

Preliminary Report

on

G R O U N D W A T E R I N B E A U F O R T C O U N T Y
With Special Reference to Potential Effects of Phosphate Mining

By

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INTRODUCTION

An investigation of the ground-water resources of Beaufort County was begun in 1963 by the Division of Ground Water as a part of continuing programs to appraise the ground-water resources of the State. Since the study began, exploratory work has been done toward developing the phosphate deposits that lie beneath most of the county. As development of phosphate mining would greatly affect the ground-water resources, the purpose of this report is to present some preliminary results of the ground-water study, some potential effects of phosphate mining on the ground-water resources and recommended measures to protect these resources.

Beaufort County comprises an area of about 830 square miles in the east-central Coastal Plain of North Carolina (fig. 1), bounded on the north by Martin and Washington Counties, on the east by Hyde County and Pamlico Sound, on the south by Pamlico and Craven Counties, and on the west by Pitt County. The broad estuary of the Pamlico River roughly bisects the county in an east-west direction.

Most of the county is relatively flat with extensive swampy areas or "pocosins", many of which have been drained to provide highly fertile farmland. Most of the eastern part of the county is about 5 to 15 feet above sea level, and most of the western part is generally about 25 to 50 feet above sea level. The county is drained by many broad, sluggish streams and irrigation ditches that empty into the Pamlico and Pungo Rivers, which flow into Pamlico Sound.

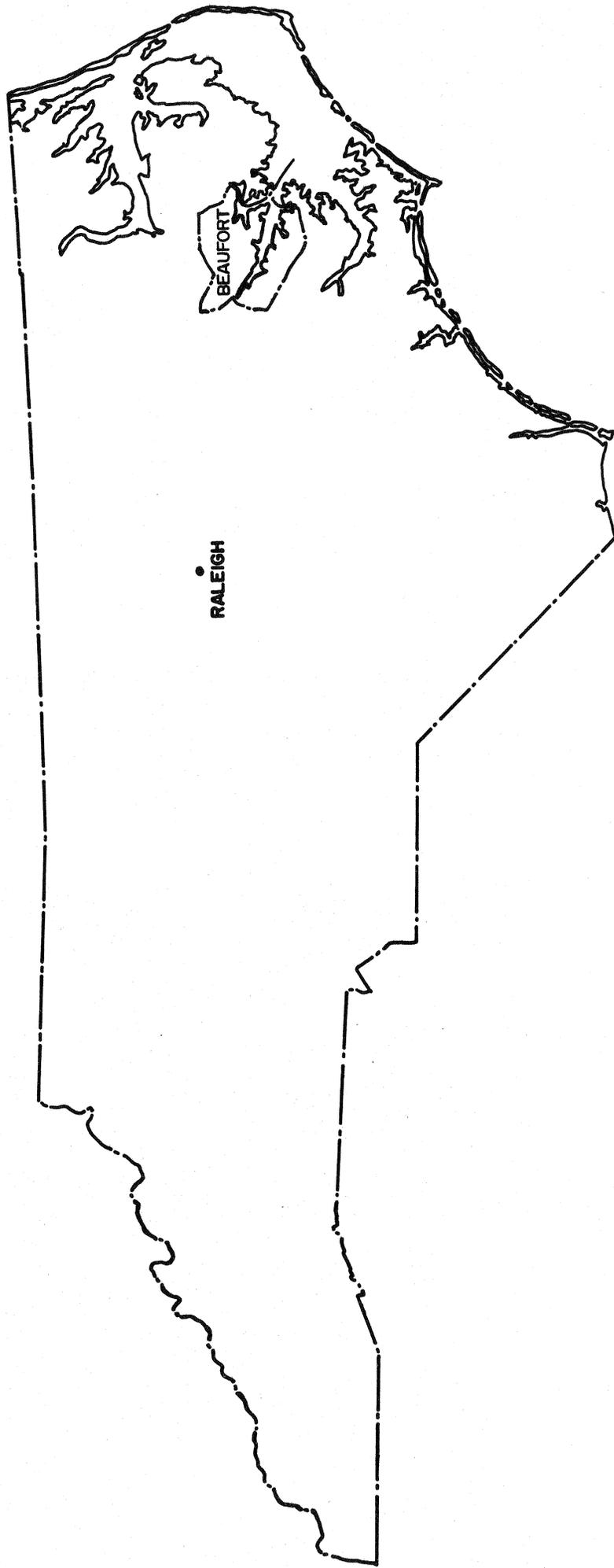


Figure 1 - Map showing the location of Beaufort County

GEOLOGY

The Coastal Plain of North Carolina, including Beaufort County, is underlain by sedimentary rocks that range in age from Cretaceous to Recent. These sediments, consisting chiefly of sand, clay, marl, shells and shell limestone, form a wedge-shaped body that rests on older crystalline basement rocks, and whose thin edge lies along the fall zone. The wedge of sediments is oriented in a general northeast-southwest direction and dips southeastward, with the thickness increasing in this direction to more than 10,000 feet at Cape Hatteras.

Only the upper few hundred feet of sediments are of significance as sources of water supply in much of the coastal area, as most of the section contains mineralized water. The geologic cross section in figure 2 shows the formations that yield fresh water to wells in Beaufort County.

Water-Bearing Units in Beaufort County

The Peedee formation of late Cretaceous age is the oldest formation generally penetrated by water wells in Beaufort County. The Peedee consists predominantly of sand and clay and is a productive aquifer in the western part of the County, but has been developed only to a limited extent. The depth to the top of the formation ranges from about 250 feet in the western part of the County to about 700 feet in the eastern part. Because of its depth, the formation probably contains water of relatively high salinity in much of the eastern part of the county, and is not considered a potential source of water in this area.

The Beaufort formation of Paleocene age lies above the Peedee formation and consists chiefly of glauconitic sands, gray clayey sand with some shells

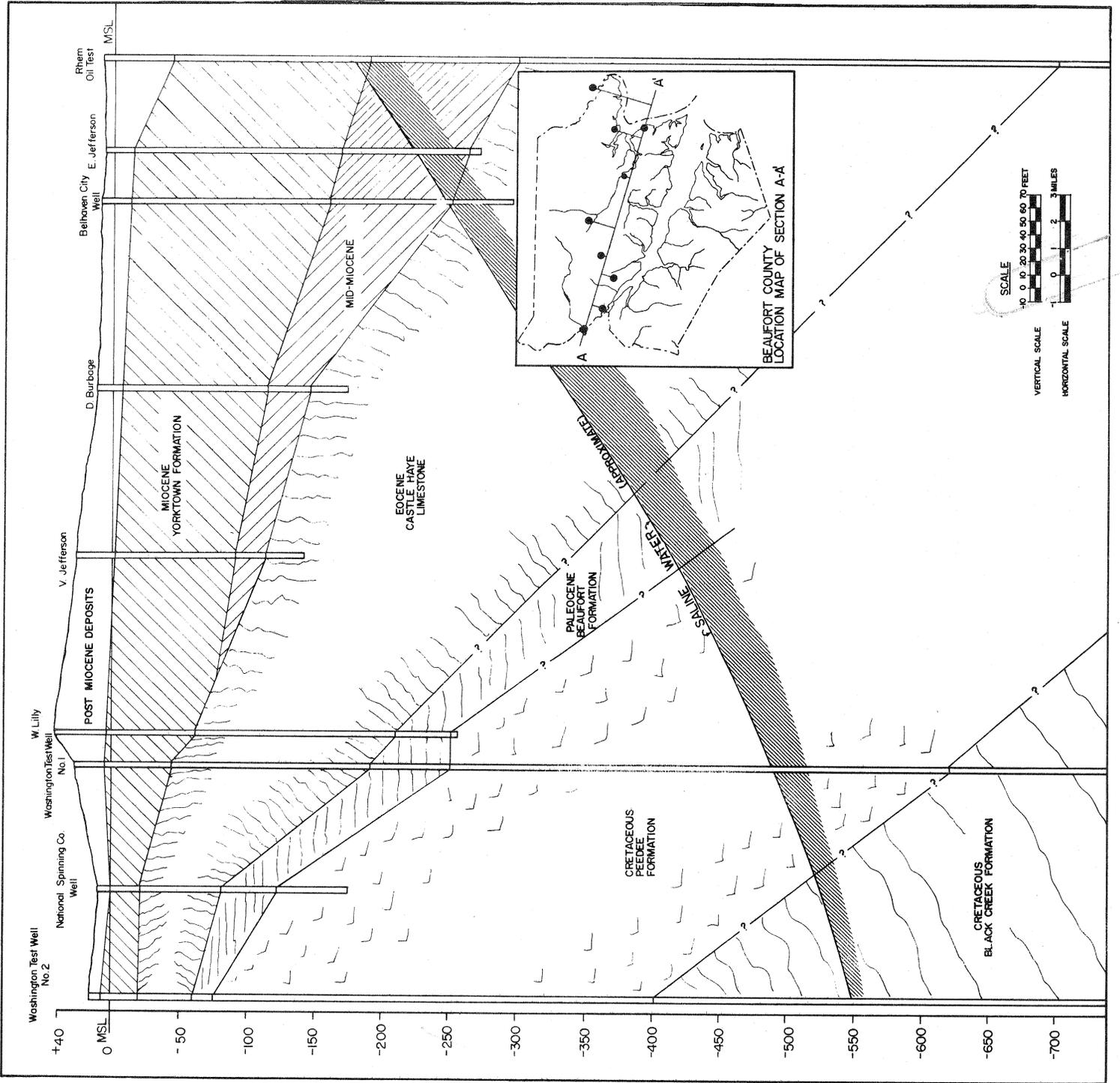


Figure 2 - Geologic cross section A-A' through Beaufort County, North Carolina.

and shell limestone. Available information indicates that the formation is about 20 to 40 feet thick in the western part of the county. Few wells have penetrated the formation in the eastern part of the county, and the character and thickness of the formation is not well known.

The Castle Hayne limestone of late Eocene age overlies the Beaufort formation unconformably, and consists mainly of white to gray, porous shell limestone and calcareous sand. The formation ranges in thickness from about 60 feet in the western part of the county to about 250 feet in the eastern part. The Castle Hayne is a highly productive artesian aquifer and principal source of water supply in Beaufort County and adjacent areas, although it has not been developed to a great extent. The contours on the map in figure 3 represent the top of the Castle Hayne which lies at depths ranging from about 75 feet in the western part of the county to more than 260 feet in the eastern part. The lower part of the aquifer probably contains salt or brackish water in eastern Beaufort County.

The Castle Hayne is unconformably overlain by unnamed deposits that have been designated as middle (?) Miocene in age (Brown 1958). This formation consists predominantly of phosphatic sand containing varying amounts of silt and clay, with a thin bed of shell limestone at the top of the section, and other thin limestone layers occurring within the phosphatic sands. The formation ranges from a few feet to about 100 feet in thickness in Beaufort County but is generally less than 50 feet thick.

The Yorktown formation of late Miocene age lies above the phosphatic sand formation and consists mainly of lenticular beds of shell marl, shells, clays and sands. The thickness of the formation is about 30 feet in western Beaufort County, increasing eastward to about 125 feet in the eastern part.

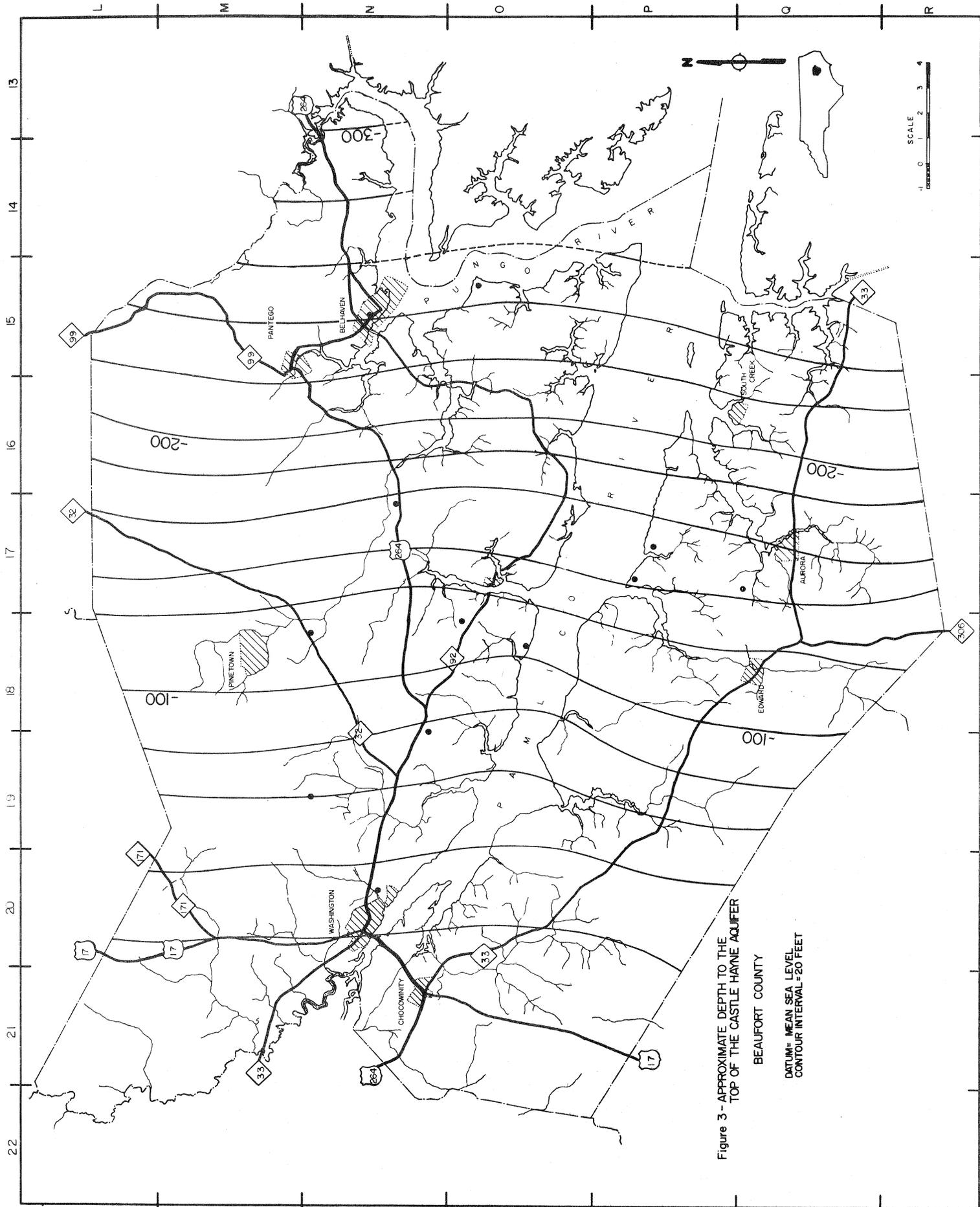


Figure 3 - APPROXIMATE DEPTH TO THE TOP OF THE CASTLE HAYNE AQUIFER
 BEAUFORT COUNTY
 DATUM= MEAN SEA LEVEL
 CONTOUR INTERVAL= 20 FEET

The Yorktown formation is overlain by surficial deposits of Pleistocene and Recent age consisting predominantly of sand with local beds of clay, and having a thickness of about 10 to 35 feet.

GROUND WATER

Ground water is the source of practically all water supplies in Beaufort County except the supply for the City of Washington. Large quantities of water, generally of good quality, are available throughout the area from one or more aquifers, however, development of the ground water resources has not been extensive to date. Salt water encroachment that may result from local overpumping and excessive drawdowns is the principal problem of potential development in much of the county.

The sand and shell beds of the Yorktown and younger formations are the source of many domestic water supplies throughout Beaufort County and yields up to 200 to 300 gallons per minute can be obtained at many places from these aquifers. The phosphatic sands of middle (?) Miocene age also comprise a fairly productive artesian aquifer at some places, but this formation has not been developed extensively as a source of supply. The Beaufort and Peedee formations are both productive artesian aquifers and principal sources of larger quantities of water in the western part of the county where the Castle Hayne is relatively thin. Over most of the county the Castle Hayne limestone is the most productive and most extensively developed aquifer, capable of yielding 1,000 gpm or more to individual wells.

Piezometric Surface

The piezometric surface of an artesian aquifer is an imaginary surface representing the height above sea level that water will rise in tightly cased wells that penetrate the aquifer. The contours on the map in figure 4 represent the approximate position of the piezometric surface of the Castle Hayne aquifer in the summer of 1963. The configuration of the contours indicates the direction of movement of water in the aquifer. The water moves from the area of highest artesian head in the direction of steepest gradient, which is generally at right angles to the contours, toward the areas of lowest artesian head, representing areas of discharge.

In the area north of the Pamlico River, the water moves from the area of highest head in the northwest corner of the county, toward the Pungo and Pamlico Rivers where the artesian head is five feet above sea level or less. In the southern half of the county, the water moves generally from southwest to northeast toward the Pamlico River. The trough-like depression in the piezometric surface along the Pamlico River indicates the discharge of large quantities of water from the aquifer by natural leakage beneath the river, where the confining beds are fairly permeable, absent or broken.

Seasonal fluctuations of the piezometric surface occur largely as a result of differences in rainfall and recharge to the aquifer. Present withdrawals of ground-water from wells are not of sufficient magnitude to significantly affect the configuration of the piezometric contours, and unless significant increases in withdrawals occur, the configuration of the contours will change very little from year to year. The hydrographs in figure 5 shows the fluctuation of the artesian water level in well Q-17, d-2 during the period from January 1963 to February 19, 1964.

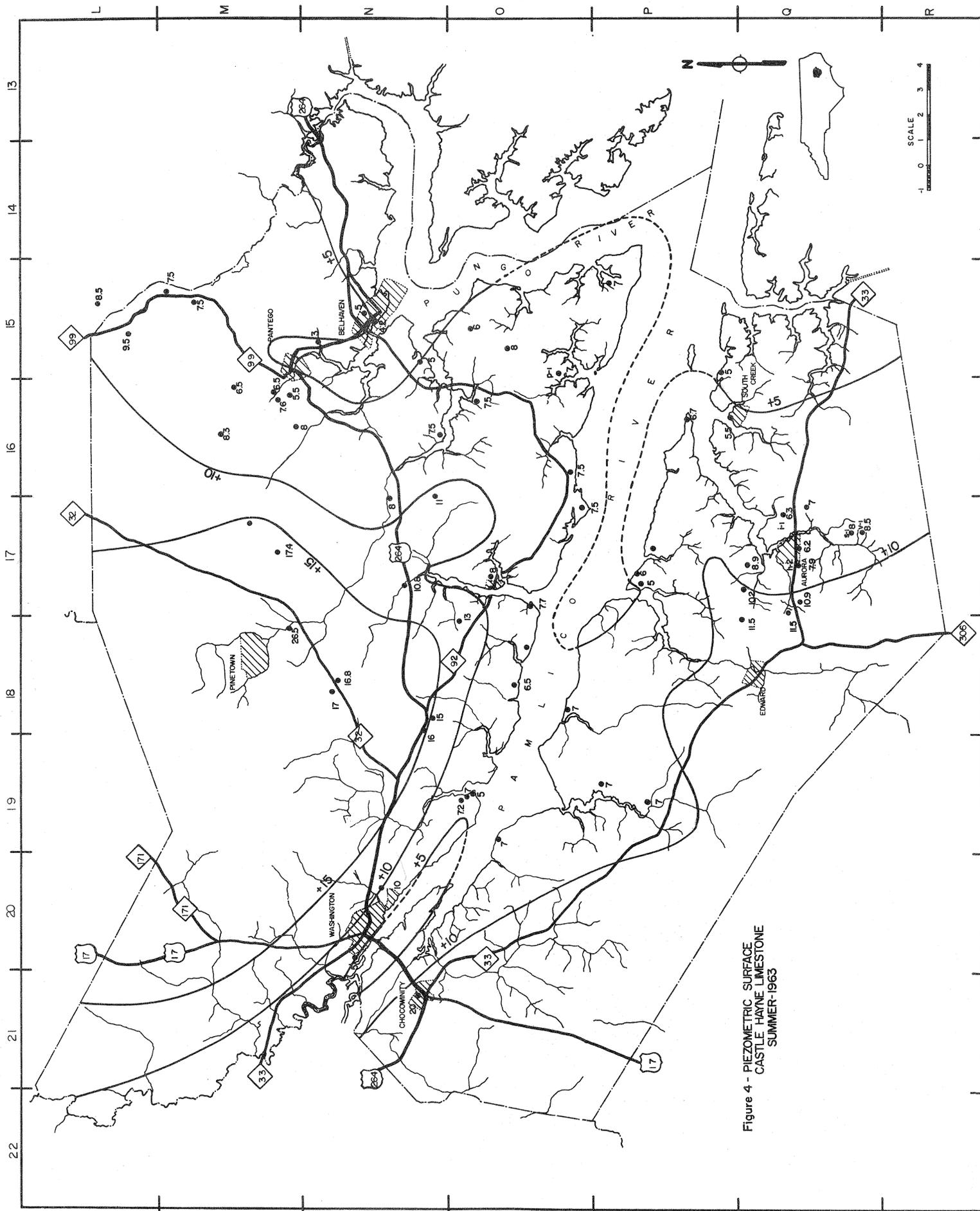


Figure 4 - PIEZOMETRIC SURFACE
 CASTLE HAYNE LIMESTONE
 SUMMER-1963

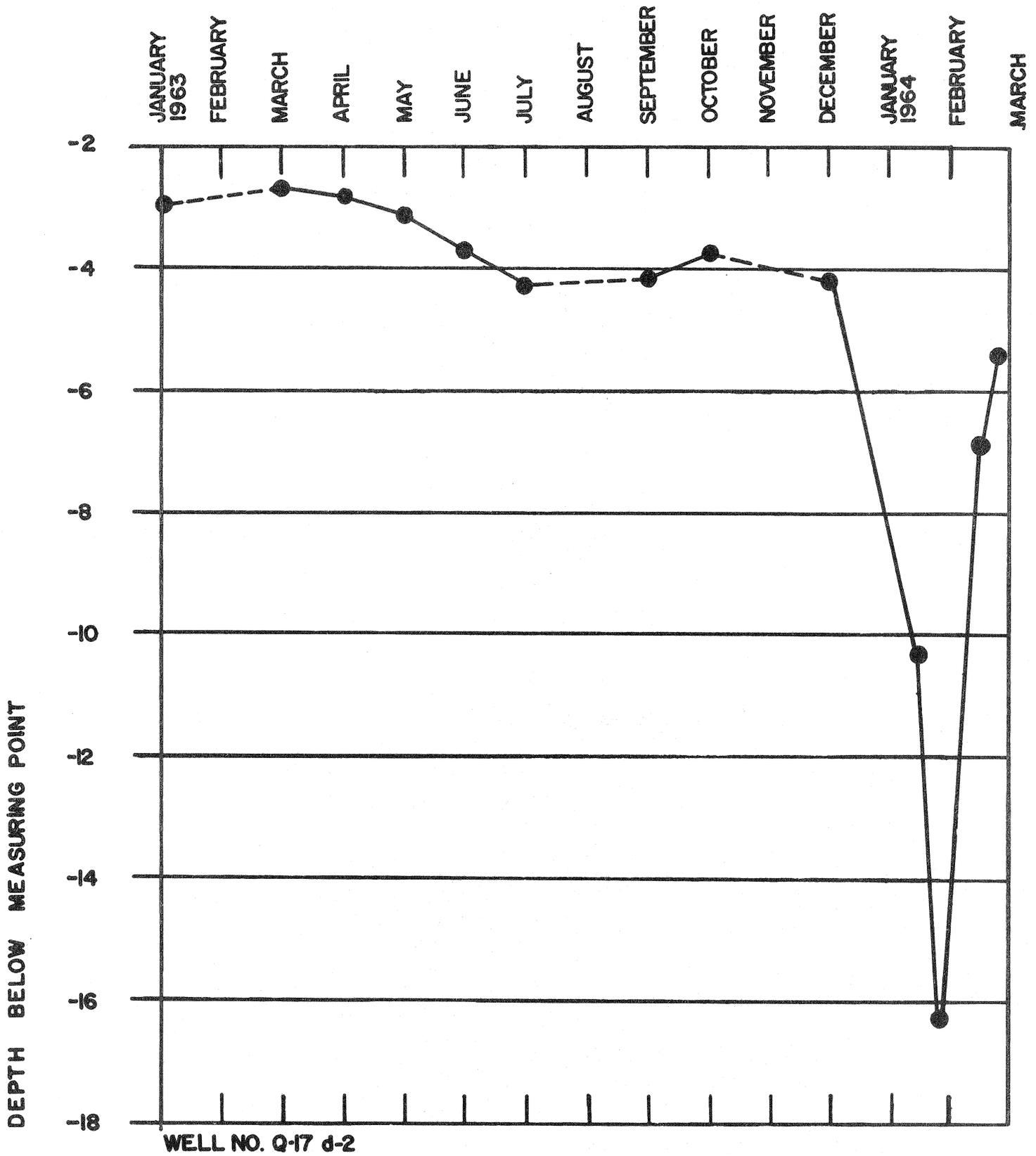


Figure 5- Hydrograph of well Q-17 d-2 from January 1963 to February 1964

Salt Water Encroachment

Salt water occurs at moderate to shallow depths throughout much of the coastal area of North Carolina as a result of conditions that have existed for many hundreds and probably thousands of years. Present conditions apparently represent a more or less established balance between fresh ground water, the salty ground water and the sea. Disturbance of this balance by lowering the water table or the artesian pressure head will result in the encroachment of salt water into the fresh-water aquifers.

The relationship between sea water and fresh water in coastal aquifers is often described through an analogy to a hollow U-tube filled with two liquids of different densities, the lighter liquid representing fresh water and the heavier, sea water (fig. 6). In the U-tube, the lighter liquid will stand at a higher level than the heavier liquid and the interface between the two will stand at a certain depth in the tube, dependent on the ratio of the liquid densities.

The specific gravity of sea water differs somewhat from place to place, but is generally considered to be 1.025, whereas, the specific gravity of fresh ground water is, for practical purposes, 1.000. Thus, the ratio of the specific gravity of sea water to that of fresh water is 1.025 : 1.000 or 41 : 40. Using this ratio, it may be seen that a column of fresh water 41 units in height would exactly balance a column of sea water 40 units in height.

Application of this relationship to aquifers hydraulically connected to the sea, shows that, theoretically, for each foot that the water table (or Piezometric surface) stands above sea level there is an additional 40 feet of fresh water below sea level, as illustrated in figure 6. This

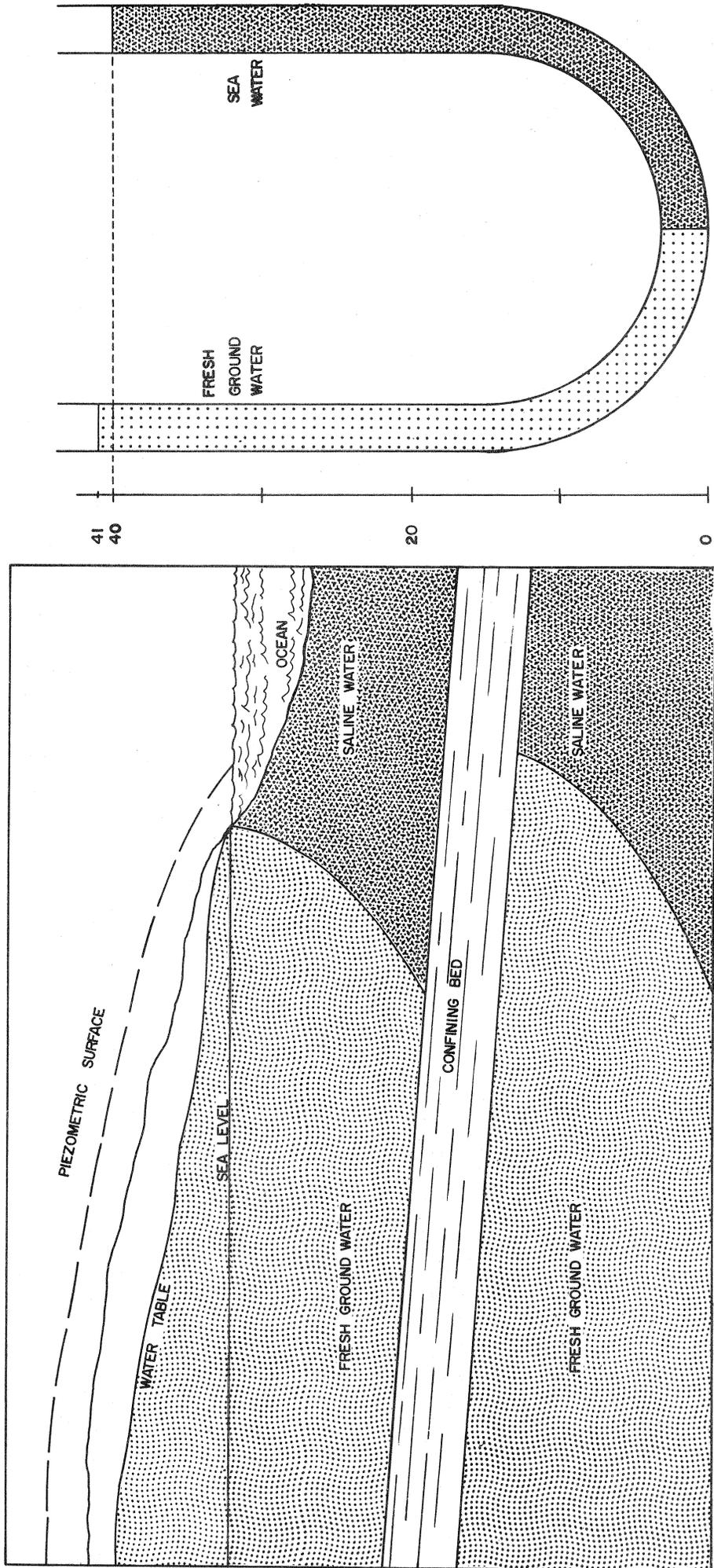


Figure 6 - Diagram showing relationship of fresh ground water and sea water

relationship commonly referred to as the Ghyben-Herzberg principal (Brown 1925, p. 16) is generally not strictly applicable without modification to allow for local conditions. However, it is generally sufficiently accurate to determine the approximate depth to salt water and to predict changes in depth that may result from significant changes in the fresh water head.

Chloride Content of Ground Water as an Index of Contamination

Chloride salts comprise about 90 per cent of the total salinity of sea water. Thus, the chloride content of ground water is generally a reliable index to the total salinity and, therefore, to the degree of mixing or contamination by sea water. The chloride content of sea water varies slightly from place to place, but is normally about 19,500 parts per million (ppm), whereas the chloride content of fresh ground water in coastal aquifers is generally less than 25 ppm.

A chloride content of 250 ppm is the upper limit recommended by the U. S. Public Health Service for drinking water. Water containing higher concentrations of chloride is considered brackish, but is used in many areas where better water is not available. Water containing as much as 600 ppm of chloride does not generally have a distinctive salty taste to most people.

Depth to Brackish Water in Beaufort County

Very little information is presently available on the exact depth to brackish water in the aquifers beneath Beaufort County, as existing wells in most areas are completed well above the depth salt water might be expected to occur. Data from a few wells in the western part of the county indicate the depth to brackish water is more than 550 feet. In the vicinity of

Belhaven, well data indicate the water is brackish at a depth of less than 250 feet.

General application of the 40 : 1 ratio to Beaufort County on the basis of the piezometric surface in the summer of 1963 (fig. 4) indicates that the depth to salt water along the Pamlico River and in much of the eastern part of the county probably ranges from about 400 feet below sea level to as little as 200 feet below sea level. Thus, lowering of the piezometric surface only a few feet for long periods of time in this area would result in contamination of most of ^{or} all of the fresh-water aquifers in these areas.

TEST MINING OF PHOSPHATE AT LEE'S CREEK

In the late fall of 1963, a test mining pit was opened at Lee's Creek, on the south side of the Pamlico River, to determine the feasibility of recovering phosphate ores by dredging methods. Dredging from the open pit required dewatering of the ore body and overlying formations in the vicinity of the pit, accomplished by lowering the water levels of each water-bearing formation to the mining level by pumping from wells completed in the ore body and from the pit.

Figure 7 shows, diagrammatically, a generalized cross section through the pit site near the end of the test period on January 22, 1964. The Yorktown formation lying above the ore body consists generally of clay, marl and sand and is the source of many domestic water supplies in the area. Draining of the formation resulted in lowering the water level for a considerable distance from the pit, so that water levels in some wells completed in this formation fell below pump settings or even below the bottom of the well in some cases. The water level of the Yorktown formation was lowered below the

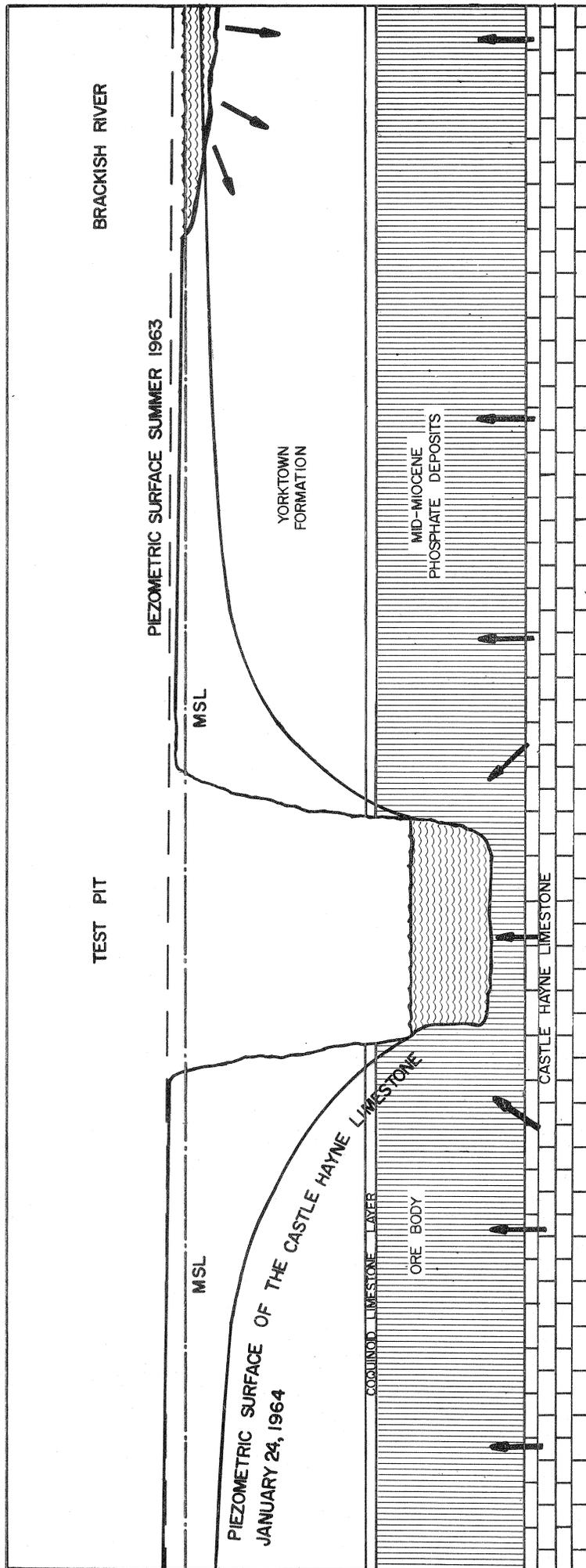


Figure 7 - Diagram showing geology and hydrologic conditions at test site.....

level of the river in the vicinity of the pit, so that some recharge from the river probably occurred. Continued recharge from the river would, of course, result in gradual contamination of the aquifer by brackish water.

The phosphatic sands that constitute the ore body also comprise a fairly productive artesian aquifer in the area, although it has not been extensively developed. The water in this aquifer is confined largely by limestone layers in and immediately above the sands and by the clays and marls of the overlying Yorktown formation. Apparently, there is no continuous confining bed between the phosphatic sands and the underlying Castle Hayne limestone, so that the Castle Hayne, having a higher artesian head, serves as a source of recharge to the sands. The hydraulic connection between the phosphatic sands and the limestone is such that pumping from the pit open to the sands is essentially the same as pumping directly from the limestone. Thus, the lowering of the water level in the pit to about 100 feet below sea level also resulted in lowering the piezometric surface of the Castle Hayne to about 100 feet below sea level at the pit site (fig. 7).

Effects on the Piezometric Surface

The hydrographs of selected wells in figures 5 and 8 show the lowering of water levels in the Castle Hayne during the period of pumping from the test pit and the rise of water levels after pumping stopped on January 22, 1964. As may be seen, water levels continued to decline for about two days after pumping stopped, with the maximum lowering occurring about January 25.

The map in figure 9 shows the piezometric surface of the Castle Hayne limestone on January 24, 1964, two days after completion of the test pumping at the pit. The contours show approximately the maximum lowering of

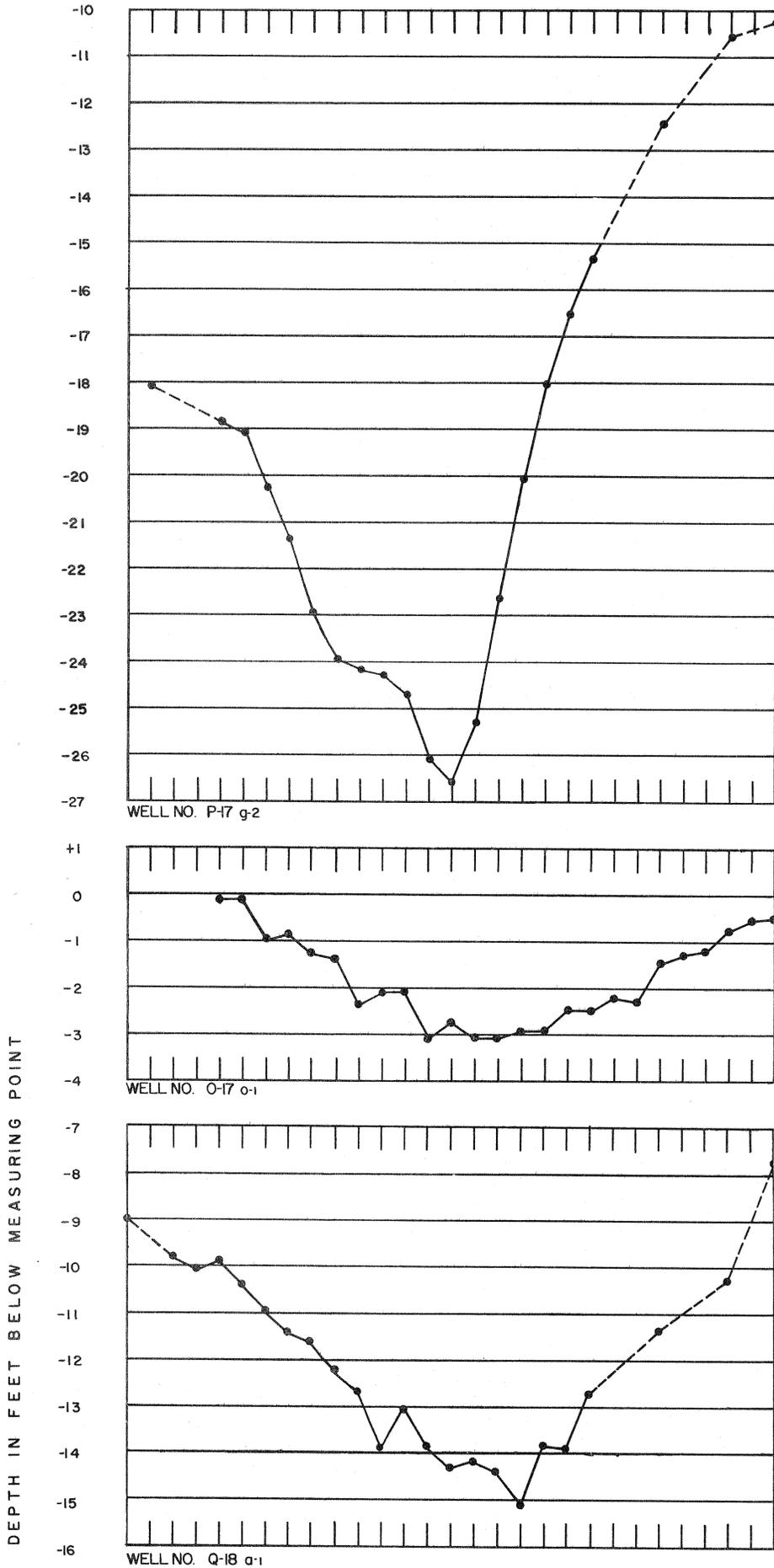


Figure 8 - Hydrographs of selected wells - January and February 1964

the piezometric surface during the testing period. As may be seen by comparing figure 5 with figure 9, pumping from the test pit lowered the piezometric surface at least several feet over much of Beaufort County and to sea level or below over an area of many square miles.

The map in figure 10 shows the piezometric surface of the Castle Hayne limestone in February 1964, several weeks after pumping at the test pit had stopped. As may be seen, the piezometric surface had recovered to approximately the seasonal level, and the configuration is essentially the same as in the summer of 1963 (fig. 4). The recovery of the piezometric surface is also reflected in the hydrographs in figures 5 and 8.

POTENTIAL EFFECTS OF CONTINUOUS PUMPING

Unless proper controls are exercised, continuous pumping of large quantities of ground water from the phosphatic sands at one or more localities in Beaufort County and subsequent leakage from the Castle Hayne limestone will drastically change existing ground-water conditions over a large area. The extensive lowering of water levels in the formations above the Castle Hayne limestone will permanently affect shallow wells in the area of influence, and will probably result eventually in the encroachment of brackish water into these formations, at least along the river.

The most significant effect, however, will be the permanent lowering of the piezometric surface of the Castle Hayne limestone. Continuous pumping even at a single site and at a rate not exceeding that of the test in January 1964, will result in the contamination of the Castle Hayne aquifer over a broad area by salt water encroachment. As shown on the map in figure 9, the piezometric surface was at sea level or below over a large area after

only a few days pumping at relatively high rates. Under these conditions, it could only be a matter of time until all formations in this area would be contaminated with salt water, and the Castle Hayne aquifer would eventually be contaminated over a large part of Beaufort County. Continuous pumping at higher rates and at two or more sites would affect a much greater area and accelerate the rate of encroachment. Thus, without any protective control, the source of fresh ground-water supplies would be destroyed over much of Beaufort and parts of adjacent counties.

PROTECTION OF THE GROUND-WATER RESOURCES

Ground water is the principal source of present water supplies in Beaufort and adjacent counties, and large quantities of good quality water are available throughout most of the area. The mining of the phosphate deposits that lie beneath the area must be accompanied by adequate protective measures, or a large part of ground-water resources will be permanently damaged or destroyed.

Significant effects of large withdrawals of ground water can be restricted to the immediate vicinity of each mining operation. Water levels of the principal aquifers can be maintained at sufficient elevations outside the immediate area of operation to prevent encroachment of salt water into these aquifers. It is believed that these protective measures can be feasibly accomplished in one or more ways.

One of the most logical methods appears to be a system of discharge and recharge wells completed in the Castle Hayne limestone as shown diagrammatically in figure 11. This system would provide a means of accurately controlling the water level both inside and outside the mining area, and also provide a source of water supply for ore processing and other needs. As mining progresses, a large part

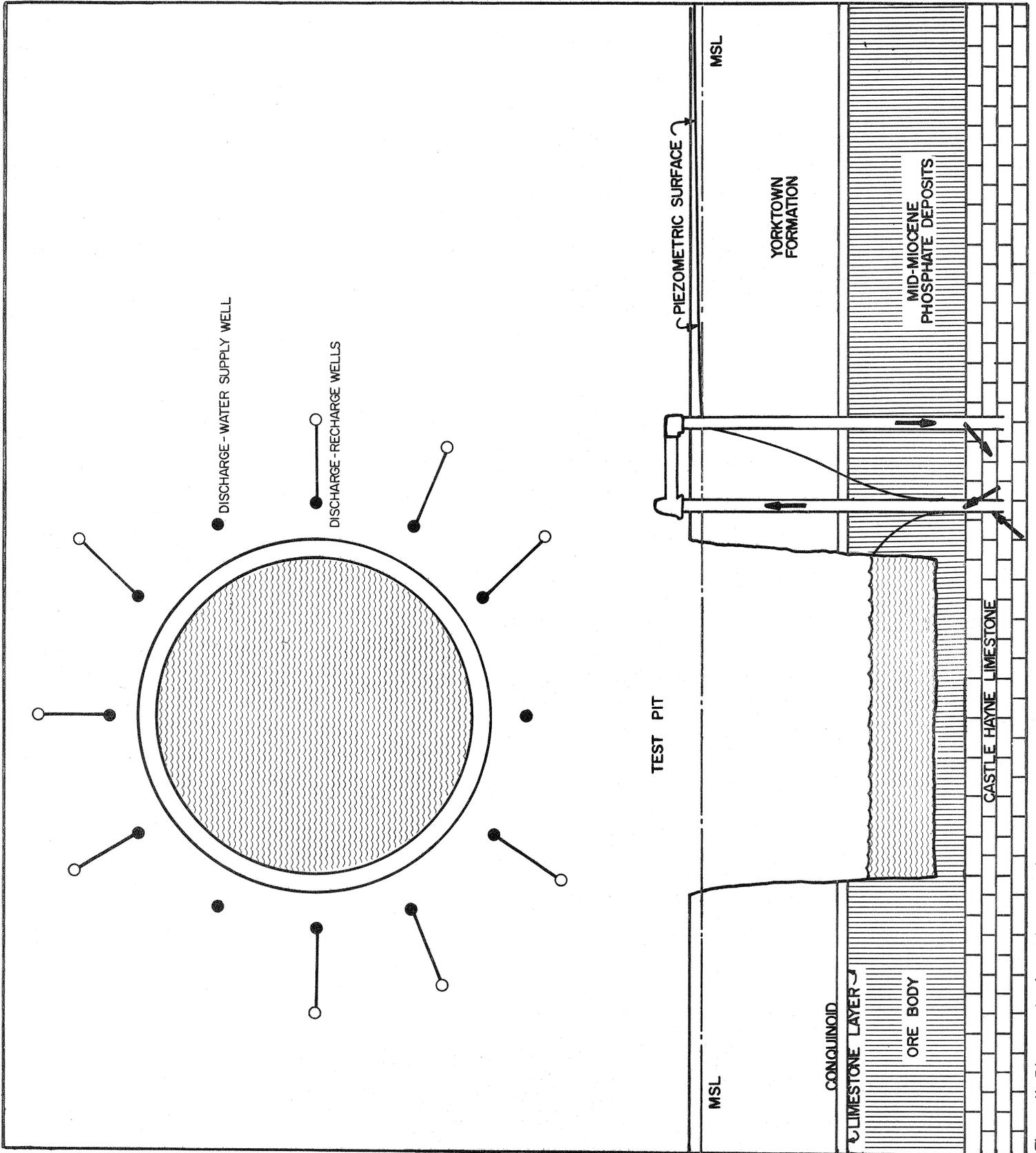


Figure 11- Diagram showing recharge-well system

of the necessary recharge might be accomplished through mined-out pits, which would serve the same purpose as recharge wells in controlling the piezometric surface.

SUMMARY AND RECOMMENDATIONS

Ground water is one of Beaufort County's most valuable resources, as it is the principal source of present and potential water supplies in the area. The extensive deposits of phosphate that lie beneath much of the area are also extremely valuable resources. Development of both of these subsurface resources can contribute much to the economy of the area and the State, and should be accomplished in the most beneficial manner possible.

Proposed methods of mining and processing of the phosphate ore in Beaufort County require the withdrawal of large quantities of ground water. Available data show that large-scale pumping from the principal aquifers on a continuous and long-term basis will lower the water table and artesian pressures sufficiently to permit encroachment of salt water into these aquifers, unless preventive measures are taken. Available data also indicate that most of the effects of pumping can be restricted to the immediate vicinity of any particular mining site by recharging the aquifers through a system of wells or pits, thereby preventing major changes in the hydrology of the area and extensive contamination of the aquifers. Therefore, minimum protective measures should be required before the withdrawal of excessive quantities of ground water is begun in Beaufort or any other county where similar conditions exist. These measures should include:

- (1) Determination of the depth of saline water at the site of withdrawal before pumping begins.

(2) Installation and maintenance of an adequate system of water-level observation stations and water-quality monitoring stations at each withdrawal site to provide records of any changes in water levels or quality resulting from pumping.

(3) Restriction of significant effects of pumping to the immediate vicinity of the pumping site.

(4) Maintenance of water levels and artesian pressures of principal aquifers at sufficient elevation above sea level outside the immediate area of ground-water withdrawal to prevent encroachment of salt water into the aquifers.

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