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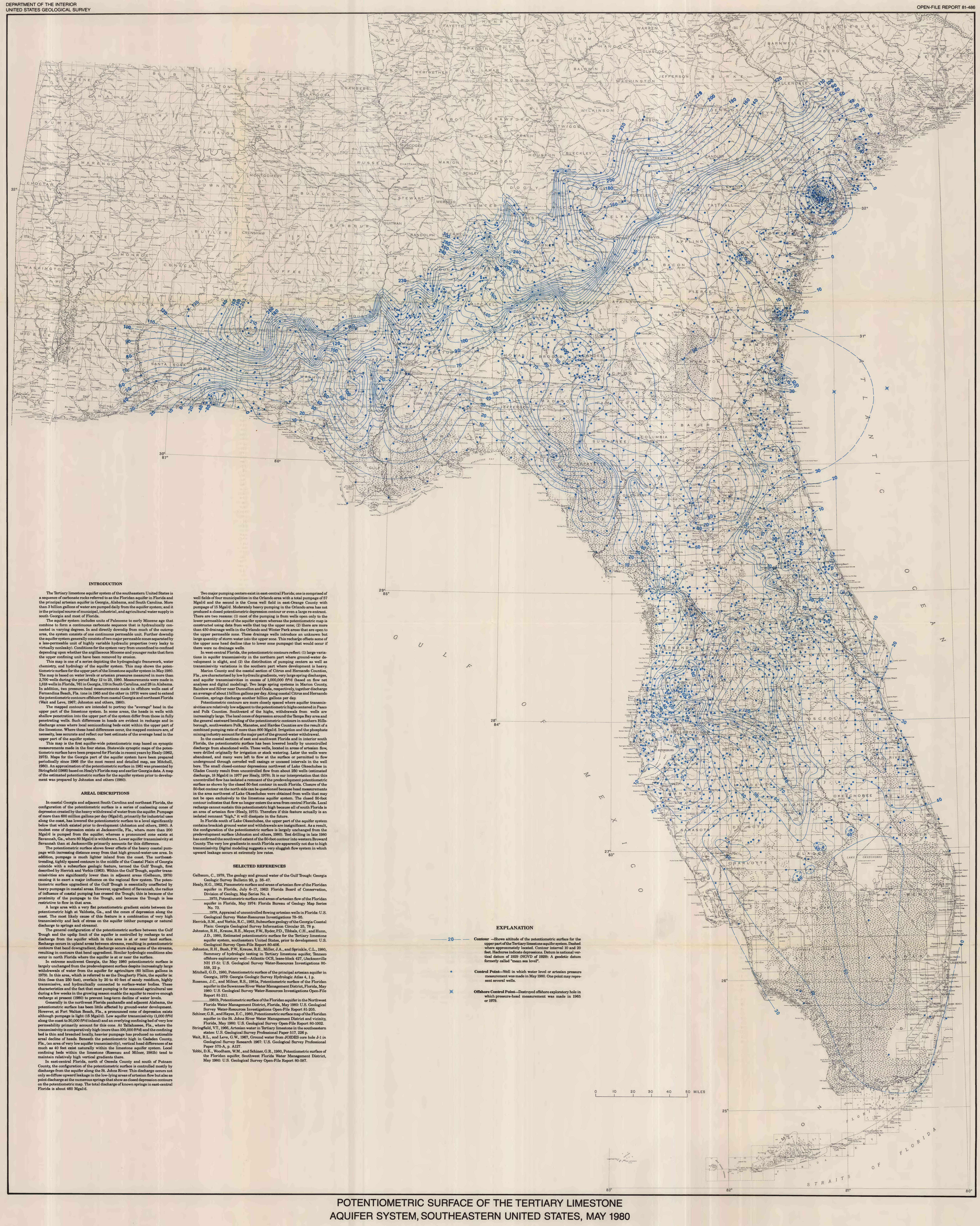

INTRODUCTION

The Tertiary limestone aquifer system of the southeastern United States is a sequence of carbonate rocks referred to as the Floridan aquifer in Florida and the principal artesian aquifer in Georgia, Alabama, and South Carolina. More than 3 billion gallons of water are pumped daily from the aquifer system; and it is the principal source of municipal, industrial, and agricultural water supply in south Georgia and most of Florida.

The aquifer system includes units of Paleocene to early Miocene age that combine to form a continuous carbonate sequence that is hydraulically connected in varying degrees. In and directly downdip from much of the outcrop area, the system consists of one continuous permeable unit. Further downdip the aquifer system generally consists of two major permeable zones separated by a less-permeable unit of highly variable hydraulic properties (very leaky to virtually nonleaky). Conditions for the system vary from unconfined to confined depending upon whether the argillaceous Miocene and younger rocks that form the upper confining unit have been removed by erosion.

This map is one of a series depicting the hydrogeologic framework, water chemistry, and hydrology of the aquifer system. This map shows the potentiometric surface for the upper part of the limestone aquifer system in May 1980. The map is based on water levels or artesian pressures measured in more than 2,700 wells during the period May 12 to 23, 1980. Measurements were made in 1,818 wells in Florida, 761 in Georgia, 119 in South Carolina, and 28 in Alabama. In addition, two pressure-head measurements made in offshore wells east of Fernandina Beach, Fla. (one in 1965 and the other in 1979) were used to extend the potentiometric contours offshore from coastal Georgia and northeast Florida (Wait and Leve, 1967; Johnston and others, 1980).

The mapped contours are intended to portray the "average" head in the upper part of the limestone system. In some areas, the heads in wells with shallow penetration into the upper part of the system differ from those in fully penetrating wells. Such differences in heads are evident in recharge and in discharge areas where local semiconfining beds exist within the upper part of the limestone. Where these head differences occur, the mapped contours are, of necessity, less accurate and reflect our best estimate of the average head in the upper part of the aquifer system.

This map is the first aquifer-wide potentiometric map based on synoptic measurements made in the four states. Statewide synoptic maps of the potentiometric surface have been prepared for Florida in recent years by Healy (1962, 1975). Maps for the Georgia part of the aquifer system have been prepared periodically since 1966 (for the most recent and detailed map, see Mitchell, 1980). An approximation of the potentiometric surface in 1961 was presented by Stringfield (1966) based on Healy's Florida map and earlier Georgia data. A map of the estimated potentiometric surface for the aquifer system prior to development was prepared by Johnston and others (1980).

AREAL DESCRIPTIONS

In coastal Georgia and adjacent South Carolina and northeast Florida, the configuration of the potentiometric surface is a series of coalescing cones of depression created by the heavy withdrawal of water from the aquifer. Pumpage of more than 600 million gallons per day (Mgal/d), primarily for industrial uses along the coast, has lowered the potentiometric surface to a level significantly below that which existed prior to development (Johnston and others, 1980). A modest cone of depression exists at Jacksonville, Fla., where more than 200 Mgal/d is pumped from the aquifer; whereas a pronounced cone exists at Savannah, Ga., where 80 Mgal/d is withdrawn. Lower aquifer transmissivity at Savannah than at Jacksonville primarily accounts for this difference.

The potentiometric surface shows fewer effects of the heavy coastal pumpage with increasing distance away from that high ground-water-use area. In addition, pumpage is much lighter inland from the coast. The northeast-trending, tightly spaced contours in the middle of the Coastal Plain of Georgia coincide with a subsurface geologic feature, termed the Gulf Trough, first described by Herrick and Vorhis (1963). Within the Gulf Trough, aquifer transmissivities are significantly lower than in adjacent areas (Gelbaum, 1978) causing it to exert a major influence on the regional flow system. The potentiometric surface upgradient of the Gulf Trough is essentially unaffected by heavy pumpage in coastal areas. However, upgradient of Savannah, the radius of influence of coastal pumping has crossed the Trough; this is because of the proximity of the pumpage to the Trough, and because the Trough is less restrictive to flow in that area.

A large area with a very flat potentiometric gradient exists between the potentiometric high at Valdosta, Ga., and the cones of depression along the coast. The most likely cause of this feature is a combination of very high transmissivity and lack of stress on the aquifer (either pumpage or natural discharge to springs and streams).

The general configuration of the potentiometric surface between the Gulf Trough and the updip limit of the aquifer is controlled by recharge to and discharge from the aquifer which in this area is at or near land surface. Recharge occurs in upland areas between streams, resulting in potentiometric contours that bend downgradient; discharge occurs along some of the streams, resulting in contours that bend upgradient. Similar hydrologic conditions also occur in north Florida where the aquifer is at or near the surface.

In extreme southwest Georgia, the May 1980 potentiometric surface is largely unchanged from the predevelopment surface despite increasingly large withdrawals of water from the aquifer for agriculture (60 billion gallons in 1979). In this area, which is referred to as the Dougherty Plain, the aquifer is: thin (less than 250 feet), overlain by 20 to 40 feet of sandy residium, highly transmissive, and hydraulically connected to surface-water bodies. These characteristics and the fact that most pumping is for seasonal agricultural use during a few weeks in the growing season enable the aquifer to receive enough recharge at present (1980) to prevent long-term decline of water levels.

Generally in the northwest Florida panhandle and adjacent Alabama, the potentiometric surface has been little affected by ground-water development. However, at Fort Walton Beach, Fla., a pronounced cone of depression exists although pumpage is light (15 Mgal/d). Low aquifer transmissivity (1,000 ft^2/d along the coast to 30,000 ft^2/d inland) and an overlying confining bed of very low permeability primarily account for this cone. At Tallahassee, Fla., where the transmissivity is comparatively high (more than 100,000 ft^2/d) and the confining bed is thin and breached locally, heavier pumpage has produced no noticeable areal decline of heads. Beneath the potentiometric high in Gadsden County, Fla., (an area of very low aquifer transmissivity), vertical head differences of as much as 40 feet exist naturally within the limestone aquifer system. Local confining beds within the limestone (Rosenau and Milner, 1981b) tend to maintain relatively high vertical gradients there.

In east-central Florida, north of Osceola County and south of Putnam County, the configuration of the potentiometric surface is controlled mostly by discharge from the aquifer along the St. Johns River. This discharge occurs not only as diffuse upward leakage in the low-lying areas of artesian flow but also as point discharge at the numerous springs that show as closed depression contours on the potentiometric map. The total discharge of known springs in east-central Florida is about 460 Mgal/d.

Two major pumping centers exist in east-central Florida; one is comprised of well fields of four municipalities in the Orlando area with a total pumpage of 57 Mgal/d and the second is the Cocoa well field in east-Orange County with pumpage of 15 Mgal/d. Moderately heavy pumping in the Orlando area has not produced a closed potentiometric depression contour or even a large re-entrant. There are two reasons: (1) most of the pumping is from wells open only to the lower permeable zone of the aquifer system whereas the potentiometric map is constructed using data from wells that tap the upper zone; (2) there are more than 450 drainage wells in the Orlando and Winter Park areas that are open to the upper permeable zone. These drainage wells introduce an unknown but large quantity of storm water into the upper zone. This recharge offsets some of the upper zone head decline (due to lower zone pumpage) that would occur if there were no drainage wells.

In west-central Florida, the potentiometric contours reflect: (1) large variations in aquifer transmissivity in the northern part where ground-water development is slight, and (2) the distribution of pumping centers as well as transmissivity variations in the southern part where development is heavy.

Marion County and the coastal section of Citrus and Hernando Counties, Fla., are characterized by low hydraulic gradients, very large spring discharges, and aquifer transmissivities in excess of 1,000,000 ft^2/d (based on flow net analyses and digital modeling). Two large spring systems in Marion County, Rainbow and Silver near Dunnellon and Ocala, respectively, together discharge an average of about 1 billion gallons per day. Along coastal Citrus and Hernando Counties, springs discharge another billion gallons per day.

Potentiometric contours are more closely spaced where aquifer transmissivities are relatively low adjacent to the potentiometric highs centered in Pasco and Polk Counties. Southward of the highs, withdrawals from wells are increasingly large. The local cones of depression around the Tampa Bay area and the general eastward bending of the potentiometric contours in southern Hillsborough, southwestern Polk, Manatee, and Hardee Counties are the result of a combined pumping rate of more than 800 Mgal/d. Irrigation and the phosphate mining industry account for the major part of the ground-water withdrawal.

In the coastal sections of east and southwest Florida and in interior south Florida, the potentiometric surface has been lowered locally by uncontrolled discharge from abandoned wells. These wells, located in areas of artesian flow, were drilled originally for irrigation or stock watering. Later the wells were abandoned, and many were left to flow at the surface or permitted to flow underground through corroded well casings or uncased intervals in the well bore. The small closed-contour depressions northwest of Lake Okeechobee in Glades County result from uncontrolled flow from about 250 wells (estimated discharge, 18 Mgal/d in 1977 per Healy, 1978). It is our interpretation that this uncontrolled flow has isolated a remnant of the predevelopment potentiometric surface as shown by the closed 50-foot contour in south Florida. Closure of the 50-foot contour on the north side can be questioned because head measurements in the area northwest of Lake Okeechobee were obtained from wells that may not be open exclusively to the limestone aquifer system. The closed 50-foot contour indicates that flow no longer enters the area from central Florida. Local recharge cannot sustain this potentiometric high because all of south Florida is an area of artesian flow (Healy, 1975). Therefore if this feature actually is an isolated remnant "high," it will dissipate in the future.

In Florida south of Lake Okeechobee, the upper part of the aquifer system contains brackish ground water and withdrawals are insignificant. As a result, the configuration of the potentiometric surface is largely unchanged from the predevelopment surface (Johnston and others, 1980). Test drilling in late 1980 has confirmed the southward extent of the 50-foot contour into western Broward County. The very low gradients in south Florida are apparently not due to high transmissivity. Digital modeling suggests a very sluggish flow system in which upward leakage occurs at extremely low rates.

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EXPLANATION

—— 20 —— —— **Contour** —Shows altitude of the potentiometric surface for the upper part of the Tertiary limestone aquifer system. Dashed where approximately located. Contour interval 10 and 20 feet. Hachures indicate depressions. Datum is national vertical datum of 1929 (NGVD of 1929): A geodetic datum formerly called "mean sea level".

• **Control Point**—Well in which water level or artesian pressure measurement was made in May 1980. One point may represent several wells.

⊠ **Offshore Control Point**—Destroyed offshore exploratory hole in which pressure-head measurement was made in 1965 or 1979.

POTENTIOMETRIC SURFACE OF THE TERTIARY LIMESTONE AQUIFER SYSTEM, SOUTHEASTERN UNITED STATES, MAY 1980

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