SUMMARY OF GEOLOGY AND GROUND-WATER CONDITIONS IN THE VICINITY OF TAPPAHANNOCK, ESSEX COUNTY, VIRGINIA

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INTRODUCTION

This memorandum has been prepared in response to a recent inquiry from the city officials of Tappahannock, Essex County, Va., regarding the availability of ground water in the Tappahannock area. The memorandum was prepared as a part of the ground-water studies of the Geological Survey in cooperation with the Virginia Division of Geology.

Location of Area

Tappahannock is in Essex County in Tidewater Virginia, on the south shore of the southeast-flowing Rappahannock River. Essex County is in the northern part of the Virginia Coastal Plain.

The accompanying sketch map (figure 1, page 2), shows the Tappahannock area and the locations of the wells listed in table 1, page 11.

GENERAL GEOLOGY AND WATER-BEARING CHARACTERISTICS OF THE ROCKS

The Tappahannock area is underlain by sands, clays, and minor gravels of the Coastal Plain province. These unconsolidated rocks, deposited by terrestrial and marine waters, range in geologic age from Cretaceous to Recent. They have a gentle eastward dip—a few feet per mile. They grow thinner westward, disappearing in a featheredge along the Fall Zone where the crystalline basement rocks such as are exposed in the Piedmont province come to the surface. The Fall Zone is marked

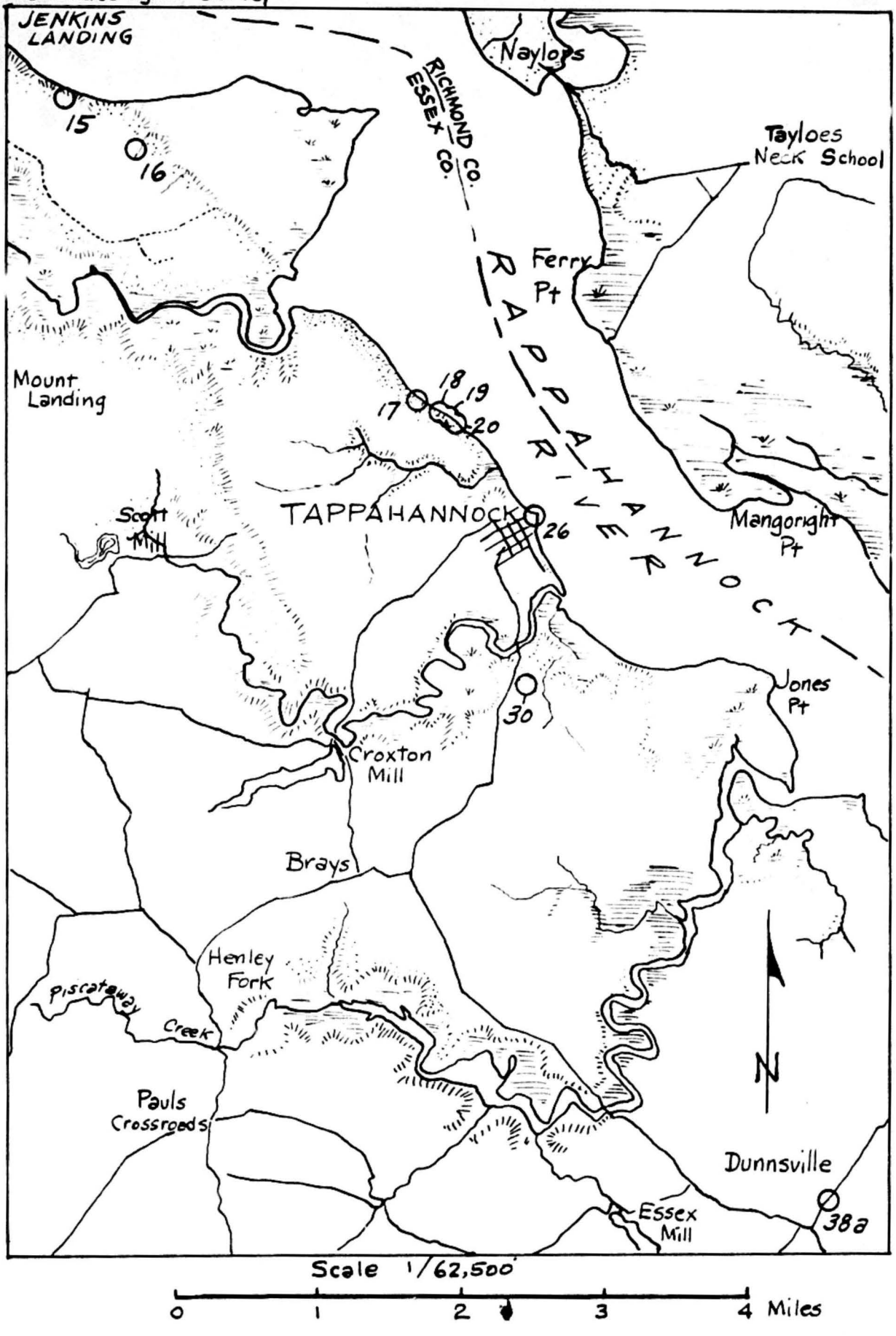

Figure 1.--Sketch map showing Tappahannock area and locations of wells listed in table 1.

by a north-south belt of falls and rapids extending from beyond Washington on the north through Fredericksburg to Richmond and beyond on the south.

Marine deposits of Pleistocene age form the principal rocks near the surface and are collectively referred to as the Columbia group. These deposits are mantled locally by minor Recent deposits. (See well logs, table 2.)

Underlying the Columbia group are Tertiary rocks--the Chesapeake group of Miocene age and the Pamunkey group of Eocene age. The Chesapeake group is not subdivided in this area. The Pamunkey group consists of the Nanjemoy formation, of middle and early Eocene age, and the underlying Aquia formation, of early Eocene age. The rocks of both groups are of marine origin.

The Mattaponi formation underlies the Pamunkey group. This formation is thought to be of Paleocene and Late Cretaceous age (Cederstrom, 1954, ms. p. 32) and also is of marine origin.

In the Tappahannock area, only the Recent, Miocene, and Pleistocene deposits are exposed at the surface.

The oldest rocks of the Coastal Plain--the Potomac group, of fluvial and deltaic origin--are not, so far as known, reached by any deep wells in the Tappahannock area; they are not described in this memorandum.

A brief discussion of the rocks above the Potomac group is presented below, in the order in which the rocks would be encountered in drilling wells--the order of increasing geologic age.

Deposits of Recent age

The youngest deposits in the area are those of Recent age which are represented in the Tappahannock area by alluvium in creek beds and marshlands, and beaches and spits forming the shore of the Rappahannock River. So far as known, these deposits are so thin and localized that they are not tapped for ground water anywhere in the area.

Columbia group (Pleistocene)

The Columbia group comprises a series of marine terrace deposits consisting of yellowish sands and fine gravels. According to Wentworth (1930, map, fig. 24), three of these terrace formations are represented in the Tappahannock area. The lowest and youngest, or Princess Anne, is marked by a low terrace adjacent to the Rappahannock River, and ending in an ancient wave-cut scarp about 10 feet high whose base averages 10 feet above sea level. The general surface elevation of the Princess Anne terrace ranges from 0 to 13 feet above sea level. A higher terrace and formation, called by Wentworth the Dismal Swamp but generally known as the Pamlico, locally extends to the river shore but is developed over a wider area, paralleling the Rappahannock shore and the Princess Anne terrace escarpment. The elevation of the Pamlico terrace ranges from about 20 to 30 feet above sea level.

Southwest of the Princess Anne and Pamlico terraces lies the dissected upland terrace of the Sunderland formation. The elevation of the upland surface ranges from about 100 to 140 feet in this area. This surface has been greatly dissected by many northeastward-flowing creeks which are tributary to the Rappahannock River.

The rocks of the Columbia group are commonly tapped by shallow dug or driven wells for small domestic supplies. The quality of the water generally is not as satisfactory as that of water from the deeper rocks, owing to high iron content and the likelihood of pollution from surface sources or of contamination by brackish water from the Rappahannock River. Further, shallow wells are likely to be affected by prolonged droughts and therefore are not as dependable as are those developed in deeper water-bearing beds.

Chesapeake group (Miocene)

The several formations into which the Chesapeake group is divided in other areas are not recognized in this area because all the sediments are similar lithologically. The group locally is about 50 feet thick, and during drilling it is usually first reached between 20 and 40 feet below the surface.

The Chesapeake group was deposited in marine waters during several marine transgressions, some of which extended as far west as the Fall Zone.

The Chesapeake group is not generally satisfactory as a source of ground water in this part of the Coastal Plain, because it is largely clay or sandy clay, with only a few thin beds of shells and sand.

Pamunkey group (Eocene)

The sand beds of the Pamunkey group are characteristically high in glauconite, and they are frequently reported by drillers as black sand or green sand. These rocks also are of marine origin, deposited during

transgressions of the sea over the Coastal Plain as far west as the Fall Zone.

Nanjemoy formation.--The younger of the two formations of the Pamunkey group is the Nanjemoy, which in this area consists chiefly of sand and clay and ranges in thickness from about 80 to 165 feet. The Nanjemoy formation is usually reached between 100 and 130 feet below the surface. Locally, the base of the formation is marked by a pink clay (Darton, 1948), called the Marlboro clay member. The Nanjemoy is generally considered to be of middle and early Eocene age.

Aquia formation.--Underlying the Nanjemoy is the Aquia formation, of early Eocene age. Lithologically it is similar to the Nanjemoy, commonly containing glauconitic sands. The Aquia formation is reached between 215 and 270 feet below the surface. Locally it may be nearly 200 feet thick.

Water-bearing properties.--The two formations of the Pamunkey group contain many thin beds of fine glauconitic sand and white sand. Many of these sands are thick enough to be important aquifers. However, the fine-grained character of the sands may cause trouble during well development, and well screens should be selected with care. (See later discussion.)

Mattaponi formation (Paleocene and Upper Cretaceous)

Deeper wells in the Tappahannock area pass through the Aquia formation and extend into the underlying Mattaponi formation. The total thickness of the Mattaponi locally is not known, but in the Bennett well (16, table 1) it extends from 415 to 550 feet below the surface.

In the northern Virginia Coastal Plain, the Nattaponi is characterized by variegated clays, and in its lower portion it generally contains one or more good, though fine-grained, water-bearing sands. On the basis of available information, supported by additional geologic evidence from adjacent counties of the Northern Neck and York-James Peninsula, it is believed that the water-bearing sands of this formation should be encountered at a depth of about 520 feet below the surface in the Tappahannock area.

OCCURRENCE OF GROUND WATER AND DEVELOPMENT OF SUPPLIES

As mentioned above, geological studies show that the sedimentary rocks that form the Coastal Plain have an eastward dip of a few feet per mile. The water-bearing sands are capped by relatively impervious clay, silt, and marl beds, and, because they are exposed at the surface some 20 to 30 miles west of Tappahannock along the Fall Zone at an elevation considerably higher than that of the Tappahannock area, the water confined in them is under artesian pressure. The water rises in the casings of wells tapping these beds to levels above the beds themselves. In many wells constructed on low ground the height to which the water will rise is above the land surface, so that the wells have a natural flow.

There appears to be little danger that pumping will lower the artesian pressure head to such an extent that the yields of wells will decrease, at least in the near future. The lowering of water levels by prolonged pumping merely induces more recharge (or replenishment) into the beds. This recharge occurs partly by leakage through the confining clay layers, but chiefly by infiltration of rainfall and streamflow into the outcrop areas to the west.

Beds of white sand, in places 20 feet or more in thickness, in the Pamunkey group and Wattaponi formation, underlie the Tappahannock area at depths of about 350 to 550 feet below the surface. These sands generally yield water freely to wells. There are also minor beds of sand of Late Eocene age at shallower depths, between 100 and 350 feet below the surface. Locally, these sands also are water bearing.

Properly developed wells 6 to 8 inches in diameter, tapping all water-bearing zones encountered below about 100 feet, should yield between 50 and 100 gpm (gallons per minute) each. To avoid undue interference with each other, wells of such yield should be spaced several hundred feet apart.

The water-bearing sands of the Nanjemoy, Aquia, and Wattaponi formations are so fine grained that some difficulty is commonly experienced in screening the sands for maximum capacities. Too small a screen opening is to be avoided, as it reduces the maximum potential yield. A screen opening should be selected so as to allow the finer grained 60 to 70 percent of the sand immediately around the screen to enter the well during development.

QUALITY OF GROUND WATER

In table 3 are chemical analyses of ground water from several wells in the Tappahannock area ranging in depth from 265 to 515 feet. The water is generally soft and high in sodium and bicarbonate, with very low chloride, sulfate, and nitrate concentration. The fluoride content of the water from the 515-foot Tappahannock well, 3.1 ppm (parts

per million) is somewhat higher than the maximum of 1.5 ppm, given in the drinking-water standards of the Public Health Service.

CONCLUSION

According to the available information, it is believed that a considerable number of wells yielding 50 to 100 gpm each could be put down safely in the Tappahannock area. The water quality should be satisfactory, and there appears to be no danger that increasing mineralization would result from prolonged withdrawals.

Records of selected wells in the Tappahannock area are given in table 1, p. 11; well logs in table 2, p. 12-18; and chemical analyses in table 3, p. 19.

REFERENCES

Cederstrom, D. J., 1954, Geology and ground-water resources of the York-James Peninsula, Va.: U. S. Geol. Survey Water-Supply Paper 1361 (in preparation).

Darton, N. H., 1948, The Marlboro clay: Econ. Geology, v. 43, no. 2, p. 154-155.

Wentworth, C. K., 1930, Sand and gravel deposits of the Coastal Plain of Virginia: Virginia Geol. Survey Bull. 32.

Table 1.--Records of wells in the vicinity of Tappahannock, Essex County, Virginia

No.	Location	Owner or tenant	Driller	Year completed	Topographic situation	Approximate altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing zone (Tentative correlations)		Approximate water level above (+) or below (-) measuring point (feet)	Approximate yield (gpm)	Use of water	Remarks
										Geologic age	Stratigraphic unit or named aquifer (fm = formation)				
15	1 mi. SSE of Jenkins Landing	J. A. Luttrell	W. S. Reynolds & Sons		River bank	9	Jetted	388	3-2	Eocene	White sand in Aquia fm; 362-383 ft	+	15	Dom.	Flows naturally at low rate. See accompanying well log.
16	1 3/4 mi. SSE of Jenkins Landing	R. E. Bennett	W. S. Reynolds & Sons		Creek Valley	11½	Jetted	550	2	Paleocene-Late Cretaceous	White sand in Mattaponi fm; 520-540 ft	+	5	Dom.	See accompanying well log.
17	1 mi. NNW of Tappahannock	Lewis Carears	W. S. Reynolds & Sons		River bank	2	Jetted	397	2	Eocene	White sand in Aquia fm; 340-397 ft	+(?)	20	Dom.	
18	1 mi. NNW of Tappahannock	Overton Brooks	W. S. Reynolds & Sons		River bank	5	Jetted	397		Eocene	White sand and clay, Aquia fm; 316-397 ft	+(?)		Dom.	See accompanying well log.
19	1 mi. NNW of Tappahannock	C. F. Hicks	W. S. Reynolds & Sons	1946	River bank	2	Jetted	377	3	Eocene	White sand, Aquia fm; 348-367 ft				
20	1 mi. NNW of Tappahannock	Dr. J. L. Shepard	W. S. Reynolds & Sons	1946	River bank	2	Jetted	390	2	Eocene	White sand, Aquia fm; 381-390				
26	Tappahannock	Town	H. Lyons		River bank	5	Jetted	515	3	Paleocene-Late Cretaceous	Mattaponi fm	+	110(?46)	Pub. supply	Reported pumped 155 gallons per minute, 1950. See accompanying chemical analysis.
30	3/4 mi. S of Tappahannock	Dumpkins Garage	W. S. Reynolds & Sons	1946	Terrace	35	Jetted	414	3	Eocene	Fine white sand, Aquia fm; 395-398 ft		10	Dom.	See accompanying log.
38a	Dunnsville	Kriete & Parker Cannery			Terrace escarpment	80	Jetted	390	2	Eocene	(Below 290 feet)	(-)	4	Ind.	See accompanying chemical analysis.

Table 2.--Logs of wells in the Tappahannock area, Virginia

Well 15, 4 mi. NW of Tappahannock; John A. Lutwell

(Log by W. R. Reynolds & Sons; correlations by U. S. Geological Survey)

Altitude, 9 feet

	Thickness (feet)	Depth (feet)
Columbia group (Pleistocene):		
Yellow sand and clay	25	25
Chesapeake group (Miocene):		
Blue clay	64	89
White sand and shells	2	91
Blue clay	6	97
Pamunkey group (Eocene):		
Manjemoy formation:		
Black sand	½	97½
Hard blue clay	17½	115
Limestone	½	115½
Black sand	1	116½
Limestone	20½	137
Moderately hard clay	53	190
Black sand	1	191
Moderately hard clay	39	230
Sand	1	231
Soft brown clay	34	265

(Continued on next page)

Table 2.--Logs of wells in the Tappahannock area, Virginia--Continued

Well 15, 4 mi. NW of Tappahannock; John A. Lutwell--Continued

	Thickness (feet)	Depth (feet)
Pamunkey group (Eocene):--Continued		
Aquia formation:		
Black sand	1½	266½
Moderately hard clay	35½	302
Soft clay	5	307
Moderately hard clay	26	333
Red brown clay	29	362
White sand	21	383
Hard clay	5	388

Table 2.--Logs of wells in the Tappahannock area, Virginia--Continued

Well 16, B. F. Bennett, Tappahannock (1-3/4 mi. SSE of Jenkins Landing)

(Log by W. S. Reynolds & Sons; correlations by U. S. Geological Survey)

Altitude, 11½ feet

	Thickness (feet)	Depth (feet)
Columbia group (Pleistocene):		
Clayey sand	13	13
Chesapeake group (Miocene):		
Blue clay	28	95
White sandy shell marl with thin rock at base	28	123
Pamunkey group (Eocene):		
Nanjemoy formation:		
Black and white sand	2	125
Clay with rock streaks	25	150
Hard clay	100	250
Red clay	22	272
Aquia formation:		
Clayey grey sand	30	302
Hard rock	½	302½
Hard blue clay	50½	353
Light to dark brown clay	62	415
Mattaponi formation (Paleocene and Upper Cretaceous):		
White to yellow clay	65	480
Hard clay	25	505
Medium sticky red to brown clay	15	520
White sand, water	20	540
Clay	10	550

Table 2.--Logs of wells in the Tappahannock area, Virginia--Continued

Well 18, Overton Brooks, Tappahannock

(Log by W. R. Reynolds & Sons; correlations by U. S. Geological Survey)

Altitude, 5 feet

	Thickness (feet)	Depth (feet)
Columbia group (Pleistocene):		
Sandy clay	18	18
Chesapeake group (Miocene):		
Blue clay	67	85
Shells and gray sand	2½	87½
Blue clay	11½	99
Shells and sand	1½	100½
Pamunkey group (Eocene):		
Manjemoy formation:		
Clay and rock	19½	120
Black and gray sand	1½	121½
Limestone and white sand	4	125½
Compact clay	18½	144
Limestone	½	144½
Hard clay	18½	163
Limestone	½	163½
Compact clay	26½	190
Black sand	2	192
Compact clay	58	250
Red clay	5	255

(Continued on next page)

Table 2.--Logs of wells in the Tappahannock area, Virginia--Continued

Well 18, Overton Brooks; Tappahannock--Continued

	Thickness (feet)	Depth (feet)
Pamunkey group (Eocene):--Continued		
Aquia formation:		
Black sand	55	310
Hard clay	5	315
Very hard limestone	1	316
Alternating stratum of clay and white sand	81	397

Table 2.--Logs of wells in the Tappahannock area, Virginia--Continued

Well 30, Lumpkins Garage; Tappahannock

(Log by W. S. Reynolds & Sons; correlations by U. S. Geological Survey)

Altitude, 35 feet

	Thickness (feet)	Depth (feet)
Columbia group (Pleistocene):		
Soil	30	30
Chesapeake group (Miocene):		
Undescribed	70	100
Blue clay	30	130
Shells and sand	1	131
Pamunkey group (Eocene):		
Nanjemoy formation:		
Blue clay	10	141
Rock	½	141½
Soft clay	3½	145
Sand and rock	1	145½
Stone and sand	4½	150
Hard clay	9	159
White sand	2	161
Rock	29	190
Medium clay	25	215
Aquia formation:		
Black sand	1½	216½
Undescribed	38½	254
Blue clay	19	273

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Table 2.—Logs of wells in the Tappahannock area, Virginia—Continued

Well 30, Lumpkins Garage; Tappahannock—Continued

	Thickness (feet)	Depth (feet)
Pamunkey group (Eocene):—Continued		
Aquia formation:—Continued		
Rock	1	273½
Black sand	1½	275
Hard clay	60	335
Medium clay	10	345
Hard clay	50	395
White sand	3	398
Undescribed	16	414

Table 3.--Chemical analyses of ground waters in the Tappahannock area, Va.

(Analyses by U. S. Geological Survey, chemical constituents in parts per million)

Well number			26	28a
Location	Tappahannock	Tappahannock	Tappahannock	Dunnsville
Depth (feet)	265	280	515	390
Date	July 24, 1918	June 19, 1951	Feb. 13, 1941	Aug. 23, 1950
Silica (SiO_2)	—	—	—	—
Iron (Fe)	—	—	—	—
Calcium (Ca)	3.2	—	—	—
Magnesium (Mg)	1.6	—	—	—
Sodium (Na)	159	—	—	—
Potassium (K)	—	—	—	—
Bicarbonate (HCO_3)	449	190	404	198
Carbonate (CO_3)	24	—	—	—
Sulfate (SO_4)	8.2	—	8	8
Chloride (Cl)	2	1.5	2	2
Fluoride (F)	—	.4	2.1	.6
Nitrate (NO_3)	1	.6	—	.6
Hardness as $CaCO_3$	14	13	0	32
Dissolved solids	461	—	—	—
Specific conductance (micromhos at 25°C)	—	288	—	321
pH	—	8.1	—	—