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**GROUND-WATER CONDITIONS IN THE VICINITY
OF CHOCTAWHATCHEE BAY,
NORTHWEST FLORIDA**

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GROUND-WATER CONDITIONS IN THE VICINITY OF
CHOCTAWHATCHEE BAY, NORTHWEST FLORIDA

By Douglas E. Barr

NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT
Water Resources Special Report 83-10

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GROUND-WATER CONDITIONS IN THE VICINITY OF
CHOCTAWHATCHEE BAY, NORTHWEST FLORIDA

By Douglas E. Barr, Senior Hydrogeologist

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GROUND-WATER CONDITIONS IN THE VICINITY OF CHOCTAWHATCHEE BAY, NORTHWEST FLORIDA

INTRODUCTION

Purpose and Scope

Study was initiated in October, 1982 to determine qualitatively the interaction between Choctawhatchee Bay and the ground-water regime. The primary objectives of the study were to: 1) provide a description of the various hydrogeologic units underlying the bay; 2) identify those units which may be discharging to the bay and the principal areas where such discharge takes place; 3) summarize the chemical quality of the ground-water discharging to the bay; and 4) evaluate the importance of ground water discharge relative to surface water sources.

Previous Investigations

Sellards and Gunter (1912, p. 105-110) describe the water resources, physiography, drainage, wells, and soils of Walton County, which originally included what is now Okaloosa County, and indicate several locations adjacent to Choctawhatchee Bay where flowing artesian wells could be drilled. Matson and Sanford (1913, p. 42-426) discuss the surface features, geology, and water supply of the Walton-Okaloosa County area. Barraclough and Marsh (1962) describe the system of aquifers and ground-water quality along the gulf coast from the Choctawhatchee River to the Perdido River (the western boundary between Florida and Alabama). Foster and Pascale (1971, p. 95) provide data on the streamflow, water quality, and ground-water levels in Okaloosa County and adjacent areas. Pascale's report on Walton County (1974) describes in detail the hydrogeologic characteristics, hydraulic properties, yield, and water quality of the upper part of the Floridan Aquifer and to a lesser extent, the sand-and-gravel aquifer. The results of an extensive investigation of the water resources of Okaloosa County and part of western Walton County were published in a report by Trapp and others (1977). Wagner and others (1980) give a comprehensive listing of basic hydrologic data for Okaloosa and Walton counties. More recently, Barr and others (1981) described the ground and surface water resources of southern Okaloosa and Walton counties including the results of model simulations of various pumping schemes for both the Floridan and sand-and-gravel aquifers. A report by Hayes and Barr (1982) provides

a detailed examination of the sand-and-gravel aquifer in southern Okaloosa and Walton counties with a large section on the quality of water in the aquifer.

Hydrogeologic Setting

The Middle Eocene to Recent Series contain the major aquifers and confining beds in the vicinity of Choctawhatchee Bay. The strata consist mainly of marine limestone, clay and sand. The stratigraphic units of importance, their approximate thickness, lithologic description and water-bearing characteristics are given in Table 1. Traditionally, the formations underlying the area are grouped into six major hydrogeologic units based primarily on permeability contrasts and lithology. In descending order, these are: the sand-and-gravel aquifer, the Pensacola Clay confining bed, the upper limestone of the Floridan Aquifer, the Bucatunna Clay confining bed, the lower limestone of the Floridan Aquifer, and the Claiborne confining unit.

EPOCH	STAGE	FORMATION	THICKNESS	LITHOLOGIC DESCRIPTION	HYDROGEOLOGIC UNIT	HYDROLOGIC CHARACTERISTICS
Recent to Pliocene		Pliocene Recent Sands	50-250	Unconsolidated, white to light gray fine to medium quartz sand. Accessories include heavy minerals and phosphate.	Sand and Gravel Aquifer	Water mainly unconfined. In Fort Walton Beach, includes surficial unconfined unit and lower leaky artesian unit. Yields range from less than 20 gal/min in coastal lowlands of Walton County to 1000 gal/min in uplands of western Okaloosa County. Tapped by shallow wells for domestic supply and a few larger capacity wells for irrigation. Currently not used by municipal systems for public consumption.
		Citronelle Formation	50-250	Predominantly non-marine quartz sands with thin stringers of clay or gravel discontinuous over short distances.		
		Miocene Coarse Clastics	50-200	Found only along the western portion of Okaloosa County, the Miocene coarse clastics are comprised of poorly consolidated sand, gravel, clay and shell beds.		
Upper Miocene	Choctawhatchee	Intracoastal	0-360	Lithologically, the Intracoastal is made up of a poorly consolidated, sandy, clayey, microfossiliferous limestone.	Pensacola Clay Confining Bed	Restricts vertical movement of water because of thickness and comparatively low permeability. In the area of investigation grades laterally from dense clay and sandy clay in western part to clayey, silty sand in the eastern part. Not a source of water.
Upper to Middle Miocene	Alum Bluff	Alum Bluff Group (Northern Portion Only)	0-300	The Alum Bluff occurs as a mixture of sands, clays and shell beds in relatively well sorted thin beds. The matrix material is commonly clay or carbonate cement.		
		Pensacola Clay	0-190	In the western half of the study area, the Pensacola Clay interfingers with the Intracoastal Formation and Alum Bluff Group. The Pensacola is predominantly a bluish gray to olive gray, dense, silty clay.		
Lower Miocene	Tampa	Bruce Creek Limestone	20-220	Light gray to white in appearance, the Bruce Creek is moderately indurated, granular, and occurs as a clastic limestone. Accessories include a sand fraction which increases north and east.	Upper Limestone Of The Floridan Aquifer	Principal source of water in area of investigation. Yields large quantities of fresh water under confined conditions. Yields range from 250 gal/min to over 1000 gal/min. Sustained yields are generally lowest immediately adjacent to the coast in Okaloosa County. Individual zones vary greatly in permeability and vertical hydraulic connection. Contains over 250 ppm chlorides in parts of southeastern Walton and southwestern Okaloosa counties.
		Tampa Stage Limestones	30-140	Lithologically, similar to Chickasawhay Limestones but slightly less dolomitic. Silt and clay content increase towards the top of the formation.		
Upper Oligocene	Vicksburg	Chickasawhay	30-260	Primarily a tan sucrosic dolomite but may also occur as a cream to buff fossiliferous limestone.		
Middle to Lower Oligocene		Bucatanna Clay-Member of Byram Formation	0-130	The Bucatanna is a medium brown to dusky, yellowish-brown calcareous clay. Accessories include up to 10 percent quartz sand and up to 1 percent phosphate. The top contact of the Bucatanna Clay is sharp and well defined from the overlying limestone.	Bucatanna Clay Confining Bed	Where present, restricts vertical movement of water between overlying and underlying hydrogeologic units. Generally present in coastal Walton and Okaloosa counties but absent in northern parts of area.
Upper Eocene	Jackson	Ocala Group Limestones	165-600	A white to light gray, chalky, fossiliferous relatively pure calcium carbonate limestone. Occasionally the limestone is interlayered with thin streaks of light brown to tan dolomite layers.	Lower Limestone Of The Floridan Aquifer	Comprises a separate hydrogeologic unit in coastal Walton and Okaloosa counties. In other parts, cannot be hydrologically distinguished from upper limestone aquifer.
Middle Eocene	Claiborne	Lisbon/Tallahatta Formations	345-500 170-300	Massive shaly to chalky limestones often dark gray to brownish gray to cream in color. Thin shaly beds predominate in the more calcareous portions.	Claiborne Confining Unit	Predominantly impermeable strata. Comprises the base of the groundwater flow system.

HYDROLOGY

Confining Units

Pensacola Clay Confining Bed

Throughout almost all of southern Okaloosa and Walton counties, the Floridan Aquifer is overlain by relatively impermeable clay, sandy clay, or clayey sand of the Pensacola clay confining bed. Trapp and others (1977) named these sediments the Pensacola clay confining bed because they correspond approximately to the lower part of the Pensacola Clay of Marsh (1966). Trapp and others (1977) define the Pensacola Clay confining bed as "the material of relatively low permeability between the sand-and-gravel aquifer above and the Floridan Aquifer below. It may include material older, younger, or beyond the limits of the Pensacola Clay stratigraphic unit." Geologically, the unit is comprised of the Pensacola Clay, the Alum Bluff Group, and the Intracoastal Formation of Middle to Upper Miocene age. The Pensacola Clay confining bed dips generally to the south across Choctawhatchee Bay. Surrounding the bay, it occurs at depths ranging from 140 feet below sea level at Destin to five feet below sea level at Bluewater Bay, southeast of Niceville (Figure 1). The thickness of the unit ranges from 393 feet along the perimeter of the bay to less than 50 feet along the northeast shore of the bay, south of Freeport (Figure 2).

The Pensacola Clay confining bed consists predominantly of gray to bluish-black and light brown calcareous clay; light gray to brown, very fine to coarse, clayey sand; coarse, angular, clayey gravel; and some clayey limestone and shell fragments. In the area of investigation, the confining bed grades laterally from dense clay and sandy clay in the west to sandy clay, clayey sand and clayey limestone in the east. On the basis of geophysical and lithologic logs and aquifer tests, the average vertical hydraulic conductivity of the confining bed is estimated to range roughly from 1×10^{-2} to 1×10^{-6} ft/d. It averages about 1×10^{-5} ft/d in Okaloosa County and 1×10^{-3} ft/d in Walton County.

Bucatanua Clay Confining Bed

Where present, the Bucatanua Clay confining bed subdivides the Floridan Aquifer into the upper and lower limestones of the Floridan Aquifer. Geologically, the unit is composed of the Bucatanua Clay member of the Byram Formation and of other clastic unconsolidated materials of low permeability that occur between the two principal carbonate aquifers. The Bucatanua is present up to 15 miles north of Fort Walton Beach in Okaloosa County and generally is present in coastal Walton County (Figure 3). The confining bed dips

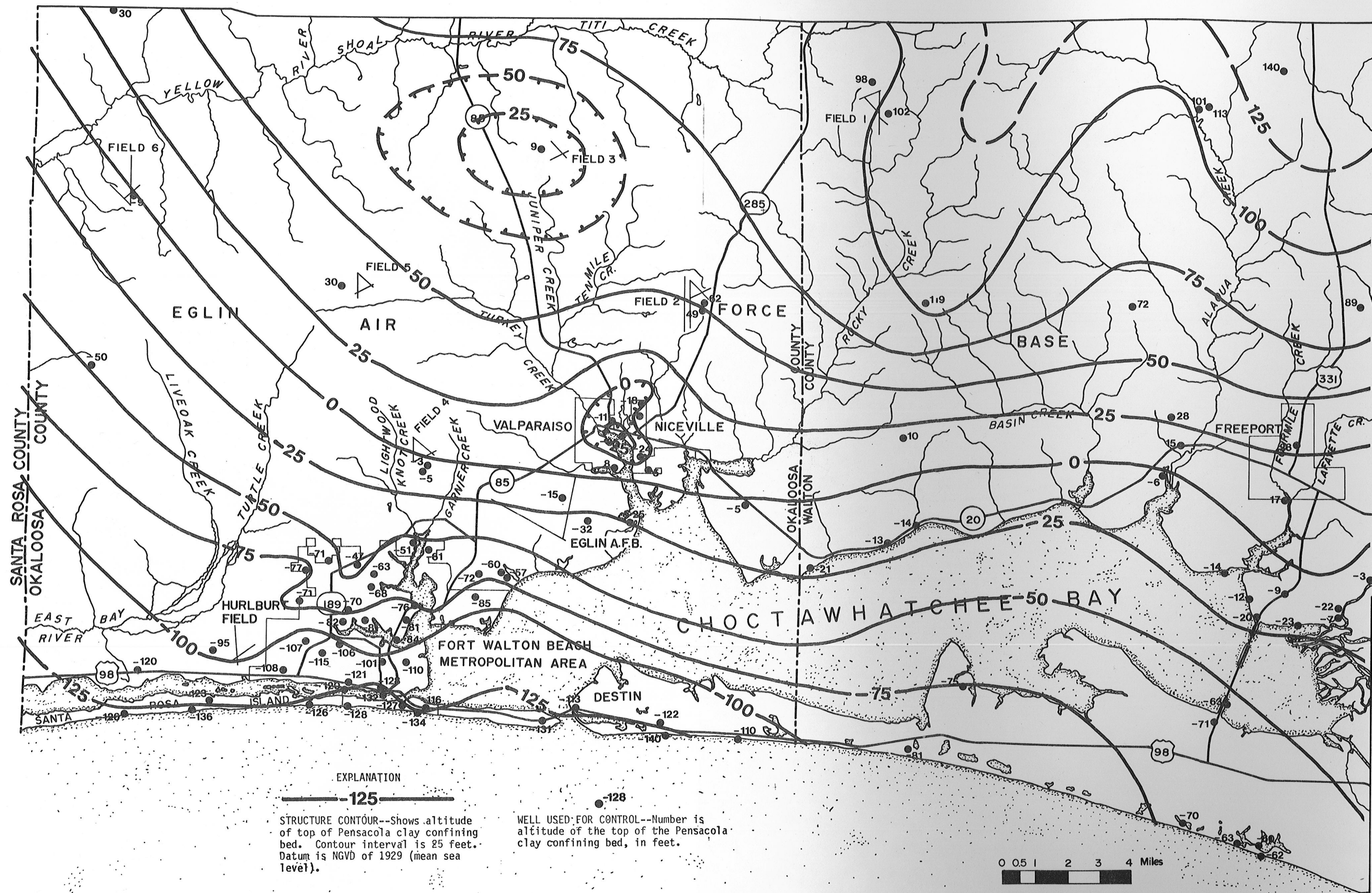


Figure 1. Map showing altitude of the top of the Pensacola clay confining bed

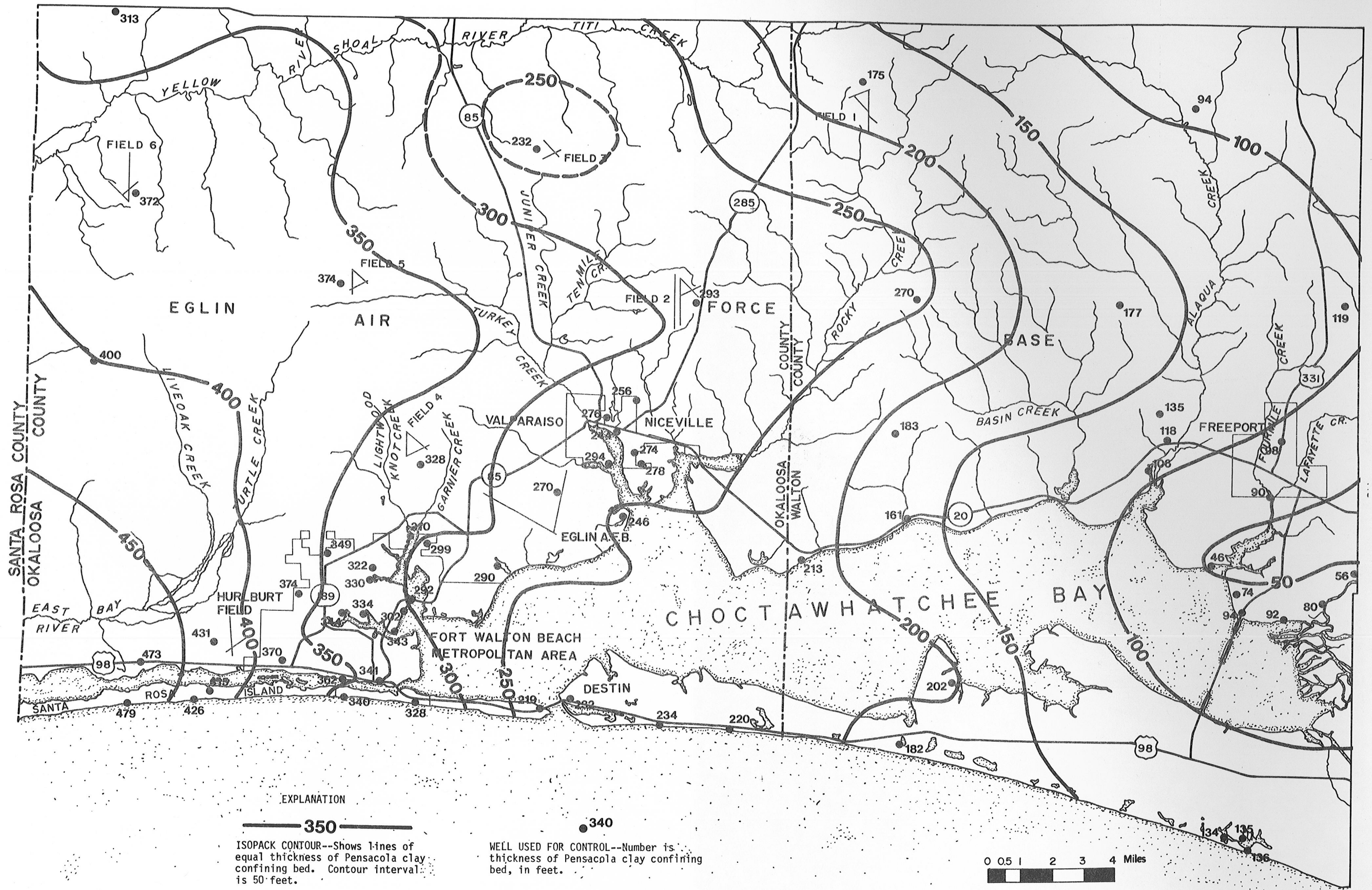


Figure 2 . Map showing thickness of the Pensacola clay confining bed

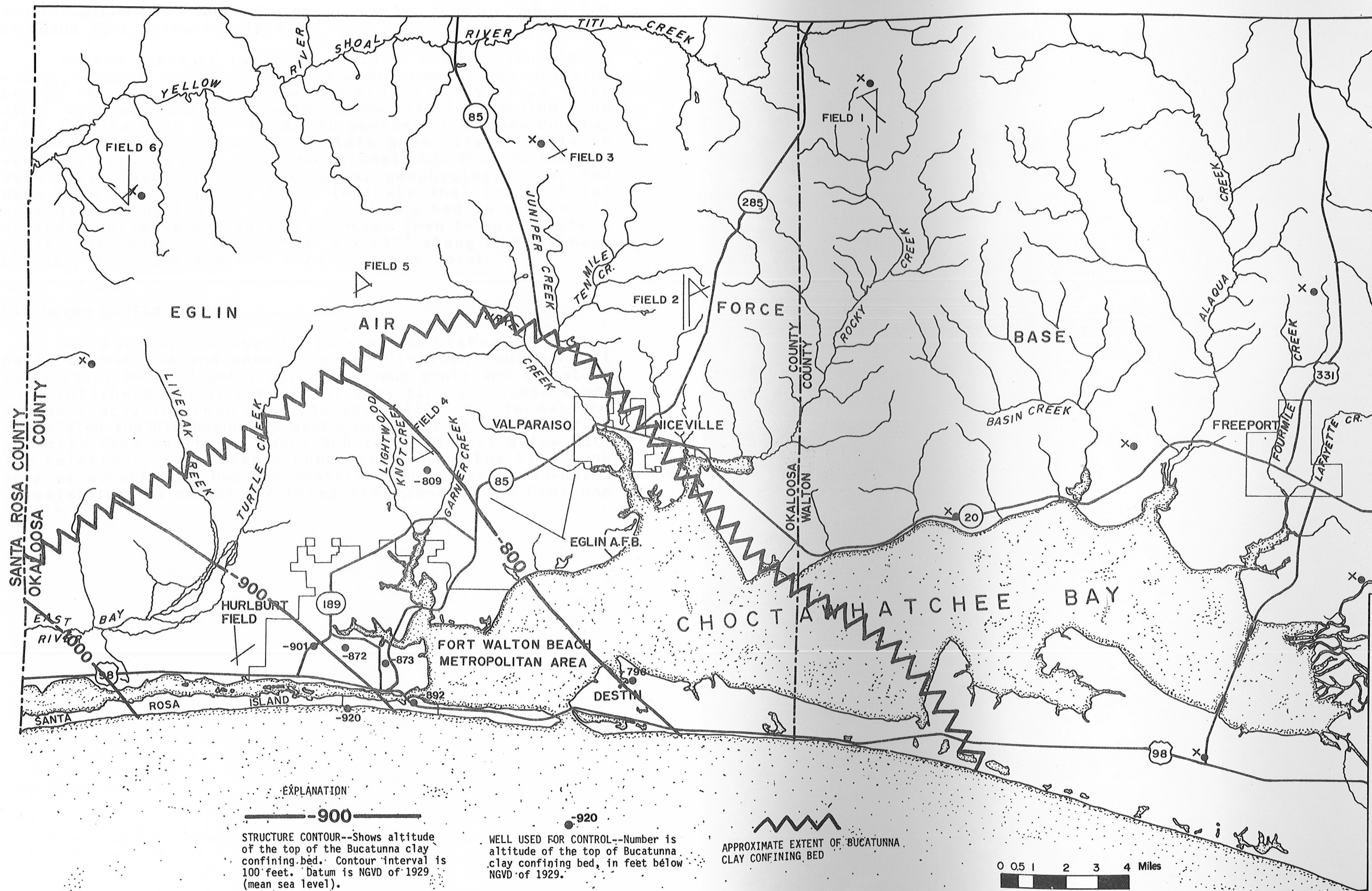


Figure 3. Map showing approximate altitude of the top and extent of the Bucatunna clay confining bed

south-southwest at about 25 feet per mile, from depths of 600 to 1,000 feet below sea level.

On the basis of two test wells in eastern Santa Rosa county, Pascale (1976) reported the Bucatunna Clay confining bed to consist of waxy, dark to medium gray, very dense clay, with vertical hydraulic conductivities ranging from 2.9×10^{-6} to 2.6×10^{-7} ft/d. In southern Okaloosa County, however, the confining bed consists generally of silty to sandy calcareous clay, with occasional thin beds of blue to dark gray clay. Drillers' samples, geophysical logs, and data from seven aquifer tests indicate that the vertical hydraulic conductivity of the confining bed is greater in southern Okaloosa and Walton counties than in southeastern Santa Rosa County. It is about 1×10^{-3} along the northern boundary and about 1×10^{-5} ft/d along the coast.

Claiborne Confining Unit

The Claiborne Stage consists of the Lisbon and Tallahatta formations and underlies the Floridan Aquifer. It consists of hard, light gray, calcareous shale and siltstone with interbedded gray limestone, very fine to coarse sand, and some gray to brown clay (Marsh, 1966). The formations comprising the Claiborne dip south-southwest at about 19 feet per mile from depths of about 500 to 1,400 feet below MSL. The relatively impermeable upper section of the Claiborne acts as a confining bed and restricts the vertical movement of water into or out of the lower limestone of the Floridan Aquifer.

SAND-AND-GRAVEL AQUIFER

General Description

The sand-and-gravel aquifer in the vicinity of Choctawhatchee Bay comprises sediments that range in age from late Miocene to Holocene. The aquifer covers all the land area surrounding the bay and extends from land surface to the top of the underlying Pensacola Clay confining bed (Figure 4). In the area surrounding the bay, the aquifer ranges, in thickness, from 150 feet at Destin to less than 20 feet along much of the northern perimeter of the bay in Walton County (Figure 4). In the Fort Walton Beach area and much of the Destin Peninsula from Destin to Santa Rosa Beach, differences in lithology and hydraulic properties allow the sand-and-gravel to be divided into at least three hydrologic zones, in descending order these are: a surficial zone (water table), an intermediate zone of relatively low permeability, and a main producing zone (artesian). Typically in these areas the surficial zone consists of white to light gray fine to medium sand extending from ground surface to a depth of 20 to 60 feet. Below the surficial zone are 10 to 65 feet - thick beds of clay, clayey sand and silty sand; the permeability of this zone varies widely, but is fairly low throughout the area. The lower main producing zone is usually the most permeable part of the aquifer; it consists of white to light brown medium to coarse sand and fine gravel. This zone generally functions as a confined (artesian) aquifer in that it is hydraulically separated from the surficial zone by the lower permeability intermediate zone. Aquifer tests conducted in southern Okaloosa County (see Hayes and Barr, 1982), and more recently in southern Walton County near Santa Rosa Beach produced drawdown responses typical of leaky confined aquifers. Along the northern perimeter of the bay, from Niceville to the eastern extent of the bay, only the surficial zone is present.

Quality of Water

Water from the sand-and-gravel aquifer usually has a dissolved solids concentration of less than 50 mg/l (Figure 5), a temperature of 20-25 degrees Celsius, and pH of 4.5-6.5. Chemical analyses and physical characteristics of water from the aquifer are summarized in Table 2; Table 3 lists major chemical constituents and physical properties of water from 11 wells open only to the main producing zone of the aquifer. Data in Table 4 show that chemical constituent concentration range, mean, and standard deviation are usually greater for water from the water-table zone than the main producing zone. For example, chloride concentration range, mean, and standard deviation in water from the water-table zone are, respectively 2.5-154, 22, and 29 mg/l; for water

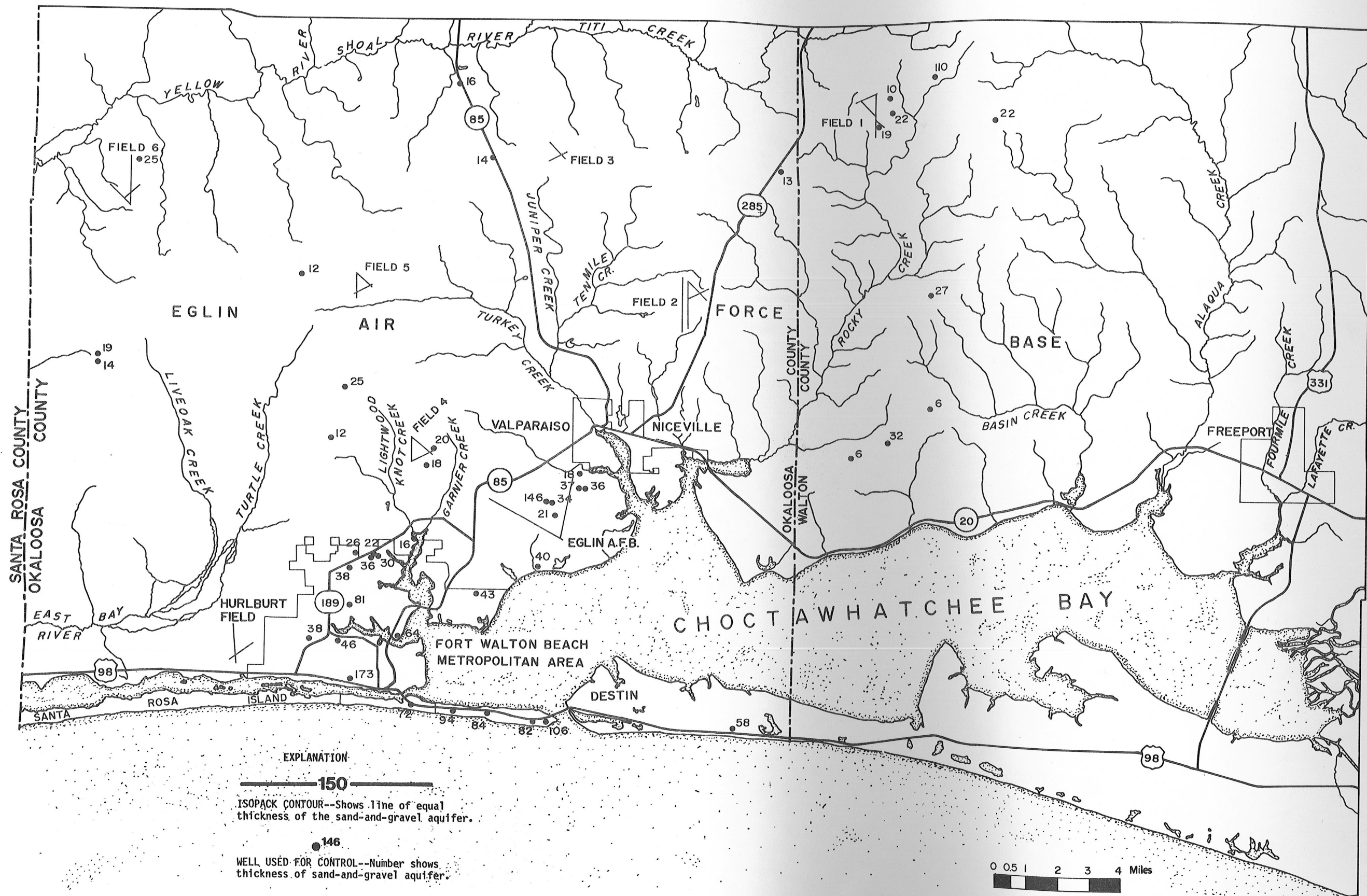


Figure 4. Lines of equal thickness of the sand-and-gravel aquifer

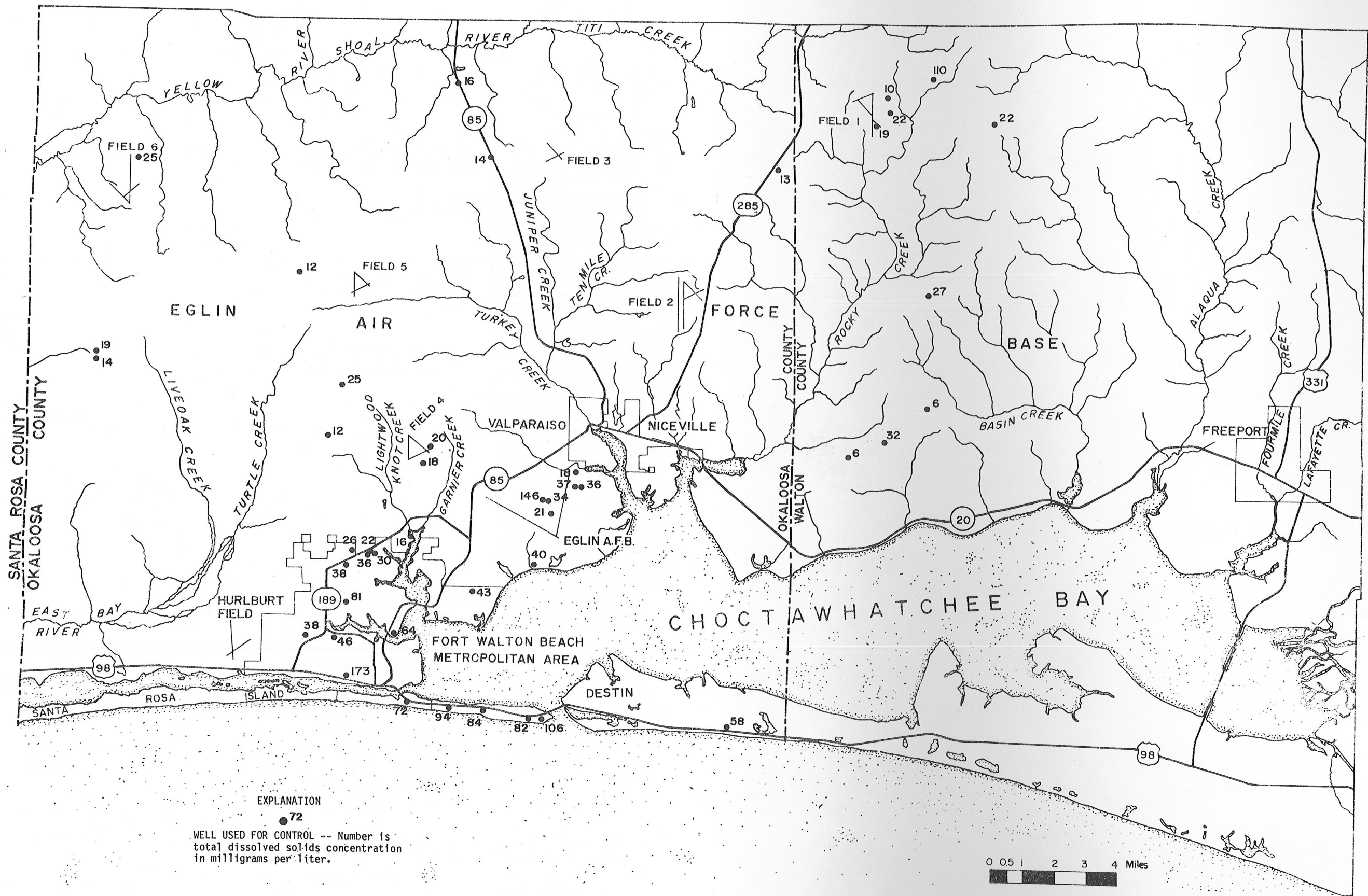


Figure 5. Map showing distribution of total dissolved solids in water from the sand-and-gravel aquifer in 1979

Table 2. -- Summary, source, and significance of chemical analyses of water from the water table zone (S) and the main producing zone (D) of the sand-and-gravel aquifer (results in milligrams per liter unless otherwise noted).

		Range	Mean	Standard deviation	Number of samples		
Bicarbonate (HCO ₃)	S	10 - 114	48	31	24	Action of carbon dioxide in water or carbonate minerals. Chief anion in all but the most highly mineralized water in the study area.	Causes carbonate hardness in combination with calcium or magnesium. Bicarbonate of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas.
	D	0 - 20	7	4	59		
Chloride (Cl)	S	2.5 - 154	22	29	24	Chloride salts, mainly NaCl, in consolidated rocks of marine origin. Abundant constituent of sea water.	In high concentrations imparts salty taste to water and makes water highly corrosive and makes water unsuitable for irrigation. May be removed by distillation, reverse osmosis or electrodialysis.
	D	0 - 15	4.4	3.4	73		
Fluoride (F)	S	0 - 0.5	0.2	0.1	24	Occurs in trace amounts in most of the soils and rocks.	Optimum concentrations tend to reduce tooth decay of children's teeth; large amounts may cause mottling of the enamel of teeth. Concentrations of more than 4 mg/L may affect bone structure.
	D	0 - 1.5	0.1	0.2	70		
Sulfate (SO ₄)	S	0 - 64	11	15	24	Gypsum, iron sulfides, and other sulfur compounds. Commonly present in many industrial wastes.	Sulfates of calcium and magnesium from hard scale and are cathartic and unpleasant to taste. Sulfide bearing ground water may contain hydrogen sulfide, which imparts a rotten egg odor to the water and may make water corrosive.
	D	0 - 14	2.0	3.0	70		
Dissolved solids	S	16 - 428	106	83	24	An approximation of the total quantity of dissolved mineral matter in a water sample.	The U.S. Geological Survey has classified water according to total dissolved solids in the following manner: fresh - less than 1,000 mg/L; slightly saline - 1,000 to 3,000 mg/L; moderately saline - 3,000 to 10,000 mg/L; very saline - 10,000 to 35,000 mg/L; briny - more than 35,000 mg/L.
	D	6 - 106	29	18	70		
Hardness (as CaCO ₃)	S	7 - 105	50	32	24	Hardness is attributable to the presence of all alkaline earth minerals but is primarily due to calcium and magnesium.	Hardness in water may be recognized by the lack of suds produced by soap. The U.S. Geological Survey has classified water according in the following manner: soft - 0-60 mg/L; moderately hard - 61-120 mg/L; hard - 121-180 mg/L; very hard - more than 180 mg/L. Moderately hard water is generally suitable for most purposes, but does increase soap consumption; hard water may be troublesome for some industrial and domestic uses. Hardness may be removed by passing the water through a zeolite-type water softener.
	D	1 - 23	7	5	66		
pH	S	5.7 - 7.7	6.9	0.5	24		Values of pH below 6.5 may cause corrosion, incrustations, and bitter taste.
	D	4.5 - 6.9	6.0	0.6	73		
Silica (SiO ₂)	S	2.8 - 22	7.3	4.4	30	Most abundant element in earth's crust resistant to solution.	Causes scale in boiler and deposits on turbine blades.
	D	0.5 - 14	5.1	2.6	59		
Iron (Fe)	S	0.01 - 4.3	0.70	1.23	27	Very abundant element, readily precipitates as hydroxide.	Stains laundry and porcelain, bad taste.
	D	0.01 - 3.1	0.54	0.80	63		
Calcium (Ca)	S	1.6 - 32	15	9.8	24	Limestone, dolomite, and gypsum are the most common sources.	Principal cause of hardness and commonly a major constituent in scale deposits.
	D	0.0 - 6.6	1.5	1.4	70		
Magnesium (Mg)	S	0.4 - 5.7	2.7	2.9	24	Dissolved from almost all rocks present in the area but primarily the ferro-magnesium materials and magnesium carbonate. Is an abundant constituent of sea water.	Second of the major causes of hardness.
	D	0.0 - 2.1	0.7	0.5	70		
Nitrate (NO ₃)	S	0.0 - 20	1.7	4.6	36	Domestic sewage effluents, animal and plant processing wastes, animal manure, fertilizers and agriculture runoff and decayed organic matter.	Relative high values may be an indication of pollution. Concentrations greater than 45 mg/L may cause cyanosis "blue baby".
	D	0.0 - 8.8	1.4	2.4	52		
Potassium (K)	S	0.0 - 4.8	1.2	1.1	24	Same as sodium.	Small amount essential for proper plant nutrition.
Sodium (Na)	S	1.7 - 80	13	15	24	Dissolved from almost all rocks present in the area and an abundant constituent of sea water.	Large amounts in combination with chloride may give water a salty taste. Excessive amounts may reduce soil permeability and limit use of water for irrigation. Concentrations larger than 50 mg/L may cause foaming in boiler water.
	D	0.8 - 15	3.3	2.7	70		

TABLE 3.--MAJOR CHEMICAL CONSTITUENTS AND PHYSICAL PROPERTIES OF WATER FROM THE MAIN PRODUCING ZONE

OF THE SAND-AND-GRAVEL AQUIFER IN THE FORT WALTON BEACH AREA

(Results in milligrams per liter except where noted)

PARAMETER	MAP LOCATION NUMBER										
	111	129	134	178	189	210	213	216	222	224	279
Date of collection	06/14/79	06/14/79	06/14/79	06/14/79	06/14/79	01/16/79	01/16/79	01/16/79	01/16/79	06/27/78	06/14/79
Bicarbonate (HCO_3)	18	6	2	5	5	6	5	7	5	0	41
Calcium (Ca)	5.5	1.6	1.0	5.9	2.7	1.7	1.5	1.2	1.3	0.4	6.6
Chloride (Cl)	11	9.2	9.5	15	8.0	10	6.4	6.1	4.1	4.5	3.5
Dissolved solids (residue at 180°C)	52	38	46	81	43	38	36	30	22	26	69
Fluoride (F)	0.1	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.1
Hardness (as CaCO_3):											
Total	20	8	9	23	12	10	7	6	6	3	20
Noncarbonate											
Total	2	2	7	18	7	4	2	0	1	3	0
Iron (Fe)	0.14	0.41	0.54	0.16	0.34	--	--	--	--	--	0.80
Magnesium (Mg)	1.6	1.0	1.5	2.0	1.2	1.4	0.9	0.8	0.6	0.4	0.8
Nitrate (NO_3)	--	--	--	--	--	0.54	1.10	0.83	0.25	--	--
pH (units)	5.2	4.5	4.7	5.2	4.7	5.2	4.8	5.3	5.7	4.6	6.1
Potassium (K)	6.4	5.4	0.2	2.6	0.5	0.7	1.0	0.7	0.5	0.2	0.9
Silica (SiO_2)	13	7.0	7.3	4.5	6.0	4.2	4.8	3.7	3.6	3.5	5.1
Sodium (Na)	13	6.5	6.7	13	8.0	6.6	5.0	4.8	2.8	2.2	15
Sulfate (SO_4)	3.3	5.6	7.5	14	4.0	6.5	5.0	2.8	3.0	0.6	7.4
Specific conductance (micromhos at 25°C)	67	53	55	130	62	53	42	34	22	27	103
Temperature (°C)	22.0	22.5	22.5	21.5	23.0	20.5	21.0	20.5	20.5	22.0	23.0

from the main producing zone, 0-15, 4.4, and 3.4 mg/l, respectively. The range, mean and greater variability of chemical constituents in water from the water-table zone most likely result from contamination by surface water sources, such as saline water from Choctawhatchee Bay and the Gulf of Mexico. The water-table zone is also more likely to be contaminated by sewage effluent and other pollutants arising from man's activities.

FLORIDAN AQUIFER

General Description

The principal source of potable water in the area around Choctawhatchee Bay is the Floridan Aquifer. This regionally extensive aquifer is composed primarily of limestone and dolomite of Upper Eocene to Miocene age. The geologic units which comprise this aquifer consist of, in descending order: the Bruce Creek Formation, Tampa Stage limestone, Chickasawhay Formation, and the Ocala Group. Ground-water storage and movement within the aquifer take place through a combination of small solution fissures, larger cavities, and solution channels. Water in the aquifer occurs under confined or artesian conditions throughout the study area.

In general the top of the Floridan Aquifer corresponds to the top of the Bruce Creek Formation (Figure 6). It is a gently sloping surface which dips toward the southwest. Near Freeport, the top of the aquifer lies at an elevation of approximately 100 feet below mean sea level. To the west at Fort Walton Beach, the top has an elevation of approximately 450 feet below mean sea level.

Lithologically, the Bruce Creek Formation consists of white to gray, fine grained, fossiliferous, moderately indurated limestone with traces of clay and sand. In this area, the basal portion of the Bruce Creek Formation may include lenses of loose, fine grained to gravel sized quartz sand and blue-green clay. The thickness of this formation ranges from 100 to 170 feet. Owing to its distinctive, predominantly limestone lithology, the Bruce Creek Formation is readily distinguishable from the overlying and underlying geologic units.

Underlying the Bruce Creek Formation are the Tampa Stage limestones and the Chickasawhay Formation. The Tampa Stage limestones present in the Choctawhatchee Bay area are part of the Chattahoochee Formation (Schmidt, 1983). These two formations are grouped into one undifferentiated unit due to the difficulty of distinguishing between them. This difficulty arises from the fact that both units consist of white, moderately to well indurated, fine grained limestone, dolomitic limestone and well indurated, tan, sucrosic dolomite.

These three limestone units comprise the upper limestone of the Floridan Aquifer. Although these carbonate rocks differ vertically and horizontally in texture, porosity and permeability, they can be treated as a single hydrologic unit in that their internal hydrologic dissimilarities are

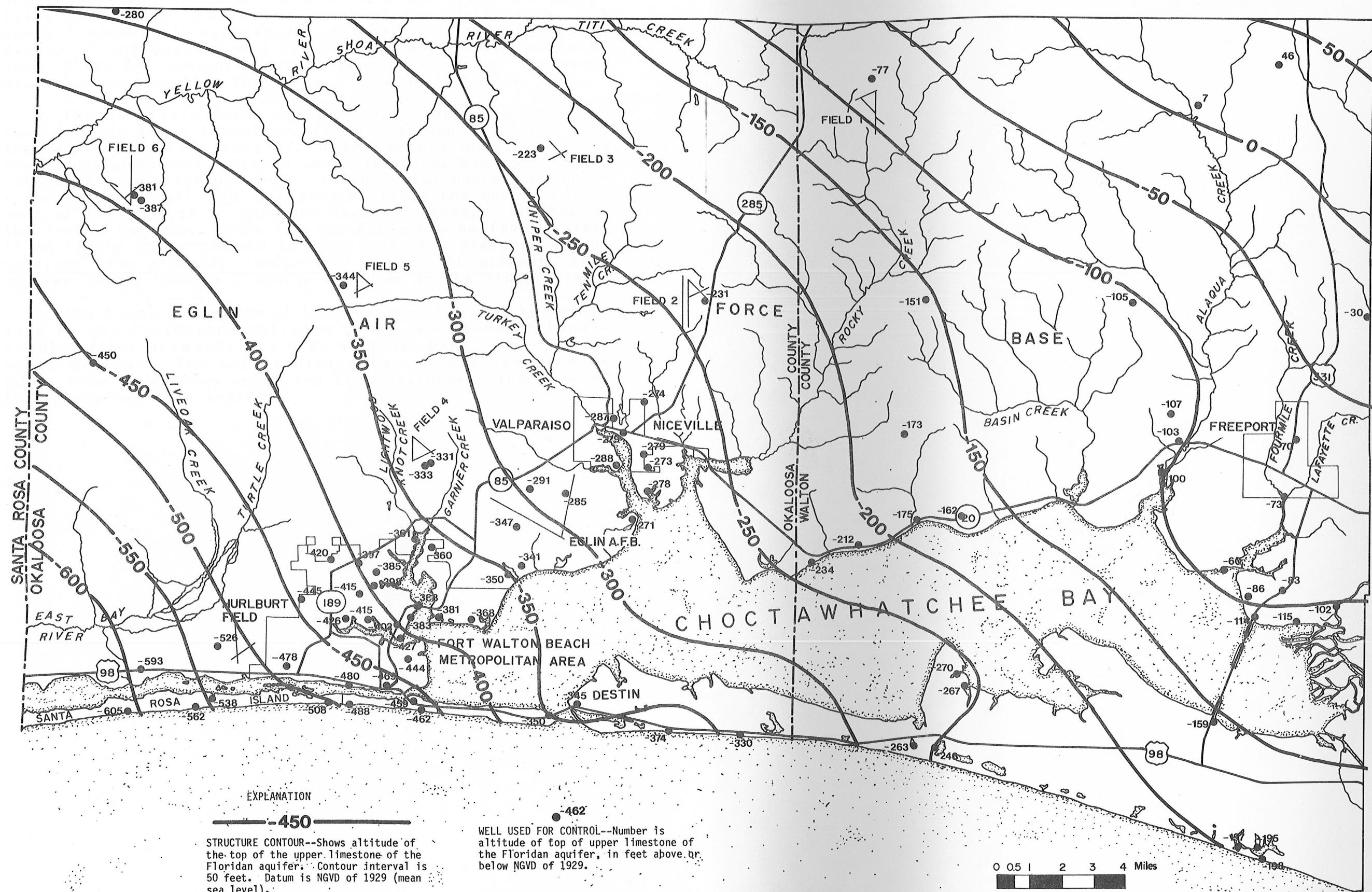


Figure 6. Map showing altitude of the top of the Floridan aquifer

small compared to dissimilarities with overlying and underlying units. In the western part of the study area, the upper limestone is hydrologically separated from the limestones of the Ocala Group by the Bucatunna Clay confining bed. Where the confining bed is absent, the upper limestone directly overlies the limestones of the Ocala Group.

The carbonate rocks of the Ocala Group of Eocene age comprise the lower limestone of the Floridan Aquifer. Like the upper limestone aquifer, water occurs under confined conditions and moves through the aquifer via microscopic and macroscopic solution openings. Saline water containing chlorides in excess of 1,000 ppm occurs within the entire thickness of the aquifer in southern Okaloosa County. Further to the north, however, where the aquifer contains fresh water, it is likely that moderate to high sustained yields could be obtained from properly constructed wells. At present, this aquifer is not used as a source of water in the study area.

The lower limestone of the Floridan Aquifer is underlain by the Claiborne confining unit, comprised of impermeable or low permeability beds of dense sand, shale, clay, and limestone. The unit inhibits the upward movement of water from underlying units and also delineates the base of the subsurface flow regime.

Quality of Water

Information on the chemical quality of water from the upper limestone of the Floridan Aquifer is available throughout the study area. Most of this data was generated as by-products of three studies: a water resource investigation of Walton County, initiated in 1968 and completed in 1970 (Pascale, 1974, and Pascale and others, 1972); a water resources investigation of Okaloosa County, initiated in 1966 and completed in 1969 (Trapp and others, 1977, and Foster and Pascale, 1971); and a water resources investigation of the southern part of Okaloosa and Walton counties, initiated in 1977 and completed in 1980 (Barr and others, 1981). Additional water quality data are available for U. S. Geological Survey monitor wells, which are maintained as a part of a regional monitoring network covering northwest Florida.

Distribution of Major Inorganic Constituents

Water from the upper limestone of the Floridan Aquifer is generally of suitable quality for most uses. Water temperature generally varies between 20 and 25 degrees centigrade but is nearly constant in any individual well. Hardness, as calcium carbonate, is usually below 150 milligrams per liter (mg/l), the pH usually ranges between 7.5 and 8.5, and the chloride concentration is normally less than 10 mg/l. In coastal areas, however, chloride concentrations usually range between 25 and 75 mg/l, except in more seriously degraded areas where chloride concentrations exceed 250 mg/l. Table 4 provides a summary of the source and significance of major inorganic constituents and pH of water from the upper limestone of the Floridan Aquifer.

The predominant ion in Floridan Aquifer water is bicarbonate, which occurs at concentrations of approximately 100 mg/l over the entire study area. Concentrations range from slightly under 100 mg/l in west-central Walton County to over 250 mg/l in western Okaloosa County (Figure 7).

In Walton County, the sodium concentration in the water from the upper limestone aquifer is greater in the southeastern parts of the county than in the more northern areas. Water from some wells in this area has a sodium concentration which exceeds 250 mg/l (Figure 8). High sodium concentrations, ranging from 49 to 170 mg/l, are also found in southwestern Okaloosa County. An increase in chloride concentrations normally accompanies an increase in sodium within the study area. High chloride concentrations, in some wells greater than 250 mg/l, occur in southeastern Walton County and southwestern Okaloosa County (Figure 9).

Table 4.--Sources, significance, and concentration ranges of major chemical constituents in water from the upper part of the Floridan aquifer in southern Okaloosa and Walton counties

(For each constituent there are four rows of values: rows 1, 2, 3, and 4 refer, respectively, to samples from Walton County south of latitude 30° 30' 00", Walton County north of latitude 30° 30' 30", Okaloosa County south of latitude 30° 28' 58", and Okaloosa County north of latitude 30° 28' 58".)

Constituent	Concentration range			Principal sources	Significance with respect to use
	Mean	Minimum	Maximum		
Calcium (Ca)	29	15	49	Limestone, dolomite, and gypsum are the most common sources.	Principal cause of hardness and commonly a major constituent in scale deposits.
	24	17	29		
	13	2.5	29		
	23	3	33		
Magnesium (Mg)	20	7.3	37	Dissolved from almost all rocks present in the area but primarily the ferro-magnesium minerals and magnesium carbonate; is an abundant constituent of sea water.	Second of the major causes of hardness.
	12	8.5	16		
	8	1.0	24		
	14	1.9	19		
Potassium (K)	4.3	1.6	8.6	Same as sodium.	Small amounts essential for proper plant nutrition.
	2.4	1.4	3.1		
	4.7	0.6	11		
	3.0	1.3	5.9		
Sodium	179	3.3	450	Dissolved from almost all rocks present in the area and an abundant constituent of sea water.	Large amounts in combination with chloride may give water a salty taste. Excessive amounts may reduce soil permeability and limit use of water for irrigation. Concentrations larger than 50 mg/L may cause foaming in boiler water.
	6.6	1.6	10		
	16	6.0	291		
	23	3.8	140		
Bicarbonate	147	80	198	Action of carbon dioxide in water or carbonate minerals. Chief anion in all but the most highly mineralized water in the study area.	Causes carbonate hardness in combination with calcium or magnesium. Bicarbonate of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas.
	139	92	152		
	198	78	326		
	167	91	308		
Chloride (Cl)	326	2.0	760	Chloride salts, mainly NaCl, in consolidated rocks of marine origin. Abundant constituent of sea water.	In high concentrations imparts salty taste to water, makes water highly corrosive, and unsuitable for irrigation. May be removed by distillation, reverse osmosis or electrodialysis.
	3.3	1.0	11		
	45	2.4	280		
	8.2	1.0	57		
Fluoride (F)	0.7	0.2	1.5	Occurs in trace amounts in most of the soils and rocks.	Optimum concentrations tend to reduce tooth decay of children's teeth; larger amounts may cause mottling of the enamel of teeth. Concentrations of more than 4 mg/L may affect bone structure.
	0.2	0	0.9		
	0.7	0.1	5.0		
	0.3	0	1.6		
Sulfate (SO ₄)	22	0	67	Gypsum, iron sulfides, and other sulfur compounds. Commonly present in many industrial wastes.	Sulfates of calcium and magnesium form hard scale and are cathartic and unpleasant to taste. Sulfide bearing ground water may contain hydrogen sulfide which imparts a rotten egg odor to the water and may make water corrosive.
	8.0	0	11		
	7.7	0	26		
	7.9	0	37		
Dissolved Solids	539	184	1,040	An approximation of the total quantity of dissolved mineral matter in a water sample.	The U.S. Geological Survey has classified water according to total dissolved solids in the following manner: fresh - less than 1,000 mg/L; slightly saline - 1,000 to 3,000 mg/L; moderately saline - 3,000 to 10,000 mg/L; very saline - 10,000 to 35,000 mg/L; briny - more than 35,000 mg/L.
	133	101	151		
	266	143	744		
	174	116	368		
Hardness (as CaCO ₃)	160	68	280	Hardness is attributable to the presence of all alkaline earth minerals but is primarily due to calcium and magnesium.	Hardness in water may be recognized by the lack of suds produced by soap. The U.S. Geological Survey has classified water according to hardness in the following manner: soft - 0 to 60 mg/L; moderately hard - 61 to 120 mg/L; hard - 121 to 180 mg/L; very hard - more than 180 mg/L. Moderately hard water is generally suitable for most purposes, but does increase soap consumption; hard water may be troublesome for some industrial and domestic uses. Hardness may be removed by passing the water through a zeolite-type water softener.
	109	2	132		
	64	14	169		
	111	26	166		

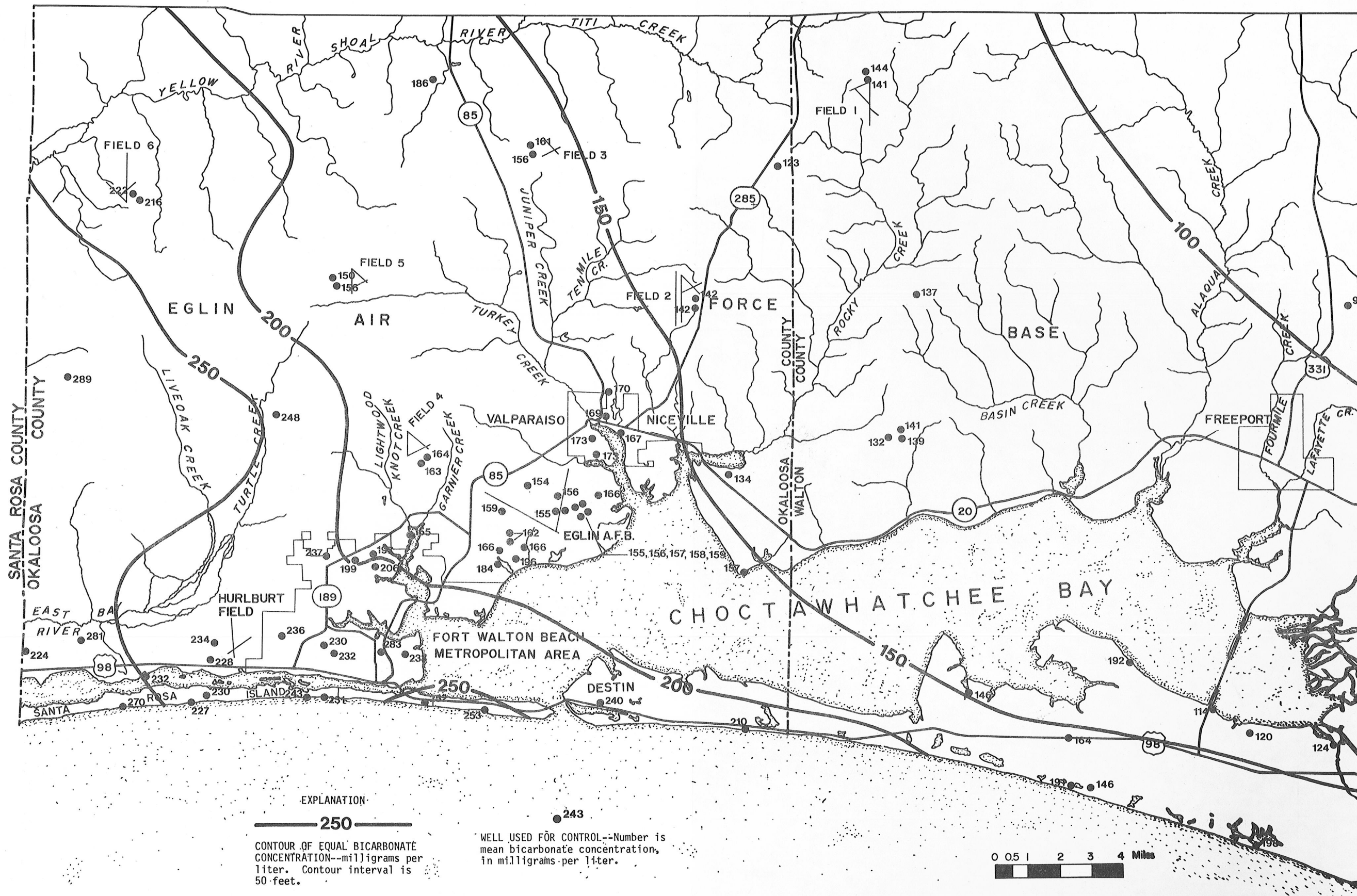


Figure 7. Map showing mean bicarbonate concentrations in water from the upper limestone of the Floridan aquifer

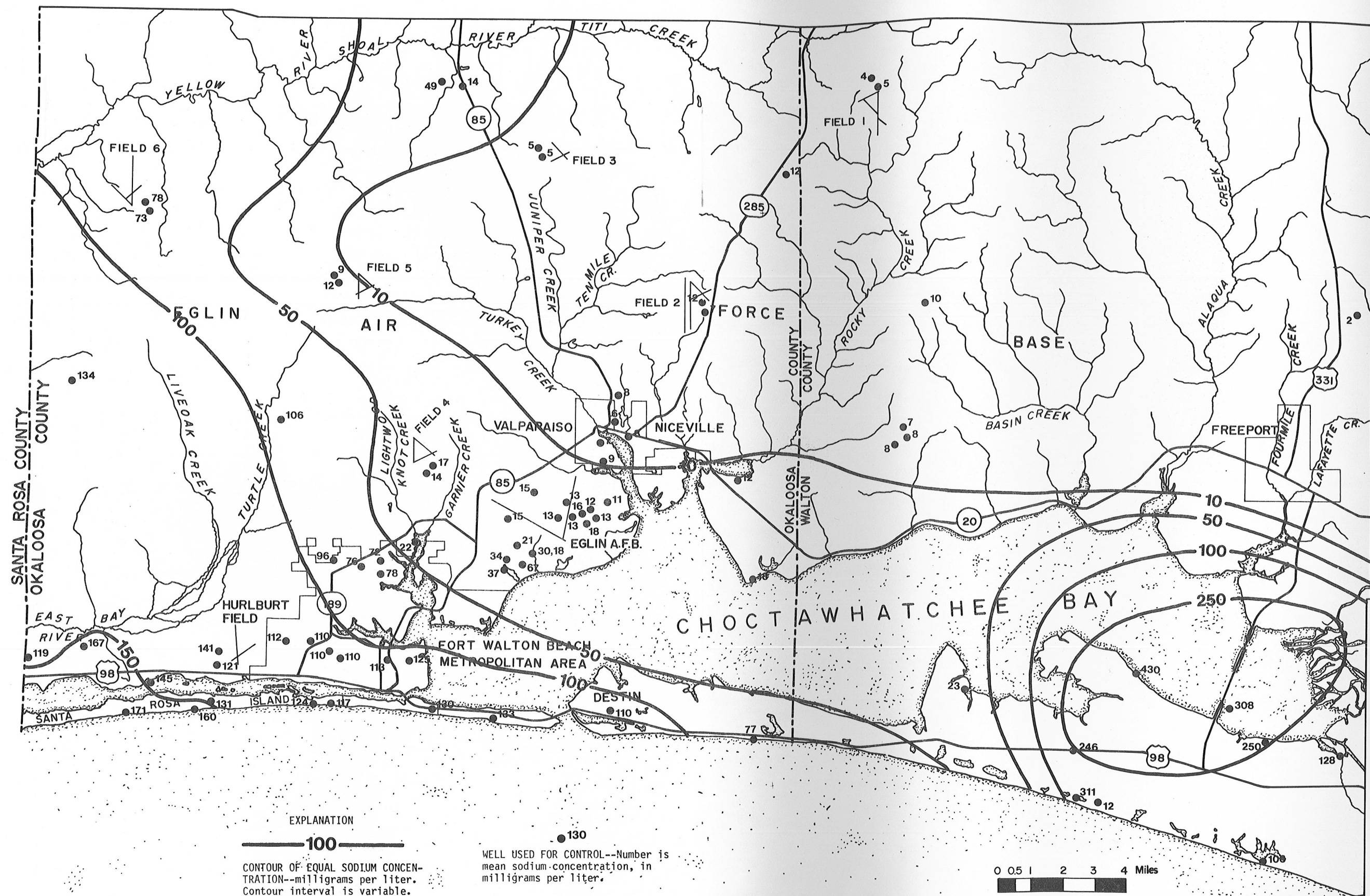


Figure 8. Map showing mean sodium concentrations in water from the upper limestone of the Floridan aquifer

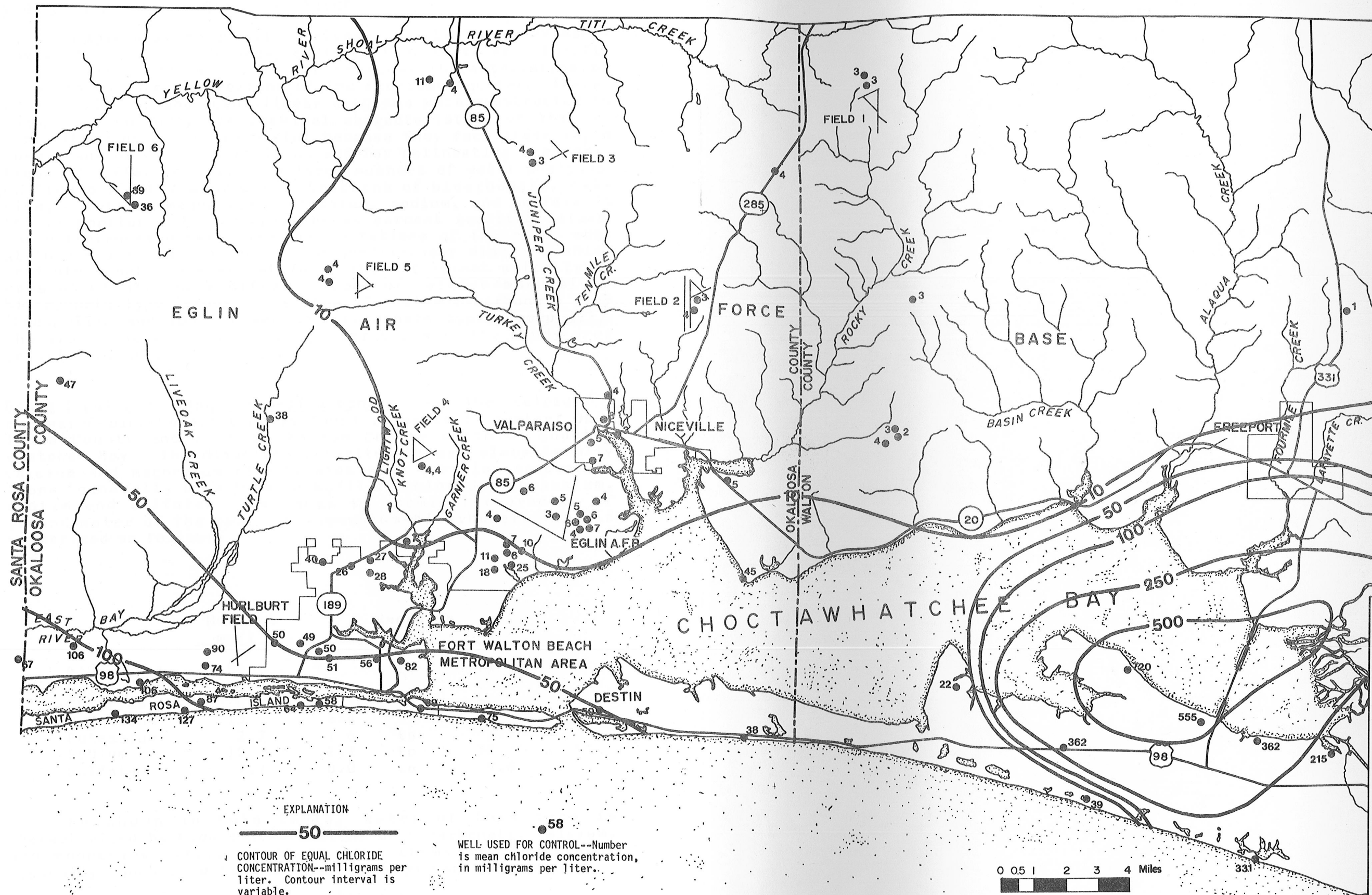


Figure 9. Map showing mean chloride concentrations in water from the upper limestone of the Floridan aquifer

Character and Geochemistry of Water

Complete water quality analyses, available for 79 monitor wells in the study area, indicate that there are significant lateral differences in the chemical characteristics of water in the upper limestone of the Floridan Aquifer. Therefore, trilinear and quadrilinear diagrams were constructed to graphically display the chemical characteristics of the water. These diagrams are useful because they facilitate rapid comparison of chemical analyses and for delineating similarities and differences between large numbers of water analyses. On Figure 10, the mean concentrations of bicarbonate, calcium, chloride, magnesium, potassium, sodium, and sulfate in the 79 monitor wells are plotted as percent reacting values. The differences between the concentrations of the major constituents are most obvious on the quadrilinear diagram, which indicates that there are at least three distinct water types present within the aquifer: a zone of calcium/magnesium-bicarbonate type (Group I), a zone of sodium-bicarbonate type (Group II), and zone of sodium-bicarbonate type (Group III). The distribution of the three water types in the study area is illustrated on Figure 11.

Group I Calcium / Magnesium-Bicarbonate -- The calcium/magnesium-bicarbonate type is found in wells in central Okaloosa County and most of Walton County north of Choctawhatchee Bay. The dissolved constituents are almost wholly calcium and magnesium bicarbonates with very low concentrations (generally less than 10 mg/l) of chloride, potassium, sodium and sulfate. The range in chemical character of ground water of the calcium/magnesium-bicarbonate type is summarized as follows:

	Mean in mg/l	Range in mg/l		
Bicarbonate	152	92	to	173
Calcium	23	16	to	33
Chloride	6.2	1.2	to	45
Magnesium	13	8.4	to	18
Potassium	2.7	1.6	to	3.7
Sodium	12	2.1	to	34
Sulfate	7.7	0.0	to	9.6

As shown in this table, water of this type is characterized by high concentrations of bicarbonate, calcium, and magnesium. Each of these is a chemical constituent typically found in waters flowing through carbonate rocks.

Group II Sodium-Chloride-Bicarbonate Type -- Water of a sodium-chloride type occurs in southeastern Walton County. The area covers a large portion of the Destin peninsula south of Choctawhatchee Bay and a smaller area adjacent to the northern shore of the bay on each side of Highway 331. Chloride and sodium are the predominant anion and cation. The range in general chemical character of ground water of the sodium-chloride type is as follows:

	Mean in mg/l	Range in mg/l		
Bicarbonate	166	114	to	227
Calcium	30	5.5	to	49
Chloride	404	127	to	720
Magnesium	22	3.6	to	37
Potassium	5.9	3.7	to	8.6
Sodium	245	106	to	405
Sulfate	27	16	to	67

The chemical character of the water found in these areas is similar to the Group I waters with the exception of chloride, sodium, and sulfate. Salinity generally increases with depth in the area (Pascale, 1974), indicating that the source of the high chlorides in some wells is attributable to upward migration of saline water from depth. In still other areas, immediately adjacent to saline surface water bodies, it is probable that the Group II waters represent a mixture of Group I water with modern seawater which has moved downward from Choctawhatchee Bay and/or the Gulf of Mexico either through a direct connection between the Floridan Aquifer and the salt water or by downward movement through the Pensacola Clay confining bed where it is thin or absent.

Group III Sodium - Bicarbonate Type -- Water of a sodium-bicarbonate type is obtained from wells along the coast in the westernmost parts of southern Okaloosa County. Typically, the water has higher concentrations of sodium, chloride, and bicarbonate and lower concentrations of calcium and magnesium than waters in Groups I and II. The range in concentrations of the major inorganic constituents is summarized as follows:

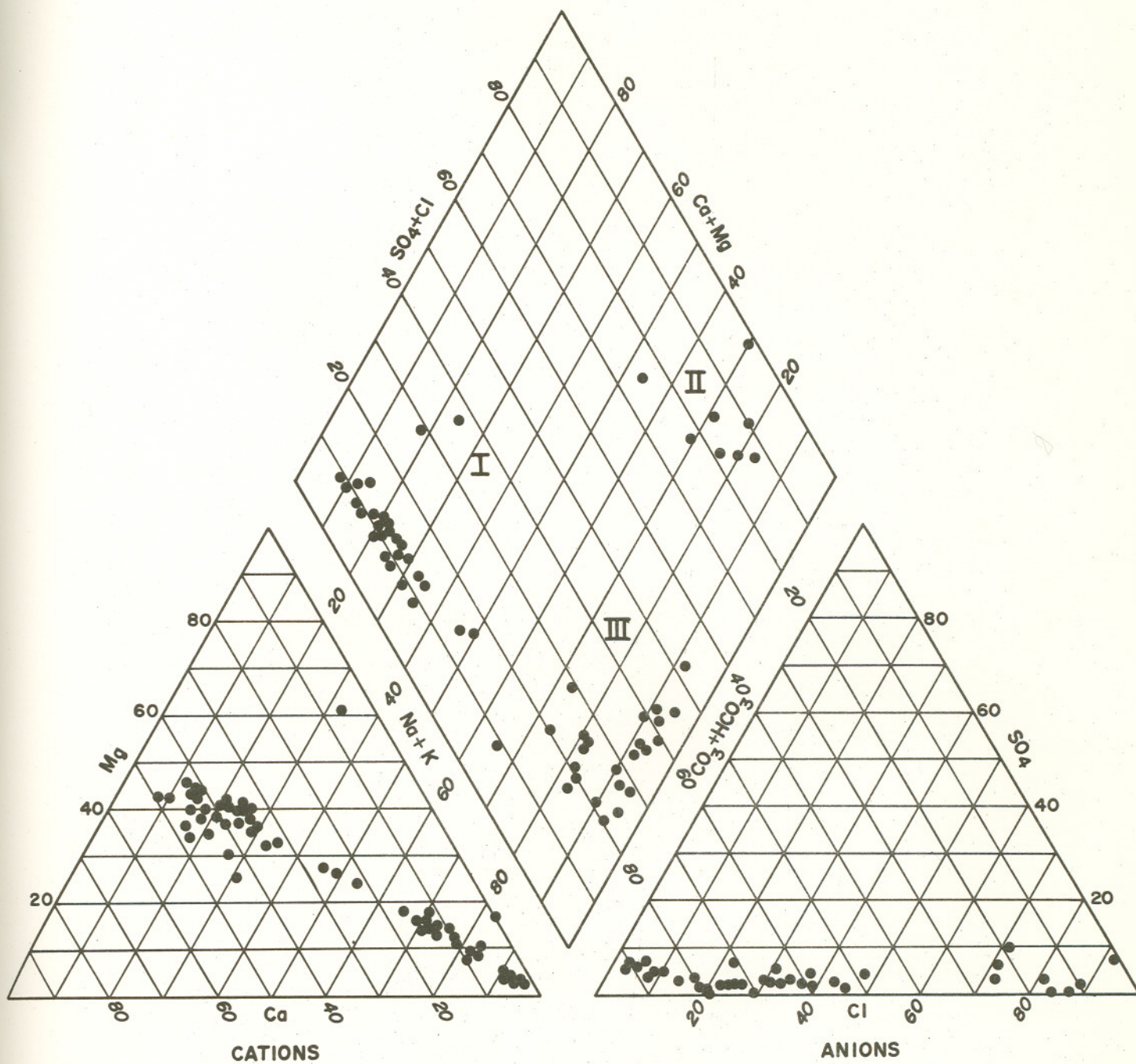


Figure 10. Quadrilinear and trilinear diagrams of mean concentrations of major inorganic constituents

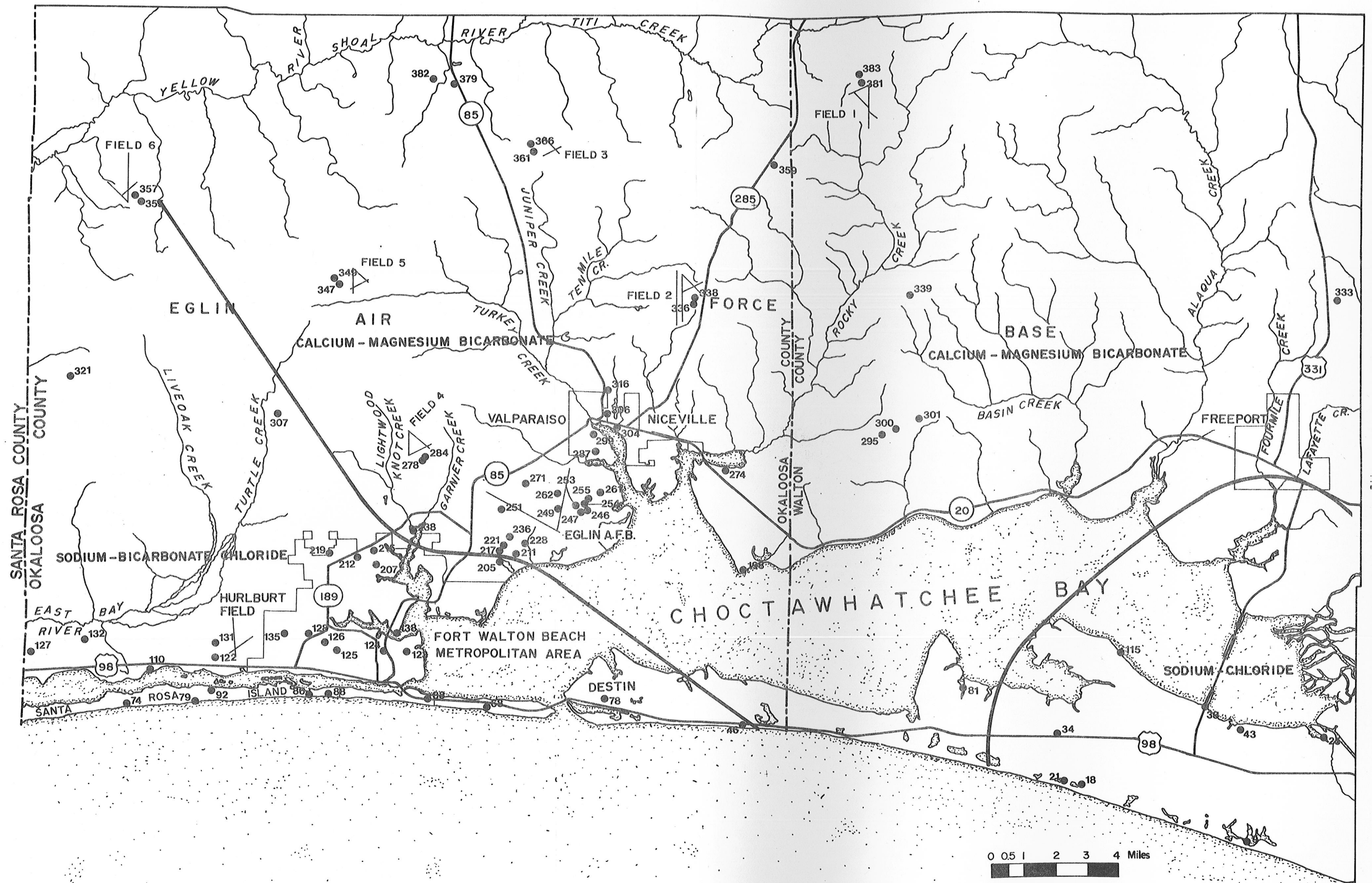


Figure 11. Map showing location of hydrochemical facies

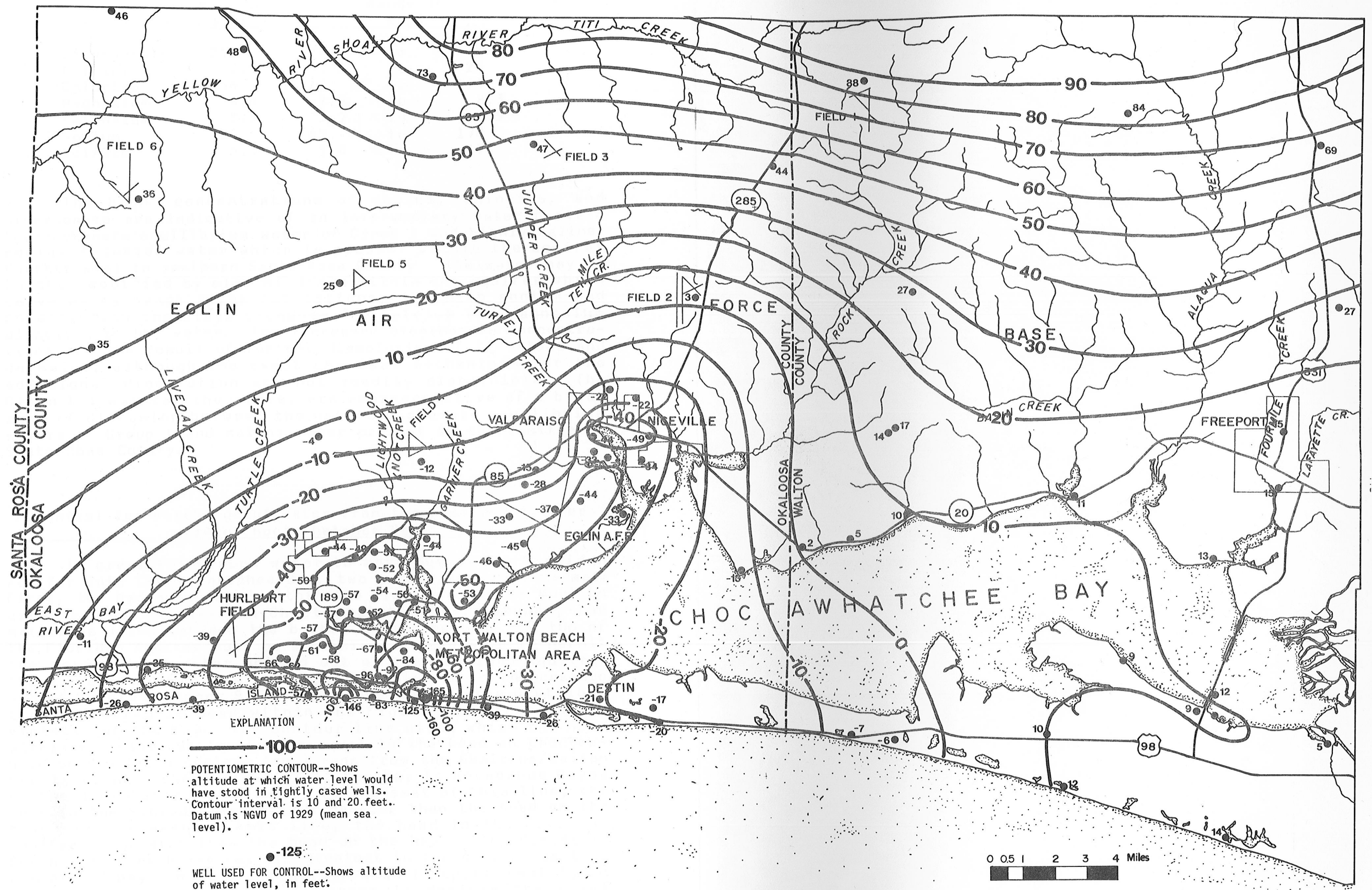


Figure 12. Map showing the potentiometric surface of the upper limestone of the Floridan aquifer in July 1978

	Mean in mg/l	Range in mg/l		
Bicarbonate	241	170	to	335
Calcium	7.3	3.1	to	26
Chloride	56	11	to	134
Magnesium	4.4	2.8	to	8.3
Potassium	5.5	3.7	to	7.9
Sodium	108	49	to	170
Sulfate	5.3	1.4	to	17

The high concentrations of sodium, chloride, and bicarbonate are indicative of an intermediary water between the carbonate equilibrium water of Group I and highly saline, sodium-chloride water which is present within the aquifer further west in southern Santa Rosa County. The water may be further modified by clay minerals within the aquifer which serve as exchange sites for cations, in which sodium and potassium in the clays exchange for calcium and magnesium dissolved in the water. The increased bicarbonate concentrations are the result of further dissolution of limestone and dolomite, although the exact chemical mechanisms for the additional dissolution are not readily discernible. The Group III waters, therefore, are representative of a broad zone of diffusion between the native carbonate equilibrium waters of Group I and saline water present in the aquifer in Santa Rosa County.

Potential for Discharge of Water from the Floridan Aquifer into Choctawhatchee Bay

In order for ground water to move out of the Floridan Aquifer into Choctawhatchee Bay, two conditions must be met. First, the hydraulic head within the Floridan Aquifer must be greater than the head on Choctawhatchee Bay. Second, the materials lying between the bottom of the bay and the top of the Floridan Aquifer must be sufficiently permeable to permit the movement of water upward out of the Floridan Aquifer. These two conditions are most nearly satisfied in the eastern end of Choctawhatchee Bay. Figure 12 depicts the distribution of hydraulic head within the Floridan Aquifer in the vicinity of the bay. The contour line along which the head within the Floridan Aquifer is equal to the head on Choctawhatchee Bay (zero contour line) runs from the Okaloosa/Walton County line on the north side of the bay to Horseshoe Bayou on the south side of the bay. To the east of this line, the head in the Floridan Aquifer is greater than the head on the bay. To the east of this line, the head in the Floridan Aquifer is greater than the head on the bay. Floridan Aquifer heads beneath the bay are greatest in the extreme eastern end of the bay. Here the Floridan head is approximately 20 feet above mean sea level. Figure 13 depicts the areal

distribution of Pensacola Clay confining bed leakance coefficient for the area around the bay. The leakance coefficients are highest in the extreme eastern end of the bay and decrease toward the west.

The potential for movement of water out of the Floridan Aquifer into Choctawhatchee Bay is greatest in the extreme eastern end of the bay south of Freeport. Elsewhere, the combination of Floridan hydraulic heads at or below sea level and low leakance coefficient effectively preclude the upward movement of water. The extent to which water is interchanged in the eastern end of the bay is unknown. However, it is safe to say that the contribution of water to the bay from the Floridan Aquifer is minor, if it exists at all, when compared to other sources of water.

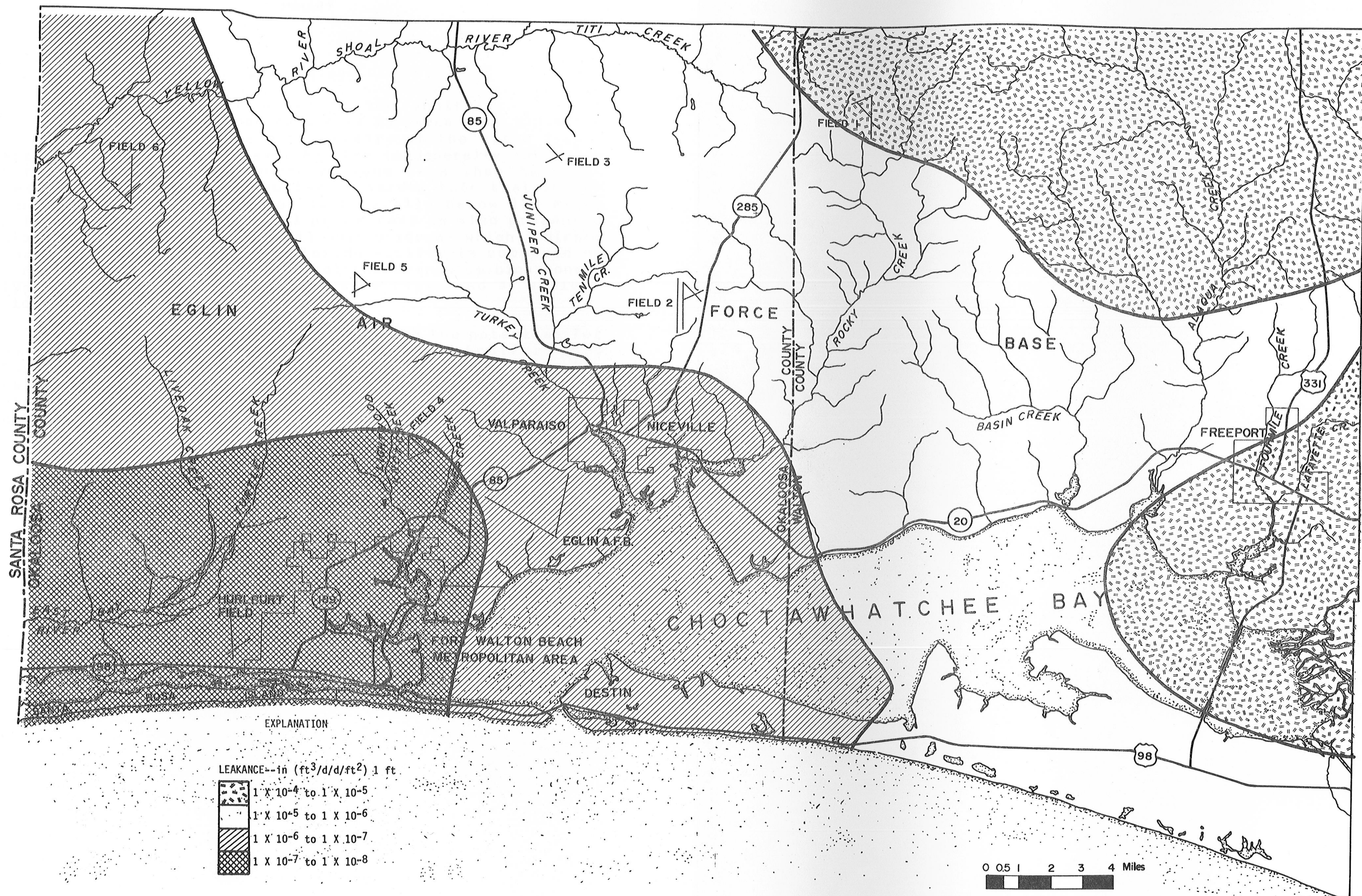


Figure 13. Map showing leakance coefficients of the Pensacola clay confining bed, as used in the model

SUMMARY

Conclusions

The hydrogeologic setting, the aquifers, and the confining units in the Choctawhatchee Bay Area were discussed in detail along with the geochemistry of the water types. Water for the Sand and Gravel Aquifer is generally soft with total dissolved solid concentrations less than 50 mg/L. Water from the Floridan Aquifer is harder than that in the Sand and Gravel Aquifer, but is generally below 150 mg/L. Data on other common chemical parameters is also presented along with trilinear and quadrilinear diagrams which indicate that upper limestone of the Florida Aquifer is composed of three distinct water types - 1. calcium/magnesium bicarbonate type; 2. sodium chloride-bicarbonate type; and 3. sodium-bicarbonate type.

Finally, the head differentials and the potential for movement of water out of the Floridan Aquifer into Choctawhatchee Bay are discussed and are greatest in the extreme eastern end of the bay. If it does occur, this contribution to the bay system is minor when compared to other sources of water.

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