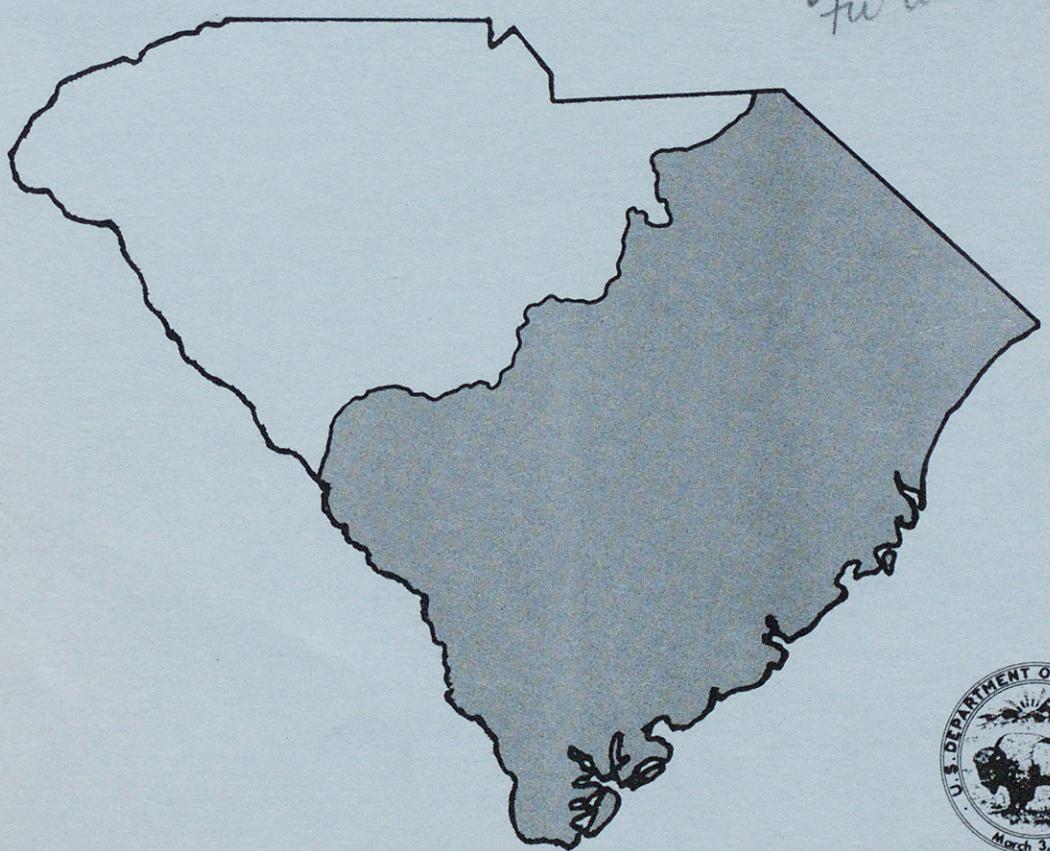
FLUORIDE CONCENTRATIONS IN WATER FROM FOUR PRINCIPAL COASTAL PLAIN AQUIFER SYSTEMS, SOUTH CAROLINA

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations
Open-File Report 81-140



Prepared in cooperation with the
SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL

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by

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Columbia, South Carolina

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UNITED STATES DEPARTMENT OF THE INTERIOR

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FLUORIDE CONCENTRATIONS IN WATER FROM FOUR PRINCIPAL COASTAL PLAIN AQUIFER SYSTEMS, SOUTH CAROLINA

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INTRODUCTION

Ample supplies of ground water are available throughout most of the Coastal Plain of South Carolina, but in many places the fluoride concentrations far exceed (as high as 5.8 mg/L, milligrams per liter) the MCL (maximum concentration limit) established for drinking water by the EPA (U.S. Environmental Protection Agency) and SCDHEC (South Carolina Department of Health and Environmental Control).

Fluoridation of drinking water for the prevention of dental caries is a well known practice in many parts of the country. Low concentrations of fluoride have an apparent beneficial effect whereas high concentrations may cause dental fluorosis (mottled teeth enamel) in young children. The recommended concentration of fluoride, as established by EPA (1975) in South Carolina ranges from 1.4 to about 2.4 mg/L depending on the daily air temperature (tables 1 and 2). A lower fluoride concentration in drinking water is considered optimum in areas of high air temperature because generally more water is consumed by individuals in these areas. The total fluoride intake in a warm area where the concentration is low, therefore, will be approximately the same as in a cooler area where the concentration is higher. However, it has been established by SCDHEC that the MCL for fluoride in public drinking water in the coastal areas will be 1.6 mg/L (R. Lewis Shaw, written commun., 1976).

Table 1.--Recommended fluoride concentrations for various daily air temperatures (modified from U.S. Environmental Protection Agency, 1975)

Annual average range of maximum daily air temperatures, in degrees Fahrenheit	Recommended control limits fluoride concentrations, in milligrams per liter			Approval limit, in milligrams per liter
	Lower	Optimum	Upper	
50.0-53.7	1.1	1.2	1.3	2.4
53.8-58.3	1.0	1.1	1.2	2.2
58.4-63.8	0.9	1.0	1.1	2.0
63.9-70.6	0.8	0.9	1.0	1.8
70.7-79.2	0.7	0.8	0.9	1.6
79.3-90.5	0.6	0.7	0.8	1.4

Table 2.--Daily air temperature for selected South Carolina cities (National Oceanic and Atmospheric Administration Office of Climatological Statistics)

Cities in South Carolina Coastal Plain	Annual average of maximum daily air temperatures, in degrees Fahrenheit
Beaufort	75.4
Charleston	75.4
Florence	72.6
Myrtle Beach (Brooke Green Gardens)	74.1
Orangeburg	74.5

PURPOSE AND SCOPE

This study was designed to give an areal distribution of the fluoride concentrations by aquifer in ground-water supplies in the Coastal Plain of South Carolina. This initial attempt to delineate by aquifer the fluoride concentration of the ground water can assist water management, well drillers, and potential well owners as a guide to the developing of water supplies that will meet the MCL without excessive treatment costs.

OCCURRENCE

Ground water in the Coastal Plain of South Carolina occurs in the interlayered sand, gravel, and limestone which form the principal aquifer systems within the Coastal Plain. The principal aquifers are (1) Santee, (2) Black Mingo, (3) Peedee, and (4) Black Creek. Other aquifers include the Hawthorn, Barnwell, McBean, and Middendorf. Data on fluoride concentrations in these latter aquifers were not sufficient to construct maps. However, all of these aquifers are not everywhere present across the Coastal Plain of South Carolina. The stratigraphic position of these eight aquifers named for the geologic formations in which they occur in South Carolina is shown in the stratigraphic column (fig. 1).

The cause of excessive fluoride concentrations in the aquifers is not known. Sufficient data and research to document the origin, occurrence, distribution, and concentrations of naturally occurring fluoride in all of the aquifers of the Coastal Plain of South Carolina are not available. However, the geochemistry of the Black Creek aquifer has been examined extensively in Horry and Georgetown Counties by Allen Zack (1979). Zack concludes that the fluoride is coming from the mineral fluorapatite, as found in fossil sharks teeth, within the marine sediments of the Black Creek Formation. The fluoride ions are liberated to the ground-water system by anion exchange. Whether this is the case in the four principal aquifers illustrated is not certain; however, all have marine depositional history (Hazel and others, 1977, p. 75).

REMOVAL OF FLUORIDE BY TREATMENT

Owing to the excessive fluoride concentrations in the public water supplies, especially along the coast, some municipalities and water districts have resorted to using the low-fluoride ground water from the shallower Tertiary and Quaternary aquifers and mixing it to dilute the high-fluoride water found in the deeper Tertiary aquifers and in the Cretaceous aquifers. Ground water from the shallower aquifers usually needs to be treated for iron and hydrogen sulfide removal, but this can be achieved by aeration at reasonable cost. However, there are many places where sufficient supplies of shallow ground water are not available. Therefore, if use of the high-fluoride water is going to be continued and still meet the MCL as set forth by SCDHEC, it will be necessary to undertake a method of defluoridation.

Maier (1970, p. 437) presents three methods whereby fluoride may be removed from water. Depending on the type of water and availability of treatment materials, the methods include the use of bone char, activated alumia, or magnesium compounds. Maier claims these methods are efficient and cost effective.

SYSTEM	SERIES	FORMATION
Quaternary	Holocene Pleistocene	Waccamaw
Tertiary	Pliocene	Yorktown / Raysor
	Miocene	Hawthorne
	Oligocene	Cooper Marl
	Eocene Upper	Barnwell / Ocala
	Eocene Middle	McBean / Santee
	Eocene Lower	Black Mingo
	Paleocene	Undifferentiated
Cretaceous	Upper	Peedee
		Black Creek
		Middendorf

Figure 1.--Generalized stratigraphic column for South Carolina.

Zack (1979, p. 38) was successful in removing fluoride ions by passing high-fluoride water through a cylinder containing hydroxylapatite. He states that depending on the rate of passage through the column, 10 to 100 percent of fluoride ion was removed from the water. Further development of this method may prove to be a feasible way to solve the high-fluoride water problem.

DATA AVAILABLE

SCDHEC has the responsibility of monitoring the quality of water for public water supplies in the State and as part of this project has produced a map showing the fluoride concentrations of public drinking water supplies that use ground water in the Coastal Plain of South Carolina (fig. 2). The concentrations shown in figure 2 were derived from analyses of water samples taken at the wellhead or at a convenient tap and reflect the total fluoride in the drinking water. Most of the ground-water supplies are withdrawn from more than one aquifer because the well screens are placed at the potentially best water-producing zones in the well. This means that the water at the well head is a mixture of all the water zones screened. Since these water zones do not produce equal amounts of similar quality water, the composite water sample represents proportionately the contribution of each water-producing zone.

The Geological Survey has on file in its computer hundreds of chemical analyses of ground-water samples which have been collected over the past 30 or more years.

From the data available, a selection of wells, having fluoride analysis of their water, was made on the basis of location, depth, well construction (wells screened or tapping a single aquifer), and a knowledge of the geology and hydrology to designate the probable producing aquifer for the well. In places the chemical analyses of the water also aided in identifying the aquifer.

DATA ANALYSIS

Fluoride concentrations for four individual aquifers were plotted by the Geological Survey's computer program Water Quality Mapping System (QWSYMAP) using data in the WATSTORE water-quality computer file for South Carolina (figs. 3, 4, 5, 6). In essence, the program gives a density plot of different values of fluoride concentrations. The different patterns delineate the change from one density to another. Erratic patterns are caused by the weight attached to an isolated sample in respect to other samples and by the lack of data. The maps show the occurrence and distribution of fluoride concentrations for four of the aquifer systems in the Coastal Plain of South Carolina.

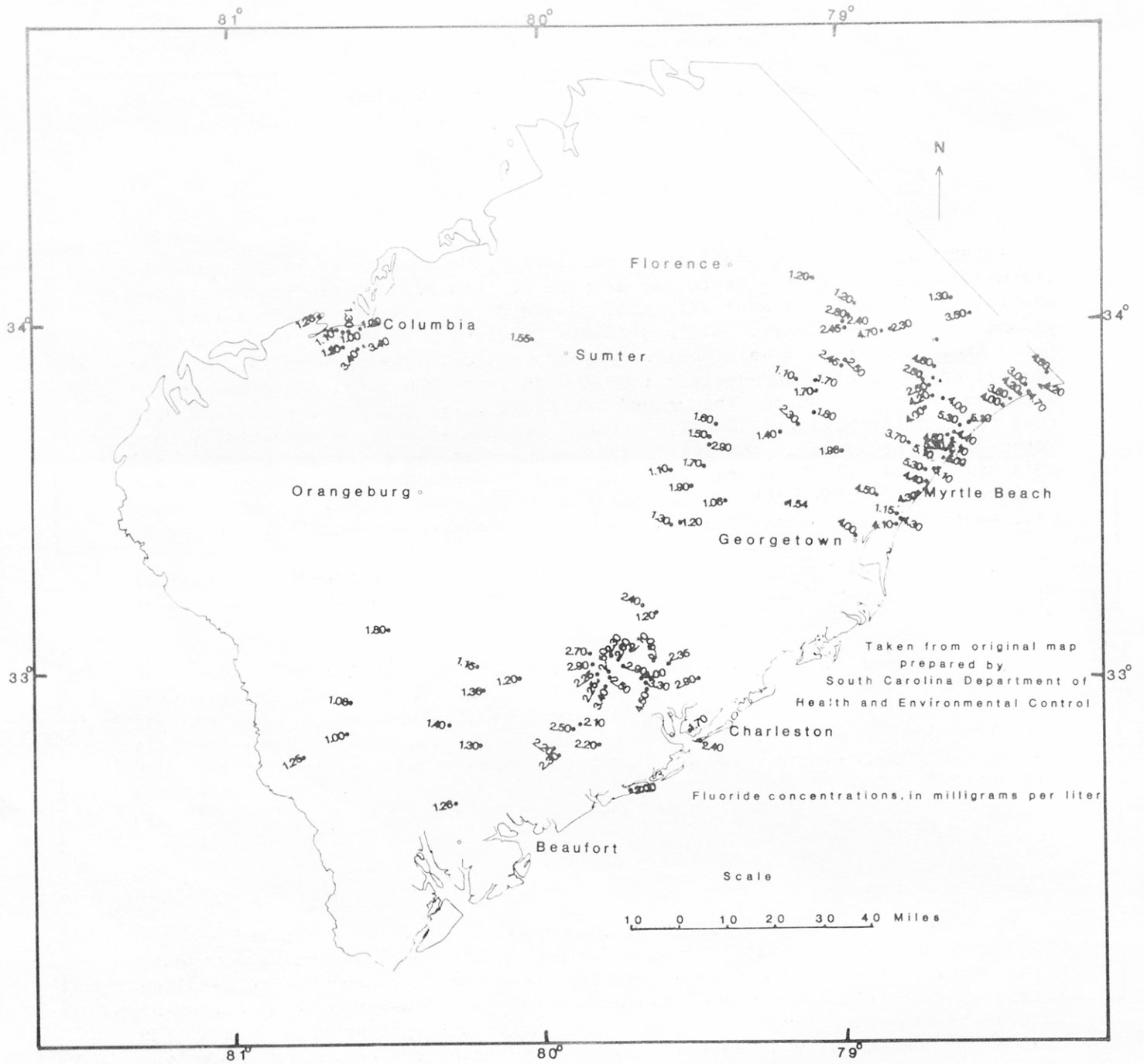

Figure 2.--Map showing natural fluoride in public drinking water systems utilizing ground water in the Coastal Plain South Carolina.

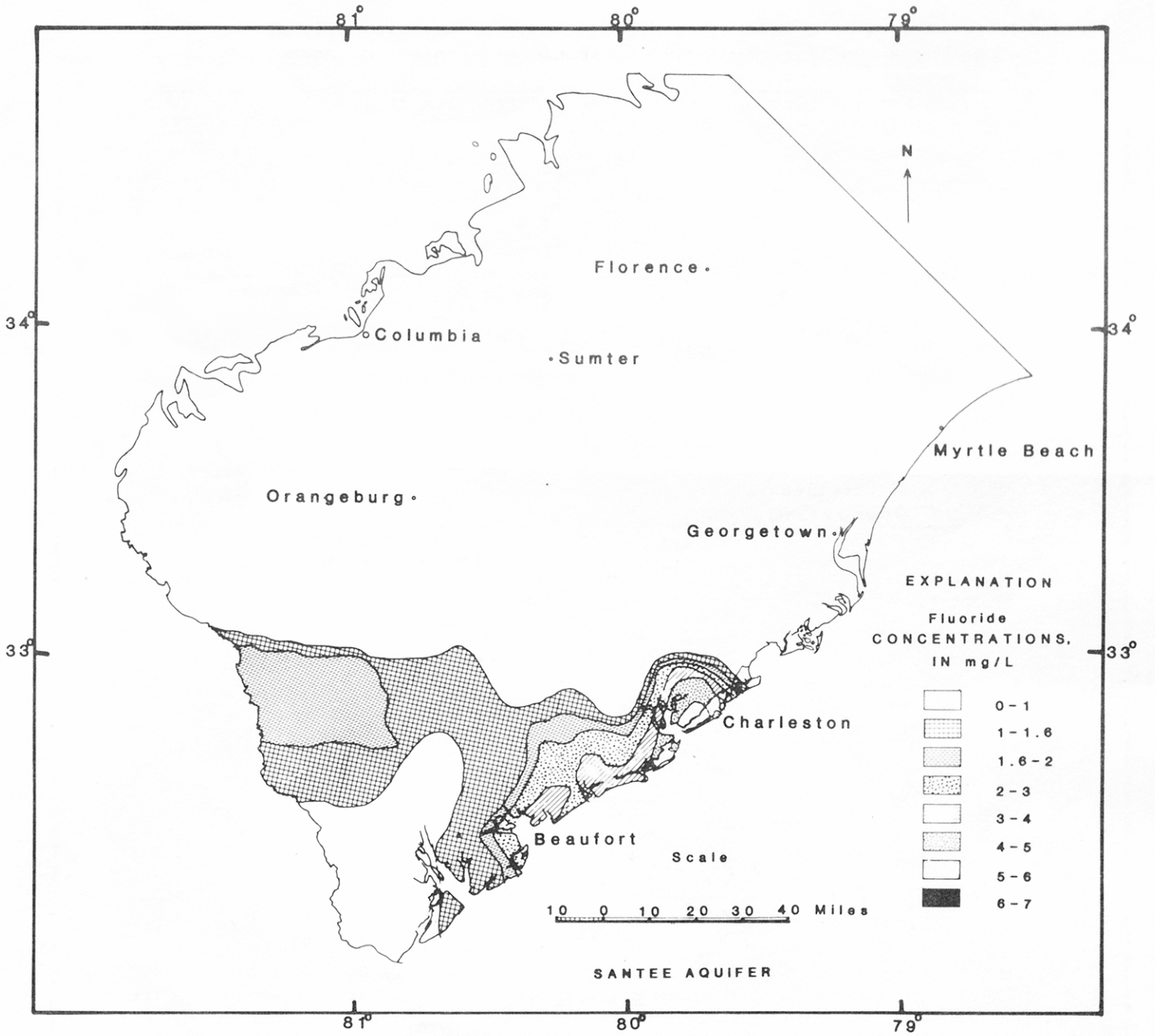

Figure 3.--Fluoride concentrations in the Santee aquifer system.

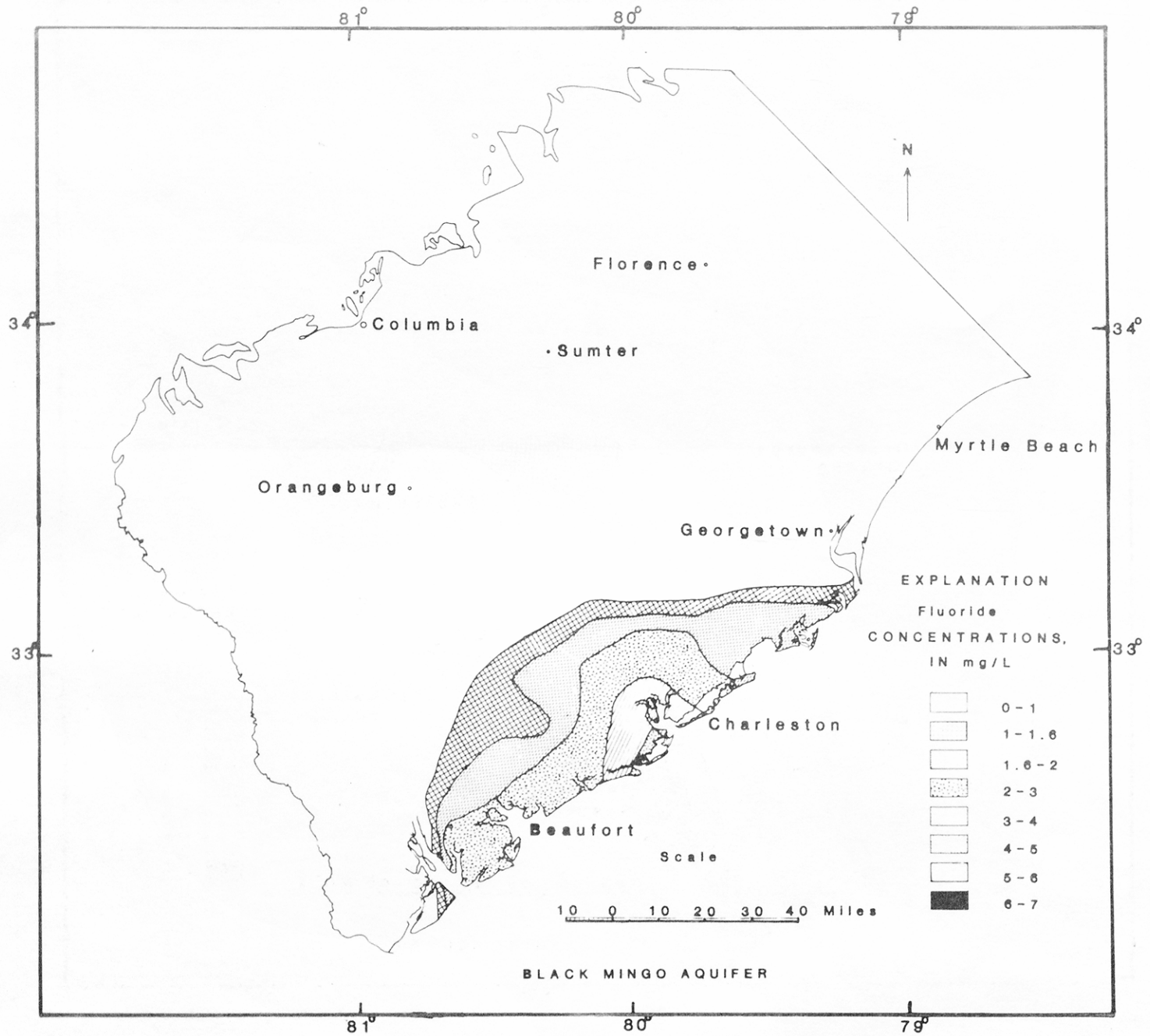

Figure 4.--Fluoride concentrations in the Black Mingo aquifer system.

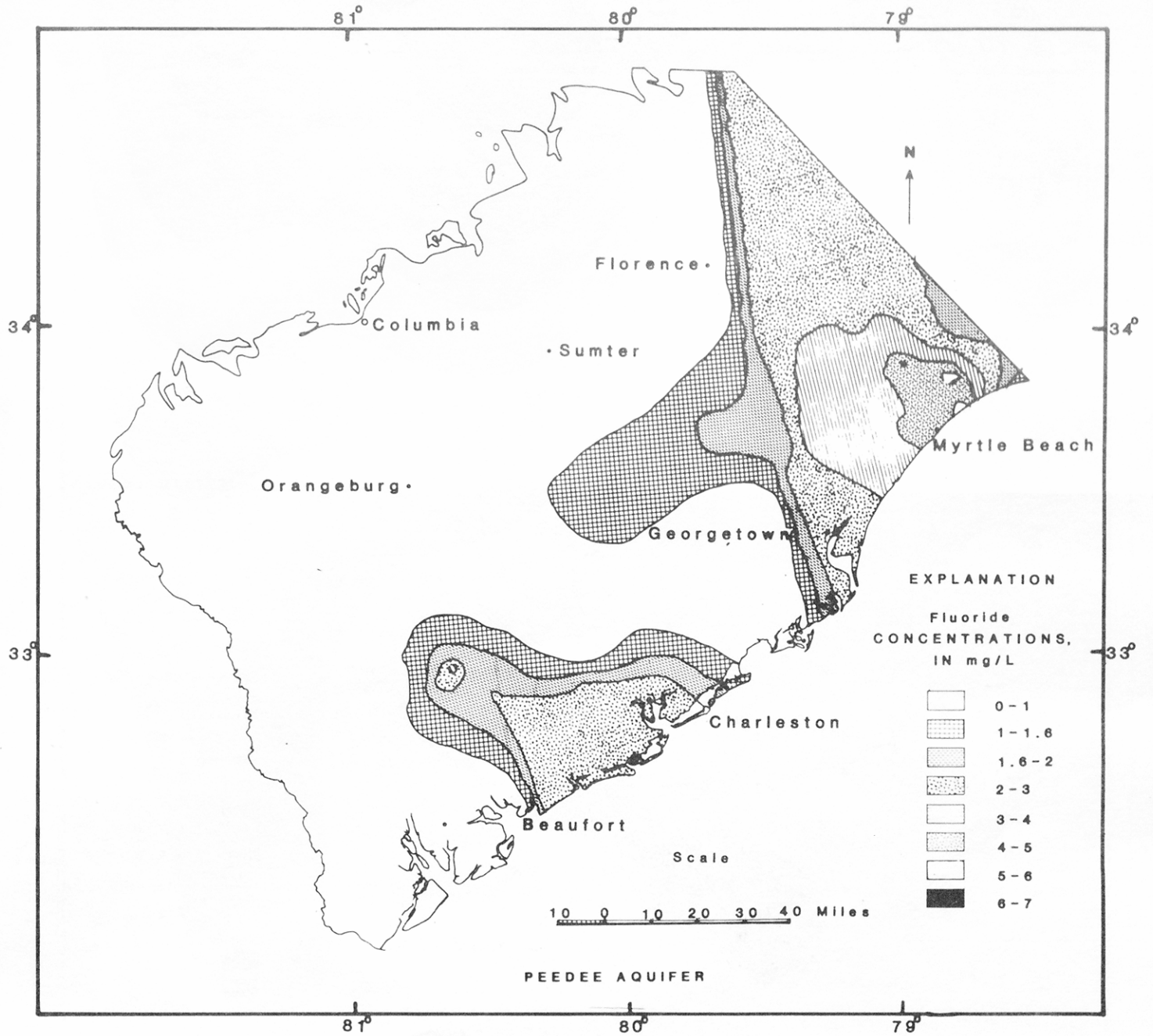

Figure 5.--Fluoride concentrations in the Peedee aquifer system.

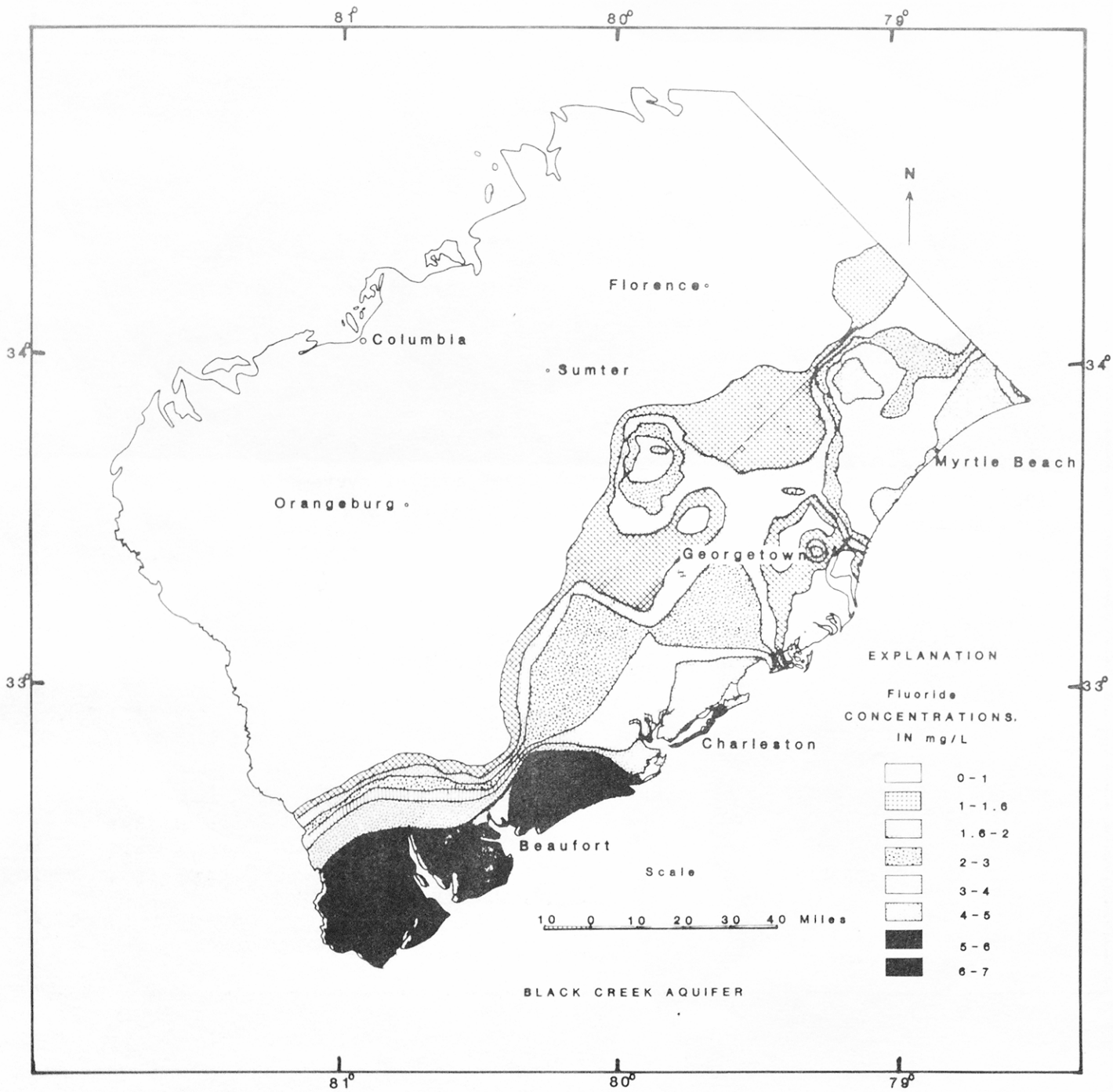

Figure 6.--Fluoride concentrations in the Black Creek aquifer system.

Inasmuch as the fluoride concentration varies between aquifers and areally within an aquifer, the fluoride concentration of the water withdrawn from a well depends on the location of the well and the relative amount of water from each aquifer. These maps will provide a guide to possible locations where the proper construction and selective screening of a well could produce a water supply that would meet the acceptable fluoride standards.

SUMMARY

Ample ground water is available in the Coastal Plain of South Carolina but in many places the fluoride concentrations far exceed the National and State standards. The presence of fluoride in the ground water has been shown areally by computer derived concentration densities in four principal aquifer systems and in depth by their relative stratigraphic position. The maps show possible locations where water supplies meeting fluoride standards could be developed from properly constructed and selectively screened wells.

The source of fluoride in the Black Creek aquifer system is the mineral fluorapatite found in fossil shark teeth. Because of similar type deposition, fluorapatite may also be the source in the other aquifer systems.

There are places where the only ground water available will exceed the MCL for fluoride. However, treatment for the removal of fluoride can be a viable alternative. Work by Maier (1970) and Zack (1979) has indicated that feasible methods for the removal of fluoride may be available.

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