

State of North Carolina
Division of Water Resources

AQUIFER CHARACTERISTICS
AND DEVELOPMENT POTENTIAL
IN NORTHEASTERN NORTH CAROLINA

A General Groundwater Resource Evaluation

Raleigh, North Carolina
May, 1987

PREFACE

Groundwater is an important resource in northeastern North Carolina, as it is the principal source of potable water. Area citizens have expressed concern as to the ability of the resource to continue supporting development. Surface water development capability is limited throughout much of northeastern North Carolina and groundwater pumping in southeastern Virginia has had a measurable impact on water levels in the principal groundwater aquifer system which underlies the region. The purpose of this report is to describe the groundwater resource characteristics of northeastern North Carolina and to discuss the potential for development of groundwater supplies to support continued growth in the region.

This report is a preliminary investigation and should be viewed as such. The data used in compiling this report were insufficient to adequately identify all of the important aquifers, owing to sparse well coverage and well test data. Further research, including the use of computer modelling techniques, is merited.

CONTENTS

	<u>Page</u>
Summary-----	1
Location-----	2
Introduction-----	2
Aquifer Characteristics-----	5
Surficial Aquifer-----	10
Tertiary Aquifer System-----	14
Cretaceous Aquifer System-----	18
Groundwater Resources Development and Potential-----	20
Acknowledgements-----	26
References-----	27

ILLUSTRATIONS

<u>Figure</u>	<u>Page</u>
1. Study area-----	3
2. Principal use areas of the lower Cretaceous and Tertiary aquifers-----	9
3. Approximate areal extent of brackish groundwater in the confined aquifers of northeastern North Carolina-----	11
4. Yields of public water supply wells-----	12
5. Potentiometric surface of the lower unit of the Tertiary aquifer system, November, 1985-----	17
6. Potentiometric surface of the lower unit of the Cretaceous aquifer system, November, 1985-----	21
Table 1. Approximate correlation of geology with aquifer names used in this report-----	7
Plate 1. Hydrogeologic cross-section through northeastern North Carolina----- (inside back cover)	

SUMMARY

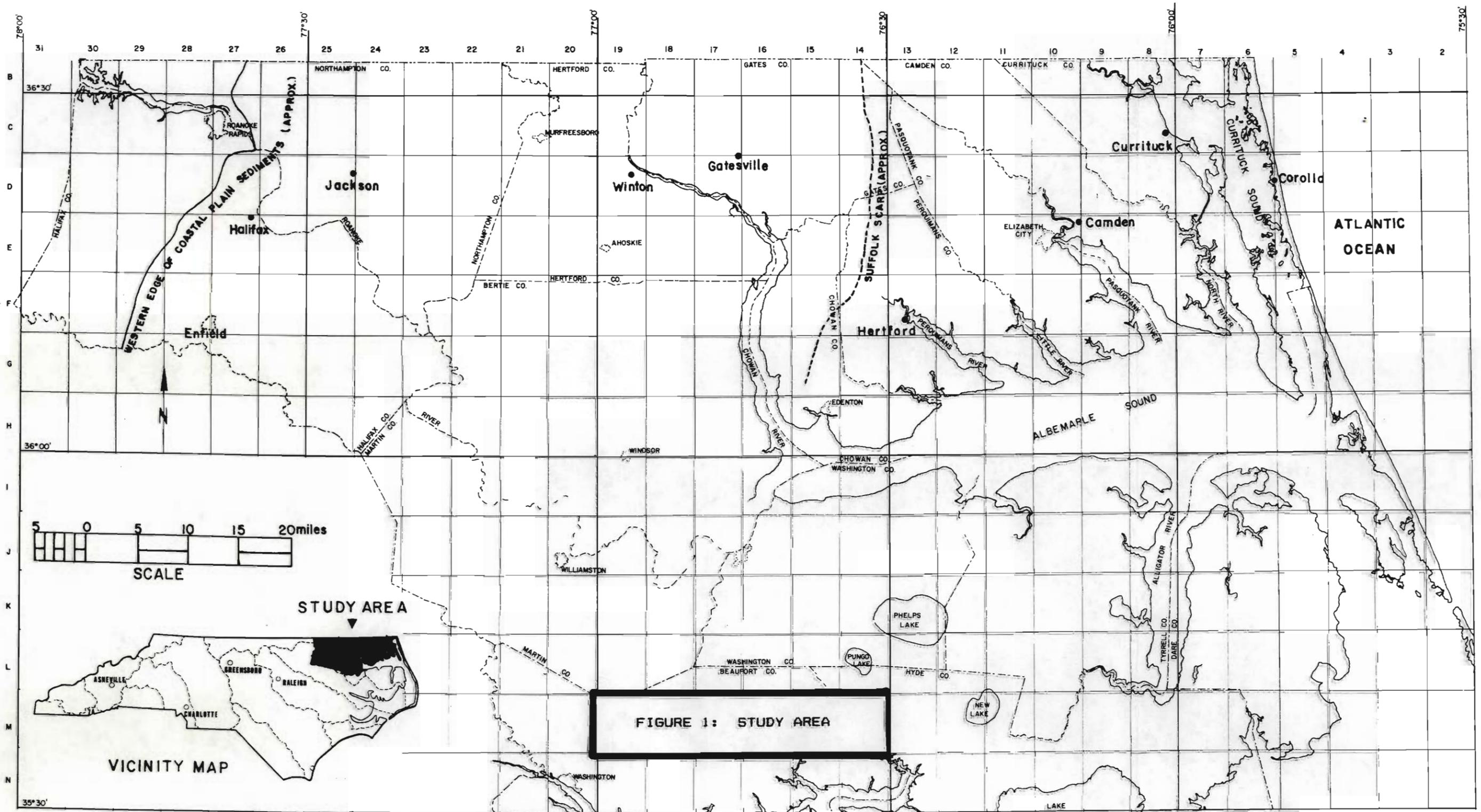
Three major aquifer systems serve as sources of water supply in northeastern North Carolina: the Surficial, Tertiary, and Cretaceous aquifer systems. The Cretaceous aquifer system is used to a greater extent in the region west of the Chowan River, while the other two systems are used more extensively east of the river. Groundwater use from the Surficial Aquifer and the Tertiary aquifer system can be expanded without any adverse impact except in localized areas where overpumping or saltwater incursion could occur. Groundwater use from the Cretaceous aquifer system is more critical owing to possible storage depletion from overpumping. The storage depletion rate for the Cretaceous aquifer system can be reduced through cautious management of pumping rates and well distribution. Computer models are needed to guide water supply management strategies for all of the aquifer systems in northeastern North Carolina.

LOCATION

The northeastern North Carolina region, as defined in this report, extends eastward from from the fall line to the Atlantic Ocean, and northward from the Roanoke River to the North Carolina-Virginia state line, including the eastern three fourths of Halifax County (Figure 1). Counties in the region and their 1980 census populations include: Bertie (21,024), Camden (5,829), Chowan (12,558), Currituck (11,089), Gates (8,875), Halifax (55,076), Hertford (23,368), Northampton (22,584), Pasquotank (28,462), and Perquimans (9,486) counties. The region is approximately 3,500 square miles in area. Major rivers and estuaries include the Albemarle Sound, the Chowan River, the Currituck Sound, the Meherrin River, the Pasquotank River, and the Roanoke River.

INTRODUCTION

Groundwater is the principal source of potable water supply in the coastal plain of northeastern North Carolina. Groundwater in this region is relatively economical to develop, is available in reasonable quantities, and has adequate quality for irrigation, livestock watering, and domestic uses. All municipalities in the region use groundwater as their sole potable water supply source, except Elizabeth City. Elizabeth City maintains a groundwater supply as a backup to their recently developed surface supply source. The most water-intensive industries in northeastern



North Carolina are located along major streams and use surface water. Agricultural irrigation in the region uses surface water where croplands are adjacent to streams, but high capacity wells also have been developed for agricultural use in Bertie and Northampton counties. As of June, 1984, rates of groundwater use in northeast North Carolina were 6.2 MGD for municipal supplies, 3.0 MGD for industrial supplies, and 3.1 MGD for agricultural uses (Division of Water Resources open files).

Though groundwater is available throughout the northeastern North Carolina region, there is considerable variability in the quantity and quality available. The most common undesirable groundwater quality constituents include high iron and/or sulfide concentrations and low pH (acidic) water. High chloride concentrations are also common in areas near estuaries and coastline, and are present in the deeper aquifers of the eastern part of the region.

The aquifers of the study area are confined in sand units by overlying clays and shales. Some of the sands were deposited in bars and channels of ancient river deltas. These deltaic sands are commonly lens-shaped and, in some instances, up to 100 feet in thickness. Where intervening shales and clays are thin, bundles of overlapping sand lenses effectively behave as a single aquifer unit. Where shale and clay interbeds thin between aquifer units, the units behave as a single aquifer system. Other aquifer-bearing sands of the study area were deposited on beaches and in shoals of an

ancient shallow sea. These marine sands commonly are laterally more pervasive than the underlying deltaic sands. Thicknesses range up to 200 feet for the marine sands. The sparseness of control well locations in the study area makes lateral correlation of the different types of sand units uncertain in most instances.

In approximately the central third of the region, the principal groundwater aquifers are thick and relatively deeply buried. These aquifers produce large quantities of good quality groundwater with low mineral content. In both the western and eastern thirds of the region, the principal aquifers are thinner and closer to the surface, and potable water is commonly highly mineralized and lower in overall quality and quantity than the groundwater in the central third. The thickness of the groundwater system in Halifax and Northampton counties is limited by the depth to bedrock. East of Gates County, freshwater aquifer thickness is limited by the depth to brackish water.

AQUIFER CHARACTERISTICS

Northeastern North Carolina is part of the lower Roanoke and Chowan River basins, which are located within the Coastal Plain physiographic region of North Carolina. The subsurface in this region is characterized by interlayered sediments, consisting principally of unconsolidated gravel, sand, silt, and clay. Limestone and marl are found in the subsurface formations near the coast. The Coastal Plain

sediments are deposited upon an eroded consolidated rock surface similar in composition and origin to the rocks that are found at the surface in the North Carolina Piedmont region. The bedrock surface slopes from the Coastal Plain-Piedmont boundary (fall line) toward the coast at approximately 14 feet per mile (0.150 slope). The overlying Coastal Plain sediments are thin and irregular adjacent to the Piedmont, but sediment thickness increases from west to east. A sediment thickness of more than 4,500 feet has been recorded in Currituck County (Plate 1). The cross section of Plate 1 is based upon test hole data from a USGS report on coastal plain geology (Brown, et al., 1972) and from an additional test hole (Morgans Corner C-12) from a DEM report (Peek, 1977).

The groundwater system in northeastern North Carolina is divided, for this report, into three major systems that reflect differences in hydrogeologic characteristics and ground-water use. The interbedded aquifers and aquitards in each system have common hydrologic and geologic characteristics. The characteristics used to distinguish aquifer systems include: relative geologic position and composition, nature and degree of confinement, flow characteristics, yield, and water quality. The approximate correlation between aquifer system names used in this report and common North Carolina Coastal Plain geologic terminology is shown in Table 1.

The three principal aquifer systems, distinguished

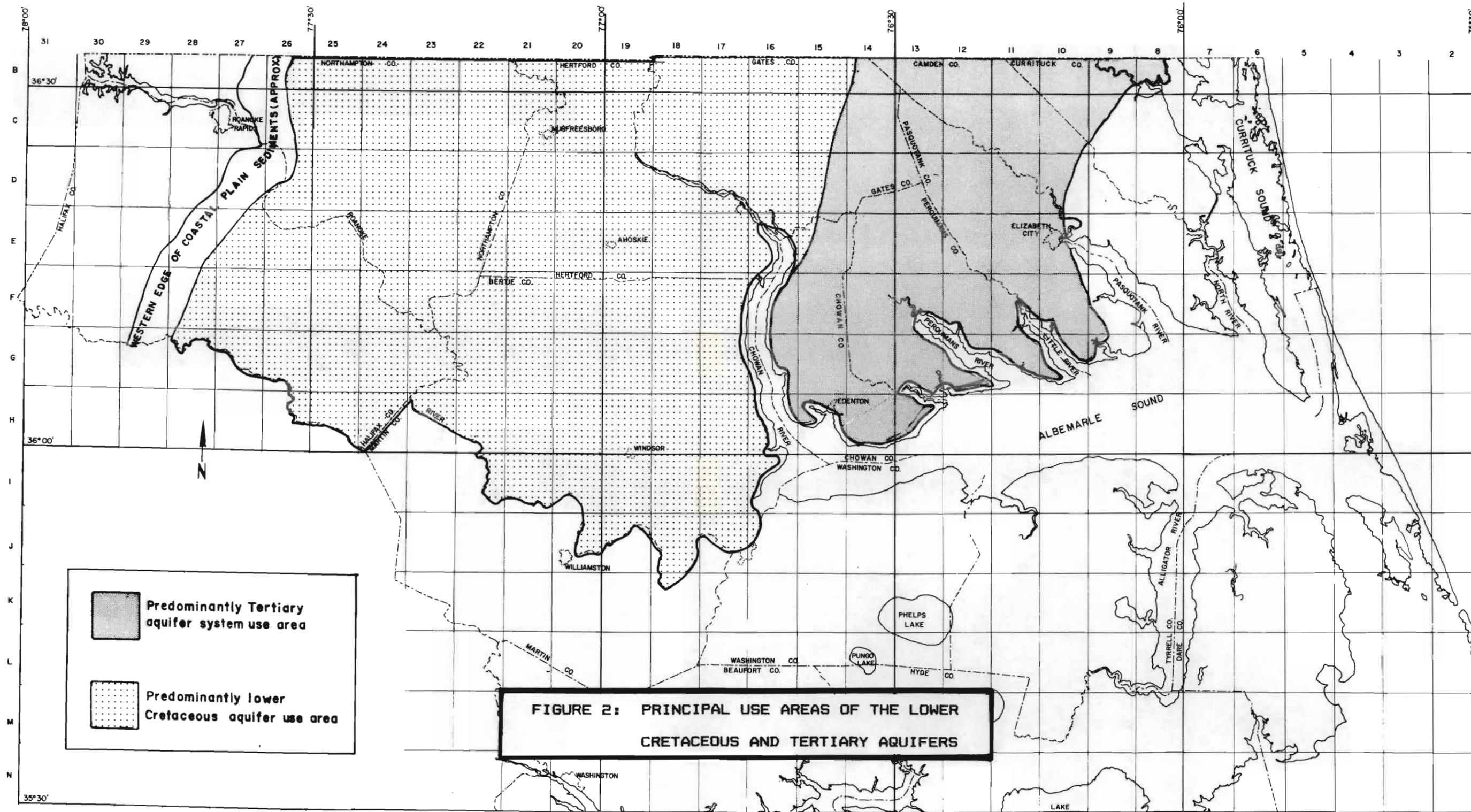
TABLE 1. APPROXIMATE CORRELATION OF GEOLOGY WITH AQUIFER NAMES
USED IN THIS REPORT

GEOLOGIC AGE	GEOLOGIC FORMATION	AQUIFER NAME USED IN THIS REPORT	NORTH CAROLINA USGS RASA AQUIFER DESIGNATIONS
Quaternary	Undifferentiated	Surficial Aquifer	Surficial Aquifer
Pliocene	Yorktown	Tertiary aquifer system	Yorktown aquifer
Miocene			
Eocene	Castle Hayne		Castle Hayne aquifer
Paleocene	Beaufort		Beaufort aquifer
Cretaceous	Peedee	upper Cretaceous aquifer unit	Peedee aquifer
	Black Creek		Black Creek aquifer
	Cape Fear	lower Cretaceous aquifer unit	upper Cape Fear aquifer
			lower Cape Fear aquifer
	Lower Cretaceous Undifferentiated		Lower Cretaceous aquifer

by the above criteria, for northeastern North Carolina are the Surficial, Tertiary, and Cretaceous aquifer systems. The system of aquifers nearest the land surface is classified as the Surficial Aquifer. The Surficial Aquifer is separated from the deeper aquifers by a relatively thick confining bed that restricts the downward flow of water. The deeper lying confined aquifers include the Tertiary aquifer system and the Cretaceous aquifer system. "Tertiary" and "Cretaceous" refer to the periods in geologic time in which the sediments encompassed by these aquifer systems were deposited. The Cretaceous aquifer is the principal aquifer in the western part of the study area, while the Tertiary aquifer is the principal aquifer through much of the area east of the Chowan River. The Cretaceous aquifer is confined in sands of deltaic origin, whereas the Tertiary aquifer is confined in sands of shallow marine origin. Figure 2 shows the location of the principal confined aquifer systems.

The aquifer systems are composed of permeable sediments, including gravel, sand, and limestone. Interlayered with the permeable sediments are silt and clay sediments of low permeability aquitards which restrict the movement of groundwater. The amount of water that can be potentially withdrawn from an aquifer is dependent upon the thickness of the aquifer, the permeability of the sediments, the amount of aquifer recharge, and the number of wells and quantity of discharges from the aquifer.

Where the coastal plain sediments are thin, that is,



Predominantly Tertiary aquifer system use area
 Predominantly lower Cretaceous aquifer use area

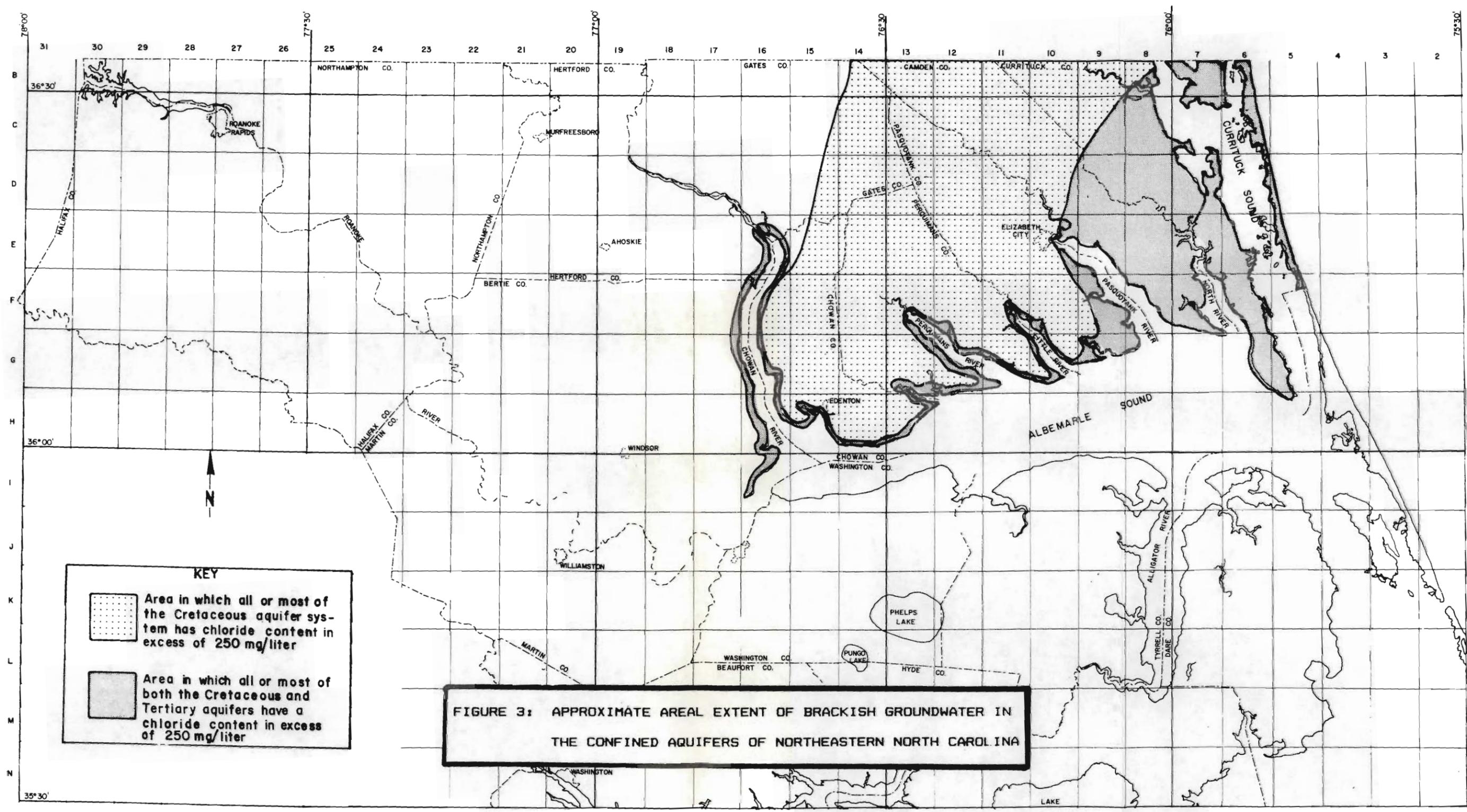
FIGURE 2: PRINCIPAL USE AREAS OF THE LOWER CRETACEOUS AND TERTIARY AQUIFERS

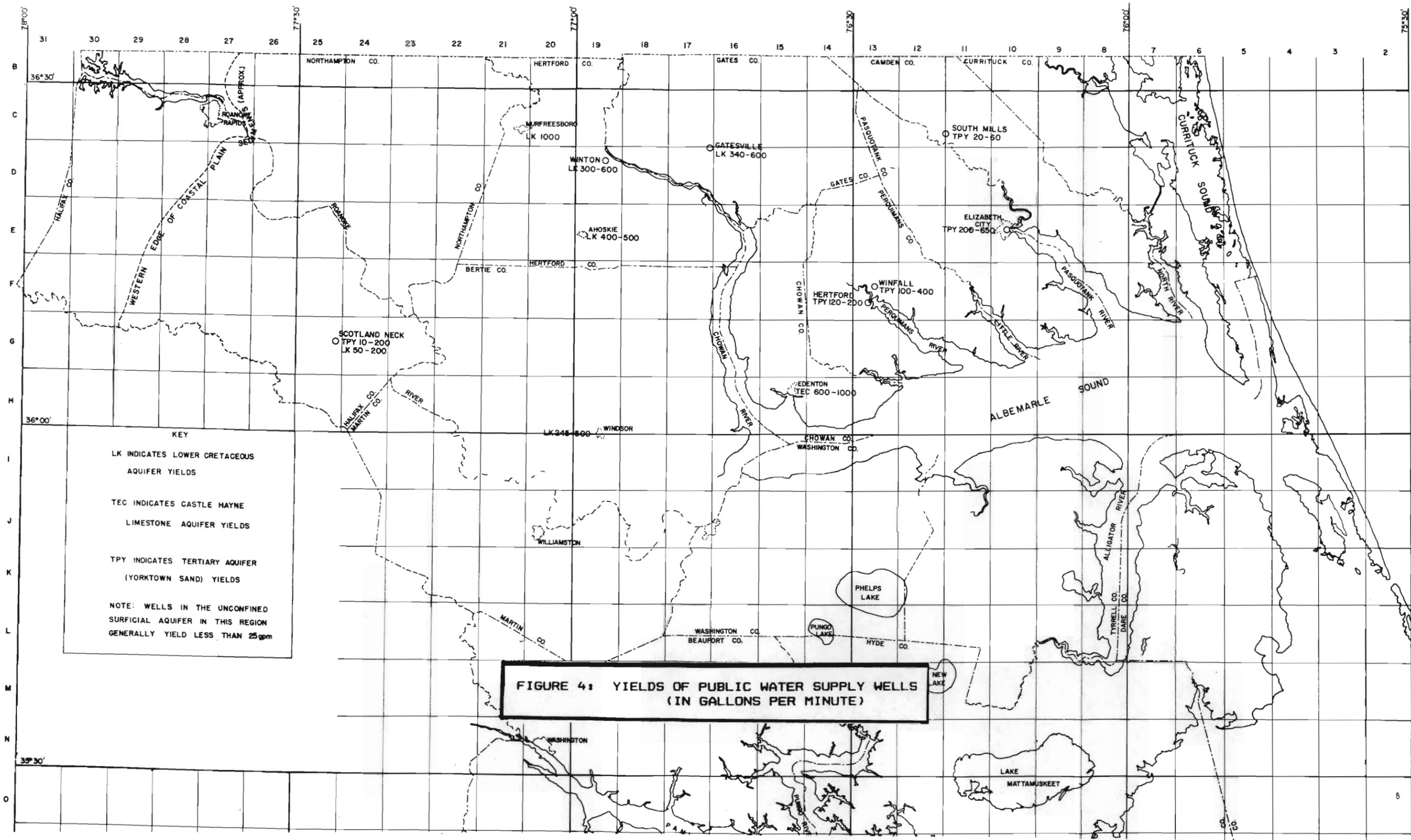
adjacent to the Piedmont, the aquifer systems also are thin and the potential for groundwater development is low. Along the estuaries and near the coast, the permeable sediments are thick, but fresh groundwater development is limited by the degree of brackish water intrusion. The approximate depth to bedrock in the coastal plain area is shown in Plate 1 and the approximate extent of brackish groundwater in the confined aquifers of the northeastern region is shown in Figure 3 (data from N.C. Water Resources Framework Study, 1977). The yields of some public water supply wells throughout the region are shown in Figure 4 (data from N.C. Division of Water Resources open files and Robison, 1977).

Surficial Aquifer

The Surficial Aquifer is generally ubiquitous across northeastern North Carolina. This aquifer is unconfined and exists in those permeable sediments from the water table down to the first thick impermeable silt or clay beds. The Surficial Aquifer may be present in sediments belonging to a number of geologic formations, but it is commonly restricted to relatively recent (i.e. Quaternary in age) sediments.

Precipitation in northeastern North Carolina ranges from 44 to 56 inches per year (Wilder, 1978). Recharge to the Surficial Aquifer is estimated to average about 10 inches per year (Peek, 1977) and is equivalent to approximately 170 million gallons per day (MGD) per square mile. Part of the total water table recharge percolates through the confining





beds underlying the Surficial Aquifer to reach the confined aquifers of the Tertiary and Cretaceous systems below. The remainder is lost through evapotranspiration, discharge to streams, or withdrawal for consumption.

Ranging in thickness from a few feet to more than 100 feet, the Surficial Aquifer is generally less than 50 feet thick. The aquifer is commonly thinnest in the western areas of Halifax and Northampton counties. Available data does not exhibit any thickening of the Surficial Aquifer system from west to east. Depth to water varies seasonally in the Surficial Aquifer and ranges from 0 to 15 feet below land surface. Small diameter wells tapping the Surficial Aquifer yield less than 25 gallons per minute (gpm).

Groundwater quality within the Surficial Aquifer is characterized by low dissolved solids and somewhat acidic water. This relatively good quality groundwater is available in small quantities throughout much of the area and is suited for most domestic uses. It is not usually possible to predict the exact location and extent of undesirable groundwater quality constituents without a test drilling program. Iron concentrations may exceed recommended drinking water standards in water from the Surficial Aquifer throughout the region. Shallow groundwater may also be noticeably colored. The Surficial Aquifer serves a critical function as the conduit by which the underlying confined aquifers are recharged. In parts of Camden, Currituck, and Pasquotank counties, the Surficial Aquifer is the sole source

of available water supply, because the deeper, confined aquifers are brackish. The Surficial Aquifer is the primary source of water supply in areas adjacent to brackish water estuaries and sounds and also on the barrier islands along the coast. It also plays an important role in checking the incursion of brackish groundwater in these areas.

Tertiary Aquifer System

Sediments of Tertiary age are found in the subsurface throughout Northeastern North Carolina; however, the associated aquifer system is not an important water source in Halifax and Northampton counties because of the higher groundwater yields available from the underlying Cretaceous aquifer system and the unconfined nature of the Tertiary aquifer at some localities. The Tertiary aquifer system encompasses groundwater in a number of geologic formations of Tertiary age, including the Yorktown, Castle Hayne, and Beaufort formations.

The Yorktown Formation immediately underlies the Quaternary sediments throughout the region and contains two major sand units. The top of the upper sand unit delineates the top of the Tertiary aquifer system from southeastern Gates County (in the vicinity of the Suffolk Scarp, see Figure 1) eastward to the coast of Currituck County. West of southeastern Gates County, the upper sand of the Yorktown Formation is no longer overlain by a confining unit in most areas and merges with the Quaternary sands bearing the

Surficial Aquifer. The top of the Tertiary aquifer system effectively drops to the top of the lower sand unit of the Yorktown Formation westward of southeastern Gates County. The Castle Hayne and Beaufort formations contain limestones important as the "limestone aquifer" south of the Albemarle Sound. In northeastern North Carolina, however, groundwater in the Castle Hayne and Beaufort formations is only significant as a water supply source in southern Chowan County in the vicinity of Edenton. The limestone aquifer disappears in the subsurface north and west of this area and contains brackish groundwater to the east.

The confining beds overlying the Tertiary aquifer restrict the amount of recharge from the Surficial Aquifer. The amount of recharge varies from area to area and depends on the difference in groundwater levels between the two aquifers and the thickness of the confining beds. Wilder (1978) estimates the recharge rate to the Tertiary aquifer at 500,000 gpd per sq. mi. The Surficial Aquifer recharges the Tertiary aquifer throughout northeastern North Carolina except in southwestern Pasquotank County where the Tertiary aquifer discharges upward to the Surficial Aquifer at a rate of approximately 5 MGD (Cheek, 1982).

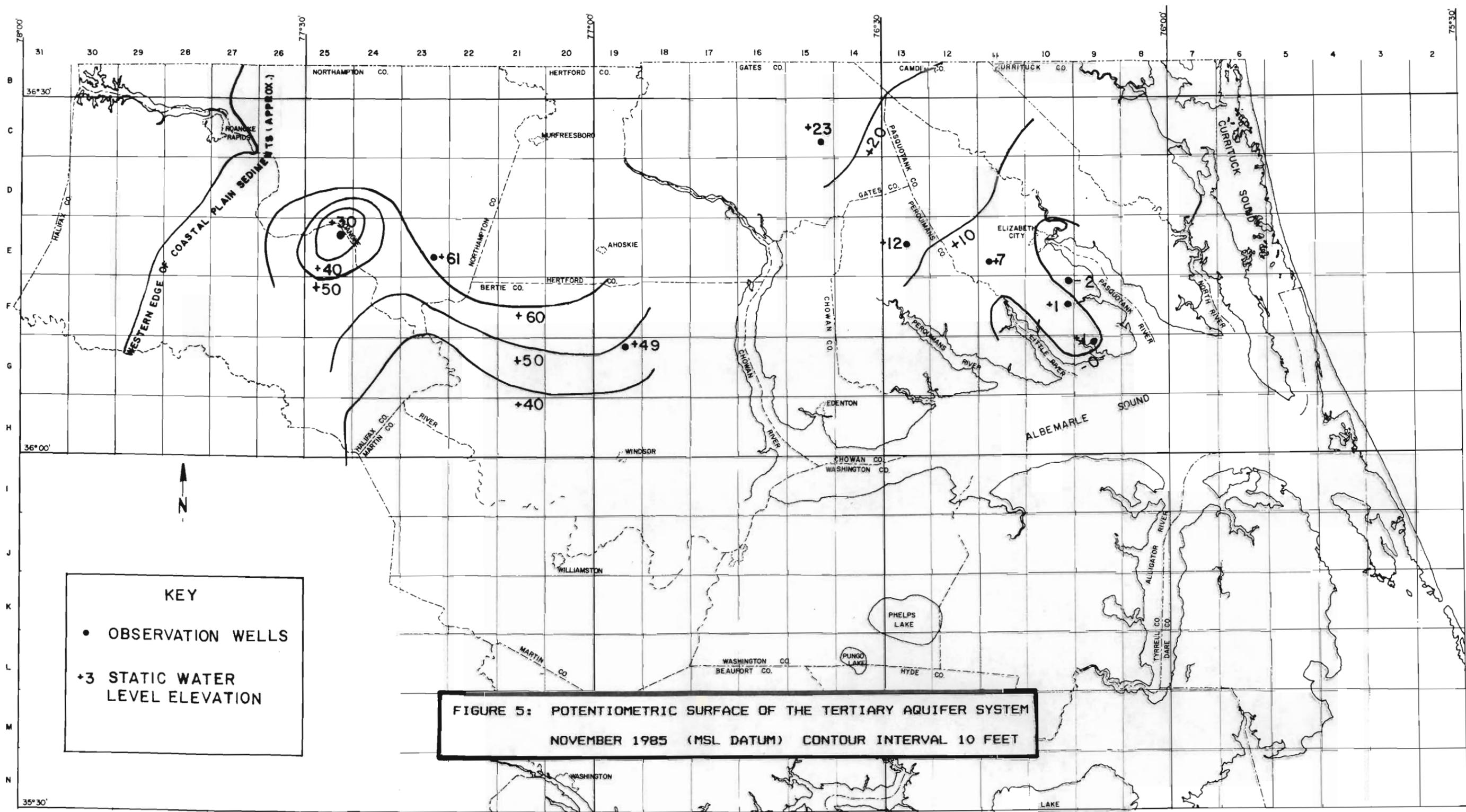
The confined portion of the Tertiary aquifer system ranges in thickness from 25 feet in western Hertford County to just under 550 feet near Morgans Corner in Pasquotank County (Plate 1). Although the Tertiary sediments continue to thicken along a traverse east from Pasquotank County, the

effective thickness of the aquifer decreases in that direction as the result of brackish groundwater intrusion. The individual aquifer units within the Tertiary aquifer system vary in thickness from 10 feet or less in the western sector to as much as 200 feet thick in Pasquotank County.

In November, 1985, the elevation of the potentiometric surface of the Tertiary aquifer system ranged from greater than 60 feet above sea level in parts of Northampton and Halifax counties to less than 10 feet above sea level in areas east of the Chowan River (Figure 5, data from DEM open files). The "potentiometric surface" is a map of the elevation of water levels in wells tapping an aquifer. This map indicates the water pressure (or head) in the Tertiary aquifer at various locations throughout the study area. Areas with high potentiometric elevations indicate areas of high water pressure in the Tertiary Aquifer, and vice versa for areas of low potentiometric elevation. Groundwater flows from areas of high potentiometric elevation to low potentiometric elevations.

It is important to note that the potentiometric surface to the east of the Chowan River is distinct from the surface west of the Chowan. Continuity does not exist between the potentiometric surfaces in the two areas, because the top of the aquifer system is defined by the upper Yorktown sand east of the Chowan and by the lower Yorktown sand west of the Chowan (i.e. the aquifer surface changes).

In the western counties where the Tertiary aquifer



KEY

- OBSERVATION WELLS
- +3 STATIC WATER LEVEL ELEVATION

**FIGURE 5: POTENTIOMETRIC SURFACE OF THE TERTIARY AQUIFER SYSTEM
NOVEMBER 1985 (MSL DATUM) CONTOUR INTERVAL 10 FEET**

is thin or the aquifer is unconfined and merges with the Surficial Aquifer, small diameter wells typically yield from 5 to 15 gpm. In the central and eastern portions of the study area, where the Tertiary aquifer system is thicker, small diameter wells may range in yield from 200 to 500 gpm.

Water quality in the Tertiary aquifer system is generally good. Some groundwater with high iron concentration is occasionally encountered, and in the eastern part of the study area, hard water is common. The Tertiary aquifer system is the principal source of water supply in those counties east of the Chowan River, because with the exception of Gates County, groundwater of the Cretaceous aquifer system contains more than 250 mg/l of chlorides. In Gates, Hertford, and Bertie Counties the Tertiary aquifer system is the principal source of potable water supply for most domestic and small municipal users because it is economical to develop and has good quality.

Cretaceous Aquifer System

The Cretaceous aquifer system is located below the Tertiary aquifer system throughout northeastern North Carolina. This lowermost freshwater aquifer system is named for the period of geologic time when the sediments, in which it is confined, were deposited. In this report, the Cretaceous aquifer system is divided into upper and lower aquifer units on basis of lithology, flow characteristics, yields, and water quality. The upper and lower units are

separated by a substantial confining bed.

The upper Cretaceous aquifer unit is confined in sands of the Peedee and Black Creek formations. The Peedee Formation is restricted to the southeastern portion of the northeastern North Carolina area, and the Black Creek Formation is found throughout the area. The upper aquifer unit is recharged from the overlying Tertiary aquifer system, through the confining silts and clays which intervene. The confining beds are generally sufficiently permeable to allow relatively rapid recharge to the upper Cretaceous aquifer unit. The upper Cretaceous aquifer unit thickens toward the east from about 10 feet at NOR-T-12 in Northampton County to approximately 150 feet in southeastern Gates County (Plate 1). East of Gates County, brackish groundwater permeates the entire upper Cretaceous aquifer unit.

The lower unit of the Cretaceous aquifer system is confined in sands of the Cape Fear Formation. A significant confining bed lies between the upper and lower Cretaceous aquifer units. This confining bed contains nearly impermeable silt and clay sediments that severely restrict downward recharge to the lower Cretaceous aquifer unit. Wilder (1978) estimates the recharge rate to the lower Cretaceous aquifer at 50,000 gpd per sq. mi. As the lower aquifer unit is highly confined and poorly recharged, most water withdrawn from this aquifer unit is taken from storage.

The lower Cretaceous aquifer unit thickens in an eastward direction from 40 feet at NOR-T-12 in Northampton

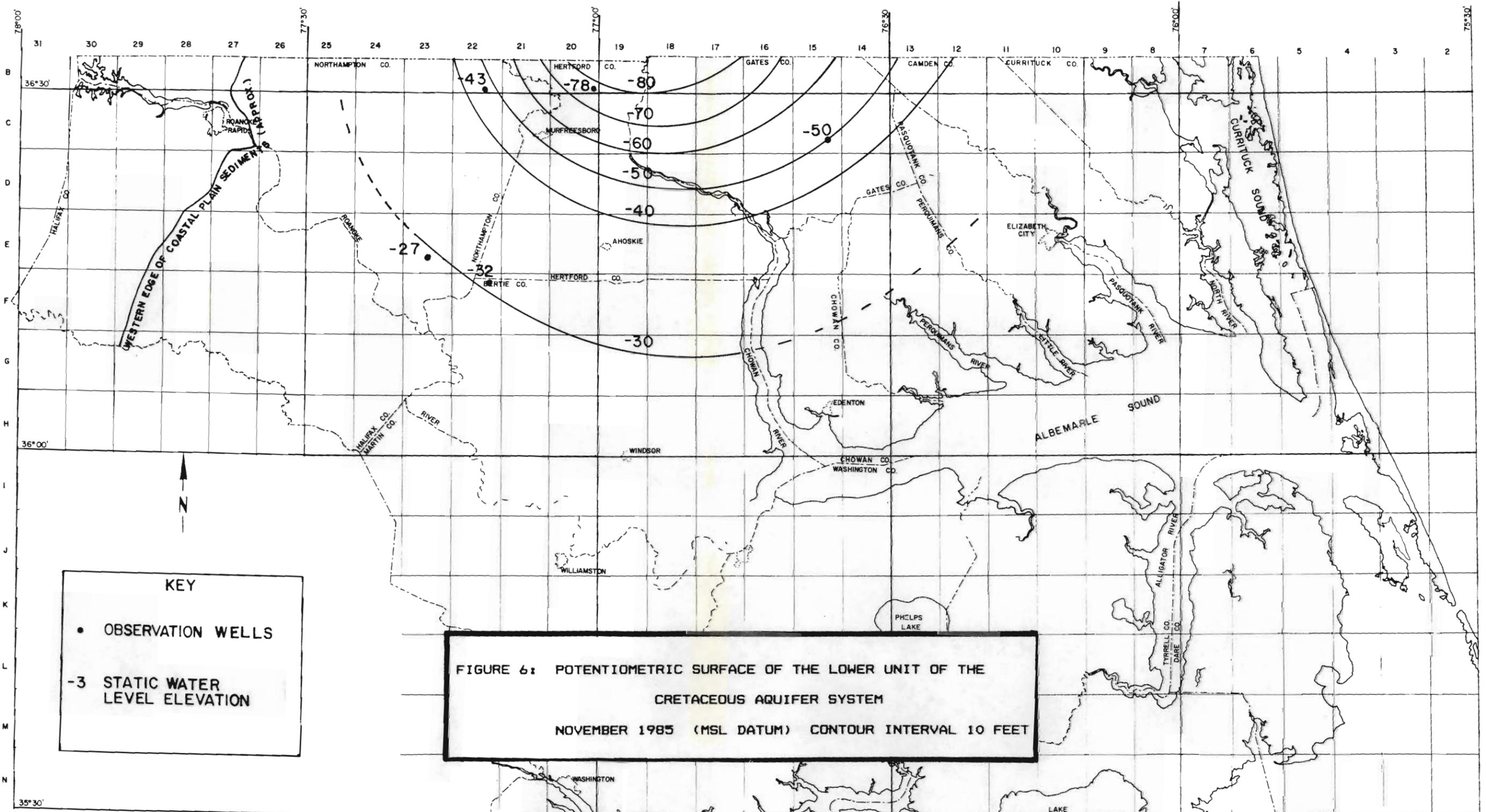
County to approximately 175 feet in southeastern Gates County (Plate 1). Further east, though its thickness continues to increase, the lower Cretaceous unit is unusable as a result of its brackish water content. The lower Cretaceous aquifer unit is the more important of the two Cretaceous units, because it contains better quality groundwater and has higher yields throughout most of northeastern North Carolina. However, low recharge to the lower Cretaceous aquifer unit coupled with extensive pumping in the vicinity of Franklin, Virginia (north of the study area) has led to the formation of a large drawdown cone in the potentiometric surface of this aquifer (Figure 6, data from DEM open files).

Large diameter gravel packed wells with multiple screens in the lower Cretaceous aquifer unit yield from 50 gpm to 1000 gpm in northeastern North Carolina. Because of the high yields and high quality water, the lower Cretaceous aquifer unit is the aquifer of choice for the larger municipal, industrial, and agricultural groundwater users in those counties west of the Chowan River and Gates County.

GROUNDWATER RESOURCES DEVELOPMENT AND POTENTIAL

Approximately forty-one percent of the total groundwater used in northeastern North Carolina is withdrawn from the Surficial and Tertiary aquifer systems. In the areas east of the Chowan River, excluding Gates County, the Surficial and the Tertiary systems are the only feasible subsurface sources of freshwater.





KEY

- OBSERVATION WELLS
- 3 STATIC WATER LEVEL ELEVATION

FIGURE 6: POTENTIOMETRIC SURFACE OF THE LOWER UNIT OF THE CRETACEOUS AQUIFER SYSTEM
NOVEMBER 1985 (MSL DATUM) CONTOUR INTERVAL 10 FEET

Total withdrawals from the Surficial and Tertiary aquifer systems are moderate and are balanced by moderate to high recharge rates. Therefore, there is little regional potentiometric decline associated with existing groundwater withdrawals from these aquifers. Isolated aquifer overpumping could occur in these two aquifer systems however, and could cause localized potentiometric declines and saltwater incursion.

Areas adjacent to Albemarle Sound and along the Outer Banks are especially susceptible to problems from localized overpumping, because the freshwater aquifers are relatively thin there and are underlain by brackish groundwater at shallow depths. Groundwater development in these critical areas needs to be assessed in terms of historic groundwater recharge patterns and aquifer yield capacity. Also, in low-lying areas along the coast, storm wave overwash must be considered as a potential water quality problem, especially for wells situated in the Surficial Aquifer. Failure to develop adequate protective aquifer management measures in these critical areas may lead to well failure or increased saltwater intrusion into the aquifers.

The Cretaceous aquifer system units are a very important water resource for northeastern North Carolina. Approximately 59 percent of total groundwater withdrawals in this region is from these aquifer units. All of this use occurs in the counties west of the Chowan River and in Gates County. The lower Cretaceous aquifer unit contains

relatively high quality groundwater and individual wells may yield as much as 1000 gpm in some areas.

Proper well design and adequate well and well field spacing is an important consideration for groundwater supply development of these aquifer units, especially in regard to the lower Cretaceous aquifer unit. The characteristics of the lower Cretaceous unit that cause it to be a desirable water supply source also contribute to the aquifer's limitations. Throughout most of its principal use area, the lower Cretaceous aquifer unit is deeply buried and highly confined in comparison to the other major aquifer systems in the region. Recharge to the aquifer unit is only fair to poor. Pumping of wells tapping this aquifer unit commonly leads to the development of extensive drawdown cones in the potentiometric surface, the effects of which may be noticed in wells tens of miles away from the point of withdrawal.

An example of the effect of large withdrawals from this aquifer is the large drawdown cone in the potentiometric surface which has resulted from pumping near Franklin, Virginia. Withdrawals of approximately 30 to 34 MGD have lowered the potentiometric surface of the lower Cretaceous aquifer unit by nearly 40 feet in northern Bertie County over the past 20 years (Figure 6 in conjunction with Peek, 1977). However, the potentiometric surface in this area would have to be drawn down another 260 feet before the lower Cretaceous aquifer would be impacted to the extreme of severe storage depletion. Upon reaching that extreme, well yields would be

severely reduced as the aquifer began to dewater. Further north, along the Virginia stateline in Hertford County, the potentiometric surface of the lower Cretaceous aquifer would have to be drawn down another 120 feet before the aquifer would begin to dewater.

The Virginia Water Control Board began addressing the decline in the lower Cretaceous aquifer potentiometric surface in 1976, when the pumping in the Franklin, Virginia area was designated as part of the Southeastern Virginia Groundwater Management Area. Virginia currently issues pumping permits to groundwater users in the Franklin area and thereby regulates groundwater withdrawal to avoid any further decline in the potentiometric surface at Franklin.

Despite the Franklin cone, the lower Cretaceous aquifer can support additional pumping from localities in northeastern North Carolina. Wells drilled in northern Hertford County feasibly could draw the potentiometric surface down another 100 feet--wells in northern Bertie County 240 feet--before there would be any danger of dewatering the aquifer (Figure 6 in conjunction with Brown, et al, 1972).

While dewatering of the lower Cretaceous aquifer is not an immediate concern in northeastern North Carolina, further decline in the potentiometric surface could put a number of well pumps out of service. Water levels could drop below the pump settings in some of the wells, thereby rendering them useless. The pumps would have to be lowered

as the potentiometric surface declines.

Planning well development on the basis of permissible potentiometric declines will allow further development of the lower Cretaceous aquifer in North Carolina. The development of specialized computer groundwater models for the northeastern North Carolina study area would greatly aid in determining acceptable pumping loads so that neighboring communities, industries, and citizens can avoid severe storage depletion of the aquifers or wellfield interference. Further work in this regard is needed.

ACKNOWLEDGEMENTS

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