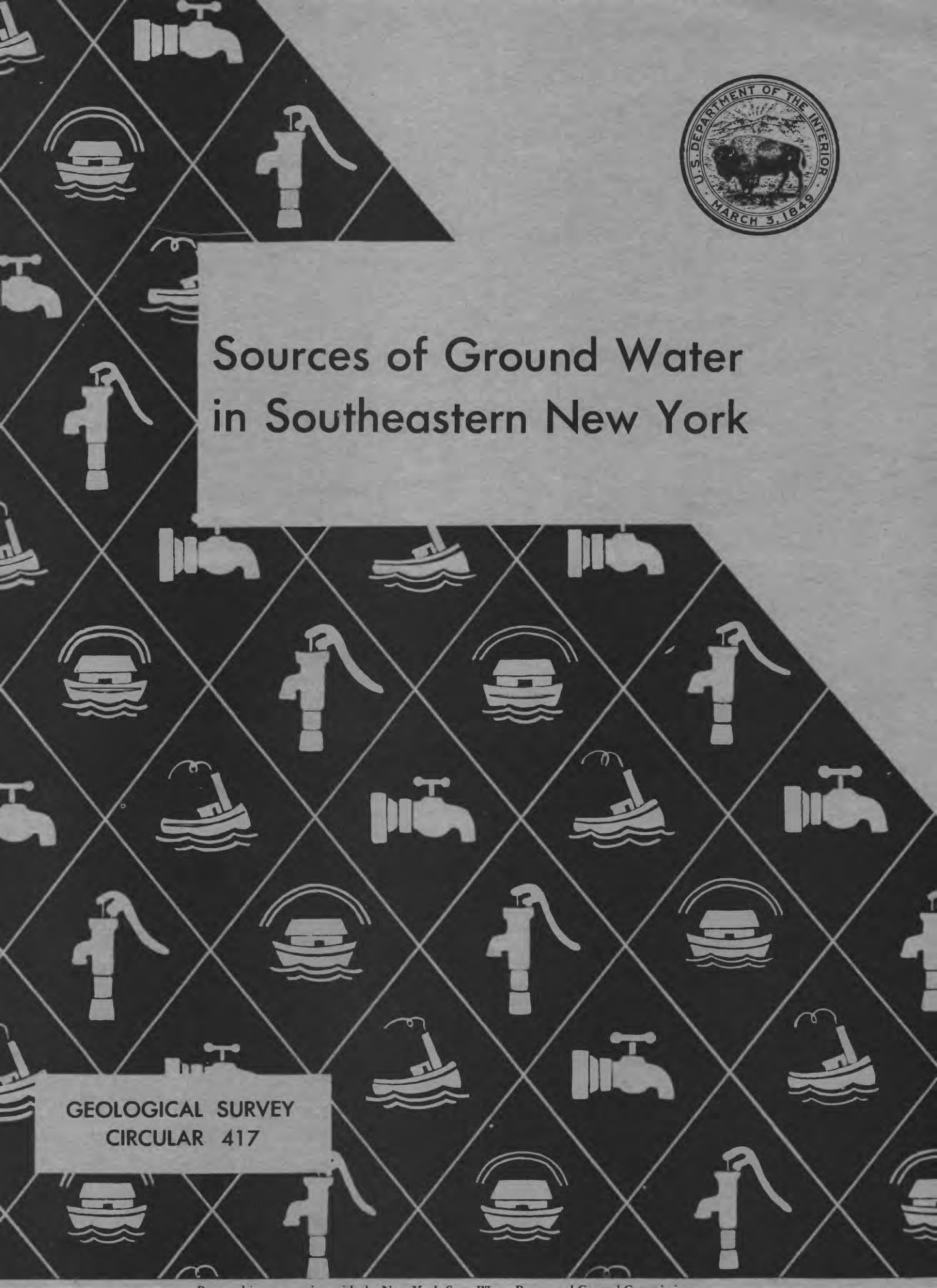

Sources of Ground Water in Southeastern New York

GEOLOGICAL SURVEY
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By Nathaniel M. Perlmutter

Prepared in cooperation with the New York State Water Power and Control Commission

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INTRODUCTION

This report summarizes the ground-water situation in six metropolitan counties of southeastern New York exclusive of those of New York City and Long Island. Conditions in the latter areas are covered in many published reports and are not discussed further. The six metropolitan counties of Dutchess, Orange, Putnam, Rockland, Ulster, and Westchester together include an area of about 3,600 square miles extending northward from New York City (fig. 1). Small parts of Ulster and Orange Counties lie in the Delaware River drainage basin, but the rest of the area is almost entirely in the adjoining Hudson River drainage basin. Some of the counties are densely populated and use relatively large quantities of ground water and surface water. Owing to the probable increase in population and the corresponding increase in water use, these counties are considered to be possible users of water from the Delaware River basin. Accordingly, a brief summary of the sources of ground water within these counties is pertinent to the overall investigation of the water resources of the Delaware River basin.

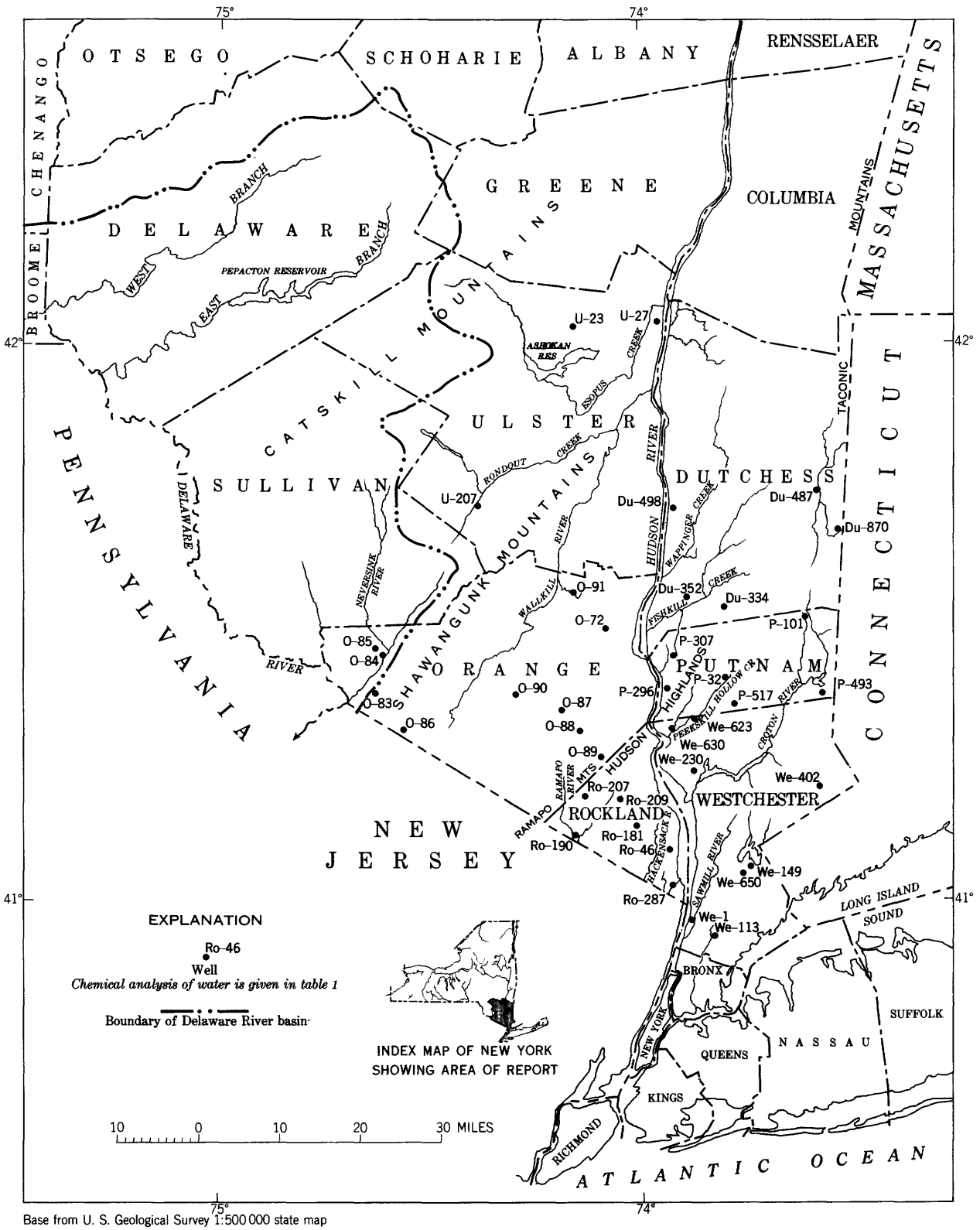
The data contained in this report were collected as part of the investigation of the ground-water resources of New York conducted by the U. S. Geological Survey in cooperation with the New York State Water Power and Control Commission. Reports on the investigations in Putnam County (Grossman, 1957) and in Westchester County (Asselstine and Grossman, 1955) have been published. At the time of publication of this circular a report on Rockland County (Perlmutter, 1959) was in press and one on Dutchess County (Simmons and others, 1959) was nearly ready for publication, but no investigations had been started in Orange and Ulster Counties. However, all the unpublished open-file data for these counties may be examined in the offices of the Geological Survey at Albany and Mineola, N. Y.

The information given in this report is based on interpretation of open-file data of the Geological Survey; published bulletins of the New York State Water Power and Control Commission, New York State Museum and New York State Department of Health, and the geologic map of New York State; and on field observations by the author, mostly in Rockland and Orange Counties. The preparation of the report was supervised by G. C. Taylor, Jr., district geologist, Ground Water Branch, Mineola District. Acknowledgment is due R. C. Heath, geologist-in-charge, subdistrict office, Albany, N. Y., for making available unpublished data.

GROUND-WATER HYDROLOGY SOUTHEASTERN NEW YORK

The source of most of the ground water in southeastern New York is the precipitation that falls directly on the area. The average annual precipitation ranges from about 50 inches in the southern part to about 42 inches in the northern part. Some ground water is derived locally by induced infiltration from lakes and streams into water-bearing deposits.

Water occurs under water-table and artesian conditions both in the unconsolidated deposits of Pleistocene and Recent age and in the consolidated bedrock which is Precambrian to Devonian and Triassic in age. The unconsolidated deposits of Pleistocene age that are composed chiefly of poorly sorted and unstratified deposits of gravel, sand, silt, clay, and boulders laid down by glaciers are called till; those composed of well-sorted and



Base from U. S. Geological Survey 1:500 000 state map

Figure 1.—Map of southeastern New York showing the metropolitan counties, location of wells for which water analyses are given, and the part of the area included in the Delaware River basin.

stratified sediments laid down by glacial melt waters are called outwash. Till covers most of the bedrock surface in the interstream areas and in minor stream valleys, and occurs also beneath outwash in the valleys of the major streams. Large bodies of outwash are distributed extensively in the valleys of the streams, shown on the map (fig. 1); numerous small, scattered bodies that occur in the valleys of minor streams and in other lowlands are not shown on the map. Thin deposits of alluvium of Recent age occur in most valleys but they are generally unimportant as sources of water.

Water in the unconsolidated deposits moves through minute openings (pores) between the constituent grains. The size, shape, and interconnection of the pores determine the permeability—the capacity of the deposits to transmit water. Owing to large differences in grain size and in sorting, the permeability ranges widely from place to place. For example, it is very high in outwash composed of well-sorted coarse sand and gravel and very small in outwash composed of silt and clay, and in till. Thus, in many places the outwash is capable of supplying more than 1,000 gpm (gallons per minute) for public supply and industrial use, whereas the yield from wells in till is generally small and sufficient for domestic use only.

The bedrock includes a large number of units of igneous, sedimentary and metamorphic rocks. In structure and composition the units range from the nearly horizontally bedded sandstone and shale of the Catskill Mountains on the west to the complexly folded and faulted granite, and gneiss, and schist of the Hudson Highlands on the east. Many of the units extend across several counties. Their distribution is on the geologic map of New York (Merrill, 1901).

Water in dense crystalline rocks, such as granite, gneiss, schist, and quartzite, occurs chiefly in openings along joints, irregular fractures, faults, and cleavage planes; water in sedimentary rocks, such as sandstone, shale, limestone, and dolomite, occurs in openings chiefly along joints, bedding planes, solution channels (restricted to limestone and dolomite), and faults. The width of the openings ranges from a hairline to several inches. The number and size of the openings and their connection with a good source of recharge largely determine the yield of wells drilled in rock. Most of the bedrock aquifers yield less than 10 gpm to individual wells; but several, such as the sandstone and shale of the Newark group of Triassic age, the Inwood limestone of Precambrian age, and the Stockbridge limestone of Cambrian and Ordovician age, commonly yield several hundred gallons per minute to individual wells.

After reaching the water table, water moves down the hydraulic gradient from areas of relatively high points on the water table to areas of relatively low points. Thus, the general pattern of movement of the ground water in bedrock is from areas of recharge in the uplands to areas of discharge on hillsides and in the bottoms of valleys. Similarly, ground water in the outwash, which is largely confined to lowlands, moves from relatively high points on the water table toward points of discharge at lower altitudes in streams and lakes. The small volume of water of many streams during the low-flow stage is furnished almost entirely by ground water issuing from springs and by direct percolation of ground water from the bedrock and outwash into the bottom of the streams.

In chemical quality, the ground water ranges from the soft, almost mineral-free water in Devonian sandstone in the Catskill Mountains to the hard, salty water in parts of the bedrock and unconsolidated deposits that border and underlie the Hudson River about as far north as Wappinger Creek in southwestern Dutchess County. The temperature of the water generally ranges between 51° and 56°F. Chemical analyses of water from selected wells tapping the principal aquifers are given in table 1.

In the following sections the general geology and water-bearing characteristics of the deposits are summarized by counties.

DUTCHESS COUNTY

Dutchess County has an area of approximately 800 square miles. The permanent population is about 145,000 (1953 census). Most of the county is a gently rolling plain ranging in altitude from about sea level along the Hudson River to about 500 feet in the central part. However, summit levels generally range from about 1,000 to 1,300 feet in the Taconic Mountains section along the eastern border and are as much as 1,600 feet in the

Table 1.—*Chemical analyses, in parts per million, of water from selected wells in Dutchess, Orange, Putnam, Rockland, Ulster, and Westchester Counties, New York*

[Asterisk (*) indicates analysis by New York State Department of Health; other analyses are by U. S. Geological Survey]

Well (fig. 1)	Location of well	Water-bearing unit	Date of collection	Depth of well (feet)	Silica (SiO_2)	Iron (Fe)		Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Yield (gpm)	Temperature (°F)
						Total	Dissolved													Total	Noncarbonate				
	Dutchess County:																								
Du-334*	About 4 miles east of Fishkill.	Stockbridge limestone..	11- 8-1951	125	.....	0.13	.....	<0.01	.....	.....	.....	.....	299	0	29	5	.....	.....	359	220	0	.....	7.4	20	.....
Du-353*	About 1 mile north of Fishkill.	Precambrian granite and gneiss.	12-20-1949	138	.....	.2	.....	2.5	.....	.....	.....	.....	151	0	62	11	.....	.....	276	104	0	.....	6.9	3	.....
Du-487	Dover Plains.....	Pleistocene outwash.....	5-27-1949	70	8.4	.17	.....	.....	47	14	.....	.....	180	.....	20	3.5	0.1	11	209	175	27	351	8.4	250	51
Du-498	Poughkeepsie.....	Hudson River formation (of former usage).	5-27-1949	1,196	11	.97	.....	.....	100	10	.....	.....	272	0	87	26	.0	3.0	425	291	.....	639	8.1	50	53
Du-670*	About 2½ miles northeast of Wingdale.	Cheshire quartzite.....	3-31-1952	65	.....	2.4	.....	.03	.....	.....	.....	.....	22	0	9.3	.6	.....	.....	60	18	0	.....	6.1	5	.....
	Orange Connty:																								
O-72	Newburgh.....	Normanskill shale.....	9-15-1953	120	13	.03	.00	.....	42	14	.....	.....	191	0	42	3.7	.1	.5	231	162	6	385	7.6	4	.....
O-83	Lake Hawthorne	Shawangunk conglomerate.	6- 4-1957	60	8	3	.00	2.00	3.2	3.5	1.1	2.1	22	0	10	1.4	.1	.0	42	23	5	63	6.0	5	51
O-84	Goddefroy	Pleistocene outwash.....	6- 4-1957	18	5	.51	.01	.02	11.1	2.1	2.0	1.1	24	0	12	3.0	.1	5.6	56	36	17	88	6.5	.....	56
O-85	Prospect Hill	Devonian sandstone and shale.	6- 4-1957	102	9.8	.74	.01	.15	9	4.0	6.1	.8	41	0	10	7.4	.1	.5	70	39	6	113	6.6	10	56
O-86	Unionville.....	Normanskill shale.....	6- 4-1957	134	9.1	.28	.06	.01	45	5.7	7.4	.6	107	0	59	4.2	.1	.3	192	136	49	308	7.4	8	53
O-87	Schunemunk Mountain, near Monroe.	Devonian sandstone	6- 3-1957	260	5.1	.22	.01	.09	4.4	3.1	1.8	.6	6	0	16	4.6	.1	.6	48	24	19	71	5.8	30	52
O-88	Harriman	Cambrian and Ordovician limestone.	6- 3-1957	175	11	.24	.02	.01	41	16	17	1.4	223	0	19	2.2	.6	.0	206	169	0	377	7.7	10	52
O-89	Lake Tiorati	Precambrian gneiss.....	6- 3-1957	206	14	.11	.04	.01	21	5.3	4.6	1.0	69	0	19	5.5	.1	2.2	113	75	18	173	7.0	6	54
O-90	Goshen	Normanskill shale.....	6- 3-1957	422	11	.05	.02	.0	24	8.2	83	1.6	254	4	48	10	.6	.1	314	94	0	518	8.3	30	52
O-91	East Walden.....	Pleistocene outwash.....	6- 5-1957	32	8.2	.04	.00	.01	55	7.6	5.3	.8	148	0	46	5.9	1	3.9	219	169	47	356	7.5	250	51
	Putnam County:																								
P-32	Tomkins Corners	Pleistocene outwash.....	8-17-1953	36	8.1	.07	.....	.01	40	15	15	2.8	176	.....	26	14	.0	12	235	162	17	378	6.9	10	68
P-101	Patterson.....	Stockbridge limestone..	3-27-1953	137	4.5	.03	.....	.00	39	14	3.4	5.8	174	.....	18	8	.0	.6	198	155	12	317	8.1	25	.....
P-296	Garrison.....	Precambrian gneiss.....	9-14-1953	125	15	.21	.....	.01	38	10	6.9	1.2	122	.....	44	5.9	.2	1.1	190	137	37	291	7.4	3	.....
P-307	About 3 miles northeast of Cold Spring.	Pochuck gabbro gneiss..	8-17-1953	227	15	.17	.....	.02	17	5.8	9.7	.8	50	.....	26	18	.1	1.3	132	72	31	194	6.8	.....	.....
P-493	About 3 miles southeast of Brewster.	Hudson River formation (of former usage).	11-27-1953	200±	17	.17	.....	.01	35	9.5	3.8	3.2	97	.....	36	14	.1	12	200	130	51	302	7.5	15	.....
P-517*	Stillwater.....	Pleistocene till.....	5- 7-1947	24	.....	.1	.....	.....	.....	.....	6	.....	174	.....	.....	55	.....	.....	.....	269	126	.....	7.2	.....	.....
	Rockland County:																								
Ro-46	West Nyack	Palisade diabase.....	7-23-1957	291	61	.1	.06	.00	5.8	.0	52	.1	27	.....	23	8.9	.3	2.8	177	15	0	246	9.6	16	.....
Ro-181*	New City.....	Newark group.....	4-24-1950	180	.....	.3	.....	.....	.....	.....	.....	.....	35	.....	.....	5.4	.1	5.4	.....	52	23	.....	6.2	75	.....
Ro-190	Suffern.....	Pleistocene outwash.....	7-23-1957	97	28	.05	.01	.36	22	7.1	8.8	1.1	55	0	39	12	.0	3.5	141	84	39	224	6.5	1,250	55
Ro-207	Lake Sebago.....	Precambrian gneiss.....	7-23-1957	205	22	.17	.01	.08	45	10	7.4	1.9	175	0	19	3.6	.3	.0	195	154	10	318	7.5	5	.....
Ro-209	Monnt Ivy.....	Newark group.	7-24-1957	371	18	.1	.05	.00	23	13	22	.4	133	0	41	2.4	.2	4.1	166	111	2	283	7.8	33	56
Ro-287	Piermont.....	Pleistocene outwash.....	7-24-1957	69	27	2.6	.05	.00	46	15	17	.8	174	0	37	16	.1	8.7	254	177	34	404	7.2	325	53
	Ulster County:																								
U-23*	Bearsville	Devonian shale and sandstone.	8-25-1949	142	.....	.1	.....	<.01	.....	.....	.....	.....	157	18	9.6	1.6	.....	.....	203	28	0	.....	8.9	.....	.....
U-27*	Glasco	Normanskill shale.....	7-14-1949	165	.....	.5	.....	.02	.....	.....	.....	.....	161	0	10	2.4	.....	.....	220	36	0	.....	8.2	.....	.....
U-207*	Ellenville.....	Pleistocene outwash	1-23-1956	101	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.6	.....	.2	.....	92	.....	.....	7.7	150	50
	Westchester County:																								
We-1*	Yonkers.....	Pleistocene sand.....	2- 6-1952	60	.....	.1	.....	<.01	.....	.....	.....	.....	262	0	58	11	.....	.....	359	270	55	.....	7.6	100	51
We-113*	Bronxville.....	Inwood limestone.....	10-17-1951	136	.....	.15	.....	.03	.....	.....	.....	.....	173	0	60	33	.....	.....	372	300	158	.....	7.7	19	.....
We-149	Silver Lake.....	Fordham gneiss.....	6-16-1953	150	14	.19	.0	.01	38	19	3.6	3.9	177	0	25	7.9	.0	9.0	212	173	28	357	7.8	300	.....
We-230*	About 2 miles northeast of Croton-on-Hudson.	Cortlandt series	11-28-1953	81	.....	.4	.....	.03	.....	.....	.....	.....	73	0	22	.....	.....	.....	126	92	32	.....	6.7	2½	.....
We-402*	Pound Ridge.....	Manhattan schist.....	11-21-1949	304	.....	.35	.....	.....	.....	.....	.....	.....	104	0	.....	11	.....	11	.....	124	39	.....	7.9	10	.....
We-623*	About 2 miles northeast of Peekskill.	Stockbridge limestone...	11-28-1953	60	.....	.15	.....	<.01	.....	.....	.....	.....	117	.....	15	4.6	.....	.....	158	88	0	.....	7.1	.....	.....
We-630*	Peekskill.....	Hudson River formation (of former usage).	11-28-1953	85	.....	.6	.....	<.01	.....	.....	.....	.....	134	0	39	6.4	.....	.....	212	128	18	.....	6.9	2	.....
We-650	North White Plains	Pleistocene outwash.....	1-28-1952	23	13	.03	.0	.0	30	12	3.7	1.9	113	0	29	6.2	.1	1.4	158	124	32	258	7.6	170	.....

Hudson Highlands along the southern border. Several prominent lowlands, developed on relatively soft rocks, occur at altitudes of 400 to 600 feet above sea level.

GENERAL GEOLOGY

The bedrock of Dutchess County consists of igneous, metamorphic, and sedimentary rocks ranging in age from Precambrian to Ordovician. Most of the rocks are closely folded and have a northeasterly strike.

The principal bedrock units are (a) undifferentiated granite and gneiss and diorite of Precambrian age, which crop out mainly along the southern border of the county; (b) the Hudson River formation (of former usage) that, as defined in this county, includes gray and red shale, slate, phyllite, and schist of the Nassau and Schodack formations of Cambrian age and the Deepkill and Normanskill shales of Ordovician age; and (c) the Cheshire quartzite of Cambrian age and the Stockbridge limestone of Cambrian and Ordovician age, which crop out in scattered elongate belts.

The Hudson River formation (of former usage) underlies more than two-thirds of the county. Unconsolidated deposits of till and outwash of Pleistocene age cover most of the bedrock surface.

WATER-BEARING CHARACTERISTICS OF THE DEPOSITS

Ground water is obtained from all three principal rock types: till, outwash, and bedrock. Deposits of till range in thickness from less than a foot to more than 100 feet and generally are thinnest on the upland areas. Yields of wells in till average only a few gallons per minute. Deposits of outwash composed of sand and gravel yield the largest quantities of water in the county. Most of these deposits are restricted to the valleys of the major streams, Wappinger Creek, Fishkill Creek, and the Hudson River. Yields of 34 screened wells tapping outwash range from 10 to 800 gpm and average 300 gpm.

About 90 percent of the existing wells tap the Hudson River formation (of former usage) and the Stockbridge limestone. Yields of 439 wells tapping the former range from 0 to 135 gpm and average 16 gpm; yields of 153 wells tapping the Stockbridge limestone range from 0 to 220 gpm and average 22 gpm. Yields from the other bedrock units average about 10 gpm. Chemical analyses of water from 5 wells are given in table 1.

Twenty-four public-supply systems serve about half the population. Most of the water used is taken from surface sources, but 16 public-supply systems are supplied wholly or in part with ground water. Withdrawals from these systems averaged about 1 mgd (million gallons per day) in 1954. Total ground-water pumpage is about 7 mgd.

ORANGE COUNTY

Orange County has an area of about 840 square miles. The permanent population is about 159,000 (1953 census). The land surface in Orange County is of four main physiographic types: (a) a broad, gently rolling plain in the central and northeastern part of the county, ranging in altitude from a few feet above sea level along the Hudson River to about 1,000 feet in the interior; (b) a dissected highland to the southeast, where the land surface reaches an altitude of more than 1,500 feet; (c) a northeasterly trending belt of narrow ridges and valleys bordering the central plain on the northwest; and (d) a small plateau in the extreme western corner of the county.

GENERAL GEOLOGY

The bedrock of Orange County consists of igneous, metamorphic, and sedimentary rocks ranging in age from Precambrian to Devonian. The rocks are folded and most of them strike northeasterly. Dips range from gentle to steep, and major faults are numerous. The central two-thirds of the county is underlain by gray slaty shale and sandstone composing the Normanskill shale and the Snake Hill formation of Ordovician age. To the southeast the Normanskill is in contact with elongate belts of infolded and faulted beds of limestone of Precambrian, Cambrian, and Ordovician age, and sandstone, conglomerate, and shale of Devonian age. These rocks, in turn, lie on and against the complex crystalline rocks of the Hudson Highlands area, which consist mainly of Precambrian granite and

gneiss. The Normanskill shale and Snake Hill formation are overlain unconformably to the northwest by the northwesterly dipping beds of the Shawangunk conglomerate and the High Falls shale of Silurian age, which form the Shawangunk Mountains. A prominent valley that parallels the northwest flank of the Shawangunk Mountains is underlain by northwesterly dipping beds of gray limestone, shale, and sandstone divided into several formations ranging in age from Late Silurian to Middle Devonian. The plateau to the northwest of the valley is underlain by sandstone and shale of Middle to Late Devonian age.

The bedrock in most of the county is covered by a mantle of unconsolidated deposits of till and outwash of Pleistocene age.

WATER-BEARING CHARACTERISTICS OF THE DEPOSITS

Records for about 200 wells and springs are available for Orange County. Because most of the data are for the extreme northwestern part, in the Neversink River valley, a detailed appraisal of the ground-water conditions requires considerably more fieldwork in other parts of the county than has been done to date.

The principal water-bearing units are till, outwash, and bedrock. The till covers the upland areas throughout most of the county. It yields to dug wells small quantities of water sufficient for domestic use. Deposits of outwash composed of sand and gravel and ranging from a few feet to several hundred feet in thickness occur in many of the stream valleys and other lowland areas; the largest deposit is in the valley of the Neversink River, and has a maximum thickness of more than 200 feet. In 1957, total withdrawals from this deposit were only a small fraction of the recharge. Other deposits of outwash, chiefly those in the valley of the Walkill River and its tributaries, are tapped by a relatively small number of wells and represent potential sources of substantial quantities of water. The yields of 13 screened wells in outwash range from 3 to 380 gpm and average 85 gpm.

Most of the wells in the county are completed in bedrock. The chief bedrock aquifer is the Normanskill shale of Ordovician age. Yields of 16 wells in the Normanskill range from 2 to 80 gpm and average 30 gpm. Yields of 21 wells in sandstone and shale of Devonian age range from 1 to 80 gpm and average 20 gpm. Yields of wells tapping limestone of Cambrian and Ordovician age are among the largest for bedrock aquifers; for 11 wells, the yields range from 18 to 150 gpm and average 80 gpm. Wells in granite and gneiss have the lowest yields; for 10 wells, the yields range from 1 to 25 gpm and average 10 gpm. In quality the water ranges from soft to hard; locally, the iron content is excessive. Table 1 gives analyses of water from 10 wells.

About 90 percent of the water used in the county is pumped from streams and other bodies of surface water. Public-supply systems for 28 communities ranging from small real-estate developments to municipalities obtain all or part of their water from wells and springs. These systems pumped about 2 mgd in 1954, chiefly from deposits of outwash. Ground water is used also for domestic, agricultural, and some industrial purposes. Total ground-water pumpage is estimated to be about 7 mgd.

PUTNAM COUNTY

A detailed report (Grossman, 1957) on the ground-water resources of Putnam County has been published by the New York State Water Power and Control Commission. The following data are summarized from that report.

Putnam County has an area of 235 square miles. Its permanent population (1953 census) is about 22,000. The county is in the Hudson Highlands, a dissected belt of low mountains that rise from about sea level along the Hudson River to as much as 1,400 feet in the upland areas.

GENERAL GEOLOGY

The bedrock of Putnam County consists of folded and faulted igneous and metamorphic rocks ranging in age from Precambrian to Ordovician. More than 90 percent of the bedrock is composed of undifferentiated granite and gneiss of Precambrian age. The remainder consists of some scattered bodies of the Pochuck gabbro gneiss of Precambrian age and a few northeast-trending narrow

infolded and faulted beds of the Cheshire quartzite of Cambrian age, the Stockbridge limestone of Cambrian and Ordovician age, and argillaceous and schistose beds of the Hudson River formation (of former usage). The consolidated rocks are overlain by an irregular mantle of unconsolidated till and outwash of Pleistocene age. In the upland areas, the till generally is less than 30 feet thick, but in some valleys it is as much as 200 feet thick. Outwash consisting chiefly of sand and gravel is limited mostly to the valleys of the Hudson River, Peekskill Hollow Creek, Canopus Creek, and the Croton River.

WATER-BEARING CHARACTERISTICS OF THE DEPOSITS

Ground water is contained in till, outwash, and bedrock. Records of a few wells in till indicate an average yield of about 2 gpm. Many wells in till go dry during periods of low rainfall, owing to decline of the water table. Yields of 50 wells tapping outwash sand and gravel range from 1 to 450 gpm and average 33 gpm.

The yields of about 370 wells that tap bedrock, chiefly granite and gneiss, range from 0 to 120 gpm and average 12 gpm. There is little difference in the average yields of wells tapping the different bedrock units. The average hardness of all the ground-water samples collected is 70 ppm, but it is as high as 480 ppm in water from the Stockbridge limestone. Locally the water has high iron content. Chemical analyses of water from six wells are given in table 1.

About one-third of the total estimated pumpage of 1.5 mgd in 1950 came from ground-water sources. Eleven public-supply systems use ground water wholly or in part. Ground water is used also for domestic, agricultural, and some industrial purposes.

ROCKLAND COUNTY

Rockland County has an area of approximately 200 square miles. The permanent population is about 114,000 (1957). The land surface ranges in altitude from about sea level along the Hudson River in the eastern part to about 1,300 feet in the mountainous northwestern part. The eastern two-thirds of the county is a gently rolling plain which is bordered on its eastern margin by a narrow, curving ridge that rises as much as 800 feet above the plain. The plain terminates against a rugged highland, the Ramapo Mountains, in the northwestern part of the county.

GENERAL GEOLOGY

The bedrock of Rockland County includes igneous, sedimentary, and metamorphic rocks; age is Precambrian, Cambrian and Ordovician, and Triassic. The eastern two-thirds of the county is underlain by beds of conglomerate, sandstone, and shale, a part of the Newark group, and igneous rocks, all of Triassic age. The largest differentiated unit of the igneous rocks is the Palisade diabase, a sill intruded into the sedimentary rocks in the eastern part of the county. The rocks of Triassic age dip gently northwest and terminate along a major fault marking the southeastern border of a belt of crystalline rocks, mostly granite and gneiss, of Precambrian age. A small area in the northeastern part of the county is underlain by an infolded and faulted belt of rocks of Cambrian and Ordovician age consisting of beds of quartzite, limestone, and phyllite. Deposits of till and outwash of Pleistocene age cover the bedrock in most of the county; in most places their total thickness is less than 30 feet but in some it is more than 300 feet.

WATER-BEARING CHARACTERISTICS OF THE DEPOSITS

Ground water is contained in till, outwash, and bedrock. Deposits of till are tapped by a small number of domestic wells, but yields generally are less than 5 gpm. Deposits of outwash composed chiefly of sand and gravel are restricted to valleys of such major streams as the Ramapo River, the Mahwah River, the Hackensack River, and Sparkill Creek. The outwash is generally less than 100 feet thick and yields about 50 to 1,500 gpm to individual wells; at some places it is composed largely of beds of clay and silt and very fine sand which do not yield large supplies.

The source of water from most of the wells in the county is the bedrock. The main water-bearing rocks are the beds of sandstone,

conglomerate, and shale of the Newark group. Yields of 200 wells tapping these rocks range from 4 to 1,500 gpm and average about 80 gpm. Public-supply wells tapping the Newark group have an average yield of about 300 gpm and an average depth of about 400 feet. Yields of 13 wells tapping the Palisade diabase average about 11 gpm. Yields of 37 wells obtaining water from granite and gneiss average about 15 gpm but most wells yield less than 10 gpm. Yields from the other, minor bedrock units are small, commonly less than 10 gpm. On the average, the water is moderately hard and is slightly alkaline. Chemical analyses of water from six wells are given in table 1.

Most of the water used in the county is taken from ground-water sources. An average of about 10 mgd was pumped in 1956. About 80 percent of the water was pumped for public-supply and industrial use and the remainder was pumped for domestic, agricultural, and other uses. A detailed report on the ground-water resources of the county has been prepared (Perlmutter, 1959).

ULSTER COUNTY

Ulster County has an area of approximately 1,140 square miles. The permanent population is about 96,000 (1953 census). The land surface ranges in altitude from about sea level along the Hudson River to almost 4,000 feet in the northwestern part of the county. The eastern half of the county is a gently rolling, dissected lowland. The Shawangunk Mountains and some minor ridges and valleys which trend northeastward across the county separate the eastern lowland from the dissected plateau, which is a part of the Catskill Mountains, in the northwestern half of the county.

GENERAL GEOLOGY

The bedrock of Ulster County consists of folded sedimentary rocks of Ordovician to Devonian age. The rocks in the eastern half of the county have a northeasterly to northerly strike. They consist of folded beds of gray and black shale and sandstone which belong largely to the Normanskill shale of Ordovician age. Unconformably overlying the Normanskill shale in the central part of the county are the northwesterly dipping beds of the Shawangunk conglomerate of Silurian age of the Shawangunk Mountains. Minor ridges and valleys immediately west and north of the Shawangunk Mountains are underlain by folded beds, mainly of marine shale, sandstone, and limestone, that constitute several formations of Late Silurian to Middle Devonian age. The Catskill Mountains area in the northwestern half of the county is underlain by nearly horizontal beds of red and gray sandstone, shale, and conglomerate of Middle and Late Devonian age. The bedrock is overlain in most of the area by unconsolidated deposits of till and outwash of Pleistocene age. The maximum thickness of these deposits is more than 200 feet.

WATER-BEARING CHARACTERISTICS OF THE DEPOSITS

Little is known of the water-bearing characteristics of the deposits in Ulster County because only a small number of records of wells and springs have been collected in the county to date. As in other nearby counties, the main water-bearing units are till, outwash, and bedrock. The till is of irregular thickness and covers most of the upland areas. Average yields of wells in till probably are a few gallons per minute. Scattered outwash deposits of sand and gravel occur in the major stream valleys, those of Rondout Creek, Walkill River, and Esopus Creek, and probably can yield large quantities of water to individual wells. The bedrock is the source of water for most of the wells in the county. The yields of wells tapping bedrock units probably are of the same order of magnitude as the yields from wells in the same units in Orange County (p. 6). Chemical analyses of water from 3 wells are given in table 1.

Most of the ground water is used for public-supply, domestic, and agricultural purposes, but a small quantity is used for industrial and miscellaneous purposes. About 10 public-supply systems depend on ground-water sources wholly or in part. The total volume of ground water pumped by these systems averaged somewhat less than half a million gallons per day in 1954.

WESTCHESTER COUNTY

Westchester County has an area of about 450 square miles. The permanent population

is about 753,000 (1957). The altitude of the land surface ranges from about sea level along the Hudson River in the western part of the county to about 700 feet in the Hudson Highlands in the northern part. The land surface in most of the county is characterized by northeastward-trending low ridges and valleys.

GENERAL GEOLOGY

In Westchester County, bedrock consists of closely folded igneous and metamorphic rocks which range from Precambrian to Ordovician in age and form northeastward-trending belts. The principal bedrock units are (a) the Fordham gneiss, (b) the Inwood limestone, and (c) the Manhattan schist, all of Precambrian age. In addition, small areas are underlain by the Harrison diorite and the Yonkers granite, of Precambrian age, and infolded belts of the Cheshire quartzite of Cambrian age, the Stockbridge limestone, slate of the Hudson River formation, (of former usage) and miscellaneous igneous rocks such as granite, pegmatite, and the undifferentiated mafic rocks of the Cortlandt series. Outcrops of bedrock are numerous, but the bedrock surface in most of the county is covered by unconsolidated deposits of till and outwash of Pleistocene age that range in total thickness from a few feet to as much as 200 feet.

WATER-BEARING CHARACTERISTICS OF THE DEPOSITS

Ground water is obtained from till, outwash, and bedrock. Deposits of till having a wide range in thickness are extensively distributed on the uplands and in some valleys. The till has a relatively low permeability and except where it contains sandy lenses yields only a few gallons per minute to dug wells. Scattered sizable deposits of outwash occur in parts of the county; the largest and thickest are restricted to large valleys, such as those of the Hudson River, Sawmill River and Croton River. The outwash consists mostly of sand and gravel but in some places is largely composed of silt and clay. Outwash deposits of sand and gravel yield the largest supplies to wells in the county. Individual wells range in yield from about 3 to 600 gpm. The average yield is about 200 gpm.

At least 70 percent of the wells in Westchester County tap the bedrock. The average yield from these wells is less than 30 gpm. Most of the bedrock wells tap schist and gneiss, and range in yield from 1 to 400 gpm. Limestone is the most productive type of bedrock, particularly in those lowland areas where it is overlain by water-bearing deposits of outwash. Yields of individual wells penetrating limestone range from 2 to as much as 450 gpm. Yields from other minor bedrock units generally are small. Chemical analyses of water from 8 wells are given in the table.

Public-supply systems, which serve about 90 percent of the population, pump most of their water from lakes and streams. However, about 21 systems use ground-water sources wholly or in part. The estimated pumpage from public-supply wells was about 6 mgd in 1956. Wells and springs also supply domestic, agricultural, and some industrial needs but the amount supplied is unknown.

Records and logs of about 1,100 wells in Westchester County are given in Bulletin GW-35 (Asselstine and Grossman, 1955) of the New York State Water Power and Control Commission.

REFERENCES CITED

Asselstine, E. S., and Grossman, I. G., 1955, The ground-water resources of Westchester County, N. Y., part 1, Records of wells and test holes: New York Water Power and Control Comm. Bull. GW-35.

Grossman, I. G., 1957, The ground-water resources of Putnam County, N. Y.: New York Water Power and Control Comm. Bull. GW-37.

Merrill, F. J. H., 1901, Geologic map of New York: New York State Mus.

New York State Department of Health, 1954, Public-water supply data: Bull. 19.

Perlmutter, N. M., 1959, Geology and ground-water resources of Rockland County, N. Y. with special emphasis on the Newark group (Triassic): New York Water Power and Control Comm. Bull. GW-42.

Simmons, E. T., Grossman, I. G., and Heath, R. C., 1959, The ground-water resources of Dutchess County, N. Y.: U. S. Geol. Survey open-file rept.

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