overburden................................	22	22
Slate (water in fractures at 122 ft--30 gal/min; 164 ft--50 gal/min; 172 ft--15 gal/min; 187 ft--20 gal/min; 242 ft--10 gal/min.........................	348	370

WELL 6. Drilled Feb. 1978 by Modern Drilling, Inc. Total depth 250 ft. Cased with 8-in. casing to 57 ft. Yield 190 gal/min. Altitude 674 ft.

Driller's log

Material	Thickness (ft)	Depth (ft)
Clay and gravel, hardpan.......................	46	46
Slate (water in fractures at 92 ft--15 gal/min; 128 ft--40 gal/min; 136 ft--30 gal/min; additional flow every few feet to bottom)...	204	250

WELL 7. Drilled April 1977 by Modern Drilling, Inc. Total depth 420 ft. Cased with 8-in. casing to 60 ft. Yield 135 gal/min. Altitude 663 ft.

Driller's log

Material	Thickness (ft)	Depth (ft)
Clay and boulders, hardpan.....................	35	35
Slate (water in fractures at 135 ft--50 gal/min; 220 ft--40 gal/min; from 220-360 ft, water every few ft)............................	325	360
Slate......................................	60	420

The water levels measured in each well are plotted in figure 2. It is apparent that drawdown in well 6 was negligible even after 15 hours of pumping. Response in well 3, 700 ft away, was apparent within minutes, which indicates good hydraulic continuity. Well 4, 1,250 ft distant, responded to the stress on the aquifer only after 20 hours. The delayed response indicates that the hydraulic continuity is probably only through indirect fracture systems. It is also possible that this well was recovering after a shutdown of well 5 that morning.

Recovery measurements were made for several hours after cessation of pumping. Ideally, measurements should be made until the original static level has been attained. The data confirmed, however, that water-level recovery was taking place far from the pumped well also. The exceptionally long delayed response in well 4 (the water level subsequently recovered) may indicate that well 4 is in a different fracture system from that intersected by wells 3 and 6 but is interconnected with it to some extent.

The ratio of pumping rate to drawdown is called specific capacity. Specific-capacity data are useful in determining a safe well yield and in estimating the water-movement capabilities of the aquifer. Because specific capacity decreases with pumping time, long periods of pumping generally give more reliable specific-capacity values than short tests. Changes in specific capacities of well 6 with time are plotted in figure 3; the plot shows that specific capacity stabilizes at about 4 (gal/min)/ft. This value, multiplied by the available drawdown of 73 ft (pump intake during test), equals 292 gal/min; therefore, 250 gal/min is a reasonable rate at which to pump the well. Higher rates may cause a disproportionately greater drawdown and may also increase the pumping costs proportionately.

Pumping test on well 4

Well 4 was tested in May 1978. Because the pumping test on well 6 had indicated the presence of faults, another test well (no. 7, fig. 1) was drilled to the west of it in the hope of intersecting the postulated east-west fault system trending through wells 3 and 6. Well 7, drilled in April 1977, was used as an observation well during the May pumping test on well 4.

A pumping rate of 75 gal/min was selected for well 4. Water-level measurements made at wells 3, 5, 6, and 7 are plotted in figure 4. Because no effects on water levels in the observation wells were discerned, the pumping rate was increased in several steps. After a pumping rate of 125 gal/min had been established, a water-level decrease was noted in all wells, including the new well 7, which was 2,000 ft away. The water-supply well (No. 5), which had been shut off only 2 hours before the start of the test, recovered during the test; therefore, it could not be determined whether nor how much it was affected by pumping at well 4.

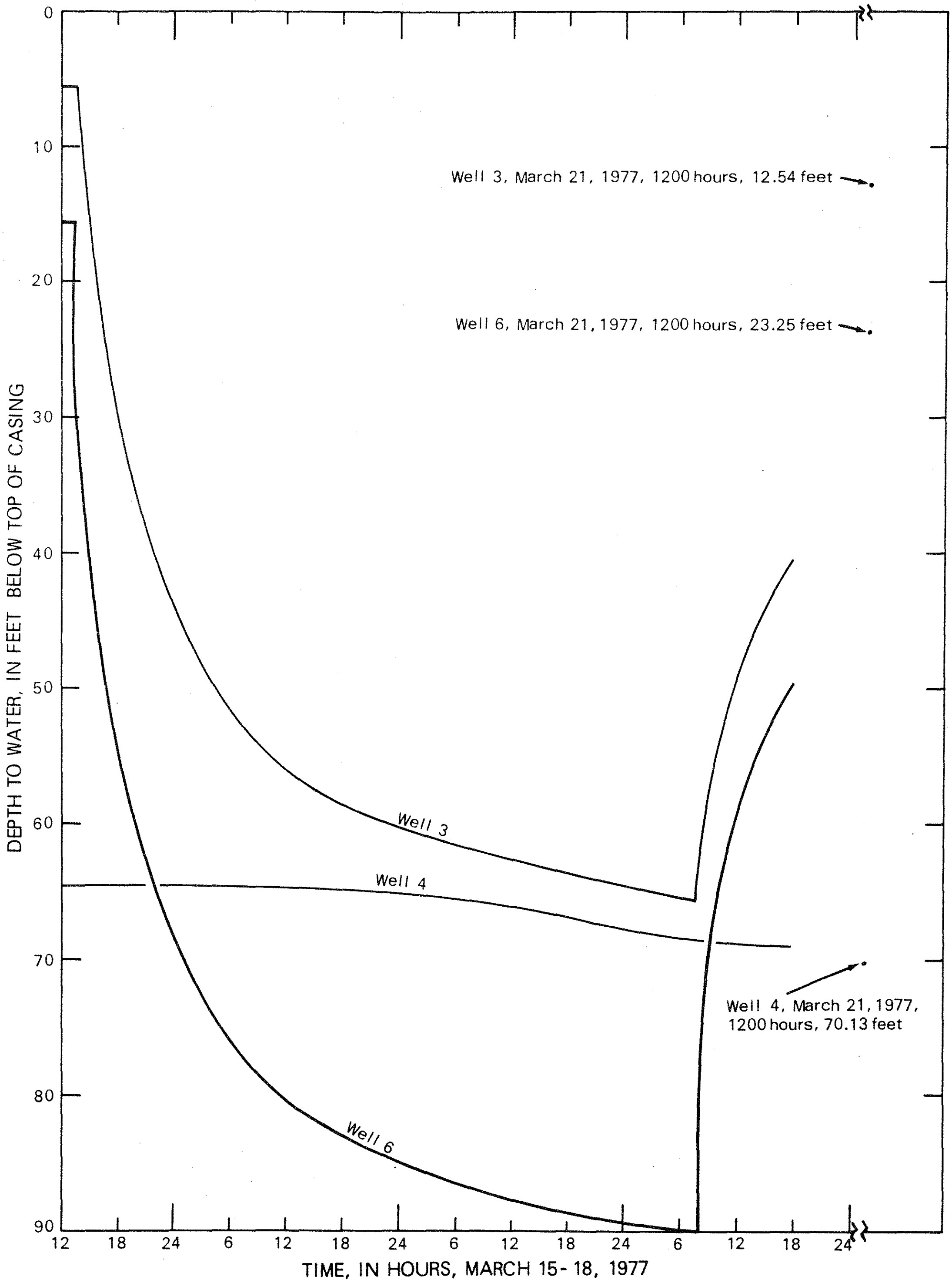


Figure 2.--Water levels during pumping of well 6.

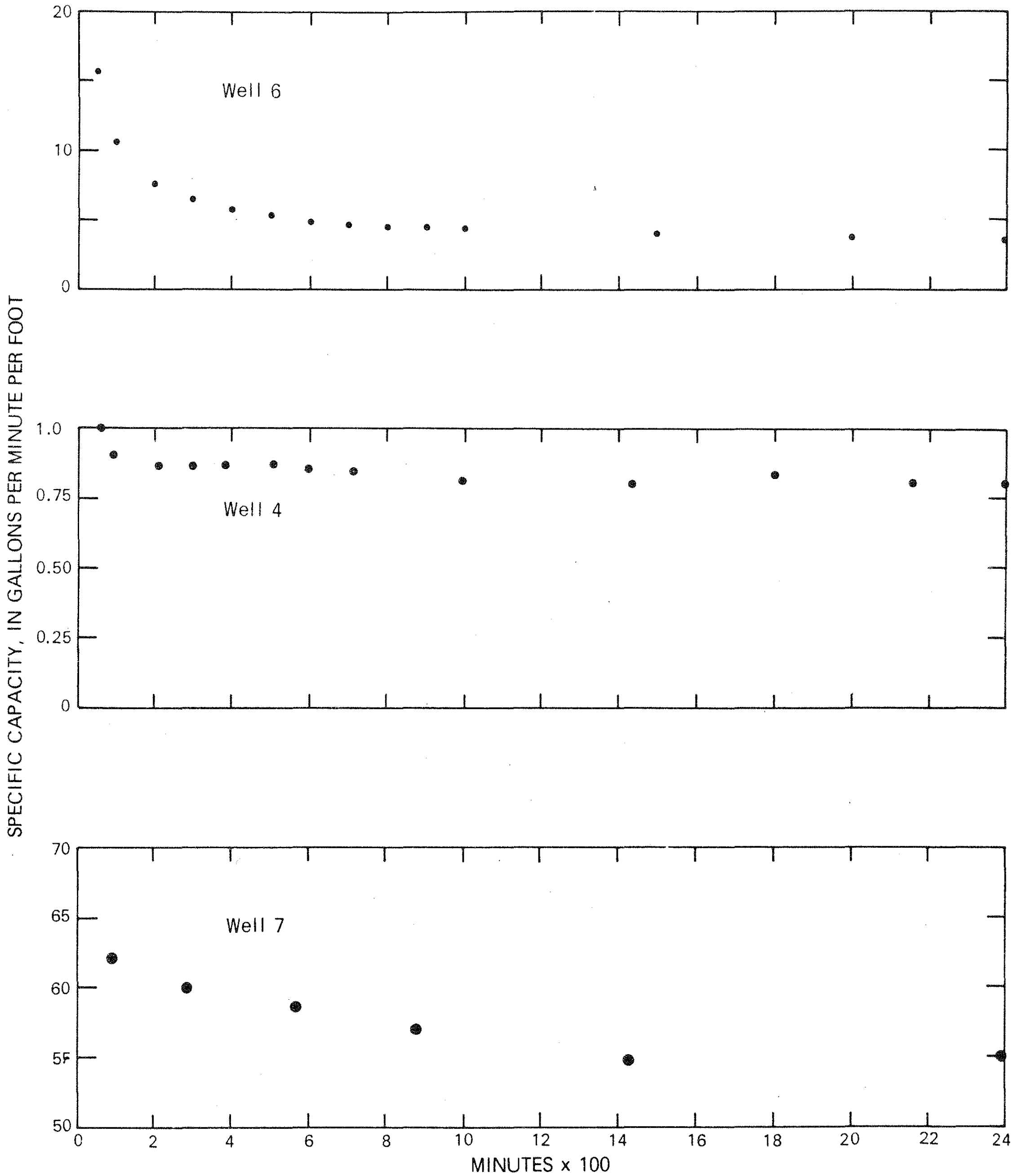


Figure 3.--Specific capacity versus time, wells 6, 4, and 7.

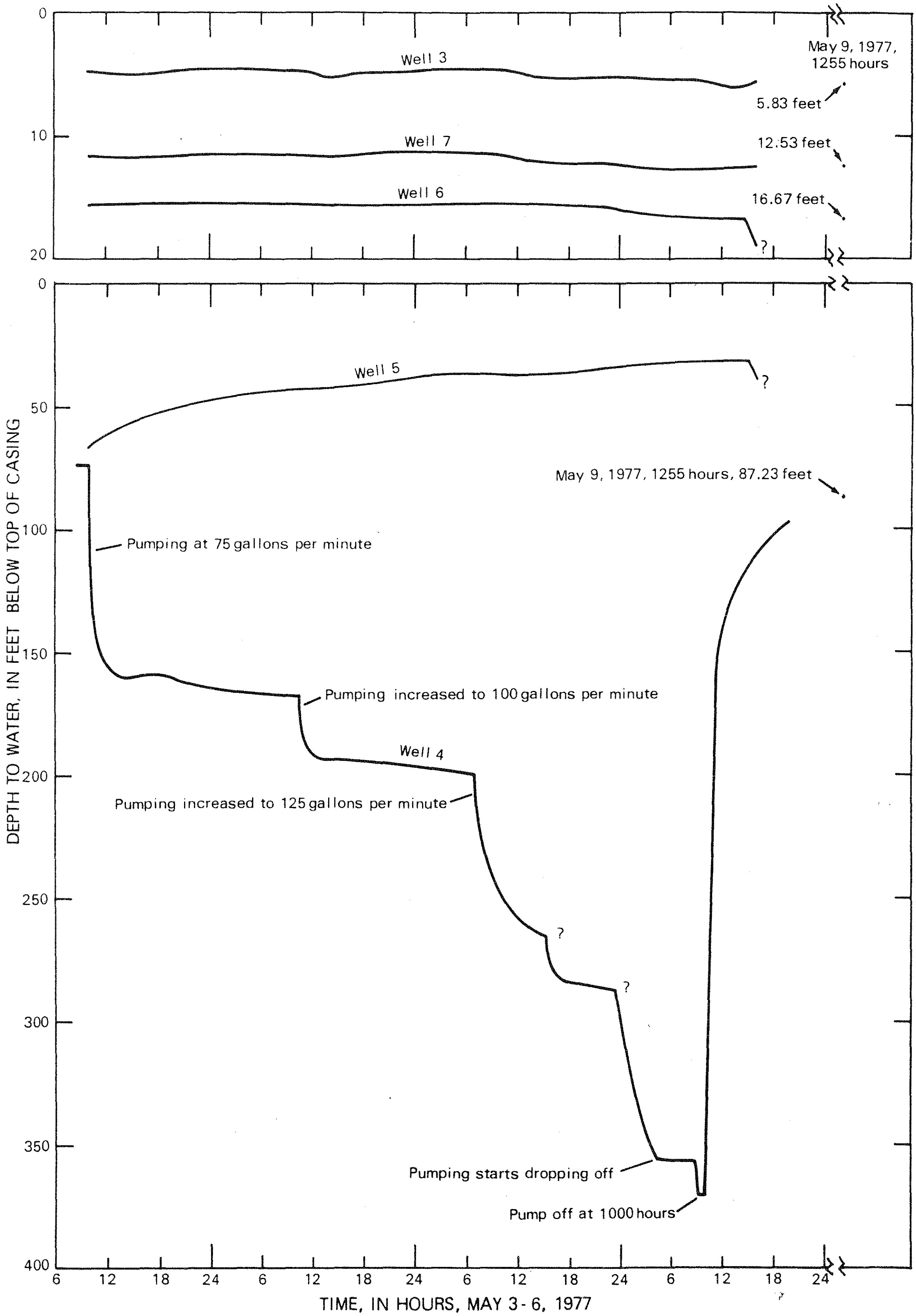


Figure 4.--Water levels during pumping of well 4.

The contrast between the substantial drawdown in well 4 and the small, delayed response in wells 3, 6, and 7 seems to indicate that well 4 is in a fracture system separate from but partially interconnected with that of the other wells. This indication is supported by the results of the March 1977 test. The pumping rate of 125 gal/min, started after 45 hours of pumping, increased the rate of drawdown to the extent that the well yield was being overtaxed. The two subsequent abrupt increases in the rate of drawdown (see fig. 4) may indicate dewatering of fractures. It is also possible, however, because the two increases coincide with a change in work shifts, that these increases are a result of human error in tape reading or adjustment of pumping rate.

The plot of specific capacity with time (see fig. 3) shows that well 4 had a stable specific capacity of 0.80 (gal/min)/ft when pumped at 75 gal/min and 100 gal/min for 45 hours. However, after 40 hours, the water level had been lowered to 198 feet, at which depth the well reportedly intersects its largest water-yielding fracture (table 1). When the pumping rate was raised to 125 gal/min, the increased drawdown could not produce a proportionately steeper gradient in the fracture nor induce greater flow toward the well, so specific capacity fell off abruptly to only 0.41 at the end of the 72-hour test. Accordingly, economical long-term pumping of this well would require a pumping rate somewhat less than 100 gal/min. The abrupt lowering of water levels in observation wells 5 and 6 near the end of this test (fig. 4) is unexplained. At well 6, a small mudslide into the open casing occurred during the last hour of measurements. At well 5, the air pressure may have been adjusted for the last measurement, or the pump may have been turned on before the measurement was read.

Pumping test on well 7

Well 7 was pumped June 26-28, 1978, to evaluate the well yield and to determine the hydraulic effects on other wells in the community. A pumping rate of 175 gal/min was selected as a starting rate. Water-level measurements were made in well 7 and in wells 3, 4, 5, and 6. The water levels are plotted on figure 5. Determination of water-level effects in the system was complicated because pumping of the community supply well (no. 5) was not halted until 3 hours before the beginning of the test and was resumed during the test and during recovery measurements. In addition, the pumping rate of 175 gal/min was not maintained because of lowered pump-lift capacity. The rate gradually decreased to 155 gal/min and stabilized at 150 gal/min in the latter part of the test.

Well 7 intersects the same water-bearing fracture system as wells 3, 4, and 6; this was indicated by an almost immediate water-level response in those wells as well 7 was pumped. The relation of well 7 to well 5 (the present supply well) is unknown because the latter was pumped intermittently and had a recovering water level during the test. The drawdown data indicate that well 7 is comparable to well 4, rather than well 6, in intersecting fractures and in overall yield potential.

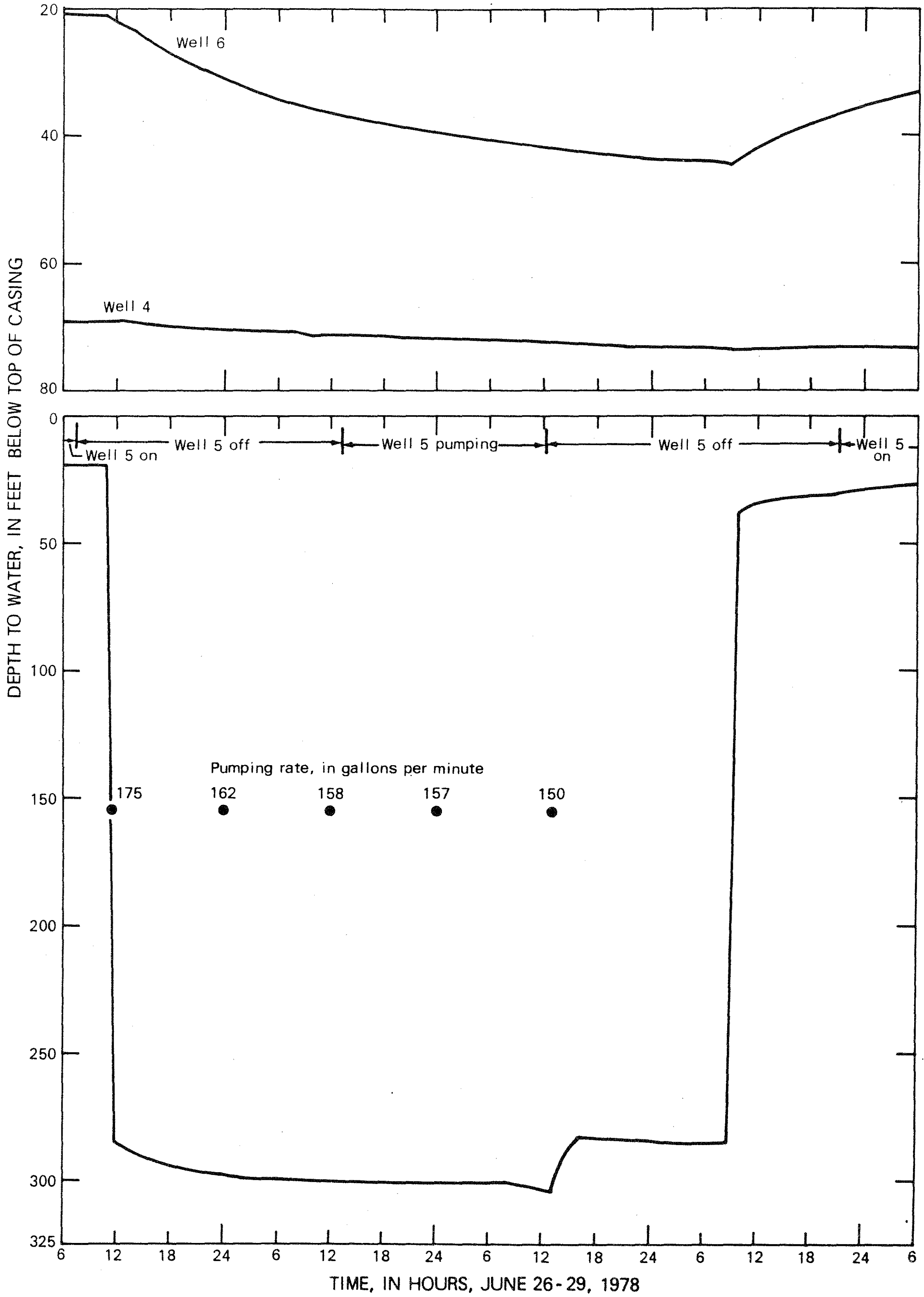


Figure 5.--Water levels during pumping of well 7.

The specific capacity of well 7 is a little less than that of well 4 and decreased from 0.62 to 0.55 (gal/min)/ft of drawdown during the test. The pumping test indicates that well 7 should be capable of producing 150 gal/min with little effect on well 4. Wells 5 and 7 probably have intersecting cones of influence and would, therefore, have slightly reduced yields if pumped simultaneously. Well 6, which is not intended as a supply well, would also have a reduced yield if pumped simultaneously with other wells.

Well-field potential

The present supply well (no. 5) and the two additional wells being considered for supply (nos. 4 and 7) have a "rated" capacity of 125, 100, and 135 gal/min (table 1), respectively. The pumping tests support the latter two values, and records of past usage (about 12 hours per day) confirm that of well 5. The combined capacity of 360 gal/min would be reduced somewhat if all three wells were pumped continuously and simultaneously because overlapping cones of influence would reduce the available drawdown in each well and thus reduce the yield. On the basis of past performance of well 5, the two new wells (4 and 7) alone appear capable of supplying 1.5 times the present demand.

Well 6 is planned for special use on a limited basis and is not being considered for use as a community supply well. Its rated capacity of 250 gal/min would bring the total well-field capability to over 600 gal/min but with a certain reduction under simultaneous pumping, as discussed above. If a greater rated capacity than that calculated for wells 4, 5, and 6 is desired, another well close to well 6 would need to be considered. Considering (1) the probability of obtaining similar yields elsewhere in the vicinity (2) the low present demand on well 6, and (3) only slight interference of drawdowns, it seems possible that an additional well could greatly increase the community supply.

AQUIFER RECHARGE

A water demand of 400,000 gal/d is easily within the capability of wells 4, 5, and 6 on a short-term basis; the tests described in the previous section indicate that wells 4 and 6 alone can be pumped at 85 and 250 gal/min, respectively, giving a total of 335 gal/min or 480,000 gal/d for several days or weeks with minimal interference. However, in a fractured-bedrock aquifer in which the extent of the water-yielding fault or fracture systems is still incompletely known, it is not certain that these yields would be sustained over many months of continuous pumping. To determine the long-term potential of the aquifer system, the recharge pattern must be evaluated.

Recharge to the fracture systems under natural conditions probably occurs chiefly by infiltration of precipitation through the surficial till. Under the climatic conditions in this area, till is estimated to permit between 10,000 and 100,000 gallons of recharge per square mile in an average year (Heath, 1964). If these estimates are correct, all recharge within at least 4 mi^2 would need to be captured by these wells to provide 400,000 gal/d; a much larger amount would be required if the till were especially clayey and poorly permeable. In a dry year, recharge is appreciably less than in an average year--30 to 50 percent less, as estimated by Randall (1977) and Randall and others (1966) from streamflow and precipitation records--although no definitive studies have been done in New York. Thus, despite the results of pumping tests at Kiryas Joel, it may be questioned whether a pumping rate of 400,000 gal/d could be maintained indefinitely in this upland area if all recharge is infiltrated through till. On the other hand, if the fault and fracture systems in the bedrock near Kiryas Joel intersect the bottoms of nearby streams, lakes, or wetlands, considerably more water could be induced to enter the bedrock under pumping conditions.

The above discussion of recharge to the bedrock is speculative. Extensive studies entailing geologic mapping, test drilling, and aquifer tests would be needed to obtain more precise estimates, and even then the results might not be conclusive. An alternative approach would be to gradually expand the water-well system and to maintain adequate records during the first years of operation so that it can later be determined whether further expansion would be feasible. This approach is commonly used by public water departments and is discussed in the final section of this report.

WATER QUALITY

Water from pumping-test wells (nos. 4 and 6) was sampled for partial chemical analysis by the U.S. Geological Survey and a commercial laboratory. (Well 7 was not sampled.) The results of these analyses are given in table 2. The low specific conductance (150 to 250 mg/L dissolved solids) indicates that the water has not been in long contact with rocks. A complete chemical analyses could give a better insight as to needs for treatment, however. The preliminary appraisal indicates no serious problems. The 2°F difference in water temperature between well 4 and well 6 (table 2) is considered normal for the differences in well depths--well 4 is deeper and therefore has cooler water. No change in temperature with pumping was noted.

Table 2.--Chemical analysis of water from selected wells, community of Kiryas Joel, Orange County, N.Y.
[All values are in milligrams per liter except as noted]

Constituent or Characteristic	Date, Well number, and Laboratory1/			
	3-15-77 No. 6 USGS	3-17-77 No. 6 RVTL	3-18-77 No. 6 USGS	5-6-77 No. 4 USGS
Specific conductance (µmho/cm at 25°C)	374	--	323	227
Hardness (Ca, Mg)	--	170	120	--
Calcium	--	--	29	--
Magnesium	--	--	11	--
Chloride	1.9	0.5	2.2	1.6
Total nitrogen	.03	--	--	--
Sulfate	--	--	6.0	--
Alkalinity	--	189.5	--	--
Manganese	--	0.39	--	--
Iron	--	0.25	--	--
Temperature (°F)	51.5°	--	51.5°	49°

1/ USGS, U.S. Geological Survey,
RVTL, Ramapo Valley Testing Laboratory, Inc.

GROUND-WATER MOVEMENT

Measurements of water level in each well under nonpumping or static conditions provide a means of determining the gradient of the water table. Water levels measured in wells 1-7 were essentially the same at the start of the March pumping tests as they were in May and were, therefore, used to define contours of equal water-surface altitude above mean sea level (figure 6). The contour lines in figure 6 show that the natural ground-water gradient is south and west, generally following the topography. The lowering of the water levels (drawdown) at the end of the first test is shown in figure 7, at the end of the second test in figure 8, and the end of the third test in figure 9. The "cones of influence" during the pumping tests can be seen to extend under streams, wetlands, or lakes, suggesting potential recharge from these sources during periods of drawdown.

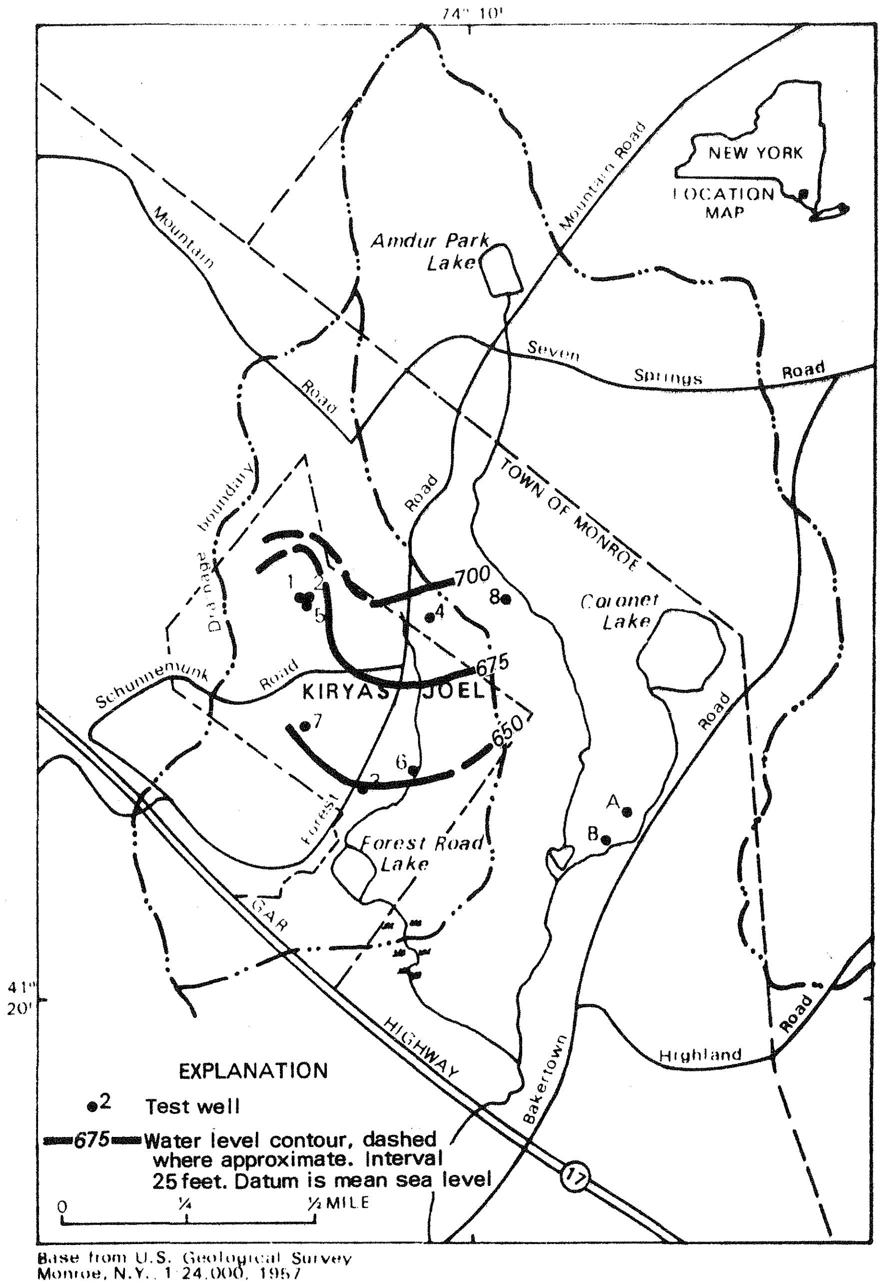


Figure 6.--Potentiometric surface in March 1977, before start of aquifer tests.

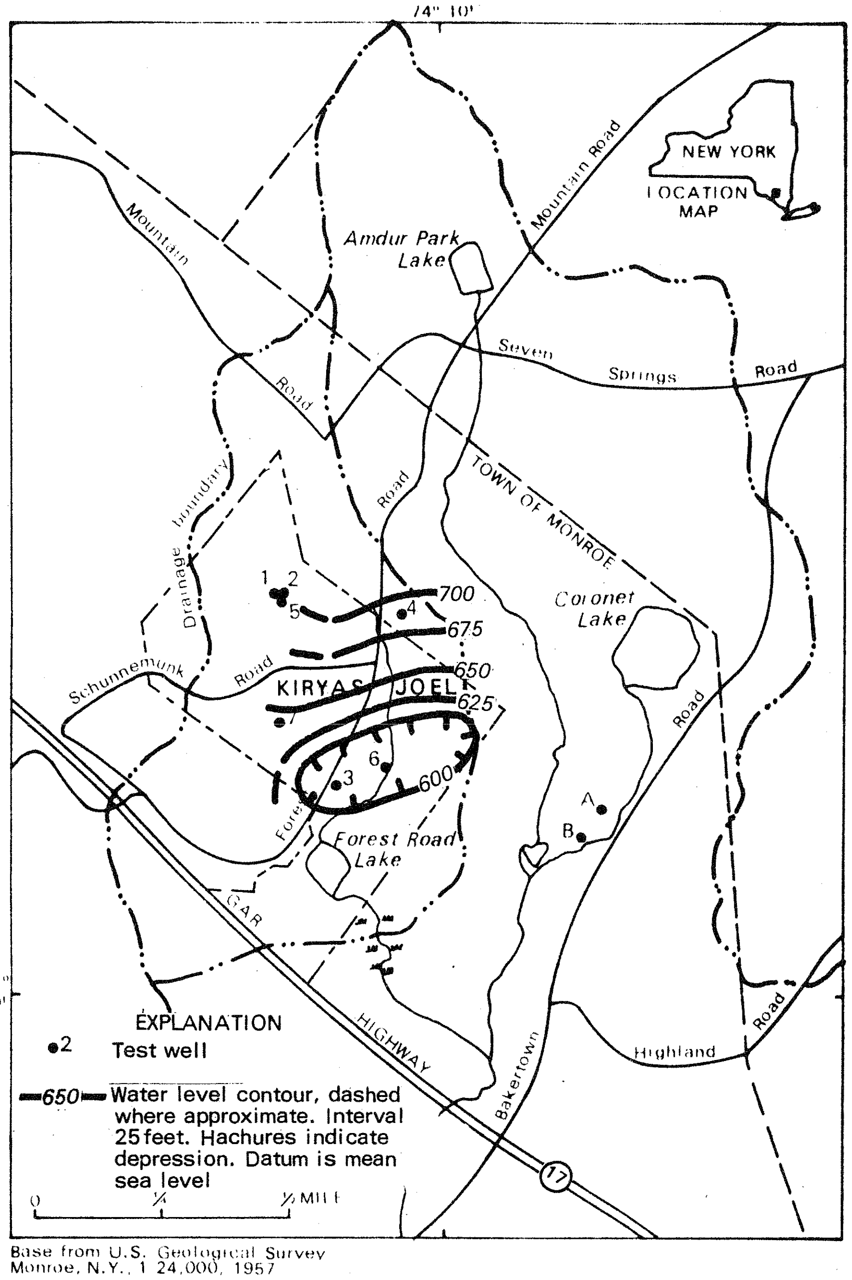
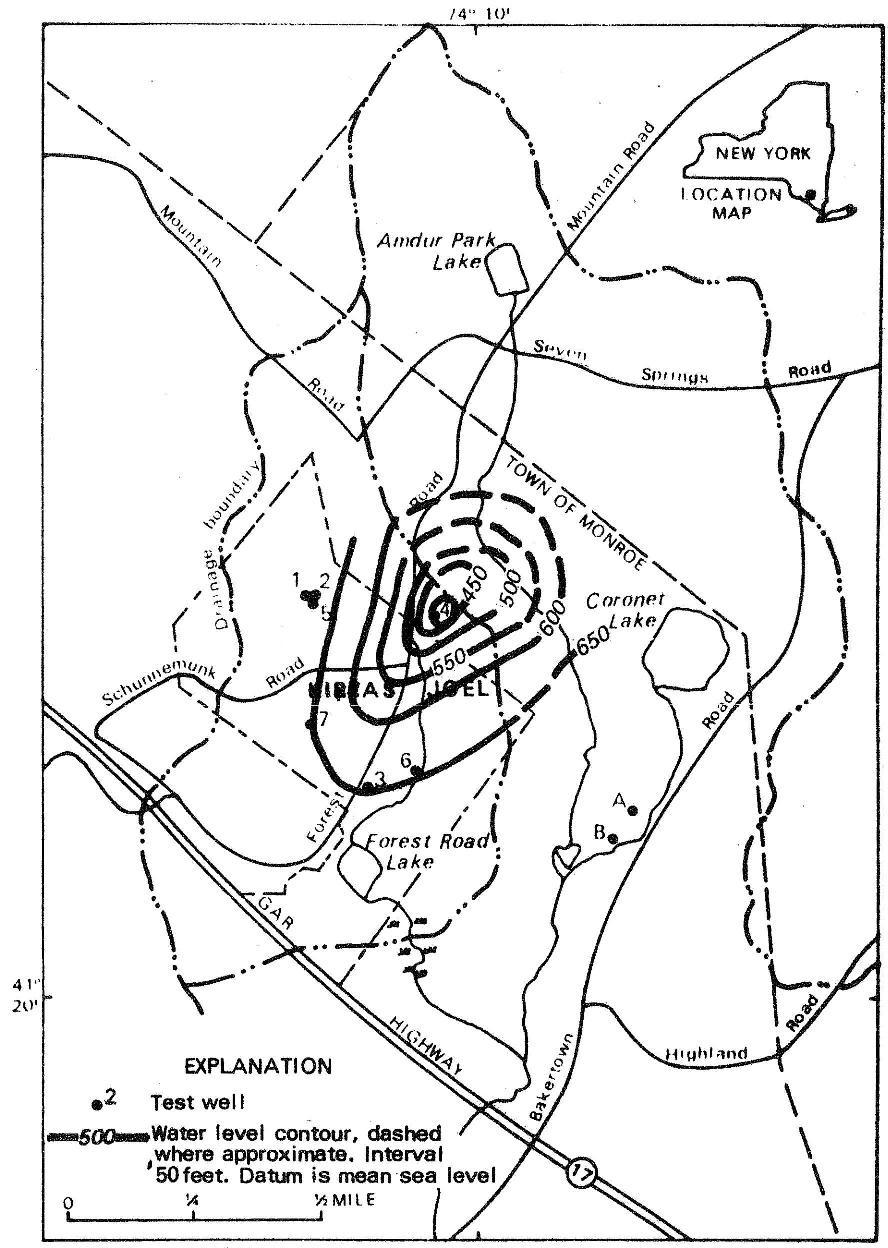


Figure 7.--Potentiometric surface at the end of well 6 pumping test, March 18, 1977.



Base from U.S. Geological Survey
Monroe, N.Y., 1:24,000, 1957

Figure 8.--Potentiometric surface at the end of well 4 pumping test, May 6, 1977.

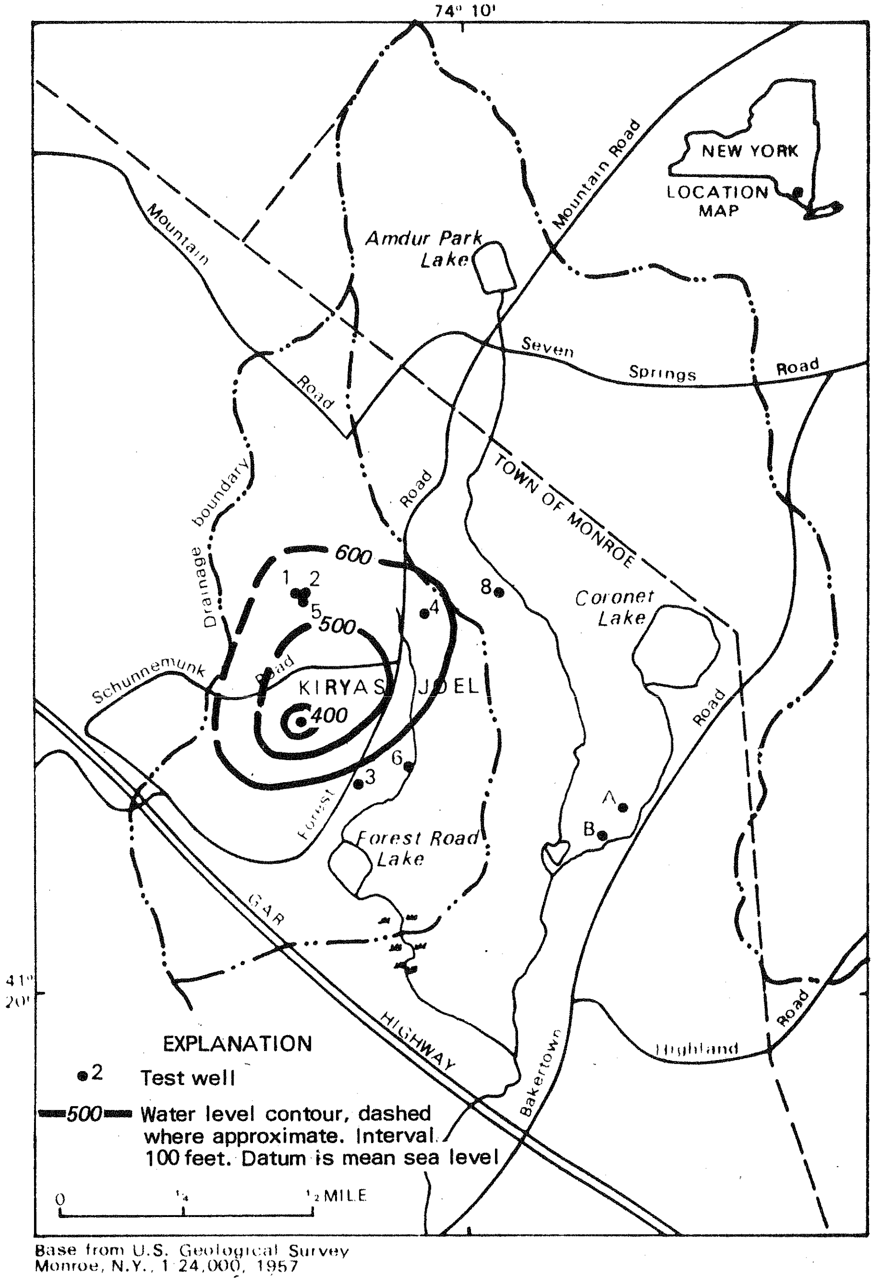


Figure 9.--Potentiometric surface at the end of well 7 pumping test, June 29, 1977.

WATER-DATA COLLECTION

As discussed earlier, maintaining records of water pumpage and use can aid in future evaluation of the ground-water resource. Currently, pumpage data are being calculated on the basis of daily metering of effluent from the community sewage-treatment plant. Thus, daily and seasonal water pumpage can be projected. Average daily water pumpage in 1977, reported on a monthly basis, is given in table 3.

Chemical analyses of municipal water provide early warning of contamination and are used in determining the necessary treatment. The State of New York has recently required all communities to obtain chemical analyses of their public-supply water every year. These analyses can also be used to detect changes in recharge sources or inflow of contaminants. A partial chemical analysis was done in 1977; results are presented in table 2 in the previous section. Records of water levels provide a means of determining the effects of pumping and natural factors such as drought. Water level in the new supply well (no. 5) can be measured by air-line gage. A record of static levels between pumping periods and a record of drawdown while pumping can disclose whether the aquifer is being depleted or if well yields are decreasing. Reduced well yield may result from dewatering, from plugging of openings around the

Table 3.--Average daily pumpage from well 1, Kiryas Joel, Orange County, N.Y.

[All values are in gallons per day]

Month		Monthly average
February (1977)		112,000
March		81,000
April		68,000
May		67,000
June		86,000
July		113,000
August		189,000
September		138,000
October		112,000
November		93,000
December		91,000
January (1978)		112,000
	Yearly Average	103,000

well bore with sediment or chemical precipitates, or from loss of pump efficiency. Where pumping is automatic, dependent on demand, judgement must be exercised in deciding when to determine static water level. Commonly, wells would be at rest during weekly low-demand periods so that static water level could be determined (for example, on Saturday mornings in this Jewish community).

Periodic measurements of water level in well 2 and the test wells can show the seasonal water-table changes as well as reflect pumpage from the system. Commonly, a schedule of monthly measurements can indicate changes readily, although weekly measurements may sometimes be needed to depict the trends.

Water-temperature variations can also be helpful in evaluating the aquifer system. Ground-water temperature in deeper aquifers seldom varies naturally. Hence, monthly or quarterly temperature readings of well discharge may be useful in detecting recharge from shallow-water sources.

Records of the factors described above, accumulated for several years, can be used to evaluate the effects of pumping on an aquifer system. The response of the system to pumping of new wells or to increased pumping of present wells is readily detectable by comparison of old and new water-data records. Of particular interest to water managers is the early detection of changes in pumping rate or water quality in the well or the aquifer system, for these provide forewarning of potential problems. For example, the expensive replacement of wells could be averted if it were determined that reduced yields were the result of a malfunction within the well system rather than aquifer depletion. Further, from adequate well records, the water-system engineer can evaluate the effects of known pumpage and can project probable effects of additional pumpage or wells.

SUMMARY

Pumping tests in 1977-78 determined that the bedrock aquifer beneath Kiryas Joel has a fracture system that is more permeable than those common in similar types of rock, and that the fractures are interconnected over at least a 1,000-ft area among the main wells. The three potential production wells and the present supply well are spaced more than 1,000 ft apart, which is adequate to prevent excessive interference of pumping levels. The three new wells seem capable of supplying three times as much water as is currently being used. However, under increasing demands for water, which would require that all wells be pumped daily, mutual interference of pumping effects is likely and would reduce yields proportionately in each well.

The extent of the aquifer system is not known, but it is assumed that it is recharged by percolation of precipitation through the overlying till. Partial chemical analyses indicate the water to be of good quality.

A water-data record is considered to be the best approach to determine the effects of current and planned expansion of the water-supply system. The measurement of pumpage and water levels and maintenance of these records can be useful in anticipating adverse effects and in predicting ultimate yields of the system.

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