U.S. Department of the Interior
U.S. Geological Survey

Prepared in cooperation with the Cape Fear Public Utility Authority

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Abstract

Data were collected from more than 230 wells in northern New Hanover County, North Carolina, to evaluate the distribution of transmissivity and yield of the surficial, Castle Hayne, and Peedee aquifers of the Coastal Plain Physiographic Province. Constant-rate, single-well aquifer test data were obtained and analyzed to calculate additional transmissivity values for 25 production wells that were completed in the Castle Hayne or Peedee aquifer. In the surficial aquifer, transmissivity values ranged from 400 to 12,700 feet squared per day, and reported yields ranged from 6 to 100 gallons per minute. In the Castle Hayne aquifer, transmissivity values ranged from 1,400 to 18,700 feet squared per day, and reported yields ranged from 9 to 640 gallons per minute. In the Peedee aquifer, transmissivity values ranged from 530 to 18,600 feet squared per day, and reported yields ranged from 8 to 1,000 gallons per minute.

Introduction

New Hanover County is one of the most populated coastal counties in North Carolina, with a population of about 194,000 people in 2009 (State of North Carolina, 2010). The demand for drinking water likely will increase over the next 20 years as the population is projected to expand by more than 20 percent (State of North Carolina, 2010). Public water systems in New Hanover County rely on a combination of surface-water withdrawals from the Cape Fear River and groundwater pumped from the underlying surficial, Castle Hayne, and Peedee aquifers. In 2008, the City of Wilmington and New Hanover County consolidated their water and sewer services to form the Cape Fear Public Utility Authority (CFPUA; *http://www.cfpua.org/*). The CFPUA operates a surface-water processing plant capable of treating up to 27.5 million gallons per day (Mgal/d) of potable water and distributing it to the central part of the county. The CFPUA also operates two small groundwater distribution plants. In 2009, a 6-Mgal/d nanofiltration groundwater processing plant that blends water withdrawn from the Castle Hayne and Peedee aquifers was constructed to supply drinking water to the northern part of New Hanover County.

Previous regional hydrogeologic studies were conducted in the New Hanover County area (Winner and Coble, 1996; Lautier, 1998, 2006). Seasonal and decadal declines in groundwater levels resulting from groundwater withdrawals were noted, as well as the potential for saltwater intrusion from underlying, more brackish aquifers as a result of upconing and lateral encroachment from the Atlantic Ocean. Future growth in New Hanover County likely will increase the need for water for industry, mining, irrigation, and aquaculture. These demands on the available freshwater resources likely will require increased groundwater withdrawals. As a result, the CFPUA is interested in expanding its groundwater supply capacity in the northern part of the county and would like a better understanding of the hydraulic properties of the surficial, Castle Hayne, and Peedee aquifers that underlie the area near the new nanofiltration groundwater plant. The U.S. Geological Survey (USGS), in cooperation with the CFPUA, conducted this study to evaluate the distribution of transmissivity and yield of the surficial, Castle Hayne, and Peedee aquifers in the northern part of New Hanover County.

Study Area

New Hanover County is located in southeastern North Carolina in the Coastal Plain Physiographic Province (fig. 1) and is bounded to the north by Pender County, to the west by saline waters of the tidally affected Cape Fear River, and to the east by the Atlantic Ocean (fig. 2A). New Hanover County encompasses 328 square miles (mi^2), of which 129 mi^2 is surface water. The altitude of New Hanover County ranges from sea level to about 75 feet (ft) above the National Geodetic Vertical Datum of 1929 (NGVD 29). This study was limited to areas in the northern part of New Hanover County outside the city limits of Wilmington and focused particularly on areas within the Murraysville and Bayshore census designated places (CDP) near CFPUA's new nanofiltration groundwater processing plant (fig. 2A). The southern limit of the study area was arbitrarily drawn along a line at 34°15' N to approximately correlate with the southern extent of water distribution from the nanofiltration plant.

Hydrogeology

The geologic formations that underlie the study area form a wedge of interbedded sand, clay, and limestone that dips to the east. The stratigraphy of New Hanover County has been described in detail by Bain (1970), Zarra (1991), and Lautier (2006). These formations range in age from late Cretaceous to Quaternary (fig. 3). In the eastern part of the study area, the sands of the Peedee Formation underlie limestone of the Tertiary age Castle Hayne Formation (fig. 2B). Late Tertiary and Quaternary age sands overlie the Castle Hayne Formation. The origin and thickness of these surficial sediments are variable and for the purposes of this report are grouped into one geologic unit. The Castle Hayne Formation is discontinuous in northern New Hanover County, causing the surficial Quaternary age sands to lie unconformably over the Cretaceous age Peedee sands in the western part of the study area (fig. 2B). Because of the extensive reworking of the surficial sediments over time, the confining unit separating the surficial sands from the Castle Hayne Formation is discontinuous (Zarra, 1991).

The principal groundwater supply aquifers in New Hanover County—the surficial, Castle Hayne, and Peedee—were formed from the late Cretaceous to Quarternary aged geologic formations (figs. 2B, 3). In 2005, these three aquifers supplied about 30 percent of all freshwater used in New Hanover County (U.S. Geological Survey, 2010). Groundwater withdrawals, however, are most prevalent in areas outside the city limits of Wilmington, particularly in the northern and southern areas of the county and on the barrier islands.

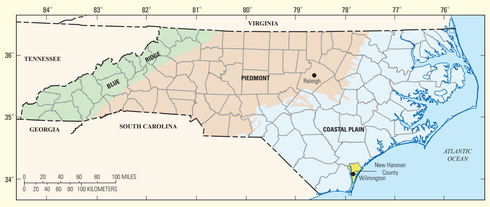

Figure 1. Location of New Hanover County within the Coastal Plain Physiographic Province of North Carolina.

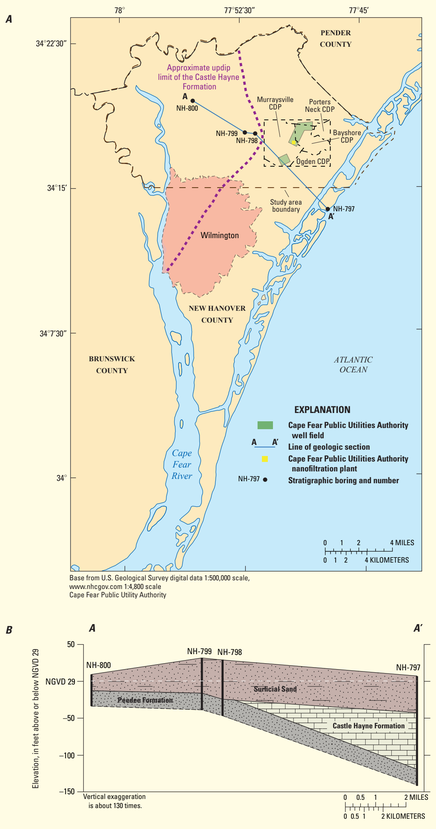

Figure 2. Location of the (*A*) study area, line of geologic section, Murraysville and Bayshore Census Designated Places (CDP), and (*B*) geologic cross section *A*–*A'* and boreholes in northern New Hanover County, North Carolina (modified from Zarra, 1991).

System[1]	Geologic Unit	Hydrogeologic Unit
Quarternary	Undifferentiated surficial sands	Surficial aquifer
Tertiary	Castle Hayne Formation	Castle Hayne aquifer and confining unit
Cretaceous	Peedee Formation	Peedee aquifer and confining unit

[1]System identification of a given hydrogeologic unit is only approximate and reflects the age or ages of the principal geologic unit or units composing each hydrogeologic unit.

Figure 3. Correlation chart of North Carolina Coastal Plain geologic and hydrogeologic units (modified from Lautier, 1998).

Although older, deeper aquifers are present throughout the county, the water within them is too saline for potable use. Until the CFPUA groundwater nanofiltration plant was brought on line in 2009, the homeowners and industries located in northern New Hanover County relied on shallow domestic wells to supply potable water.

The quality of drinking water within the surficial, Castle Hayne, and Peedee aquifers in the study area is acceptable for general use but can be aesthetically problematic (taste, odor, and color problems). Groundwater withdrawn from the surficial and Castle Hayne aquifers may contain high concentrations of dissolved iron at levels that often exceed the U.S. Environmental Protection Agency Secondary Drinking Water Standard of 0.3 milligram per liter (mg/L) (Gary McSmith, CFPUA, written commun., September 2010). Groundwater withdrawn from the Peedee aquifer may also contain elevated concentrations (greater than 0.5 mg/L) of dissolved hydrogen sulfide as well as dissolved iron, but the concentrations of dissolved iron generally are lower than those found in groundwater withdrawn from the Castle Hayne aquifer (Gary McSmith, CFPUA, written commun., September 2010). In 2009, CFPUA's groundwater nanofiltration plant made it possible for high-quality drinking water to be distributed to the most populated areas of northern New Hanover County.

Methods of Investigation

During the construction of the nanofiltration groundwater processing plant, 25 public-supply production wells were installed between December 2004 and September 2008 to supply the plant (fig. 2A). Ten of these production wells were completed in the Castle Hayne aquifer at depths of 80 to 115 ft below land surface (bls). Fifteen additional production wells were completed in the Peedee aquifer at depths of 165 to 175 ft bls. Upon completion of each production well, a constant-rate, single-well aquifer pump test was conducted.

Aquifer tests were conducted on each production well by one of the following well installation companies: Skipper's Well Drilling and Pump Service, Cayton's Well Drilling and Pump Service, or A.C. Schultes of Carolina. Each of the Castle Hayne aquifer wells was tested by pumping for 24 hours at a constant rate that ranged from 200 to 640 gallons per minute (gal/min). Fourteen of the Peedee aquifer wells were tested by pumping for 24 hours, and one well was pumped for 12 hours at a constant rate that ranged from 500 to 1,020 gal/min. Two aquifer tests were conducted on one of the Peedee aquifer wells, with constant pumping rates of 500 and 750 gal/min, respectively, used during the tests.

Water-level data were collected by the well driller during each aquifer test. Water-level measurements were made using a pressure transducer that was placed inside the pumped well. These measurements were recorded by electronic data logger throughout the duration of each test. After pumping was terminated, data collection continued until water levels in the well were 90–95 percent recovered. Data collection during recovery generally continued at least 6 hours after pumping was terminated. During each aquifer test, water-level measurements were recorded every minute for the entire duration of the test or every minute beginning at the start of pumping and gradually decreasing the frequency of measurement until pumping was terminated.

From January to July 2008, a period that included several of the aquifer tests, ambient water-level monitoring was conducted at two observation wells completed in the Castle Hayne aquifer and four observation wells completed in the Peedee aquifer. However, no drawdown in the observation wells was measurable in response to the aquifer testing because the wells selected for ambient monitoring were located too far away from the production wells tested during that time period.

All hydrologic data collected during each aquifer test, including water-level measurements and pumping rates, were provided to the USGS by CFPUA. The water-level data collected during the drawdown and recovery periods were quality assured for consistent pumping rates and analyzed with Aqtesolv Pro computer software using the Cooper-Jacob (Cooper and Jacob, 1946) and Theis Recovery (Theis, 1935) solutions. The Cooper-Jacob (Cooper and Jacob, 1946) and Theis Recovery (Theis, 1935) solutions are based on the following assumptions: (1) the aquifer has infinite areal extent, (2) the aquifer is homogenous, isotropic, and has uniform thickness, (3) the aquifer is confined, (4) the flow to the pumped well is horizontal, (5) the flow is unsteady, (6) the pumped well is fully penetrating, (7) water is released instantaneously from storage with decline of hydraulic head, and (8) the diameter of the pumped well is very small, allowing for storage inside the pumped well to be neglected. One or more of these assumptions likely were not met at each of the sites tested during this investigation. A lack of available observation well data prevented the calculation of storage coefficients for each aquifer.

Transmissivity values calculated for the 25 production wells were compared to transmissivity values reported in published literature and the USGS National Water Information System (NWIS) (*http://waterdata.usgs.gov/nwis*) for other existing domestic, public-supply, industrial, and irrigation wells located in northern New Hanover County. In addition, well yield data reported for the 25 production wells and other existing wells in the study area were obtained from published literature, the USGS NWIS, and the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality (DWQ).

Records containing reported well yields and other well information were obtained from the Raleigh and Wilmington Regional Offices of the NCDENR DWQ. Well drillers are required to provide DWQ with "GW-1" forms to document well construction for each well drilled in North Carolina. The GW-1 form documents owner information, date drilled, well depth, casing depth, screened or open interval, well yield, and general location of the well. Electronic spreadsheets containing the well data from GW-1 forms submitted to DWQ for wells drilled in New Hanover County from 1991 to 2010 were obtained (Richard Bolich, NCDENR, DWQ, written commun., November 2010). Only GW-1 forms that fully documented well depth, casing depth, well yield, and location data were used in this study. Wells with yields of 5 gal/min or less were excluded from consideration to prevent the comparison of the production wells to wells that were designed and constructed for monitoring purposes only.

Hydrogeologic Properties

The transmissivity (T) of an aquifer is a measure of its ability to transmit water over its entire saturated thickness. The higher the transmissivity, the more productive the aquifer and the less drawdown is produced in a well during pumping. Similarly, well yield is a measure of the quantity of water that can be pumped continuously from a well and delivered per unit of time (usually minutes). The magnitude of both transmissivity and well yield are dependent on the characteristics of the geologic formation or aquifer storing the groundwater. From June to October 2010, transmissivity values for 69 wells and the reported yield for 235 wells in northern New Hanover County were obtained and evaluated for this study.

Transmissivity

Transmissivity values for 69 wells in northern New Hanover County are listed by each aquifer (or combination of aquifers) and selected range of transmissivity in table 1 and displayed graphically in figure 4. Wells completed solely in the surficial, Castle Hayne, or Peedee aquifers make up about 90 percent of the wells used in this study; the remaining 10 percent were completed in two aquifers. Transmissivity values calculated from wells completed in more than one aquifer likely reflect the combined properties of both aquifers and may not reflect the true transmissivity of only one aquifer. Because these composite wells represent only a small percentage of the total number of wells used in this study, they are not discussed in detail; however, basic statistics are provided for reference (table 1).

Previously published transmissivity data are available for seven wells completed in the surficial aquifer in northern New Hanover County (Bain, 1970). The reported transmissivity values for these seven wells ranged from about 400 to 12,700 feet squared per day (ft^2/d), with a mean of about 5,800 ft^2/d (table 1). The highest transmissivity was reported for a well that was likely completed in highly permeable sand in the western part of the study area near the Cape Fear River. Published transmissivity values were not available for wells that were completed in the surficial aquifer near the area of the Bayshore and Murraysville CDPs (fig. 4).

Limited transmissivity values were available for the Castle Hayne aquifer in northern New Hanover County. This lack of information may be because the aquifer only exists in the eastern part of the study area. In addition to the transmissivity values that were calculated for the 10 CFPUA Castle Hayne production wells, only two previously published transmissivity values were available for use in this study (Bain, 1970). Eleven of the 12 Castle Hayne wells used in this study were located in the area of the Bayshore, Murraysville, and Porters Neck CDPs (fig. 5).

Historical and recent transmissivity values determined for the Castle Hayne aquifer ranged from 1,400 to 18,700 ft^2/d with a mean of 5,600 ft^2/d (table 1). This mean likely is skewed high because the transmissivity value calculated for 11 of the 12 wells used in this study was less than 7,500 ft^2/d. The transmissivity values calculated for the 10 Castle Hayne production wells ranged from about 3,300 to 6,100 ft^2/d with a mean of about 4,700 ft^2/d. The highest transmissivity determined for the Castle Hayne aquifer was from a 6-inch-diameter private irrigation well located in Porters Neck CDP (Bain, 1970).

The majority of wells located in the study area with transmissivity values available for use in this study were completed in the Peedee aquifer. Twenty-eight of the 43 Peedee aquifer wells had previously published transmissivity values available for analysis (Bain, 1970; Lautier, 1998). The remaining 15 Peedee aquifer wells were the CFPUA production wells. Across northern New Hanover County, the transmissivity values reported for wells completed in the Peedee aquifer ranged from 530 to 18,600 ft^2/d with a mean of 5,000 ft^2/d (table 1). Transmissivity values calculated for the 15 Peedee production wells in the area of the Bayshore and Murraysville CDPs ranged from about 2,700 to 10,100 ft^2/d with a mean of about 5,900 ft^2/d (fig. 6).

Mean transmissivity values were similar for wells completed in the Castle Hayne and Peedee aquifers. In general, calculated transmissivity values were greatest in wells located in a horizontal band between 34°16' N and 34°18' N (fig. 4). This trend seems to be pervasive through all three aquifers in the study area and may be caused by the localized deposition of more permeable sediments in the area. However, as the northern part of the study area is sparsely developed, it is possible that this trend may be due to the limited amount of data available in some areas.

Well Yield

The yields reported for 235 wells in northern New Hanover County, sorted by aquifer (or combination of aquifers) and selected range of yield, are given in table 1 and displayed graphically in figure 7. Wells completed solely in the surficial, Castle Hayne, or Peedee aquifers make up about 94 percent of the wells used in this study with the remainder of the wells completed in multiple aquifers. Well yields reported for wells completed in multiple aquifers likely reflect the combined properties of more than one aquifer and may not reflect the true yield of only one aquifer. Because these wells represent a small percentage of the wells used in this study, they are not discussed in detail; however, basic statistics are provided for reference (table 1).

Ten wells located in northern New Hanover County that were completed in the surficial aquifer had well yield information available for use in this study. The reported yield from these wells ranged from 6 to 100 gal/min with a mean yield of about 30 gal/min (table 1). One well located in the area of the Bayshore and Murraysville CDPs was completed within the surficial aquifer and had a reported yield of 30 gal/min (fig. 7).

Eighty-six wells located in northern New Hanover County were completed in the Castle Hayne aquifer and had reported well yield information available for this study (fig. 7). The yields reported for these wells ranged from 9 to 640 gal/min with a mean of 100 gal/min (table 1). Forty-one of the Castle Hayne wells were located in the area of the Bayshore and Murraysville CDPs (fig. 8). With the exception of the 10 production wells installed by the CFPUA, all of the Castle Hayne wells were private supply or irrigation wells with reported yields of less than 250 gal/min. In contrast, the well yields reported for the production wells ranged from about 200 to 640 gal/min with a mean of about 530 gal/min.

As with transmissivity, the majority of existing well yield information in the study area was available for wells completed in the Peedee aquifer. There were 125 wells located in northern New Hanover County that were completed in the Peedee aquifer and had reported well yield available for evaluation (fig. 7). The reported yields from these wells ranged from 8 to 1,000 gal/min with a mean of 160 gal/min (table 1). Twenty-six of the Peedee wells with reported yields were located in the area of the Bayshore and Murraysville CDPs (fig. 9). Nine of the Peedee wells were private supply or irrigation wells with reported yields of less than 100 gal/min. Two of the Peedee wells had reported yields of 250 and 350 gal/min. The yields reported for the 15 Peedee production wells ranged from about 500 to 1,000 gal/min with a mean of about 650 gal/min (fig. 9). Unlike the geographic pattern observed in transmissivity values, the distribution of high yielding wells appears to be random in the surficial, Castle Hayne, and Peedee aquifers.

Summary and Conclusions

The U.S. Geological Survey, in cooperation with the Cape Fear Public Utilities Authority, conducted a study to evaluate the distribution of transmissivity and yield of the surficial, Castle Hayne, and Peedee aquifers in the vicinity of northern New Hanover County, North Carolina. Information was obtained for wells located in the northern part of New Hanover County outside the city limits of Wilmington. Particular focus was placed on records for wells located around the Murraysville and Bayshore census designated places near a new 6-million-gallon-per-day nanofiltration groundwater processing plant that withdraws water from the Castle Hayne and Peedee aquifers. Transmissivity values and reported well yield values were compiled for wells located in northern New Hanover County. In addition to existing data, constant-rate, single-well aquifer test data were obtained and analyzed for 25 production wells that had been completed in the Castle Hayne or Peedee aquifer to supply the nanofiltration plant. Transmissivity values calculated for the production wells were graphically compared to previously published transmissivity values for wells located in northern New Hanover County. Well yields reported for existing wells in northern New Hanover County were graphically compared to well yields reported for the 25 production wells. Average calculated transmissivities are of a similar magnitude for wells completed in the surfical, Castle Hayne, and Peedee wells. Reported well yields in the surficial aquifer are lower than those reported for wells completed in the Castle Hayne and Peedee aquifers.

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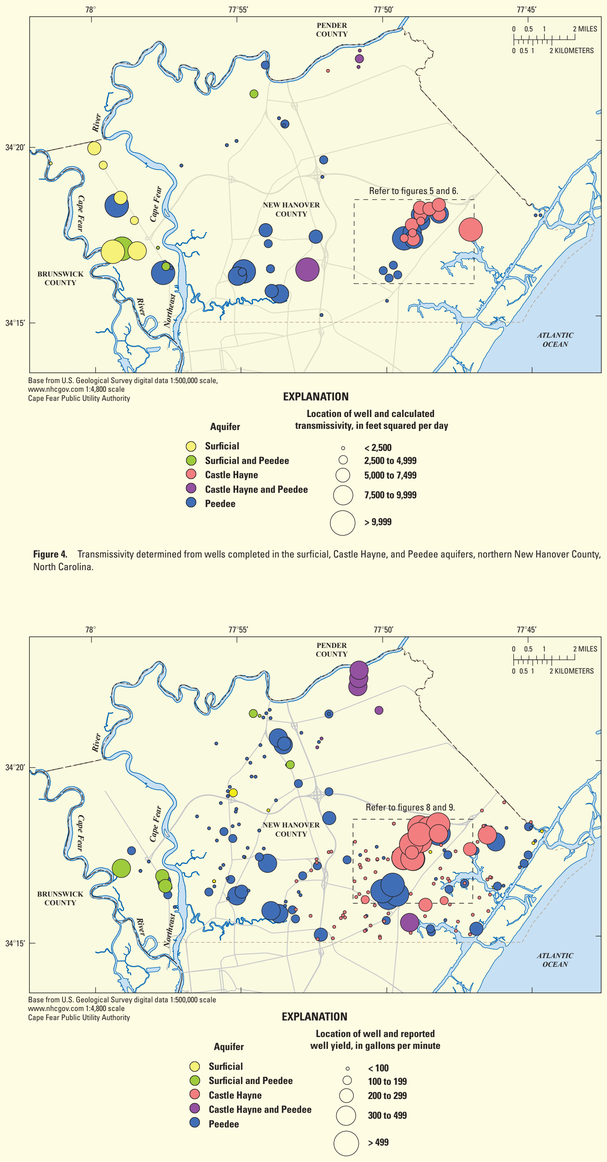

Figure 4. Transmissivity determined from wells completed in the surficial, Castle Hayne, and Peedee aquifers, northern New Hanover County, North Carolina.

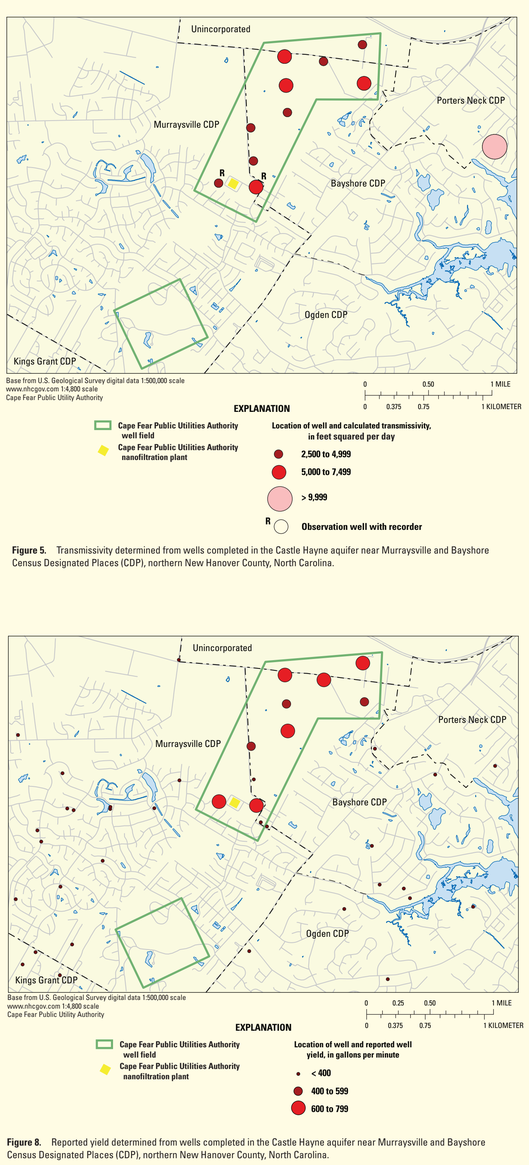

Figure 5. Transmissivity determined from wells completed in the Castle Hayne aquifer near Murraysville and Bayshore Census Designated Places (CDP), northern New Hanover County, North Carolina.

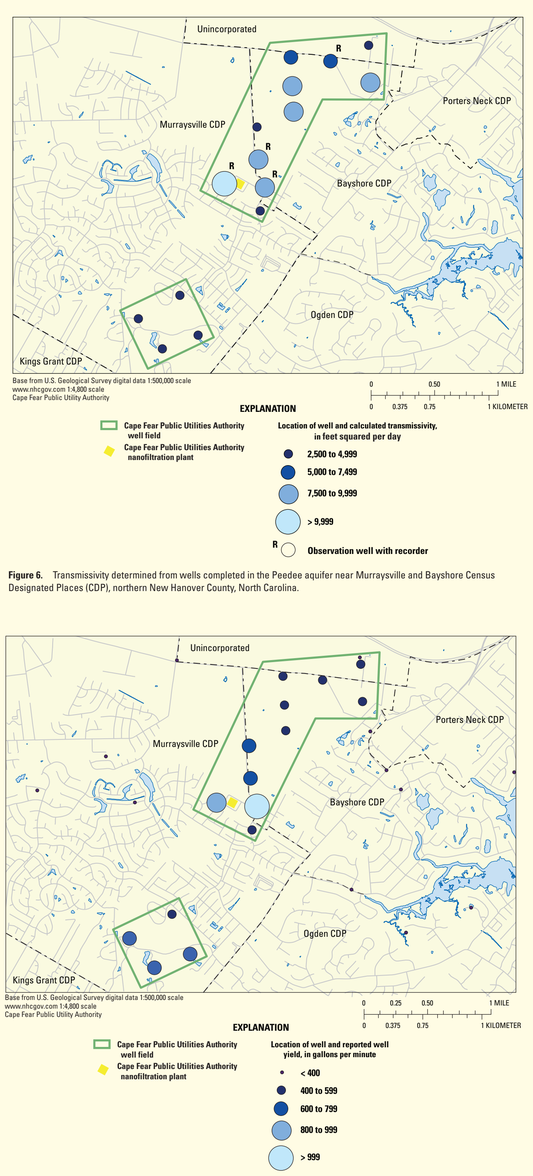

Figure 6. Transmissivity determined from wells completed in the Peedee aquifer near Murraysville and Bayshore Census Designated Places (CDP), northern New Hanover County, North Carolina.

Figure 7. Reported well yield determined from wells completed in the surficial, Castle Hayne, and Peedee aquifers, northern New Hanover County, North Carolina.

Figure 8. Reported yield determined from wells completed in the Castle Hayne aquifer near Murraysville and Bayshore Census Designated Places (CDP), northern New Hanover County, North Carolina.

Figure 9. Reported well yield determined from wells completed in the Peedee aquifer near Murraysville and Bayshore Census Designated Places (CDP), northern New Hanover County, North Carolina.

Table 1. Statistics and distribution of transmissivity and yield in wells completed in the surficial, Castle Hayne, and Peedee aquifers in northern New Hanover County, North Carolina.

Aquifer	Transmissivity in feet squared per day			Number of wells within ranges of calculated transmissivity, in feet squared per day					Total counts	Yield, in gallons per minute			Number of wells within ranges of reported yields, in gallons per minute					Total counts
	Low	High	Mean	<2,500	2,500 to 4,999	5,000 to 7,499	7,500 to 9,999	> 9,999		Low	High	Mean	<100	100 to 199	200 to 299	300 to 499	> 499	
Surficial	401	12,700	5,787	1	2	2	1	1	7	6	100	31	9	1	0	0	0	10
Surficial-Peedee	2,674	13,368	6,461	1	1	0	0	1	3	80	480	207	1	2	2	1	0	6
Castle Hayne	1,404	18,715	5,610	1	6	4	0	1	12	9	640	103	71	2	3	2	8	86
Castle Hayne-Peedee	1,337	13,368	4,679	2	1	0	0	1	4	30	400	205	3	1	0	4	0	8
Peedee	534	18,620	5,002	13	13	5	7	5	43	8	1,000	157	70	26	6	8	15	125
Total counts				18	23	11	8	9	69				154	32	11	15	23	235

Distribution of Transmissivity and Yield of the Surficial, Castle Hayne, and Peedee Aquifers in Northern New Hanover County, North Carolina

By
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