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WATER-RESOURCES INVESTIGATIONS REPORT 99–4127
Strickland, A.G., 1999, Water-level conditions in the upper Cape Fear aquifer, 1994–98, in parts of Bladen and Robeson Counties, North Carolina

ABSTRACT

Water-level measurements were made on a periodic basis from October 1994 through November 1998 in 17 wells that tap the upper Cape Fear aquifer. The approximately 730-square-mile study area in Bladen and Robeson Counties is in the southern Coastal Plain of North Carolina. Water-level declines occurred in the aquifer throughout much of the area as a result of pumping during this period. The greatest decline was about 42 feet in Bladen County.

Water levels from the wells in the fall of 1998 were used to construct a map of the potentiometric surface of the upper Cape Fear aquifer. This map can be used to infer the direction of ground-water movement in the aquifer. Withdrawals from wells at pumping centers, such as in the Tar Heel and Elizabethtown areas in Bladen County, have caused ground water to flow toward pumped wells, resulting in cones of depression in the potentiometric surface.

INTRODUCTION

In 1992, the U.S. Geological Survey (USGS) began a 3-year study of water levels in the major water-supply aquifers in the southern Coastal Plain Province of North Carolina. The study was extended for an additional 4 years and is being conducted in cooperation with the Lumber River Council of Governments (LRCOG), which is composed of local governments in Bladen, Hoke, Robeson, and Scotland Counties (fig. 1). The objective of this investigation is to assess the effects of ground-water withdrawals on water levels in major aquifers in the LRCOG area.

This report was produced, in part, to provide water-resources information that will be used by multiple parties for planning and operational purposes, one of the broad goals of the USGS. The report presents an evaluation of water-level conditions in the upper Cape Fear aquifer in parts of Bladen and Robeson Counties, North Carolina, from October 1994 through November 1998. The assessment includes the effects of ground-water withdrawals on the potentiometric surface of the aquifer in parts of the Cape Fear River valley during fall 1998.

Parts of Bladen and Robeson Counties were selected for this study on the basis of findings from the mapping of the potentiometric surface during fall 1994, water-level changes between 1992 and 1994 in the upper Cape Fear aquifer (Strickland, 1995), and increased ground-water development. The study area, which covers about 730 square miles, includes the Tar Heel and Elizabethtown areas in Bladen County (fig. 1), major pumping centers in the study area.

HYDROGEOLOGIC SETTING

The Coastal Plain Province of North Carolina consists of a southeastward dipping and thickening wedge of predominantly unconsolidated sedimentary deposits of sand and clay underlain by basement rocks. The western boundary of these deposits is the Fall Line (fig. 1; Winner and Coble, 1996). The sedimentary deposits are divided into geologic formations based on their age and lithology. The deposits are further classified according to hydraulic characteristics and grouped into hydrogeologic units called aquifers and confining units. The basement rocks consist of metamorphic and igneous crystalline rocks of pre-Cretaceous age. The relations of geologic and hydrogeologic units that underlie the study area are shown in figure 2.

Aquifers are composed of formations, groups of formations, or parts of formations that (1) contain ample saturated permeable material (sand or gravel in the LRCOG area), (2) allow the lateral movement of water within them, and (3) yield significant quantities of water to wells and springs. Confining units, however, are composed of distinctly less permeable material (clay, silty clay, and sandy clay beds) that restrict the movement of water between adjacent aquifers.

Five aquifers have been identified in the study area—the surficial, Peedee, Black Creek, upper Cape Fear, and lower Cape Fear aquifers—separated by four confining units (figs. 2, 3; Winner and Coble, 1996). Each confining unit is informally named for the aquifer it overlies. The upper Cape Fear aquifer is a major source of water for public and industrial uses in the study area and is highlighted in this report.

The upper Cape Fear aquifer is composed of alternating beds of sand and clay. This aquifer includes permeable zones in the Cape Fear Formation of Cretaceous age. Winner and Coble (1996) divided the Cape Fear Formation into two distinct hydrogeologic units—the upper and lower Cape Fear aquifers. The upper Cape Fear aquifer has the largest areal extent of the two in the LRCOG area.

DATA COLLECTION AND ANALYSIS

Wells that were used in the study are North Carolina Department of Environment and Natural Resources (DENR) and industrial observation wells. Other wells included in this study were industrial, municipal, county, State, and federally owned water-supply wells. Water levels in many of the wells have been measured periodically since fall 1988 (Strickland and others, 1992; Strickland, 1994, 1995; U.S. Geological Survey, 1997–99).

Seventeen wells that tap the upper Cape Fear aquifer were measured between fall 1994 and fall 1998 (table 1; fig. 4). Nine of these wells are observation wells, one of which is located outside of the study area in Columbus County, North Carolina. The other eight wells are water-supply wells, two of which are rarely pumped.

Water levels from observation and water-supply wells were measured during regularly scheduled data-collection periods. In order to approximate similar weekly pumping durations, the water level generally was measured on the same day of the week at each industrial observation well located at a pumping center. To ensure that water levels from water-supply wells closely represented stable conditions in these wells, pumps were switched off at least 20 minutes prior to measuring the water levels. If two consecutive measurements taken about 5 minutes apart differed by less than 0.1 foot, the water levels were considered representative of nonpumping (quasi-static) conditions.

The water level measured in a well represents the hydraulic head in the screened part of the aquifer. Hydraulic heads were computed by subtracting the water levels in the wells, in feet below land surface, from land-surface altitudes at the wells, in feet above sea level, and reported to the nearest foot (table 1). The potentiometric surface of an aquifer is a map of hydraulic heads in the aquifer and represents the altitude to which water levels would rise in tightly cased wells under static conditions.

A map showing the potentiometric surface of the upper Cape Fear aquifer was constructed by using water levels measured in these wells during late September and early October 1998 (table 1). For these measurements, pumps were switched off prior to making water-level measurements—at least 3 hours in municipal, county, and federally owned water-supply wells and at least 24 hours in industrial water-supply wells. Also, prior to making water-level measurements in industrial observation wells, pumps were switched off at least 24 hours in most or all nearby water-supply wells.

Three wells that were used in this study are not screened solely in the upper Cape Fear aquifer (table 1). This approach is not ideal, because it does not provide a precise water-level measurement for the upper Cape Fear aquifer. However, no wells that tap only the upper Cape Fear aquifer were identified in the Elizabethtown area. The water level from a well that taps more than one aquifer does not indicate the water level in an individual aquifer, but rather indicates a composite water level influenced by all the aquifers that are screened by the well. This composite water level is based on several factors, including the length of the screen in each aquifer and the aquifer transmissivity. The water level in a single aquifer at some distance from the well is likely different from the composite water level.

The locations of wells were determined by using the Global Positioning System (GPS). Latitude and longitude coordinates obtained by using GPS are referenced to the North American Datum of 1927 (table 1). Land-surface altitudes at well sites that have not been surveyed to the nearest 0.1 foot were estimated to the nearest foot from USGS 7.5-minute topographic quadrangle maps having 5- or 10-foot contour intervals.

WATER-LEVEL CONDITIONS IN THE UPPER CAPE FEAR AQUIFER

The potentiometric surface of the upper Cape Fear aquifer in the mapped area in Bladen and Robeson Counties (fig. 4) indicates that the general direction of ground-water flow is toward pumped wells. Pumping has resulted in cones of depression in the potentiometric surface of the upper Cape Fear aquifer in Bladen County along the Cape Fear River from the Cumberland-Bladen County line to Elizabethtown. Within this area, pumping at well fields in the Tar Heel and Elizabethtown areas accounts for most of the withdrawals from the upper Cape Fear aquifer.

Withdrawals averaged about 2.4 to 2.8 million gallons per day in the Elizabethtown area between 1994 and 1998 (Mr. Earl Phillips, Mr. John Hester, and Mr. Dan Boone, oral commun., 1999). Between October 1994 and November 1998, observed water-level fluctuations in well BL-121 in Elizabethtown ranged from a maximum of 100.2 feet below land surface in February 1997 to a minimum of 110 feet below land surface in September 1997 (fig. 4). Water-level fluctuations in well BL-121 generally reflect seasonal changes in pumping. Observed water levels in well BL-131, which is located near the northwestern edge of Elizabethtown (fig. 4), fluctuated between a maximum of 174.4 feet below land surface in November 1998 and a minimum of 197.2 feet below land surface in June 1996. Water levels observed in well BL-131 during October and November 1998 reflect conditions when nearby production wells were not pumped for periods of at least 24 hours, whereas water-level fluctuations observed prior to October 1998 may have been affected by intermittent pumping nearby (fig. 4).

Three wells (BL-121, BL-129, and BL-131) at pumping centers in the Elizabethtown area tap the upper Cape Fear aquifer in addition to the Black Creek and lower Cape Fear aquifers. Water levels measured in these wells represent a composite of water levels in the upper Cape Fear aquifer as well as the other two aquifers. Water levels in any single aquifer away from the multi-screened wells will be different from the composite water levels. In this area, water levels in the overlying Black Creek aquifer are higher than those measured in the multi-screened wells. However, no wells that tap only the upper Cape Fear aquifer were identified in the Elizabethtown area. This area is highlighted on the potentiometric surface map (fig. 4) because potentiometric contours in this area provide only an estimate of the actual water level in the upper Cape Fear aquifer. Any future, detailed study of the potentiometric surface of the upper Cape Fear aquifer in the Elizabethtown area will need to include the installation of a well or wells screened solely in the upper Cape Fear aquifer.

The cone of depression in the potentiometric surface of the upper Cape Fear aquifer that is centered beneath the Tar Heel area did not stabilize between 1994 and 1998. Since 1994 (Strickland, 1995), the cone has continued to deepen and expand areally away from the well field near Tar Heel. The growth of the cone is reflected in water-level declines in the aquifer throughout most of the area between fall 1994 and fall 1998 (fig. 4).

Major withdrawals from the aquifer in the Tar Heel area began in October 1992. Withdrawals increased to approximately 2.3 million gallons per day in 1994 (Strickland, 1995). Average monthly pumping rates for 1996 were reported to be between about 2.1 and 2.4 million gallons per day, and maximum daily rates at times exceeded 3 million gallons per day. Between October 1996 and December 1998, however, maximum daily rates did not exceed 3 million gallons per day. In 1997 and 1998, average monthly pumping rates were 1.8 million gallons per day, and maximum daily rates were approximately 2.3 to 2.8 million gallons per day (Mr. Charles Fiero, written commun., 1999). These withdrawals lowered the observed water level in well BL-142, which is located near the center of pumping, by 117 feet between September 1992 and October 1998. The water level in this well declined 26 feet between October 1994 and October 1998 (fig. 4). The water level measured in October 1998 reflects conditions when most nearby production wells were not being pumped. Water levels measured prior to October 1998 may have been affected by intermittent pumping nearby.

Hydrographs for selected wells that are screened in the upper Cape Fear aquifer and are located away from the center of pumping near Tar Heel illustrate the areal effects of withdrawals in the aquifer (fig. 4). The water level in observation well BL-86, which is located approximately 7 miles north of well BL-142, dropped 42 feet between October 1994 and November 1998. During the first part of this period (October 1994 to July 1996), the rate of water-level decline was about 15 feet per year. Since October 1996, however, the rate of decline has decreased to about 4 feet per year. This change in the rate of water-level decline corresponds to the period between October 1996 and December 1998 when maximum daily pumping rates from the aquifer near Tar Heel did not exceed 3 million gallons per day.

Similar responses in water-level decline were observed in wells BL-72, BL-94, BL-100, BL-147, and RB-183 (fig. 4). Water levels in wells RB-183 (DENR Littlefield observation well Y42f9) and BL-100 (DENR Bladenboro observation well Z41u2) declined 20 and 12 feet, respectively, between October 1994 and November 1998. The rates of water-level decline in wells RB-183 and BL-100 were about 6.6 and 3.6 feet per year, respectively, from October 1994 to July 1996; after October 1996, however, the rates were about 2.9 and 2.5 feet per year, respectively. This compares to rates of decline prior to 1992 of about 1.7 and 1.2 feet per year in wells RB-183 and BL-100, respectively (Strickland, 1994). These wells are located approximately 10 miles southwest and 17 miles south, respectively, of well BL-142.

A general trend in water-level decline has occurred at well BL-57, located just east of Jones Lake, as a result of regional and local pumping between 1994 and 1998 (fig. 4). Observed water levels in well BL-57 declined 13 feet between October 1994 and November 1998.

The areal extent of regional pumping effects in the upper Cape Fear aquifer is widespread throughout the mapped area. Hydrographs for observation wells that are screened in this aquifer and are located in outlying areas show water-level declines between 1994 and 1998 (fig. 4). The water level in well RB-188 (DENR Boardman observation well AA43q1), located about 12 miles southwest of Bladenboro (fig. 4), dropped 9 feet from October 1994 to November 1998. This is about a 2.2-foot-per-year rate of decline during this period. Well CO-89 (DENR Carver Moore observation well AA39v2) is located in Columbus County near the Bladen-Columbus County line and about 5.5 mi southeast of Clarkton in Bladen County. The water level in this well declined 2.7 feet, a rate of about 0.6 foot per year, from October 1994 to November 1998.

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Table 1. Selected records for wells in Bladen, Columbus, and Robeson Counties, North Carolina, September and October 1998

[BL, Bladen County; CO, Columbus County; RB, Robeson County; latitude and longitude coordinates are referenced to the North American Datum of 1927]

Well number (fig. 4)	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water level (feet below land surface)	Hydraulic head (reported to nearest foot above or below (-) sea level)
Wells screened in the upper Cape Fear aquifer					
BL-57	34°41'20"	78°35'42"	73	85.2	-12
BL-72	34°50'05"	78°49'33"	74	135.0	-61
BL-86	34°50'39"	78°50'13"	147.3	210.5	-63
BL-90	34°50'53"	78°49'36"	51.5	112.9	-61
BL-94	34°39'05"	78°43'28"	144	165.3	-21
[1]BL-100	34°30'24"	78°45'17"	106	90.3	16
BL-142	34°44'42"	78°48'24"	130	221.2	-91
BL-147	34°44'35"	78°42'31"	60	96.1	-36
BL-191	34°45'36"	78°48'31"	135	238.6	-104
BL-193	34°45'51"	78°48'27"	136	238.5	-102
BL-227	34°38'55"	78°31'58"	64	48.6	15
[2]CO-89	34°25'07"	78°36'10"	105.5	48.4	57
[3]RB-183	34°38'40"	78°55'00"	142	144.2	-2
[4]RB-188	34°26'22"	78°58'19"	80.5	56.7	24
Wells screened in the Black Creek, upper Cape Fear, and lower Cape Fear aquifers					
BL-121	34°37'26"	78°36'02"	120	105.7	14
BL-129	34°38'53"	78°38'43"	135	184.9	-50
BL-131	34°39'00"	78°38'36"	115	185.3	-70

[1]North Carolina Department of Environment and Natural Resources Bladenboro observation well Z41u2.

[2]North Carolina Department of Environment and Natural Resources Carver Moore observation well AA39v2.

[3]North Carolina Department of Environment and Natural Resources Littlefield observation well Y42f9.

[4]North Carolina Department of Environment and Natural Resources Boardman observation well AA43q1.

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Flow	
million gallons per day (Mgal/d)	0.04381	cubic meters per second

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

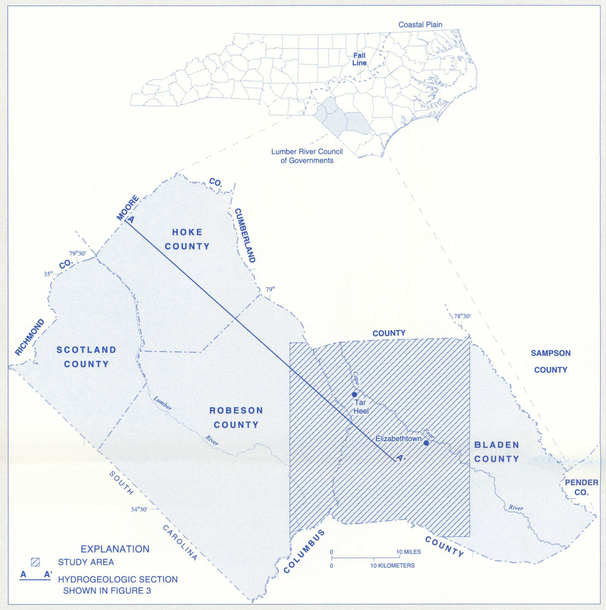

Figure 1. The study area within the Lumber River Council of Governments in the Coastal Plain Province of North Carolina, and line of hydrogeologic section A-A'.

Geologic units		Hydrogeologic units
Geologic age	Formation	Aquifer and confining unit
Tertiary	Undifferentiated	Surficial aquifer
Cretaceous	Peedee Formation	Peedee confining unit
		Peedee aquifer
	Black Creek and Middendorf Formations	Black Creek confining unit
		Black Creek aquifer
	Cape Fear Formation	Upper Cape Fear confining unit
		Upper Cape Fear aquifer
		Lower Cape Fear confining unit
		Lower Cape Fear aquifer
Pre-Cretaceous basement rocks	Undifferentiated	

Figure 2. Generalized relations of geologic and hydrogeologic units in the study area (modified from Winner and Coble, 1996).

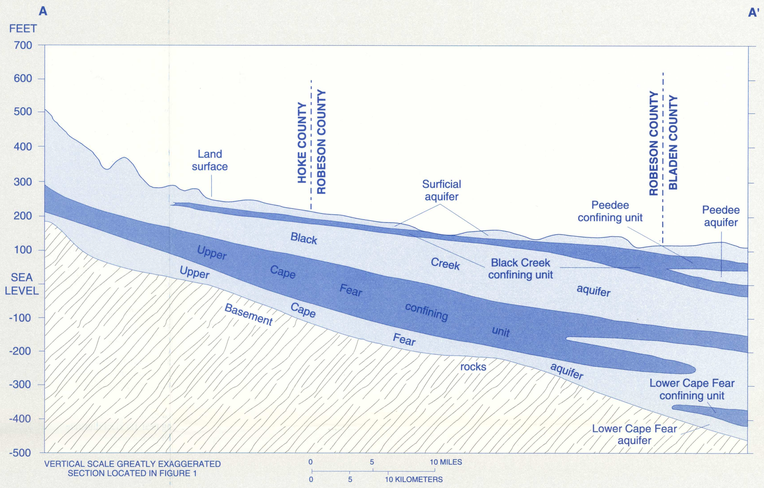

Figure 3. Generalized hydrogeologic section A-A' (modified from Winner and Coble, 1996).

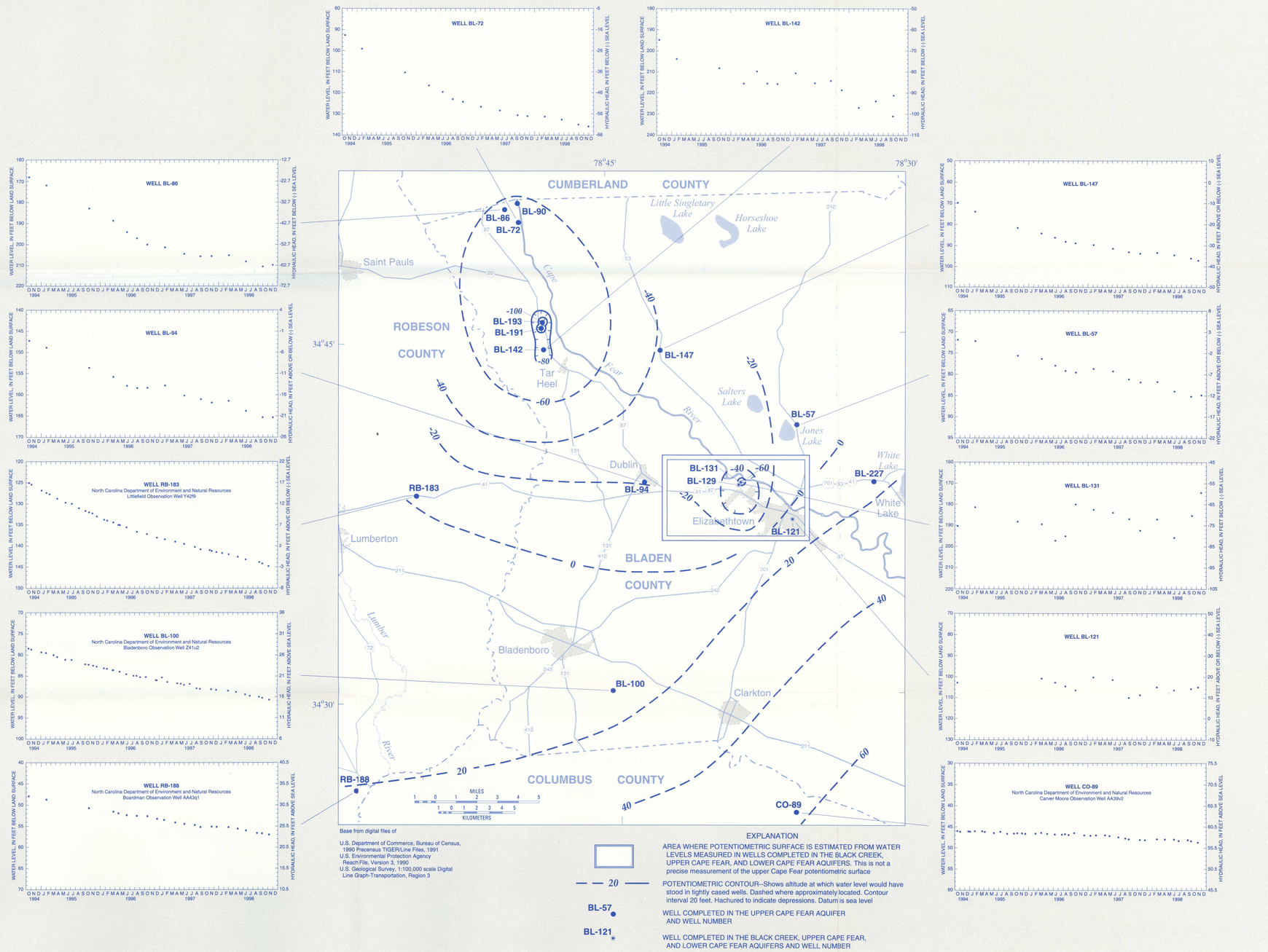

Figure 4. Potentiometric surface of the upper Cape Fear aquifer in parts of Bladen, Columbus, and Robeson Counties, North Carolina, September and October 1998.

Water-Level Conditions in the Upper Cape Fear Aquifer, 1994–98, in Parts of Bladen and Robeson Counties, North Carolina

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1999