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BUREAU OF GEOLOGY
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Report of Investigations No. 59

**THE SHALLOW-AQUIFER SYSTEM
IN
DUVAL COUNTY, FLORIDA**

By
Roy W. Fairchild

Prepared by the
U.S. GEOLOGICAL SURVEY
in cooperation with the
CITY OF JACKSONVILLE
DUVAL COUNTY
and the
FLORIDA DEPARTMENT OF NATURAL RESOURCES
BUREAU OF GEOLOGY

TALLAHASSEE, FLORIDA
1972

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LETTER OF TRANSMITTAL



Bureau of Geology
Tallahassee
November 23, 1971

Honorable Reubin O'D. Askew, *Chairman*
Department of Natural Resources
Tallahassee, Florida

Dear Governor Askew:

The Bureau of Geology is publishing Report of Investigations No. 59, entitled "The Shallow Aquifer System in Duval County, Florida," by Roy W. Fairchild, U.S. Geological Survey hydrologist. This report presents specific data pertaining to the shallow-aquifer system in Duval County.

One of the most important resources of the Jacksonville-Duval area is a large supply of potable ground water, derived mainly from the deep Floridan aquifer. However, due to increased water demands, the shallow-aquifer system has gained recognition as a potential source of fresh water.

The shallow-aquifer system, recharged by local rainfall, yields 10 to 25 million gallons per day. This water is used mainly for domestic purposes.

Sincerely yours,

C. W. Hendry, Jr., Chief

Completed manuscript received
November 23, 1971
Printed for the Florida Department of Natural Resources
Division of Interior Resources
Bureau of Geology
by St. Petersburg Printing Company
St. Petersburg, Florida

Tallahassee
1972

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THE SHALLOW-AQUIFER SYSTEM IN DUVAL COUNTY, FLORIDA

ABSTRACT

One of the most important natural resources of the Jacksonville-Duval area in northeast Florida is a large supply of potable ground water. This water is derived mainly from deep wells that tap the Floridan aquifer. However, because of increased growth of population and industry in the area in the past 30 years, the shallow-aquifer system has gained recognition as a potential source of fresh water supply to supplement that from the deeper Floridan aquifer.

The shallow-aquifer system consists of permeable beds of sand, shell, and limestone within the following stratigraphic units; the upper part of the Hawthorn Formation (middle Miocene age), the upper Miocene or Pliocene deposits, and the Pleistocene and Holocene deposits.

The aquifer is recharged by local rainfall. The amount of recharge from rainfall is estimated to be from 10 to 16 inches per year and varies from place to place within the area. Discharge is by pumpage, outflow from springs, downward percolation, and by evapotranspiration. From 40,000 to 50,000 wells penetrate the shallow aquifer in Duval County and discharge 10 to 25 million gallons per day. These wells range in depth from 20 to 200 feet and are 1½ to 6 inches in diameter; the most common diameter is 2 inches.

In the west central part of Duval County the potentiometric surface of the shallow-aquifer system is above land surface all or part of the year and shallow wells will flow.

With only a few exceptions, wells that penetrate the shallow-aquifer system yield water of good quality. The hardness of the water averages 185 milligrams per liter and ranges from 10 to 1,900 milligrams per liter. The iron content ranges from 0 to 2.8 milligrams per liter and in places causes staining of clothing and plumbing fixtures.

Water from the shallow-aquifer system is used primarily for domestic purposes, particularly in the rural areas and areas not served by private or public utilities. Other uses for the water consist of refrigerator cooling, industrial, agricultural, and schools.

INTRODUCTION

PURPOSE AND SCOPE

The deep artesian wells that penetrate the Floridan aquifer constitute the major source of fresh water in Duval County. However, a substantial quantity of water is also obtained from shallow wells (20 to 200 feet deep) that penetrate the shallow-aquifer system (see table 1). Because of increased growth in population and industry in the Jacksonville area, the demands for fresh water have increased. As a result, the shallow aquifer is becoming more and more important as an additional source of potable water.

The purpose of this report is to describe the geologic and hydrologic characteristics of the shallow-aquifer system, its thickness and extent, the amount of recharge to and discharge from the aquifer, and the quality of the water and how it is used. The study was made in an effort to determine the potential of the shallow aquifer as a primary or supplemental source of water and to supply background information for future studies to appraise the total water resources in the area.

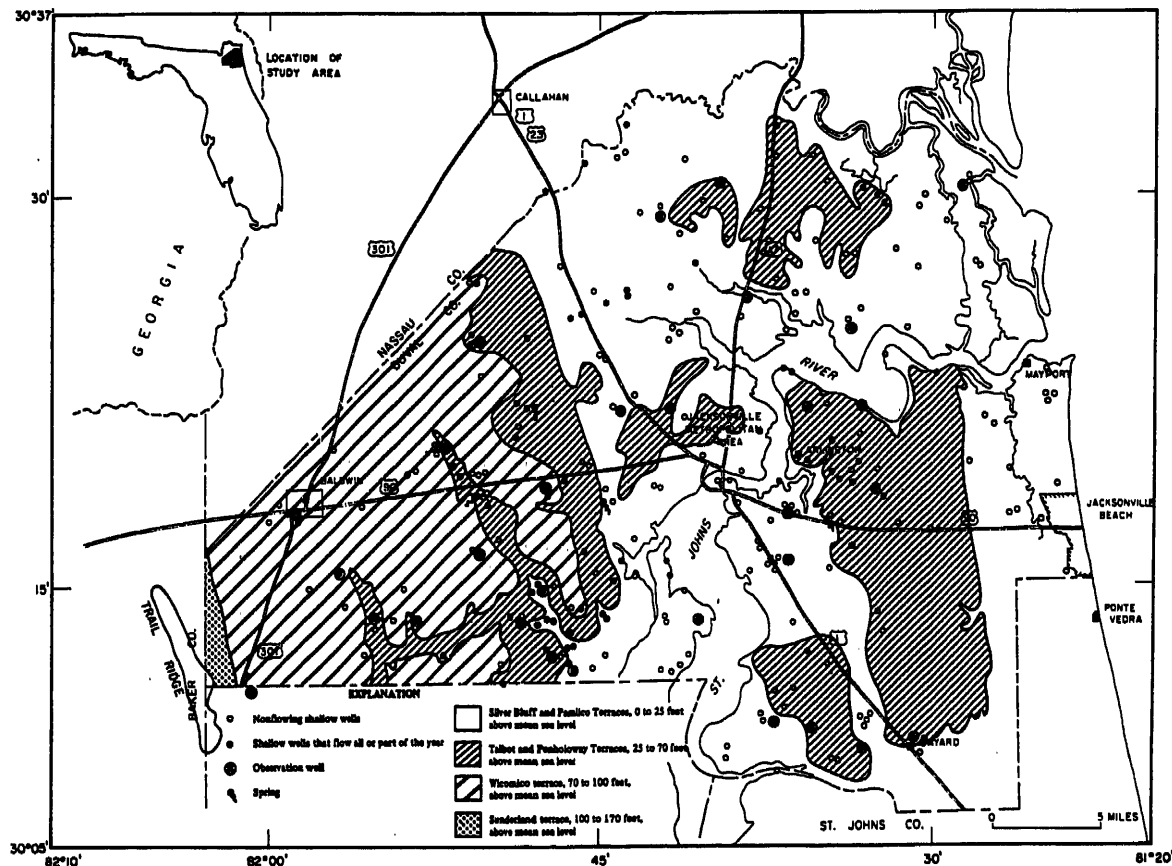
LOCATION AND EXTENT OF AREA

Duval County is in northeastern Florida, lies between $30^{\circ} 06'$ and $30^{\circ} 35'$ north latitudes and extends eastward from $82^{\circ} 03'$ west longitude to the Atlantic Ocean, and occupies about 840 square miles (figure 1). Most of Duval County is within the corporate limits of the Consolidated City of Jacksonville.

Table 1. Estimated number of wells and daily withdrawal from the shallow-aquifer system and the Floridan aquifer in Duval County.¹

	No. of wells	Range in diameter of wells	Estimated withdrawal (1960)
Shallow-water aquifer	40,000-50,000	1½-6 inches	10-25 mgd
Deeper Floridan aquifer	2,500-4,000	2-20 inches	175-190 mgd

¹ Leve and Goolsby, 1969



PREVIOUS WORK

Reports of previous investigations of the ground-water resources of the area generally are confined to discussions of the Floridan aquifer. Reports by Derragon (1955) and Leve (1961 and 1966) include brief descriptions and discussions of the shallow aquifers in northeastern Florida. Leve and Goolsby (1969) present quantitative information regarding the use of water from shallow wells.

The geology of the shallow formations underlying northeastern Florida is discussed by Cooke (1945), Vernon (1951), Puri and Vernon (1964), and Leve (1966). The reports by Leve (1966) and Puri and Vernon (1964) include generalized cross sections showing the formations which make up the shallow-aquifer system.

CLIMATE

Duval County has a humid, semitropical climate. The average annual rainfall is about 54 inches, most of which occurs in the late spring and early summer. Winters are mild and dry, with occasional frost from November through February.

The amount of rainfall varies from place to place within the county; thunderstorms may yield several inches of rain in one part of the county and only a trace in other parts. Table 2 shows the monthly rainfall totals in 1968 for nine rainfall stations in and around the Duval County area. As shown in table 2, rainfall for the year ranged from nearly 43 inches at Mayport Naval Air Station to more than 57 inches at Cecil Field Naval Air Station. Figure 2 shows the variations in yearly rainfall at Jacksonville's Imeson Airport, 1938-68. The total annual rainfall at Jacksonville for the period 1938-68 ranged from 36.83 inches in 1954 to 77.37 inches in 1947, and averaged 53.50 inches. Rainfall was approximately 4 inches below average in 1967 and was about average in 1968.

Figure 3 shows the monthly rainfall at Jacksonville's Imeson Airport, 1967-68; the greatest rainfall occurred during June, July, and August of both years.

Table 2. Monthly rainfall records for 9 stations in and around the Duval County area.

Station	Monthly Rainfall Totals, Inches, 1968												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
1	0.60	2.03	0.73	1.02	2.77	8.81	5.57	11.28	1.58	5.30	2.08	0.73	42.50
2	.56	3.08	.91	1.58	6.52	10.47	6.64	16.54	2.31	5.54	1.79	1.30	57.24
3	.65	1.07	.98	1.20	3.88	12.29	5.00	17.65	1.14	7.78	2.42	1.14	55.20
4	.82	3.05	1.20	.99	2.17	12.25	6.84	16.24	2.68	5.09	1.30	1.09	53.72
5	.86	1.76	.94	2.08	6.06	8.58	5.20	16.48	2.09	8.95	2.58	.92	56.50
6	.16	1.66	1.96	.31	4.45	7.96	3.86	10.93	1.99	7.56	1.98	1.39	44.21
7	1.05	1.55	.69	1.35	4.06	8.43	8.20	13.91	3.15	4.63	2.50	2.32	51.84
8	.98	2.82	1.37	.81	4.73	8.75	7.73	15.60	7.17	1.96	2.08	1.56	55.56
9	.76	2.01	1.64	.49	5.53	5.08	11.29	17.21	1.46	3.80	1.99	1.15	52.41

Station Locations

1. Naval Air Station, Mayport
2. Naval Air Station, Cecil Field, Jacksonville
3. Naval Air Station, Jacksonville
4. U.S. Weather Bureau, Imeson Airport, Jacksonville
5. U.S. Weather Bureau, Jacksonville Beach
6. U.S. Weather Bureau, St. Augustine
7. U.S. Weather Bureau, Fernandina Beach
8. U.S. Weather Bureau, Glen St. Mary
9. U.S. Weather Bureau, Starke

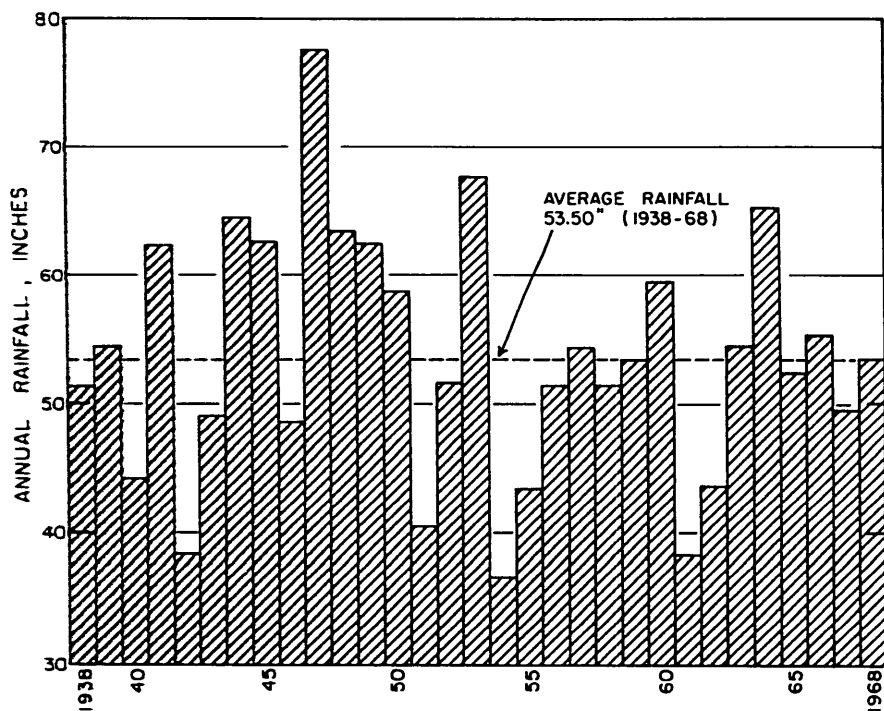


Figure 2. Bar graph showing annual rainfall at Jacksonville (Imeson Airport), 1938-68.

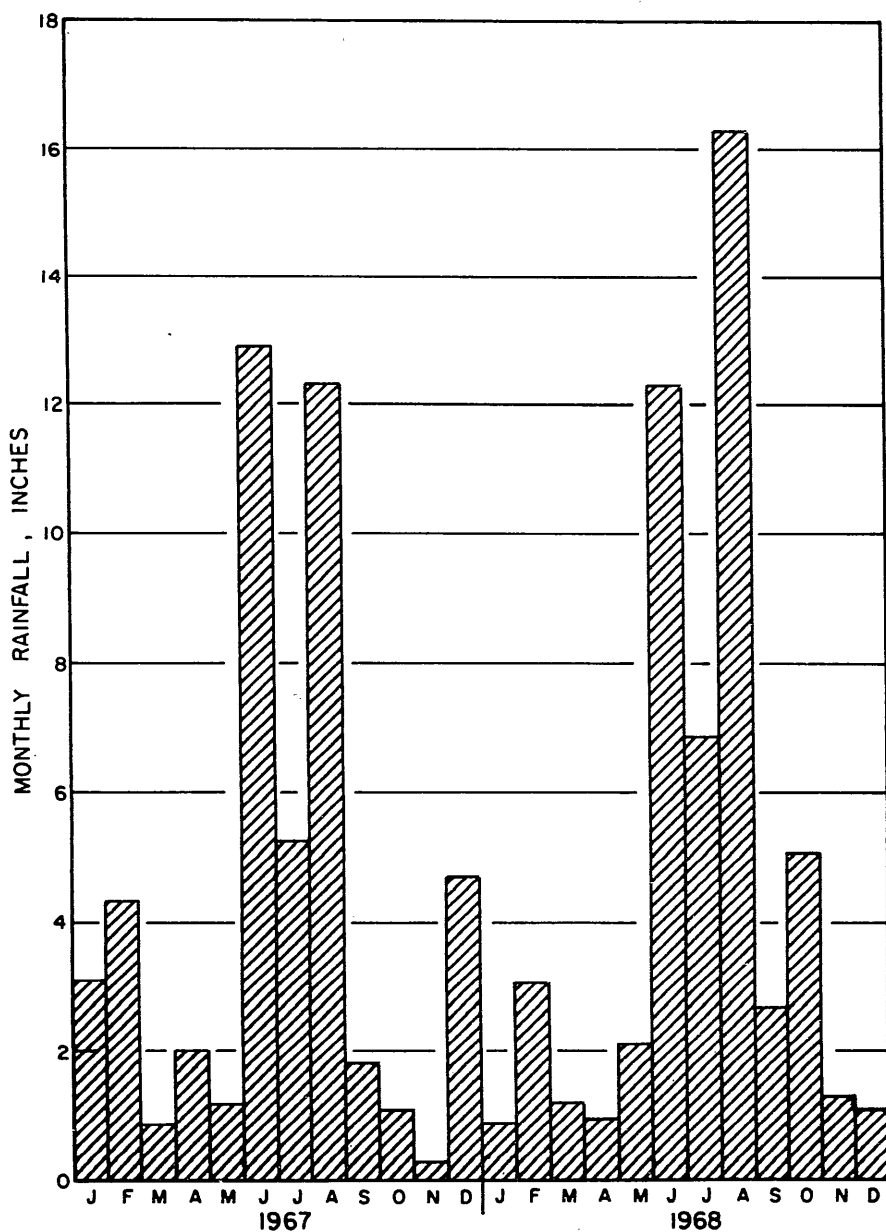


Figure 3. Bar graph showing monthly rainfall at Jacksonville (Imeson Airport), 1967-68.

TOPOGRAPHY AND DRAINAGE

The topography in Duval County is mostly low, gentle to flat, and composed of a series of ancient marine terraces. The highest altitude is about 190 feet above msl (mean sea level) in the extreme southwest corner of the county, along the eastern slope of a prominent topographic feature known as "Trail Ridge." Trail Ridge is a remnant of the highest ancient marine terrace (Coharie) in Duval County. The terraces trend parallel to the present Atlantic shoreline and become progressively higher from east to west.

These terraces have been studied in considerable detail by Cooke (1945), MacNeil (1950), Leve (1966), and Stringfield (1966). Table 3 lists the name, characteristic altitude, and presumed age of each of the terraces, as recognized by the above authors. Of those terraces listed, MacNeil (1950) recognized only four; the Okefenokee at 150 feet, the Wicomico at 100 feet, the Pamlico at 25-35 feet, and the Silver Bluff at 8-10 feet. MacNeil's Okefenokee terrace falls within the altitude range of Cooke's Sunderland terrace, but MacNeil believes that the terrace is most prominent at the 150-foot level in Florida and Georgia.

**Table 3. List of Pleistocene marine terraces in northeast Florida
(after Cooke, 1945, MacNeil, 1950, Leve, 1966, Stringfield, 1966).**

Name of Terrace	Characteristic elevation (feet)	Presumed age
Hazlehurst (Not present in Duval Co.)	270	Aftonian interglaciation
Coharie	215	Yarmouth interglaciation
Sunderland	170	
Wicomico	100	Sangamon interglaciation
Penholoway	70	
Talbot	42	
Pamlico	25	Mid-Wisconsin recession
Silver Bluff	5	

The terraces play a significant role in determining the configuration of the potentiometric surface of the shallow-aquifer system. The potentiometric surface based on water levels in wells that penetrate the shallow-aquifer system roughly follows the contour of the land surface. As a result, the potentiometric surface is highest where the terraces are highest and lowest where they are lowest. Also, the areas of flowing shallow wells roughly follow, but are not confined to, the eastern edges of the Talbot and higher terraces (fig. 1).

Surface drainage in the area is through the St. Johns and Nassau rivers and their tributaries. The St. Johns River is tidal throughout its length in Duval County, and the tributaries are tidal in their lower reaches. Drainage is primarily controlled by the ancient marine terraces. Each terrace is bounded along its east (seaward) edge by remnants of a beach ridge parallel to the ancient shoreline. These ridges direct runoff so that the streams flow parallel to the ancient shorelines. In the flat marshy areas of the northeastern part of the county, drainage is sluggish and the streams form a dendritic pattern. Because of the low relief over much of the area, drainage divides are often difficult or impossible to define.

WELL-NUMBERING SYSTEM

The well-numbering system used to catalog wells in this report is that of the Water Resources Division of the U. S. Geological Survey. It is based on the location of wells within a 1-second grid of parallels of latitude and meridians of longitude.

The number used to catalog wells is a 16-character number that defines the latitude and longitude of the southeast corner of a 1-second quadrangle in which the well is located. The first six characters of the well number include the digits of the degrees, minutes, and seconds of latitude, in that order. The six digits defining the latitude are followed by the letter N, which indicates north latitude. The seven digits following the letter N give the degrees, minutes, and seconds of longitude. The last digit, set off by a period from the rest of the number, is assigned sequentially to identify wells inventoried within a 1-second quadrangle.

An example of the well number is illustrated in figure 4. The designation 275134N0815220.1 indicates the first well inventoried in the 1-second quadrangle bounded by latitude $27^{\circ}51'34''$ on the south and longitude $081^{\circ}52'20''$ on the east.

Table 4 is a list, with descriptions, of all wells used in the study of the shallow-aquifer system in Duval County.

Table 4. Record of wells used in study of shallow-aquifer system.
 Use of water: H, domestic; I, irrigation; N, industrial; P, public supply; S, stock; T, institutional; U, unused; Z, other. Major aquifer: 1F, Floridan; 1H, Hawthorn limestone; 2H, Hawthorn clayey sand and gravel; 1N, non-artesian sand. Remarks: Florida Bureau of Geology well-log identification number.

LOCATION	LOCAL WELL NUMBER	WELL DEPTH (FT.)	CASING DEPTH (FT.)	CASING DIAMETER (IN.)	USE OF WATER	ALTITUDE OF LSD (FT.)	MAJOR AQUIFER	WATER LEVEL (FT.)	DATE WATER LEVEL MEAS.	REMARKS
DUVAL COUNTY										
30CE01N0813410.1	CS 146	76	--	2	H	15	1N	--	--	W 160
30CE06N0813435.1	DS 155	82	--	2	U	7	1N	12	12-68	
300815N0813427.1	CS-66	187	177	2	H	16	1N	12	3-68	
30CE25N0813C4C.1	C-61	448	322	6	H	22	1F	+32	12-31	
30CE89N08133C5.1	CS 17	150	--	2	U	25	1H	12	12-67	
30CE46N0813415.1	CS 131	95	--	2	U	22	1N	13	10-68	
30CE891N0813049.1	DS 147	60	--	--	H	20	1N	--	--	
30CE97N0813444.2	DS 207	92	--	--	H	--	1N	--	--	
30CE89N0813C96.1	DS 16	43	--	2	U	22	1N	4	12-67	
30CE92N0813524.1	CS 156	177	--	2	U	25	1N	4	12-68	
30C933N0813725.1	DS 1	145	--	--	H	20	1N	--	--	W 3464
30C936N0813721.1	DS 24	120	--	2	U	20	1H	3	12-67	
30C943N08133C4.1	CS 21	42	--	2	U	24	1N	14	12-67	
30C945N0813307.1	CS 20	55	--	2	U	24	1N	23	12-67	
30C945N08133C7.2	CS 19	35	--	2	U	24	1N	11	12-67	
30C948N0813259.1	CS 148	55	--	2	H	25	1N	--	--	
30C947N0813740.1	D-83	900	437	16	H	20	1F	--	3-55	
30C93N0813645.1	C-57	850	--	3	H	27	1F	--	--	
30C953N081371C.1	CS 13C	75	--	2	U	21	1N	4	10-68	
30C959N0813622.1	CS 129	62	--	2	U	30	1N	2	10-68	
30I110N0920115.1	CS 76	125	R4	2	U	90	1N	--	--	
30I110N0820115.2	CS 76A	135	--	2	H	90	1N	--	--	
30I120N0814151.1	DS-193	62	--	1	U	23	1N	10	5-69	
30I135N0814213.1	DS 27	160	84	2	H	23	1F	R	10-67	
30I144N0814138.1	D 126	403	252	4	T	16	1H	+37	8-40	
30I145N0813727.1	DS 49	126	--	--	H	26	1N	--	--	
30I154N0813458.1	DS 124	225	225	2	U	27	1N	1	10-68	
30I154N0814521.1	DS 47	177	--	2	U	21	1N	3	2-68	
30I159N081461C.1	DS-32	184	--	2	H	--	1N	+1	1-68	
30I159N0814925.1	CS 150	47	47	2	H	75	1N	--	--	
30I159N0814615.1	CS-48	147	--	2	H	20	1N	+4	2-68	
30I208N0814654.1	CS 157	131	--	2	U	40	1N	6	12-68	
30I213N0814723.1	DS 25	200	--	2	U	56	--	4	10-67	
30I213N0814723.2	CS 91	290	--	2	H	56	1N	8	6-68	
30I214N0814448.1	DS-164	175	--	--	H	20	1N	--	--	
30I216N0813541.1	CS 149	75	--	2	H	25	1N	--	--	
30I216N0815545.1	DS 95	94	--	2	I	82	1N	8	6-68	
30I217N08152CC.1	CS-194	81	--	2	U	70	1N	63	5-69	
30I220N08141C7.1	C-78	645	271	12	P	20	1F	+39	11-42	
30I222N0814620.1	CS-195	160	--	2	U	20	1N	+7	5-69	

Table 4.- Record of wells used in study of shallow aquifer system. Continued

LOCATION	LOCAL WELL NUMBER	WELL DEPTH (FT.)	CASING DEPTH (FT.)	CASING DIAMETER (IN.)	USE OF WATER	ALTITUDE OF LSD (FT.)	MAJOR AQUIFER	WATER LEVEL (FT.)	DATE WATER LEVEL MEAS.	REMARKS
DUVAL COUNTY										
301230N0814615.1	DS-80	189	169	2	H	25	1N	+3	6-68	
301255N0813710.2	DS 85	89	--	--	H	8	--	--	--	
301306N0813221.1	D-406	1060	510	12	H	35	1F	+6	4-69	
301308N0814107.1	D 161	1015	318	12	P	24	1F	+46	7-50	
301324N0815506.1	DS 142	125	--	2	--	70	1N	--	--	
301326N0814754.1	DS 138	--	--	--	H	42	1N	+6	12-68	
301327N0813630.1	DS 123	--	--	2	U	10	1N	5	10-68	
301333N0814043.1	DS 26	108	--	6	U	15	--	4	10-67	
301334N0814432.1	DS 79	159	--	2	P	23	1N	+5	6-68	
301338N0814828.1	DS 29	72	--	2	I	54	1N	1	10-67	
301338N0814828.2	DS 30	67	--	2	U	54	--	2	10-67	
301340N0814754.1	DS-202	60	--	2	H	50	1N	--	--	
301340N0815310.1	D-222	980	431	10	P	80	1F	16	5-41	
301342N0814900.1	DS 139	72	60	2	H	60	1N	+4	12-68	
301342N0815310.1	D 113	1303	485	12	P	85	1F	28	11-56	
301345N0815310.1	D 328	950	572	12	P	75	1F	22	6-53	
301347N0814218.1	D-65	987	400	12	P	5	1F	+4	9-42	
301347N0815505.1	DS 94	64	--	1	U	70	1N	+1	6-68	
301348N0814455.1	DS 78	150	--	--	H	22	1N	+14	6-68	
301348N0814621.1	DS 206	160	86	6	H	70	1N	--	--	
301354N0815320.1	DS 143	136	--	4	U	80	1N	7	11-68	
301358N0813237.1	D-361	800	575	--	P	39	1F	0	4-64	
301400N0814458.1	DS 77	120	--	2	N	22	1N	+9	4-68	
301401N0814626.1	DS 86	51	--	2	U	83	1N	16	7-68	
301402N0815630.1	DS-172	120	--	2	H	80	1N	--	--	
301435N0814755.1	D-79	1082	500	8	P	75	1F	29	8-63	
301443N0814244.1	DS 88	165	--	--	H	7	1N	--	--	
301450N0814749.1	DS 107	100	--	2	U	30	1N	2	7-68	
301450N0814802.1	DS-110	--	--	--	--	40	1N	--	--	
301452N0814110.1	D-428	669	286	8	P	--	1F	+42	6-22	
301454N0814754.1	DS-72	68	--	2	U	40	1N	+19	4-68	
301454N0814754.2	DS 73	64	--	2	U	40	1N	+18	4-68	
301455N0814720.1	DS C6	108	--	2	H	80	1N	6	10-67	
301455N0815355.2	D-66	780	502	8	I	80	1F	--	--	
301458N0813654.1	D 344	706	--	--	P	26	1F	+13	5-66	
301458N0815918.1	D-426	708	444	6	U	85	1F	31	4-69	
301501N0814431.1	DS 55	175	170	2	H	25	1N	+6	3-68	
301508N0814125.1	D-60	705	120	8	P	5	1F	--	--	
301514N0815658.1	DS 96	107	--	2	H	80	1N	4	6-68	
301516N0812350.1	DS-189	112	--	2	U	10	1N	13	5-69	

Table 4. Record of wells used in study of shallow aquifer system. Continued

LOCATION	LOCAL WELL NUMBER	WELL DEPTH (FT.)	CASING DEPTH (FT.)	CASING CIAM-ETER (IN.)	USE OF WATER	ALTI-TUDE-OF LSD (FT.)	MAJOR AQUIFER	WATER LEVEL (FT.)	DATE WATER LEVEL MEAS.	REMARKS
DUVAL COUNTY										
3C1527N0814512.1	D 286	1000	460	12	P	30	1F	+7	5-62	W 161
3C1529N0813826.1	D 304	1187	757	10	P	--	1F	+31	3-65	
3C1534N0813656.1	D-62	739	538	8	N	25	1F	+20	-25	
3C1535N0813453.1	D5-69	57	57	2	H	15	1N	5	4-68	
3C1535N0813709.1	D5-64	84	73	--	N	25	1N	6	--	
3C1537N0814419.1	D-75	1302	488	8	P	10	1F	+30	5-68	
3C1540N0813713.1	D5-62	37	--	2	U	25	1N	3	3-68	
3C1540N0813713.2	D5 62A	36	--	1	U	25	1A	3	3-68	
3C1551N0814157.1	129	600	47C	4	H	9	1F	+40	7-6C	
3C1554N0814410.1	C5-192	78	--	2	H	10	1N	+5	5-69	
3C1555N0813641.1	D5-52	75	--	2	U	25	1N	4	2-68	
3C1555N0813703.1	D5 23	54	--	2	U	25	1N	3	12-67	
3C1602N0815054.1	C5 5	146	--	2	U	90	1H	10	10-67	
3C1602N0815054.2	D5 5A	140	--	2	H	90	1H	--	--	
3C1612N0814545.1	D5 08	78	--	2	U	65	1N	23	10-67	
3C1632N0813348.1	D5-68	84	64	2	H	30	1N	5	4-68	
3C1725N0813921.1	D-48	--	--	--	H	15	1F	+16	5-66	
3C1725N0815845.1	254	750	433	10	N	85	1F	25	1-61	
3C1726N0813715.1	D5 28	58	--	1	U	20	1N	14	12-67	
3C1730N0820000.1	C5 93	97	--	2	S	85	1N	5	6-68	
3C1737N0813437.1	D 281	1004	487	15	P	13	1F	--	--	
3C1737N0813447.1	D-88	675	--	4	H	27	1F	+30	6-39	
3C1738N0813608.1	D5-1	245	--	2	U	--	1N	5	2-61	
3C1740N0813629.1	D5 151	65	--	2	H	10	1N	--	1	
3C1741N0812629.1	C5 75	144	105	2	H	10	1N	--	5-68	
3C1743N0813625.1	C5-2	68	--	2	H	--	1N	10	2-61	
3C1745N0812623.1	D5 74	21	19	1	U	--	1N	4	5-68	
3C1745N0813630.1	D53	90	--	1	U	--	1N	13	2-61	
3C1747N0813624.1	C5 203	55	--	2	U	20	1A	--	11-66	
3C1801N081242C.1	C5-208	168	100	2	H	18	2H	--	--	
3C1801N0813843.1	C34	1071	505	10	H	20	1F	+30	3-39	
3C1801N0813843.2	D-54A C-34	1348	505	10	P	20	1F	+30	3-39	
3C1803N0814426.1	D5 136	76	--	2	U	25	1N	15	10-68	
3C1804N0815010.1	C5 98	--	--	--	S	70	1A	+3	7-68	
3C1807N0815854.1	D5 92	78	--	2	U	80	1N	3	6-68	
3C1808N0815825.1	C 413	716	460	8	H	85	1F	--	--	
3C1812N0815552.1	D5-197	100	--	6	S	85	1N	5	5-69	
3C1812N0815932.1	D5 137	135	7C	2	H	80	1N	--	5-69	
3C1817N0813212.1	C5-190	39	--	2	U	42	1N	2	5-69	
3C1817N0813749.1	C 425	2486	752	8	U	--	1F	--	5-66	

Table 4.- Record of wells used in study of shallow aquifer system. Continued

LOCATION	LOCAL WELL NUMBER	WELL DEPTH (FT.)	CASING DEPTH (FT.)	CASING DIAMETER (IN.)	USE OF WATER	ALTITUDE OF L.S.D. (FT.)	MAJOR AQUIFER	WATER LEVEL (FT.)	DATE WATER LEVEL MEAS.	REMARKS
DUVAL COUNTY										
301817N0813749.2	CS 90	--	--	--	I	22	1N	--	--	
301818N0813007.1	DS 1C1	102	--	2	U	70	1N	+14	7-68	
301820N0813007.1	DS-99	140	--	2	H	70	1N	--	--	
301822N0814007.2	CS 100	80	--	--	I	70	1N	--	--	
301834N0813937.1	DS 111	37	--	2	U	4	1N	4	8-68	
301836N0813233.1	CS-37	125	--	2	U	40	1N	+10	1-68	
301839N0813924.1	D-347 C-27	1048	506	10	P	5	1F	+33	6-66	
301839N0813924.2	D-347A C-27	1307	506	10	P	5	1F	+33	6-66	
301840N0813935.1	D-53 C-35	1037	510	10	P	5	1F	+48	3-39	W 403
301840N0813935.2	D-53A C-35	1265	510	10	P	5	1F	+48	3-39	W 403
301840N0814445.1	DS-163	110	--	2	H	8	1N	--	--	
301842N0814220.2	D-50A C-15	1303	540	12	P	20	1F	--	--	W 28
301843N0814733.1	C-80	1 16	530	8	P	46	1F	+2	4-65	
301844N0814235.1	D-59 C-22	1260	--	10	P	20	1F	--	--	W 157
301844N0814235.2	D-59A C-22	1260	--	10	P	20	1F	--	--	W 157
301845N0812404.1	D-20	622	382	10	H	10	1F	+40	12-38	
301848N0813704.1	D-55	600	--	3	S	20	1F	--	--	
301848N0813925.1	D-244	753	516	8	Z	22	1F	+12	10-61	
301849N0814740.1	DS 07	132	108	2	U	65	1H	11	10-67	
301859N0813340.1	DS 14	100	--	2	U	50	1H	14	9-67	
301857N0813429.1	DS 65	70	60	2	H	30	1N	6	3-68	
301900N0814642.1	DS 121	100	--	2	H	25	1N	+4	5-68	
301901N0815115.1	DS 102	118	--	2	H	63	1N	+6	7-68	
301905N0815111.1	DS-201	--	--	--	U	66	1N	+1	5-66	
301907N0813230.1	CS-182	102	--	2	H	45	1N	1	1-69	
301907N0814821.1	DS-204	286	--	4	H	86	1N	--	--	
301909N0813430.1	DS-53	92	75	2	H	--	1N	20	3-68	
301910N0813348.1	DS 22	98	--	2	U	50	1N	13	12-67	
301910N0813436.1	DS-205	100	96	3	H	15	1N	--	--	
301912N0815040.1	DS 108	21	--	1	U	87	1N	2	7-68	
301912N0815040.2	DS 109	159	--	2	U	87	1N	21	7-68	
301913N0815346.1	D-44	700	466	6	S	90	1F	45	4-68	
301915N0813515.1	DS 20C	200	--	16	P	--	1N	--	--	
301918N0813839.1	D-64	1074	515	10	N	--	1F	+42	7-42	W 649
301921N0812628.1	DS-117	137	--	2	U	8	1N	7	9-68	
301922N0812634.1	CS 84	40	40	2	H	10	1N	--	--	
301922N0815023.1	DS-162	219	--	2	H	--	1N	--	--	
301925N0813309.1	D 359	750	600	12	Z	58	1F	--	--	
301925N0813309.2	D-73	1016	600	8	P	57	1F	12	1-66	
301926N0814552.1	DS-159	165	--	2	H	25	1N	--	--	

Table 4.- Record of wells used in study of shallow aquifer system. Continued

LOCATION	LOCAL WELL NUMBER	WELL DEPTH (FT.)	CASING DEPTH (FT.)	CASING DIAMETER (IN.)	USE OF WATER	ALTITUDE-LSO (FT.)	MAJOR AQUIFER	WATER LEVEL (FT.)	DATE WATER LEVEL MEAS.	REMARKS
DULAL COUNTY										
3C1926N0815329.1	CS-170	150	--	2	H	90	1N	--	--	
3C1931N0814554.1	DS 140	39	--	1	U	25	1N	4	11-68	
3C1931N0814700.1	D-67	1060	583	6	H	59	1F	+5	7-29	H 116
3C1932N0815131.1	CS 97	116	--	2	U	65	1N	0	7-68	
3C1938N0813333.1	D 414	1050	--	--	U	55	1F	--	--	
3C1940N0813546.1	CS-36	73	--	2	U	30	1N	15	1-68	
3C1942N0812825.1	CS-183	100	--	1	--	19	1N	--	--	H 5825
3C1959N0814029.1	C-70	974	591	10	A	25	1F	--	--	
3C2008N0812421.1	D-307	1300	407	12	P	--	1F	F	--	
3C2017N0815228.1	DS-56	190	--	2	H	77	1N	--	--	
3C2018N0815715.1	DS-196	135	--	2	U	75	1N	R	5-69	
3C2019N0815207.1	CS 115	115	--	2	U	74	1N	45	9-68	
3C2020N0815216.1	CS 160	185	--	2	U	75	1N	3	1-69	
3C2022N0813528.1	D-63 C-29	1244	501	10	P	10	1F	+33	8-36	H 303
3C2022N0813528.2	D-63A C-29	1244	501	10	P	10	1F	+33	8-36	H 303
3C2041N0813805.1	CS195	28	--	--	--	10	1N	--	6-41	
3C2043N0814856.1	CS 106	--	--	--	H	47	1N	+6	7-68	
3C2049N0813315.1	CS-185	275	--	2	H	50	1N	--	--	
3C2100N0812707.1	CS 13	22	--	1	U	10	1N	15	9-67	
3C2100N0814840.1	CS-167	125	--	2	H	45	1N	--	--	
3C2123N0812742.1	DS-184	100	--	2	H	10	1N	--	--	
3C2136N0814255.2	DS 87	80	--	--	H	25	1N	--	--	
3C2143N0814410.1	DS 10	57	--	2	U	15	1N	7	10-67	
3C2143N0814413.1	CS 09	67	--	2	U	15	1N	7	10-67	
3C2143N0813542.1	C-43	67	--	2	U	15	1N	7	10-67	
3C2146N0814157.1	CS 11	64	--	1	I	24	1N	7	10-67	
3C2147N0813313.1	DS 15	61	--	2	U	20	1N	5	9-67	
3C2149N0813307.1	C2113302	38	38	2	H	--	1N	--	--	
3C2150N0813550.1	DS-35	91	--	2	U	42	1N	7	1-68	
3C2151N0814826.1	CS 112	75	--	2	H	37	1N	+10	9-68	
3C2155N0813310.1	C211332	39	35	2	H	--	1N	--	--	
3C2157N0813450.1	C-415	1104	620	12	H	10	1F	+41	12-68	
3C2200N0812454.1	CS-145	110	--	2	H	10	1N	--	--	
3C2203N0812455.1	CS 119	98	--	2	U	10	1N	6	9-68	
3C2203N0812455.2	DS-119A	162	--	2	H	R	1N	--	--	
3C2217N0814340.1	C 181	690	469	6	I	10	1F	+47	11-40	
3C2218N0813605.1	D-356	1016	573	8	P	10	1F	+32	7-65	
3C2230N0815025.1	CS-166	150	--	2	H	95	1N	--	--	
3C2237N0812938.1	D-424	700	426	6	Z	15	1F	32	12-66	
3C2239N0812931.1	CS-193	200	--	--	P	30	1N	--	--	

Table 4.- Record of wells used in study of shallow aquifer system. Continued.

LOCATION	LOCAL WELL NUMBER	WELL DEPTH (FT.)	CASING DEPTH (FT.)	CASING DIAMETER (IN.)	USE OF WATER	ALTITUDE OF SURFACE (FT.)	MAJOR AQUIFER	WATER LEVEL (FT.)	DATE WATER LEVEL MEAS.	REMARKS
DUVAL COUNTY										
3C231N0813309.1	D-74	1326	566	1C	F	5	1F	+34	5-68	
3C2450N0814147.1	CS-58	9C	69	2	H	22	1N	14	1-68	
3C2501N0813358.1	CS-186	65	--	2	H	10	1N	--	--	
3C2620N0814518.1	D-269	70C	--	5	S	20	1F	28	1-56	
3C2641N0815055.1	CS 105	75	--	2	U	57	1N	11	7-68	
3C2641N0815055.2	DS-105A	95	93	2	H	52	1N	--	--	
3C2644N0813705.1	CS 176	86	--	2	H	20	1N	--	--	
3C2701N081275C.1	CS-177	88	--	2	S	5	1N	--	--	
3C2703N0813819.1	CS-81	12C	1CC	2	H	27	1N	--	--	
3C2705N0813C41.1	CS-175	9C	--	2	H	10	1N	--	--	
3C2710N0812800.1	CS-191	78	--	2	H	10	1N	4	5-68	
3C2711N0814042.1	DS 124A	--	--	--	H	12	1N	+1	10-68	
3C2715N0814635.1	CS-165	11C	--	2	H	24	1N	--	--	
3C2736N0813355.1	CS61	132	116	2	H	21	1N	4	3-68	
3C2739N0813338.1	CS-40	90	--	2	U	25	1N	6	1-68	
3C2740N0813751.1	CS-181	125	--	2	H	30	1N	--	--	
3C2743N0813743.1	CS-43	105	--	2	U	28	1N	4	1-68	
3C2750N0813138.1	DS 135	84	--	2	U	10	1N	4	11-68	
3C2800N081404C.1	CS 116	55	--	2	U	15	1N	2	9-68	
3C2801N0813516.1	DS-187	11C	--	2	H	25	1N	--	--	
3C2804N0813733.1	CS-198	190	--	2	U	28	1N	8	5-68	
3C2814N0813512.1	CS-54	38	9d	2	U	21	1N	4	1-68	
3C2829N0814128.1	DS-63	15C	--	2	H	24	1N	--	--	
3C2855N0812512.1	CS-51	58	--	2	U	5	1N	5	2-68	
3C2955N0814303.1	CS-171	145	--	2	H	20	1N	--	--	
3C2908N0814214.1	CS 125	133	--	2	U	22	1N	6	10-68	
3C2910N0814216.1	C-362	1105	590	12	T	27	1F	+16	10-67	
3C2915N0814215.1	DS 4	142	126	2	U	20	1N	7	10-67	
3C2920N0813755.1	C-427	915	578	6	P	26	1F	+14	11-68	
3C2922N0813C41.1	CS-46	26	--	1	U	--	1N	4	1-68	
3C2923N0813C53.1	CS-33	87	87	2	I	1C	1N	--	--	
3C2935N0813214.1	DS-158	110	--	2	U	20	1N	--	--	
3C2948N0814021.1	CS 31	90	--	2	U	--	1N	7	2-68	
3C2958N0813234.1	CS-41	75	--	2	U	22	1N	9	1-68	
3C3007N0813315.1	DS-178	99	--	2	H	30	1N	--	--	
3C3015N0813433.1	D-77	7C6	466	6	P	15	1F	+25	4-69	
3C3017N0812821.1	CS 49	4C	--	2	U	7	1N	+11	2-68	
3C3017N0812821.2	CS-50	54	--	1	U	7	1N	5	2-68	
3C3020N0813455.1	CS 124	71	--	2	U	25	1N	6	5-68	
3C3022N0813937.1	DS-44	89	--	2	U	26	1N	6	1-68	

Table 4.- Record of wells used in study of shallow aquifer system. Continued

LOCATION	LEGAL WELL NUMBER	WELL DEPTH (FT.)	CASING DEPTH (FT.)	CASING DIAMETER (IN.)	USE OF WATER	ALTI-TUDE-OF LSD (FT.)	MAJOR AQUIFER	WATER LEVEL (FT.)	DATE WATER LEVEL MEAS.	REMARKS
DUVAL COUNTY										
303C38NC81282C.1	CS-179	90	--	2	H	15	1N	--	--	
3031C8NC814550.1	DS-174	240	--	2	H	17	1N	--	--	
303117NC8141C6.1	CS-141	140	--	2	U	24	1N	--	12-66	
303117NC8144C3.1	DS-67	108	1C5	2	H	25	1N	12	4-68	
303125NC813524.1	CS-42	67	--	2	U	--	1N	4	1-68	
303125NC813715.1	DS-34	100	--	2	J	39	1N	--	--	
303137NC814359.1	DS-173	95	--	--	H	21	1N	--	--	
303237NC813704.1	DS-45	75	--	2	U	21	1N	15	1-68	
303245NC814356.1	DS-122	--	--	2	S	4	1N	+7	9-68	
303356NC813645.1	CS-82	95	--	2	H	5	1N	--	--	
CLAY COUNTY										
300831NC814445.1	C-10	864	358	12	P	27	1F	--	--	
301C58NC820C49.1	CS-3	57	--	2	U	83	1N	2	6-68	
3011C4NC814924.1	CS-2	117	--	6	U	69	1N	7	3-68	
NASSAU COUNTY										
303C2CNC814735.1	AS-13	200	--	--	H	10	1N	+1	9-65	
3031C5NC814621.1	NS-3	103	94	2	H	20	1N	12	4-68	
303552NC815248.1	N-6	770	532	6	S	60	1F	--	8-65	

ACKNOWLEDGMENTS

The author is indebted to many people throughout the area for their cooperation and helpful assistance. The following companies provided ready access to their drilling records and permitted on-site collection of rock samples: Duval Drilling Company, Ricket's Well and Pump Company, O. E. Smith's Sons, Harry S. Meir Well Drilling, Williams Nursery, Partridge Well Drilling Company, Trout Well Drilling Service, Law Engineering Testing Company, and Jacksonville Engineering and Testing Company.

Especially appreciated is the cooperation extended by the city of Jacksonville, Water and Sewer Dept. and the many residents who permitted access to their land and who often assisted in the measuring of water levels in wells.

The author is particularly indebted to his colleagues for their many suggestions and assistance throughout the study; especially G. Warren Leve under whose supervision the fieldwork was conducted.

SHALLOW-AQUIFER SYSTEM
GEOLOGY¹

All the formations that overlie the Ocala Limestone of Eocene age comprise the shallow-aquifer system in Duval County. These rocks range in age from Miocene to Holocene. The formations that lie above the Hawthorn Fomation, of Miocene age, have not been given formal names in this report, and they will be referred to here by their geologic age. In ascending order, the formations that comprise the shallow-aquifer system are: the Hawthorn Formation, middle Miocene age; upper Miocene or Pliocene deposits; and Pleistocene and Holocene deposits. The stratigraphic units making up the shallow-aquifer system in Duval County are listed and described in table 5. A map showing the thickness of all the sediments that overlie the Ocala group is shown in figure 5.

¹The stratigraphic nomenclature in this report follows that of the Bureau of Geology, Florida Department of Natural Resources.

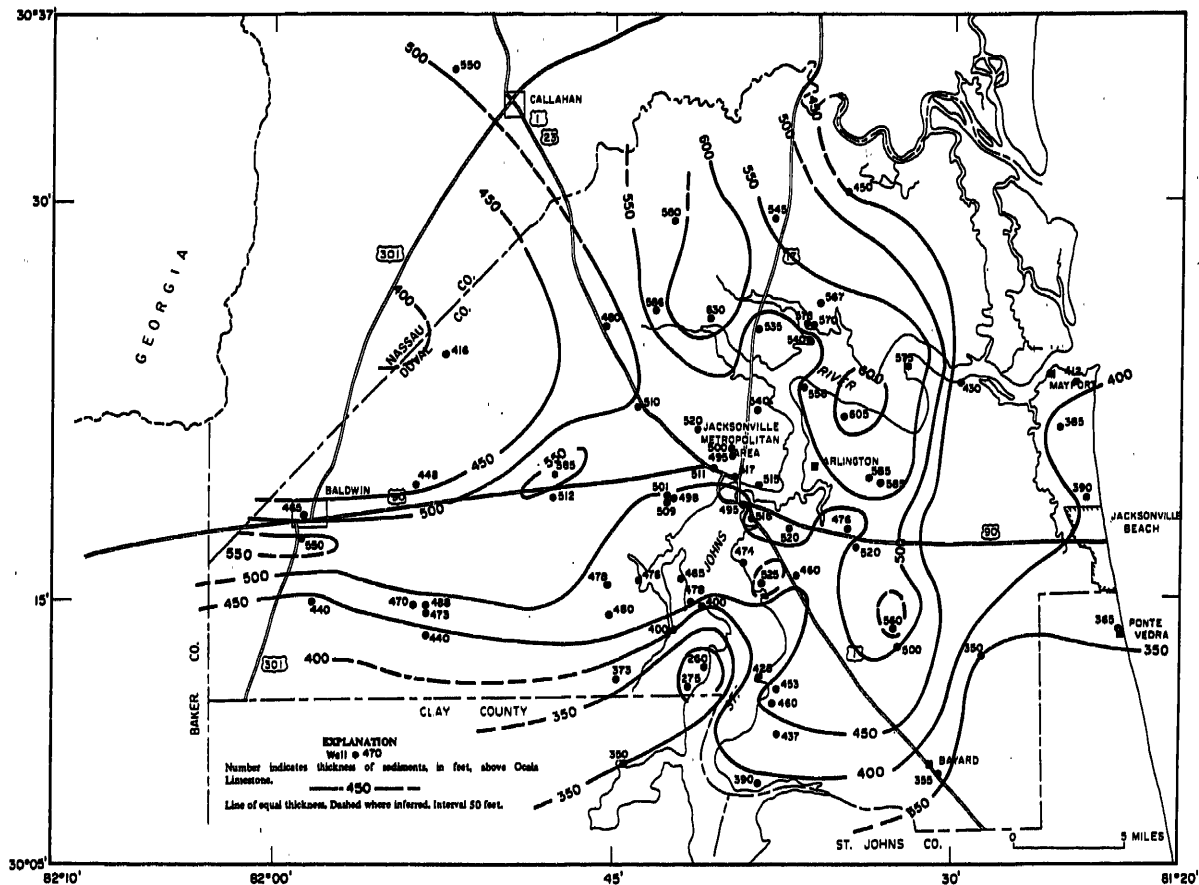


Figure 5. Map of Duval County showing the thickness of the sediments overlying the Ocala Limestone of the Floridan aquifer.

Table 5. Stratigraphic units making up the shallow aquifer system in Duval County.

System	Series	Formation	Thickness	Lithologic Description
Quaternary	Holocene	Pleistocene and Holocene Deposits	0 to 90'	Sand, tan to yellow, loose, medium to fine quartz, sometimes with shells and/or minor clay content—often has hardpan layer of iron oxide-cemented, rusty red to dark brown medium to fine sand in upper part of section—source of water to shallow sandpoint wells.
	Pleistocene			
Tertiary	Pliocene	Upper Miocene or Pliocene Deposits	10' to 110'	Upper part—tan to buff, fine to coarse sand and gray to light gray sandy clay, clayey sand, and shell beds; clay often contains abundant mollusk shells. Lower part—limestone, tan to yellow, often highly sandy, porous, and cavernous—also few thin beds of brown crystalline, dolomitic, limestone—section is major source of water to shallow wells.
	Miocene	Hawthorn Formation	250' to 500'	Gray to blue-green and olive-green clay, sandy clay, and sandy limestone—usually phosphatic with abundant, well-rounded, polished, granules and pebbles of phosphate. Formation not usually considered a good source of water; some wells tap lenses of sand and limestone in the upper part.

HAWTHORN FORMATION

The name "Hawthorn beds" was originally proposed by Dall and Harris (1892, p. 107) to include beds exposed at several localities in the central part of Florida. More recently, Puri and Vernon (1964, p. 146) designated exposed sections of the Hawthorn Formation at Devils Mill Hopper and Brooks Sink near Gainesville, Florida, as the "cotype" localities to form the basis for later correlation.

The Hawthorn Formation, of middle Miocene age, consists mainly of dark-gray and olive-green sandy to silty clay, clayey sand, clay, and sandy limestone, all containing moderate to large amounts of black phosphate sand, granules, and pebbles. In most places the upper surface of the Hawthorn is marked by the presence of phosphate-rich sediments. In the western part of the county the upper part of the Hawthorn consists mainly of coarse-grained sandy phosphatic limestone.

Throughout most of northeast Florida the clay and silty clay within the Hawthorn Formation serves as a confining layer (aquiclude) that retards upward movement of water from the underlying artesian Floridan aquifer. However, in parts of eastern Duval County, from Mayport to Ponte Vedra, coarse- to very coarse-grained pebbly sand within the Hawthorn Formation is tapped by wells 140 to 165 feet deep. Wells penetrating this zone will yield at least 20 gpm (gallons per minute).

The Hawthorn Formation ranges in thickness from about 250 to as much as 500 feet in Duval County (Leve, 1966, p. 18). Although the formation thickens generally to the northeast, it varies in thickness from place to place because of both an irregular upper and lower surface. The Hawthorn Formation is not exposed in Duval County but occurs at depths ranging from about 50 to 200 feet below land surface throughout the county.

Sharks' teeth are common in the clay and sandy clay, but the only other fossils found consist of poorly preserved mollusk shells, usually as external or internal molds and casts in the sandy limestone.

The sediments of the Hawthorn Formation are considered by Puri and Vernon (1964) to be deltaic deposits. The delta extended southward from Florida's northern boundary line, to about the Gainesville area (Alachua County about 65 mi. southwest of Jacksonville) and possibly farther south. The sediments were deposited on an irregular surface of the Ocala group (Eocene) and were later subjected to subaerial erosion.

UPPER MIOCENE OR PLIOCENE DEPOSITS

The upper Miocene or Pliocene deposits consist of sand, shell, sandy clay, and limestone. The sediments generally can be distinguished from the

Hawthorn Formation by their lack of phosphate and by their lighter colors, usually tan, buff or light gray. Figure 6 is a lithologic log of a typical shallow well (well 302915N0814215.1). As shown in the log the upper 55 feet of sediments penetrated consists of clayey sand and sandy clay. The middle section (55 to 90 feet) consists of sandy clay and shell, and the lower section (90 to 140 feet) consists of interbedded sandy clay, clay, and soft porous bioclastic limestone, which is sandy and cavernous in places.

The limestone section (112 to 140 feet) is the major water-yielding zone in the shallow-aquifer system. Most shallow wells obtain water from this limestone section. Where the limestone is missing, lesser amounts of water are obtained from less permeable sand and shell beds.

The thickness of the upper Miocene or Pliocene deposits ranges from as little as 10 feet in the extreme southwest part of Duval County to as much as 130 feet in the west-central part of the county. Differences in thickness are the result of deposition of the upper Miocene or Pliocene deposits on the irregular Hawthorn Formation. The upper Miocene or Pliocene deposits are thickest over the lows and thinnest over the highs on the Hawthorn surface, as shown in figure 7, generalized geologic sections of the shallow-aquifer system in Duval County. The configuration of the upper surface of the upper Miocene or Pliocene deposits is similar to the upper surface of the Hawthorn Formation but with considerably less relief.

There are no known exposures of the upper Miocene or Pliocene deposits in Duval County. However, dredge spoil indicates that the river may be incised into the deposits, particularly in the reach east of Jacksonville. Several small streams west of Jacksonville may also be eroded into the upper Miocene or Pliocene deposits where the overlying sediments are relatively thin.

No attempt has been made to correlate the sediments making up the upper Miocene or Pliocene deposits in Duval County with other post-Hawthorn sediments in the surrounding areas. Table 6 lists the Hawthorn and younger formations as mapped in the surrounding areas by various authors. As indicated in the table, the stratigraphic nomenclature used in this report follows that of Leve (1966 and 1968). The table also serves to indicate that the shallow-aquifer system is continuous beyond Duval County.

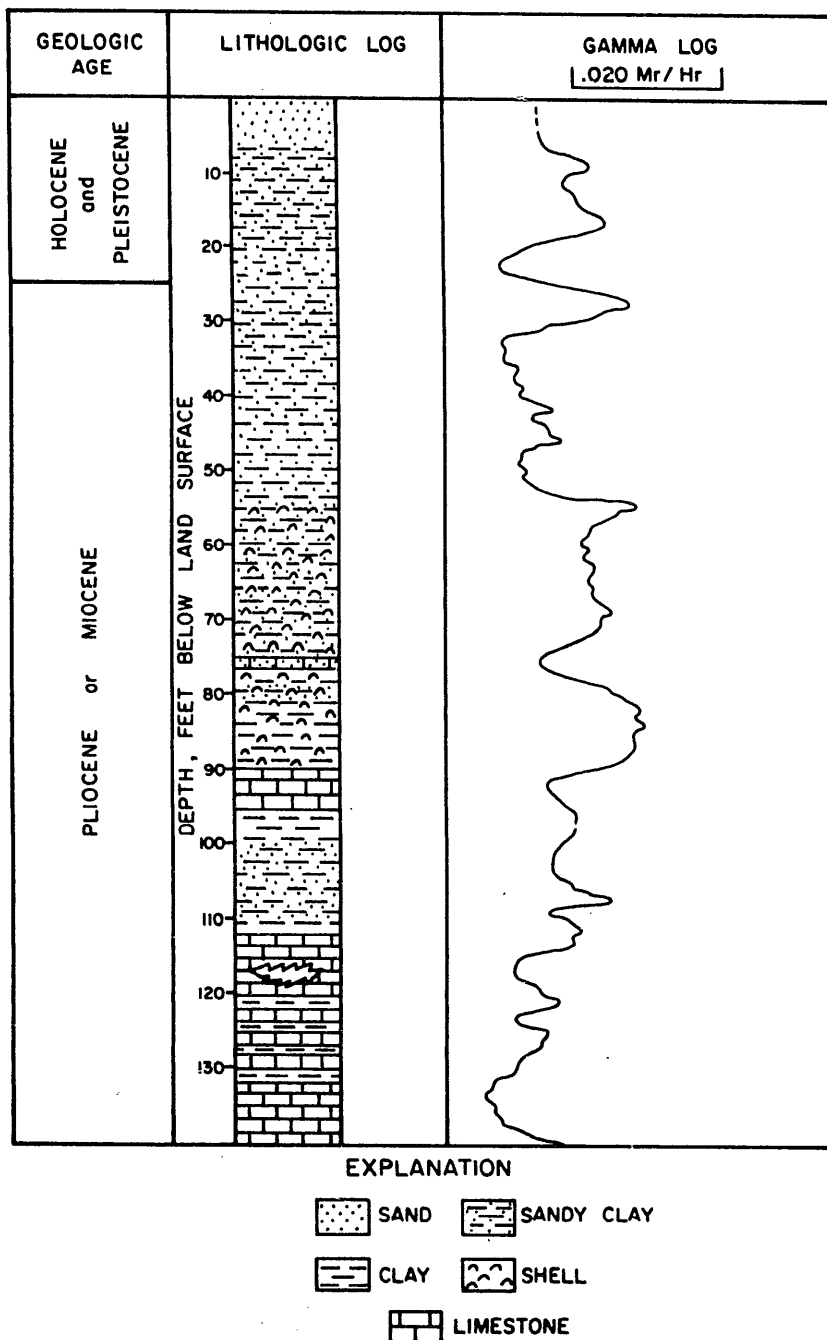


Figure 6. Lithologic and gamma logs of a typical shallow well in Duval County (well 302915N0814215.1).

Table 6. Hawthorn and post-Hawthorn stratigraphy in northeast Florida.

System	Series	Clark, and others (1964)	Bermes, and others (1963) (Western Putnam County)	Bermes, and others (1963) Leve, (1966) Leve, (1968) This report	Purl and Vernon, (1964) Plate 2B
Quaternary	Holocene	Younger marine and estuarine terrace deposits	Post-Hawthorn deposits	Pleistocene and Holocene deposits	Several lower marine and estuarine terrace deposits
	Pleistocene	Older Pleistocene terrace deposits			Anastasia Formation
		Unnamed coarse clastics			
Tertiary	Pliocene	? Alachua Formation ?		Late Miocene or Pliocene deposits	Pliocene(?) - Pleistocene
					Citronelle Formation
	Miocene	Choctawhatchee Formation	Hawthorn Formation	Hawthorn Formation	Charlton Formation (Pliocene)
					Jackson Bluff Formation
		Hawthorn Formation			Fort Preston Formation
					Hawthorn Formation

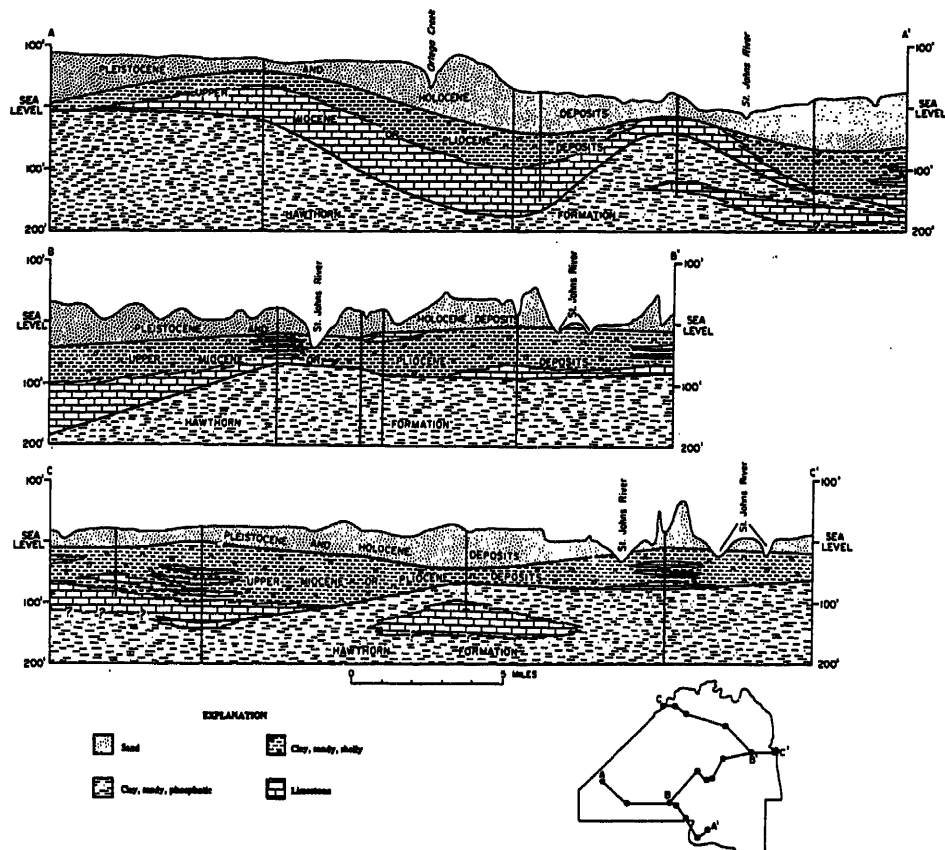


Figure 7. Generalized geologic sections of the shallow-aquifer system in Duval County.

PLEISTOCENE AND HOLOCENE DEPOSITS

Sediments of Pleistocene and Holocene age were deposited during the formation of marine terraces and beach ridges and the sediments blanket all of Duval County. They overlie the upper Miocene or Pliocene deposits and were deposited on a slightly irregular, undulating surface.

The thickness of the Pleistocene and Holocene deposits ranges from less than 10 feet in the St. Johns River valley to about 100 feet in western Duval County. The deposits are thickest below the ridges and where they overlie depressions in the upper surface of the upper Miocene or Pliocene deposits. See figure 7.

The Pleistocene and Holocene deposits consist primarily of tan to yellow medium- to fine-grained loose quartz sand, locally stained rusty brown and red from iron oxide. The deposits locally contain thin gray sandy clay beds, which, in places, contain mollusk shells, particularly near the coast. Discontinuous layers of rusty brown hardpan, composed of slightly to well-indurated iron-oxide cemented quartz underlie some of the higher areas. The hardpan is generally 2 to 3 feet below the surface and ranges in thickness from 1/2 to 20 feet. In places it is so well indurated that dynamite must be used to break through its upper surface during road and foundation construction.

In the east central part of the area Pleistocene and Holocene sand ridges as much as 90 feet in altitude parallel the present shoreline. The sand, although made up predominately of medium to fine quartz, also contains heavy minerals such as rutile, zircon, sphene, and leucoxine. In the past the heavy minerals were strip mined along the ridges; the mines are no longer in operation.

HYDROLOGIC CHARACTERISTICS

WATER LEVELS AND WATER-LEVEL FLUCTUATION

During the 1½ years of field study, water-level fluctuations were monitored in a network of 30 wells throughout Duval County. The locations of the observation wells are shown in figure 1.

Where the water level in a well rises above the top of the aquifer that yields the water, artesian conditions may exist. The level to which water will rise in such wells is called the "potentiometric surface." Figure 8 is a map of the potentiometric surface of the shallow-aquifer system for May 1969. Also shown in the figure are profiles of the land surface and the potentiometric surface of the Floridan aquifer. As can be seen in the diagram, the shallow-aquifer potentiometric surface roughly follows the configuration of the land surface and in places, where it crosses the stream valleys, it is above land surface.

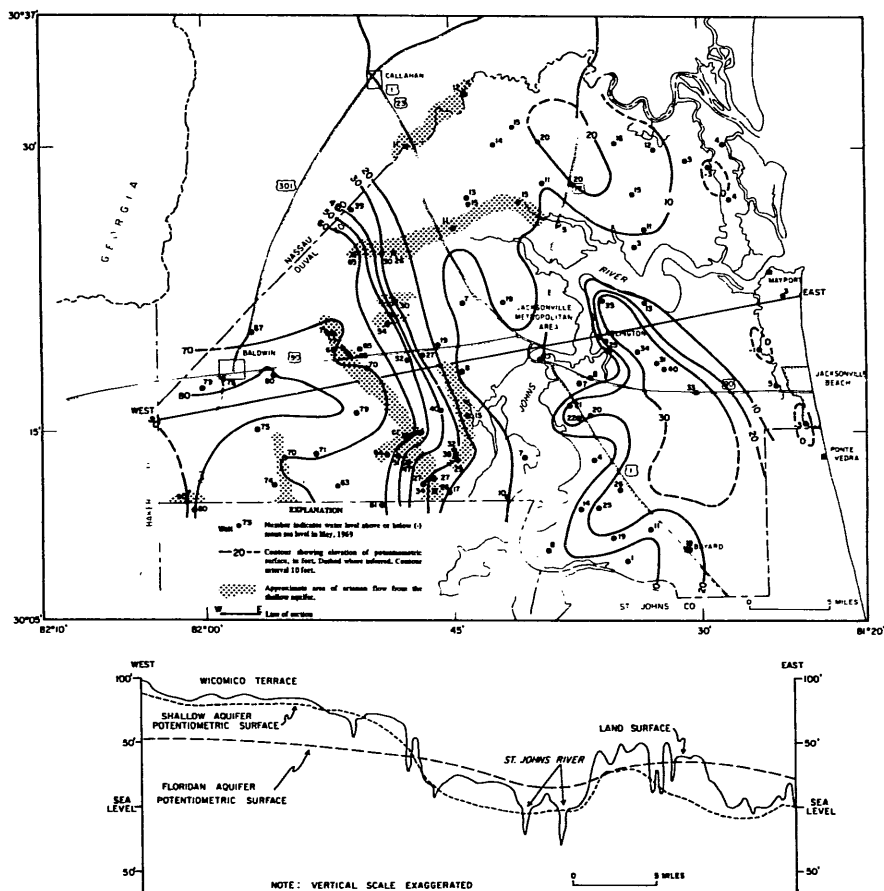


Figure 8. Map of Duval County showing the potentiometric surface of the shallow-aquifer system and the area of flow in May 1969.

Hydrographs showing the relation of rainfall to water levels in wells 302604N0813835.1 and 302456N0813358.1 in the northeast part of the area are shown in figure 9. As indicated by the graphs, high water levels occur after periods of heaviest rainfall, and lowest water levels occur after the drier periods of the year. As can be seen from the hydrograph in figure 10, the water level in well 301333N0814043.1 rises only a short time after the rain begins. Rainfall August 27 to 31, 1968, totaling 15.3 inches, resulted in a 1.5-foot rise in water level. The water level then declined slowly during September, when about one inch of rain fell. The rate of rise and decline of the water levels is a function of the hydraulic and geologic properties of the aquifer and the rate of recharge to or discharge from the aquifer.

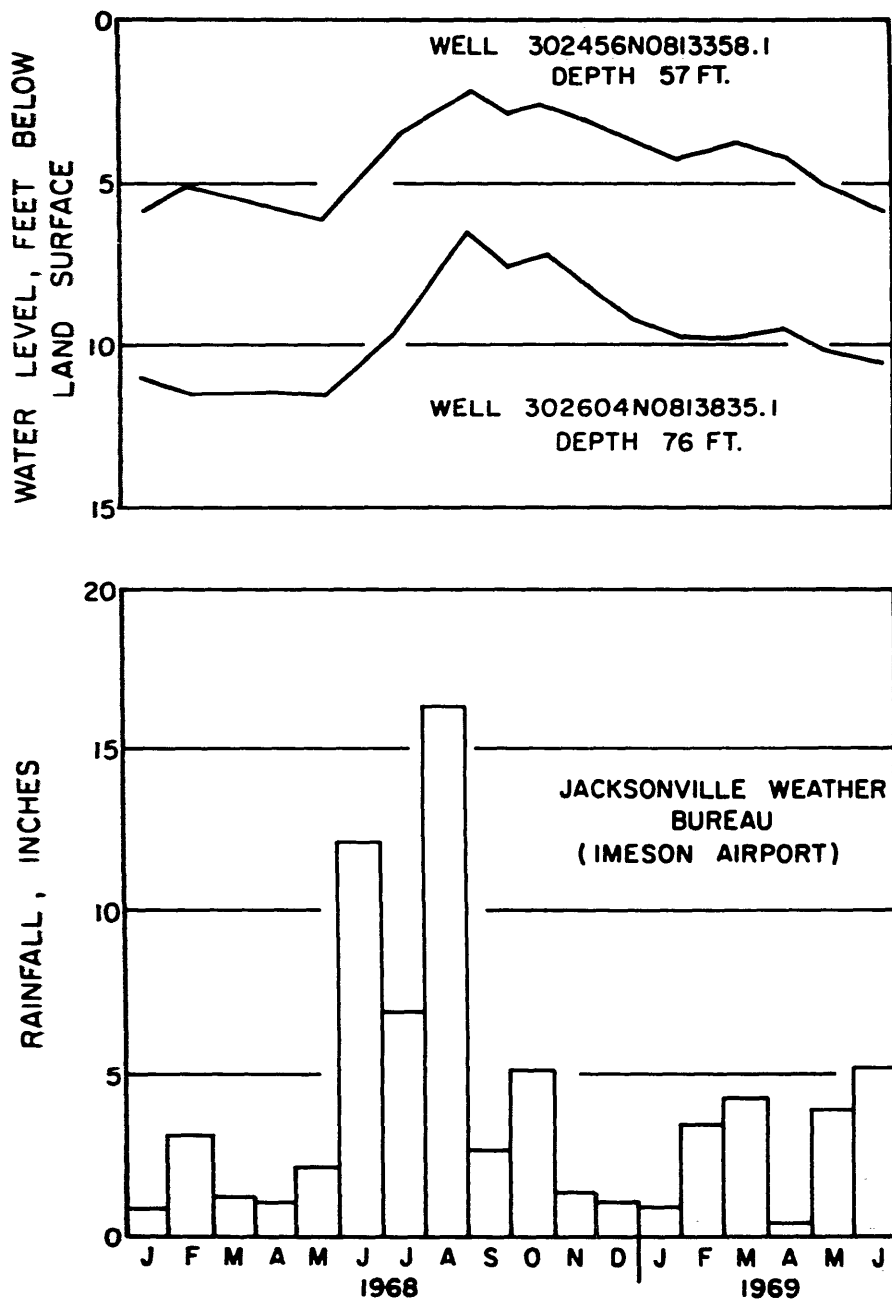


Figure 9. Graphs showing the relation of ground-water levels in wells in northeast Duval County and the rainfall at Jacksonville Weather Bureau, Imeson Airport.

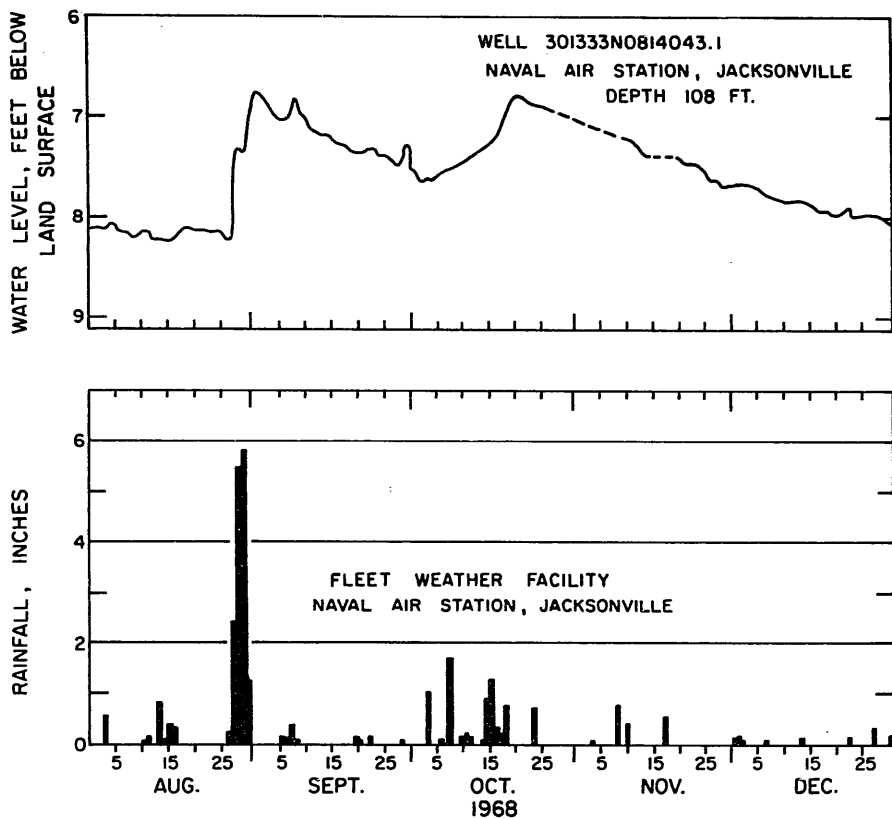


Figure 10. Graphs of rainfall and ground-water levels in well 301333N0814043.1 at Naval Air Station, Jacksonville.

Water levels range from as much as 35 feet below land surface to as much as 22 feet above land surface. Water levels generally are farthest below land surface in areas of higher altitude, as in western Duval County.

The yearly water-level fluctuation in wells during the period of study ranged from about 2 to 5 feet.

AREA OF FLOW

In areas where the shallow-aquifer potentiometric surface is above land surface, wells that tap the shallow limestone aquifer flow. Several such areas occur in Duval County and are shown in figure 8. The flowing wells are mainly in the west-central part of the county in low areas such as stream valleys.

Artesian heads of the shallow wells range from a few inches to more than 20 feet above land surface. Some wells stop flowing during the dry

season when the potentiometric surface is below land surface. In the area of 103rd Street and Ortega Creek several 60- to 70-foot-deep wells flow perennially and yield an adequate supply of water for domestic use.

RECHARGE

Recharge to the shallow-aquifer system is directly from local rainfall. The relation between local rainfall and water levels in wells that penetrate the shallow-aquifer system are shown in figures 9 and 10.

An estimate of the amount of recharge to the shallow-aquifer system from local rainfall can be obtained from rainfall and runoff records and estimated evapotranspiration. Rainfall in Duval County averages about 54 inches per year, and the average annual runoff from streams is about 20 inches (calculated from U. S. Geological Survey Surface Water Records). Base flow in the streams is sustained by ground-water inflow from the shallow-aquifer system and accounts for about 10 to 12 inches of the annual runoff (20 inches). The remainder of the annual runoff is direct runoff from overland flow.

Studies by Visser and Hughes (1969) indicate a difference between rainfall and potential evaporation in this area of approximately 8 inches per year. Accordingly, potential evaporation for the Duval County area is approximately 46 inches per year. This value is based on meteorologic factors such as solar radiation, wind movement, air temperature, and humidity. It is considered equivalent to the amount of natural evaporation from an extensive water surface of little thickness and under the prevailing meteorologic conditions. This value represents maximum annual evaporation and probably is far in excess of the actual evaporation. Factors such as topography, geology, vegetal cover, and the permeability of the soil all play a part in reducing evaporation below the potential rate. Hughes (oral commun., 1970) suggests that a valid estimate of the evapotranspiration for the Duval County area is from 36 to 38 inches per year. Subtracting the 20-inch average annual runoff from the average annual rainfall leaves 34 inches of evapotranspiration per year, a value that compares favorably with Hughes' estimate.

Hydrographs of water levels in wells indicate that from 10 to 16 inches of rainfall recharges the shallow-aquifer system annually (based on the amount of the total annual rise in water level in the aquifer and an estimated effective porosity of 20 percent for the aquifer material). About this same amount is discharged from the aquifer as ground-water outflow to streams and by evapotranspiration from the soil zone.

Average annual runoff varies from place to place. In the upper Yellow Water Creek basin in southwestern Duval County, runoff averages about 5 inches per year (Clark and others, 1964). Runoff from the Ortega Creek basin

averages about 24 inches per year. The high runoff rate in the Ortega Creek basin indicates that little or no recharge to the shallow-aquifer system takes place within the basin or that the shallow aquifer is full and that ground-water outflow to Ortega Creek is high in the rainy season. In the upper Yellow Water Creek basin there may be as much as 11 to 13 inches of recharge to the aquifer. The area near the head of Yellow Water Creek is flat and swampy. Rain that falls on the ground stands for long periods and considerable evaporation, transpiration, and seepage to the water table occurs. If the average recharge in that area is 12 inches per year, the average evapotranspiration would be about 37 inches per year.

Throughout most of the eastern two-thirds of Duval County, the potentiometric surface of either the Floridan aquifer or the shallow-artesian aquifer is above land surface, and in these areas recharge does not take place. Also, as much as 50 sq mi in western Duval County is underlain by fresh-water swamps and has a sparse drainage system. Most of the rain on this area either seeps downward very slowly to recharge the aquifer or is consumed by evapotranspiration. Probably less than 200 sq. mi. within the county can be considered as a potential recharge area.

The areas of greatest recharge to the shallow-aquifer system are usually those having the highest altitudes, particularly the high sand ridges. However, some high areas are underlain by a hardpan layer, which retards downward percolation, and perched water-table conditions exist. In such areas the surface is often swampy and is marked by groves of cypress trees. In some places, where construction has taken place and the hardpan has been broken or removed, the swamp water drains into the underlying permeable sand, drying the surface and making the area suitable for development.

Another possible source of recharge to the shallow-aquifer system may be by upward leakage from the deeper Floridan aquifer. Figure 5 is a map showing the thickness of the sediments overlying Eocene limestones of the Floridan aquifer. In those places where post-Eocene sediments are thinnest, and where the potentiometric surface of the Floridan aquifer is above land surface, upward leakage would most likely be greatest. As can be seen by comparing figure 5 and figure 8, one of the most likely places for upward leakage would be south of Jacksonville on the west side of the St. Johns River. Water entering the shallow sand and limestone layers probably does not move directly upward but follows lenses of permeable sand, shell, or limestone along paths of least resistance. Further studies (p. 47, step c) in areas of large withdrawals from deep wells should lead to a better understanding of the hydraulic relation between the deep and shallow-aquifer systems.

Some recharge to the shallow-aquifer system may be derived from ground-water underflow—water that percolates into the ground at higher altitudes outside the area and moves underground through the aquifer into

Duval County. Such possible recharge areas lie to the west of Duval County in Baker County and to the southwest in Clay County.

DISCHARGE

Discharge from the shallow-aquifer system is through springs and seeps, by evapotranspiration, by pumpage from wells, and by downward percolation into underlying formations.

SPRINGS

Springs discharge an undetermined amount of water from the shallow-aquifer system. These springs are of two types; (1) depression springs or "seeps" where the water table intercepts the land surface (usually along stream valleys), and (2) "sand boils" issuing under artesian pressure (Ferris and others, 1962), generally through an opening in the confining beds that overlie the shallow aquifer in areas where the potentiometric surface is above land surface (fig. 1).

The depression springs or "seeps" contribute water to streams in the area as long as the water table is above the level of the bottom of the stream. When the water table declines, the seeps dry.

In most areas of artesian flow the potentiometric surface is above land surface the year around and the artesian springs (sand boils) continue to contribute to stream flow throughout the year. However, as the artesian flow diminishes considerably during the dry season, the water discharged into the stream bed may flow only a short distance downstream and then percolate into the sand in the stream bed. Thus the stream may have water flowing in one reach while other reaches are dry.

The specific conductance of water in several of the artesian springs was determined and found to be similar to that of the water in nearby wells penetrating the shallow aquifer. The spring water has a moderate hydrogen sulfide odor, as does the water in the shallow aquifer wells. In most springs the specific conductance of water is slightly less than that of the well water, indicating less mineral content. Where springs discharge into the bottom of a stream, they can be easily detected during the summer when the temperature of the spring water is considerably less than that of the streamflow.

The springs were not studied in detail. However, the similarity of the spring water to water in the shallow-artesian aquifer shows that the shallow aquifer leaks and that a considerable amount of groundwater discharge is contributing to flow in the streams.

EVAPOTRANSPIRATION

Four to 6 inches of water per year is discharged from the shallow-aquifer system by evaporation and transpiration. Rain percolates into the surface sand, where some is held in the soil and some continues downward to the water table. Water held in the soil is discharged into the atmosphere either by evaporation directly from the soil or by transpiration of plants. Water in a saturated zone moves laterally downgradient, where it may come close enough to the surface to be discharged from the soil as above or may discharge as seeps into a stream.

PUMPAGE

Estimates of pumpage from the shallow-aquifer system by Leve and Goolsby (1969) indicate that approximately 45,000 to 50,000 domestic wells discharge 10 to 25 mgd (million gallons per day). Most wells are 2 inches in diameter or less, and water is withdrawn from them by small-capacity jet pumps powered by 1/4 to 1 horsepower motors.

DOWNWARD PERCOLATION

Quantitative studies of the Floridan aquifer presently underway in Duval County suggest the occurrence of downward percolation (leakage) from the shallow-aquifer system into the Floridan aquifer (Leve, oral commun., 1970). In areas such as western Duval County, where the potentiometric surface in the shallow-aquifer system is above that in the Floridan aquifer, the hydraulic gradient is downward, and considerable water may be moving from the shallow-aquifer system into the Floridan aquifer below.

Figure 8 indicates that the potentiometric surface of the aquifer west of the St. Johns River slopes generally eastward. A considerable amount of water from the aquifer may be discharging into the St. Johns River, particularly where dredging has been deep enough to remove less permeable silt and clay, exposing permeable layers of coarse sand and porous limestone.

QUALITY OF WATER

The water in the shallow-aquifer system is generally of good chemical quality, well within the limits for water used on interstate carriers recommended by the U. S. Public Health Service (1962). The chemical quality was determined by analyzing water from 32 wells throughout Duval County. The results of the analyses are listed in table 7. In addition to the 32 "standard complete" analyses, water from 45 other wells was analyzed for iron content and the results are listed in table 8. The significance of the various chemical constituents normally analyzed for in a sample of water is

Table 7. Chemical analyses* of water from the

Well Number	Date Collected	Depth (feet)	Depth Cased (feet)	Iron (Fe)	Silica (SiO ₂)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO ₃)
300857N0813444.2	5-20-65	92	—	2.0	29	83	15	14	1.3	0
301110N0820115.2	11-8-65	135	—	2.6	19	58	22	7.8	2.2	—
301145N0813727.1	5-19-65	126	98	.5	43	83	14	14	2.9	0
301255N0813710.1	5-20-65	89	—	.9	25	99	5.1	15	2.2	0
301324N0815506.1	11-8-68	125	—	1.0	26	58	13	14	2.1	—
301340N0814754.1	11-3-66	60	—	.01	19	43	16	6.6	1.2	—
301443N0814244.1	5-27-65	165	125	.04	29	57	11	12	2.5	0
301450N0814802.1	8-6-65	—	—	.21	9.0	33	9.5	3.8	.6	0
301454N0814754.1	4-16-68	68	—	—	9.7	43	9.1	4.1	.7	—
301602N0815054.2	10-11-67	146	—	.65	22	56	20	6.4	1.9	—
301706N0812957.1	11-7-68	85	—	2.8	13	61	2.2	8.8	.6	—
301718N0812538.1	6-6-66	140	92	—	52	63	29	19	5.7	0
301747N0813624.1	11-1-66	55	—	.02	32	39	3.3	9.2	1.2	—
301812N0815932.1	11-8-68	135	—	.1	38	75	13	28	2.9	—
301817N0813749.2	3-19-65	—	—	.31	43	39	16	15	6.1	0
301820N0815007.1	7-2-68	140	—	—	32	90	5.4	8.7	2.1	—
301820N0815007.2	7-2-68	60	—	—	6.8	.2	2.2	7.8	1.1	—
301905N0815111.1	5-13-66	—	—	.03	33	85	52	0	1.5	0
301907N0814821.1	8-02-65	286	—	.02	26	88	2.3	7.4	1.8	0
301915N0813515.1	5-20-65	200	—	—	22	72	25	14	2.1	0
301922N0812634.1	9-21-66	40	40	1.6	2.3	1.9	2.0	2.0	.3	0
301017N0815228.1	3-25-68	190	—	—	36	596	100	23	8.2	0
302136N0814255.1	5-27-65	80	—	2.8	18	73	12	13	1.1	0
302148N0813307.1	5-19-65	38	—	.11	11	32	14	5.8	.9	0
302155N0813310.1	5-19-65	39	—	.09	11	34	2.7	6.1	.8	0
302203N0812455.1	9-26-68	162	—	—	55	46	16	25	4.7	—
302424N0815042.1	7-2-68	107	—	—	15	41	7.5	4.4	.3	—
302703N0813819.1	9-22-66	120	100	.08	33	32	2.4	7.6	1.3	0
302829N0814128.1	4-3-68	150	—	—	31	630	70	20	22	0
302915N0814215.1	9-27-67	142	126	—	35	64	9.9	17	4.4	126
302923N0813053.1	1-19-68	87	87	.68	23	111	6.2	17	.9	0
303125N0813715.1	1-19-68	100	—	.92	14	55	28	8.5	1.4	0
303356N0813645.1	9-22-66	90	—	2.7	49	59	9.0	19	1.8	0

*Chemical analyses in milligrams per liter except where otherwise indicated.

**Sum of determined constituents.

shallow aquifer in Duval County, Florida.

Bicar- bonate (HCO ₃)	Sulfate (SO ₄)	Chlo- ride (Cl)	Fluo- ride (F)	Ni- trate (NO ₃)	Phos- phate (PO ₄)	Dis- solved Solids**	Hardness Cal- cium Mag- ne- sium (CaMg)	Non- car- bon- ate	Specific Con- duct- ance (micro- mhos at 25°C)	pH	Color
328	0.0	21	.2	.0	—	326	268	0	533	7.3	0
284	.4	8.0	.2	.1	.04	253	225	0	440	7.8	5
328	4.0	15	.2	.0	—	338	264	0	521	7.5	0
344	0.0	16	.1	.0	—	331	268	0	542	7.2	0
256	.8	12	.4	.1	.04	253	198	0	418	7.9	5
213	.8	12	.5	.1	.56	205	174	0	349	7.8	0
236	4.8	9.0	.3	.0	—	242	186	0	395	7.6	5
166	0.0	6.0	.2	.0	—	149	134	0	272	7.8	0
172	.4	6.0	.2	.6	—	159	145	4	279	7.5	0
270	0.0	14	.3	.2	.27	254	222	2	548	8.1	10
206	.8	11	.1	.1	.25	199	162	0	338	7.9	5
212	122	16	1.4	.1	0	393	288	114	600	7.9	10
138	3.6	12	.2	.0	.27	165	111	0	270	7.4	10
324	.8	28	.2	.3	.14	347	241	0	560	7.7	5
204	4.0	18	1.4	.0	—	243	162	0	353	7.8	0
304	0.0	12	.3	.2	—	301	249	0	440	7.3	0
0	16	9.8	.1	.0	—	44	10	10	97	4.3	30
296	.8	8.0	.4	.2	.16	289	234	0	470	7.9	10
286	.4	10	.2	.3	—	278	230	0	450	8.0	10
160	146	24	.7	.0	—	385	284	153	580	7.6	0
8	0.0	25	.1	.1	0	48	12	6	105	5.5	5
232	1660	12	1.0	.1	—	2560	1910	1720	2700	7.5	5
236	38	18	.3	.0	—	289	232	38	472	7.9	10
164	.8	8.0	.1	.0	—	154	136	2	263	7.5	0
116	0.0	10	.1	.0	—	122	96	1	208	7.6	0
228	14	25	.9	.3	0	299	182	0	442	8.1	5
108	0.0	7.0	.2	.0	—	159	134	0	275	7.7	0
112	0.0	8.0	.2	.0	.10	140	90	0	220	7.4	10
220	1650	12	.7	.0	—	2550	1870	1690	2620	7.3	5
256	0.0	16	.2	.0	—	272	200	0	440	7.9	5
372	.4	25	.3	.0	—	367	303	0	615	7.5	10
300	.4	12	.4	.5	—	268	252	6	480	8.0	0
188	80	23	.5	.0	—	344	226	72	535	7.3	0

shown in table 9. Table 10 lists the drinking water standards recommended by the U. S. Public Health Service.

Table 8. Iron content in water from shallow wells in Duval County.

Well number	Depth (feet)	Date sampled	Iron content, mg/l
300801N0813410.1	76	12-17-68	.03
300815N0813927.1	187	12-19-68	.10
300851N0813049.1	60	12-17-68	.16
300933N0813725.1	145	12-19-68	.99
300948N0813259.1	55	12-19-68	.15
301135N0814213.1	160	1-09-69	.10
301155N0814925.1	47	12-16-68	.48
301214N0814448.1	175	1-09-69	.37
301216N0813541.1	75	12-19-68	.66
301408N0815630.1	120	1-09-69	.71
301535N0813453.1	57	12-20-68	.13
301632N0813758.1	120	12-20-68	1.4
301647N0814943.1	148	1-09-69	.41
301740N0813629.1	65	12-20-68	.16
301840N0814449.1	110	1-08-69	.18
301907N0813230.1	102	1-30-69	.07
301922N0815023.1	219	1-09-69	.08
301926N0814552.1	165	1-08-69	2.8
301926N0815329.1	150	1-09-69	.46
301942N0812825.1	100	1-30-69	.28
302019N0815207.1	115	1-09-69	1.2
302049N0813319.1	275	1-31-69	.04
302100N0814840.1	125	1-10-69	.09
302123N0812742.1	100	1-31-69	.05
302200N0812454.1	110	12-12-68	.02
302300N0815025.1	150	1-10-69	.87
302309N0812951.1	200	12-12-68	.22
302309N0813630.1	90	12-11-68	2.2
302446N0814136.1	90	1-16-69	.35
302501N0813358.1	65	2-03-69	.12
302515N0814625.1	85	1-15-69	.29
302641N0815055.2	95	1-09-69	.65
302644N0813705.1	86	1-17-69	.60
302701N0812750.1	88	1-17-69	.46
302705N0813041.1	90	1-17-69	.51
302715N0814635.1	110	1-10-69	.17
302740N0813751.1	129	1-24-69	.15
302801N0813516.1	110	2-03-69	.24
302905N0814303.1	145	1-16-69	.73
303007N0813315.1	99	1-17-69	.11
303038N0812820.1	80	1-17-69	.45
303108N0814550.1	240	1-16-69	.20
303125N0813524.1	67	1-16-69	.22
303137N0814359.1	95	1-16-69	.21
303237N0813704.1	75	1-16-69	.21

Table 9. Water quality characteristics and their effects.*

Constituent	Source and/or solubility	Effects
Silica (SiO_2)	Most abundant element in earth's crust resistant to solution.	Causes scale in boiler and deposits on turbine blades.
Iron (Fe)	Very abundant element, readily precipitates as hydroxide.	Stains laundry and porcelain, bad taste.
Manganese (Mn)	Less abundant than iron, present in lower concentrations.	Stains laundry and porcelain, bad taste.
Calcium (Ca)	Dissolved from most rock, especially limestone and dolomite.	Causes hardness, forms boiler scale, helps maintain good soil structure and permeability.
Magnesium (Mg)	Dissolved from rocks, industrial wastes.	
Sodium (Na)	Dissolved from rocks, industrial wastes.	Injurious to soils and crops, and certain physiological conditions in man.
Potassium (K)	Abundant, but not very soluble in rocks and soils.	Causes foaming in boilers, stimulates plankton growth.
Bicarbonate (HCO_3) Carbonate (CO_3)	Abundant and soluble from limestone, dolomite, and soils.	Causes foaming in boilers and embrittlement of boiler steel.
Sulfate (SO_4)	Sedimentary rocks, mine water, and industrial wastes.	Excess: cathartic, taste.
Chloride (Cl)	Rocks, soils, industrial wastes, sewage, brines, sea water.	Unpleasant taste, increases corrosiveness.
Fluoride (F)	Not very abundant, sparingly soluble, seldom found in industrial wastes except as spillage, some sewage.	Over 1.5 mg/l causes mottling of children's teeth, 0.88 to 1.5 mg/l aid in preventing tooth decay.
Nitrate (NO_3)	Rocks, soil, sewage, industrial waste, normal decomposition, bacteria.	High indicates pollution, causes methemaglobanemia in infants.
Hardness as CaCO_3		Excessive soap consumption, scale in pipes interferes in industrial processes. up to 60 mg/l – soft 60 to 120 mg/l – moder, hard 120 to 200 mg/l – hard over 200 mg/l – very hard

*After Leve and Goolsby, 1969.

Table 10. U.S. Public Health Service drinking-water standards.

Chemical substance	Limit not to be exceeded	Cause for rejection
Physical		
Color	15 units	
Taste	Unobjectionable	
Threshold odor number	3	
Turbidity	15 units	
Chemical		
	(mg/l)	(mg/l)
Alkyl benzene sulfonate	.5	
Arsenic	.01	.05
Barium		1.0
Cadmium		.01
Chloride	250	
Chromium (hexavalent)		.05
Copper	1.	
Carbon chloroform extract*	.2	
Cyanide	.01	.2
Fluoride**	.7-1.2	14.24
Iron	.3	
Lead		.05
Manganese	.05	
Nitrate	45	
Phenols	.001	
Selenium		.01
Silver		.05
Sulfate	250	
Total dissolved solids	500	
Zinc	5	

*Organic contaminants

**The concentration of fluoride should be between 0.6 and 1.7 mg/l, depending on the listed and average maximum daily air temperatures.

HARDNESS

The hardness of water is reported by the Geological Survey in terms of an equivalent quantity of calcium carbonate in a sample of water. Table 7 gives the hardness of water sampled from shallow wells in Duval County. Hardness ranged from 10 mg/l (milligrams per liter) to greater than 1,900 mg/l. With the exception of water from wells 302829N0814128.1 and 302017N0815228.1, which has anomalously high mineral content, the average hardness is 187 mg/l. As a comparison, water in the Floridan aquifer in Duval County has a hardness ranging from 50 to about 350 mg/l and averaging about 250 mg/l. In some places waters from both the shallow and the Floridan aquifer show similarity in hardness, as well as in other mineral constituents.

The two wells that have anomalously high mineral content of water (table 7) are apparently isolated occurrences. Chemical analyses indicate that

the quality of the water is related to aquifer constituents at those two places, possibly gypsum or anhydrite. Water in wells a few hundred feet away and the same depth was field tested for specific conductance, and results indicate a relatively low mineral content.

Figure 11 shows the relation of hardness with depth. In general the hardness increases with depth down to about 100 feet. Above this level, 13 analyses showed an average hardness of 165 mg/l, whereas, below, 14 analyses resulted in an average hardness of 213 mg/l. Wells that tap sandy zones usually yield softer water than those that tap carbonate rocks. As rain recharges the aquifer, water near the surface is relatively soft but becomes progressively harder as it passes downward through the aquifer.

The generalized distribution of hardness of water pumped from the shallow-aquifer system of Duval County is shown on figure 12. Although hardness varies somewhat with depth, the map on figure 12 shows the distribution of hardness, as reflected by the predominant well depth in each area. Most of the wells in a given area are about the same depth and obtain water from the same zone.

DISSOLVED SOLIDS

The generalized map showing distribution of dissolved solids in water in the shallow-aquifer system throughout Duval County is shown on figure 13.

Dissolved solids are lowest in the east-central part of the county and southwest of metropolitan Jacksonville. The area of lowest dissolved solids generally coincides with an ancient coastal ridge, which roughly parallels the present shoreline. The ridge is underlain by permeable sand, which readily accepts recharge from rainfall.

The Geological Survey uses the residue-on-evaporation method and the calculation method to determine dissolved solids in a water sample. Calculated values determined from analyses of water from shallow wells are listed in table 7. Dissolved solids range from about 50 mg/l to 2,560 mg/l. A plot of dissolved solids versus depth is shown in figure 11 and shows a general increase with depth to 100 feet.

CHLORIDE

All chloride content of water in the shallow aquifer ranges from 6 mg/l to less than 30 mg/l, far below the maximum concentration of 250 mg/l suggested by the U. S. Public Health Service. Figure 14 is a map of Duval County showing chloride distribution in the shallow-aquifer system. Although none of the water tested showed excessively high concentrations of chloride, local well drillers report that water from shallow wells along the St. Johns River east of Jacksonville and on the north side of the river is relatively salty.

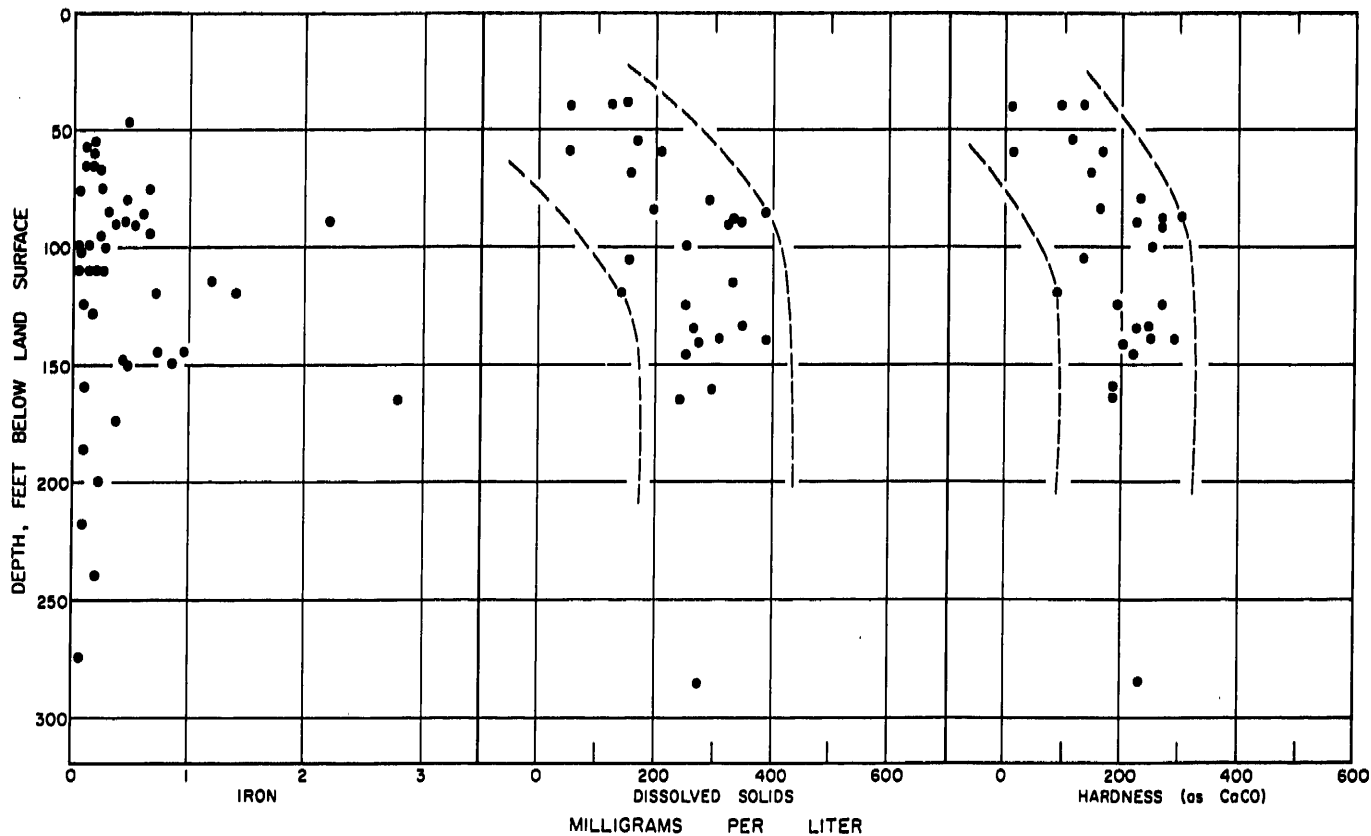


Figure 11. Graph showing the relation of hardness, dissolved solids, and iron content to depth of water from the shallow-aquifer system.

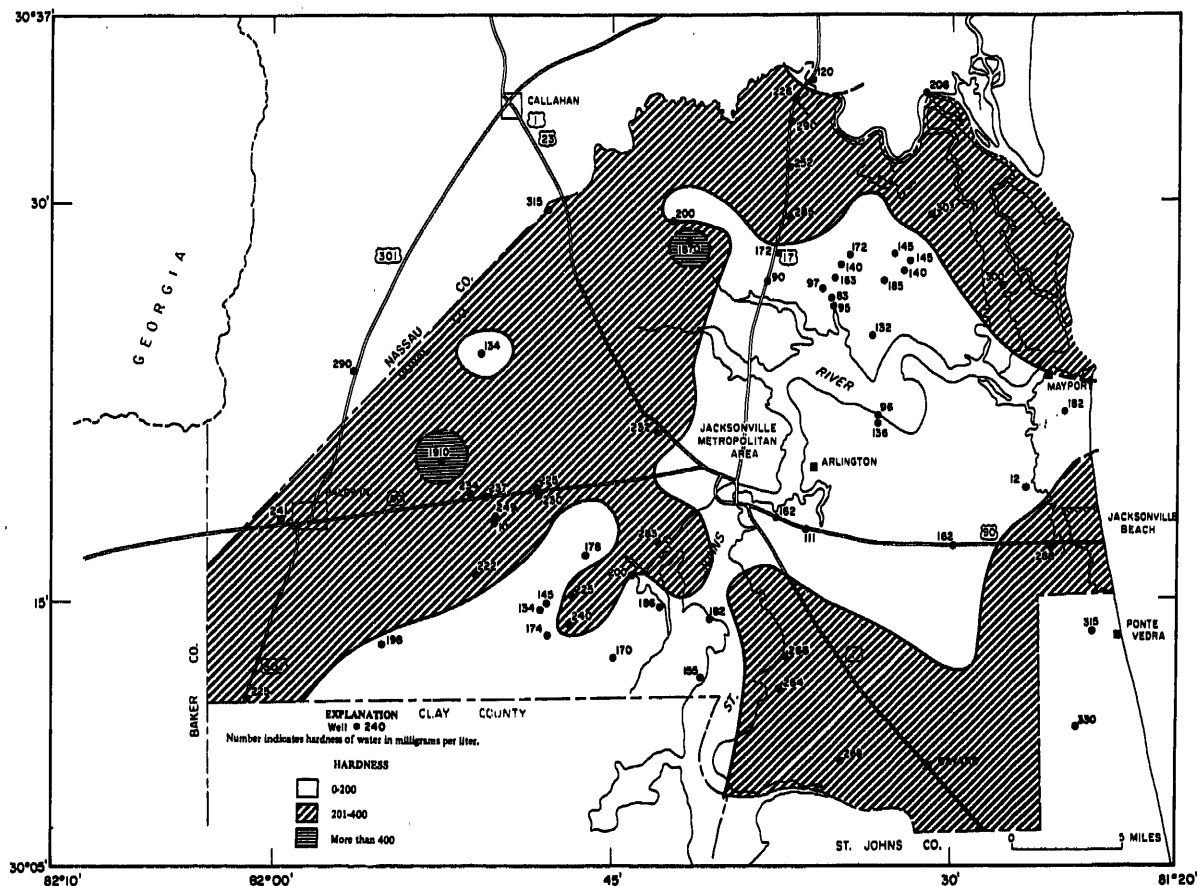


Figure 12. Generalized distribution of hardness of water in wells that tap the shallow-aquifer system in Duval County.

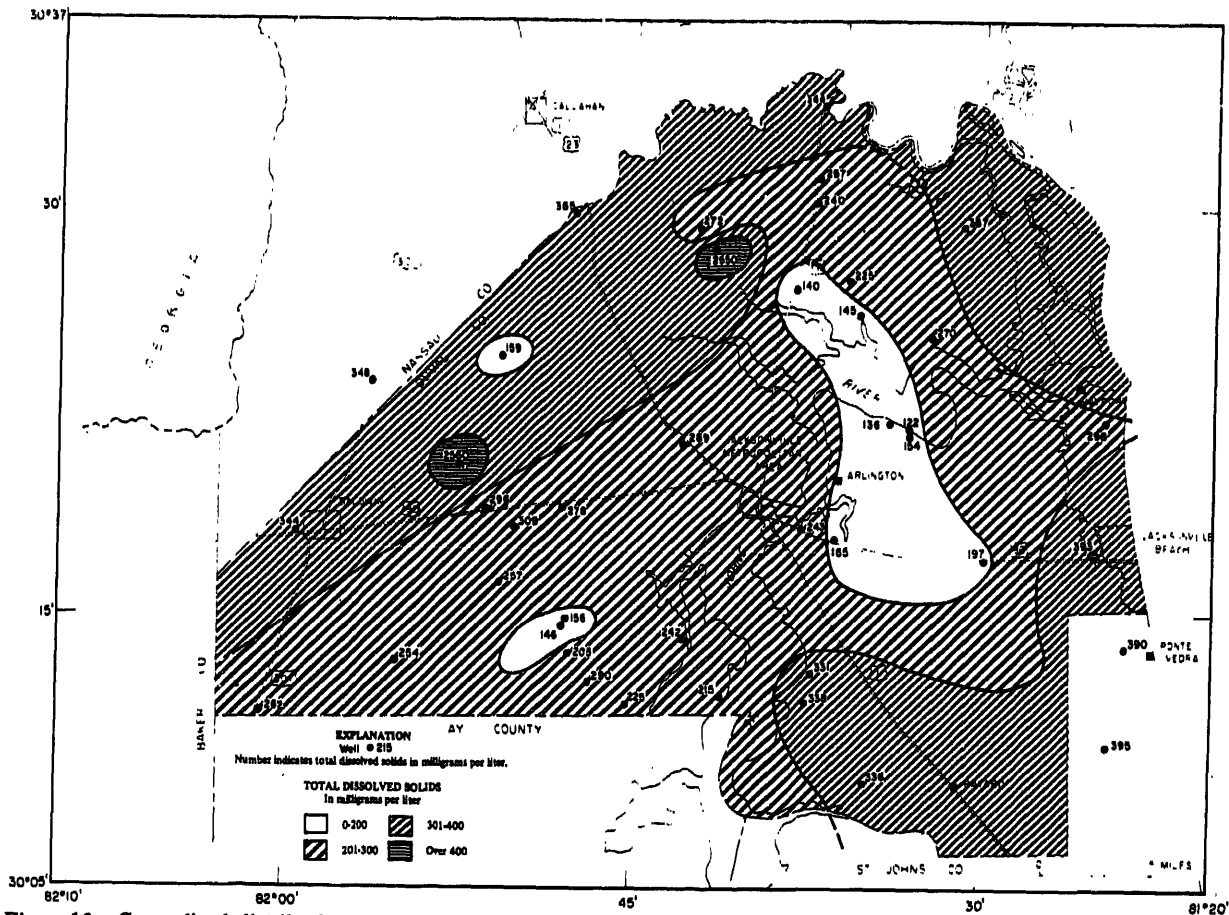


Figure 13. Generalized distribution of dissolved solids in water from wells that tap the shallow-aquifer system in Duval County.

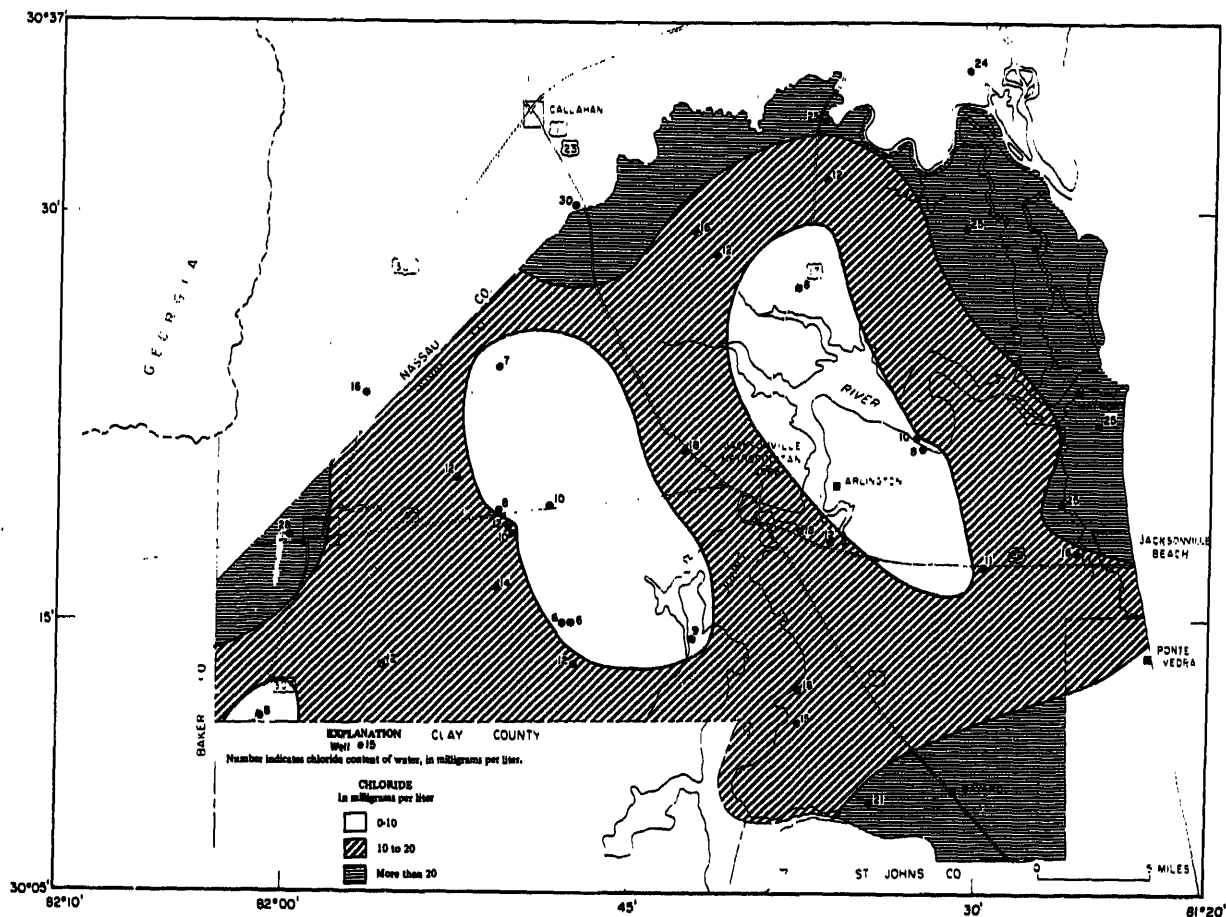


Figure 14. Map of Duval County showing the distribution of chloride in water from the shallow-aquifer system.

In that area the river has been dredged to a shallow limestone layer, and it is possible that salt water is entering the limestone from the river.

IRON

Iron occurs in varying amounts in the water from shallow wells throughout Duval County. As indicated in table 8 and on figure 11, the iron content ranges from 0.01 mg/l to 2.8 mg/l. Many of the waters tested had an iron content much higher than that recommended by the Public Health Service standard of 0.3 mg/l. Such water may stain clothing and plumbing fixtures, turning them a yellow or rusty color. In some places filters have been used with moderate success to remove the iron.

Forty-five samples were collected from shallow wells throughout the county and analyzed for iron content only. All samples were filtered with a 0.45 micron filter at the time of collection to remove any possible iron-bearing solids from the water.

The iron content of the water in many shallow sandpoint wells often increases after a few years' use of the wells. This is primarily caused by the corrosive nature of the water in the aquifer, which corrodes the pipes and fittings inside the wells and water systems. The iron can be partly removed by filtering, by aeration, or by softening equipment. The relation of iron content with depth is shown in the graph in figure 11. Only those samples that had been filtered at the time of collection are plotted on the graph. As indicated by the graph, the highest concentrations of iron occur at the depth interval between 70 and 150 feet.

Figure 15 is a map showing the distribution of iron in the shallow-aquifer system in Duval County. Throughout much of the area the iron content is 0.5 mg/l or less. In those areas of highest iron concentration, much of the land is marshy. Doubtless, the marshy land, with its reducing environment, insofar as iron is concerned, creates a condition whereby rainfall, saturated with oxygen as it infiltrates the land surface, can take into solution a relatively large amount of iron. At least a part of this iron is carried downward into the aquifer.

The main chemical factors that control the solubility of iron in natural waters are the hydrogen ion concentration (pH) and the oxidation-reduction potential (Eh). Hem (1970, p. 114-126) gives a fairly complete description of the chemical and physical factors that control the occurrence of iron in ground water.

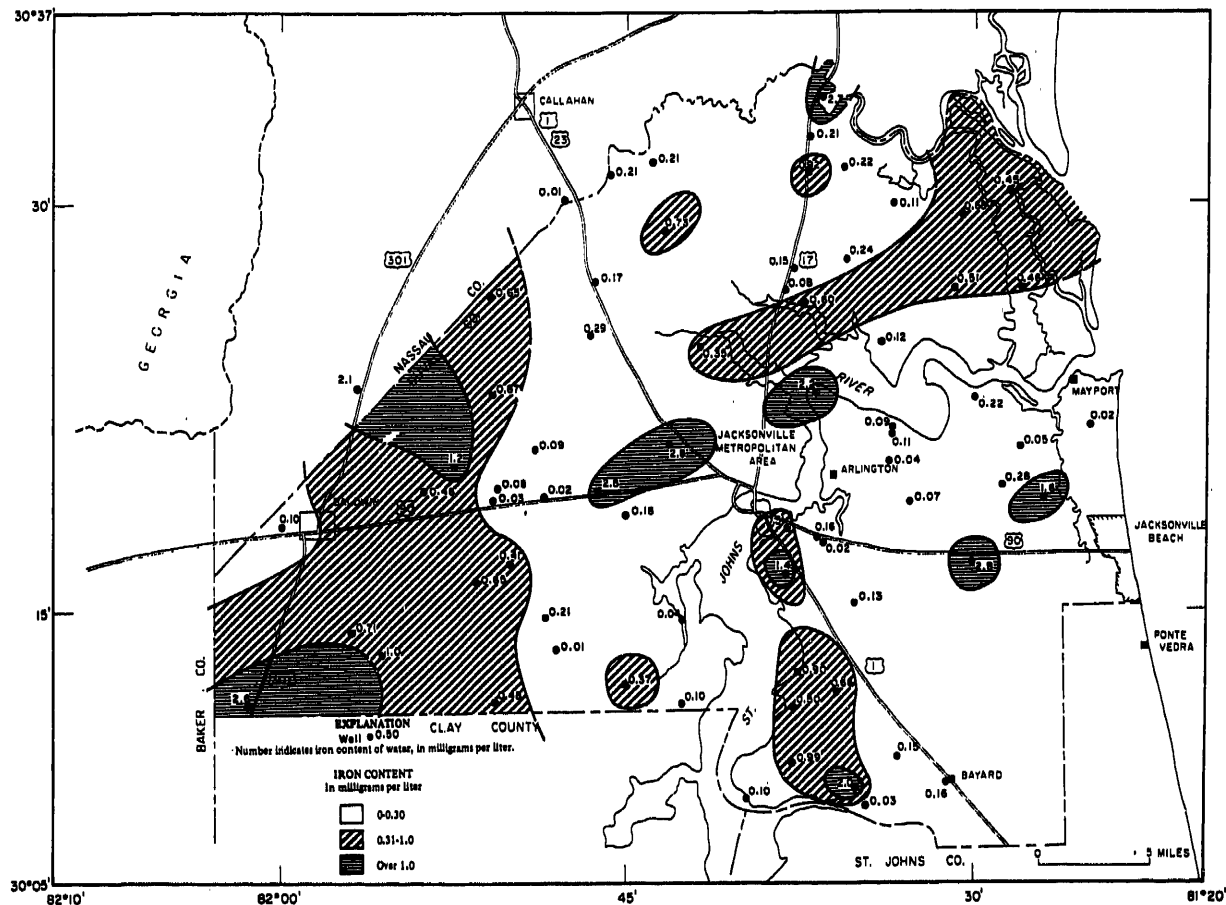


Figure 15. Map of Duval County showing the approximate areal distribution of iron in the water from the shallow-aquifer system.

HYDROGEN SULFIDE

Hydrogen sulfide occurs in the water from many of the wells that penetrate the shallow-aquifer system. Water from wells that are less than about 50 feet deep usually contains no noticeable hydrogen sulfide; however, a few wells 60 feet deep yield water having a moderate to strong hydrogen sulfide odor.

Hydrogen sulfide is corrosive to pipes and fixtures and is undesirable in drinking water. As hydrogen sulfide is a gas, it can be easily removed by a simple aeration process.

WATER USE

Water from the shallow-aquifer system is used for domestic, industrial, commercial, and agricultural purposes. Most of the water withdrawn is used for washing, toilets, drinking, swimming pools, and lawn irrigation. In many residential areas served by water utilities, private shallow-aquifer wells supply supplemental water for swimming pools or to irrigate lawns and small gardens. The most common industrial use is for heat-exchange units in large air-conditioning systems. Several small commercial establishments, including laundries, stores, fishing camps, and service stations, use water from the shallow aquifer. Several schools in Duval County are supplied water from wells that penetrate the shallow-aquifer system.

A considerable amount of water is used for irrigation in Duval County. Besides water for irrigating lawns and small gardens, several small truck farms and nurseries in the Jacksonville area use water from shallow wells. Shallow wells also supply water for cattle, hogs, horses, and chickens.

WELL CONSTRUCTION PRACTICES

The shallow-aquifer system is present throughout all of Duval County, and wells of varying depths obtain dependable supplies of water from it. Most obtain water from highly permeable, sometimes cavernous, limestone, and in places a single 2-inch well may supply water to as many as four homes. These wells are often referred to locally as "rock wells." The shallow limestone is missing in the Arlington area and along the coastline from Mayport to Ponte Vedra. In the Arlington area, many wells obtain water from coarse sand and shell beds 75 to 100 feet below land surface. Along the coastline they obtain water from coarse sand in the Hawthorn Formation, 140 to 160 feet below land surface.

Wells that obtain water from the shallow-aquifer system are usually constructed by either of two methods by jetting or by hydraulic rotary. A

water-bearing zone is indicated when circulation is lost, that is, when drill cuttings and drilling fluid no longer return to the surface. The well is then jetted or drilled a few feet deeper to insure adequate penetration of the water-yielding zone. The well is then cased with the appropriate diameter casing which usually is seated into the top of the water-yielding zone, leaving from 10 to 20 feet of open hole below the end of the casing. When the water-yielding bed is sand or shell, the wells are usually equipped with a short well screen to prevent sand from getting into the water system.

After completion, the well is equipped with a jet pump and a $\frac{1}{4}$ to 1 horsepower electric motor. Where the water level in the well is greater than 10 feet below land surface, a deep-well jet pump is used to insure adequate lifting power during low water level periods.

During the dry season, when water levels are lowest, wells may yield sand upon heavy pumping. This may be the result of improper screen selection or inadequate well construction. In a few places water has been pumped from wells at velocities sufficient to carry sand out of the wells, causing the uncased part of the wells to cave in or to yield sand. When limestone is tapped, the problem of caving or pumping of sand can be avoided by setting the casing in the top of the limestone, thus preventing the overlying clay or sandy clay from collapsing or flaking into the well bore.

ADDITIONAL STUDIES NEEDED

To further evaluate the water in the shallow-aquifer system and to determine its importance in the overall water resources of Duval County, considerable knowledge is yet to be gained. The following steps should be taken in an effort to obtain this knowledge:

- (a) obtain detailed data on the amount of water withdrawn from the shallow-aquifer system;
- (b) conduct aquifer tests to determine the ability of the aquifer to transmit water, to define the best producing zones, and to delineate the areas where greatest yields can be expected;
- (c) continue to monitor water levels and quality of water in shallow wells in an effort to determine the relation between the shallow-aquifer system and the Floridan aquifer;
- (d) investigate those areas where salt water is suspected to enter the shallow-aquifer system, particularly along the St. Johns River east of Jacksonville; and,
- (e) investigate areas of artesian spring flow to determine the amount of ground-water discharge to streams in the area. A detailed inventory of all springs in the area coupled with periodic measurements of their discharge should lead to valuable information regarding the relation of spring discharge to surface-water runoff.

Information obtained in establishing the hydraulic relation between the shallow-aquifer system and the Floridan aquifer will be used in conjunction with an analog model of the Floridan aquifer to determine the future water supplies for the Jacksonville area.

CONCLUSIONS

Present growth trends indicate that the population of the Jacksonville area will increase 30 percent from 1966 to 1980 (Leve and Goolsby, 1969). In addition to this estimated increase in population, present industries will probably expand, and new industries will probably be established, and more water will be needed. If total pumpage in the Jacksonville area increases 25 to 40 percent, the shallow-aquifer system, which underlies all of Duval County, could be further tapped to supplement the supply from the Floridan aquifer.

The water in the shallow-aquifer system is generally of good quality and meets the U. S. Public Health Service standards for drinking water. In most places it has less mineral content than water from the Floridan aquifer. In some places the water in both aquifers is similar in quality, suggesting that they may be hydraulically connected.

Recharge to the shallow-aquifer system is from local rainfall. Water levels respond rapidly to rainfall and are highest during the rainy season (June to October) and lowest during the dry season (November to May). Ten to sixteen inches of rainfall is estimated to recharge the aquifer, the amount varying from place to place. The main recharge area is in the western one-third of the county and along high sand ridges east of Jacksonville.

The shallow-aquifer system is discharged through springs and seeps, by evapotranspiration, by pumping from wells, and by downward percolation to the deeper Floridan aquifer. Discharge varies from place to place within the county, but 10 to 16 inches of water is estimated to discharge from the aquifer annually, of which 4 to 6 inches is discharged into the atmosphere.

Water is obtained from three principal zones in the shallow-aquifer system: (1) Surficial sand beds of Pleistocene and Holocene age, (2) a relatively continuous layer of shell, limestone, and sand of late Miocene or Pliocene age, and (3) lenses of coarse sand and sandy limestone within the upper part of the Hawthorn Formation of middle Miocene age.

Because the water in the shallow-aquifer system is easily accessible, is directly replenished by rainfall, and is of good quality, it represents a reliable source of fresh water for future use. In some parts of Duval County large quantities of water are obtained from large-diameter wells that penetrate the permeable limestone of the shallow-aquifer system. In other areas, where

water is withdrawn from coarse sand and shell beds, large-diameter, properly constructed gravel-packed or screened wells could yield larger quantities of water.

Many areas now being supplied with water from individual wells in the shallow-aquifer system, may, in the future, be supplied by municipal utilities pumping from the Floridan aquifer; more water from the shallow aquifer, therefore, could be used for other purposes.

In places where the shallow aquifer yields large quantities of water, the water may prove to be suitable for some industrial use, if water of better quality than that in the Floridan aquifer is required. The water is already used for irrigation and dairy farming in parts of Duval County.

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