DISTRIBUTION OF SALTWATER IN THE COASTAL PLAIN AQUIFERS OF VIRGINIA

by

J. D. Larson

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UNITED STATES DEPARTMENT OF THE INTERIOR

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Note: The term sea level used in this report refers to the National Geodetic Datum of 1929 (NGVD of 1929). The NGVD of 1929 is a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

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ABSTRACT

The depth to the top of the zone of saline ground water (chloride concentration equals 250 milligrams per liter) in the Coastal Plain aquifers in eastern Virginia ranges from less than 100 feet below sea level near the Atlantic Coast to greater than 1400 feet below sea level on the Northern Neck Peninsula. Analysis of samples collected over the past 70 years from more than 700 wells completed in the Coastal Plain sediments show only local increases in chloride, principally in pumping wells located very near salty surface-water bodies; that is Chesapeake Bay and its estuarine tributaries. The present-day occurrence and concentration of chloride in the sediments is probably due to one, or a combination, of the following causes: incomplete flushing of marine deposits; concentration of salts by movement of water through clay-rich sediments; solution of former evaporite deposits; or intrusion of seawater, either natural or induced by pumping.

INTRODUCTION

The Coastal Plain province of Virginia is a 9,700-square-mile area covering the eastern quarter of the State (fig. 1). The area is underlain by a series of eastward dipping layers of sand, gravel, marl, silt, and clay. These sediments, which range in age from Holocene through Cretaceous, thicken toward the east to form aquifers that are the most extensive and productive source of ground water in the State. Present pumpage exceeds 100 million gallons per day. As a result of this pumping, the potentiometric surface of the major aquifers has been lowered, natural discharge of freshwater has been decreased or been halted (Hopkins and others, 1981), and saline water may be intruding the previously freshwater aquifers. Concern by water suppliers and water-use planners about the effect of potential seawater intrusion on public and private water supplies prompted this study of the occurrence and extent of saltwater in these aquifers.

This report summarizes and evaluates chloride data on approximately 1,000 ground-water samples obtained during the past 70 years from more than 700 wells completed in the Coastal Plain sediments in Virginia. The horizontal and vertical distribution of chloride concentrations are shown in a series of geohydrologic cross sections. Both historic and present-day chloride data were examined to assess the possible changes in concentration that may have occurred, and the possible origins of chloride in the sediments are discussed.

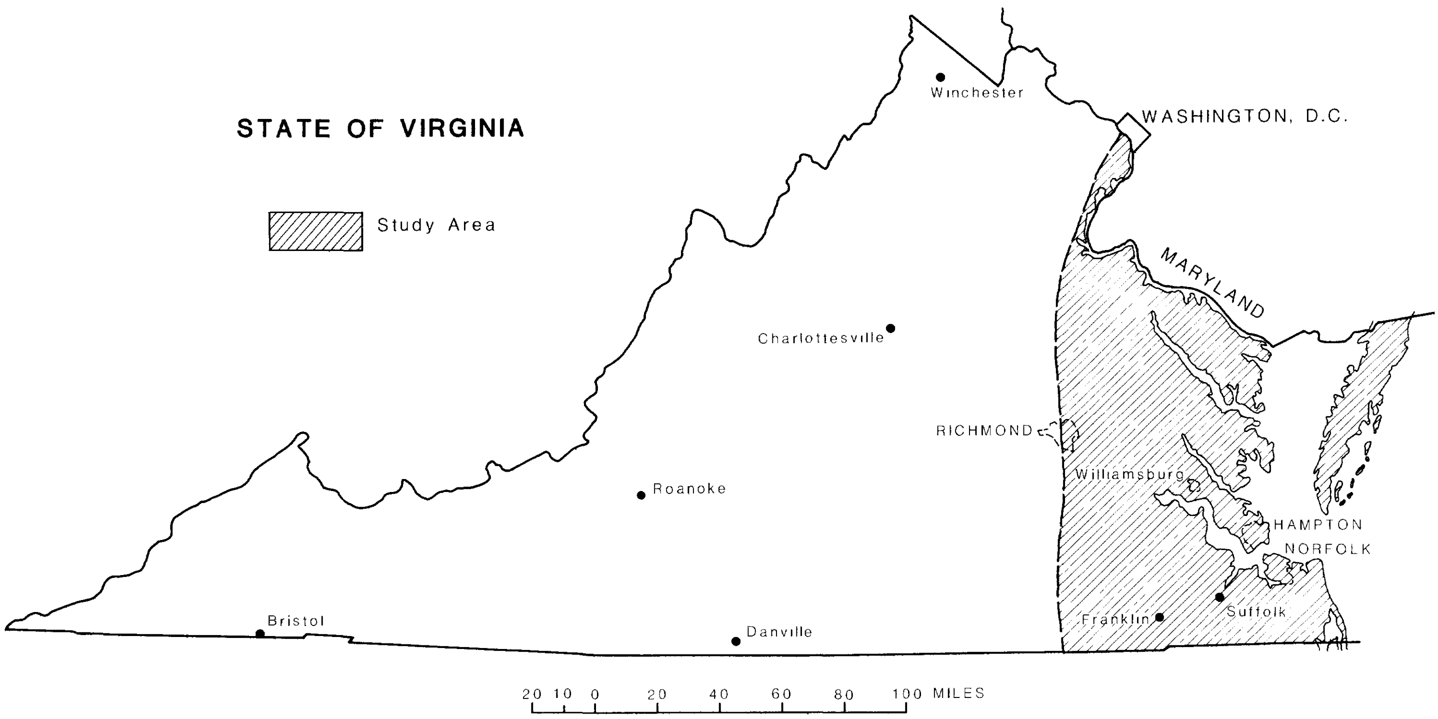


Figure 1.--Map of Virginia showing area of study.

ACKNOWLEDGMENTS

The author wishes to thank the Virginia State Water Control Board personnel in the Richmond and Tidewater offices for providing data and assistance in preparing this report. Significant help was furnished by well drillers and well owners who provided data and access for sampling.

HYDROGEOLOGY

The Coastal Plain of Virginia is underlain by eastward dipping and thickening beds of gravel, sand, marl, silt and clay. The sediments thicken eastward to greater than 2,000 feet at Norfolk and greater than 6,000 feet near Chincoteague on the Eastern Shore. The Fall Line, which marks the western edge of these sediments, extends approximately north-south through Washington D.C., Fredericksburg, Richmond, and Emporia. The Coastal Plain sediments are underlain by sedimentary rocks of Triassic and Jurassic age and by older metamorphic and igneous rocks.

Sands and clays of Early Cretaceous age overlie the basement rocks. These sediments, of nonmarine origin, are referred to as the Potomac Group. They contain the most prolific water producing zones or aquifers in the Coastal Plain. Because major pumping centers in the Coastal Plain draw water from sands of the Potomac Group, these aquifers are the most vulnerable to saltwater intrusion due to pumping.

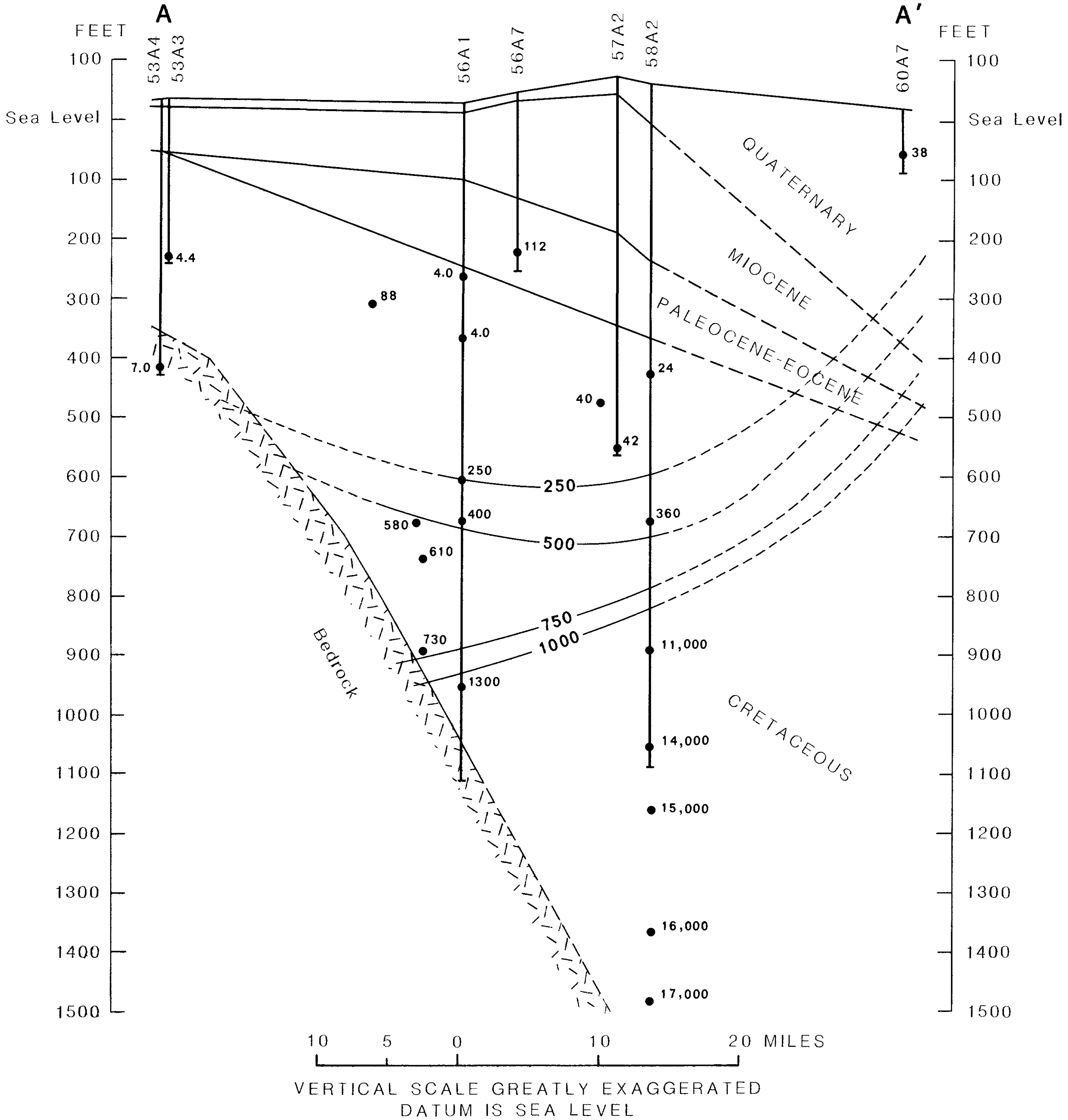
Overlying the Potomac Group are thin, discontinous marine sands and clays of Late Cretaceous age. These beds of high clay content act as a confining layer between the Potomac Group and the overlying Eocene sediments.

Marine sands and marls of Paleocene and Eocene age, designated the Pamunkey Group, overlie the Cretaceous sediments. These sands are glauconitic and are referred to on drillers' logs as "black" or "pepper" sand. The Pamunkey Group has not been heavily stressed by pumping in Virginia, but yields up to 900 gallons per minute have been reported from wells completed in these sediments.

The Pamunkey sediments are overlain by another sequence of marine sands and marls termed the Chesapeake Group of Miocene and Pliocene age. Sand lenses are less extensive here than in the deeper formations, but the Chesapeake Group does provide water for most domestic water supplies in the Virginia Coastal Plain and is the major source of water in areas where the deeper formations are salty. The Chesapeake Group is overlain by a veneer of Quaternary sands, clays, and gravels.

CHLORIDE IN GROUND WATER

Chloride concentrations in ground water in the Coastal Plain sediments of Virginia range widely. Chloride concentrations within a given range do not appear to be restricted to particular aquifers but available data show that concentrations generally increase with increasing depth in a specific well. In order to map chloride concentrations, seven generalized geologic cross sections (figures 2-8) were constructed and the chloride values



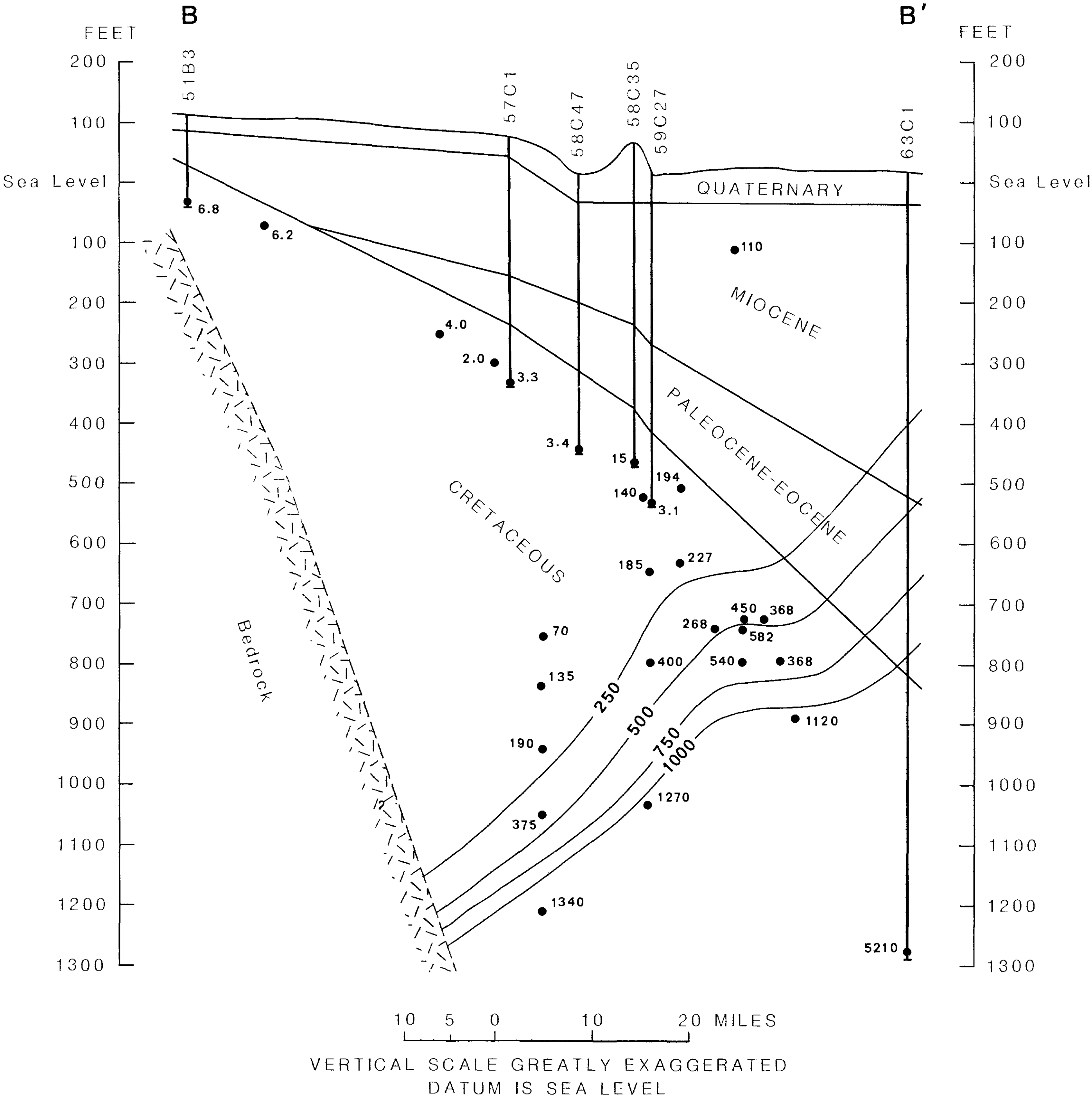
EXPLANATION

54A4 U.S.G.S. Local well number

• 360 Data point and chloride concentration, in milligrams per liter

——500--- LINE OF EQUAL CHLORIDE CONCENTRATION--Dashed where approximately located. Interval 250 milligrams per liter. Datum is sea level.

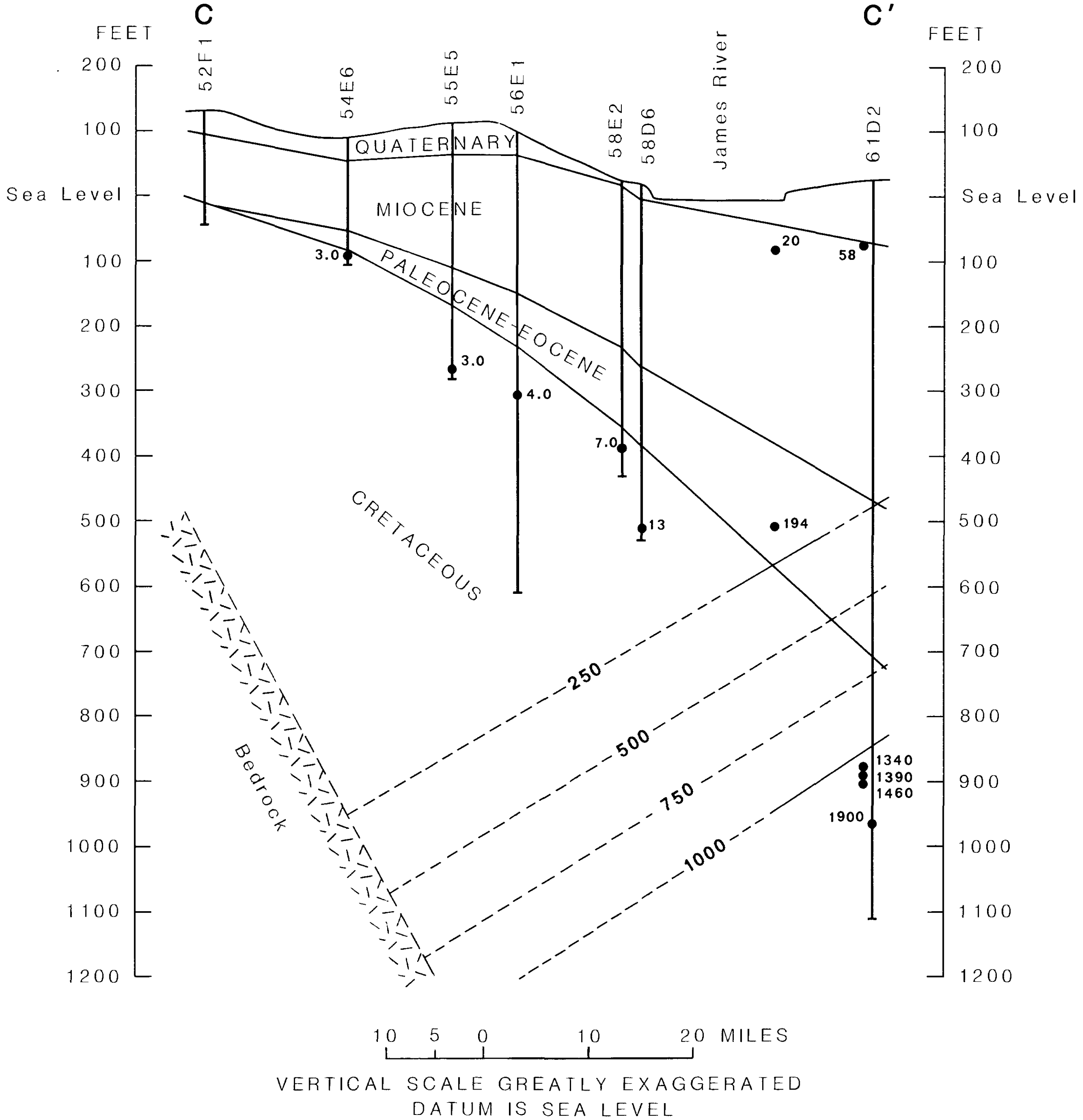
Figure 2.--Geohydrologic cross-section A-A', from near Boykins to east of Dismal Swamp.



EXPLANATION

51B3	U.S.G.S. Local well number
• 140	Data point and chloride concentration, in milligrams per liter
—— 500 – – –	LINE OF EQUAL CHLORIDE CONCENTRATION--Dashed where approximately located. Interval 250 milligrams per liter. Datum is sea level.

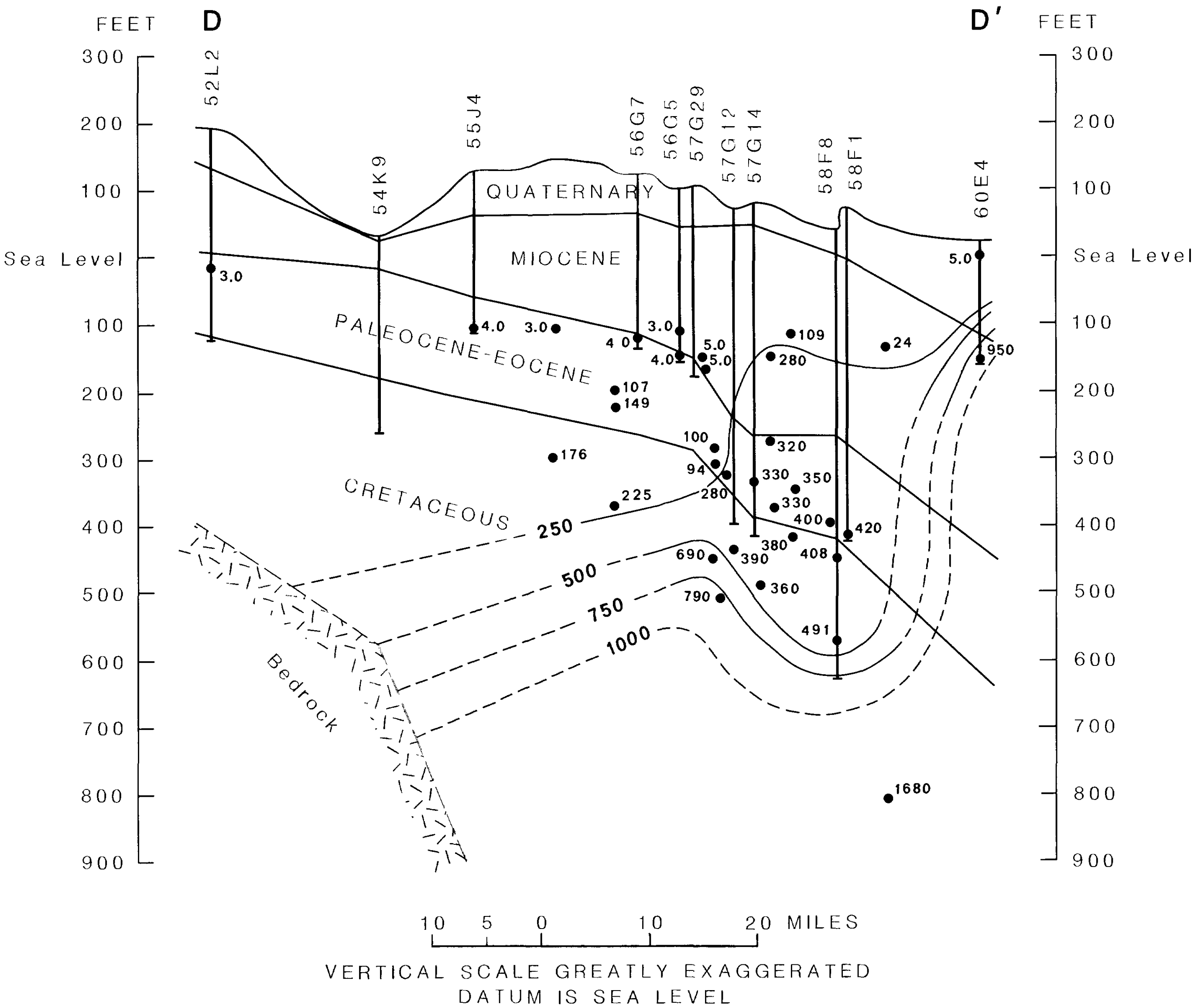
Figure 3.--Geohydrologic cross-section B-B', from near Jarratt to Virginia Beach.



EXPLANATION

52F1	U.S.G.S. Local well number
• 194	Data point and chloride concentration, in milligrams per liter
—— 500 – – –	LINE OF EQUAL CHLORIDE CONCENTRATION--Dashed where approximately located. Interval 250 milligrams per liter. Datum is sea level.

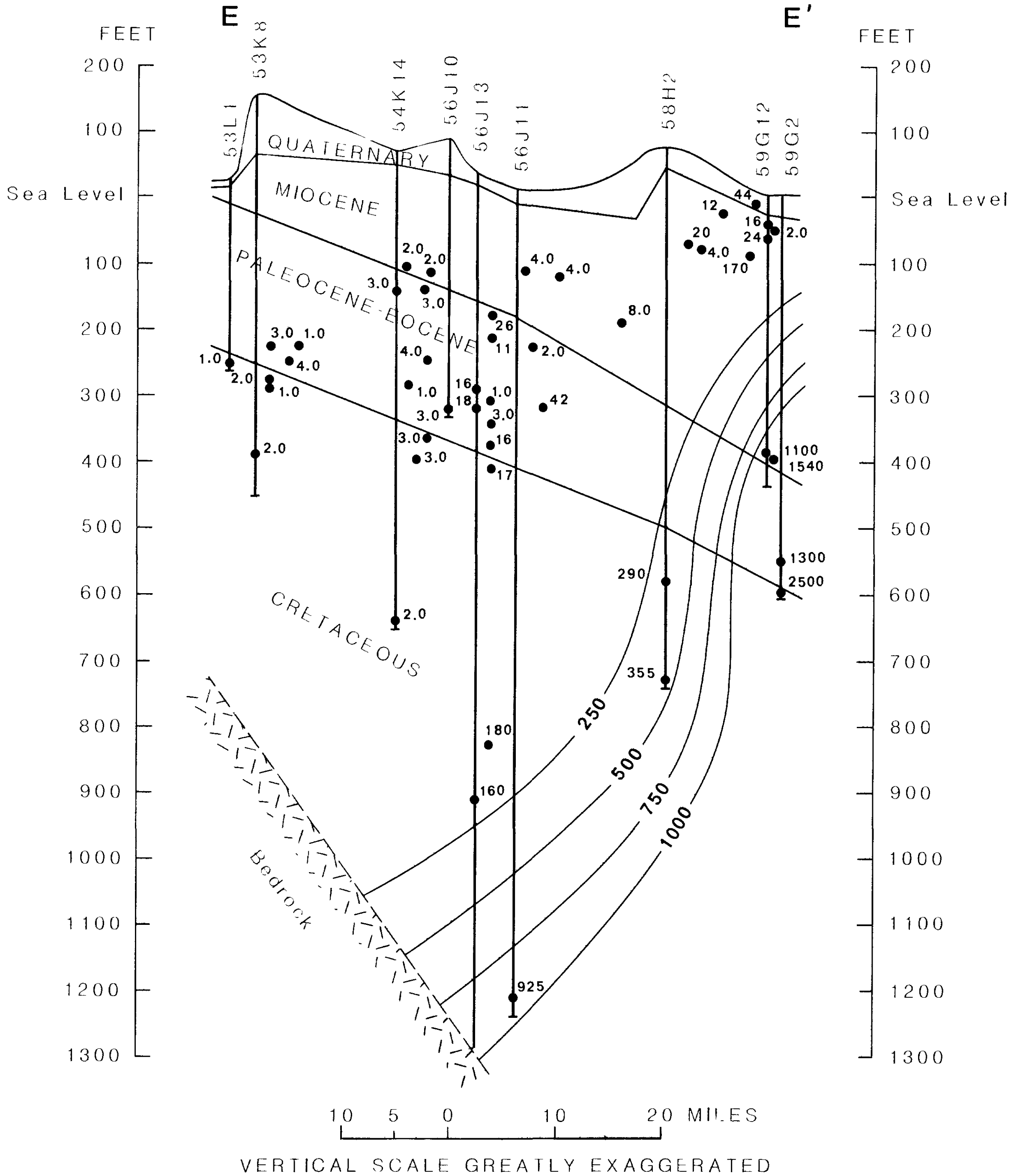
Figure 4.--Geohydrologic cross-section C-C', from Colonial Heights to Norfolk.



EXPLANATION

52L2	U.S.G.S. Local well number
● 176	Data point and chloride concentration, in milligrams per liter
—— 500 - - -	LINE OF EQUAL CHLORIDE CONCENTRATION--Dashed where approximately located. Interval 250 milligrams per liter. Datum is sea level.

Figure 5.--Geohydrologic cross-section D-D', from near Hanover to Hampton.



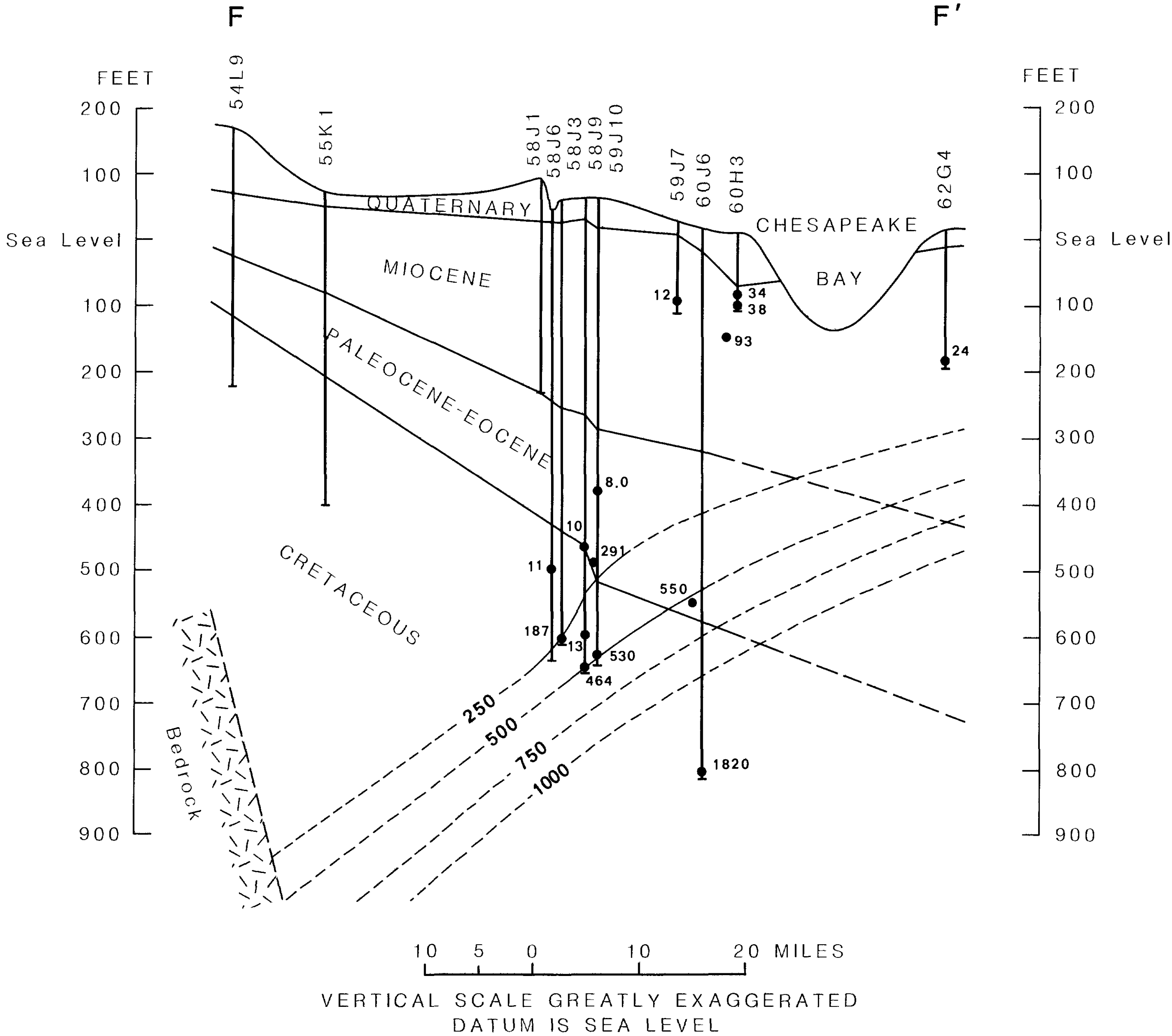
EXPLANATION

53L1 U.S.G.S. Local well number

● 290 Data point and chloride concentration, in milligrams per liter

—— 500 - - - LINE OF EQUAL CHLORIDE CONCENTRATION -Dashed where approximately located. Interval 250 milligrams per liter. Datum is sea level

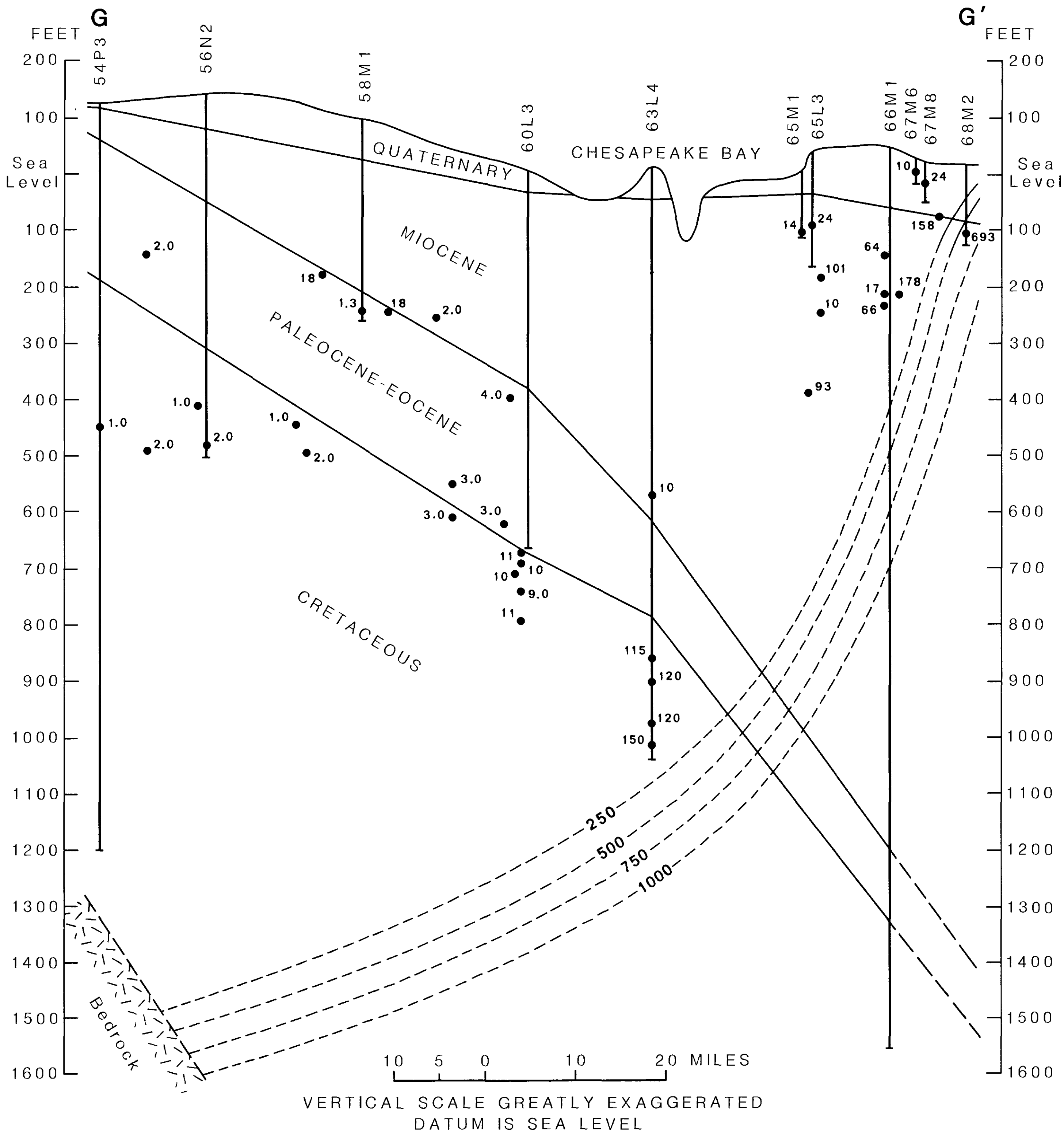
Figure 6.--Geohydrologic cross-section E-E', from near Penola to near Gloucester Point.



EXPLANATION

54L9	U.S.G.S. Local well number
● 187	Data point and chloride concentration, in milligrams per liter
—— 500 - - -	LINE OF EQUAL CHLORIDE CONCENTRATION--Dashed where approximately located. Interval 250 milligrams per liter. Datum is sea level.

Figure 7.--Geohydrologic cross-section F-F', from near Owenton to Eastville.



EXPLANATION

54P3	U.S.G.S. Local well number
●693	Data point and chloride concentration, in milligrams per liter
—— 500 - - -	LINE OF EQUAL CHLORIDE CONCENTRATION--Dashed where approximately located. Interval 250 milligrams per liter. Datum is sea level.

Figure 8.--Geohydrologic cross-section G-G', from Oak Grove to Chincoteague.

reported in chemical analyses were plotted at the depth of the well screens. Locations of the cross sections and wells are shown on plate 1. Chloride values shown on the cross sections are taken principally from wells within 5 miles of the section line. Lines of equal chloride-concentration were then drawn on each cross section. Finally a depth-contour map (plate 2) showing the depth below sea level of the top of the 250-mg/L (milligrams per liter) chloride-concentration zone was constructed. The 250-mg/L value is the U.S. Environmental Protection Agency (1976) recommended maximum for chloride in drinking water.

The depth to the 250-mg/L chloride-concentration contour ranges from less than 100 feet below sea level in the extreme southeast corner of the State, in the York-James Peninsula and part of the Eastern Shore, to greater than 1,400 feet below sea level in the Northern Neck area, as shown on Plate 2. The dashed lines in the extreme southeastern section, under the Chesapeake Bay, and on the Eastern Shore indicate a scarcity of data from these areas (see eastern ends of cross sections, figs. 2, 3, 4, 5, 7, and 8).

The -100-foot-depth contour of the 250-mg/L chloride concentration coincides closely with the mouth of Chesapeake Bay in the York-James Peninsula area. The configuration of the contour line indicates the presence of a wedge of saltwater at shallow depth, possibly due to the effect of tides in inhibiting flushing of the sediments by freshwater.

Analysis of data on chloride concentrations in ground water on the Eastern Shore by Eugene Siudyla of the Virginia State Water Control Board (oral communication, 1980) indicates a slightly different configuration than that shown on plate 2. Siudyla suggests that the 250-mg/L chloride-concentration level is "depressed" beneath the central topographic ridge of the Eastern Shore peninsula and is shallower toward both the Atlantic Ocean and Chesapeake Bay shorelines. The dashed lines shown on plate 2 reflect this uncertainty in the depth to saltwater in the area.

HISTORICAL CHANGES IN CHLORIDE CONCENTRATIONS

In order to determine the extent of ground-water deterioration resulting from any saltwater encroachment, a comparison must be made between past and present water-quality data. Water-quality samples have been collected as part of several earlier studies of ground water in the Coastal Plain of Virginia. Chloride was one of the major ions analyzed and used to help define the ground-water flow system in these studies. In 1979-80, an attempt was made to sample as many wells as possible for which chloride data from the first half of the century are available. Unfortunately, most of those wells were either destroyed or inaccessable for sampling. Data for 72 sites in the Coastal Plain for which more than one analysis is available are given in table 1. A criterion used in the compilation of table 1 was a 5 year or greater time span between successive samples.

Table 1. Selected data and chloride values for wells in the Coastal Plain aquifers of Virginia.

Local Well Number	Local Identifier	Station Number	Date of Sample	Depth of Well, Total Feet	Geologic Unit	Depth to top of Water-Bearing Zone (Feet)	Depth to top of Sample Interval (Feet)	Chloride, Dissolved (mg/L as CL)
52B4	So. Hampton St Frm	364332077152101	69-06-27	199	Potomac	--	--	7.4
			75-05-09	199	do.	--	--	6.1
52B7	So. Hampton St Frm	364331077151401	69-06-27	219	do.	110	209	6.4
			75-05-09	219	do.	110	209	5.4
55B19	Franklin 3	364050076552201	49-07-04	604	do.	--	--	6.2
			68-09-24	604	do.	--	--	3.2
55D2	Wakefield 2	365817076592201	37-11-26	230	Upper Cretaceous	--	--	2.2
			68-01-08	230	do.	--	--	2.4
55J7	Cohoke Fishing Clb	373151076475001	43-09-02	125	Pamunkey	--	--	3.0
			72-12-08	125	do.	--	--	2.4
55J9	Cohoke Fishing Clb	373920077000501	43-09-02	375	Eocene-Paleocene	--	--	3.0
			71-08-04	375	do.	--	--	3.0
55P3	Wash Birthpl Nps4	381122076553101	74-07-24	452	Potomac	349	394	2.1
			74-07-24	452	do.	349	394	.0
			74-07-25	452	do.	349	394	2.9
			79-12-05	452	do.	--	394	1.8
56C1	Zuni Prsb Sch	365305076380001	69-08-05	434	do.	270	418	3.2
			71-01-13	434	do.	270	418	2.0
			80-02-05	434	do.	--	418	1.8
56E1	Bacon Castle Tw2	370408076460101	42-02-12	705	do.	330	401	4.4
			69-07-30	705	do.	330	401	3.8
			69-07-30	705	do.	330	401	3.7
			69-07-30	705	do.	330	401	3.8
56F1	National Park Ser	371311076463601	72-04-27	337	do.	280	325	200
			79-02-02	337	do.	280	325	240
56F12	Jamestown Vis Ctr	371233076464001	71-07-20	340	do.	290	331	34
			77-08-02	340	do.	290	331	--
56F13	Jmestwn Fstivl Pk	371325076470701	71-07-01	336	do.	298	309	3.5
			77-08-02	336	do.	298	309	13
			78-01-27	336	do.	298	309	12
56G13	Sydnr-Indigo Pk 1	371640076473001	71-07-08	382	do.	370	371	100
			79-02-05	382	do.	370	371	100
56J3	Chesapeake Corp	373232076475701	52-04-02	710	do.	420	430	20
			54-06-01	710	do.	420	430	17
			68-12-05	710	do.	420	430	17
			69-02-20	710	do.	420	430	3.2
56J7	West Point, Town	37381007700501	41-02-10	376	do.	319	330	11
			71-08-10	376	do.	319	330	8.2
56J14	Chesapeake Corp	373317076490402	68-12-05	670	do.	340	315	18
			73-07-27	670	do.	340	316	16

Table 1. continued.

Local Well Number	Local Identifier	Station Number	Date of Sample	Depth of Well, Total Feet	Geologic Unit	Depth to top of Water-Bearing Zone (Feet)	Depth to top of Sample Interval (Feet)	Chloride, Dissolved (mg/L as CL)
56J18	Chesapeake Corp	373206076481201	41-02-11	446	Potomac	390	210	11
			69-02-15	446	do.	390	210	14
56M13	Jenkins, Lyell	375840076515001	18-07-10	385	Eocene-Paleocene	--	--	3.7
			41-02-27	385	do.	--	--	2.0
			48-06-07	385	do.	--	--	2.0
			53-05-15	385	do.	--	--	3.8
56M14	Tappahannock Town	375521076515101	68-11-01	528	Potomac	495	513	1.7
			73-06-20	528	do.	495	513	1.4
56N2	Coca-Cola Bottlng	380542076494701	44-01-01	648	do.	536	630	2.8
			48-06-09	648	do.	536	630	3.5
			53-05-20	648	do.	536	630	2.6
			79-12-05	648	do.	--	630	2.0
57A1	Whaleyville H D	363608076400701	68-10-10	620	do.	--	--	34
			80-02-05	620	do.	--	610	32
57B6	Forest Glen H S	364248076391301	69-07-08	678	do.	658	--	20
			75-05-06	678	do.	--	--	15
57D11	Pine Hts Sub Smfd	365933076381301	69-07-28	472	do.	380	452	4.2
			75-05-23	472	do.	380	452	2.6
57F2	Wllamsbrg Co Club	371421076382801	72-11-29	490	do.	460	465	350
			78-05-17	490	do.	460	465	200
57G1	VA OW 1	371749076441801	67-03-20	550	do.	400	410	453
			72-03-29	550	do.	400	410	10
57G12	Col Williamsbrg H	371623076420501	72-12-19	471	do.	399	--	280
			77-12-12	471	do.	--	--	250
57G24	Col Williamsbrg	371628076414501	72-12-19	445	do.	350	--	300
			75-05-20	445	do.	--	--	300
			77-12-12	445	do.	--	--	300
			78-06-01	445	do.	--	--	330
57G25	Col Williamsbrg G	371605076420301	71-07-13	470	do.	480	--	190
			75-05-20	470	do.	--	--	190
			77-12-12	470	do.	--	--	180
57G32	Col Williamsbrg A	371618076422301	71-07-13	438	do.	409	--	200
			77-12-12	438	do.	--	--	180
57G50	Willow Oaks Subd	371522076453201	72-11-29	252	Pamunkey	230	212	120
			79-02-05	252	do.	230	212	92
57J1	Rilee, E L	373236076421601	48-05-18	320	do.	--	--	2.5
			68-11-01	320	do.	--	--	2.3
57M1	Garland, E	375730076422701	06-01-01	188	do.	184	187	5.0
			18-07-09	188	do.	184	187	18
57M4	Holton, W C	375523076431801	46-08-29	180	Chesapeake	10	177	1.0

Table 1. continued.

Local Well Number	Local Identifier	Station Number	Date of Sample	Depth of Well, Total Feet	Geologic Unit	Depth to top of Water-Bearing Zone (Feet)	Depth to top of Sample Interval (Feet)	Chloride, Dissolved (mg/L as CL)
57M4	Holton, W C	375523076431801	48-06-09	180	Chesapeake	10	177	2.0
			53-01-15	180	do.	10	177	--
			53-05-15	180	do.	--	--	1.0
			75-10-23	180	do.	10	177	1.5
57N2	Davis, W B	380553076440501	46-08-16	153	do.	20	50	1.0
			48-06-07	153	do.	20	50	1.0
			53-05-20	153	do.	20	50	1.3
58A1	VA. OW 36	363704076334501	39-08-04	420	Upper Cretaceous	--	--	26
			70-09-10	420	do.	410	--	30
			72-04-28	420	do.	--	--	30
58B2	Suffolk, City of	364450076351801	29-08-08	717	Potomac	677	--	18
			29-09-14	717	do.	677	--	--
			29-09-14	717	do.	677	--	25
			39-08-05	717	do.	677	--	26
58B11	Harrell & Sons	364428076333201	69-07-08	654	do.	634	--	17
			75-04-21	654	do.	634	--	15
58B235	Planters Nuts 1	364328076345201	39-08-03	570	do.	530	--	19
			54-07-29	570	do.	530	--	22
			69-07-15	570	do.	530	--	22
58B236	Planters Nuts 3	364314076345801	52-02-12	718	do.	540	--	38
			54-07-29	718	do.	540	--	15
			69-07-15	718	do.	540	--	41
58B267	Green Pines Motel	364030076380001	70-09-08	500	do.	--	--	22
			79-09-11	500	do.	--	--	21
58F15	Dow Badische 6	371151076363801	69-10-27	545	do.	470	450	360
			71-08-02	545	do.	470	450	370
			78-06-02	545	do.	470	450	400
58H3	Vepco Gloucester	372459076323601	69-06-27	688	do.	577	660	295
			80-01-17	688	do.	--	--	290
58J3	St. Clare Wlker HS	373639076262901	70-01-13	700	do.	--	--	187
			80-01-16	700	do.	--	--	2.4
58K2	Wtervew Packng Co	374326076370901	48-05-15	311	Pamunkey	200	284	2.5
			80-01-16	311	do.	--	283	1.8
58K6	Urbanna, Town of	373818076344201	70-01-13	625	Potomac	480	470	7.7
			80-01-15	625	do.	480	470	5.7
58L2	Sydnor, Lively Tn	374641076305001	46-05-14	365	Eocene-Paleocene	--	--	53
			48-06-09	365	do.	--	--	4.0
			53-05-15	365	do.	--	--	3.6
58L5	Welch, J W	375032076370801	48-06-09	622	Upper Cretaceous	--	--	2.8
			53-05-15	622	do.	--	--	3.0

Table 1. continued.

Local Well Number	Local Identifier	Station Number	Date of Sample	Depth of Well, Total Feet	Geologic Unit	Depth to top of Water-Bearing Zone (Feet)	Depth to top of Sample Interval (Feet)	Chloride, Dissolved (mg/L as CL)
58M1	Syndr Callao Town	375806076333201	46-03-01	356	Pamunkey	325	347	2.8
			48-06-08	356	do.	325	347	2.0
			53-05-15	356	do.	325	347	1.5
			79-12-05	356	do.	--	347	1.3
58N2	Sydnor Kingsdale	380147076351201	46-05-01	280	do.	--	--	1.8
			48-06-08	280	do.	--	--	1.0
			53-05-20	280	do.	--	--	1.0
59D8	Tdewtr Comm Col	365418076260501	69-07-17	90	Chesapeake	--	--	34
			76-11-05	90	do.	--	--	23
59D10	Tdewtr Comm Col 4	365411076260801	69-07-17	82	do.	--	--	17
			76-11-05	82	do.	--	--	14
59D12	Tdewtr Comm Col 5	365411076260201	69-07-17	92	do.	--	--	24
			76-11-05	92	do.	--	--	22
59D13	Tdewtr Comm Col 6	365408076260401	69-07-31	81	do.	--	--	16
			76-11-05	81	do.	--	--	23
59D14	Tdewtr Comm Col 7	365405076260001	69-07-31	83	do.	--	--	18
			76-11-05	83	do.	--	--	15
59G2	Shackelford, L	371729076253701	06-12-31	610	Potomac	--	--	2500
			41-02-01	610	do.	--	--	2675
59G14	Hamilton, P	371947076272401	06-01-01	719	do.	--	--	1630
			41-02-01	719	do.	--	--	1700
			50-08-04	719	do.	--	--	1800
59K12	Mcateer, W R	373749076233101	41-02-27	680	do.	--	--	33
			48-06-09	680	do.	--	--	30
			53-05-15	680	do.	--	--	16
59K13	Willing, B	373919076252201	41-02-28	750	do.	--	--	11
			48-06-09	750	do.	--	--	12
			53-05-15	750	do.	--	--	5.6
59M2	Lewisetta Pack Co	375946076275001	18-07-05	550	Eocene-Paleocene	--	--	3.9
			41-02-27	550	do.	--	--	3.0
			79-12-05	550	do.	--	--	48
59M4	Bray, G E	375729076245001	48-06-08	404	do.	--	--	2.0
			53-05-15	404	do.	--	--	3.8
60H3	Morton, S	372810076181001	18-06-01	115	Chesapeake	80	115	28
			79-12-18	115	do.	80	115	34
60J5	Wndmll Pt Mar Ldg	373702076173101	73-07-31	682	Potomac	650	667	370
			76-01-19	682	do.	650	667	390
			79-12-04	682	do.	--	667	390
60K10	Clayton Ice Co	373754076205401	41-02-28	580	do.	--	--	113
			48-06-09	580	do.	--	--	113

Table 1. continued.

Local Well Number	Local Identifier	Station Number	Date of Sample	Depth of Well, Total Feet	Geologic Unit	Depth to top of Water-Bearing Zone (Feet)	Depth to top of Sample Interval (Feet)	Chloride, Dissolved (mg/L as CL)
60K10	Clayton Ice Co	373754076205401	53-05-15	580	Potomac	--	--	122
			79-12-04	580	do.	--	--	150
60K11	So States Coop	374202076210801	18-07-05	610	do.	--	--	11
			41-02-27	610	do.	--	--	5.0
60K13	Dupont, E I	374357076191801	48-06-19	580	Eocene-Paleocene	--	--	8.0
			53-05-15	580	do.	--	--	9.2
			79-12-05	580	do.	--	--	8.3
60L1	Blunden & Hinton	375028076163201	32-10-22	685	Potomac	640	670	14
			38-02-16	685	do.	640	670	8.0
			48-06-08	685	do.	640	670	11
			53-05-15	685	do.	640	670	11
60L3	Slaughter, T C	374858076162301	48-06-08	711	do.	670	700	13
			53-05-15	711	do.	670	700	11
			79-12-03	711	do.	670	700	9.6
60L9	Haynie, J W	375042076163401	18-07-01	740	do.	--	--	10
			41-02-27	740	do.	--	--	7.0
			53-05-15	740	do.	--	--	8.9
60L10	Booth, A J	375056076220501	48-06-08	625	Eocene-Paleocene	--	--	3.0
			53-05-15	625	do.	--	--	4.6
60L12	Fleeton, Town of	374900076165501	18-07-02	690	Potomac	--	--	9.5
			41-02-27	690	do.	--	--	7.0
60L13	Lowry, J B	374920076164301	18-07-02	740	do.	--	--	10
			41-02-27	740	do.	--	--	8.0
64H2	Memorial Hospital	372834075514401	55-04-05	304	Chesapeake	53	238	29
			75-09-24	304	do.	53	238	15

The location of wells that had a chloride increase greater than 10 mg/L during their sampling period is shown on plate 1. The 10-mg/L concentration change was used to eliminate any discrepancies that have resulted from sampling or analytical errors. All wells that showed a significant increase in chloride are located near bodies of salty surface water with the exception of well 57M1 near Warsaw. Wells 56F1, 57G24, 59G2, and 59G14 on the York-James and Middle Neck Peninsulas had reported chloride increases of 40, 30, 175, and 170 mg/L respectively. Wells 59M2, 60J5, and 60K10 on the Northern Neck showed chloride increases of 44, 20, and 37 mg/L respectively. Pumping from these wells may be inducing water from the nearby bays or estuaries. Saltwater drawn into an aquifer by heavy pumping can move directly into the well bore. If wells are gravel packed to near the surface, saltwater can be drawn either upward or downward through the gravel to the well openings.

ORIGIN OF SALTWATER IN COASTAL PLAIN SEDIMENTS

The origin of brackish or saline water in the Coastal Plain sediments is not completely understood. The obvious source of saltwater is the ocean; Cederstrom (1943b) attributed the presence of chloride to incomplete flushing of marine-deposited sediments. With the exception of the Potomac Group, the sediments in the Coastal Plain of Virginia are of marine origin. In some places, brines which are saltier than normal seawater have been found in the sediments. These brines may have resulted from the movement of seawater through clays that acted as membranes to concentrate the salts, or by leaching of former evaporite deposits

Before any ground-water pumping occurs, saline water underlies freshwater in equilbrium with the prepumping water table or potentiometric surface. Any change in the altitude of this surface, such as lowering or drawdown caused by pumping, induces the saltwater to seek a new equilibrium with the overlying freshwater. The saltwater may move either laterally or vertically upward into the previously freshwater part of the aquifer. Figure 5 (cross-section D-D') shows an example of such "up-coning" of saltwater due to pumping.

SUMMARY AND CONCLUSIONS

Over 1,000 chemical analyses from more than 700 wells were evaluated to assess the location, extent, historical changes, and origin of saltwater in the Coastal Plain of Virginia. These data are put in a geohydrologic framework utilizing seven cross sections that show concentration of chloride at the depth sampled. Chloride values of 250, 500, 750, and 1,000 mg/L were contoured on the cross sections. The depth to the top of the 250-mg/L chloride-concentration zone ranges from less than 100 feet below sea level near the Atlantic Coast to more than 1,400 feet below sea level on the Northern Neck Peninsula. A wedge of saltwater coincident with the mouth of Chesapeake Bay extends into the York-James and southern Middle Neck Peninsulas.

Historical changes in chloride were found to be more a local than a regional phenomenon. More wells showed a decrease or virtually no change in chloride concentration than wells which showed an increase in chloride. The greatest increase in chloride concentration, 175 mg/L was in a well at the southeastern tip of the Middle Neck Peninsula.

The obvious origin of saltwater in ground water of the Virginia Coastal Plain is the Atlantic Ocean. Present day chloride levels may be due to saltwater intrusion (either natural or induced by pumping), incomplete flushing of marine sediments, solution of former evaporite deposits, or concentration by movement of water through clay-rich sediments.

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