Geology and Hydrology of the West Milton Area Saratoga County, New York

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1747

Prepared in cooperation with the U.S. Atomic Energy Commission

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By F. K. MACK, F. H. PAUSZEK, *and* J. R. CRIPPEN

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GLOSSARY OF TECHNICAL TERMS

Aquifer, A formation, group of formations, or part of a formation that is water-bearing.

Artesian conditions, Occurrence of ground water under sufficient pressure to rise above the level at which it is encountered by a well, but which does not necessarily rise to or above the surface of the ground.

Base flow, Sustained or fair-weather flow. In most streams, base flow is composed largely of ground-water discharge.

Bed material, Sediment deposited on the surface of a stream bed.

Carbonate hardness, Hardness of water due to calcium and magnesium bicarbonate and (or) carbonate.

Clay, Sediment composed of particles having diameters less than 0.004 mm.

Color (of water), A visual effect due to material in solution.

Cone of depression, The depression, roughly conical in shape, produced in a water table or piezometric surface by pumping (or artesian flow).

Correlation, coefficient of, A measure of the degree of relationship between variables. Numerically, the coefficient of correlation (r) ranges from 0 (no correlation) to ± 1 (perfect correlation). The sign is positive if the dependent variable (ordinate value) increases with increases of the independent variable (abscissa value); negative if the dependent variable decreases with an increase in the independent variable.

Discharge area, Area of land or body of surface water where ground water discharges naturally directly from the zone of saturation.

Dissolved solids, Residue from a clear measured sample of water after evaporation and drying for 1 hour at 180°C. Expressed as parts per million.

Drainage area, The area above a specified location that contributes water to a stream. It is measured in a horizontal plane, which is enclosed by a topographic divide in such a way that direct surface runoff from precipitation normally would drain by gravity into the stream above the specified point.

Flow-duration curve, A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.

Fluvial sediment, Fragmental material transported by, suspended in, or deposited by water.

Gaging station, A particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or discharge are obtained. A primary gaging station provides a long-term sample of the rate and amount of flow in the hydrologic province for which it serves as an index station. A secondary station provides a short-term sample of rate and flow in an area, which, through correlation techniques, can be related to flow at a primary gaging station. A partial-record station is a particular site where limited streamflow data are collected over a period of years.

Ground water, The part of subsurface water that is in the zone of saturation.

Hardness, The effect of calcium, magnesium, and other cations having soap-consuming and encrusting properties. Expressed as the calcium carbonate ($CaCO_3$) equivalent in parts per million.

Mean annual flood, The flood having a recurrence interval of 2.33 years.

Micromicro, Prefix meaning 10^{-12}; symbol, $\mu\mu c$=micromicrocuries.

Noncarbonate hardness, Hardness due to salts of calcium and magnesium other than those of bicarbonate and carbonate.

Parts per million (ppm), One pound of substance per million pounds of solution or water mixture.

Permeability, Capacity of a rock or soil to transmit a fluid such as water.

pH, A logarithmic expression of the hydrogen-ion concentration. Acidity or alkalinity is indicated by the pH value. Water having a pH value of 7 is considered neutral being neither acid nor alkaline. A pH higher than 7 indicates alkalinity and a value less than 7 denotes acidity.

Piezometric surface, An imaginary surface that everywhere coincides with the static level of the water in an artesian aquifer.

Porosity, The ratio of the aggregate volume of interstices in a rock or soil to its total volume. It is usually stated as a percentage.

Recurrence interval, The average interval of time within which a flood of given magnitude will be equaled or exceeded once.

Recharge area, Area where water infiltrates to the zone of saturation.

Sand, Sediment particles having diameters between 0.062 and 2.000 mm.

Sediment concentration, Ratio of the weight of sediment in a water-sediment mixture to the total weight of the mixture; expressed as parts per million.

Sediment load, Weight of sediment transported per unit of time; expressed as tons per day.

Silt, Sediment particles having diameters between 0.004 and 0.062 mm.

Size analysis, Definition of particle-size distribution in percentage of total weight; expressed as a cumulative percentage.

Specific conductance, The reciprocal of resistance which indicates the ability of a water to conduct an electric current per unit cross-sectional area of solution and is expressed as micromhos per centimeter at 25°C. This property is related to the quantity and kind of dissolved mineral matter in solution and is an approximate measure thereof. A high specific conductance generally indicates a larger concentration of dissolved mineral matter than a lower value.

Standard error of estimate, A measure of scatter of points about a central line or curve relating two variables.

Station, A site where hydrologic data has been collected.

Storage, coefficient of, The volume of water released from storage in each vertical column of the aquifer having a base of 1 square foot when the water table or other piezometric surface declines 1 foot.

Subsurface water, All water that exists below the surface of the solid earth.

Suspended sediment, Sediment in suspension in water.

Transmissibility, coefficient of, The rate of flow of water, in gallons per day, through each vertical strip of aquifer 1 foot wide having a height equal to the thickness of the aquifer and having a unit hydraulic gradient.

Water table, The upper surface of a zone of saturation (except where that surface is formed by an impermeable body).

Water year, Begins October 1 of one year and ends September 30 the following year.

Zone of aeration, The zone in which the interstices of permeable rocks are not filled (except temporarily) with water.

Zone of saturation, The zone beneath the earth's surface in which all pores and other openings are filled with water under a pressure equal to or greater than atmospheric pressure.

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By F. K. Mack, F. H. Pauszek, and J. R. Crippen

ABSTRACT

This report describes the geology, ground-water conditions, streamflow characteristics, and quality of water in the West Milton area, Saratoga County, N.Y.

The West Milton area is in the east-central part of New York in the hilly region that forms a transition zone between the Adirondack Mountains and the Hudson-Mohawk valley lowland. Bedrock underlying the area consists of crystalline rocks of Precambrian age and sandstone, dolomite, limestone, and shale formations of Cambrian and Ordovician age. The formations have been moderately folded and have been displaced as much as several hundred feet along at least three northeast-trending normal faults. The bedrock is overlain in nearly all parts of the area by a layer of unconsolidated deposits which ranges in thickness from a few feet to more than 200 feet. The unconsolidated deposits are of Pleistocene age and consist of unstratified materials (till) laid down by glacial ice and stratified sediments deposited by glacial meltwaters. The topography of the bedrock surface differs greatly from the topography of the land surface. Although not evident in the present topography, at least two channels, cut in bedrock by preglacial streams, pass through the area.

Ground-water supplies adequate to satisfy domestic requirements can be obtained from wells in any part of the area. Large ground-water supplies may be taken from coarse-grained stratified deposits comprising two aquifers in the valley of Kayaderosseras Creek. The Atomic Energy Commission has pumped as much as 1 mgd from a horizontal well drawing from the uppermost aquifer which is composed of flood-plain deposits. Part of the water yielded by this well during extended periods of pumping is induced flow from the creek. Three nearby vertical wells drilled by the Commission comprise a separate well field capable of yielding at least 2 mgd and possibly as much as 3 mgd from the deeper stratified deposits underlying the valley. A pumping test showed that near the center of this well field the coefficient of transmissibility is about 125,000 gpd per ft and the coefficient of storage is about 0.0003. The water obtained from the sand and gravel has a hardness of about 125 ppm and contains about 150 ppm of dissolved solids.

Most of the Government reservation is drained by Glowegee Creek, one of the larger tributaries of Kayaderosseras Creek. The average streamflow of Kayaderosseras Creek at West Milton is 141 cfs or about 1.5 cfs per sq mi. The monthly mean discharge has ranged from a low of 21.7 cfs in September 1958 to a high of 866 cfs in March 1936, and the annual mean discharge has ranged from 94.5 cfs in 1941 to 198 cfs in 1952. The mean annual flood is 1,740 cfs and the 50-year flood is 5,300 cfs.

Streamflow data have been collected on Glowegee Creek since 1948 at a station 0.5 mile south of West Milton. The average streamflow of Glowegee Creek at this

station is 41 cfs or about 1.5 cfs per sq mi. The mean annual flood is 740 cfs and the 50-year flood is 2,250 cfs.

The quality of the water in both Kayaderosseras Creek and Glowegee Creek is satisfactory for public supply and most industrial purposes. The mineral content of both streams is low—the dissolved-solids content averaging about 93 ppm in Kayaderosseras Creek and about 131 ppm in Glowegee Creek. The average hardness of water in Kayaderosseras Creek and Glowegee Creek is 68 ppm and 102 ppm, respectively. During periods of low flow, suspended sediment discharge in both streams is less than 10 tons per day, but during periods of high flow, the sediment discharge has been as great as 163 tons per day in Glowegee Creek and 437 tons per day in Kayaderosseras Creek.

INTRODUCTION

In 1948, the United States Government acquired approximately 4,000 acres of land in the West Milton area of Saratoga County as a site for a reactor research installation of the Atomic Energy Commission. The installation is an adjunct to the Knolls Atomic Power Laboratory at Schenectady.

Use of the site for reactor research required information on certain geologic and hydrologic subjects. Chief among these were:

1. The availability of water to supply the installation.
2. The foundation conditions that would be encountered in the construction of buildings.
3. The suitability of the area for the disposal of radioactive wastes either by burial or by discharge into streams.
4. The location of gravel for use in road building and other construction work.

At the request of the Schenectady Operations Office, Atomic Energy Commission, studies of these subjects were undertaken by the U.S. Geological Survey. This report presents the acquired data and discusses their significance with respect to the geology and hydrology of the area.

ACKNOWLEDGMENTS

The investigation was started in 1948 at the request of L. E. Johnson, then area manager of the Schenectady Operations Office of the Atomic Energy Commission. Other personnel of the Atomic Energy Commission and of the General Electric Co., which operates the Knolls Atomic Power Laboratory for the Atomic Energy Commission, have aided materially both in the early planning and in the various phases of the investigation. Among those who participated in the planning of the programs and furnished specialized assistance and advice are J. D. Anderson, A. E. Gorman, S. W. Nitzman, A. A. Batza, L. J. Cherubin, J. J. Fitzgerald, B. F. Knapp, and A. J. Delong.

The investigations of the geology and ground-water resources were under the general technical supervision of the following district geol-

ogists: M. L. Brashears, Jr. (resigned April 1952), J. E. Upson (October 1952 to May 1957), and G. C. Taylor, Jr. (after May 1957). The investigations of the geology and ground-water resources from 1948 to 1954 were made by E. S. Simpson. The fieldwork after 1955 and the preparation of the report were carried out by F. K. Mack under the direct supervision of R. C. Heath, geologist in charge of the Ground Water Branch office in Albany. H. C. Spicer, George Edwards, R. M. Hazelwood, R. E. Miller, and R. A. McCullough, all of the U.S. Geological Survey participated in geophysical investigations made in the area during 1952 and 1953.

The surface-water investigations were made under the direct supervision of A. W. Harrington, district engineer. D. B. Bogart, engineer in charge of the Hydrologic Unit of the New York District, supervised the surface-water investigations from 1949 to October 1957. The section of the report pertaining to the streamflow was completed by B. J. Frederick under the direct supervision of L. E. Carroon who succeeded Mr. Bogart as engineer in charge of the Hydrologic Unit. Most of the field studies, computations, and interpretation of records of the surface-water resources were made by F. H. Ruggles.

Quality-of-water investigations were made under the direct supervision of W. F. White and F. H. Pauszek (after 1953). Fieldwork was conducted by W. A. Beetem.

J. G. Broughton, State geologist; D. W. Fisher, State paleontologist; and other geologists of the Geological Survey—New York State Museum and Science Service, provided valuable assistance and advice regarding the geology of the area. The New York State Department of Public Works, Bureau of Soil Mechanics, made seismic surveys to determine the depth to bedrock at 24 sites in the area. The State Department of Public Works also contributed financial support to the operation of the stream-gaging station on Kayaderosseras Creek. Well data were furnished by: Stewart Brothers, Schenectady, N.Y.; B. Uhlinger, Amsterdam, N.Y.; R. G. Voehringer, Ballston Spa, N.Y.; and R. E. Chapman Co., Oakdale, Mass.

Data from six programs of test-well and test-hole drilling at locations on the government reservation have been included in and were freely drawn upon in the preparation of this report. These programs, which were carried out for the Atomic Energy Commission, include drilling by (1) the U.S. Army Corps of Engineers in 1948; (2) Raymond Concrete Pile Co. in 1950; (3) Pennsylvania Drilling Co., Pittsburgh, Pa., in 1952 and again in 1956; (4) Stewart Bros., Schenectady, N.Y., in 1955 and 1956; and (5) R. E. Chapman Co., Oakdale, Mass., in 1957.

Finally, appreciation is due the land owners and other individuals who have furnished data and information regarding their wells and water supplies.

SCOPE OF INVESTIGATION

The geologic and hydrologic studies in the West Milton area may be conveniently divided into three categories: (1) geologic studies, (2) ground-water studies, and (3) surface-water studies.

The geologic studies consisted of:

1. Mapping of the unconsolidated deposits and bedrock underlying the area.
2. Geophysical surveys along selected roads.
3. Collection and study of rock cuttings from test wells and collection and study of the logs of bore holes.

The ground-water studies consisted of:

1. Collection of data on the depth, diameter, yield, and other features of the existing wells in the area.
2. Measuring the depth to water, either by means of continuous recorders or at weekly intervals, in selected wells.
3. Two pumping tests made to estimate the quantity of water that could be obtained from the deposits underlying the valley of Kayaderosseras Creek.
4. Measuring the temperature of the water in selected wells at weekly intervals.
5. Chemical analysis of the water from selected wells.

The surface-water studies consisted of:

1. The collection and analysis of records of the discharge, temperature, chemical quality, and suspended sediment load of Kayaderosseras and Glowegee Creeks.
2. Measurement of the discharge of selected small streams.
3. Surveys of the snow cover at selected stations.
4. Measurements of the rate of movement of water in Kayaderosseras and Glowegee Creeks.
5. Determination of the grain size of the bed material at selected stations on Kayaderosseras, Fish, and Glowegee Creeks.

Stations at which hydrologic data were collected in the Kayaderosseras-Fish Creek drainage basin are shown on the map of the drainage basin (pl. 1) and are described in table 1.

PREVIOUS INVESTIGATIONS

The earliest investigations of the water resources in the vicinity of West Milton were concerned with the nature, source, and occurrence of mineral waters in the Saratoga Springs-Ballston Spa area. Reports on investigations related to these mineral waters have been

TABLE 1.—*Stations at which hydrologic data were collected in the Kayaderosseras-Fish Creek drainage basin*

STREAMBED MATERIAL AND SURFACE-WATER STATIONS

Station	Location	Drainage area (square miles)	Streambed material	Type of data and length of record						
				Discharge measurements			Chemical quality	Radiochemical quality	Temperature	Suspended sediment
				Continuous	Periodic	One or two				
1	Kayaderosseras Creek; 1.1 miles east of Porter Corners; near the center of downstream side of bridge on graded road.		11/ 9/54 6/24/55							
2	Kayaderosseras Creek; 1.5 miles north of Middle Grove; on downstream side of highway bridge; near right bank.		11/ 9/54 6/24/55							
3	Clover Mill Brook; 1.5 miles northwest of Rock City Falls; east of State Highway 29 and 10 ft downstream from culvert, 0.6 mile north of confluence with Kayaderosseras Creek.	2.22				6/25/52 7/31/52				
4	Kayaderosseras Creek; 0.4 mile west of junction of West Milton-Rock City Falls road with State Highway 29; 25 ft upstream from dam at upper plant of Cotrel Paper Co., 3 to 5 ft from concrete wall along left bank.		11/ 9/54 6/24/55							
5	Star Brook; 0.9 mile northeast of junction of West Milton-Rock City Falls road with State Highway 29; 15 ft upstream from culvert under Middle Grove-North Milton Road.	1.16				6/25/52 7/31/52				
6	Crook Brook; 1.0 mile northwest of road intersection at hamlet of West Milton; about 500 ft upstream from confluence with Kayaderosseras Creek.	4.06				4/26/57				
7	Kayaderosseras Creek; 0.4 mile northeast of road intersection at hamlet of West Milton; near left bank; 500 ft upstream from east end of breached dam.		6/24/55							
8	Kayaderosseras Creek; 0.4 mile northeast of road intersection at hamlet of West Milton; 30 ft upstream from bridge on West Milton-Rock City Falls Road.	61.9				7/ 8/53				
9	Glowegee Creek; 2.2 miles west of road intersection at hamlet of West Milton; at bridge 400 ft east of intersection of graded roads. Bed-material sample collected 75 ft downstream from bridge. Stream-discharge measurements were made at various distances upstream or downstream from the bridge depending on stream stage.	18.2	6/24/55		7/27/49- 4/27/53		7/27/49- 4/27/53	3/13/51- 4/27/53		
10	Glowegee Creek; 1.0 mile west of road intersection at hamlet of West Milton; 50 ft upstream from bridge on Atomic Project Road.		6/24/55							

TABLE 1.—*Stations at which hydrologic data were collected in the Kayaderosseras-Fish Creek drainage basin*—Continued

Station	Location	Drainage area (square miles)	Stream-bed material	Type of data and length of record: Discharge measurements: Continuous	Discharge measurements: Periodic	Discharge measurements: One or two	Chemical quality	Radio-chemical quality	Temperature	Suspended sediment
11	Glowegee Creek; 0.8 mile southwest of road intersection at hamlet of West Milton; at bridge on abandoned road; 0.3 mile southwest of junction of abandoned road with Atomic Project Road. Stream-bed material collected 25 ft below bridge near left bank. Stream-discharge measurements were made at various distances upstream or downstream from the bridge depending on stream stage.	23.2	11/ 9/54		7/14/48–7/31/52					
12	Glowegee Creek; 0.5 mile south of road intersection at hamlet of West Milton; 1.5 miles from confluence with Kayaderosseras Creek; at highway bridge. Bed-material sample collected near left bank 20 ft upstream from bridge.	26.0	11/ 2/54	4/ 4/48–present (1961)			7/27/49–6/30/56	3/13/51–1/13/53	3/ 1/53–present (1961)	3/ 4/52–9/ 7/55
13	Glowegee Creek; 0.8 mile southeast of road intersection at hamlet of West Milton; 50 ft upstream from bridge on Dewar Road; near left bank of stream.		11/ 9/54–6/24/55							
14	Glowegee Creek; 1.1 miles east of road intersection at hamlet of West Milton; under upstream side of bridge on Lewis Road.		11/ 9/54–6/24/55							
15	Kayaderosseras Creek; 1.0 mile east of road intersection at hamlet of West Milton; 500 ft downstream from confluence with Glowegee Creek; near left bank.	90		7/30/27–present (1961)					6/ 1/50–6/30/56	
16	Kayaderosseras Creek; 1.4 miles east of road intersection at hamlet of West Milton; at bridge on Lewis Road.		11/ 2/54				11/23/49–6/30/55	3/13/51–4/27/53		2/24/53–6/30/55
17	Kayaderosseras Creek; 0.7 mile southeast of road intersection at Milton Center; at swimming hole; near left bank.		11/ 9/54 6/24/55							
18	Kayaderosseras Creek; in Ballston Spa; 500 ft upstream from State Highway 50; 250 ft upstream from dam. Sample collected 11/9/54 near left bank; sample collected 6/24/55 near right bank.		11/ 9/54 6/24/55							
19	Kayaderosseras Creek; 100 ft downstream from bridge on U.S. Highway 9; near left bank.		11/ 9/54 6/24/55							
20	Kayaderosseras Creek; about 0.3 mile from confluence with Saratoga Lake; near left bank.		11/ 9/54							
21	Saratoga Lake; 1.0 mile southwest of bridge over Fish Creek on State Highway 9P; at Kayaderosseras Park; near bathing beach; 200 ft from shore.		11/ 9/54							

22	Fish Creek; 0.25 mile downstream from bridge on State Highway 9P; near center of stream.		11/ 9/54							
23	Fish Creek; 2.0 miles downstream from State Highway 9P; 50 ft upstream from abutment of Stafford Bridge.		11/ 9/54							
24	Fish Creek; 0.8 mile southwest of Victory Mills; 600 ft downstream from bridge on State Highway 32; 50 ft upstream from abandoned railroad bridge; 3 ft from left bank.		11/ 9/54							

SNOW COURSES AND WEATHER STATIONS

Station	Location	Type of data and length of record			
		Snow cover	Precipitation	Temperature	Wind
25	1 mile southeast of road intersection at Greenfield Center		1898–1955	1898–1955	
26	At reactor site; 1.3 miles west of road intersection in hamlet of West Milton		1948–present (1961)	1948–present (1961)	1948–present (1961)
27	500 ft south of road intersection in hamlet of West Milton, on west side of highway		1955–present (1961)		
28	1 mile northeast of junction of West Milton-Rock City Falls Road with State Highway 29; 250 ft south of Middle Grove-North Milton Road; 1,000 ft northwest of culvert on Star Brook.	3/ 3/52–present. (1961)			
29	700 ft south of road intersection at hamlet of West Milton; 250 ft west of road	3/ 3/52–present. (1961)			

TABLE 1.—*Stations at which hydrologic data were collected in the Kayaderosseras-Fish Creek drainage basin*—*Continued*

GROUND-WATER OBSERVATION WELLS

Well	Location	Type of data and length of record: Water-level measurements, Continuous	Water-level measurements, Periodic	Chemical quality	Radio-chemical quality	Temperature
Sa 545	0.9 mile west of road intersection at hamlet of West Milton; 100 ft south of Glowegee Creek, 200 ft south of Atomic Project Road.			5/ 1/51	5/ 1/51	
546	0.6 mile south of road intersection at hamlet of West Milton; 200 ft northeast of road intersection.			9/24/52	9/24/52	
566	0.2 mile south of road intersection at hamlet of West Milton; at school on west side of highway.			9/24/52	9/24/52	
603	0.8 mile southeast of road intersection at Milton Center; 100 ft northeast of Kayaderosseras Creek; 100 ft south of highway.			9/24/52	9/24/52	
838	1.1 miles southwest of road intersection at hamlet of West Milton; 0.7 mile southeast of reactor site; near junction with abandoned road; 140 ft west of graded road.		10/22/54–11/ 7/55			
839	1.7 miles west of road intersection at hamlet of West Milton; 0.6 mile southwest of reactor site; 0.1 mile west of road junction; 70 ft south of graded road.		10/22/54–11/ 7/55			
840	2.5 miles northwest of road intersection at hamlet of West Milton; 2.0 miles west of confluence of Crook Brook with Kayaderosseras Creek; 0.4 mile south of road junction; 50 ft west of graded road.		10/22/54–11/ 7/55			
841	1.6 miles northwest of road intersection at hamlet of West Milton; 0.6 mile north of reactor site; 0.4 mile west of road junction; 125 ft south of graded road.		10/22/54–11/ 7/55			
843	0.9 mile northwest of road intersection at hamlet of West Milton; 50 ft west of Kayaderosseras Creek; 250 ft east of graded road; 50 ft south of confluence of Crook Brook with Kayaderosseras Creek.	2/ 3/55– 6/25/59				2/ 3/55– 9/ 4/58
848T	0.8 mile northwest of road intersection at hamlet of West Milton; 200 ft west of Kayaderosseras Creek; 60 ft southwest of centerline of graded road.	5/23/56–12/28/56		4/13/56 4/26/56 8/30/56		
849T	0.9 mile northwest of road intersection of hamlet of West Milton; 220 ft west of Kayaderosseras Creek; 34 ft east of centerline of graded road.					8/30/56– 9/ 4/58
1026T	0.8 mile northwest of road intersection at hamlet of West Milton; 440 ft west of Kayaderosseras Creek; 300 ft southwest of graded road.	12/17/56– 6/25/59				
1028T	0.8 mile northwest of road intersection at hamlet of West Milton; 700 ft west of Kayaderosseras Creek; 600 ft southwest of graded road.	12/28/56– 6/25/59				
25Sp	1.3 miles west of road intersection at hamlet of West Milton; 0.2 mile southwest of reactor site; 100 ft north of graded road.			5/ 1/51	5/ 1/51	

prepared by Kemp (1912), Cushing and Ruedemann (1914), Colony (1930), and Strock (1941).

Reports by Miller (1911a, 1911b), Cushing and Ruedemann (1914), and Ruedemann (1930), describe the general geology of the area drained by Kayaderosseras and Fish Creeks. Reports by Stoller (1916), Fairchild (1917), Chadwick (1928), and Brigham (1929), describe the Pleistocene history and glacial features of various parts of the basin. Fisher and Hanson (1951) remapped the bedrock geology of an area just east of West Milton and in so doing, revised the interpretation of the geologic age of some of the formations in the West Milton area.

A report by Maxon, Bromley, and others (1919), contains a generalized map and description of the soils of Saratoga County. A new and more detailed map of the soils of the county was in preparation in 1959.

SYSTEM OF NUMBERING WELLS, TEST HOLES, AND SPRINGS

In accordance with the numbering system used by the Geological Survey in New York State, all wells, test holes, and springs referred to in this report are numbered serially in the order in which the records were collected. The prefix "Sa" for Saratoga County is added to each number to indicate the county in which the well, test hole, or spring is located. The suffixes "T" and "Sp" are added to the numbers for test holes and springs, respectively. Water wells and test holes are distinguished from one another on the basis of the purpose for which they were constructed. Those holes constructed primarily to produce water are classified as water wells whereas those constructed to explore subsurface geologic or hydrologic conditions are classified as test holes.

The locations of wells, test holes, and springs referred to in this report are shown in figures 3, 7, 8, and 9. Records of wells, test holes, and springs are on file in the U.S. Geological Survey, Ground Water Branch office, Albany, N.Y. A table of selected well records is contained in a report by Heath and others (1963, table I-3).

GEOGRAPHY

LOCATION

The West Milton area is in Saratoga County in the east-central part of New York. (See pl. 1.) The report area consists of a government-owned reservation of 4,000 acres and the adjoining area in which studies relating to the geology and hydrology of the reservation were made. The area is centered about 17 miles north of the city of Schenectady and about 9 miles southwest of Saratoga Springs. Ballston Spa, the nearest incorporated village, is approximately 6 miles to the southeast.

714-971 O—64——2

The most conspicuous landmark in the area is a hollow steel sphere 225 feet in diameter, which is located near the center of the government reservation. The sphere is used as a reference point for locating data collection points throughout this report.

TOPOGRAPHY AND DRAINAGE

The West Milton area consists of a series of irregular, northeast-trending topographic steps, which descend in a southeasterly direction from the Kayaderosseras Range, a group of low hills that separate the Adirondack Mountains on the northwest from the Hudson Valley on the southeast. The steps are generally less than a mile wide and become progressively higher toward the Kayaderosseras Range. They appear to be controlled, at least in part, by a series of normal faults that parallel the front of the range. The surface of each step is marked by low, rounded hills elongated northeast-southwest, most of which are composed of unconsolidated deposits.

Where Glowegee Creek, Crook Brook, and other streams draining the area cross the scarps separating the different steps, their valleys are relatively narrow and steep sided. On the steps, the stream valleys are generally broad and less well defined.

Altitudes in the area range from about 400 feet above sea level along Kayaderosseras Creek to about 900 feet along the southeast flank of the Kayaderosseras Range. The steepest slopes in the area are generally found along the southeast side of the hills that border the scarps. In places, the relief is as much as 50 feet in a horizontal distance of 100 feet.

The West Milton area is drained by Glowegee Creek and Crook Brook, both of which are tributaries of Kayaderosseras Creek. Kayaderosseras Creek heads about 12 miles north of West Milton and flows in a southerly direction generally parallel to the Kayaderosseras Range. Near West Milton, it turns and flows in an easterly direction for about 10 miles and empties into Saratoga Lake. The overflow of Saratoga Lake discharges through Fish Creek into the Hudson River.

CLIMATE

The climate of the area is humid-continental and is marked by seasonal extremes of heat and cold. Prior to 1955, the nearest station of the U.S. Weather Bureau was at Greenfield Center, 7 miles northeast of West Milton. Because of the death of the observer, this station (sta. 25, pl. 1) which had been operated for 52 years, was discontinued and a station for the collection of precipitation records was established at the hamlet of West Milton (sta. 27, inset map, pl. 1). Records of precipitation, temperature, relative humidity, and wind velocity and direction also have been collected more or less continuously for the Atomic Energy Commission at station 26 at the West Milton installation since 1948.

Temperature and precipitation data for station 25 are shown in figure 1. The normal annual precipitation at this station is 40.40

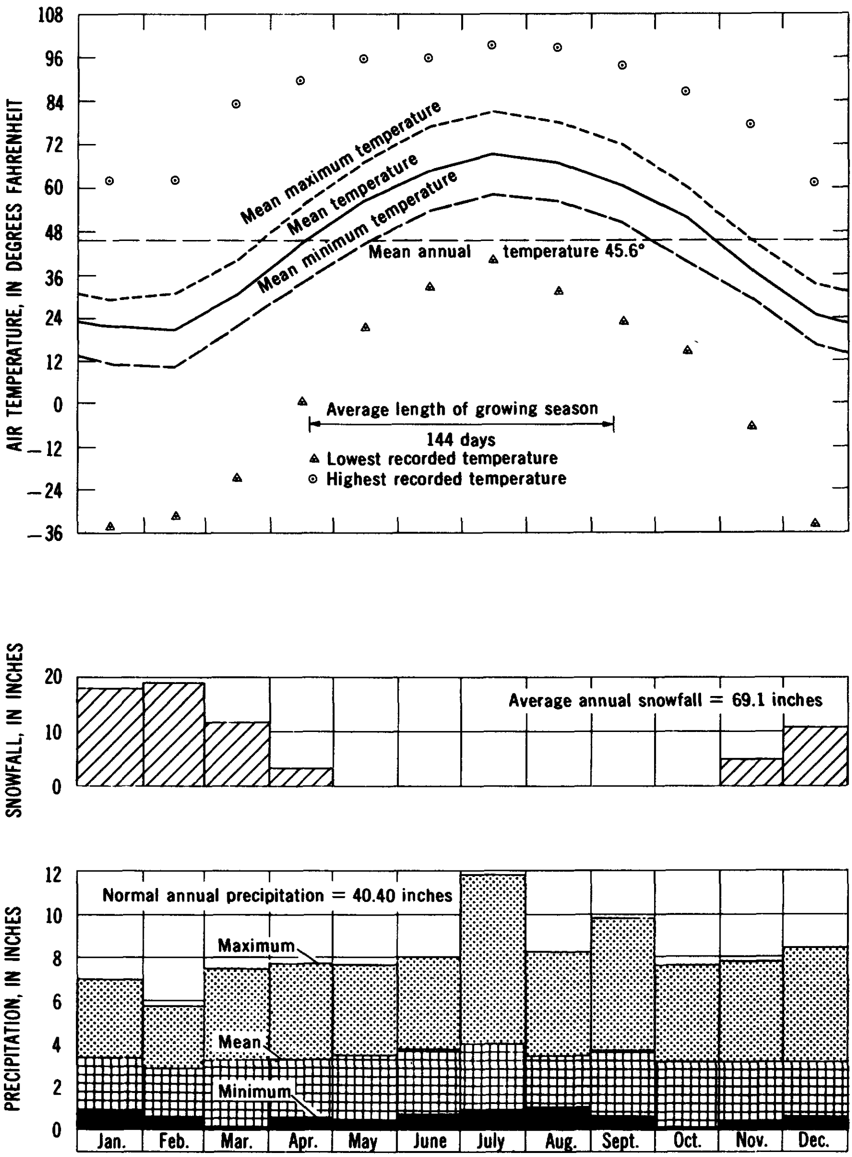

FIGURE 1.—Graphs showing monthly air temperatures and precipitation at Greenfield Center, N.Y., for the period 1898–1954 (sta. 25).

inches, and the average annual snowfall is 69.1 inches. In general, precipitation is rather evenly distributed throughout the year. The mean annual temperature for the period from 1898 through 1954 is 45.6°F and the extremes of temperature have ranged from a low of −37°F to a high of 98°F.

The depth and water content of the snow cover have been determined periodically since March 1952 during the winter months at five stations in the area. The location of two of these, stations 28 and 29, is shown on plate 1. The location of all the stations, including stations 28 and 29, is shown in figure 25.

GEOLOGY

Ground water occurs in all the rock formations in the West Milton area. With respect to ground-water occurrence these formations are placed in two major groups: (1) consolidated rocks and (2) unconsolidated deposits. The distribution of the consolidated rocks is shown in figure 2. These rocks underlie the entire area but crop out only on some steep hillsides and in some stream valleys. Everywhere else the consolidated rocks are overlain by unconsolidated deposits, which range in thickness from a few feet in the lower parts of some stream valleys to more than 200 feet in a buried valley that crosses the eastern part of the government reservation. The areal distribution of surficial deposits in an area centered around the government-owned reservation is shown in figure 4.

CONSOLIDATED ROCKS

The consolidated rocks underlying the West Milton area may be divided into two groups: (1) metamorphosed rocks of Precambrian age, and (2) unmetamorphosed rocks of Paleozoic age. The metamorphosed rocks of Precambrian age are made up of gneiss, schist, quartzite, and limestone of sedimentary origin, and syenite and granite of igneous origin (Cushing and Ruedemann, 1914, p. 16 and 17). The Paleozoic rocks consist of several sedimentary types including sandstone, dolomite, limestone, and shale. The areal distribution of the formations comprising the consolidated rocks is shown in figure 2.

ROCK UNITS

CRYSTALLINE ROCKS UNDIFFERENTIATED

The oldest rocks known to underlie the West Milton area consist of gneiss and granite of Precambrian age. These rocks are a part of the complex mass of crystalline rocks that comprise the Adirondacks. Although they crop out at the surface only in two small tracts along the west side of the West Galway fault (fig. 2) in the northwestern part of the area, they doubtless underlie the entire area at depths

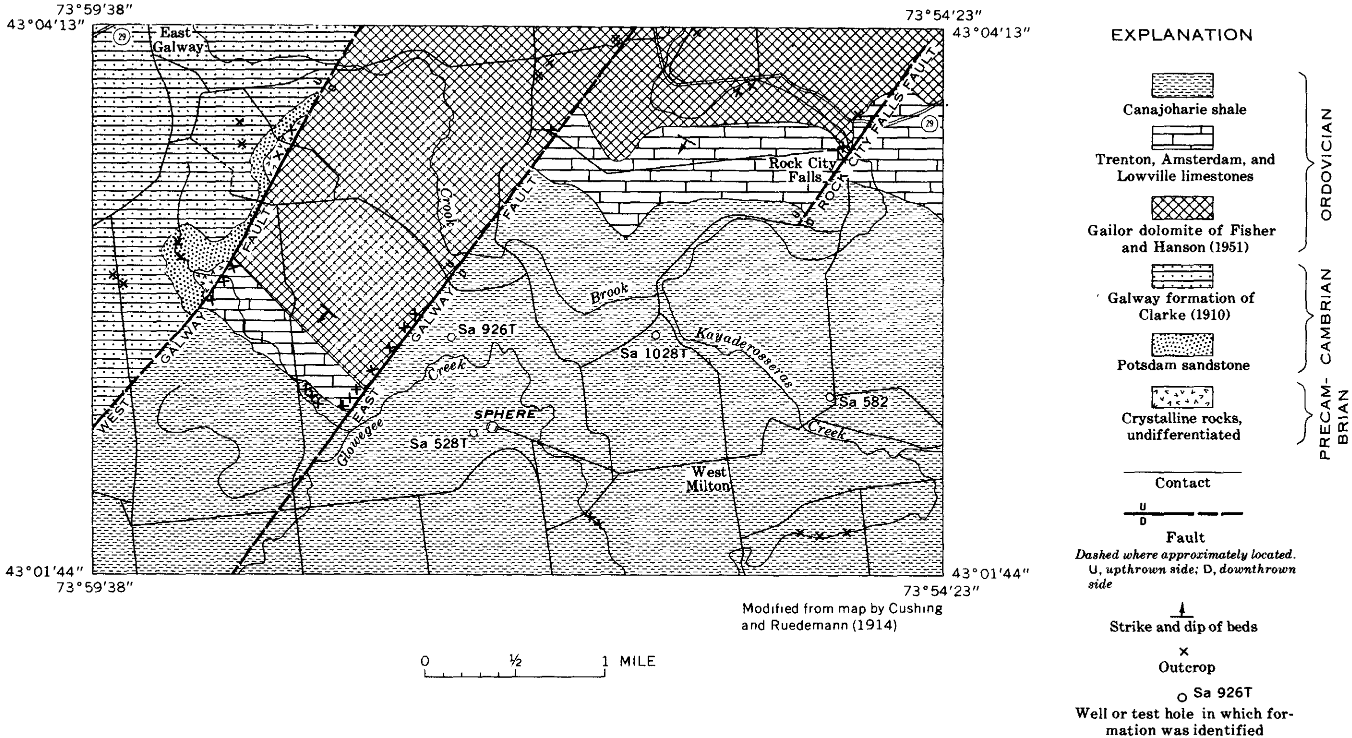

Figure 2.—Map of the West Milton area showing the areal distribution of bedrock formations.

ranging from less than 100 feet in the northwest part of figure 2 to more than 1,000 feet in the southeast.

The southernmost outcrop of Precambrian rocks shown in figure 2 underlies a part of a small stream valley. The rock here is a gneiss consisting of alternating layers of biotite and quartz. It apparently was a sedimentary rock which was intruded by granite prior to deposition of the overlying Paleozoic rocks. This rock was mapped by Cushing and Ruedemann (1914) as Grenville schist.

The other known outcrop of Precambrian rocks, located 0.5 mile to the northeast, consists of a fine-grained gray granite in which the light and dark minerals show incipient banding. The light minerals consist of quartz and a small percent of feldspar. The dark minerals consist of biotite and other dark silicates. The outcrop consists of a line of smoothly rounded, steep-faced knobs which form a scarp from 20 to 30 feet high and more than 0.25 mile long.

POTSDAM SANDSTONE

The Precambrian rocks are unconformably overlain in the West Milton area by the Potsdam sandstone. The Potsdam is composed of coarse well-rounded quartz grains which have been cemented into a tough, compact gray to buff sandstone. In the lower part of the formation, layers as much as several feet thick containing quartz pebbles are interbedded with the sandstone layers. Although they have not been observed in the West Milton area, thin beds of calcareous sandstone and sandy dolomite are reported (Cushing and Ruedemann, 1914, p. 35) to be present in the upper part of the formation. The surface on which the Potsdam was deposited was apparently somewhat irregular and as a result, the thickness of the formation varies from place to place. In general, however, it is believed to be from 50 to 100 feet thick throughout the West Milton area.

As shown in figure 2, the Potsdam outcrops in the West Milton area in a relatively narrow band to the west of the Precambrian rocks.

GALWAY FORMATION OF CLARKE (1910)

The Potsdam sandstone grades upward without definite break into alternating sandy dolomites, dolomites, sandstones, and calcareous sandstones of Clarke's Galway formation. In parts of the Saratoga Springs area the Galway grades upward into sandy, dolomitic limestones which are referred to as the Hoyt limestone (Fisher and Hanson, 1951, p. 802). Thus, sediments of the Galway formation were laid down during a period of fluctuating depositional conditions. The Galway is exposed only in the northwest corner of the area, west of the West Galway fault (fig. 2). Although the entire thickness of the formation is not exposed, it is estimated to be about 120 feet thick.

The name Galway formation was first applied by Clarke (1910, p. 12) to these rocks in the vicinity of the hamlet of Galway, 3 miles west of West Milton. Subsequently, they were renamed Theresa formation by Cushing and Ruedemann (1914, p. 35). Because the Theresa formation contains beds of both Cambrian and Ordovician age at the type locality near Theresa, N.Y., Fisher and Hanson (1951, p. 802) reapplied the name Galway to this formation in the West Milton area.

Where the entire sequence of Cambrian formations is preserved, as in parts of the Saratoga Springs area, the Hoyt limestone member of the Theresa dolomite conformably overlies the Galway formation. However, in the West Milton area, the Hoyt was probably removed during a period of erosion that followed its deposition. As a result, the Galway formation is unconformably overlain throughout the area by the Gailor dolomite.

GAILOR DOLOMITE OF FISHER AND HANSON (1951)

The Gailor is composed mostly of dark-gray fine-grained dolomite, but part of the formation is light gray and coarsely crystalline. Black to dark-gray chert nodules are found in the upper part of the Gailor and vugs lined with dolomite, calcite, or quartz crystals are common. The dolomite crystals in much of the coarse phase are cemented with calcite. In parts of the formation the calcite has been removed by ground water, leaving projecting dolomite crystals which give the formation a sandy porous appearance. As shown in figure 2, the Gailor dolomite underlies a relatively large tract in the north-central part of the area. A 40-foot section of the formation is exposed approximately 0.5 mile northwest of the sphere where a small tributary of Glowegee Creek crosses the East Galway fault. The maximum thickness of the formation in the area is probably not more than 150 feet.

The name Gailor dolomite was first proposed by Fisher and Hanson (1951) who found stratigraphic and paleontologic evidence to indicate that the formation was of Early Ordovician age. Prior to that time, the formation had been considered to be of Late Cambrian age and was mapped as the Little Falls dolomite (Cushing and Ruedemann, 1914, p. 42).

LOWVILLE, AMSTERDAM, AND TRENTON LIMESTONES

Fisher and Hanson's Gailor dolomite is overlain by a section of limestone approximately 55 feet thick which Fisher and Hanson (1951, p. 808–809) reported to contain beds of the Lowville, Amsterdam, and Trenton limestones. The lowermost of these, the Lowville, is only 1 foot thick at Rock City Falls. The Lowville is overlain by a 3-foot section of the Amsterdam limestone. The remainder of the section, approximately 50 feet thick, is composed of Trenton limestone.

Because the total thickness of the Lowville and Amsterdam limestones is only about 4 feet, they have been included with the Trenton limestone in figure 2 and in table 4. As shown in figure 2, these limestones form three relatively narrow belts which have been offset by the movements along the West Galway, East Galway, and Rock City Falls faults.

Lithologically, all three of these limestone formations are similar; the greatest differences being between the Lowville and the overlying limestones. The Lowville is a light-blue fine-grained limestone whereas the Amsterdam and Trenton are both bluish black in color. The Amsterdam is generally thick bedded and coarse grained. The Trenton, on the other hand, is thin bedded, fine grained, and much more fossiliferous than the Amsterdam and Lowville.

CANAJOHARIE SHALE

More than half of the area shown in figure 2 is underlain by the black carbonaceous calcareous shales of the Canajoharie formation. Except for a few massive layers that appear to be irregularly interspersed throughout some parts of the formation, the Canajoharie is notably fissile and splintery. The formation contains some pyrite, which causes staining of the rock and which probably is the source, at least in part, of the hydrogen sulfide contained in water from the formation. The maximum thickness of the formation in the area is not known. However, test well Sa 528T, which was drilled a few hundred feet southwest of the sphere, penetrated approximately 500 feet of the formation.

The formation is exposed about 1 mile west of the sphere in the bed and banks of a small tributary of Glowegee Creek. It is also exposed at two places in the bed of the creek; one about 0.75 mile southeast of the sphere at the site of an abandoned bridge (sta. 11, inset map, pl. 1) and the other about 2 miles east of the sphere (fig. 2).

STRUCTURE

The West Milton area is located in a region of major faulting which extends from south of the Mohawk River northeastward along the southeast border of the Adirondack Mountains. All the major faults in this region are of the normal type and have displacements ranging from about 100 feet to more than 1,500 feet. The area west of each fault always moved upward relative to the area east of the fault. Generally these faults strike northeast and have steep angles of dip. The age of the faults is not precisely known, but they were probably formed during development of the Appalachian Mountains about 200 million years ago.

The two most prominent faults in the West Milton area, the East Galway and West Galway faults, are branches of the Hoffman's Ferry fault. This fault has been traced for 40 miles through the region from Hoffman's Ferry, on the Mohawk River, to Fort Ann, north of the Hudson River. Movements and subsequent erosion along the East Galway, West Galway, and the Rock City Falls fault have resulted in the distinctive outcrop pattern shown in figure 2. An indication of the magnitude of the displacements that have occurred along some of these faults may be obtained from observations along the West Galway fault. For example, southeast of East Galway, granite and gneiss of Precambrian age overlain by horizontally stratified rocks of Paleozoic age occur along the west side of the West Galway fault at the same altitude as Trenton limestone, a few hundred feet east of the fault (fig. 2). As the Trenton is normally at least 300 feet stratigraphically higher than the granite and gneiss, the vertical displacement along the fault at this point is at least 300 feet. Displacement along the East Galway fault is of similar magnitude but along the Rock City Falls fault it is relatively small.

Because of the relatively large displacements that have occurred along the West Galway and East Galway faults, their positions may be determined readily by geologic mapping. However, observations made in the excavation for the foundation of the sphere at the reactor site revealed numerous small-scale displacements along faults that cannot be detected by surface mapping. The sphere excavation covered several hundred square feet and penetrated 15 to 20 feet into the Canajoharie shale. Detailed study of the shale exposed in the excavation revealed the presence of slickensides along some of the bedding and cleavage planes. Although it was not possible to determine the extent of the displacement along most of these planes, a joint crossing one of the bedding planes showed a horizontal displacement of 2.5 feet.

BEDROCK TOPOGRAPHY

Previous work on the topography of the bedrock surface in the West Milton area was done by Cushing and Ruedemann (1914, p. 12, 13, and accompanying geol. map) during their investigation of the geology of the Saratoga and Schuylerville quadrangles. On the basis of topographic evidence and data from bedrock outcrops, they concluded that the northern part of Kayaderosseras Creek follows the valley of a preglacial stream which drained a much larger part of the southeastern Adirondack Mountain area than Kayaderosseras Creek now drains. Because this valley in the West Milton area is filled with unconsolidated materials deposited during the Pleistocene epoch, Cushing and Ruedemann were unable to determine its exact location. However, they indicated on their geologic map that the valley curves to a southerly direction about 2 miles northeast of Middle Grove and passes about 1 mile east of West Milton.

The present investigation of the bedrock topography of the area utilized data obtained from (1) bedrock mapping, (2) wells and test holes, and (3) seismic studies. These data are summarized on plate 2 and in figure 3, which show the altitude of the top of bedrock in the West Milton-Rock City Falls area. As may be seen from these illustrations, the configuration of the bedrock surface in the area is very irregular—probably more irregular than the land surface. Owing to the lack of detailed data, the contours on the bedrock surface on plate 2 are generalized and therefore probably do not reflect many of the minor irregularities in the bedrock surface. This is substantiated by figure 3, which shows that the top of the bedrock in the vicinity of the sphere is actually considerably more irregular than would be suggested by the contours on plate 2. Total relief of the bedrock surface is at least 450 feet and may be as much as 550 feet. A comparison of the contours on the land surface with those on the top of the bedrock shows that it is impossible, on the basis of the land-surface topography alone, to predict the depth of the underlying bedrock surface.

Plate 2 shows that the bedrock surface in the northwestern part of the West Milton-Rock City Falls area declines relatively steeply along a northeast-southwest trending scarp from an altitude of about 650 feet to an altitude of about 450 feet. A comparison of the geologic map, figure 2, with plate 2 shows that this scarp coincides with the East Galway fault. Southeast of the scarp, the principal irregularities appear to be preglacial valleys.

Section *B–B′* of plate 2 shows that one of these valleys crosses Armer Road in a north-south direction about 1 mile south of Hatch bridge. The data available on the extent of this valley and on the configuration of the bedrock surface in the eastern part of the area are not sufficient to show whether this valley is a continuation of the preglacial valley followed by Kayaderosseras Creek north of Middle Grove or merely a tributary to it. It is doubtful on the basis of its relatively narrow width that this valley was cut by a large stream such as would be required to drain the southeastern part of the Adirondack Mountains. Therefore, this valley probably was cut by a tributary of the preglacial stream described by Cushing and Ruedemann (1914, p. 13).

Plate 2 shows that the valley described above is joined about 1 mile northwest of the hamlet of West Milton by a small tributary valley which extends in an east-west direction a few hundred feet north

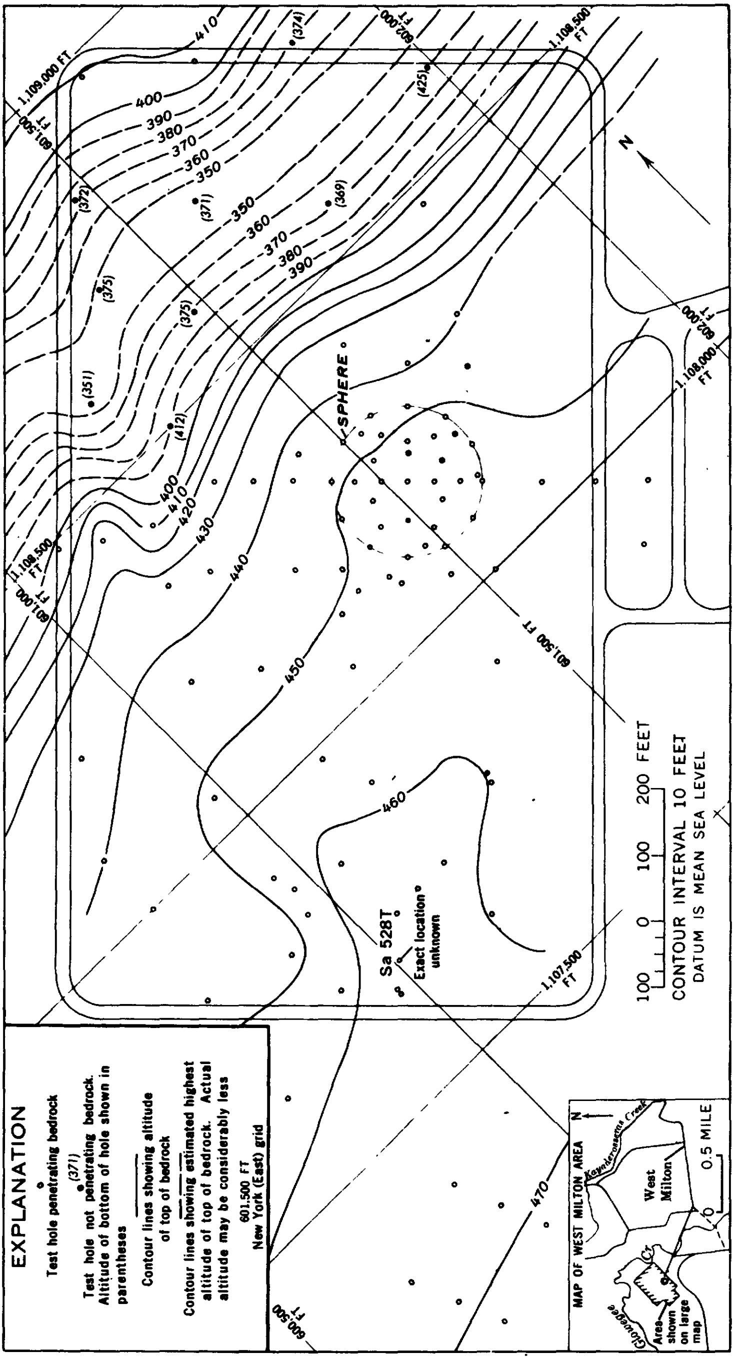

FIGURE 3.—Map of the West Milton reactor site showing the altitude of the top of bedrock.

of the sphere. This valley, where crossed by section *A–A′* of plate 2, is relatively narrow and is entrenched to a depth of about 100 feet in bedrock. Figure 3, which is based on drill-hole data, shows that the axis of this valley is located approximately 500 feet north of the sphere and that the surface of bedrock at the sphere slopes downward to the north toward the axis of the valley. The western extent of this valley has not been determined.

UNCONSOLIDATED DEPOSITS

The consolidated rocks in the West Milton area are overlain by several types of unconsolidated deposits. These deposits range in thickness from zero, in places where bedrock crops out, to more than 200 feet beneath the hills west of Kayaderosseras Creek. The average thickness of the deposits in the area is 50 feet or more. The unconsolidated deposits can be subdivided into: (1) till—an unstratified mixture of glacially deposited rock particles ranging in size from clay to boulders; (2) kames—irregularly stratified glacial deposits consisting of alternating layers of sand and gravel; (3) flood-plain deposits—generally horizontal, imperfectly stratified layers of stream-deposited clay, silt, and fine sand; (4) lake-bottom deposits—horizontally stratified layers of clay, silt, and fine sand; and (5) deltaic deposits—relatively homogeneous deposits of fine to coarse sand.

Figure 4 is a map of a part of the West Milton area showing the areal extent of the different types of unconsolidated deposits that underlie the present surface. The figure also contains two generalized sections showing the relative position and the thickness of each of the deposits. As may be observed from the sections, the deposits were laid down in a more or less regular sequence. The lowermost, and also the oldest, consists predominantly of a relatively thick section of fine-grained (lake-bottom) sediments which overlie bedrock in the buried valley near the sphere and in the valley of Kayaderosseras Creek. Between layers of these fine-grained deposits in the valley is a mass of sediments composed of medium to coarse sand containing some gravel. These coarser sediments appear to have formed a delta in the same lake in which the finer grained lake-bottom deposits were accumulating. In the valley of Kayaderosseras Creek, the lake-bottom deposits are overlain by approximately 25 feet of coarse-grained flood-plain deposits. West of the creek valley, the lake-bottom deposits are overlain by till. The till is in turn overlain either by a second series of lake-bottom deposits and deltas or by kames.

TILL

Till consists of rock debris deposited directly by ice sheets, either during their advance or at the time of melting. Thus, it is mainly

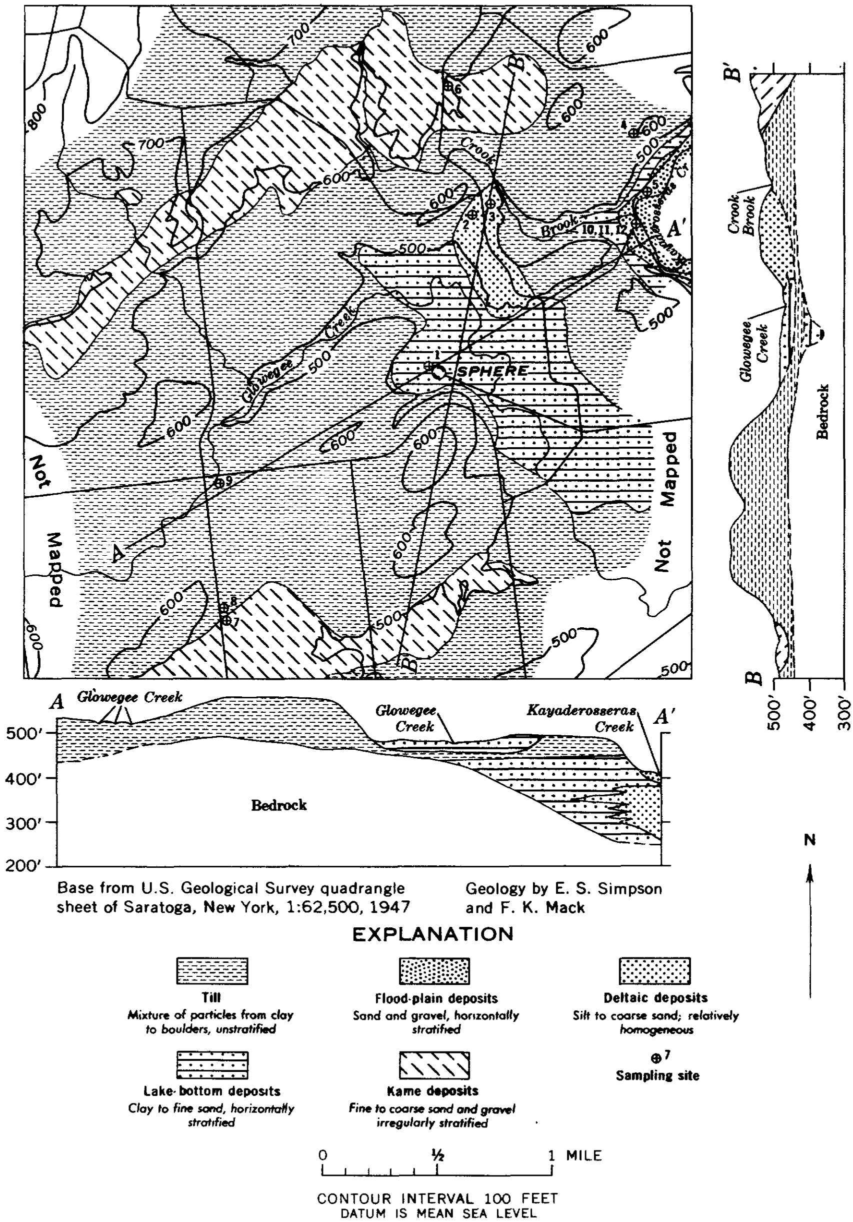

FIGURE 4.—Geologic map and sections showing the areal distribution of surficial deposits of Pleistocene age in the western part of the West Milton area.

unsorted material with a wide range in the size of its constituent particles. The composition of the till is related to that of the rocks cropping out in the area over which the ice sheet passed. In the West Milton area, the till is noticeably clay poor as shown in particle-size analyses of samples 1d, 1f, 4, 8, and 9 in table 2. This fact complicated field mapping for the present investigation because it was difficult to determine from surface exposures alone, whether material exposed was till or a coarse stratified deposit. Till probably extends beneath many of the stratified deposits shown in figure 4 and therefore has a much greater subsurface extent than that indicated by the map of surficial deposits. In fact, in the absence of information to the contrary, it may be presumed that till underlies the entire area. Its presence beneath lake-bottom deposits is indicated in sections *A′–A′* and *B–B′* of figure 4.

Drumlins, oval hills consisting mostly of till deposited under moving ice, are prominent features in the area. They range from 0.5 to 0.8 mile in length and are generally between 100 and 150 feet high. The direction of their long axes is northeast-southwest. Test hole Sa 888T penetrated 150 feet of till in the drumlin south of the sphere before entering bedrock.

The till deposits in areas between drumlins generally range in thickness from a few feet to as much as 40 feet. As shown in geologic section *B–B′* of figure 5, which is based on test drilling and exposures made while excavating for a water main, 40 feet of till overlies as much as 190 feet of stratified deposits west of Kayaderosseras Creek. At the sphere, till rests on bedrock and underlies beds of silt and fine sand (fig. 6). Samples 1d and 1f (table 2) were collected from the till near the base of the sphere excavation.

LAKE-BOTTOM SEDIMENTS

Lake-bottom sediments consist of well-sorted fine sand, silt, and clay deposited in the quiet waters of lakes which presumably were impounded behind dams of ice or glacial drift. Particle-size analyses of samples 1a, 1b, 1c, and 1e (table 2), which were collected from various layers of the lake-bottom sediments penetrated in the excavation for the sphere, show the grain size and degree of sorting of these sediments.

Two extensive deposits of lake-bottom sediments occur in the West Milton area (sections on fig. 4). The oldest of these deposits was formed in a lake which appears to have covered most of the area below an altitude of 440 feet. Sediments deposited in this lake now underlie at least 2 or 3 square miles adjacent to the valley of Kayaderosseras Creek. However, except for a few small outcrops, these deposits are covered by till and other younger deposits and are,

Table 2.—*Results of particle-size analyses of unconsolidated deposits in the West Milton area* [1]

[Samples collected and analyzed by U.S. Geol. Survey. Trace, less than 1 percent]

Sample	Percent finer than (millimeters)—												Type of deposit	Depth of sampling point below land surface (feet)	Remarks
	4.00	2.00	1.00	0.50	0.25	0.125	0.062	0.031	0.016	0.008	0.004	0.002			
															Sphere excavation—
1a						100	89					2	Lake bottom	8	Southeast side.
1b		100	99	98	97	87	84					Trace	do	9	Northwest side.
1c		89	70	51	38	21	13					Trace	do	9	Northwest side.
1d		87	81	71	42	35	20					2	Till	16	Northwest side, blue.
1e		98	95	93	92	75	72					1	Lake bottom	5	Southeast side.
1f		97	91	82	68	50	35					Trace	Till	3	West side, blue.
2		98	92	75	41	10	3					Trace	Deltaic	5	Faint horizontal bedding.
3		100	99	96	88	49	24					Trace	do	3	
4		97	93	86	36	13	4					Trace	Till (drumlin)	2	Brown color.
5			100	95	74	27	9					Trace	Recent alluvium(?).		Bank of Kayaderosseras Creek.
6			100	97	43	8	2					Trace	Kame	4	Faint horizontal bedding.
7	99	99	99	96	69	24	8					Trace	do	4	Yellow color.
8	98	98	97	95	91	82	56	45	33	25	16	11	Till	4	Stiff, yellow to brown.
9	96	93	91	84	63	39	25	19	15	12	9	6	do	8	Hard, brown.
	Gravel		Sand					Silt				Clay			

[1] See figure 4 for location of sampling sites.

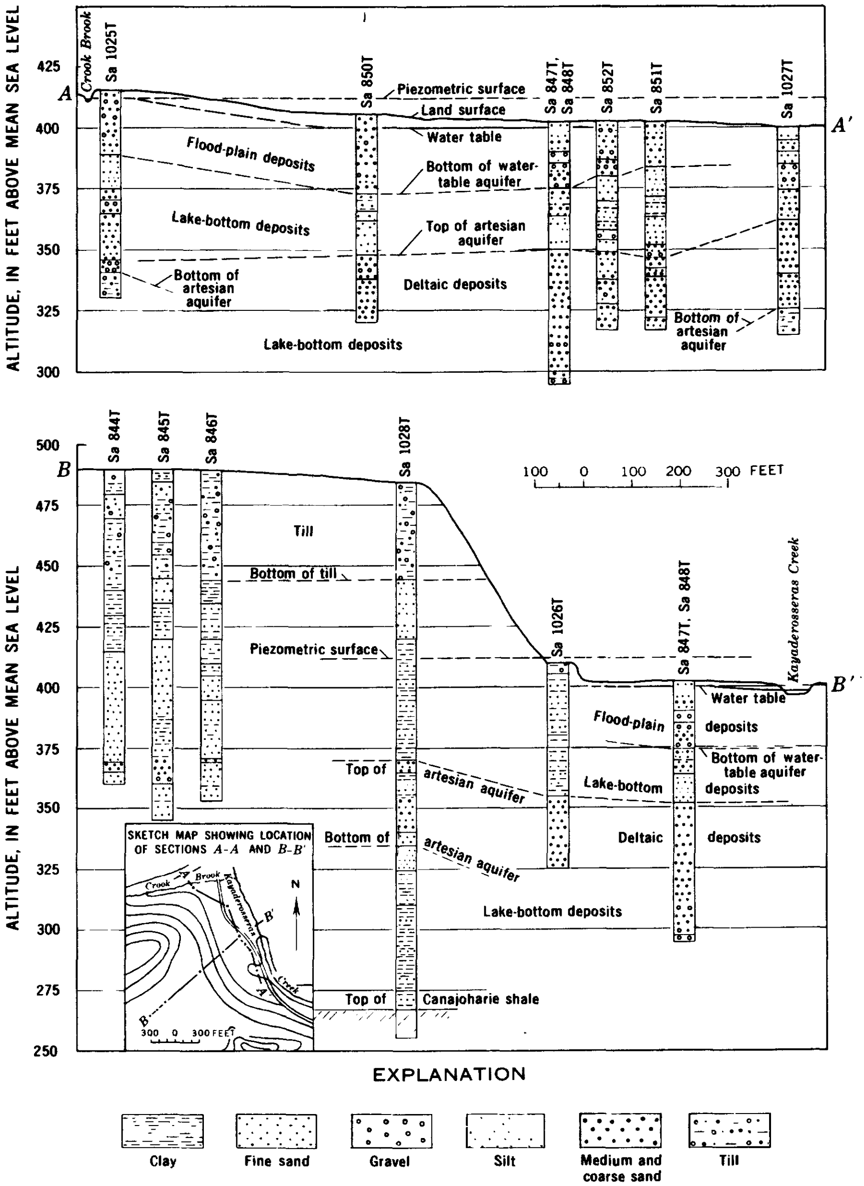

FIGURE 5.—Geologic sections showing the materials penetrated by test wells in the vicinity of Kayaderosseras Creek.

therefore, not shown on the map of surficial deposits (fig. 4). Test well Sa 1028T, 0.8 mile north of West Milton; well Sa 853, at West Milton; and well Sa 582, 0.6 mile northeast of West Milton, penetrate more than 100 feet of these fine-grained sediments. Beds of clay and silt believed to be a part of the same lake-bottom deposit also crop out along Glowegee Creek southeast of the hamlet of West Milton.

The second, and youngest, deposit of lake-bottom sediments is confined to the valley of Glowegee Creek in the vicinity of the sphere. The extent of these deposits, as revealed by well data and other observations, is shown in figure 4. Figure 6 is a photograph of lake-bottom sediments at the sphere and also underlying till and bedrock. This deposit consists of horizontally bedded layers of sand and silt ranging from less than an inch to several inches in thickness. These layers are not varves because they do not show internal gradation of grain size from coarse at the bottom to fine at the top. Instead, the grain-size distribution of each layer is fairly constant. This suggests that each layer resulted from a single flood inflow, perhaps an annual spring flood. The lake in which the lower layers of this deposit were laid down probably had a surface altitude of about 470 feet and was formed behind a dam of glacial ice. The lake in which the upper layers of the deposit were laid down probably had a surface altitude of 550 feet and was formed behind a dam of glacial debris having a spillway located in the broad flat area between Glowegee Creek and the hamlet of West Milton. Eventually the dam of glacial debris

FIGURE 6.—View of east side of sphere excavation showing bedrock, till, and lake-bottom sediments. Photograph furnished by General Electric Co., Knolls Atomic Power Laboratory.

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was breached and Glowegee Creek eroded a channel down into shale bedrock at the presumed site of the dam. Some of the lake deposits were removed by the creek and replaced in part by the Recent flood-plain alluvium that presently borders the creek.

During the first stages of exploration for a water supply for the reactor installation, it was thought that an adequate supply could be developed near the site if an extensive deposit of coarse gravel were found adjacent to Glowegee Creek. The many test holes drilled in the area for water supply and foundation exploration failed to penetrate water-bearing deposits sufficiently coarse textured and permeable to furnish the required amount of water. The geologic sections *A–A′* and *B–B′* of figure 7, which were prepared from logs of 30 of these test holes, show the generally fine grained or poorly sorted nature of the deposits.

KAME DEPOSITS

Kame deposits consist of irregularly stratified silt, sand, and gravel deposited by melt-water streams in temporary channels formed along ice crevasses or between ice and land newly exposed during wasting of the ice sheet. Kame deposits contain numerous irregular crossbedded, interlayered beds of sharply differing grain size. Such deposits are present in two relatively large kames in the West Milton area, one about 1 mile north and the other about 1 mile south of the sphere (fig. 4). Both kames trend east-west and are a little more than 1 mile in length. Gravel used on the Government reservation is obtained from a pit near the east end of the kame south of the sphere. In both kames, coarse gravel generally tends to grade into finer grained material toward the southwest. The east end of the kame north of the sphere consists mostly of sand and may actually be a separate sand delta similar to those described in the following section, rather than part of the kame as mapped. Sample 6 (table 2) was collected near the east end of this kame. Sample 7 (table 2) was collected from the northwest side of the kame south of the sphere. A third relatively small kame is present near the northwest corner of the area (fig. 4).

DELTAIC DEPOSITS

Unconsolidated deposits that are believed to have been deposited in deltas underlie (1) a small area approximately 0.5 mile north of the sphere, and (2) a part of the valley of Kayaderosseras Creek. The first of these deposits is exposed at the surface and is shown in figure 4. The deltaic deposit in the valley of Kayaderosseras Creek is covered by about 55 feet of lake-bottom and flood-plain deposits and is shown in the section (*A–A′*) but not on the map of surficial deposits (fig. 4).

The deltaic deposit north of the sphere is flat topped and its west-facing slope is gently arcuate in plan view. The altitude of the top

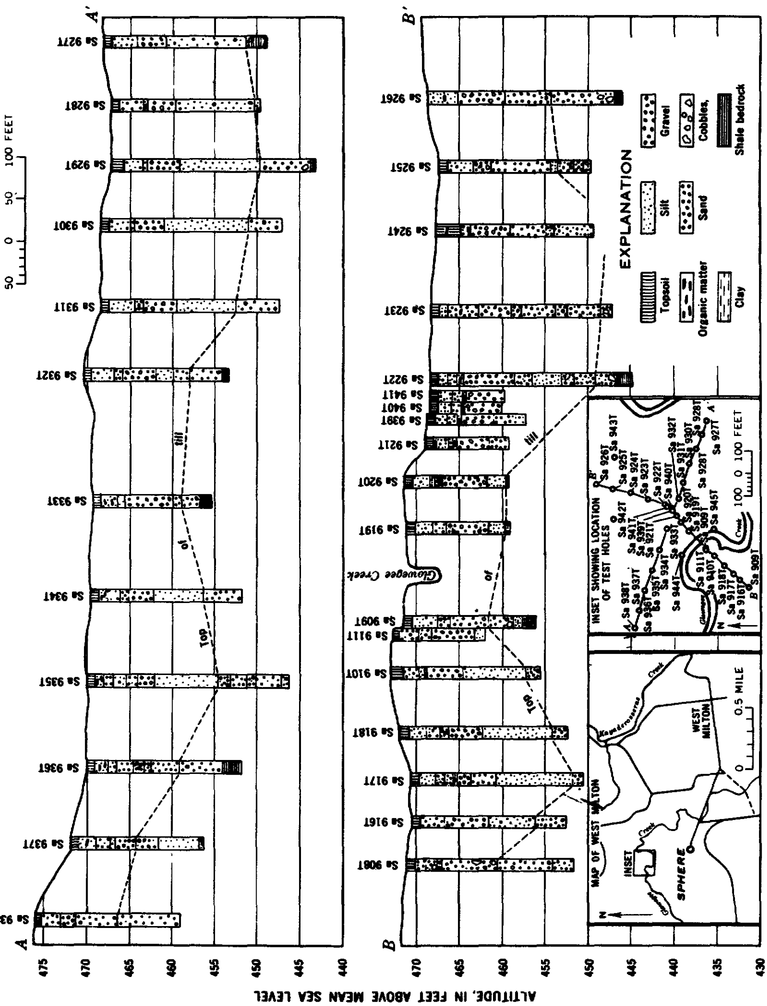

FIGURE 7.—Geologic sections showing the materials penetrated by test wells in the vicinity of Glowegee Creek.

of the deposit is about 550 feet above mean sea level, suggesting that the level of the lake in which the deposit was formed was at least 550 feet above sea level. The deposit was apparently laid down at the mouth of a stream which entered the lake from the north or northeast. The relation of this delta to the lake-bottom sediments underlying the valley of Glowegee Creek is not known. The delta may have been deposited during the initial stages of deposition of the lake-bottom sediments. In the absence of evidence to the contrary, the deltaic deposits are shown on section *B–B′* in figure 4 to be contemporaneous in age with the lake-bottom sediments.

The delta is composed of fine to coarse sand containing a small amount of silt. The particle-size analyses of samples 2 and 3 (table 2) show the range in grain size. The bedding planes in the deposit are extremely faint. This suggests that the conditions of deposition were relatively constant throughout the period in which the delta was formed.

The deltaic deposit beneath the valley of Kayaderosseras Creek is overlain by approximately 55 feet of lake-bottom and flood-plain deposits. As this deposit is not exposed at the surface, its extent and character can be determined only from test-well data. Test wells Sa 848T through Sa 852T and Sa 1025T through Sa 1028T (figs. 5 and 8) show that this deposit underlies a large part of the flood plain of Kayaderosseras Creek near its confluence with Crook Brook. However, the actual extent of the deposit cannot be determined from the data available. Section *B–B′*, figure 5, indicates that the deltaic deposit becomes thinner west of the flood plain of Kayaderosseras Creek and apparently interfingers with lacustrine silts and clays. Section *A–A′*, figure 5, indicates that the deposit also becomes thinner and finer grained toward the north. It should be noted, however, that test well Sa 1025T used in this section was drilled near the west side of the flood plain and approximately 500 feet west of the creek; therefore, a well closer to the creek possibly would penetrate a thicker section of coarse deposits.

Nothing is known regarding the lithologic character and extent of the deltaic deposits east of the creek. However, the analysis of data obtained from a pumping test in April 1956 (see section entitled "Quantitative studies") suggests that the coarse deltaic deposits may extend for a considerable distance east of the creek. The log of well Sa 1027T (section *A–A′*, fig. 5) suggests that the deposits may thin toward the south. However, they may extend for a considerable distance south of test well Sa 1027T.

The deposits comprising the delta consist of medium to coarse sand interbedded with thin layers of gravel and range in thickness from about 5 feet in well Sa 844T to about 58 feet in well Sa 847T (fig. 5).

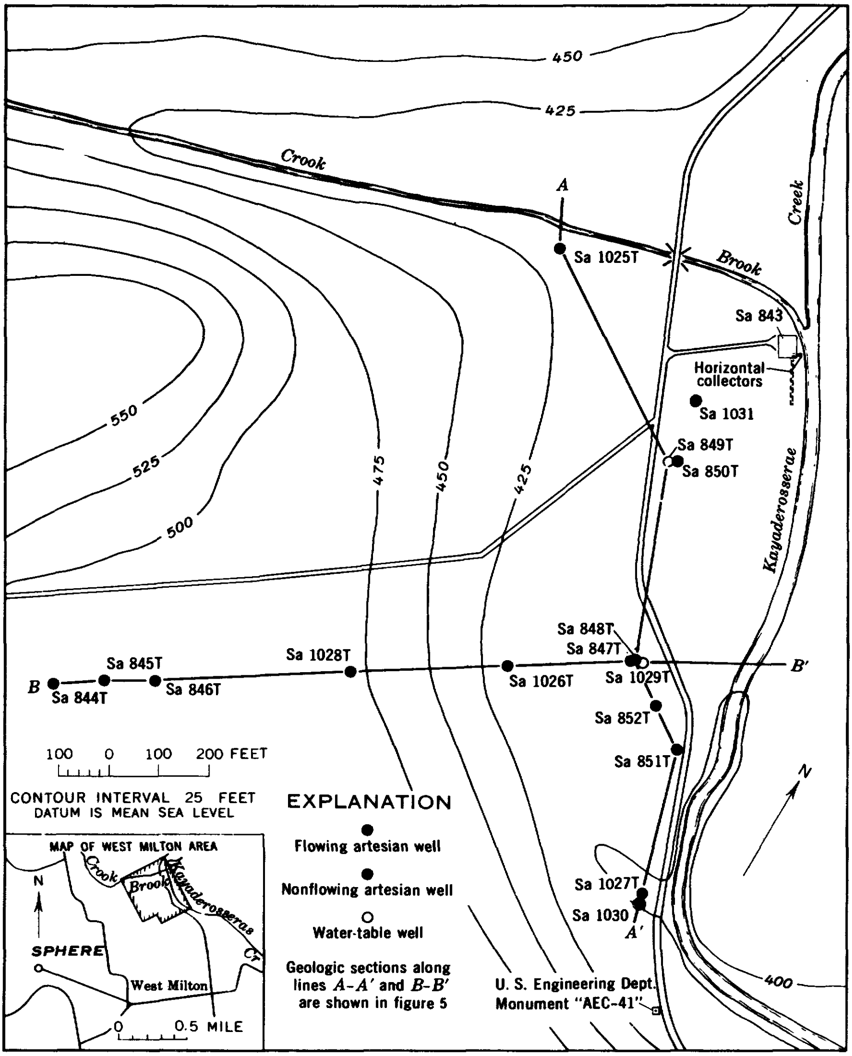

FIGURE 8.—Map showing the locations of supply and test wells in the vicinity of Kayaderosseras Creek.

Although the greatest thickness of these deposits was penetrated in well Sa 847T, it is likely that the deposits are thicker in other parts of the area, particularly toward the east.

In addition to the deltaic deposits described above, a third and much larger delta underlies large parts of the area between the village of West Milton and Ballston Spa. Because it is beyond the boundary of the government reservation, it is not shown on the map of surficial deposits (fig. 4) and will not be discussed in detail in this report. This delta has been mapped by Stoller (1916) and by Chadwick (1928, p. 903). It is composed of interbedded sands and gravels generally less than 50 feet thick. Many of the wells shown in figure 13 draw from this deposit.

FLOOD-PLAIN DEPOSITS

The valley of Kayaderosseras Creek in the area shown in figure 4 is underlain directly by a layer of coarse sand, gravel, and boulders approximately 30 feet thick. The extent of this deposit is not known but observations along the west side of the creek indicate that it is restricted to the present flood plain. As shown in sections *A–A′* and *B–B′* in figure 5, the lithologic character of these deposits is variable although there is a tendency for the lower part of the deposits to be coarser grained than the upper part. This is illustrated by particle-size analyses of samples collected during the construction of supply well Sa 843 (table 3).

TABLE 3.—*Results of particle-size analyses of flood-plain deposits at site of well Sa 843* [1]

Sample	Percent smaller than (millimeters)—										Location of sampling point		
	Gravel					Sand							
	50.8	38.1	19.0	9.53	4.76	2.00	0.420	0.250	0.149	0.074	Distance south of well sump (feet)	Depth below land surface (feet)	Side of excavation for gallery
10a	------	------	------	------	100	99	92	82	60	37	25	2	East.
10b	86	86	72	63	56	43	19	10	6	4	25	16	Do.
10c	------	100	96	90	87	84	68	48	30	18	25	2	West.
10d	100	96	78	62	52	44	21	10	6	4	25	[2] 16	Do.
11a	------	100	99	91	87	84	71	55	36	21	65	2	East.
11b	------	100	89	76	68	61	25	10	3	2	65	[2] 16	Do.
11c	------	------	------	------	------	100	95	78	50	25	65	2	West.
11d	------	100	93	80	72	63	26	9	4	2	65	[2] 16	Do.
12a	------	------	------	------	------	100	97	89	63	37	103	2	East.
12b	------	100	90	81	74	64	26	10	4	3	103	[2] 16	Do.
12c	------	------	------	------	------	100	97	95	63	38	103	2	West.
12d	------	100	92	82	74	67	27	22	5	3	103	[2] 16	Do.

[1] Sampled at various times during the construction of well Sa 843. See figure 8 for location of well. Samples taken by S. K. Johnson, construction contractor; particle-size analyses by Bureau of Soil Mechanics, N.Y. State Department of Public Works.
[2] Particles larger than 2 inches in diameter, which comprised about 25 percent of the deposit, were discarded at the time of sampling.

GROUND WATER

OCCURRENCE AND AVAILABILITY

Ground water is derived from that small part of precipitation that does not run off the surface of the land to streams nor return to the atmosphere through evaporation and transpiration. Among the factors determining the amount of water that is absorbed by the ground are the following: (1) the porosity and permeability of the surficial materials; (2) the slope of the land; (3) the amount and kind of vegetal cover; and (4) the intensity and amount of precipitation. It is obvious that rain falling at a slow, steady rate on dry, porous, flat ground results in more infiltration than rain falling at a rapid rate on moist, steep, relatively impermeable ground.

Once water reaches the zone of saturation it begins to move laterally under the influence of gravity toward points of discharge, such as wells, springs, lakes, or streams. Water thus in transit may occur under either water-table or artesian conditions. The quantity of water stored in an aquifer depends on the porosity of the aquifer. The rate at which water moves in aquifers, and the readiness with which it may be withdrawn through wells or discharged by springs is controlled by the permeability of the aquifer.

Definitions of ground-water terms used in this report are listed in the glossary.

On the basis of the types of openings in which the ground water occurs, the geologic formations in the West Milton area may be divided into two groups: (1) consolidated rocks of Precambrian and early Paleozoic age and (2) unconsolidated deposits of Pleistocene and Recent age. In the unconsolidated deposits, most of the openings consist of pore spaces between the constituent grains. In the consolidated rocks, however, the intergranular openings are extremely small and most of the ground water occurs in joints and other fractures opened after the rocks were consolidated. The permeability of both the consolidated rocks and the unconsolidated deposits varies widely. Thus, those parts of the consolidated rocks in which the joints and other fractures are relatively closely spaced have a much higher permeability than those parts in which the openings are widely spaced. Similarly, those unconsolidated deposits that are composed of well-sorted, coarse-grained material, such as sand and gravel, have a much higher permeability than fine-grained deposits or unsorted deposits such as till composed of particles ranging in size from clay to boulders. The porosity also differs markedly between the consolidated rocks and the unconsolidated deposits. Open joints and other fractures in the consolidated rocks occupy a relatively small proportion of the total volume of the rock. Thus, the porosity of these rocks is probably less than 5 percent. In the unconsolidated deposits, however, openings exist between the constituent grains and, depending on the degree of sorting, may occupy 30 percent or more of the total volume of the rock. Although their permeability is low, because of the small size of their intergranular openings, clays commonly have high porosity; as much as 50 percent or more in some places.

The thickness, character, and water-bearing properties of the formations underlying the West Milton area are summarized in table 4. Most of the information in this table and in the following discussions of the occurrence of water in the consolidated rocks and in the unconsolidated deposits is based on the records of springs and wells.

Figure 9 shows the location of nearly all privately owned wells adjacent to Kayaderosseras Creek from West Milton to the village of Ballston Spa that existed in 1952. Wells on the government-owned reservation and test holes drilled by the Atomic Energy Commission are also shown in figure 9 and in figures 3, 7, and 8. Data for all wells and test holes are on file in the office of the U.S. Geological Survey, Albany, N.Y.

OCCURRENCE IN CONSOLIDATED ROCKS

Where the consolidated rocks are not exposed at the surface, they underlie the area at depths ranging from a few feet near outcrops to more than 200 feet near the east end of the buried valley west of Kayaderosseras Creek. These rocks consist of granite, gneiss, sandstone, limestone, dolomite, and shale, all of which are dense and compact so that the movement and storage of ground water in them are controlled by joints, faults, and other openings. The spacing of these openings is irregular, ranging from a few inches to several feet. Except for solution-enlarged joints in limestones and other soluble rocks, openings along joints are generally less than 0.1 inch wide.

Where the consolidated rocks crop out or are covered by only a thin veneer of unconsolidated deposits, they contain water under water-table conditions. Water in the consolidated rocks may be under artesian conditions where the rocks are overlain by relatively impermeable deposits, such as glacial till, or where joints and other openings in the upper part of the bedrock are filled with impermeable material.

Relatively few wells in the West Milton area draw from consolidated rocks (fig. 9). No wells in the area are known to draw water from either the granite and gneiss or the Potsdam sandstone. However, records of wells drawing from these rocks in other parts of the county indicate that their yield averages only 5 to 10 gpm (gallons per minute). The relatively thick section of carbonate rocks, including the Galway formation, Gailor dolomite, and Trenton, Amsterdam, and Lowville limestones, are the most productive bedrock formations in the area. The relatively high yield of these formations, which averages about 25 gpm, is probably due principally to the enlargement of joints and other openings through solution.

The Canajoharie shale, which underlies more than 50 percent of the area, supplies water to several wells in the area. The yield of these wells ranges from less than 5 gpm to about 50 gpm and averages about 7 gpm. Several of the test holes drilled to determine foundation conditions and to locate a water supply for the Atomic Energy Commission have penetrated the Canajoharie. The deepest of these, test hole Sa 528T, passed through approximately 500 feet of the for-

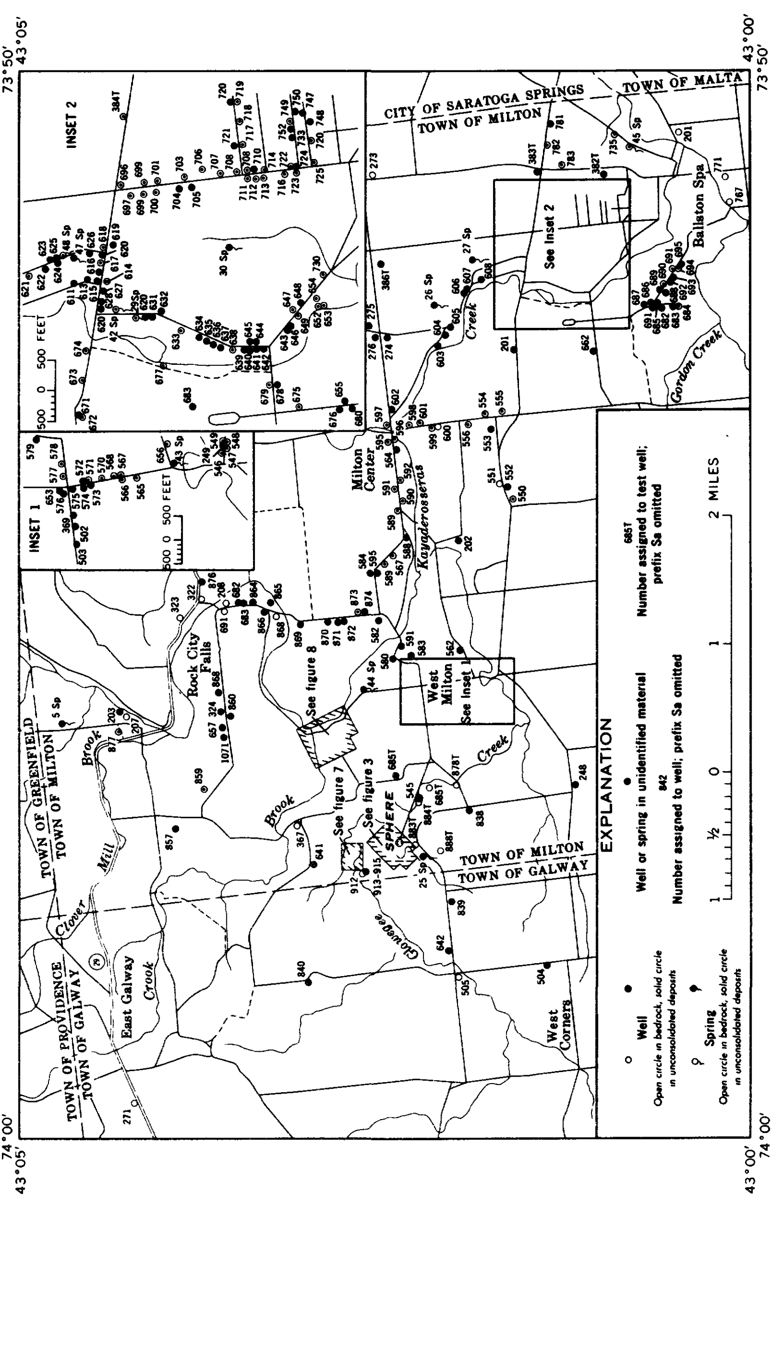

FIGURE 9.—Map of the West Milton-Ballston Spa area showing the locations of selected water wells, test holes, and springs.

TABLE 4.—*Rock formations in the West Milton area and their water-bearing properties*

Class	Age		Formation		Thickness (feet)	Character of material	Water-bearing properties
Unconsolidated rocks	Quaternary	Recent	Alluvium		0–20	Clay, silt, sand, and gravel deposited by present-day streams.	Not important as source of water because of limited extent and thickness. Restricted to discontinuous areas adjacent to streams.
		Pleistocene	Stratified deposits	Deltas, kames, and flood-plain deposits	0–80	Irregular, interbedded, and interlensing deposits of sand and gravel deposited by glacial meltwater streams.	Most productive water-bearing deposit in Saratoga County. Comprises the aquifers from which the supply of the Atomic Energy Commission installation at West Milton is obtained. Yields moderate supplies to many shallow domestic wells in sand-plain areas near Ballston Spa. In places, these deposits are capable of yielding several hundred gallons of water per minute to screened wells.
				Lake-bottom deposits	0–125	Clay, silt, and fine sand deposited in glacial lakes.	Yield little water. Generally act as confining bed where underlain by permeable deposits.
			Unstratified drift	Till	0–150	Heterogeneous mixture of boulders, gravel, sand, and clay deposited by glacial ice.	Underlies relatively large parts of the West Milton area. Will yield small supplies of water to large diameter dugwells

Consolidated rocks	Ordovician	Middle Ordovician	Canajoharie shale	500+	Soft, black, carbonaceous, more or less calcareous, splintery shale.	Most extensive bedrock formation in the area. Yield of wells averages about 7 gpm.[1] Water from some wells contains hydrogen sulfide.
			Trenton, Amsterdam, and Lowville limestones	55	Trenton—Thin-bedded fine-grained blue-black fossiliferous limestone containing thin layers of shale. Thickness about 50 ft. Amsterdam—Thick-bedded blue-black limestone. Thickness 0-3 ft. Lowville—Fine-grained gray limestone. Thickness 0-1 ft.	Underlies only a small part of the West Milton area. Not important as a source of water.
		Early Ordovician	Gailor dolomite of Fisher and Hanson (1951)	150	Massive beds of dark-gray rarely fossiliferous dolomite, largely fine grained. Contains black to dark-gray chert nodules and vugs lined with dolomite, calcite, and quartz.	Yield of wells averages about 30 gpm.[1] Supplies large quantities of water to areas north and east of city of Saratoga Springs. Yields mineral water at Saratoga Springs.
	Cambrian	Late Cambrian	Galway formation of Clarke (1910)	120	Alternating sandy dolomite, dolomitic sandstone, and calcareous sandstone. Sandstone in excess in lower part of formation and dolomite in excess in the upper part.	Yield of wells averages about 20 gpm and depth of wells averages about 45 ft.[1]
			Potsdam sandstone	50-100	Siliceous sandstone in lower half and a few beds of calcareous sandstone. Upper 50 ft. is more calcareous and contains a few beds of blue sandy dolomite.	Yield of wells averages about 10 gpm and depth of wells averages about 67 ft.[1]
	Precambrian		Crystalline rocks undifferentiated	Unknown	Highly metamorphosed sediments; gneiss, schist, quartzite, and limestone which have been intruded by syenite and granite.	Yield of wells averages about 5 gpm.[1]

[1] Information based on records of selected wells from the entire county.

mation before penetrating the underlying limestone. At a depth of 580 feet the well was test pumped for 7 hours at a rate of about 17 gpm with a drawdown of 250 feet. The well was again test pumped at a depth of 675 feet without any detectable increase in yield. Studies in other areas have shown that the yield of bedrock wells is generally not increased by drilling below a depth of a few hundred feet because the joints and other openings that transmit water are effectively closed. Thus, although the yield of test hole Sa 528T was not determined until it had reached a depth of 580 feet, it appears likely that most if not all of the water produced by the well was derived from the upper part of the formation.

OCCURRENCE IN UNCONSOLIDATED DEPOSITS

Water occurs in the unconsolidated deposits in the pore spaces between individual grains. The porosity of the different unconsolidated deposits varies widely. The till, which consists of a heterogeneous mixture of particles ranging in size from clay to boulders, probably has the lowest porosity of any of the deposits in the area. On the basis of porosity determinations made in other areas, it appears safe to assume that the porosity of the till ranges from about 15 to 25 percent. The porosity of the other deposits probably varies widely depending on the degree of sorting, and probably ranges from as little as 20 percent to 40 percent or more.

The permeability of the unconsolidated deposits, and consequently the yield of wells tapping the deposits, is largely dependent on the size of the interconnected openings. The till, lake-bottom, and flood-plain deposits contain a relatively high proportion of silt and clay. Thus, the interconnected openings in these deposits are generally small and the permeability of the deposits is low. Most wells drawing from these deposits are large-diameter dug wells which provide a large area for the infiltration of water and a large volume for storage. The kame and deltaic deposits, on the other hand, are composed of fairly well-sorted and coarse-grained materials. Both of these deposits are capable of yielding moderate to large quantities of water to properly developed screened wells.

Relatively large yields also may be obtained from the flood-plain deposits from specially constructed wells. The initial water supply of the Atomic Energy Commission installation in the West Milton area was obtained from well Sa 843. This well, which is located about 40 feet west of Kayaderosseras Creek, draws from the flood-plain deposits. The well consists of two horizontal laterals 36 inches in diameter buried about 10 feet deep. One lateral is 100 feet long and parallels the creek; the other is 20 feet long and is perpendicular to the creek. This well has been pumped at a rate of 750 gpm for extended periods of time; it is discussed in greater detail in the section entitled "Utilization."

The deltaic deposit in the valley of Kayaderosseras Creek comprises the most productive aquifer in the area. Studies of this deposit show that it is capable of yielding as much as 800 gpm to a single screened well. A relatively detailed discussion of these studies and of the water-bearing characteristics of the deposit is contained in the section entitled "Quantitative studies."

Water in the unconsolidated deposits occurs principally under water-table conditions, although in parts of the Kayaderosseras Creek valley and possibly in other areas where sand and gravel deposits are overlain by lake-bottom, till, and other relatively impermeable sediments the water is under artesian conditions. The water in the deltaic deposits in the valley of Kayaderosseras Creek is, for instance, under sufficient pressure to rise to a height of as much as 12 feet above land surface (fig. 5).

In most of the West Milton area, ground water probably moves parallel to the topographic slope. However, exceptions to this may occur in the buried valleys described in the section entitled "Bedrock topography."

EFFECT OF BURIED VALLEYS

Buried valleys almost always complicate the general pattern of occurrence and movement of ground water in an area. This is because the permeability of the materials filling them usually differs noticeably from the permeability of the surrounding bedrock. As pointed out in the section entitled "Bedrock topography," there are two relatively deep valleys in the surface of the bedrock in the West Milton-Rock City Falls area. During the Pleistocene epoch, materials ranging in thickness from a few feet to more than 200 feet were deposited in this vicinity. The two valleys were completely filled with these materials and are no longer recognizable at the land surface. Thus, the thickness of the unconsolidated deposits is greater in these valleys than in the intervening areas.

Unfortunately, even though the valleys are known to be filled with great thicknesses of unconsolidated deposits, information relating to the character of the valley-filling materials is available for only the small area near the reactor installation and for a small area including and adjacent to the Commission's well field. The material filling the east-west valley near the sphere (fig. 4) occurs in three distinct layers consisting of a layer of till lying between layers of lake-bottom deposits. The sequence of unconsolidated deposits filling the part of the north-south valley near the well field is, from bottom to top: (1) till, (2) coarse-grained deltaic deposits, (3) lake-bottom deposits, and (4) till (fig. 5). The character of the unconsolidated deposits filling the other parts of these buried valleys may differ considerably from the sections shown.

The permeability of the unconsolidated materials filling the valleys varies from less than that of bedrock to many times that of bedrock. Where they are composed principally of stratified silt and clay or of till, their permeability is probably as low as or even lower than that of bedrock. Where the permeability is lower than that of bedrock, the valleys will serve as barriers to the movement of ground water. Where it is the same as bedrock, the existence of the buried valley will have no significant effect on the movement of ground water. However, where the valleys are filled with sufficient quantities of stratified materials of silt size and larger, the permeability may be considerably greater than that of bedrock and water will tend to move into and within valley fill rather than following the path it would take if the valley did not exist; that is, approximately parallel to the slope of the land surface. This complication of the general pattern of ground-water movement raises important practical questions with regard to the flow of water in both valleys.

Because there is a small buried valley just north of the reactor installation, its effect on the movement of ground water must be considered in determining the course of liquids percolating into the ground at the installation. Undoubtedly, if the unconsolidated materials in the valley have a low permeability, liquids entering the ground will percolate downward to the water-table aquifer and then move laterally within it until they eventually reach Glowegee Creek. On the other hand, if the material filling the buried valley has a high permeability, the liquids may move into the valley and along it, eventually passing under Glowegee Creek and eastward to reach Kayaderosseras Creek at a point somewhere near or downstream from the Commission's well field.

Likewise, the effect that the north-south valley extending across Armer Road between Hatch Bridge and the Commission's well field (pl. 2) has on the ground-water hydrology of that area is not known. The fact that the ground-water level in well Sa 1071, which is located near the deepest part of the buried valley, is only 24 feet below land surface or about 515 feet above mean sea level indicates that there is a water-table divide between Hatch Bridge and the well field. This means that ground water is moving northward toward Hatch Bridge in the north end of the valley to discharge into Kayaderosseras Creek and is moving southward in the south end of the valley to discharge into Kayaderosseras Creek in the vicinity of the well field. However, the presence of a divide in the water table does not completely rule out the possibility that the buried valley contains a core of highly permeable deposits through which water may move from Kayaderosseras Creek in the vicinity of Hatch Bridge southward to the vicinity of the well field. Such movement is possible because Kayaderosseras Creek drops about 100 feet from Hatch Bridge to the well field.

WATER-LEVEL FLUCTUATIONS

Ground-water levels fluctuate almost continuously. During rains or when snow is melting, water percolating downward to the zone of saturation causes a rise in water levels. Discharge of ground water through springs, seepage into streams, evapotranspiration, and pumping of wells results in a decline in water levels. In addition to fluctuations caused by recharge and discharge, the water levels in artesian wells also fluctuate in response to changes in barometric pressure, earthquakes, and other forces which either temporarily change the volume of the aquifer or the quantity of water stored in the aquifer.

In order to determine the extent to which water levels in the West Milton area fluctuate in response to changes in the rates of recharge and discharge and to other factors, records have been collected of the depth to water in selected wells. The records for wells Sa 838–841 for the period October 1954 to November 1955 are shown graphically in figure 10. These are large-diameter dug wells

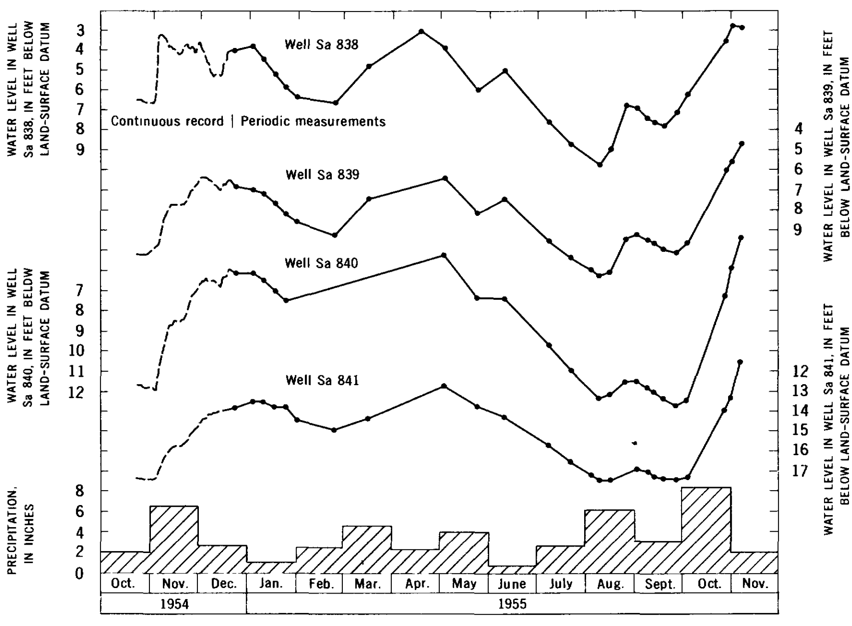

FIGURE 10.—Graphs showing seasonal fluctuations of the water level in dug wells penetrating unconsolidated deposits and monthly precipitation at station 26, West Milton, N.Y.

penetrating unconsolidated deposits which contain water under water-table conditions. Wells Sa 838, Sa 839, and Sa 841 tap till, and Sa 840 taps water in the kame deposit north of the sphere. Thus, the fluctuation of the water levels in these wells is probably indicative of the fluctuations of water levels in most of the area underlain by till and kames.

The hydrographs in figure 10 show that the relatively high precipitation in November 1954 together with the onset of cold weather, which stopped consumption of water by plants and decreased the rate of evaporation, resulted in a rise in water levels. The water levels remained relatively unchanged through December but began to decline in most of the wells early in January 1955. This decline correlates with freezing of the ground which diminished recharge to the aquifer. As the ground began to thaw late in February, permitting water to percolate downward to the zone of saturation, the water levels began to rise. This rise generally continued until early May 1955 when resumption of plant growth and increase in the rate of evaporation initiated a new decline of the water levels. This decline continued throughout the summer of 1955 until rains in August and again in October induced a marked rise of water levels in November. Fluctuations of the water table in most of the West Milton area may be expected to follow the general pattern shown in figure 10. However, departures from the pattern may occur from year to year owing to variations in precipitation and temperatures.

Fluctuations of pressure in the artesian aquifer underlying Kayaderosseras Creek are shown in the hydrographs of wells Sa 848T, Sa 1026T, and Sa 1028T given in figure 11. As may be seen in these hydrographs, the pattern of seasonal fluctuations in artesian pressures in this aquifer is similar to that of the water-table aquifer (fig. 10). Continuous records from the recording gages installed on these wells also show daily fluctuations in artesian pressure due to changes in barometric pressure. Such fluctuations are generally less than 0.1 foot.

CHEMICAL QUALITY

The unconsolidated deposits of sand and gravel, the most productive sources of ground water in the area, contain varying amounts of limestone and dolomite derived from the carbonate rocks to the north. Because of this heterogeneous admixture, chemical quality of ground water from these sources varies from place to place. Concentrations of dissolved solids ranged from 102 to 312 ppm (parts per million) and the hardness ranged from 75 to 224 ppm (table 5).

The cations consisted principally of calcium and somewhat lesser concentrations of magnesium. Concentrations of calcium in the water samples analyzed were two to four times greater than those

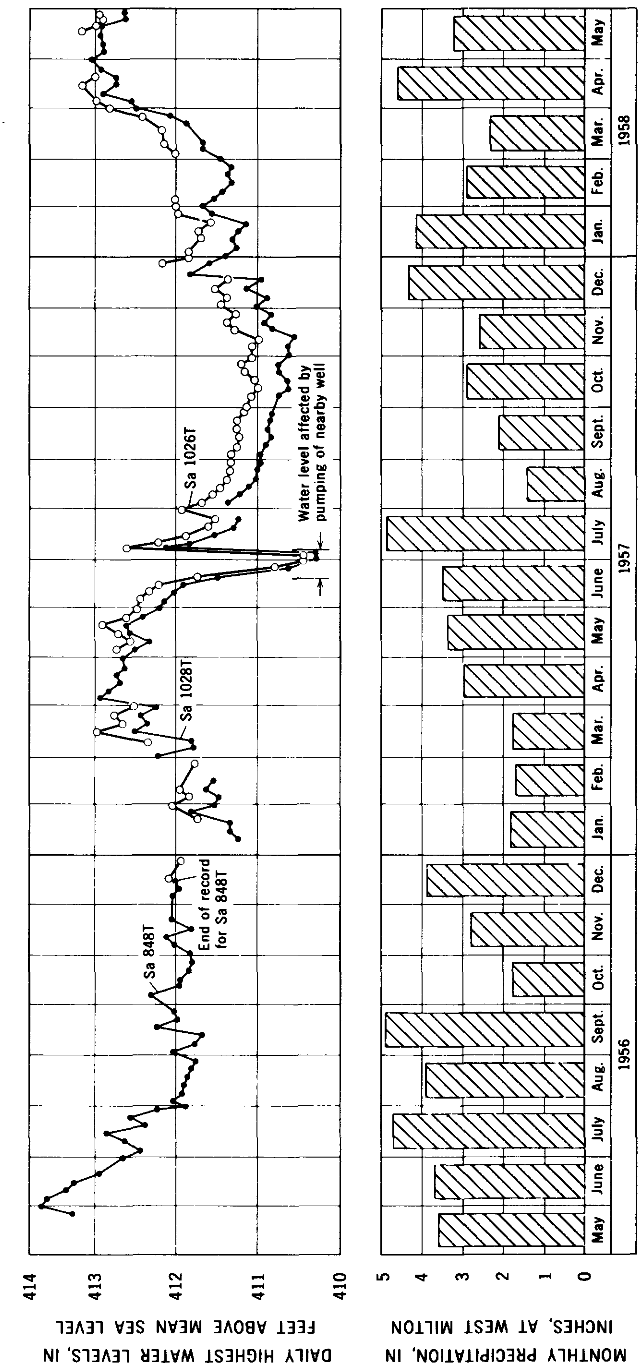

FIGURE 11.—Graphs showing fluctuations of the water level in wells penetrating the artesian aquifer in the vicinity of Kayaderosseras Creek and monthly precipitation at station 27.

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TABLE 5.—*Chemical analyses of water from unconsolidated deposits*

[All results in parts per million except specific conductance, pH, and color]

Well or spring	Water-bearing material	Depth of well (ft)	Date of collection	Water temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
Sa 545	Pleistocene sand	7	5- 1-51	------	10	0.31	0.00	42	13	2.4	0.2
546	Pleistocene deposit	12	9-24-52	------	9.9	.08	.43	76	8.4	11	8.4
566	Pleistocene sand	17	9-24-52	50	7.1	.97	.01	33	11	2.1	.7
603	do	14	9-24-52	------	11	.16	.04	36	9.0	5.4	.6
848T [1]	do	99	4-13-56	49	11	.05	.01	22	11	5.8	.8
848T [2]	do	99	4-26-56	49	11	.02	.00	22	11	5.8	.6
849T	Pleistocene sand and gravel.	26	8-30-56	47	14	.22	.00	28	11	4.1	.6
25Sp	Pleistocene till	------	5- 1-51	47	9.5	.06	.00	19	6.8	3.5	.5

Well or spring	Water-bearing material	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium and magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Sa 545	Pleistocene sand	177	19	1.0	0.1	0.3	186	158	13	306	8.1	5
546	Pleistocene deposit	245	29	14	.1	10	312	224	23	481	7.0	2
566	Pleistocene sand	129	20	4.0	.0	2.1	149	128	22	244	7.7	7
603	do	135	23	6.8	.0	.2	161	127	16	251	7.5	5
848T [1]	do	119	9.1	3.9	.1	.8	121	100	3	219	7.9	4
848T [2]	do	121	10	3.2	.1	1.1	121	100	1	218	8.2	4
849T	Pleistocene sand and gravel.	128	15	4.8	.0	.2	127	115	10	218	7.8	3
25Sp	Pleistocene till	80	12	3.0	.1	1.0	102	75	10	167	7.9	5

[1] Collected 10 days before start of first pumping test. See section entitled "Quantitative studies."
[2] Collected 1 hour before end of first pumping test.

of magnesium; except in the water of well Sa 546 in which the concentration of calcium was 76 ppm and that of magnesium 8.4 ppm. Quantitatively, other cations contributed very little to the dissolved solids. Iron and manganese concentrations, however, in water samples from wells Sa 545, Sa 546, and Sa 566 (0.31, 0.51, and 0.98 ppm respectively) were sufficient to cause staining and deposition in distribution systems.

Of the anions, concentrations of bicarbonate were predominant in all supplies examined, although substantial concentrations of sulfate were present also. The other anions—chloride, nitrate and fluoride—did not contribute significantly to the dissolved solids except in well Sa 546.

The hardness of waters from sand and gravel ranged from moderate to very hard (100 to 224 ppm), varying in the main with the concentrations of calcium and to a lesser extent with those of magnesium. Calcium and magnesium equivalent to the bicarbonate produce carbonate hardness, characterized by the deposition of a soft scale. Some noncarbonate hardness was also present because of the combination of calcium or magnesium with sulfate and chloride. This type of hardness produces a hard scale.

Ground water from till generally is softer and contains less dissolved solids than water from sand and gravel. In a water sample collected from till the concentration of dissolved solids was 102 ppm and the hardness was 75 ppm (table 5). The chemical composition was principally calcium and bicarbonate with lesser concentrations of other solutes normally found in water.

No data are available on the chemical quality of ground water from bedrock in the area.

On the basis of mineral content, water from the unconsolidated deposits generally is satisfactory for many uses. In places where ground water is more mineralized and harder, its chemical quality could be improved for most uses by softening. Iron and manganese concentrations in some of the ground waters may be troublesome and should be reduced.

RADIOCHEMICAL QUALITY

Radiochemical analyses were also made of water samples collected in 1951 and 1952 from four wells and one spring. The analyses consisted of determination of radium and beta-gamma activity. In all sources examined, no significant concentration of beta-gamma or radium was present (table 6).

QUANTITATIVE STUDIES

The expansion of the Atomic Energy Commission installation at West Milton during 1958 created a need for an additional supply of water of 3 mgd (million gallons per day). As the source of supply in 1955, well Sa 843, could not supply the demand, studies were undertaken by the Commission to locate a new supply. The most important

TABLE 6.—*Radiochemical analyses, in micromicrocuries, of ground water in the West Milton area*

[Analyses made by Trace Elements Laboratory, U.S. Geol. Survey]

Well or spring	Date water sample collected	Beta (μμc per liter) [1]	Radium (μμc per liter) [1]
Sa 25Sp	5- 1-51	<50	<1
545	5- 1-51	<100	<1
546	9-24-52	<200	------------
566	9-24-52	<100	------------
603	9-24-52	<100	------------

[1] Numerical expressions of "less than" vary with volume sample analyzed converted to a liter basis and instrument detection level. Includes all beta activity and about 2 percent gamma activity.

phases of these studies consisted of the construction of test wells and two pumping tests.

LOCATION AND CONSTRUCTION OF TEST WELLS

The test wells in the area were drilled as a part of two separate contracts. The wells provided for in the first contract were drilled by Stewart Bros., Schenectady, N.Y., in late 1955 and early 1956. The wells provided for in the second contract were drilled by R. E. Chapman and Co., Oakdale, Mass., in November and December 1956.

The first three test wells drilled by Stewart Brothers, wells Sa 844T–Sa 846T (fig. 8), were drilled about 1,400 feet west of Kayaderosseras Creek. These wells were drilled to depths ranging from 130 to 145 feet without penetrating permeable deposits capable of yielding the required quantity of water (fig. 5). As a result, the Commission decided that further exploration in this area was not warranted. The next test well, Sa 847T, was drilled in the valley of Kayaderosseras Creek, approximately 700 feet south of well Sa 843 (fig. 8). This well reached a total depth of 107 feet and penetrated a bed consisting mostly of coarse sand between 50 and 105 feet and gravel below 105 feet. The water in these deposits was found to be under sufficient pressure to flow at the surface. Because water obtained while the casing was set at 107 feet contained hydrogen sulfide, the casing was pulled and the well destroyed. However, data obtained during the construction of the well indicated that the coarse sand overlying the gravel contains water free of hydrogen sulfide. Moreover, the thickness and lithologic character of the sand indicate that it is capable of yielding large quantities of water.

In order to determine the extent and the yield of this sand a production well 12 inches in diameter, Sa 848T, and three observation wells 2 inches in diameter, Sa 850T–852T, were drilled. The production well was cased to a depth of 79 feet and screened from 79 to 99 feet with 25-slot screen. The observation wells were cased to a depth of 82 feet and screened from 82 to 85 feet. Because cobbles in the flood-plain deposits made drilling of small-diameter wells difficult, these wells were constructed by first drilling 6-inch pilot holes. When the 6-inch pilot holes reached a depth of 85 feet a string of 2-inch casing equipped with a screened drive point was inserted in the well and the 6-inch casing was removed. In order to observe water-level fluctuations in the flood-plain deposits a 2-inch observation well, Sa 849T, was drilled 400 feet north of the discharge well and screened between depths of 23 and 26 feet.

The second group of test wells, those drilled by R. E. Chapman and Co., consisted of five 6-inch wells, Sa 1025T–Sa 1029T (fig. 8).

Wells Sa 1025T to Sa 1027T were drilled to depths of 85 feet. A 5-foot section of screen was placed in well Sa 1026T between depths of 80 and 85 feet. As shown in figure 5, wells Sa 1025T and Sa 1027T were drilled through the aquifer and into the relatively impermeable deposits underlying it. An attempt was made to screen well Sa 1025T in the permeable deposits that were penetrated between depths of 70 and 75 feet. However, as the yield of the well upon completion was found to be only one-third of a gallon per minute per foot of drawdown, the well is believed to be screened in the impermeable deposits underlying the aquifer. Well Sa 1027T is screened between depths of 73 and 78 feet. Thus, as the bottom of the aquifer is at 75 feet, only the lower 2 feet of this well is screened in the aquifer.

Well Sa 1028T was drilled about 800 feet west of Kayaderosseras Creek to determine the character and thickness of the unconsolidated deposits beneath the upland. The artesian aquifer was penetrated between depths of 115 and 150 feet and bedrock was reached at a depth of 218 feet (fig. 5). To prevent caving of the unconsolidated deposits it was necessary to case the well to bedrock. In order to permit the well to be used for the observation of pressure changes in the artesian aquifer, the casing was broken opposite the aquifer by exploding five sticks of dynamite at a depth of 135 feet.

To better define the effect of pumping from the artesian aquifer on the water in the flood-plain deposits, a 6-inch observation well, Sa 1029T, was drilled 10 feet east of well Sa 848T. This well was screened between depths of 24 and 29 feet.

PUMPING TESTS

A pumping test was conducted following the completion of each of the groups of test wells described above. During each of these tests, well Sa 848T was pumped and the effect of the pumping on the artesian and water-table aquifers was determined by measuring the depth to water in the observation wells.

The withdrawal of water from an aquifer causes water levels to decline in the vicinity of the point of withdrawal. As a result of this decline, the water table or piezometric surface assumes the approximate shape of an inverted cone having its apex at the center of withdrawal. The size, shape, and rate of growth of the cone of depression depend on several factors. Among these are: (1) the water-transmitting and water-storing capacities of the aquifers; (2) the rate of pumping; (3) the increase in recharge resulting from the decline in water levels; (4) the amount of natural discharge intercepted by the pumping; and (5) the extent of the aquifer. The amount that water levels are lowered by the pumping at any point in the cone of depression is termed "drawdown."

FIRST TEST

In the first pumping test, well Sa 848T was pumped for a continuous period of 72 hours between April 23 and April 26, 1956. To prevent an upward flow of water from the artesian aquifer around the outside of the casing, the well was permitted to flow free from the time the screen was installed on April 9 to the beginning of the test. During the 4-day period immediately preceding the test, the well flowed at a rate of approximately 300 gpm (fig. 12). Prior to this, the rate of flow was approximately 200 gpm. During the first part of the pumping test, from 10:48 a.m., April 23, to 6:25 p.m., April 24, the well was pumped at a rate of 556 gpm or at a rate of 256 gpm more than the rate of natural flow. At 6:25 p.m., April 24, the pumping rate was increased to 726 gpm and this rate was maintained to the end of the test, 11:02 a.m., April 26. Upon cessation of pumping, the natural flow of the well resumed at a rate of approximately 300 gpm.

Prior to the test, the natural flow of the well passed through a 6-inch pipe into a shallow drainage ditch 65 feet east of the well. Water pumped from the well was passed through a 6-inch pipe directly into

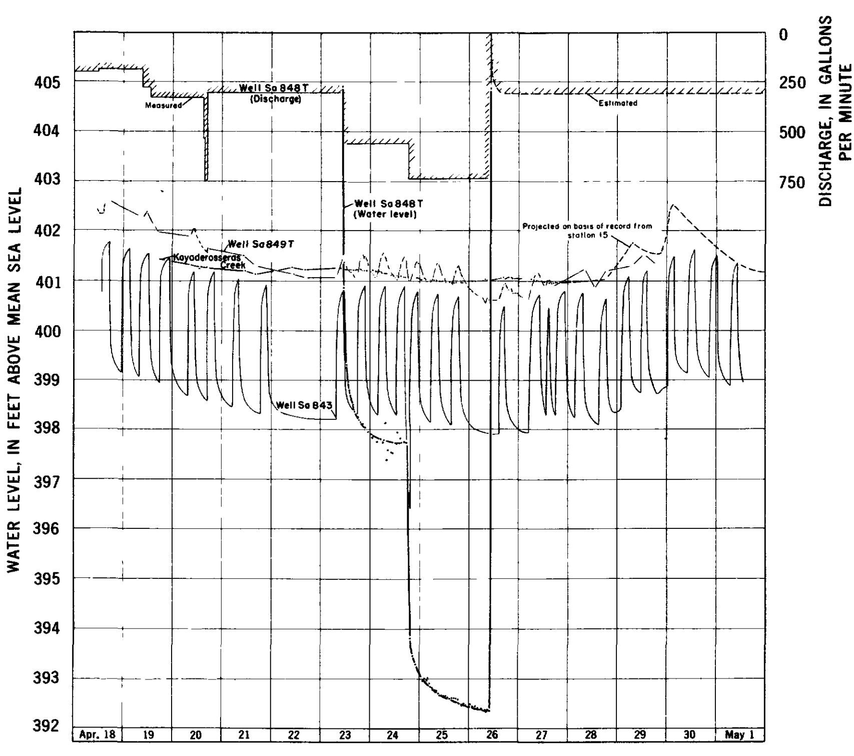

FIGURE 12.—Graphs showing water level and discharge of well Sa 848T, water levels in wells Sa 843 and Sa 849T, and the stage of Kayaderosseras Creek during the pumping test of April 1956.

Kayaderosseras Creek. During the pumping test and for short periods both before and after the test, water-level measurements were made in wells Sa 849T–Sa 852T. Water-level measurements were also made during the test in the pumping well. The stage of Kayaderosseras Creek was measured at a temporary staff gage located 200 feet east of well Sa 848T.

Analysis of data

Graphs of the water levels and other data collected during the pumping test are shown in figures 12 and 13. A drawdown of water level in well Sa 850T during the afternoon of April 20 indicated in figure 13 resulted from pumping well Sa 848T (see discharge graph on fig. 12) for a period of about 1½ hours. This was done to determine the throttle setting for the pump motor and in a general way to determine how much drawdown to expect during the pumping test. The changes in the drawdown curves of well Sa 848T (fig. 12) and of wells Sa 850T–852T (fig. 13) during the morning of April 24 were caused by the change in the rate of pumping in well Sa 848T.

In an analysis of pumping-test data it is desirable to know the natural trend of water levels before, during, and after the test in order to determine true drawdowns. However, the first observation well to be drilled, well Sa 850T, was not completed until April 16 and the rate of flow of well Sa 848T was not held constant until April 20. Consequently, it was not possible to determine the natural trend. However, the hydrographs of figure 13 show that the water levels appear to stabilize after the test at about the same positions as before the test. This is believed to indicate that the static water level did not change significantly during the test.

The water levels in wells penetrating the artesian aquifer also respond to changes in barometric pressure. Thus, rises in barometric pressure are accompanied by a decline in the water levels in the wells. However, because changes in barometric pressure during the test were relatively small and because the barometric efficiency of the aquifer was found to be less than 10 percent, the water-level measurements made during the test were not corrected for barometric fluctuations.

The uncorrected drawdowns were analyzed by the Theis nonequilibrium formula (Wenzel, 1942, p. 87–89) to determine the coefficients of transmissibility and storage.

The Theis formula relates the drawdowns in the vicinity of a discharging well to the rate and duration of discharge. This formula is as follows:

$$s=\frac{114.6Q}{T}\int_{u}^{\infty}\frac{e^{-u}}{u}\,d\,u=\frac{114.6Q}{T}W(u)$$

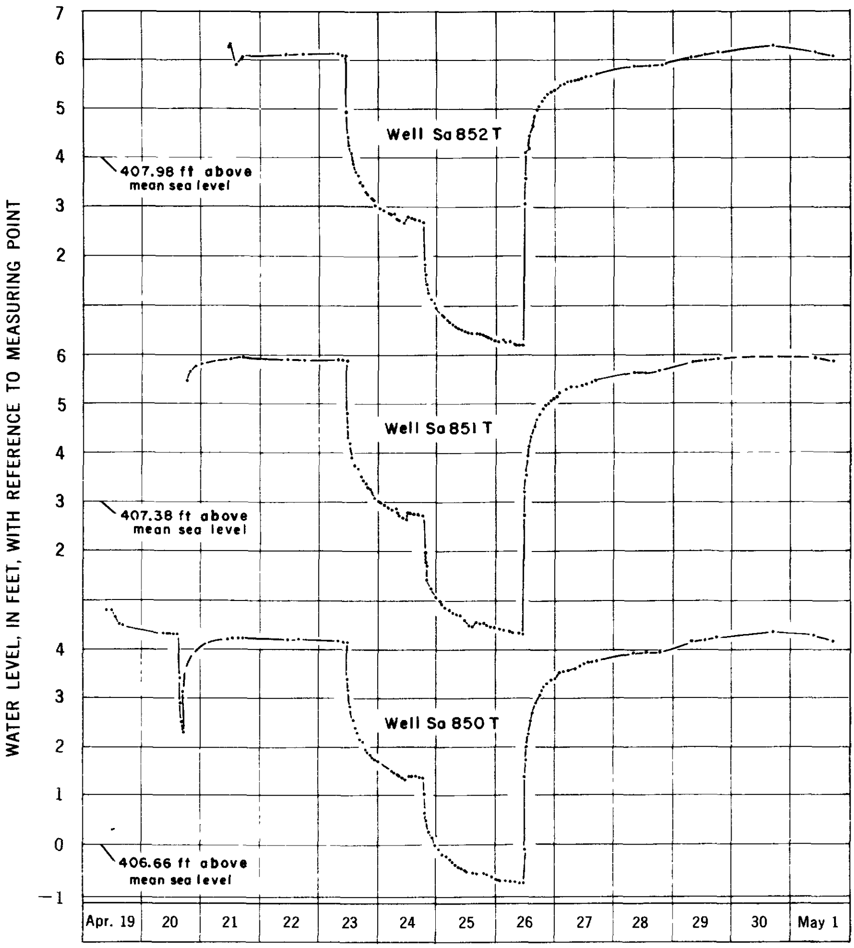

FIGURE 13.—Graphs showing the water levels in test wells Sa 850T–Sa 852T during the pumping test of April 1956.

where:

$$u=\frac{1.87r^2S}{Tt}.$$

s= drawdown, in feet, at distance r and time t.
r= distance, in feet, from pumped well.
Q= pumping rate, in gallons per minute.
t= time since pumping began, in days.
T= coefficient of transmissibility, in gallons per day per foot.
S= coefficient of storage, a dimensionless fraction.

For determination of T and S, the formulas given above are rewritten as follows:

$$T=\frac{114.6Q}{s}W(u)$$

$$S=\frac{Tt/r^2}{1.87\left(\frac{1}{u}\right)}.$$

The Theis nonequilibrium formula is based on the assumption that the aquifer is constant in thickness, infinite in areal extent, homogeneous, and isotropic (transmits water with equal facility in all directions); that there is no recharge to the aquifer or discharge other than that from the one well within the area of influence of the discharging well; and that water may enter the well throughout the full thickness of the aquifer.

When T and S are to be determined, the log of the drawdown in the wells is plotted against the log of t/r^2. The resulting curve is a segment of the type curve produced by plotting the log of the exponential integral, $W(u)$, against the log of the quantity $\frac{1}{u}$. The curve of observed data is then superposed on the type curve and the values of $\frac{1}{u}$, $W(u)$, s and $\frac{t}{r^2}$ are selected at any convenient match point. These values are inserted in the formulas for T and S given above.

The uncorrected drawdowns for wells Sa 850T–852T during the first stage of the pumping test are plotted against $\frac{t}{r^2}$ in figure 14. Theoretically, if the artesian aquifer met all the assumptions of the Theis nonequilibrium formula, the observed data for each well would plot along the same line and all parts of this line would coincide with the type curve. However, as may be seen from figure 14, the plots of the data for each well are relatively widely separated and the plots for wells Sa 850T and Sa 852T coincide with the type curve only during the first several minutes of pumping. The position of the type curve that matches the plot for well Sa 851T is not shown on the figure.

The T and S values for wells Sa 850T and Sa 852T, which were computed from the data collected during the first stage of the pumping test, are shown in figure 14. As pointed out previously, well Sa 848T was flowing at a rate of 300 gpm prior to the beginning of pumping. Thus, the pumping rate used in the computations of T and S values during the first part of the test is 256 gpm, or the difference between the actual pumping rate of 556 gpm and the natural flow of 300 gpm. The values for all wells for both stages of the test

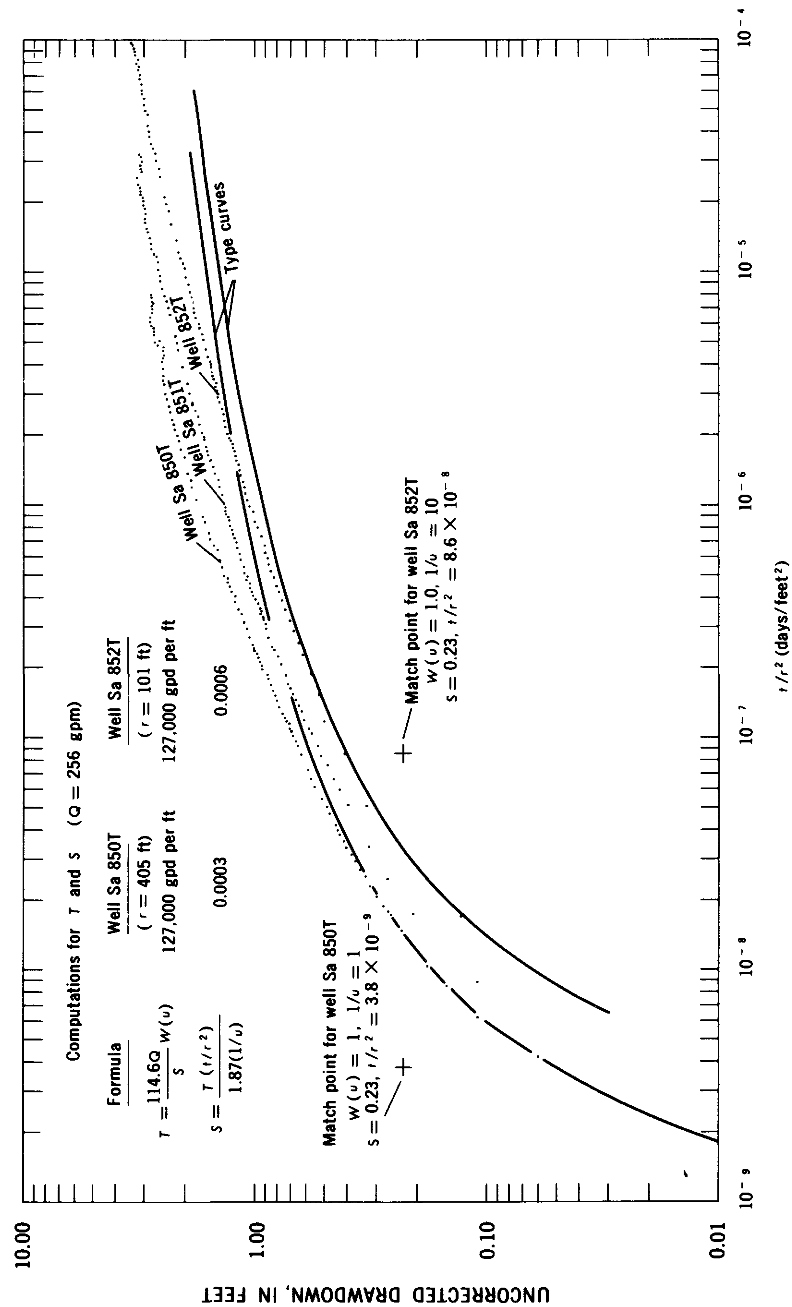

FIGURE 14.—Log plot of drawdowns versus t/r^2 for the first stage of the pumping test of April 1956.

are listed in table 7. Note that none of the drawdowns used in the computation of the T and S values listed in table 7 was corrected. As pointed out above, the water-level measurements made before and after the test did not suggest any progressive natural trend, thus, no corrections for trend were applied to the water-level measurements.

TABLE 7.—*Transmissibility and storage coefficients computed from the data collected during the pumping test of April 1956*

Well	Distance from well Sa 848T (ft)	First stage of drawdown (Q=256 gpm)		Second stage of drawdown (Q=170 gpm)	
		Trans-missibility (gpd per ft)	Storage coefficient	Trans-missibility (gpd per ft)	Storage coefficient
Sa 850T	405	127, 000	0. 0003	111, 000	0. 0003
851T	201	140, 000	. 0003	120, 000	----------
852T	101	127, 000	. 0006	126, 000	----------

In order to analyze the data collected during the second stage of the test, it must be assumed that the pumping rate of 556 gpm was continued unchanged and that an additional pump began drawing water from well Sa 848T at a rate of 170 gpm. Thus, the water levels in the observation wells not only continue to decline as a result of the pumping at a rate of 556 gpm but start to decline as a result of the additional withdrawal of 170 gpm. However, as only the drawdowns measured during the first several minutes of the second stage of the test were used in determining the T and S values, the additional drawdown resulting from a continuation of the pumping at a rate of 556 gpm can be neglected.

The values for transmissibility listed in table 7 range from 111,000 to 140,000 gpd per ft. All the values for the storage coefficient except one are 0.0003. These values would suggest that in the vicinity of well Sa 848T the transmissibility of the artesian aquifer is about 125,000 gpd per ft and the storage coefficient is about 0.0003.

As noted above, the plots for each of the wells shown in figure 14 are relatively widely separated and this is apparently owing to differences from place to place in the water-transmitting and water-storing properties of the aquifer. Such differences are common in deltaic deposits such as those comprising the aquifer. The sections in figure 5 show that both the thickness and the lithologic character of the deposit differ from place to place, thus, the simplifying assumptions of the Theis nonequilibrium formula—that the aquifer is constant in thickness and isotropic—are not actually satisfied. Even so, it is believed that the physical constants of the aquifer are sufficiently close to the assumptions of the formula to permit use of the T and S values in predicting the effect of pumping on the aquifer.

As previously stated, the plots of observed data for wells Sa 850T and Sa 852T in figure 14 depart relatively widely from the type curves after the first several minutes of pumping. Thus, the actual drawdowns in the observation wells were considerably greater than they would have been if they had followed the type curve. The departure of the observed drawdowns from the type curve suggests the presence of impermeable boundaries. Using the method of images (Ferris, 1949, p. 247), an attempt was made to analyze these departures in order to determine the position of the boundaries. From this analysis the two most prominent boundaries appear to be located approximately 500 feet west and approximately 2,000 feet east of the pumping well. Although the analysis of the data did not indicate the presence of boundaries to the north and south, such boundaries may exist within the area of influence of the pumping well. In regard to the western boundary, well Sa 1028T, drilled about 575 feet west of well Sa 848T, penetrated approximately 35 feet of deltaic deposits containing a relatively high proportion of fine sand, silt, and clay. Thus, the aquifer gradually thins and becomes less permeable toward the west rather than abruptly terminating along a line 500 feet west of the pumping well. The aquifer probably also thins and interfingers with less permeable deposits in other directions.

The analysis of the pumping-test data indicates that the artesian aquifer is capable of yielding 700 gpm to one well with a drawdown of less than 25 feet. However, it was not possible to determine accurately the boundaries of the aquifers and the conditions governing recharge and discharge, and consequently, it was not possible to predict the drawdowns that would be produced by pumping water at the rate required by the Commission. In order to obtain additional information on the extent of the aquifer and other factors affecting its yield, the second group of test wells was constructed in November and December 1956. Following the completion of these wells, a second pumping test was run.

SECOND TEST

The second test consisted of pumping well Sa 848T at a rate of 748 gpm for a continuous period of 168 hours, between December 28, 1956 and January 4, 1957. Except for a short period on December 19, while the pump was being installed, the well had not been permitted to flow for a period of several months. The well was pumped for a short period on December 22 in order to determine the proper throttle setting. Water pumped from the well during the test was discharged into Kayaderosseras Creek. Recording gages were maintained on wells Sa 1025T–1028T. In addition, the depth to water in wells Sa 848T–852T and Sa 1029T and the stage of Kayaderosseras Creek were measured periodically during the test.

Analysis of data

Graphs of the water levels and other data collected during the pumping test are shown in figures 15 and 16. The results of the analysis of the data collected during the test are highly significant with respect to the yield of the aquifer. As may be seen from the graphs, the water levels in all wells had stabilized by the end of the fifth day of pumping. In fact, comparison of the changes in barometric pressure with the water-level records suggests that stabilized conditions may actually have been reached early in the fourth day. Prior to reaching stabilized conditions, a part of the pumpage was

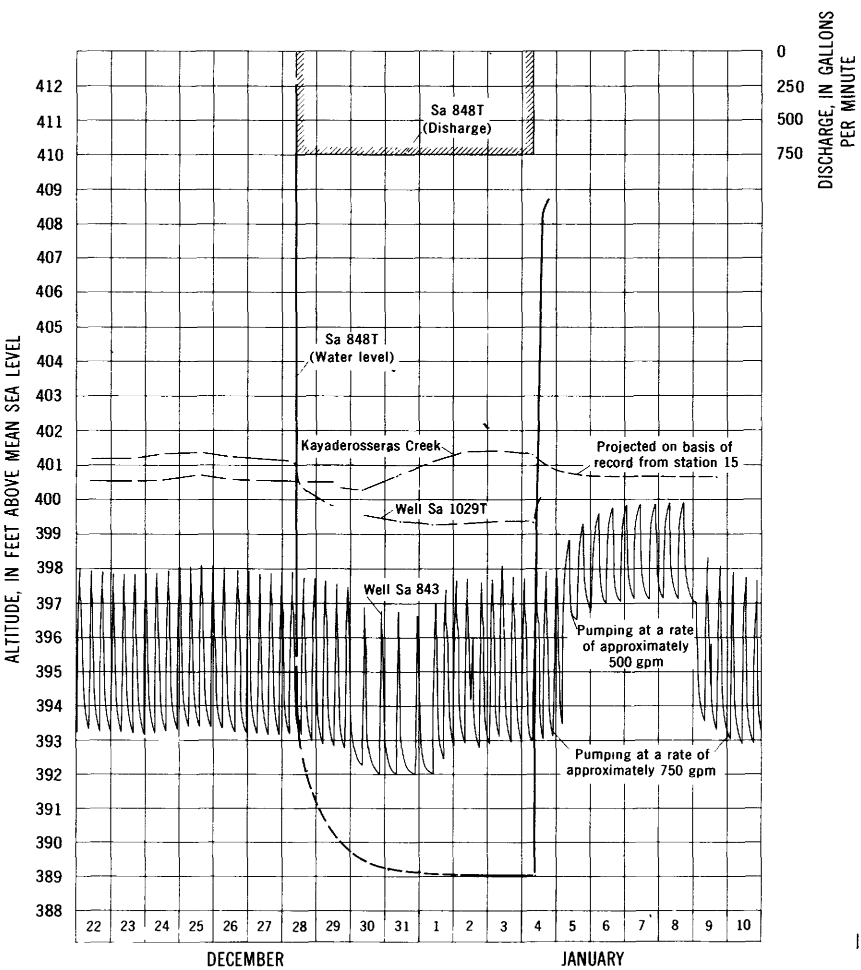

FIGURE 15.—Graphs showing the water level and discharge of well Sa 848T, water levels in wells Sa 843 and Sa 1029T, and the stage of Kayaderosseras Creek during the pumping test of December 1956–January 1957.

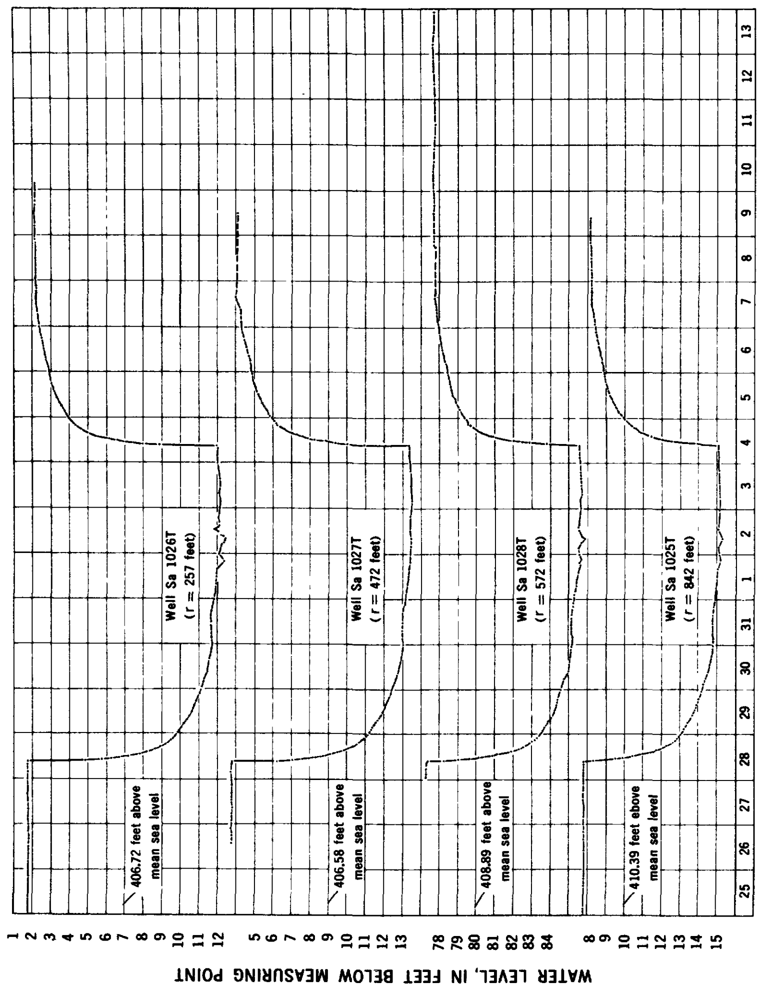

FIGURE 16.—Graphs showing the water levels in test wells Sa 1025T–1028T during the pumping test of December 1956–January 1957.

supplied by water released from storage in the aquifer. After stabilized conditions were reached, all the pumpage was derived either from an increase in recharge or a decrease in natural discharge, or both.

Water-level measurements made in well Sa 1029T, which is screened in the water-table aquifer, showed an immediate response to pumping from well Sa 848T. By the end of the fourth day the water level in well Sa 1029T had declined 1.8 feet. The water level in the well rose slightly after the fourth day, probably as a result of the rise in the stage of Kayaderosseras Creek. The cessation of pumping from well Sa 848T was accompanied by an immediate rise in the water level in well Sa 1029T. The hydrographs in figure 15 show that the water level in well Sa 848T prior to the start of pumping was approximately 11 feet higher than the water level in well Sa 1029T. As a result of this difference in head, water probably was leaking upward from the artesian aquifer into the water-table aquifer prior to the start of pumping. During pumping, the water level in well Sa 848T declined to a position about 10 feet below the water level in well Sa 1029T. As a result, the movement of water upward from the artesian aquifer probably ceased in the vicinity of the pumping well and water may have begun moving downward from the water-table aquifer.

SUMMARY OF PUMPING TEST RESULTS

The artesian aquifer consists principally of medium to coarse sand and thin layers of gravel. It apparently extends several hundred feet west of and more than 1,000 feet east of Kayaderosseras Creek. Its extent to the north and south of the pumping test site is not known but may be as much as 1,000 feet in both directions. The aquifer interfingers and grades to the west into less permeable sediments. It doubtless also grades into less permeable sediments in other directions.

The aquifer is recharged in those areas where the water table stands at a higher altitude than the piezometric surface. This includes both the higher areas bordering the creek and the higher parts of the creek valley. Most recharge probably takes place by a slow seepage of water into the aquifer from the less permeable beds surrounding it. The water in the aquifer percolates upward through the confining bed into the overlying deposits wherever the piezometric surface stands at a higher altitude than the water table. This includes most of the Kayaderosseras Creek valley below an altitude of about 412 feet.

During any relatively long period under natural conditions, the discharge of the aquifer is virtually equal to the recharge. When the recharge exceeds the discharge, as during periods of heavy precipitation, the quantity of water in storage in the aquifer increases and the artesian pressure rises. This rise in pressure is reflected in the rise in water level in artesian wells. When discharge exceeds recharge, as during long dry periods, the quantity of water in storage in the aquifer decreases and the artesian pressure declines. This decline in pressure is indicated by a decline in water level in artesian wells. Most of the water withdrawn from a well during the first few minutes of pumping is derived from storage in the aquifer and during this period the water level in the pumping well and in nearby observation wells declines rapidly. As the artesian pressure declines, the gradient between the artesian aquifer and the water-table aquifer is reduced. This reduction in the upward gradient results in a decline in the rate of natural discharge through the confining bed. As the natural discharge thus intercepted is diverted to the pumping well, the rate at which water is removed from storage declines. If the decline in artesian pressure extends into areas in which the aquifer is being recharged, the rate of recharge is increased. When the reduction in natural discharge and the increase in recharge equal the rate of pumping, both the removal of water from storage and the decline in artesian pressure cease.

During the second pumping test the decline in artesian pressure ceased after about 5 days of pumping (fig. 16). From this time on all the 750 gpm being pumped from well Sa 848T consisted of water that otherwise would have been discharged naturally from the aquifer and water that entered the aquifer as a result of an increase in the rate of recharge. At the time stabilized conditions were reached, the drawdown in the pumped well was approximately 23 feet. This drawdown consists of three parts. These are: (1) the head lost in transmitting the water through the well screen and up the well casing; (2) the head lost because the well was not screened throughout the full thickness of the aquifers; and (3) the drawdown required to transmit the quantity of water being pumped from the well through the aquifer. Thus, if the well had been screened throughout the full thickness of the aquifer, the head loss due to partial penetration of the screen would have been eliminated and the head loss required to move water through the screen would have been reduced. Water-level observations in well Sa 852T, 101 feet south of the pumping well, and in well Sa 1027T, 472 feet south of the pumping well, showed stabilized drawdowns of 10.8 and 10.0 feet, respectively. Thus, if well Sa 848T had been screened throughout the full thickness of the aquifer, the drawdown in the well probably would have been less than 15 feet.

On the basis of the data collected during the construction of the test wells and during the pumping tests, the Commission equipped a well, Sa 848T, with a permanent pump and constructed two additional supply wells. One well, Sa 1030, is located 500 feet south of well

Sa 848T. The other well, Sa 1031, is located approximately 500 feet north of well Sa 848T. In order to obtain the required quantity of 3 mgd from these wells the average pumpage of the three wells must be about 700 gpm each or total 2,100 gpm. The field had not been tested at this rate as of December 1958, and it is not possible to predict accurately the effect on the artesian aquifer of pumping at this rate. However, on the basis of the data available, stabilized conditions probably will be reached after a period of several days. Before stabilized conditions are reached, upward leakage in the vicinity of the pumping wells probably will have stopped and water from the water-table aquifer will move downward to replenish the artesian aquifer. This downward leakage will be accompanied by a decline in the water table which, at least during dry seasons, may be sufficient to cause a movement of water from Kayaderosseras Creek into the water-table aquifer.

SURFACE WATER

The investigation of the surface waters of the West Milton area consisted of collecting and analyzing data on streamflow, chemical quality, temperature, concentration of suspended sediment, and particle-size analyses of bed material.

Streamflow data available consist of continuous records of flow at gaging stations and periodic or occasional measurements of flow at other sites. Table 1 includes detailed information concerning the location, drainage area, and type and length of record for each gaging station. All stations are shown on plate 1. Two gaging stations were being operated in the West Milton area in 1958. The gaging station on Kayaderosseras Creek near West Milton (sta. 15) has been operated by the Geological Survey in cooperation with the New York State Department of Public Works since July 1927 and is a part of the primary network of gaging stations in the State. The gaging station on Glowegee Creek at West Milton (sta. 12) has been operated by the Geological Survey in cooperation with the Atomic Energy Commission since April 1948 and is a secondary station established especially for this study. Periodic measurements of discharge were made at two other sites on Glowegee Creek (stas. 9 and 11) during the years 1948–53. These measurements were made over a sufficient range of base-flow conditions to establish the relationship of the flow at each site to that at station 12. These sites are known as partial-record stations. At four other partial-record stations on various streams in the area (stas. 3, 5, 6, and 8) measurements of streamflow have been made as needed in the interpretation of data on chemical quality, or as background data for future investigation. Records of daily flow at gaging stations and results of

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discharge measurements at other sites are published in annual Water-Supply Papers of the U.S. Geological Survey. Monthly and yearly mean discharges of Kayaderosseras Creek at station 15 and Glowegee Creek at station 12 are listed in table 8 of this report. Discharge determinations at other sites are shown in table 9.

A streamflow gaging station was operated on Kennyetto Creek near Broadalbin, Fulton County, N.Y. from July 1939 to September 1946, and several measurements of discharge and chemical analyses of water were made at this station in the period 1949–53. A correlation of mean daily discharge under base-flow conditions between Kayaderosseras Creek and Kennyetto Creek has been computed, but data used in the correlation are not contained in this report as they have no current bearing on the surface-water hydrology of the West Milton area. However, if at any future time appreciable changes occur in the flow pattern in the Kayaderosseras Creek basin which might be attributable to operations of the West Milton reactor or other installations, the magnitude of such changes might be estimated by use of the correlation.

FLOW CHARACTERISTICS OF KAYADEROSSERAS AND GLOWEGEE CREEKS

Variations in streamflow from time to time and from place to place are the result of variations in precipitation, vegetation, and air temperature and areal differences in topography, geology, and size of drainage basin. In a single drainage basin, the topography, geology, and size are constant factors, and variation in flow is generally dependent upon precipitation, vegetation, and temperature. As might be expected, variation between extremes on unregulated streams of the size of those discussed in this report are pronounced.

The extent of the variation between monthly mean discharges and annual mean discharges of Kayaderosseras Creek at Station 15 and Glowegee Creek at station 12 are shown in table 8. The data in this table are summarized in figure 17, which shows maximum, median, and minimum monthly mean and annual mean discharges at the station. As may be seen in figure 17 and table 8, the monthly mean discharge of Kayaderosseras Creek at station 15 ranged from 21.7 cfs (cubic feet per second) in September 1948 to 866 cfs in March 1936, and the annual mean discharge ranged from 94.5 cfs in 1941 to 198 cfs in 1952. No significant trend toward either an increase or a decrease of annual flow for Kayaderosseras or Glowegee Creeks can be discerned in the data in table 8.

In general, the longer the period of record of streamflow at a station, the better that record is for interpretation and analysis. For this reason, the record of station 15 on Kayaderosseras Creek is by far

TABLE 8.—*Monthly mean and annual mean discharge, in cubic feet per second, of Kayaderosseras Creek near West Milton, N.Y. (sta. 15) and of Glowegee Creek at West Milton, N.Y. (sta. 12)*

Year ending Sept. 30	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Kayaderosseras Creek (sta. 15)													
1928	132	272	263	172	149	214	290	190	202	171	115	65.5	186
1929	75.6	78.0	88.8	89.1	66.1	515	417	240	138	78.5	50.6	68.9	159
1930	68.4	106	114	178	221	342	197	122	108	37.1	23.9	27.3	128
1931	26.7	54.5	49.4	32.8	42.4	164	250	155	100	204	65.5	90.7	103
1932	60.8	92.8	182	248	139	138	404	106	52.6	49.7	51.8	30.6	129
1933	113	245	100	134	120	220	457	150	45.6	31.6	103	63.8	148
1934	62.3	70.4	82.8	133	47.6	248	396	99.9	68.4	31.3	25.1	54.1	110
1935	49.2	64.9	70.9	174	66.4	330	204	152	124	372	80.6	77.2	148
1936	77.8	252	135	167	70.3	866	359	146	51.6	31.6	38.0	31.6	186
1937	105	155	179	319	233	136	301	194	97.9	59.8	41.2	31.8	154
1938	48.7	93.3	96.9	94.5	178	233	197	96.7	36.6	36.5	32.5	164	108
1939	61.0	84.3	199	78.3	127	233	476	112	56.5	32.7	30.6	29.6	126
1940	42.7	72.9	53.7	38.4	47.1	75.6	757	206	137	80.8	35.5	48.2	132
1941	39.3	114	216	116	110	124	219	48.6	36.2	28.4	23.3	62.2	94.5
1942	49.3	93.6	111	100	80.4	339	179	124	89.0	68.5	61.6	87.0	116
1943	98.0	129	131	106	114	377	315	313	152	59.0	58.6	42.3	158
1944	79.1	156	79.3	43.7	55.9	283	408	119	148	47.9	27.4	48.4	124
1945	60.2	69.7	70.1	96.3	108	423	245	278	138	94.5	30.8	93.7	143
1946	200	210	134	130	78.4	403	139	223	144	64.3	39.1	32.8	151
1947	58.4	53.2	52.7	142	91.1	195	394	322	174	68.9	40.0	29.1	135
1948	31.2	91.9	57.8	46.5	98.1	436	285	187	124	59.9	33.8	21.7	123
1949	35.6	102	203	208	209	236	177	95.6	44.4	27.3	32.8	41.4	125
1950	48.6	72.7	116	225	100	298	387	153	79.4	50.5	41.4	76.9	137
1951	45.6	85.0	110	108	193	375	360	126	101	131	103	116	155
1952	141	221	205	223	178	233	490	303	178	85.3	56.1	58.7	198
1953	45.9	96.2	201	159	180	362	290	336	73.2	44.7	40.8	30.9	155
1954	43.0	49.3	109	84.7	248	225	251	250	173	48.7	41.8	74.9	132
1955	51.0	237	145	56.1	102	334	415	121	79.4	31.2	63.4	42.8	140
1956	286	237	115	136	81.9	160	557	217	125	76.7	42.8	79.9	176
Glowegee Creek (sta. 12)													
1949	4.90	22.7	61.5	80.1	72.0	61.0	38.6	20.4	8.33	2.84	3.14	5.07	31.5
1950	9.05	14.6	27.4	78.2	27.0	109	113	39.0	15.1	8.25	7.28	19.6	39.0
1951	8.15	18.2	32.7	30.2	68.5	133	90.7	21.3	17.7	35.9	28.4	27.5	42.5
1952	37.1	66.6	54.3	59.5	47.8	74.9	124	78.1	36.2	15.9	8.12	9.17	50.9
1953	5.49	19.7	55.8	39.3	51.2	102	79.8	97.4	10.6	6.54	4.22	3.20	39.6
1954	7.10	10.1	25.4	17.3	77.2	62.2	70.0	66.4	33.4	4.84	4.97	8.95	32.0
1955	7.67	73.0	40.9	12.0	25.7	114	114	29.1	16.7	4.72	20.2	9.98	38.9
1956	108	70.2	31.0	38.9	21.0	57.6	178	57.4	34.9	17.0	8.26	20.2	53.4

the best record in the area for use in surface-water studies. However, it is usually possible to extend short records in areas where such records cover periods that are concurrent with parts of longer records, especially when the streams involved are streams whose flow is not affected by regulation.

Curves have been prepared showing certain streamflow characteristics of Kayaderosseras and Glowegee Creeks at station 12 and correlation between the records of Glowegee Creek at station 12 and at partial-record stations 9 and 11. These correlations are discussed in subsequent paragraphs and, assuming that future flow will follow the pattern of flow measured in the past, these relationship curves may be used to estimate the frequency of occurrence of a specified discharge. Modification of the streams in the Kayaderosseras Creek basin by dams, channel improvement, or other artificial means can.

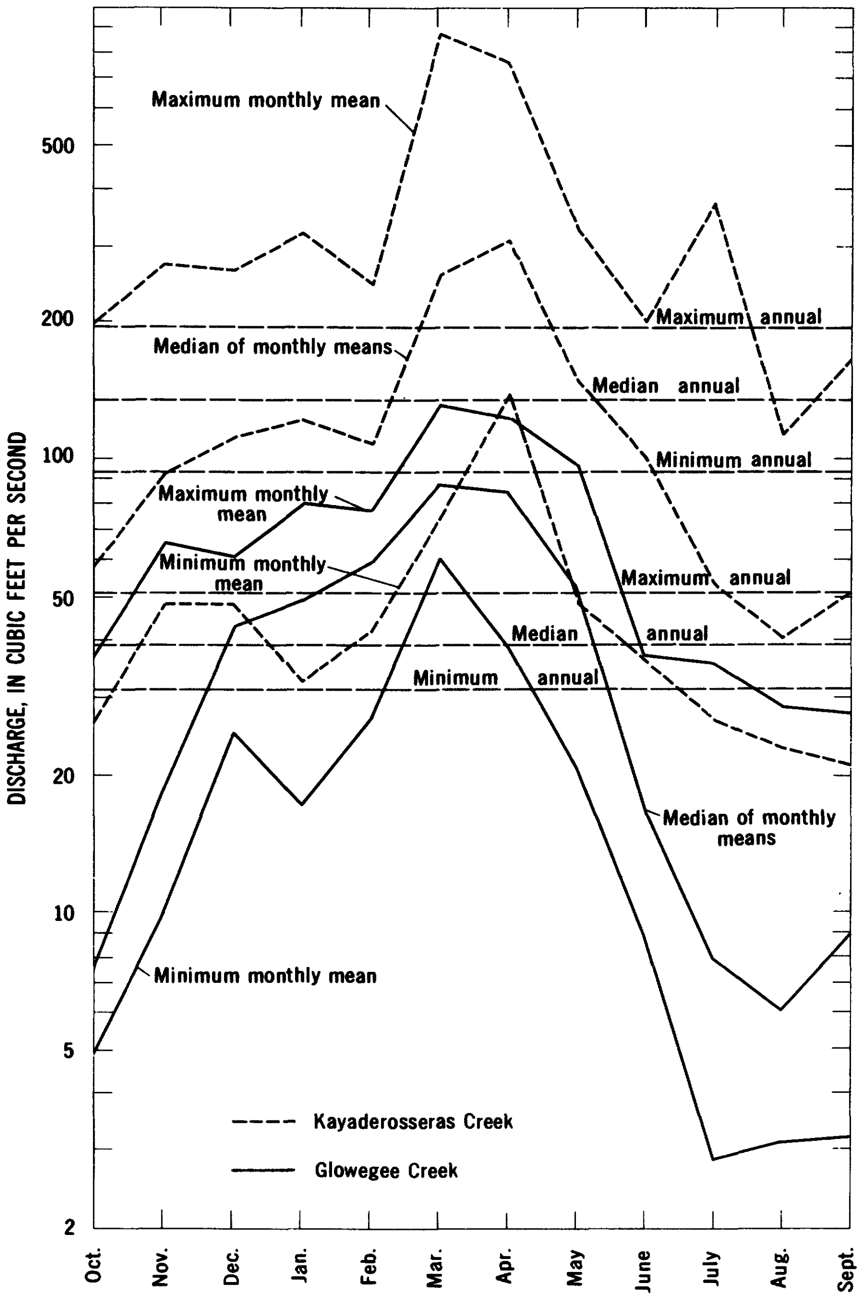

FIGURE 17.—Graph showing maximum, median, and minimum monthly mean and annual mean discharge of Kayaderosseras Creek near West Milton, N.Y. (sta. 15) for the period October 1927–September 1956 and of Glowegee Creek at West Milton, N.Y. (sta. 12) for the period October 1948–September 1956.

however, appreciably change the flow pattern and invalidate the relationship curves.

During the period of operation of S1G reactor (March 1955 to March 1957), cooling water of an indeterminate amount up to 1.5 cfs, or as much as 68 percent of the minimum daily flow of Glowegee Creek during the period of reactor operation, was discharged into Glowegee Creek about 2.6 miles upstream from station 12. Therefore, data from the continuous record on Glowegee Creek during the period of operation of the reactor were not used in these correlations.

DURATION OF FLOW

The discharge of Kayaderosseras Creek for the period 1927–54 is shown as a solid line on the flow-duration curve in figure 18. This curve shows that during the period of record, the discharge of Kayaderosseras Creek equaled or exceeded 82 cfs 50 percent of the time. In a strict sense, a duration curve applies only to the period for which data were used to develop the curve. However, if the period is long enough to give a reasonable representation of the flow pattern and if no appreciable change is made in the drainage basin, a duration curve may be used to estimate the percent of time a specified discharge will be equaled or exceeded in the future. The upper dashed line in figure 18 is the duration curve for Kayaderosseras Creek during the period 1948–54.

The duration curve for Glowegee Creek during the period 1948–54 is shown as a solid line in figure 18. The curve shows that a discharge of 19.5 cfs was equaled or exceeded 50 percent of the time during this period.

To extend this short record for Glowegee Creek into a longer, more useful record, the relation between the two duration curves for Kayaderosseras Creek and the duration curve for Glowegee Creek was used to produce the lower dashed line in figure 18. This dashed line is a duration curve for Glowegee Creek adjusted to a 27-year record. This curve shows that during the 27-year period 1927–54, a discharge of 16.5 cfs was probably equaled or exceeded 50 percent of the time. The slope of a duration curve is a good index of the total natural storage within a basin. A flat slope in the upper part of a duration curve is indicative of considerable surface storage, which reduces peak flows and prolongs high flows. Flatness in the lower part is indicative of sustained low flow, resulting from discharge of ground water from storage. A change of slope between the upper and lower parts indicates a change in the water-retaining factors prevailing at higher and lower flows.

The overall slope of the duration curve for Kayaderosseras Creek is flatter than that of the curve for Glowegee Creek, indicating a

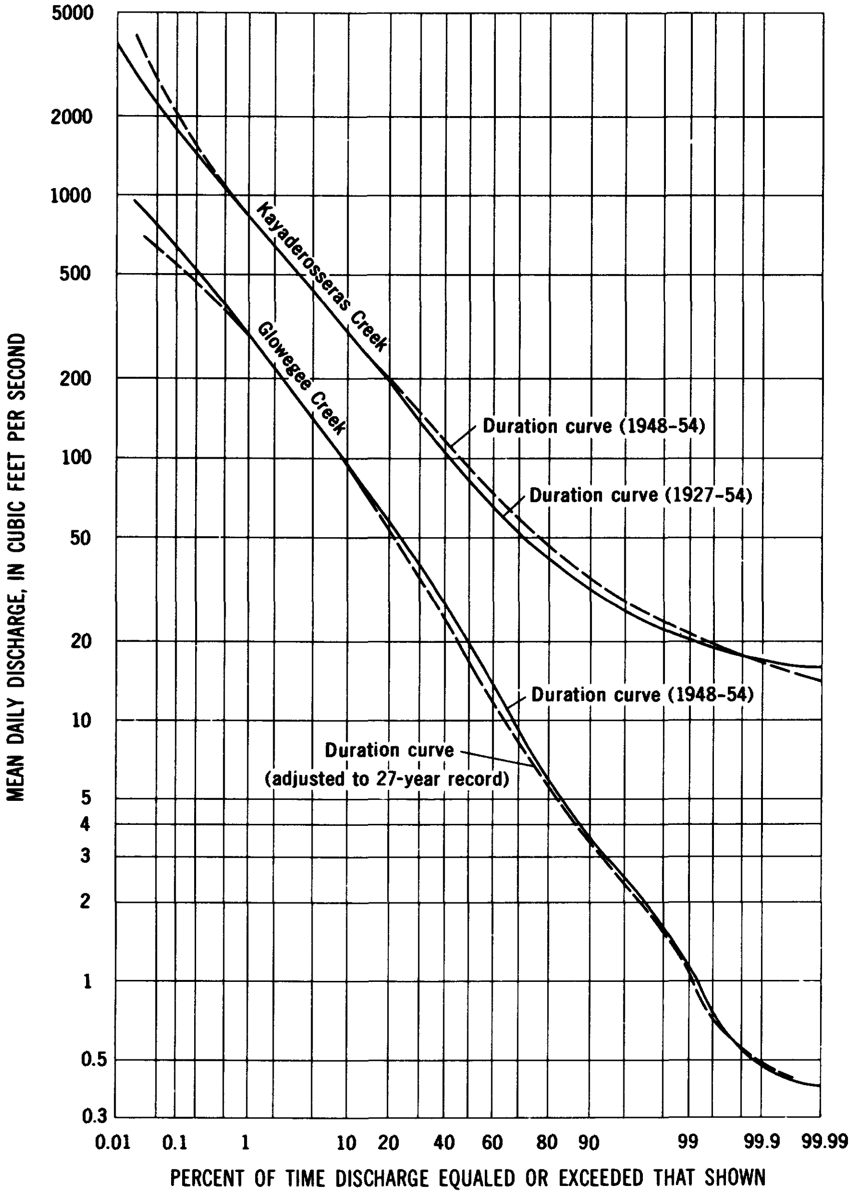

FIGURE 18.—Flow-duration curves for Kayaderosseras Creek near West Milton, N.Y. (sta. 15) and for Glowegee Creek at West Milton, N.Y. (sta. 12).

more uniform flow in Kayaderosseras Creek. Furthermore, the curve for Kayaderosseras Creek is considerably flatter in the lower part, indicating that the natural storage within the basin is quite effective in maintaining a sustained low flow. The absence of an appreciable change in slope in the Glowegee Creek curve, however, indicates that storage is not sufficient to maintain a sustained low flow.

LOW FLOW

As normally drawn, a flow-duration curve may be used to estimate the percent of time a given flow may be equaled or exceeded. By simple subtraction, the percent of time that flow may be equal to or less than a specified amount may also be estimated. For example, from the duration curve for Kayaderosseras Creek, we may estimate that a flow of 26 cfs may be equaled or exceeded 95 percent of the time. Conversely, the flow will be equal to or less than 26 cfs 5 percent of the time. However, the curve does not show either how frequently, or the number of consecutive days during that period of time, discharges of a lesser magnitude will occur. Such data are shown by the use of curves of low-flow frequency and maximum period of deficient discharge. Such curves show, respectively, the average interval at which a specific discharge may be expected to recur as the lowest discharge in the climatic year (April 1 to March 31), and the maximum number of consecutive days during which the flow was equal to or less than a specified discharge. These data for the West Milton area are discussed subsequently in the section entitled "Frequency and duration."

BASE-FLOW RELATIONS

Base flow is defined as the sustained or fair-weather flow of a stream. To establish the relation between Kayaderosseras and Glowegee Creeks during base-flow periods, concurrent daily mean discharges during periods of base flow at each station were plotted as shown in figure 19. It is apparent that several lines of various slopes could reasonably be drawn through these points.

To aid in establishing the discharge-relation curve, a line of equal yield per square mile—a drainage-area ratio line—was drawn dashed in figure 19. Because geology is the primary factor affecting base flow, differences in geology are reflected in differences in yield per square mile at the two stations. As base flow increases, the effect of differences in geology becomes smaller, relatively, and the relation line tends to approach the equal-yield line. At high flows, when storm runoff constitutes a greater part of the discharge of the streams, the relatively minor effect of differences in geology is largely obscured, and the relation line tends to merge with, or become parallel to, the equal-yield line. At low base flows, the relation line tends to diverge from the equal-yield line, as in figure 19, or it might cross the equal-yield line toward the other ordinate, depending upon which ordinate represents the basin having the greater storage. From the duration curves, a straight line was drawn in figure 19 through the upper group

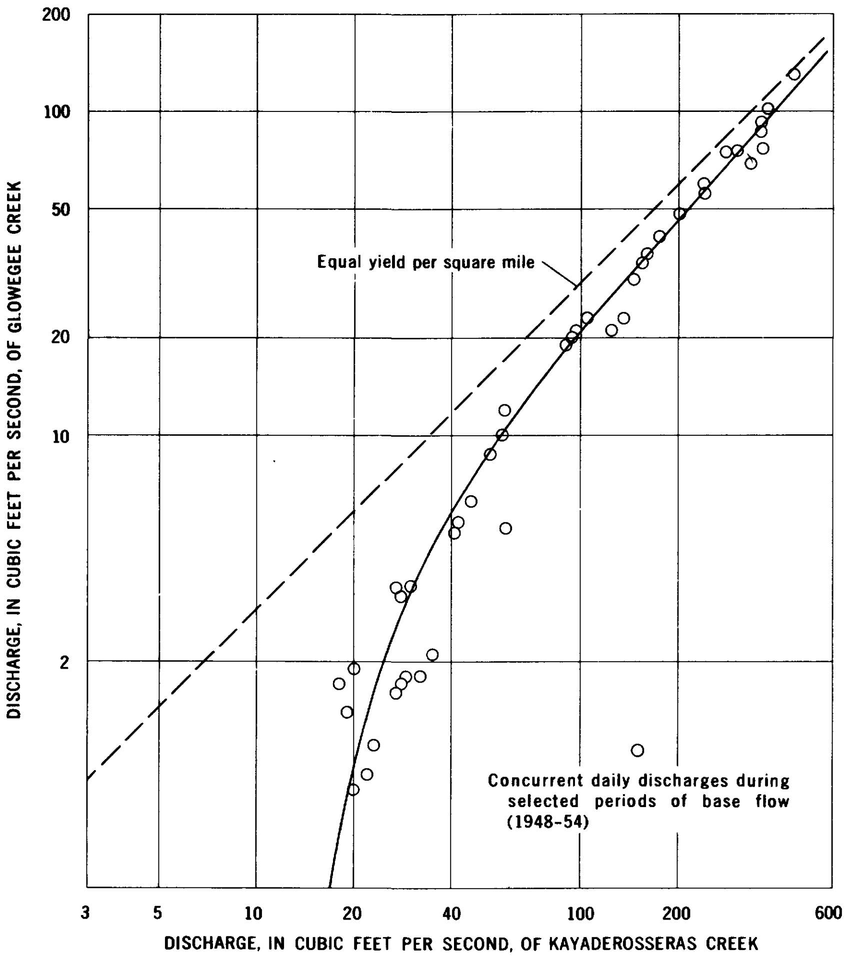

FIGURE 19.—Correlation of base flow of Kayaderosseras Creek near West Milton, N.Y. (sta. 15) with base flow of Glowegee Creek at West Milton, N.Y. (sta. 12).

of points (above 80 cfs for Kayaderosseras Creek and above 15 cfs for Glowegee Creek), and a curve was drawn through the lower group of points. The curvature starts at substantially the same discharge as does the change in curvature of the Kayaderosseras Creek duration curve—the point where the greater ground-water discharge of the Kayaderosseras Creek basin influences the relation.

It is sometimes desirable to establish a relation between an ungaged site and a gaging station. This may be done by making several measurements of flow at the ungaged site during periods of base flow and by using figures of discharge at the gaging station for the same periods. At stations 9 and 11 on Glowegee Creek (pl. 1 and table 1), a sufficient number of measurements have been made (table 9) to

TABLE 9.—*Stream-discharge measurements at sites other than gaging stations in the Kayaderosseras Creek basin*

Date	Discharge (cfs)	Date	Discharge (cfs)
Glowegee Creek—station 9 [1]			
1949		*1951*—Continued	
July 27	1.89	June 20	6.80
July 28	.94	Oct. 2	6.83
Nov. 23	11.1		
		1952	
1950		June 24	6.81
Feb. 27	15.1	July 31	2.90
May 2	55.1	Sept. 30	3.48
Aug. 14	1.33		
		1953	
1951		Jan. 13	12.0
Mar. 13	46.4	Apr. 27	116
Glowegee Creek—station 11 [2]			
1948		*1948*—Continued	
July 14	5.56		
July 20	2.84	Dec. 15	12.0
Aug. 3	2.04	Dec. 28	6.08
Aug. 27	1.60	Jan. 10, 1949	69.1
Sept. 2	1.24	Dec. 1, 1950	17.9
Sept. 24	1.32	Mar. 13, 1951	72.9
Oct. 8	1.37		
Oct. 26	3.31	*1952*	
Nov. 12	7.78	June 24	8.44
Nov. 26	15.6	July 31	3.48
Clover Mill Brook—station 3 [3]			
1952		*1952*—Continued	
June 25	8.43	July 31	2.28
Star Brook—station 5 [4]			
1952		*1952*—Continued	
June 25	4.05	July 31	.79
Kayaderosseras Creek—station 8 [5]			
July 8, 1953	42.8		
Crook Brook—station 6 [6]			
Apr. 18, 1957	6.14		

[1] Drainage area = 18.2 sq mi.
[2] = 23.2 sq mi.
[3] = 2.27 sq mi.
[4] Drainage area = 1.16 sq mi.
[5] = 61.9 sq mi.
[6] = 4.06 sq mi.

establish such a relation between each of these sites and the gaging station on the same stream (sta. 12). In each graph, the equal-yield line is a reasonable representation of the curve, as shown in figure 20. As all three stations are relatively close together on the same stream and the ground-water contribution is the governing factor in the base flow, it is not surprising that the discharge relation is substantially the same as the equal-yield line. Should there be a large difference in area of drainage basins, or a marked difference in the type of aquifer between the stations and a resulting difference in ground-water inflow, the equal-yield line probably would not serve as a base-flow relationship curve.

FREQUENCY AND DURATION

After the base-flow relation between a station with a long-term record and one with a short-term record has been established, the short-term record may be extended for use in determining low-flow frequency curves. The recurrence intervals of minimum 1-day, 7-day, and 30-day discharges of Kayaderosseras Creek at station 15, as computed from the 1928–55 period of record, are shown as the upper curves in figure 21. These curves show that a minimum discharge of 30 cfs for a 1-day period will occur, on the average, about every 15 months (recurrence interval 1.24 years); for a 7-day period every 17 months (recurrence interval 1.35 years); and for a 30-day period every 23 months (1.95 years). Using the base flow relation curves of figure 19, the frequency curves of Kayaderosseras Creek in figure 21, and a procedure similar to the one used in extending the duration curve for Glowegee Creek, the curves of low-flow recurrence of Glowegee Creek for a long-term record were computed. These curves are shown as the lower curves in figure 21. This figure shows that a minimum mean discharge of 1 cfs for 1 day may be expected to occur, on the average, every 3 years; for a 7-day period every 4 years, and for a 30-day period every 14 years.

At times, it may be desirable to know the maximum number of consecutive days during which the flow was equal to, or less than, a specified discharge. Curves showing such data, called the maximum period of deficient discharge, have been prepared for station 15 on Kayaderosseras Creek and station 12 on Glowegee Creek (fig. 22). Curves of this type have the disadvantage of being associated with a single event during a period of record without indicating its probable frequency, and are therefore not conducive to adjustment to a longer period. Figure 22 shows that during the years 1948–55 the longest continous period during which the flow of Kayaderosseras Creek did not exceed 30 cfs was 20 days, but during the years 1927–55 there was a period of 48 consecutive days during which this discharge was not exceeded.

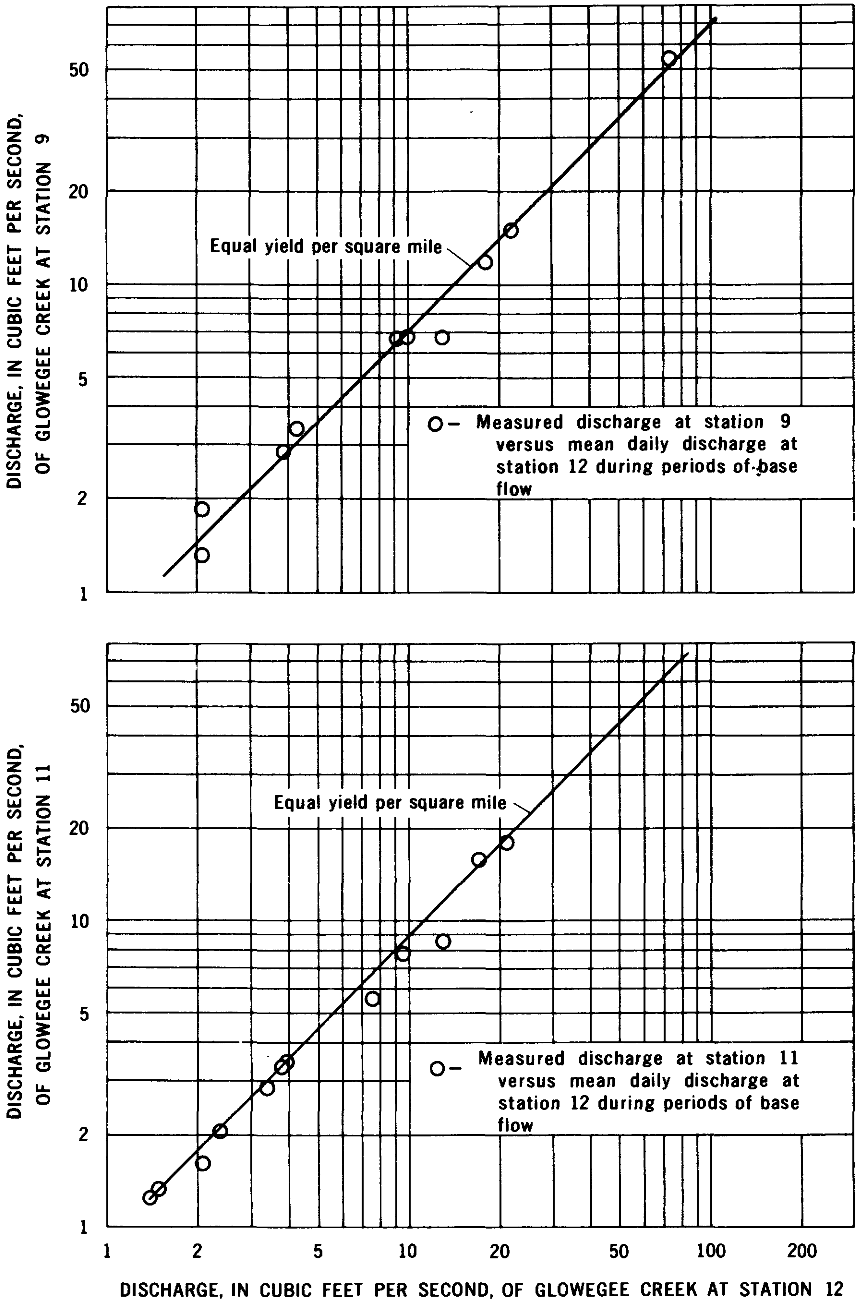

FIGURE 20.—Correlation of base flow of Glowegee Creek at West Milton, N.Y. (sta. 12) with base flow of Glowegee Creek at stations 9 and 11.

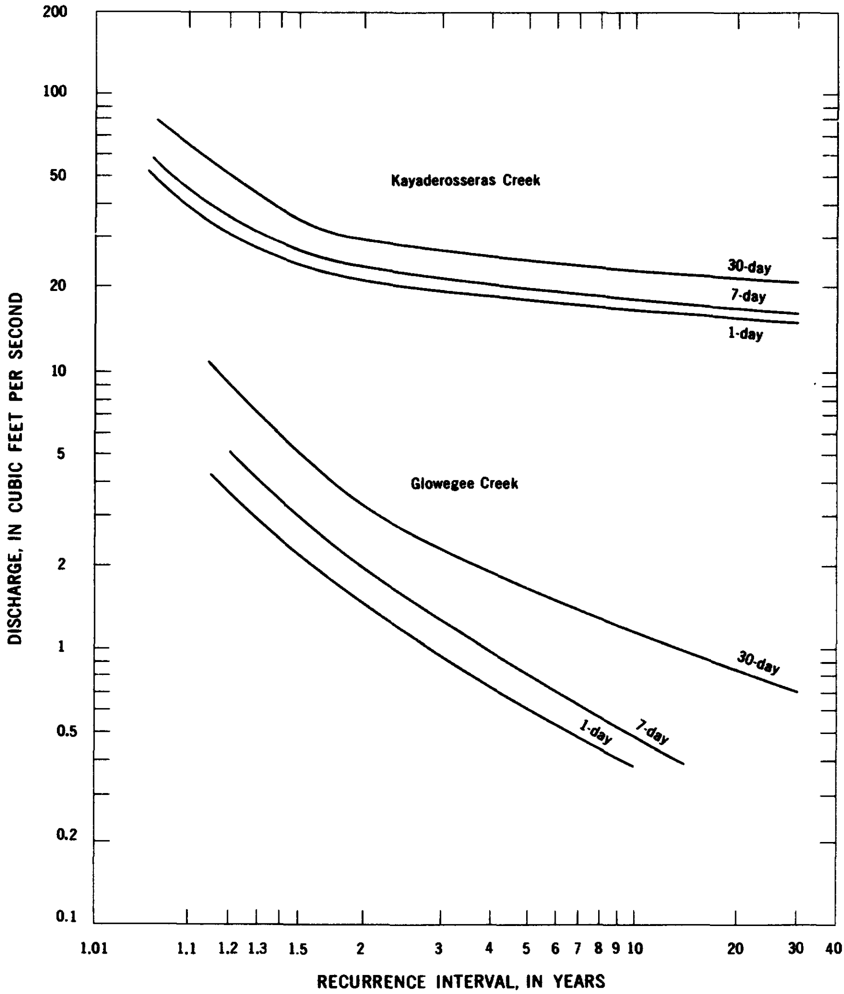

FIGURE 21.—Magnitude and frequency of annual low flows of Kayaderosseras Creek near West Milton, N.Y. (sta. 15) and of Glowegee Creek at West Milton, N.Y. (sta. 12).

FLOODFLOW

A knowledge of the magnitude and frequency of floods that may be expected to occur is essential in the design of bridges, culverts, or other structures affected by floods, and in studies of flood damage, and design of flood-control structures. Flood-magnitude and flood-frequency relations based on a study of the peak discharges at each of several gaged stations in a region are the most reliable sources of flood-magnitude and flood-frequency estimates. Such a regional study has not yet been completed for New York. Therefore, only the records of Kayaderosseras Creek at station 15 and Glowegee Creek at station 12 have been considered in computing such data for the West Milton area.

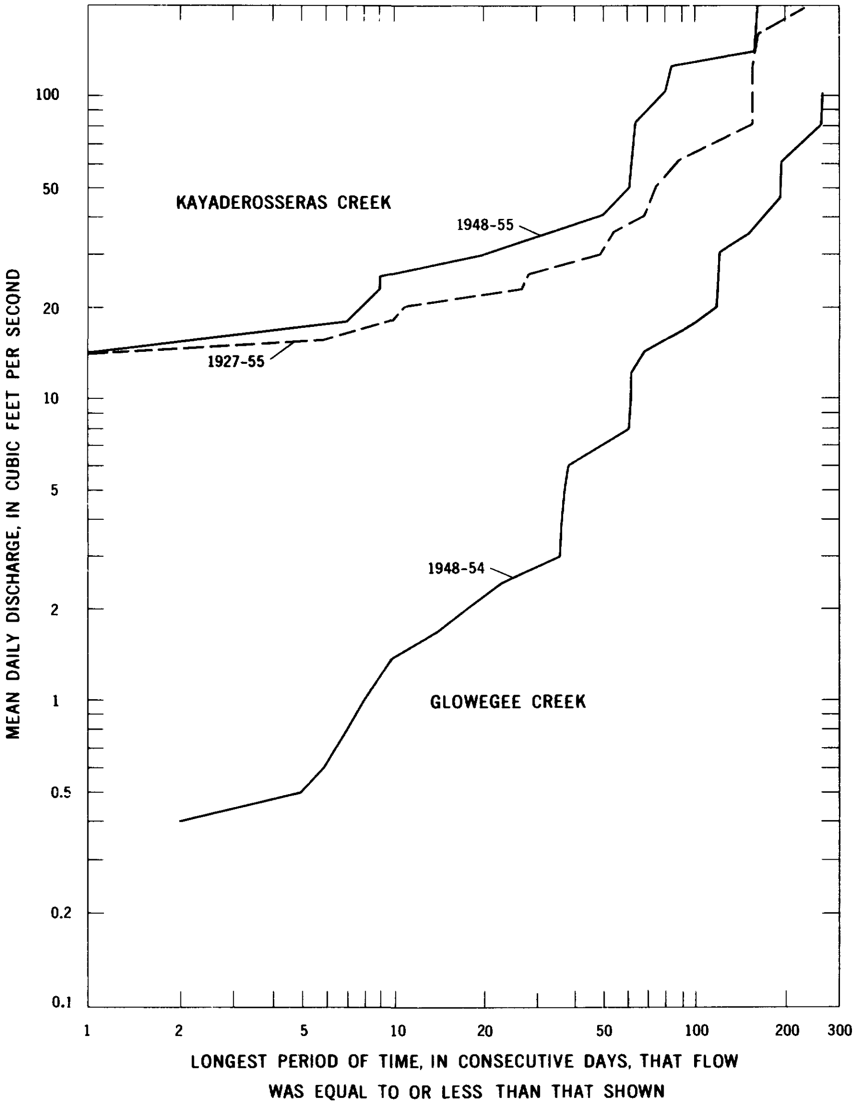

FIGURE 22.—Maximum period of deficient discharge of Kayaderosseras Creek near West Milton, N.Y. (sta. 15) and of Glowegee Creek at West Milton, N.Y. (sta. 12).

An annual flood is the maximum instantaneous peak discharge occurring in a water year (Oct. 1 to Sept. 30). Annual floods for both Kayaderosseras and Glowegee Creeks are listed in table 10. Using the complete record for Kayaderosseras Creek at station 15, a flood frequency curve for this stream was drawn, as shown in figure 23. From this curve, the mean annual flood, which by definition is that flood having a recurrence interval of 2.33 years, or that flood which, on

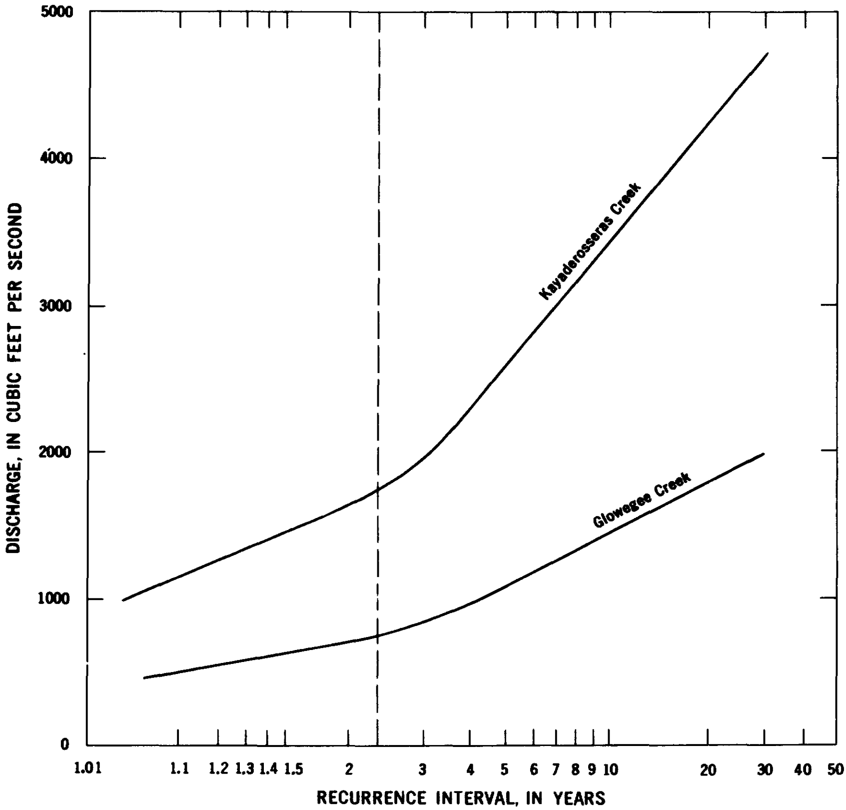

FIGURE 23.—Frequency of floods on Kayaderosseras Creek near West Milton, N.Y. (sta. 15) and on Glowegee Creek at West Milton, N.Y. (sta. 12).

the average, will be equaled or exceeded once every 2.33 years, is computed to be 1,740 cfs. The flood that may be expected, on the average, to be equaled or exceeded once in 50 years is estimated to be 5,300 cfs.

A similar curve for Glowegee Creek, adjusted to the period 1928–56, is also shown in figure 23. This curve shows the mean annual flood on Glowegee Creek to be 740 cfs. The 50-year flood on Glowegee Creek is estimated to be 2,250 cfs.

The ratio between the mean annual floods of the two streams (2.35:1) closely approximates the 0.7 power of the ratio of the respective drainage areas (2.39:1). Such a relation is common between small, proximate streams.

To compare the characteristics of a flood affecting both Kayaderosseras and Glowegee Creeks, the runoff for the period December 29, 1948, to January 4, 1949, was plotted in the form of discharge versus time as shown in figure 24. The precipitation record for the weather station at Conklingville, N.Y., about 20 miles north of West Milton,

TABLE 10.—*Annual floods of Kayaderosseras Creek near West Milton, N.Y. (sta. 15) and of Glowegee Creek at West Milton, N.Y. (sta. 12)*

Year ending Sept. 30	Date	Gage height (ft)	Discharge (cfs)	Year ending Sept. 30	Date	Gage height (ft)	Discharge (cfs)
Kayaderosseras Creek							
1928	Dec. 8, 1927	5.3	1,120	1943	Dec. 31, 1942	5.12	1,200
1929	Mar. 16, 1929	7.5	2,350	1944	Mar. 17, 1944	5.80	1,510
1930	Mar. 8, 1930	6.0	1,600	1945	Apr. 26, 1945	5.63	1,430
1931	July 10, 1931	6.25	1,720	1946	Mar. 9, 1946	5.90	1,560
1932	Apr. 12, 1932	5.46	1,330	1947	May 6, 1947	5.93	1,570
1933	Nov. 19, 1932	6.05	1,620	1948	Mar. 22, 1948	7.74	2,620
1934	Apr. 12, 1934	5.36	1,280	1949	Dec. 31, 1948	10.31	4,340
1935	July 8, 1935	8.92	3,360	1950	Mar. 29, 1950	6.34	1,800
1936	Mar. 18, 1936	10.78	4,710	1951	Mar. 31, 1951	7.65	2,570
1937	Feb. 22, 1937	8.09	2,830	1952	Apr. 6, 1952	7.73	2,620
1938	Sept. 21, 1938	6.56	1,920	1953	Dec. 11, 1952	6.82	2,070
1939	Apr. 2, 1939	5.09	1,140	1954	June 2, 1954	5.05	1,140
1940	Apr. 8, 1940	6.63	1,920	1955	Mar. 1, 1955	5.68	1,440
1941	Sept. 1, 1941	5.67	1,450	1956	Oct. 17, 1955	6.11	1,670
1942	Mar. 22, 1942	6.12	1,660				
Glowegee Creek							
1949	Dec. 31, 1948	7.04	1,670	1953	Dec. 11, 1952	6.59	1,040
1950	Mar. 28, 1950	5.68	934	1954	May 8, 1954	5.17	402
1951	Mar. 31, 1951	5.53	867	1955	Mar. 1, 1955	6.13	790
1952	Apr. 6, 1952	5.77	933	1956	Oct. 16, 1955	5.95	704

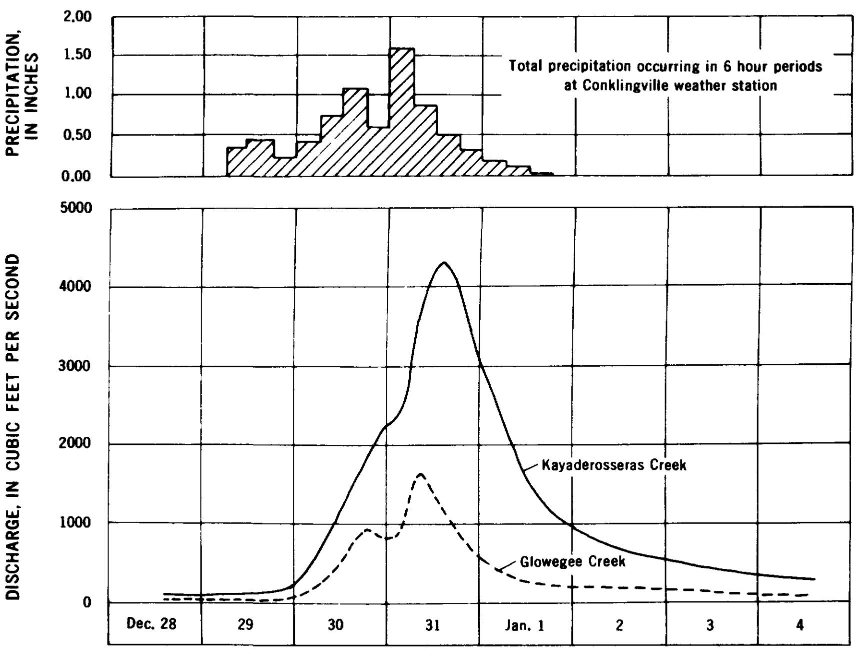

FIGURE 24.—Hydrographs of Kayaderosseras Creek near West Milton, N.Y. (sta. 15) and Glowegee Creek at West Milton, N.Y. (sta. 12) and graph of precipitation at Conklingville, N.Y., during the flood of December 31, 1948.

is also shown in figure 24. (Other weather stations used in this report could not be used in this instance, because they were established subsequent to December 1948, or are nonrecording stations.) The hydrographs indicate that for this flood, both streams began to rise about the same time, but Glowegee Creek crested somewhat earlier than Kayaderosseras Creek and returned to a base-flow condition more quickly. It is interesting to note that about 3.3 inches of flood runoff occurred on both streams whereas 6.5 inches of precipitation was recorded at Conklingville for the period December 29, 1948, to January 1, 1949.

VELOCITY OF FLOW

The rate of movement of water from the reactor at West Milton through Glowegee Creek, Kayaderosseras Creek, and Saratoga Lake cannot be determined with any degree of accuracy. In periods of low discharge, the average rate of flow toward Saratoga Lake might be in the magnitude of half a foot per second. In the vicinity of the lake, the rate of flow likely would be less because of backwater from the lake. In the lake itself it would be very low, and the direction of movement might even be temporarily reversed by wind effect.

A study was begun in July 1953 utilizing dye to determine certain stream characteristics of Glowegee and Kayaderosseras Creeks. It was intended as a pilot study to determine the feasibility of a more intensive study of the movement of water in the streams in the West Milton area. The results of the pilot study are included here as they may prove of value if in the future the rate of flow of contaminants in the streams must be determined.

The dye used in these studies was the sodium salt of fluorescein. Dye was added to each stream at several points and the time of addition recorded. Next the time of arrival of the dye at various points downstream was noted. The time of travel of the dye through various reaches of the stream at different rates of discharge was then computed and is shown in table 11. It should be noted that rate of flow varies directly with the stream discharge. However, the rates of flow listed will not necessarily prevail for conditions of discharge other than those that existed at the time of the study.

STORAGE

Under normal conditions, for a given amount of contaminant in a stream or lake, the resulting level of pollution in that stream or lake is inversely proportional to the amount of water stored in that stream or lake. Upstream from station 15 on Kayaderosseras Creek, at which point the drainage area is slightly less than half the total drainage area of the creek, surface storage consists of several small swamps and natural ponds, and small-capacity reservoirs for indus-

TABLE 11.—*Results of dye-tracer studies in Kayaderosseras and Glowegee Creeks*

Reach of stream	Length of reach (mi)	Date of test	Travel time through reach (hr)	Apparent rate of flow in reach (mph)	Average discharge during test [1] (cfs)
Glowegee Creek					
Sta. 9 to sta. 10	2.4	July 1-2, 1953	14½	0.2	6
		Feb. 25, 1954	2⅓	1.0	94
Sta. 10 to point 0.2 miles downstream from sta. 12	2.5	July 8-9, 1953	16¼	.2	8
		Feb. 25, 1954	3	.8	95
Sta. 13 to sta. 14	.6	July 9, 1953	1⅚	.3	8
		Feb. 24, 1954	5/12	1.5	116
		Feb. 25, 1954	½	1.2	110
Sta. 9 to sta. 14	8.6	Feb. 25, 1954	6½	1.3	99
Kayaderosseras Creek					
Mouth of Glowegee Creek to sta. 16	0.4	July 10, 1953	⅚	0.5	44
		Feb. 25, 1954	⅓	1.3	293
Sta. 16 to point 0.6 miles upstream from sta. 17	.8	July 9, 1953	2¼	.4	51
		Feb. 25, 1954	½	1.6	293

[1] At sta. 12 on Glowegee Creek; at sta. 15 on Kayaderosseras Creek.

trial facilities at Rock City Falls. From station 15 to its mouth, several other swamps and ponds exist, and there are reservoirs at Ballston Spa similar to those at Rock City Falls. The total surface storage capacity in the basin is not known, but it is undoubtedly less than that of Saratoga Lake, at the mouth of Kayaderosseras Creek.

Although the total capacity of Saratoga Lake is also unknown, a fair approximation of the change in storage with changes in stage can be presented. The area of the lake, including the lake-level pool in the lake outlet, Fish Creek, above the dam half a mile upstream from Grangerville, N.Y., at normal operating level is about 6.7 square miles. The change in storage of the lake and pool per foot of change in stage is, therefore, about 178 million cubic feet. This storage increment could be appreciably greater in periods of high lake level because of the additional storage that would become available in nearby marshy areas. It should be noted that only about 15 percent of the total area drained by Fish Creek at the dam near Grangerville is outside the Kayaderosseras Creek drainage basin.

SNOW COVER

The meteorologic factors governing the accumulation and depletion of snow cover are beyond the scope of this report. However, snow cover can be considered a surface-water feature, because it represents potential runoff, and as such is noted here.

Snow on a drainage basin forms a storage reservoir with a measureable content but has an unpredictable rate of discharge. In the West Milton area, the water content of the snow cover may be as much as 6 inches. The snow cover may be depleted by sublimation or melting.

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If the depletion is by melting and is not accompanied by rainfall, the snow cover usually maintains streamflow at a high level for a few days or weeks. Rapid melting accompanied by even moderate rainfall can cause floods of considerable magnitude. Most high floodflows in the Kayaderosseras Creek basin have resulted from a combination of water from melting snow and direct precipitation and have occurred during the months of December to April, inclusive.

Snow cover in and near West Milton varies principally with altitude and with exposure. The Geological Survey established five snow courses in the Schenectady-Saratoga Springs area in 1952 (fig. 25).

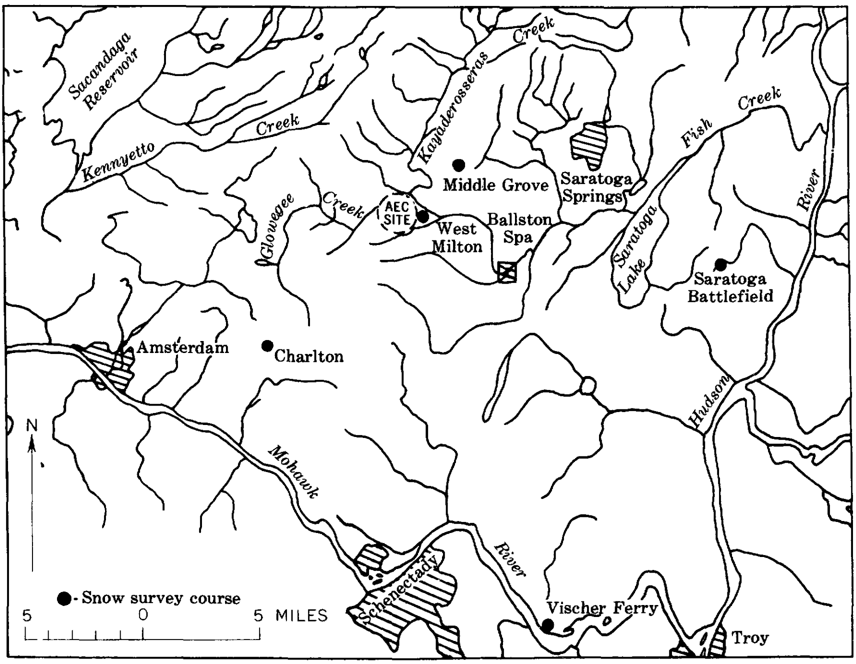


FIGURE 25.—Map showing locations of snow-survey courses in the Schenectady-Saratoga Springs area.

The information obtained from these snow courses through 1956 has been summarized in table 12. These data show that snow cover is present in the West Milton area in most years from the beginning of January through the middle of March.

At present, periodic snow-cover data are most valuable as an index of probable spring runoff and for establishing relations between past events and normal conditions. However, as meteorology becomes a more exact science, the forecasting of snow-pack behavior probably will become more reliable. To date (1958), the amount of data collected on snow cover at West Milton is too limited to warrant interpretation.

TABLE 12.—*Average depth and water content of snow in the Schenectady-Saratoga Springs area*

[Snow depth and water content in inches]

Snow survey period	Drainage basin and course name										Average	
	Star Brook basin near Middle Grove (sta. 28)		Glowegee Creek basin at West Milton (sta. 28)		Kroma Kill basin at Saratoga Battlefield		Alplaus Kill basin near Charlton		Stony Creek basin at Vischer Ferry			
	Snow depth	Water content	Snow depth	Water content	Snow depth	Water content	Snow depth	Water content	Snow depth	Water content	Snow depth	Water content
1952												
Mar. 3-5	16.0	4.31	13.2	3.75	9.3	1.84	9.0	1.62	10.0	2.11	11.5	2.73
Mar. 17-19	19.3	6.30	17.1	5.44	7.5	2.71	5.9	2.41	6.5	2.33	11.3	3.84
1953												
Jan. 5-7	1.0	Trace	1.0	Trace	1.0	Trace	1.0	Trace	1.4	Trace	1.1	Trace
Feb. 2-4	5.6	1.47	5.4	1.30	1.0	do.	1.0	do.	2.3	.35	3.1	.62
Mar. 2-4	3.8	1.17	1.2	Trace	Trace	do.	*1	do.	1	Trace	1.4	.23
Mar. 16-18	----	----	0	0	0	0	0	0	0	0	0	0
1954												
Jan. 4-6	----	----	4.9	.67	5.4	.56	6.2	.67	6.2	.74	5.7	.66
Feb. 1-3	12.7	3.35	11.7	3.27	4.6	1.4	8.7	2.37	4.4	1.68	8.4	2.41
Mar. 1-3	0	0	0	0	0	0	0	0	0	0	0	0
Mar. 15-18	*1	Trace	*1	Trace	*1	Trace	Patches	Trace	Patches	Trace	.6	Trace
1955												
Jan. 3-5	3.7	.56	1.0	do.	1.2	do.	----	----	1.0	do.	1.7	.14
Feb. 1-2	6.1	1.05	5.8	1.20	4.0	.40	----	----	3.0	.24	4.7	.72
Mar. 1-2	7.6	2.60	6.5	2.25	5.0	1.63	----	----	Patches	Trace	4.8	1.62
Mar. 14-16	Patches	Trace	0	0	0	0	----	----	0	0	0	0
Mar. 30, 31	4.2	1.32	3.9	1.25	3.5	.49	----	----	0	0	2.9	.76
1956												
Jan. 3-5	10.9	1.34	9.9	1.20	9.0	1.07	6.7	.87	5.1	.50	8.3	1.00
Feb. 1	3.7	.60	2.4	.40	4.6	.82	2.4	.35	2.0	.4	3.0	.51
Mar. 5-7	10.4	3.04	10.6	3.48	6.1	2.52	4.6	1.69	2.2	.5	6.8	2.25
Mar. 19-21	24.5	6.34	22.5	5.61	20.9	5.33	18.3	3.30	16.5	2.58	20.5	4.63
Apr. 2, 3	18.4	5.83	16.2	5.04	13.5	4.56	12.0	4.27	8.7	3.01	13.8	4.54

* Estimated.

QUALITY OF WATER

CHEMICAL QUALITY

Generally, the chemical quality of surface waters in the streams in the West Milton area reflects the mineral composition of the rocks and soils in the different drainage basins. However, chemical quality is also affected during the precipitation phase of the hydrologic cycle when minute quantities of carbon dioxide, nitrogen, and other gases are absorbed by the precipitation. Chloride, nitrate, and sulfate compounds may also be absorbed before the precipitation reaches the land surface. Industrial wastes may be a contributing source of dissolved solids.

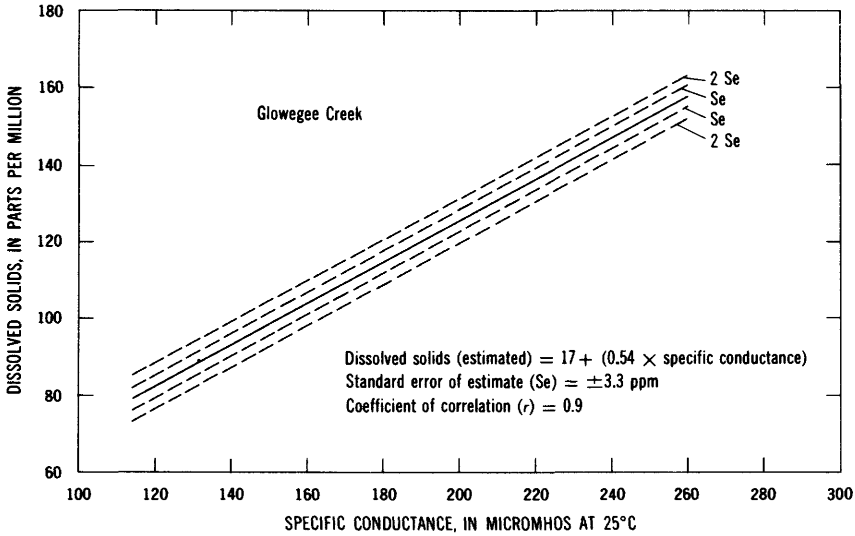
Water in contact with the consolidated and unconsolidated deposits tends to dissolve any soluble minerals that are present. Length of contact time, the chemical character of the solution, and solubility of the minerals will determine how much will be dissolved. Usually, the quantity of mineral matter dissolved by surface runoff is less than that dissolved by ground water because runoff is in contact with earth materials for a much shorter time than ground water. Then, too, vegetation may prevent initmate contact between surface runoff and rock and soil. In contrast, the slow passage of ground water through the soil and underlying deposits aids solution. Because water in a stream is a varying mixture of surface runoff and ground-water inflow, the mineral matter in the stream will also vary, in part, with the contribution from each source. Except during floods and other major storm events, the contribution from ground-water inflow is greater than that from surafce runoff.

The following discussion of the chemical quality of water from Glowegee and Kayaderosseras Creeks in the West Milton area is based on the data accumulated during the period 1949 to 1956. Initially, water samples were collected and analyzed two to four times a year. Later, daily water samples were collected from Glowegee Creek at West Milton from March 1953 through June 1956, and from Kayaderosseras Creek near West Milton from October 1953 through June 1955. Using specific conductance as an approximate measure of the concentration of dissolved solids, daily water samples of similar specific conductance were composited and analyzed. The number of consecutive daily samples composited for any one analysis ranged from 2 to 10.

The range in concentration of dissolved solids, in composites of water samples, from Glowegee Creek was 74 to 158 ppm (table 13). The computed daily concentration of dissolved solids, based on specific conductance and its relation to dissolved solids (fig. 26) ranged from 60 to 160 ppm. The dissolved-solids content equaled or exceeded 152 ppm 5 percent of the time (table 14).

Although concentrations of dissolved solids fluctuated during the period 1950–56, the average concentration of dissolved solids was about the same for each year (fig. 27).

Calcium was the main cation in solution in water samples from Glowegee Creek. The concentrations are comparable to those determined in ground water obtained from unconsolidated deposits in the area. Apparently, these deposits contain fragments of limestone and dolomite which are the sources of moderate quantities of calcium. During 1949–54, the range of calcium concentrations was 15 to 33 ppm, and the average was 27 ppm. These concentrations were about 2.5 to 3 times greater than those of magnesium; as much as 11 times greater than those of sodium; and as much as 37 times greater than those of potassium. As the concentrations of dissolved solids increased above 120 ppm, concentrations of calcium fluctuated within a narrow range of 25 to 30 ppm. The average ratio of calcium concentrations to those of dissolved solids was 0.21 or approximately



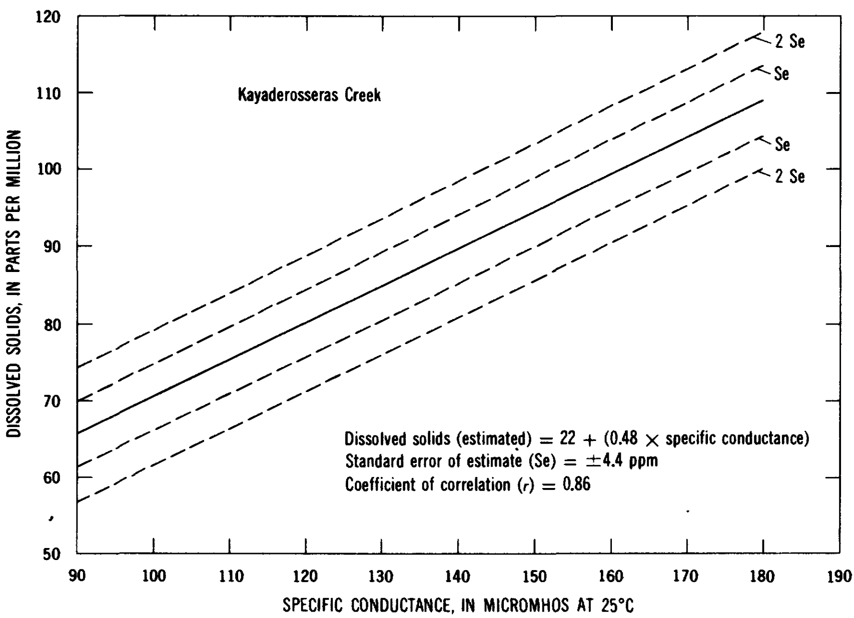


FIGURE 26—Relation between dissolved-solids content and specific conductance of water from Glowegee Creek at West Milton, N.Y. (sta. 12), during the period July 1949–February 1954, and from Kayaderosseras Creek at station 16 during the period 1949-54.

TABLE 13.—*Summary of chemical analyses of water from Glowegee Creek at West Milton, N.Y. (sta. 12) for the period 1949–56*

[Results in parts per million except as indicated]

Constituents	Minimum	Average	Maximum	Number of analyses
Silica (SiO_2)	2.8	9.8	35	73
Iron (Fe)	.00	.30	3.4	26
Calcium (Ca)	15	27	33	50
Magnesium (Mg)	5.3	9.5	14	50
Sodium (Na)	1.3	2.6	4.4	50
Potassium (K)	.4	.8	2.3	50
Bicarbonate (HCO_3)	32	102	158	164
Sulfate (SO_4)	10	19	44	76
Chloride (Cl)	1.0	4.0	7.2	161
Fluoride (F)	.0	.1	.3	50
Nitrate (NO_3)	.3	.8	1.8	76
Dissolved solids	74	131	158	50
Hardness as $CaCO_3$	51	102	138	164
Specific conductance (micromhos at 25° C)	104	206	265	164
pH	6.0	----------	9.3	164
Color	0	13	45	158

TABLE 14.—*Percent of days when concentrations of dissolved solids were equaled or exceeded in water samples from Glowegee Creek at West Milton (sta. 12) during the period 1949–56*

[Computed from daily measurements of specific conductance and 50 analyses relating conductance to dissolved solids (fig. 26)]

	Percent					
	5	10	25	50	75	90
Dissolved solids (ppm)	152	149	142	133	120	79

21 percent (in ppm) of the chemical composition of the dissolved solids.

The relatively low concentrations of calcium and magnesium were, in the main, responsible for the moderate hardness of the water from Glowegee Creek. About 75 percent of the time, during 1949–56, the hardness of the water of Glowegee Creek equaled or exceeded 89 ppm; the range for the period was 51 to 138 ppm and the average was 102 ppm (table 13). Fluctuations in hardness were evident, but the average and maximum hardness were approximately the same from year to year (fig. 27).

Bicarbonate was the principal anion in solution; approximately 40 percent of the dissolved solids (in ppm) consisted of carbonate (the altered form of bicarbonate in the residue for the determination of dissolved solids). The bicarbonate ion is the end product of the reaction of carbon dioxide in water and calcium carbonate. Apparently, concentrations of carbon dioxide in Glowegee Creek were insufficient to effect complete conversion of the carbonate to bicarbonate because carbonate ion was also present in a few samples—in concentrations of as much as 24 ppm.

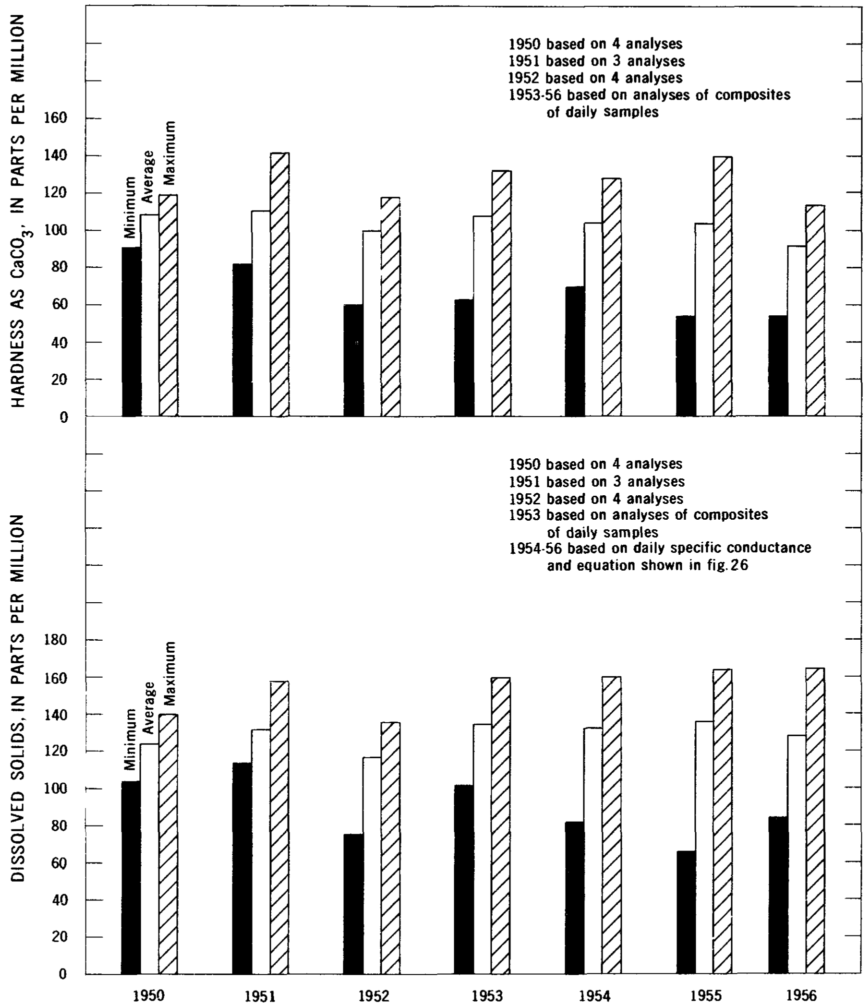


FIGURE 27.—Hardness and dissolved-solids content of water from Glowegee Creek at West Milton, N.Y. (sta. 12), during the period 1950–56.

Other cations and anions normally present in surface waters were also in solution but in lesser concentrations. Generally, these would have no significant bearing on the utility of the water from Glowegee Creek. The concentrations of iron, however, may be sufficient at times to cause staining and deposition; the maximum iron concentration determined in water samples from Glowegee Creek was 3.4 ppm; the average 0.30 ppm (table 13).

The concentrations of various dissolved constituents in water from Kayaderosseras Creek were less than those for Glowegee Creek. The range of dissolved solids in composite water samples was from

70 to 112 ppm; the average dissolved-solids content was 93 ppm (table 15). The relation between dissolved-solids content and specific conductance of water from Kayaderosseras Creek at station 16 during the period 1949–54 is shown in figure 26. In water from Kayaderosseras Creek the median concentration of dissolved solids was 95 ppm (table 16). For Glowegee Creek the median was 133 ppm (table 14).

TABLE 15.—*Summary of chemical analyses of water from Kayaderosseras Creek at station 16 for the period November 1949–September 1954*

[Results in parts per million except as indicated]

Constituents	Minimum	Average	Maximum	Number of analyses
Silica (SiO_2)	4.8	8.1	12	49
Iron (Fe)	.00	.13	.40	37
Calcium (Ca)	12	18	22	49
Magnesium (Mg)	3.2	6.0	8.2	49
Sodium (Na)	1.4	2.5	4.2	49
Potassium (K)	.2	.7	1.2	49
Bicarbonate (HCO_3)	32	[1] 68	92	101
Sulfate (SO_4)	3.2	12	22	64
Chloride (Cl)	.6	[1] 3.1	16	101
Fluoride (F)	.0	.1	.4	49
Nitrate (NO_3)	.3	.6	1.8	64
Dissolved solids	70	93	112	49
Hardness as $CaCO_3$	42	[1] 68	88	101
Specific conductance (micromhos at 25°C)	90.3	[1] 141	188	101
pH	5.8		8.1	101
Color	2	[1] 12	40	85

[1] Average for the period Nov. 1949–June 1955.

TABLE 16.—*Percent of days in which concentrations of dissolved solids tabulated were equaled or exceeded in Kayaderosseras Creek at station 16 during the period 1949–54*

[Computed from daily measurements of specific conductance and 49 analyses relating conductance to dissolved solids (fig. 26)]

	Percent					
	5	10	25	50	75	99
Dissolved solids (ppm)	106	104	100	95	87	67

A plot of the dissolved-solid concentrations of the two creeks shows a linear relation with a correlation of 0.8 (a correlation of 1 is considered perfect correlation). (See fig. 28.) On the basis of this relation, the Kayaderosseras Creek station near West Milton could serve as an index of the chemical quality of Glowegee Creek, if the chemical quality of either stream remains unaffected by pollution.

The chemical composition of water from Kayaderosseras Creek was similar to that of Glowegee Creek. Calcium was the principal cation in solution. Magnesium concentrations were approximately two-thirds less. Bicarbonate was the principal anion in solution. Other cations and anions such as sodium, potassium, iron, chloride

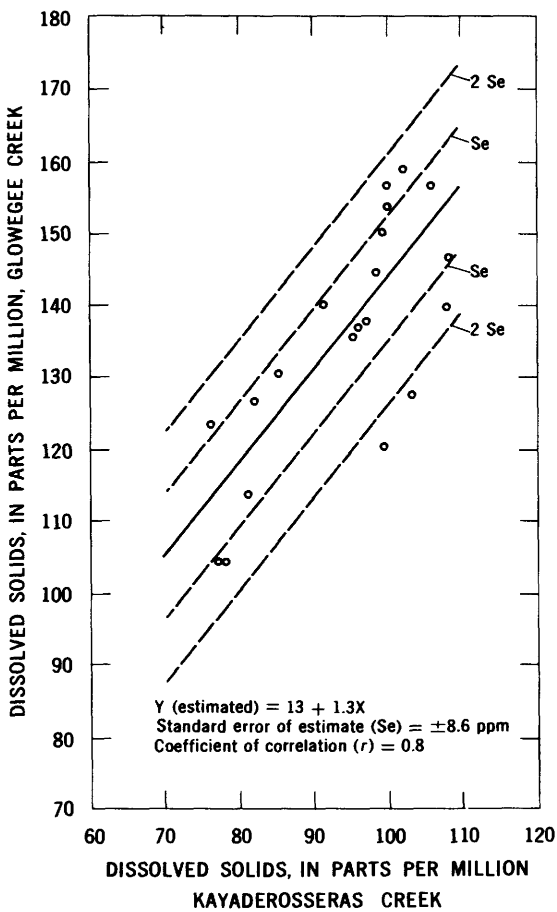


FIGURE 28.—Relation between dissolved solids in water from Glowegee Creek at West Milton, N.Y. (sta. 12) and dissolved solids in water from Kayaderosseras Creek at station 16, during the period 1949–54.

and sulfate generally contributed very little to the dissolved-solids content (table 15).

Because of the lower concentrations of calcium and magnesium, the hardness of water from Kayaderosseras Creek was less than that for Glowegee Creek. About 75 percent of the time, the hardness of Kayaderosseras Creek water equaled or exceeded 66 ppm. The range of hardness for the period of record was 42 to 88 ppm; the average, 68 ppm (table 15).

As is apparent from a review of tables 13 and 15, concentrations of dissolved solids and chemical constituents fluctuated in water samples from Glowegee and Kayaderosseras Creeks. In this, streamflow is a major factor. During periods of base flow, ground-water inflow is the principal component of streamflow. At such times, the concentrations of dissolved solids are usually at their peak. During periods of precipitation, the proportion of surface runoff to ground-water inflow increases. As mentioned previously (p. 75), surface runoff usually contains less mineral matter than ground water. Moreover, because of dilution, concentrations of dissolved solids and chemical constituents are lower during periods of precipitation than during periods of base flow. This is apparent in water from Glowegee and Kayaderosseras Creeks. (See pl. 3.) However, irrespective of the extent and duration of high flow, the specific conductance did not fall below 112 and 90.3 micromhos at 25° C in samples of Glowegee and Kayaderosseras Creeks, respectively; dissolved-solids contents computed from these conductance values are 77 and 67 ppm.

The chemical composition of water from Glowegee and Kayaderosseras Creeks is affected in large degree by the geology of the basin. However, streamflow is also a determining factor in the dissolved-solids content of the water. During the period of study the effects of these factors have been well established. Consequently, the chemical quality of either stream will not change appreciably with time, unless pollution becomes significant in streams in the Kayaderosseras Creek basin.

RADIOCHEMICAL QUALITY

Most natural waters contain small amounts of radioactive substances which are dissolved from the rocks over and through which the water has passed. Cosmic radiation and, in recent years, fallout resulting from nuclear tests are contributing sources of radioactivity. Generally, such activity is insignificant except in areas where radioactive minerals are abundant or fallout has been severe. However, use of surface waters as a means of disposing of low-level radioactive wastes resulting from use of nuclear energy in research and industry may create an unusual pollution problem and another contributing source of radioactivity.

To determine radioactivity of Glowegee and Kayaderosseras Creeks prior to operations in the West Milton area, periodic radiochemical analyses were made of water samples collected from these two creeks. The analyses included determination of radium, a naturally occurring radioactive element in water. In addition, since the artificial radioactive substances, such as fission products, are predominantly beta and gamma emitters, measurements of beta-gamma activity were also made. Because of the operational limitation of the instrument, all beta activity was measured and only about 2 percent of the gamma activity.

The analyses were made by the following laboratories: Trace Elements Laboratory and Quality of Water Branch, U.S. Geological

Survey, Washington, D.C.; National Bureau of Standards, Washington, D.C.; and Health Physics Unit, Knolls Atomic Power Laboratory, Schenectady, N.Y. A brief description of the methods used by these laboratories follows.

Laboratory	Method of Analysis	
	Radium	Beta
Health Physics Unit, Knolls Atomic Power Laboratory.	------------------------	Evaporation of a sample of water to dryness; treatment with acid; evaporation and transfer to planchet. Determination of total beta activity and about 2 percent gamma activity using a thin mica end window Geiger-Müller tube.
National Bureau of Standards.	Accumulation of radon resulting from disintegration of radium for about 10 days; purification and counting in an ionization chamber.	Do.
Quality of Water Branch, U.S. Geological Survey.	Concentration of sample and coprecipitation of radium with barium sulfate; filtration and aging of precipitate to allow build up of short-lived daughter products; counting with an alpha scintillation counter. Activity is determined by comparison of counts obtained with that of blanks and standards.	Do.
Trace Elements Laboratory, U.S. Geological Survey.	Same as used by National Bureau of Standards.	Do.

The results of the analyses show that, usually, beta activity and concentrations of radium were insignificant at all the sampling stations at the time of sample collection. (See table 17.) Any increases in beta activity shown in the table are attributed to fallout resulting from nuclear tests made in Nevada and the Pacific from 1951 through 1953.

TEMPERATURE

Generally, the temperature of surface water fluctuates in a cyclic pattern following seasonal changes. Shallow streams in particular will follow changes in air temperature closely. In contrast, deep rivers follow changes in air temperature more slowly. In many streams, thermal gradients are established from surface to bottom. This cyclic seasonal pattern, however, may be modified by inflow of industrial wastes and domestic sewage into a stream. It may also be slightly displaced from year to year depending on the variations in climate.

Temperature of water influences many of the chemical and physical processes that take place in a stream. The solubility of gases is closely related to temperature. Solution of mineral matter also is affected by temperature. Oxidation of organic material is promoted or retarded by favorable or unfavorable temperatures. Algal and bacterial growth are similarly affected. Such hydrologic properties as density and viscosity also vary with temperature. In the disposal of liquid wastes into a stream, differences of temperature between two liquids, among other factors, will determine depth of stratification and length of time before thermal equilibrium is established. A change in viscosity will effect a change in the settling rate of suspended sediment.

In addition to the temperature effects mentioned above, the temperature of water has a bearing on its utility. Because water is an excellent heat-exchange medium, it is used extensively for cooling purposes. Temperature of water is an indirect measure of its capacity to absorb heat energy and is a measure of its utility for cooling purposes.

In the Kayaderosseras Creek basin, temperature recorders were operated in conjunction with stage measurements of Glowegee Creek at West Milton (sta. 12) and Kayaderosseras Creek near West Milton (sta. 16). Air temperatures were obtained from publications of the U.S. Weather Bureau. The air-temperature data had been collected at Greenfield, NY. (sta. 25). After June 1955, air-temperature data was obtained from the Atomic Energy Commission's installation at West Milton (sta. 26).

Generally, the temperature of Glowegee Creek follows the typically erratic pattern of a shallow stream sensitive to air temperature (pl. 4). The temperature of the stream rises gradually, however, in contrast to the abrupt rises in air temperature. Surface runoff and increased streamflow are believed to be the modifying influences; the former because it usually supplies cooler water to a stream; the latter because as stream volume increases, the capacity of the stream to absorb heat becomes greater. During base flow, changes in water temperature follow the air temperature pattern closely, but the changes are not as pronounced as those of air temperature.

For the period October 1953–June 1956, the water temperature in Glowegee Creek dropped below 50°F early in November, hovered around 32°F until March, and rose to a maximum during the summer

TABLE 17.—*Radiochemical analyses, in micromicrocuries of water from Kayaderosseras Creek at station 16, and from Glowegee Creek at stations 9 and 12*

Date sample collected	Beta (μμc per liter) *	Radium (μμc per liter) *	Remarks
Kayaderosseras Creek (sta. 16)			
1951			
Mar. 13	[1]<100	[1]0.7	12 nuclear tests made in Nevada and 4 in the Pacific during 1951.
June 20	[1]<50	[1]<1	
Oct. 2	[1]<100	[1]<1	
1952			
Jan. 9	[1]<50	[1]1	8 nuclear tests made in Nevada and 2 in the Pacific during 1952.
Apr. 28	[1]<50	[3].22	
June 24	[1]<100	[3]<.1	
Sept. 30	[2]<10	[3]<.1	
1953			
Jan. 13	[2]<5	[3].65	11 nuclear tests made in Nevada during 1953.
Apr. 27	[2]<10	[3].2	
Glowegee Creek (sta. 9)			
1951			
Mar. 13	[1]<100	[1]<1	12 nuclear tests made in Nevada and 4 in the Pacific during 1951.
June 20	[1]<100	[1]<1	
Oct. 2	[1]<100	----------	
Nov. 8	[4]54	----------	
1952			
June 24	[1]<100	[3].51	8 nuclear tests made in Nevada and 2 in the Pacific during 1952.
Sept. 30	[2]<10	[2].19	
1953			
Jan. 13	[2]<10	[3].73	11 nuclear tests made in Nevada during 1953.
Apr. 27	[2]<10	[3].21	
Apr. 29	[4]60	----------	
Glowegee Creek (sta. 12)			
1951			
Mar. 13	[1]<100	[1]0.70	12 nuclear tests made in Nevada and 4 in the Pacific during 1951.
June 20	[1]<100	[1]<1	
Oct. 2	----------	[1]<1	
Nov. 5	[4]240	----------	
1952			
Jan. 9	[1]<200	[1]<1	8 nuclear tests made in Nevada and 2 in the Pacific during 1952.
Apr. 1	[1]<50	[3].32	
Apr. 2	[1]<50	[3]1.56	
Apr. 3	[1]<50	[3]<.10	
Apr. 26	[1]<50	[3]<.42	
Apr. 28	[1]<50	[3]<.75	
June 24	[1]<100	[3]<.95	
Sept. 24	[2]<10	[2]<.24	
1953			
Jan. 13	[2]<10	[3]<.1	11 nuclear tests made in Nevada during 1953.
Apr. 29	[4]100	----------	

[1] Analyses made by Trace Elements Laboratory, U.S. Geological Survey.
[2] Analyses made by Quality of Water Branch, U.S. Geological Survey.
[3] Analyses made by National Bureau of Standards.
[4] Analyses made by Health Physics unit, Knolls Atomic Power Laboratory.
* Numerical expressions of "less than" vary with volume of sample analyzed converted to a liter basis and instrument detection level. Includes all beta activity and about 2 percent of gamma activity.

months; a maximum of 81°F was reached in 1953, and 76°F was the maximum in each of the succeeding years through 1956. However, the temperature of Glowegee Creek equaled or exceeded 70°F only 10 percent of the time (fig. 29). Discharge of the plant effluent resulting from operation of the atomic reactor in the West Milton area from April 1955 to March 1957 had no apparent effect on the water temperature of Glowegee Creek.

The water temperature of Kayaderosseras Creek followed a pattern similar to that of Glowegee Creek, fluctuating seasonally and closely following changes in air temperature. The median temperature for

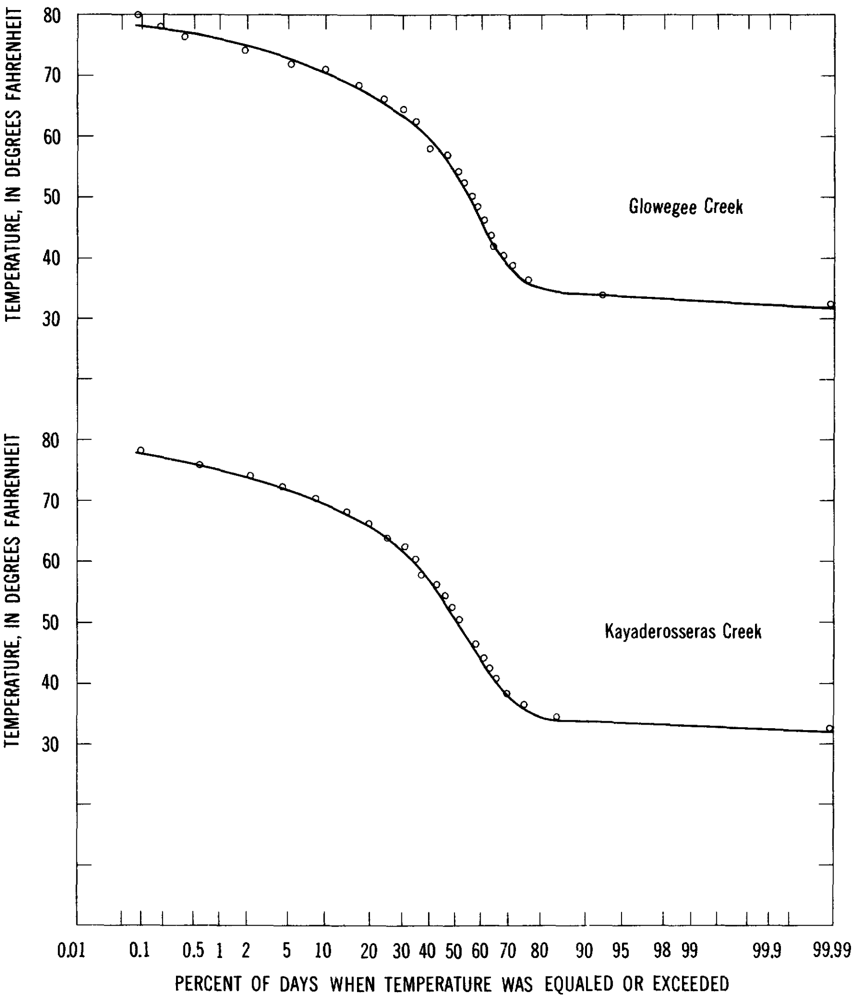


FIGURE 29.—Temperature frequency curve for water in Glowegee Creek at West Milton, N.Y. (sta. 12) for the period March 1953–September 1956 and for water in Kayaderosseras Creek near West Milton, N.Y. (sta. 15) for the period June 1949–September 1956.

the period of record was 50°F (fig. 29); the maximum was 83°F. However, the water temperature of Kayaderosseras Creek equaled or exceeded 69°F only 10 percent of the time (fig. 29). The water temperature of Kayaderosseras Creek from 1951 to 1956 is summarized in table 18.

TABLE 18.—*Annual minimum, average, and maximum temperatures of water in Kayaderosseras Creek near West Milton, N.Y. (sta. 15) for the years 1951–56*

Year	Minimum	Average	Maximum	Year	Minimum	Average	Maximum
1951	33	49	75	1954	32	49	75
1952	33	49	77	1955	32	50	83
1953	33	50	78	1956	32	47	76

SUSPENDED SEDIMENT

Stream sediment is derived principally from soil particles eroded from the land surface and transported by surface runoff. How much is eroded and transported will vary with the kind of material available, land use, stage of land erosion, vegetal cover, intensity and duration of rainfall, and topography. Generally, the composition of the stream sediment (usually clay, silt, and sand) will vary with the availability of the materials in the drainage basin.

The streambed and banks are contributing sources of supply. Sediment temporarily deposited on the bed can be picked up and transported in suspension or by a series of hops, rolls, or slides along the bottom. Gradual erosion of the banks will contribute to the sediment load; if bank cavitation takes place, substantial quantities of material will be added temporarily to the load.

Sediment in streams may present a number of problems. If deposited in reservoirs, lakes, or ponds, it will decrease the storage capacity of these facilities. Sediment in a source of water supply must be removed before the water can be used for many purposes. The recreational use of streams is impaired if they are heavily laden with sediment. In recent years, sediment has been considered in conjunction with disposal of radioactive wastes because most sediments are capable of adsorbing and transporting radioactivity in varying degrees.

During the period of March 1952 to September 1955, suspended sediment samples were collected periodically (four to six times a year) from Glowegee Creek at West Milton (sta. 12), and daily from Kayaderosseras Creek near West Milton (sta. 16) from February 1953 to June 1955.

Depth-integrated samples were collected with equipment especially designed for the collection of sediment samples. The sample was accumulated continuously as the sampler moved vertically at a constant rate. At each level in the vertical, a portion of the water-sediment mixture was collected at a velocity equal to the stream velocity at that level. Because of the size of the sampler, the sampling zone in the vertical extended from the water surface to about 0.3 foot from the streambed.

In the laboratory, the concentration (in parts per million) of suspended sediment was computed from the ratio of the dry weight of sediment to the weight of the water-sediment mixture. The suspended-sediment discharge in tons per day was then computed using the concentration, stream discharge, and a factor incorporating time and specific weight of water-sediment mixture in pounds per cubic foot.

During the low-flow periods, suspended-sediment load in Glowegee and Kayaderosseras Creeks was less than 10 tons per day. (See figs. 30 and 31.) These were periods of very little precipitation and low runoff. During the summer and early fall, the extensive vegetal cover in the Kayaderosseras Creek basin was helpful in reducing soil erosion. During the winter months, frozen ground and snow cover

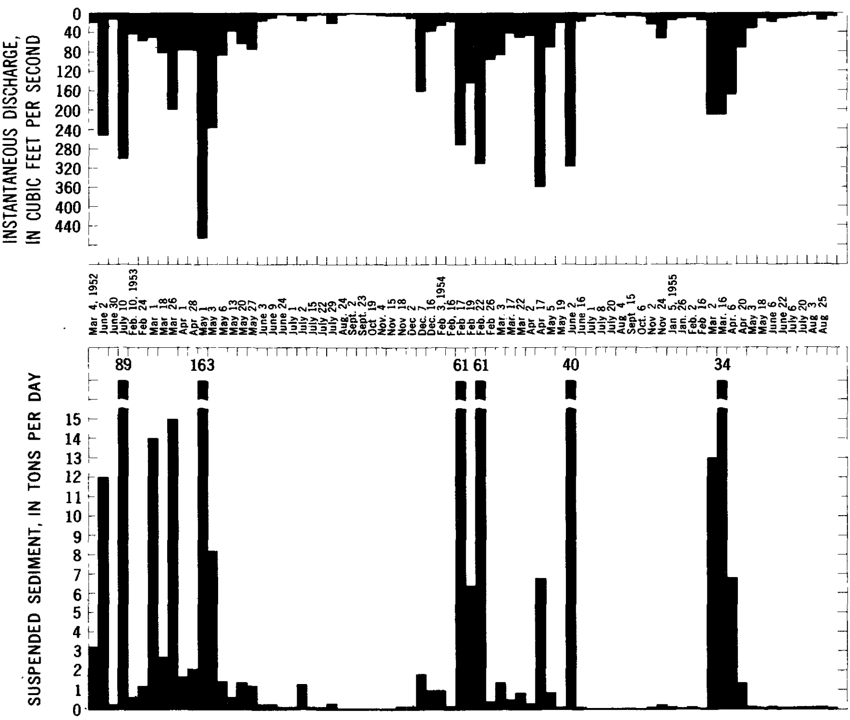


FIGURE 30.—Suspended-sediment load and instantaneous water discharge of Glowegee Creek at West Milton, N.Y. (sta. 12) during the period March 1952–September 1955.

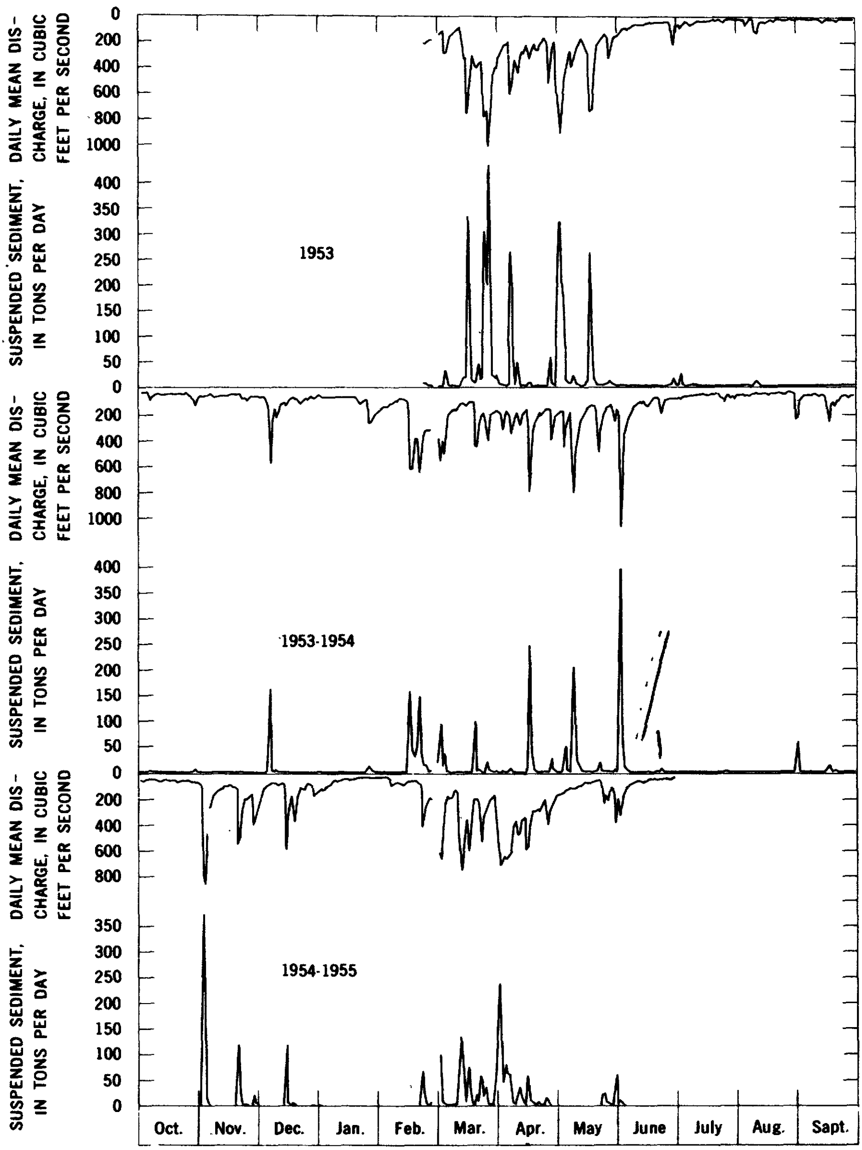


FIGURE 31.—Graphs showing the daily suspended-sediment discharge of Kayaderosseras Creek at station 16 and daily water discharge of Kayaderosseras Creek near West Milton (sta. 15), for the period February 1953–June 1955.

reduced soil erosion. Moreover, during periods of low flow, stream velocities were not sufficient to create turbulence capable of suspending sand particles above streambeds.

During flood periods, the suspended-sediment load in Glowegee Creek at West Milton (sta. 12) was somewhat greater than at lower discharges, but usually it was less than 15 tons per day (table 19).

TABLE 19.—*Suspended-sediment load and water discharge of Glowegee Creek at West Milton, N.Y. (sta. 12)*

[March 1952 to September 1955]

Date of collection	Time	Instantaneous discharge (cfs)	Suspended sediment: Concentration (ppm)	Suspended sediment: Tons per day
1952				
Mar. 4	2:00 p.m.	21	56	3.2
June 2	9:40 a.m.	254	18	12
June 30	3:00 p.m.	14	4	.2
July 10	2:10 p.m.	302	109	89
1953				
Feb. 10	3:40 p.m.	42	5	.6
Feb. 24	2:35 p.m.	58	8	1.2
Mar. 1	1:50 p.m.	51	104	14
Mar. 18	10:20 a.m.	84	12	2.7
Mar. 26	2:30 p.m.	202	28	15
Apr. 1	1:50 p.m.	78	8	1.7
Apr. 28	11:15 a.m.	77	10	2.1
May 1	9:00 a.m.	467	129	163
May 3	2:45 p.m.	236	13	8.3
May 6	4:05 p.m.	90	6	1.4
May 13	11:10 a.m.	38	6	.6
May 20	3:35 p.m.	64	8	1.4
May 27	12:30 p.m.	77	6	1.2
June 3	7:45 a.m.	17	4	.2
June 9	3:15 p.m.	12	6	.2
June 24	8:00 a.m.	4.1	2	Trace
July 1	8:25 a.m.	6.3	4	.1
July 2	2:20 p.m.	18	26	1.3
July 15	8:40 a.m.	4.8	3	Trace
July 22	10:45 a.m.	3.2	6	.1
July 29	10:30 a.m.	24	4	.3
Aug. 24	9:30 a.m.	1.5	8	Trace
Sept. 2	9:15 a.m.	.8	4	Trace
Sept. 23	12:50 p.m.	2.9	6	Trace
Oct. 19	9:45 a.m.	3.4	4	Trace
Nov. 4	1:10 p.m.	6.7	2	Trace
Nov. 15	3:35 p.m.	6.9	2	Trace
Nov. 18	9:00 a.m.	6.0	4	.1
Dec. 2	11:15 a.m.	12	2	.1
Dec. 7	10:00 a.m.	164	4	1.8
Dec. 16	1:15 p.m.	36	5	.5
1954				
Feb. 3	10:45 a.m.	28	7	.5
Feb. 16	10:30 a.m.	18	4	.2
1954—Con.				
Feb. 17	12:25 p.m.	272	83	61
Feb. 19	2:15 p.m.	147	16	6.4
Feb. 22	11:00 a.m.	311	73	61
Feb. 26	10:40 a.m.	97	13	.4
Mar. 3	10:20 a.m.	86	6	1.4
Mar. 17	10:15 a.m.	44	4	.5
Mar. 22	4:20 p.m.	50	5	.7
Apr. 2	10:15 a.m.	48	2	.3
Apr. 17	10:20 a.m.	361	7	6.8
May 5	2:15 p.m.	71	4	.8
May 19	10:10 a.m.	22	1	.1
June 2	7:55 a.m.	319	47	40
June 16	9:50 a.m.	19	1	.1
July 1	9:40 a.m.	7.6	1	Trace
July 8	1:20 p.m.	3.4	0	Trace
July 20	9:30 a.m.	4.3	1	Trace
Aug. 4	9:00 a.m.	8.0	2	Trace
Sept. 15	11:15 a.m.	4.6	1	Trace
Oct. 6	11:05 a.m.	6.1	2	Trace
Nov. 2	10:30 a.m.	23	1	.1
Nov. 24	10:40 a.m.	53	2	.3
1955				
Jan. 5	10:15 a.m.	14	4	.2
Jan. 26	10:15 a.m.	6.1	4	.1
Feb. 2	10:30 a.m.	4.4	5	.1
Feb. 16	10:45 a.m.	13	.3	Trace
Mar. 2	11:00 a.m.	208	24	13
Mar. 16	11:30 a.m.	208	61	34
Apr. 6	10:30 a.m.	168	15	6.8
Apr. 20	12:15 p.m.	70	8	1.5
May 5	1:20 p.m.	27	1	.1
May 18	11:50 a.m.	8.8	2	Trace
June 6	2:05 p.m.	20	1	.1
June 22	12:20 p.m.	5.8	2	Trace
July 6	12:45 p.m.	3.7	.5	Trace
July 20	11:45 a.m.	3.4	.3	Trace
Aug. 3	12:10 p.m.	2.3	6	Trace
Aug. 25	11:20 a.m.	16	2	.1
Sept. 7	1:30 p.m.	4.4	2	Trace

The available data indicate that the maximum sediment discharge was 163 tons per day at an instantaneous discharge of 467 cfs and a sediment concentration of 129 ppm. In contrast, on April 17, 1954, when instantaneous discharge was 361 cfs and sediment concentration was only 7 ppm, the suspended sediment discharge was only 6.8 tons per day. Such differences in sediment discharge for equal stream discharges or discharges of the same order of magnitude are characteristic of many streams. Although the relation between sediment discharge and stream discharge is complex, it is obvious that the sediment load increases sharply during periods of high overland runoff (fig. 32). Intensity and duration of rainfall, stage of land erosion, and vegetal cover are among the contributing factors. Then,

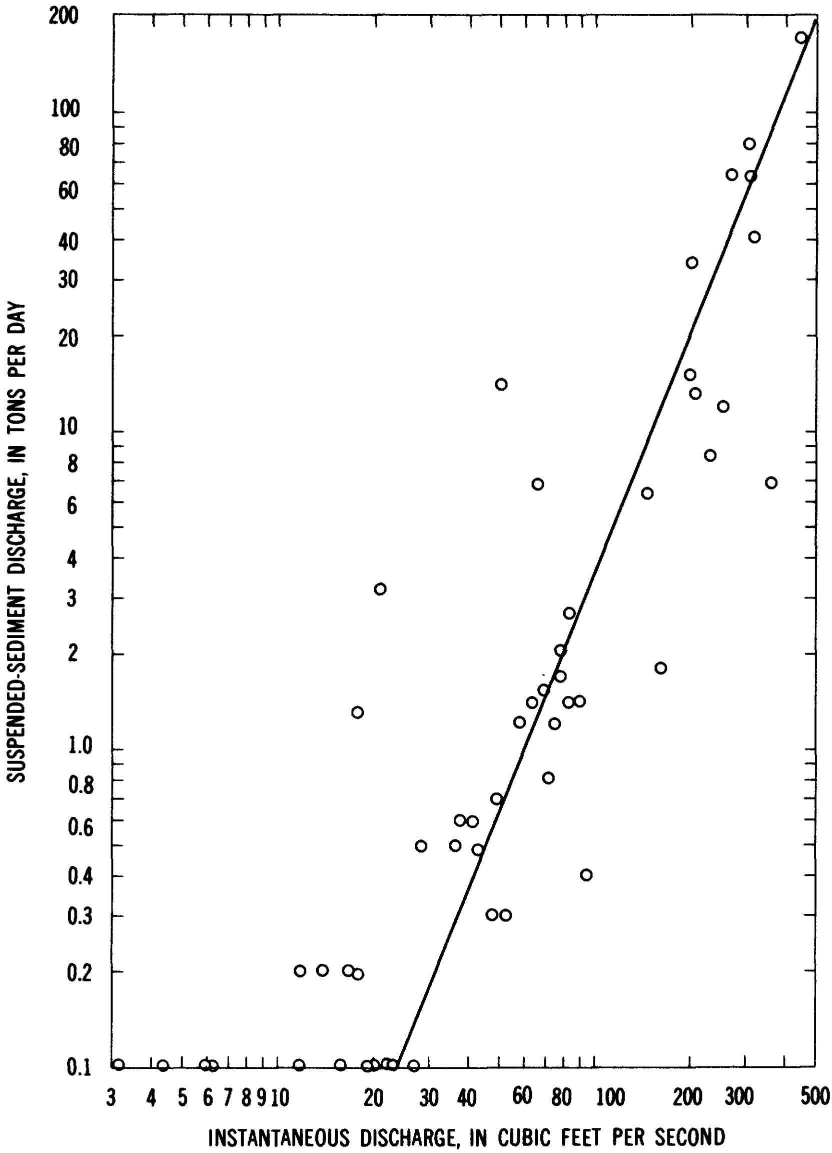


FIGURE 32.—Relation between suspended-sediment discharge and instantaneous water discharge of Glowegee Creek at West Milton, N.Y. (sta. 12), during the period March 1952–September 1955.

too, bank cavitation and bed scour may temporarily increase the sediment load.

In Kayaderosseras Creek near West Milton the suspended-sediment load did not increase appreciably with small increases of water discharge. Usually, the sediment load was low—10 tons or less per day.

As mentioned previously, the drainage basin is wooded and covered with vegetation—an effective means of reducing soil erosion. Then, too, there are dams located at Rock City Falls, about 4 miles upstream from the sampling station. Sediment accumulates behind these dams, thereby reducing the quantity of sediment carried downstream.

However, as stream discharge rose to 400 cfs and higher, sediment discharge increased to more than 50 tons per day; the maximum for the period of record was 437 tons per day. The rapid rise in sediment discharge with substantial increases of stream discharge appears to be characteristic of Kayaderosseras Creek. (See fig. 33.)

As in Glowegee Creek, the suspended-sediment load of Kayaderosseras Creek varied for a given discharge. The same factors advanced to account for the differences in load for Glowegee Creek are also advanced for Kayaderosseras Creek. Then, too, scouring of material deposited behind dams may temporarily increase the sediment load during high flow.

Total monthly sediment loads in Kayaderosseras Creek at station 16 near West Milton are given in table 20.

TABLE 20.—*Total monthly suspended-sediment load (tons) of Kayaderosseras Creek at station 16 near West Milton, March 1953–June 1955*

	1953	1954	1955
January		33. 1	11. 0
February		601. 7	117. 6
March	1, 984. 0	335. 7	1, 014. 9
April	748. 6	449. 1	908. 2
May	1, 208. 6	507. 7	110. 7
June	39. 4	503. 2	21. 0
July	41. 6	13. 2	
August	27. 5	61. 2	
September	4. 3	41. 9	
October	18. 4	3. 2	
November	7. 0	697. 9	
December	196. 8	158. 9	

It does not appear that either Glowegee Creek or Kayaderosseras Creek will transport large quantities of suspended sediment during low and even medium flows. Usually, the suspended load will be less than 10 tons per day. However, during floods, substantial increases in suspended-sediment load can be expected for short periods.

BED MATERIAL

A series of bed-material samples was collected from Kayaderosseras Creek, Glowegee Creek, and Saratoga Lake and its outlet Fish Creek. (See fig. 34 and table 21.) The first series of samples was collected on November 2, 1954, during a rising stage; the daily mean discharge of

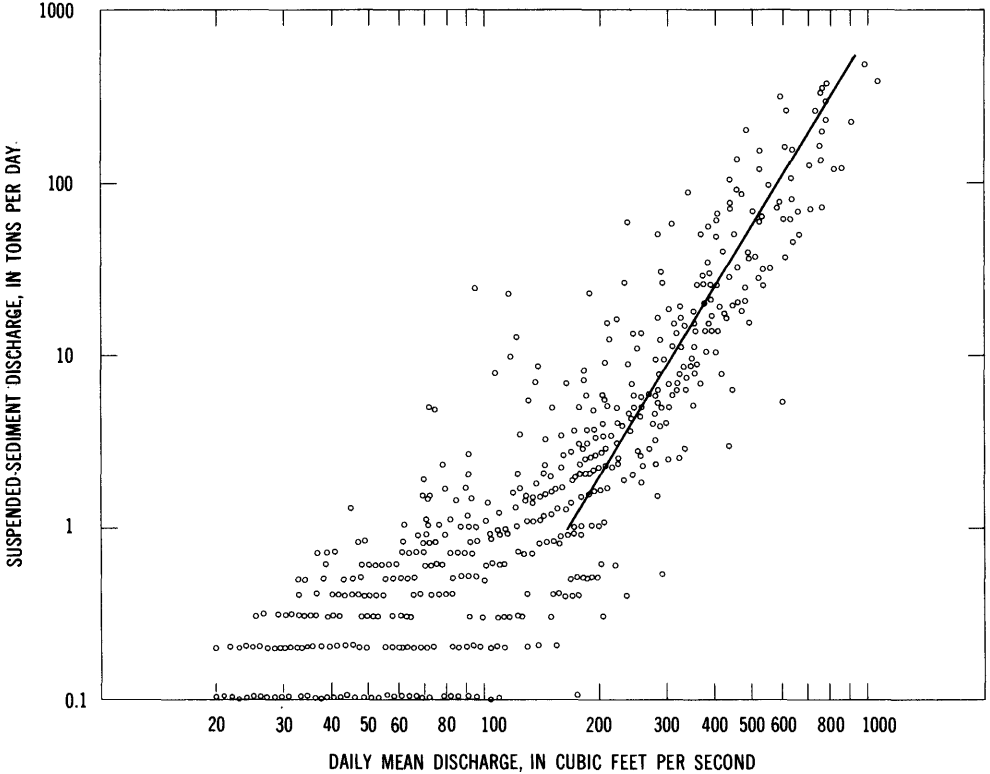


FIGURE 33.—Relation between the suspended-sediment discharge of Kayaderosseras Creek at station 16 and water discharge of Kayaderosseras Creek near West Milton, N.Y. (sta. 15), during the period February 1953–June 1955.

TABLE 21.—*Particle-size analyses of bed material in Kayaderosseras Creek-Fish Creek drainage basin*

[Methods of analysis: Bottom withdrawal tube, chemically dispersed in distilled water for sizes less than 0.062 mm, mechanically seived for sizes greater than 0.062 mm]

Site	Location	Date of collection	Bed material sediment: Percent finer than indicated size, in millimeters										
			0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	2.000
1	Kayaderosseras Creek near Porter Corners, center of downstream side of highway bridge 1.0 mile east of Porter Corners.	Nov. 9, 1954							1	11	68	98	100
		June 24, 1955							1	8	57	96	100
2	Kayaderosseras Creek at Daketown School, near right bank of downstream side of highway bridge 1.5 miles north of Middle Grove.	Nov. 9, 1954						1	3	13	76	99	100
		June 24, 1955						1	11	45	94	99	100
4	Kayaderosseras Creek at Rock City Falls, near left bank behind dam of Cotrell Paper Co., upper plant.	Nov. 9, 1954						1	2	8	39	88	100
		June 24, 1955						1	4	12	46	91	100
7	Kayaderosseras Creek at West Milton, near left bank of old dam site 0.5 mile northeast of West Milton.	June 24, 1955	1	1	3	4	6	12	31	62	94	99	100
9	Glowegee Creek near West Milton, 75 ft downstream of bridge at Bell School, 2.2 miles west of West Milton.	June 24, 1955	3	6	10	15	21	49	54	62	66	84	100
10	Glowegee Creek at West Milton, upstream of bridge on Reactor Road, 0.8 mile west of West Milton.	June 24, 1955	1	2	4	6	14	29	73	96	98	99	100
11	Glowegee Creek at West Milton, 25 ft downstream of abandoned bridge 0.8 mile west of West Milton.	Nov. 9, 1954						1	4	36	93	99	100
12	Glowegee Creek at West Milton, opposite U.S.G.S. gaging station, 0.5 mile south of West Milton.	Nov. 2, 1954	1	2	2	4	7	18	30	61	99	100	
13	Glowegee Creek at West Milton, 50 ft upstream of highway bridge on Dewar Road, 0.8 mile southeast of West Milton.	Nov. 9, 1954							1	9	78	99	100
		June 24, 1955						1	3	13	59	83	100
14	Glowegee Creek near West Milton, 50 ft upstream of bridge on Lewis Road, 1.1 miles east of West Milton.	Nov. 9, 1954							1	3	9	62	100
		June 24, 1955						3	9	24	54	85	100
16	Kayaderosseras Creek near West Milton, 100 ft downstream of bridge on Lewis Road, 1.4 miles east of West Milton.	Nov. 2, 1954	1	2	2	4	6	23	56	90	97	99	100
17	Kayaderosseras Creek at Milton Center, near left bank of swimming hole, 0.7 mile southeast of Milton Center.	Nov. 9, 1954						10	32	82	96	99	100
		June 24, 1955	2	3	5	8	12	27	59	88	96	99	100
18	Kayaderosseras Creek at Ballston Spa, near right bank 500 ft upstream of Route 50 highway bridge.	Nov. 9, 1954						5	23	76	95	99	100
		June 24, 1955						3	10	36	89	99	100

19	Kayaderosseras Creek near Saratoga Springs, near left bank 100 ft downstream of US 9 highway bridge, 3.5 miles south of Saratoga Springs.	Nov. 9, 1954	--------	--------	--------	--------	--------	--------	1	6	48	62	100
		June 24, 1955	--------	--------	--------	--------	--------	8	34	77	97	100	--------
20	Kayaderosseras Creek near Saratoga Lake, near left bauk about 0.3 mile from confluence of Kayaderosseras Creek with Saratoga Lake.	Nov. 9, 1954	--------	--------	--------	--------	--------	5	18	76	99	100	--------
21	Saratoga Lake at Kayadeross Park, 200 ft from shore, 1.0 mile southwest of Route 9 P highway bridge.	Nov. 9, 1954	13	17	25	36	45	96	97	98	99	100	--------
22	Fish Creek at Saratoga Lake, about 0.3 mile downstream of Route 9 P highway bridge.	Nov. 9, 1954	18	26	38	55	77	97	99	100	--------	--------	--------
23	Fish Creek at Stafford bridge, 2 miles northeast of Saratoga Lake.	Nov. 9, 1954	33	52	68	86	97	99	100	--------	--------	--------	--------
24	Fish Creek at Victory Mills, 50 ft upstream of railroad bridge near left bank, 600 ft downstream of U.S. 4 highway bridge.	Nov. 9, 1954	10	16	24	35	43	81	89	98	99	100	--------

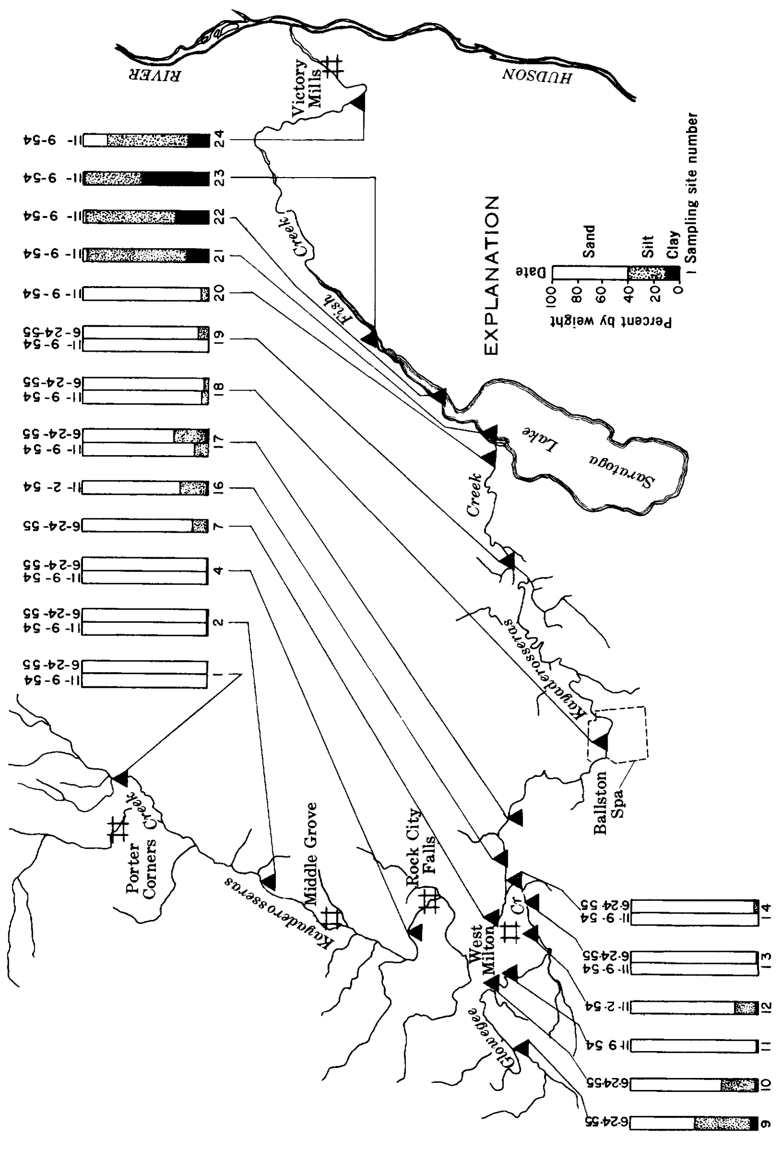


FIGURE 34.—Chart showing locations of sampling stations and composition of bed material from the Kayaderosseras Creek-Fish Creek drainage basin.

Kayaderosseras Creek (sta. 15) was 94 cfs and of Glowegee Creek (sta. 12) was 25 cfs. The second series of samples was collected on November 9, 1954, during a receding stage following a flood; the maximum daily mean discharge of Kayaderosseras Creek (sta. 15) was 860 cfs and of Glowegee Creek (sta. 12) was 230 cfs. The third series of samples was collected on June 24, 1955, during an extended low-flow period. All samples were collected from the surface of the streambed to a depth of about 3 to 4 inches using an Eckman dredge or, in shallow places, a scoop.

Although gravel, cobbles, and even boulders were present at various sampling stations, the bed material in Kayaderosseras Creek consisted principally of sand, which in some samples made up 100 percent of the total weight of sample (sta. 1, fig. 34). Downstream (sta. 2) the composition of the bed sample was about the same—99 percent sand and only 1 percent silt. At station 4, behind the upper dam at Rock City Falls, where a large quantity of sediment is entrapped, the composition of the bed material was about the same as at the upstream locations. Immediately below the upper dam, immediately below the lower dam, and a short distance donwstream the creekbed was bare rock. At West Milton (sta. 7) and downstream, the bed material contained, in addition to sand, some silt (24 percent or less by weight) and small quantities of clay—1 to 3 percent.

Generally, the composition of the bed of Kayaderosseras Creek changed very little with streamflow. Although few samples were collected, the composition (principally sand) probably is representative of the bed material of Kayaderosseras Creek during high and low streamflow. This composition probably will not change significantly with time.

Sand was also the principal component of the bed material in Glowegee Creek. However, during low flow, the percentages of silt and clay were higher than those determined in bed-material samples collected in Kayaderosseras Creek.

In contrast to the composition of bed material in Kayaderosseras and Glowegee Creeks, composition of the bed material in Saratoga Lake (sta. 21) was predominantly silt and clay. The composition of one sample collected at this site consisted of 79 percent silt, 17 percent clay, and only 4 percent sand. In Fish Creek, an outlet of Saratoga Lake, the percentage of clay was even higher; 22 percent at station 22 and 52 percent at station 23, 2 miles northeast of Saratoga Lake. However, the data obtained are from a single series of samples taken after a flood. Further study would be required to determine if the composition of the bed material at station 21 is characteristic of the entire lake bed.

UTILIZATION

Water used in industrial, domestic, agricultural, commercial, and public water supplies in the Kayaderosseras Creek-Fish Creek drainage basin is obtained from both ground-water and surface-water sources. Ground water is used to supply the needs of the Atomic Energy Commission's installation at West Milton and the needs of most farms and rural homes. Surface water is used mainly by the small industries in the area. Descriptions of these supplies follow, along with a discussion of the chemical and physical characteristics of the water that limit its utility.

UTILITY OF WATER

Chemical quality is a measure of the utility of water for industrial, agricultural, public water supply, and recreational purposes. Some waters are hard and thus are objectionable for domestic and industrial uses because they consume soap and form precipitates and scale. If iron and manganese exceed about 0.3 ppm, discoloration and deposition will usually take place. Acidity of water will promote corrosion in distribution systems, thereby increasing maintenance costs. Excessive amounts of dissolved solids, alkalies, boron, bicarbonate, and chloride in water will render it unsuitable for irrigation. Fluoride in concentrations greater than 1.5 ppm is considered undesirable in public water supplies because it causes a dental defect known as mottled enamel. Surface waters having a dissolved oxygen content of less than 5 ppm are considered unsatisfactory for the propagation of game fish. Whether or not a water is suitable for those purposes mentioned above and others can be anticipated beforehand if the chemical quality is known. However, if chemical quality limits the use of a water, its utility can be increased if proper treatment is applied. In any event, a knowledge of the chemical quality is a prerequisite.

Some of the chemical constituents usually found in water, their effects, and the user concerned are listed in table 22.

On the basis of chemical analyses, water from Glowegee and Kayaderosseras Creeks would be satisfactory for many industrial purposes, and even as a source of public water supply, if the sanitary quality were equally satisfactory. Moderate concentrations of dissolved solids are present, consisting principally of calcium bicarbonate. The hardness of the water from both creeks ranges from soft to moderately hard. Water of moderate hardness, especially from Glowegee Creek, will form scale if the water is used in boilers or heat-exchange units. Other chemical constituents contribute very little to the mineral content of both streams and would not affect their utility.

TABLE 22.—*Chemical constituents in water, occurrence, effect, and user concerned*

Chemical constituents	Occurrence	Effect	User concerned
Silica (SiO_2)	Found in all natural waters in varying concentrations. Ground waters generally contain more silica than surface waters.	Forms boiler scale and deposits on turbine blades.	Industry.
Iron (Fe) and Manganese (Mn).	In almost all natural waters; generally smaller amounts are found in surface waters than in ground waters.	Stains laundry, porcelain fixtures, and other materials when concentrations are about 0.3 ppm or more.	Industry and public water supplies.
Calcium (Ca) and Magnesium (Mg).	In all natural waters. Highest concentrations found in water in contact with limestone, dolomite, and gypsum.	Soap consuming. Forms an insoluble scum or precipitate in pipes and boiler tubes.	Do.
Sodium (Na) and Potassium (K).	In all natural waters. In very low concentrations of alkalies, concentrations of sodium and potassium are about equal. As concentration of alkalies increases proportion of sodium increases.	Large amounts may cause foaming in boiler operation. In irrigation waters, large amounts degrade the soil.	Industry, public water supplies, and agriculture.
Bicarbonate (HCO_3)	In all natural waters. Larger concentrations present in waters in contact with decaying organic matter and carbonate rocks.	Large amounts may affect taste of drinking water. Large quantities in combination with sodium degrade the soil.	Do.
Sulfate (SO_4)	Present in most natural waters. Larger amounts in waters in contact with gypsum and shale.	In conjunction with calcium and magnesium forms permanent hardness and hard scale in boiler operation.	Industry and public water supplies.
Chloride (Cl)	Present in most natural waters. Larger amounts in contaminated waters.	Taste of drinking water affected when amounts of more than about 300 ppm are present. Corrosiveness is also increased.	Do.
Fluoride (F)	Present in most natural waters in small concentrations.	About 1.0 ppm believed to be helpful in reducing incidence of tooth decay in children. Believed to cause mottled enamel on teeth at higher concentrations (Dean and others, 1941).	Public water supplies.
Nitrate (NO_3)	Present in most natural waters. Contamination by sewage and organic material increases quantity present.	Small amounts have no effect. 44 ppm or more reported to produce methemoglobinemia in infants (Waring, 1949). May indicate pollution.	Do.

Because of the range of water temperature, water from Glowegee and Kayaderosseras Creeks is satisfactory for cooling purposes.

GROUND WATER

Ground water is used extensively in the West Milton area to supply domestic and farm needs. It is also used by a few commercial establishments and small industries. Most ground-water supplies in the area are obtained from wells. Records of the depth, diameter, water-bearing deposits, and other features of wells in the area are on file in the U.S. Geological Survey Ground Water Branch office in Albany, N.Y. A few of the wells draw water from bedrock but by far the majority tap water in unconsolidated deposits. The wells in bedrock are generally cased through the unconsolidated deposits and are open holes extending from a few feet to a few hundred feet into bedrock. Most wells in till or similar relatively impermeable unconsolidated deposits are dug and generally range in diameter from 3 to 4 feet. In those areas directly underlain by sand, supplies adequate for most domestic and farm needs are obtained from small-diameter driven wells.

Springs are relatively abundant in the area and some are used as sources of supply. The location of selected springs is shown in figure 9. The springs are situated on hillsides or in valleys and appear to rise from sand and gravel at contracts with underlying less permeable deposits. In some places sand and gravel apparently occur as lenses in till.

SUPPLY OF THE ATOMIC ENERGY COMMISSION INSTALLATION

Four wells, one of which is a horizontal collector producing from a water-table aquifer and three of which are vertical wells producing from an artesian aquifer, supply the water used by the reactor installation at West Milton. From 1951 to 1958, the water supply was obtained from the horizontal well, Sa 843, which is located about 40 feet from Kayaderosseras Creek. The maximum yield of this well has not been determined but it exceeds 1 mgd. In 1954, the Atomic Energy Commission approved plans for the expansion of the reactor testing facilities at West Milton. As specifications for the new facilities called for an additional 3 mgd, three additional supply wells (Sa 848T, Sa 1030, and Sa 1031) were developed in the artesian aquifer underlying the valley of Kayaderosseras Creek. Use of these wells began in August 1958.

WATER-TABLE WELL (Sa 843)

During normal operations, this well has yielded from about 0.5 mgd to about 1 mgd. The aquifer from which the well draws is described in the section entitled "Flood-plain deposits."

CONSTRUCTION

Supply well Sa 843 consists of a sump 5 feet wide by 8 feet long and 25 feet deep and two horizontal laterals 36 inches in diameter. One lateral is 20 feet long and extends from the sump toward Kayaderosseras Creek. The other is 100 feet long and extends southward from the sump, parallel to Kayaderosseras Creek. The longer lateral consists of perforated corrugated metal pipe surrounded on the sides and bottom by 18 inches of coarse gravel and overlain by 6 feet of coarse gravel. It is not known whether the shorter lateral is also enclosed in a gravel envelope. The particle-size distribution in samples taken from the excavation for the longer lateral is listed in table 3. After construction of the sump and laterals, a low mound was built around the sump in order to protect the pump house from the floods of Kayaderosseras Creek. Thus, the depth below land surface of the laterals ranges from about 19 feet at the sump to about 10 feet beyond the mound. The centerline of the laterals is about 5 feet below the bottom of Kayaderosseras Creek. Two pumps, one rated at 750 gpm and the other at 500 gpm, were installed at the well. The switching mechanism of the pumps was arranged so that only one can be operated at a time. Under normal operations, the smaller pump turned on first and remained on until the use of water exceeded the yield of the pump. At this point, the switching mechanism turned on the larger pump and turned off the smaller pump.

EFFECTS OF PUMPING AND CHANGES IN STREAM STAGE

The water level in well Sa 843 is affected principally by pumping from the well and changes in stage of Kayaderosseras Creek and Crook Brook. A continuous record of water-level fluctuations in well Sa 843 has been obtained since February 1955 (pl. 5). The effect of pumping on the water level is shown by the hydrographs of figures 12 and 15. During the period from April 18 to May 1, 1956 shown on figure 12, only the 500 gpm pump was being used. In figure 15, periods of pumping at rates of both 750 and 500 gpm are shown. The well was generally pumped continuously for 6 hours and was off for about 2 hours (fig. 15). Because the water level did not fully recover while the pump was off, the drawdowns produced by the pumping cannot be determined from figures 12 and 15. Between periods of pumping at a rate of 750 gpm, the water level in the well was able to recover only about 4½ feet before pumping resumed. A study of the records for the well collected during periods when there was a long interval between pumping cycles shows that the 750 gpm pump produces drawdowns of 7 to 9 feet. The 500 gpm pump, on the other hand,draws the water level in the well down 3 to 4 feet.

The effect of pumping from well Sa 843 on the ground-water level in the adjacent flood-plain deposits is indicated by the hydrograph of well Sa 849T which is shown in figure 12. A comparison of the hydrographs of the two wells shows that the water level in well Sa 849T declines approximately 0.5 foot when well Sa 843 is pumped at a rate of 500 gpm, and also that the water level in well Sa 849T responds almost immediately to the pumping. This would indicate that the water in the flood-plain deposits is under artesian conditions. As shown in table 3, the flood-plain deposits at a depth of 2 feet are composed of sand and silt—considerably finer material than in the deeper section of the deposits from which well Sa 843 draws. The extent of this layer of sand and silt is not known, but the layer is probably not continuous. It is apparently permeable enough to permit slow percolation of ground water but responds as a confining bed when the water level is lowered quickly. Thus, although the water level in the flood-plain deposits responds rapidly to the effects of pumping as though it were under artesian conditions, normally the water is under water-table conditions.

The water level in well Sa 843 and the stage of Kayaderosseras Creek are shown in figures 12 and 15. The stage measurements were made at a temporary staff gage installed in the creek 200 feet east of well Sa 848T. However, in order to show the stage of the creek at well Sa 843 in figures 12 and 15, a factor of 2.7 feet was added to the readings made at the staff gage. That part of the record shown by a dashed line was projected from records obtained at a permanent gaging station (sta. 15) two miles downstream. The water level in well Sa 843 and the stage of Kayaderosseras Creek from February 1955 to September 1957 are shown on plate 5.

Figures 12 and 15 show that the pumping level of well Sa 843 ranges from about 3 feet below creek level when the 500 gpm pump is operating to about 7 or 8 feet when the 750 gpm pump is operating. Under the pumping schedule existing prior to the completion of supply wells Sa 848T, Sa 1030, and Sa 1031, the water level in well Sa 843 did not rise above the level of the creek during the brief periods when the pumps were off.

SOURCE OF WATER

Water-level and temperature measurements indicate that the water pumped from well Sa 843 is a mixture of water from the water-table aquifer, and Kayaderosseras Creek and Crook Brook. The quantity of water contributed to the well by the two streams depends on several factors, most important of which are: (1) the rate of pumping, (2) the difference in altitude between the water table and the stages of the streams, and (3) the temperatures of the streams.

As indicated in the preceding section, the pumping level of well Sa 843 ranges from 3 to 8 feet below the level of Kayaderosseras Creek. Thus, during periods of pumping, a relatively steep hydraulic gradient exists between the creek and the well, and water moves from the creek to the well. An indication of the extent to which Kayaderosseras Creek and Crook Brook contribute water to well Sa 843 is shown on plate 6 by the graphs of daily mean air temperature at station 26, minimum daily temperatures of Kayaderosseras Creek at station 15, and weekly measurements of the water temperatures in wells Sa 843 and Sa 849T. Plate 6 shows that the temperature of Kayaderosseras Creek ranges from 32°F to about 75°F, and the temperature of water from Sa 843 ranges from 43°F to about 61°F. The temperature of water in well Sa 849T during the 13 months that records have been collected ranged from 45.5°F to 48°F. The relatively wide range in the temperature of water from well Sa 843 indicates that the water from the well is a mixture of water from Kayaderosseras Creek and Crook Brook, and the water-table aquifer.

ARTESIAN WELLS

The new well field, consisting of wells Sa 848T, Sa 1030, and Sa 1031, is producing water from an artesian aquifer composed principally of coarse sand that underlies the valley of Kayaderosseras Creek. The geologic characteristics of this aquifer are discussed in the section entitled "Deltaic deposits" and the hydrologic characteristics are discussed in the section entitled "Quantitative studies." The supply wells are spaced about 500 feet apart along a north-south line located west of Kayaderosseras Creek (fig. 8).

Well Sa 1031 is at the north end of the line approximately 260 feet west of the creek. It is 16 inches in diameter, cased to a depth of 75 feet, and screened in sand from 75 to 85 feet with No. 25-slot screen and from 85 to 105 feet with No. 35-slot screen. The well has been pumped successfully at a rate of 750 gpm for a period of 72 hours and has yielded as much as 900 gpm during short tests.

Well Sa 848T, located in the middle of the line and about 200 feet west of the creek, is 12 inches in diameter, cased to a depth of 79 feet, and screened in coarse sand from 79 to 99 feet with No. 25-slot screen. The water level after 5 days of pumping at a rate of 750 gpm stabilized at a drawdown of 21 feet. The well has yielded as much as 900 gpm during short tests. The analysis of pumping-test data indicates that near this well the aquifer has a coefficient of transmissibility of 125,000 gpd per ft and a coefficient of storage of about 0.0003.

Well Sa 1030, located at the south end of the line of wells and about 60 feet west of Kayaderosseras Creek, is 16 inches in diameter, cased to a depth of 44 feet, and screened in sand from 44 to 74 feet with No. 18-slot screen. It has been pumped successfully at a rate of 750 gpm for a period of 72 hours. Tests have shown also that it is not capable of yielding 900 gpm for any appreciable length of time. The log for well Sa 1027T, which is located about 20 feet north of well Sa 1030, shows that the aquifer is finer grained, thinner, and closer to the land surface at well Sa 1030 than at wells Sa 848T and Sa 1031 (fig. 5). These differences probably account for the fact that the yield of well Sa 1031 is lower than the yield of the other supply wells.

SURFACE WATER

Industrial use of surface water in the vicinity of West Milton, including use from Kayaderosseras Creek, Saratoga Lake, and Fish Creek are discussed in the following section. In addition to this industrial use, the waters of Kayaderosseras and Glowegee Creeks below the reactor site are used for watering of livestock, and both streams are classified as public fishing streams. Saratoga Lake is used rather extensively for swimming, fishing, and boating. Recreational developments are prevalent on the lakeshore.

INDUSTRIAL SUPPLIES

As of 1958 there were four industrial plants that used water from Kayaderosseras Creek in their operation. The Cotrell Paper Co. has two paper mills at Rock City Falls, upstream from Glowegee Creek. The upper mill uses creek-run water for the generation of power only, but the lower mill uses creek-run water for generation of power and approximately 400 gpm (0.9 cfs) for process purposes, most of which is returned to the stream. The Howes Leather Co. at Ballston Spa, about 5 miles downstream from West Milton, uses a maximum draft of 400 gpm of water from Kayaderosseras Creek as an emergency supply only. The Ballston-Stillwater Knitting Co., also at Ballston Spa, draws all its process water from Kayaderosseras Creek. Its maximum draft is 200 gpm; the normal use is 17 gpm for 10 hours each day of operation.

The United Board and Carton Co. at Victory Mills uses water at the rate of 10 to 15 gpm from Fish Creek, which drains Saratoga Lake. The water is used for boiler makeup, sanitary purposes, and fire protection. The company's pumps have a maximum capacity of 65,750 gpm for fire use. The Niagara-Mohawk Power Co. uses water from Fish Creek in amounts up to about 197,000 gpm (440 cfs) for the generation of power at Schuylerville, N.Y., just upstream from the mouth of the creek.

SUMMARY

In the construction and operation of the reactor testing installation at West Milton, the Atomic Energy Commission needed information on the following subjects: (1) the development of a water supply, (2) the potential adverse effect of atomic reactors on the geologic and hydrologic environment, (3) waste disposal, and (4) availability of sand and gravel for construction and maintenance.

1. The water requirements of the installation are obtainable either from surface-water or ground-water sources. The principal sources of surface water are Kayaderosseras and Glowegee Creeks. The minimum daily flow of 5,800 gpm (13 cfs) of Kayaderosseras Creek near West Milton is substantially more than the maximum foreseeable needs of the installation. Glowegee Creek, on the other hand, has a minimum daily flow at West Milton of only about 180 gpm (0.4 cfs), and the flow is less than the estimated required amount of 2,800 gpm (6.2 cfs) about 21 percent of the time. Therefore, the use of Glowegee Creek as a source of supply would require considerable storage.

Before either Kayaderosseras Creek or Glowegee Creek could be utilized as a source of supply, consideration would have to be given to the temperature, chemical quality, and amount of suspended sediment in the water from the two creeks. Water temperature ranges from about 32°F to about 80°F during the course of a year. During 10 percent of the time, water temperature will equal or exceed about 70°F. The concentration of dissolved solids in the water ranges from a low of about 75 ppm for both creeks to a maximum of about 110 ppm for Kayaderosseras and 160 ppm for Glowegee. The range of hardness in the water of Glowegee Creek is about 50 to 140 ppm and in that of Kayaderosseras Creek it is about 40 to 90 ppm. About 75 percent of the time, the hardness of water from Glowegee Creek may be expected to equal or exceed about 90 ppm and from Kayaderosseras Creek about 65 ppm. Usually the sediment load will be less than 10 tons per day. During high flow, substantial increases in load can be expected for short periods.

The water supply at the West Milton site is obtained from one horizontal-collector well tapping a shallow water-table aquifer adjacent to Kayaderosseras Creek and three vertical wells tapping a deeper artesian aquifer. Until 1958, the Atomic Energy Commission obtained as much as 1 mgd from the horizontal collector, part of which was derived from Kayaderosseras Creek. Exploration for additional water supplies undertaken in 1955 showed that a deeper aquifer, consisting of coarse sand and containing water under artesian conditions, underlies the valley of Kayaderosseras Creek in the vicinity of the horizontal collector. Three vertical-screened supply wells constructed in this aquifer in 1957 and 1958 are now in use. These wells have been pumped at about 1 mgd each for 72 hours. Test wells show that the artesian aquifer extends only a few hundred feet west of the well field. Its extent to the north, east, and south is not known, although the data from the pumping tests indicate that the aquifer may be extensive, particularly to the east. Chemical analyses show that water from the artesian aquifer has a hardness of about 100 ppm and a dissolved-solids content of about 120 ppm.

2. The accidental release of radioactive substances to Glowegee Creek could have far-reaching detrimental effects inasmuch as Kayaderosseras and Glowegee Creeks, downstream from the reactor, are used for recreational purposes and as a source of supply by industries. The rate of travel of radioactive substances and their destination are dependent on many factors. Chief among these is whether the substances enter the ground before reaching the streams or whether they enter the streams directly. Depending on their composition and the composition of the deposits through which they move, most substances entering the ground in the area would either be adsorbed

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by the deposits or move through the deposits to Glowegee Creek. The effect of a buried valley that extends in an east-west direction across the northern part of the reactor site on the movement of ground water and, thus, on any radioactive substance in the water, is not known. Normally, ground water in the area may be expected to discharge into Glowegee Creek. However, there is a possibility, though remote, that water moving through the deposits filling the buried valley would not discharge into Glowegee Creek but would discharge some place east of the reactor, possibly into Kayaderosseras Creek.

The hazard resulting from accidental presence of radioactive substances in Glowegee and Kayaderosseras Creeks is dependent on the concentration, quantity, and kind of radioactivity; discharge and velocity of flow; and concentration and quantity of suspended sediment.

Radioactive material carried into the streams during a low stage would undergo less dilution than during periods of high stage and discharge, and whether in suspension or solution, would travel at a slower velocity. Because the concentration of suspended sediment in Glowegee and Kayaderosseras Creeks is usually less than 10 ppm at low stage, there would be limited opportunity for contact and adsorption or absorption of radioactivity. During a high stage, dilution and rate of travel would be greater. Because the concentration of suspended sediment is relatively higher, the probability of contact and adsorption or absorption of radioactivity would also increase. Then too, radioactive sediment might be deposited along the banks or on the streambed. There, the sediment might accumulate until succeeding high stages when a part or all the deposited sediment might be picked up and moved further downstream. Ultimately, the sediment would accumulate in Saratoga Lake or Fish Creek, except during severe floods when some of it might move through the lake and creek into the Hudson River.

3. Low-level radioactive wastes resulting from routine operation of reactors are disposed of by dilution and discharge into Glowegee Creek. For waste disposal purposes Glowegee Creek offers relatively little dilution potential. The flow is equal to or less than 1,600 gpm (3.5 cfs) about 10 percent of the time. On the average, once in 10 years the discharge for a period of 7 consecutive days will be 225 gpm (0.5 cfs) or less. Kayaderosseras Creek offers considerably greater dilution potential. The flow is equal to or less than 14,000 gpm (32 cfs) 10 percent of the time, and the minimum average discharge for 7 consecutive days that will occur, on the average, once in 10 years is 8,000 gpm (18 cfs).

4. Sand and gravel used in the construction and maintenance of the installation have been and are being obtained from a kame deposit on the government reservation about 1 mile south of the reactor installation. Sand and gravel are also present in another kame about 1 mile north of the reactors.

Rock types including limestone, dolomite, sandstone, shale, and granite geniss crop out at the land surface on the government reservation. Large amounts of any of these rocks could be obtained by quarrying. All except the shale would be useful in construction and maintenance work on the reservation.

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