TECHNICAL PUBLICATION SJ 87-1

APPRAISAL OF THE FLORIDAN AQUIFER PRODUCING ZONES IN THE SEBASTIAN FRESHWATER LENS

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January 1987

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INTRODUCTION

The Floridan aquifer is the primary source of water supply in the east-central Florida area. South of Volusia County, however, the Floridan generally contains water with chloride concentrations that exceed 250 milligrams per liter (mg/l), the recommended limit for public drinking water (Figure 1). Therefore, throughout much of Brevard County it is difficult to obtain ground water suitable for public supply. The City of Cocoa obtains water from both the surficial and Floridan aquifer systems in Orange County. The City of Melbourne and adjacent areas of South Brevard County rely on surface water from Lake Washington. In Indian River County, practically all of the public and domestic water supply systems tap the surficial aquifer system.

Supplies of potable water within the Floridan aquifer in southeastern Brevard and eastern Indian River counties occur only in the area bordering Sebastian Inlet. Here, the Floridan aquifer contains a lens of potable quality water completely surrounded by non-potable quality water. This lens is referred to as the Sebastian freshwater lens. The lens supplies significant quantities of water to a large number of South Brevard and Indian River counties residents.

The purpose of this study is to determine the areal extent of the Sebastian freshwater lens, to document the changes in its

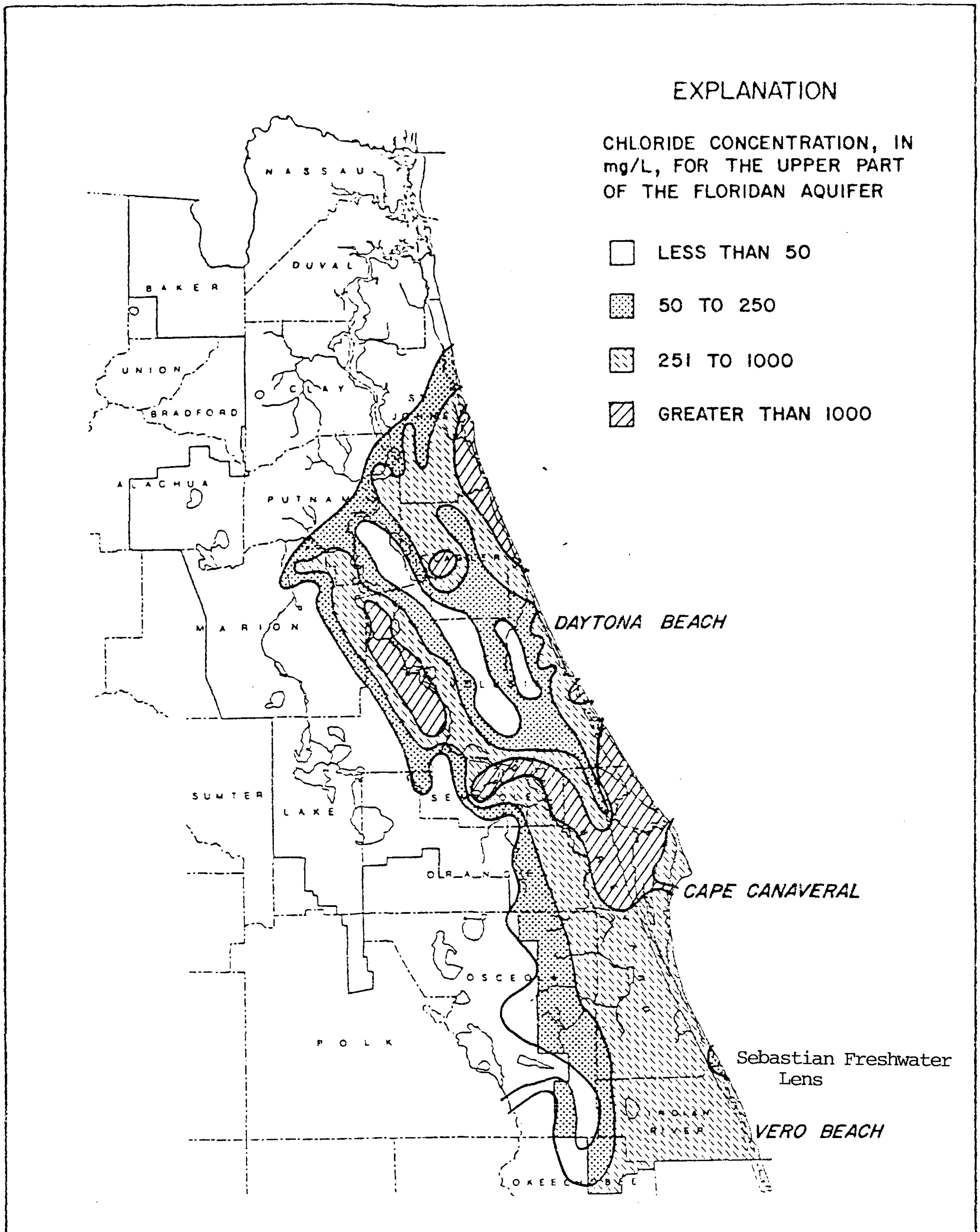

Figure 1. Chloride concentration, in mg/l, for the upper part of the Floridan aquifer in the St. Johns River Water Management District (from SJRWMD, MS-5).

size with time, and to project the future utility of the lens. This report contains a quantitative appraisal of the Floridan aquifer producing zones and should serve as an aid to water resource planners in determining management strategies to enhance the utility and duration of this water supply.

LOCATION

The study area (Figure 2) is located in the southeast corner of Brevard and the northeast corner of Indian River counties, and extends from Floridana Beach to Wabasso Beach on the barrier island. It is bordered by the Atlantic Ocean to the east and extends approximately two miles west of the Indian River's westerly shoreline. Throughout the study area, land elevations are less than 51 feet above mean sea level. For the most part, the study was centered on the barrier island where elevations are less than 24 feet above mean sea level.

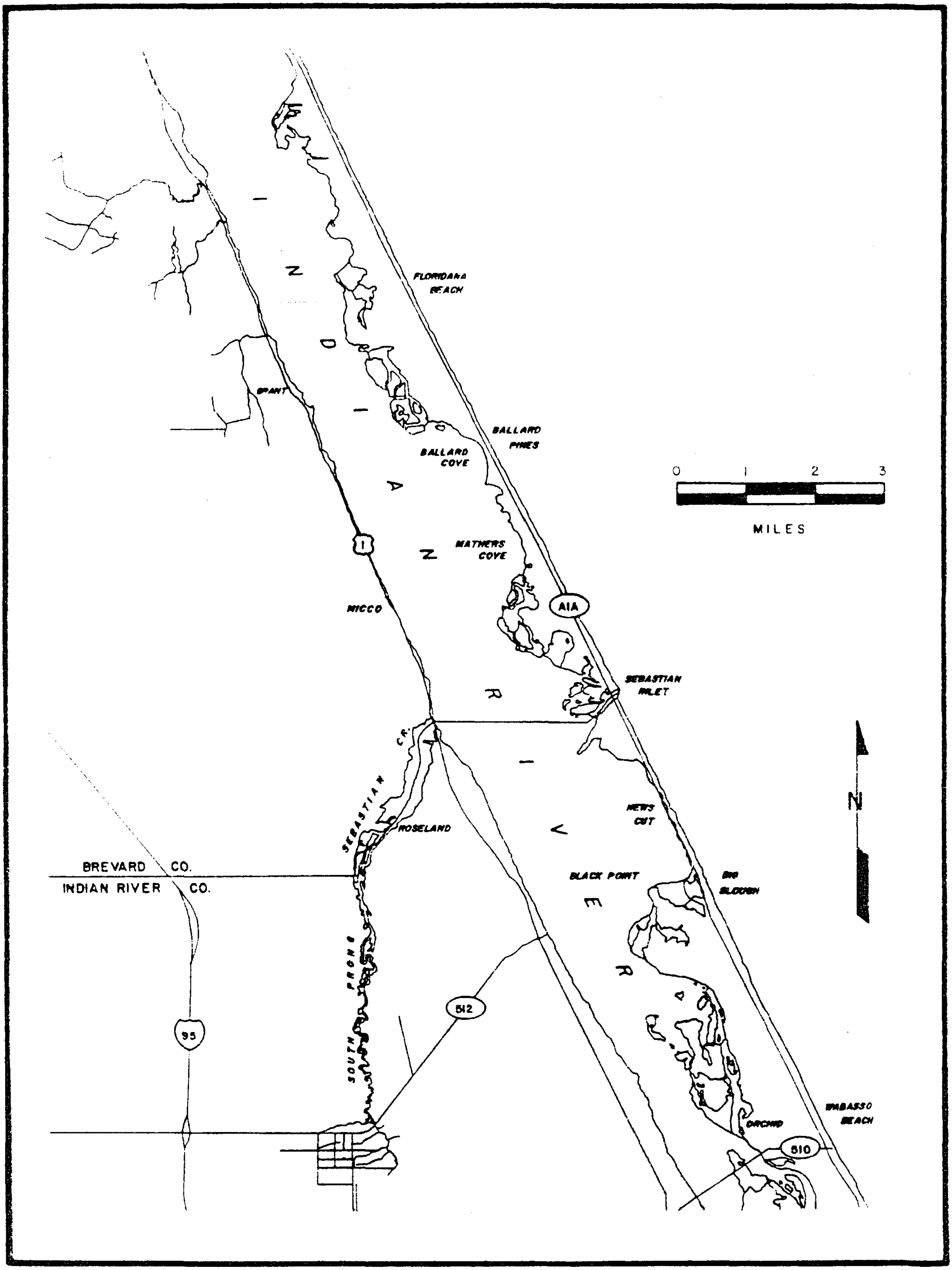

Figure 2. Study area.

METHODOLOGY

The following methods were selected to satisfy project objectives:

1. Historical ground water data describing water quality and water levels was collected from previously published data and from several governmental agencies currently working within the project boundaries.
2. The above information was added to the SJRWMD computer data base and was used to produce water quality contour maps for the study area.
3. Existing wells were inventoried and pertinent information concerning these wells was recorded. Water samples were collected from selected wells and these samples were analyzed to define current trends in water quality.
4. New test/observation wells were drilled by reverse-air method to determine trends in water quality with depth. Water quality samples were collected from the drill stem approximately every 10 feet and/or change in formation or flow (Toth, 1985).
5. Water samples for radiocarbon age dating were collected from select wells. Age determinations were made to evaluate the origin of lens water and the hydrologic charateristics of the lens.
6. Water use was inventoried and classified according to its source and type.
7. Data was synthesized to project the future availability of potable water supplies in the Sebastian freshwater lens.

HYDROGEOLOGIC FRAMEWORK

The Floridan aquifer system in coastal Brevard and Indian River counties consists of Eocene and Oligocene limestones. Eocene deposits include the Lake City, Avon Park, and Ocala limestones. Oligocene deposits are identified as Suwannee Limestone.

The Floridan aquifer underlies the study area at a depth which increases to the east and south (Figure 3). At Floridana Beach, the top of the Floridan lies at approximately 275 feet below National Geodetic Vertical Datum (NGVD) and increases to 400 feet below NGVD at Wabasso Beach. In this region the top of the Suwannee Limestone defines the top of the Floridan aquifer system. Early to middle Miocene clay, limestone, and layers of interbedded sand and shell of the Hawthorn Formation form the confining unit.

Two potable water-bearing zones within the Floridan aquifer have been recognized in the study area (Frazee, 1981;Toth, 1985) and are separated by relatively impermeable limestone and dolomite at the top of the Avon Park Limestone. The first zone, henceforth referred to as the upper zone, occurs in wells tapping the Ocala and Suwannee limestones and is less than 500 feet below NGVD. The second zone occurs in the Avon Park Limestone, and is referred to as the lower zone. This zone occurs in wells with total depths between 500 and 800 feet below NGVD.

Since potable water of the Sebastian freshwater lens occurs in the Avon Park, Ocala, and Suwannee limestones, further

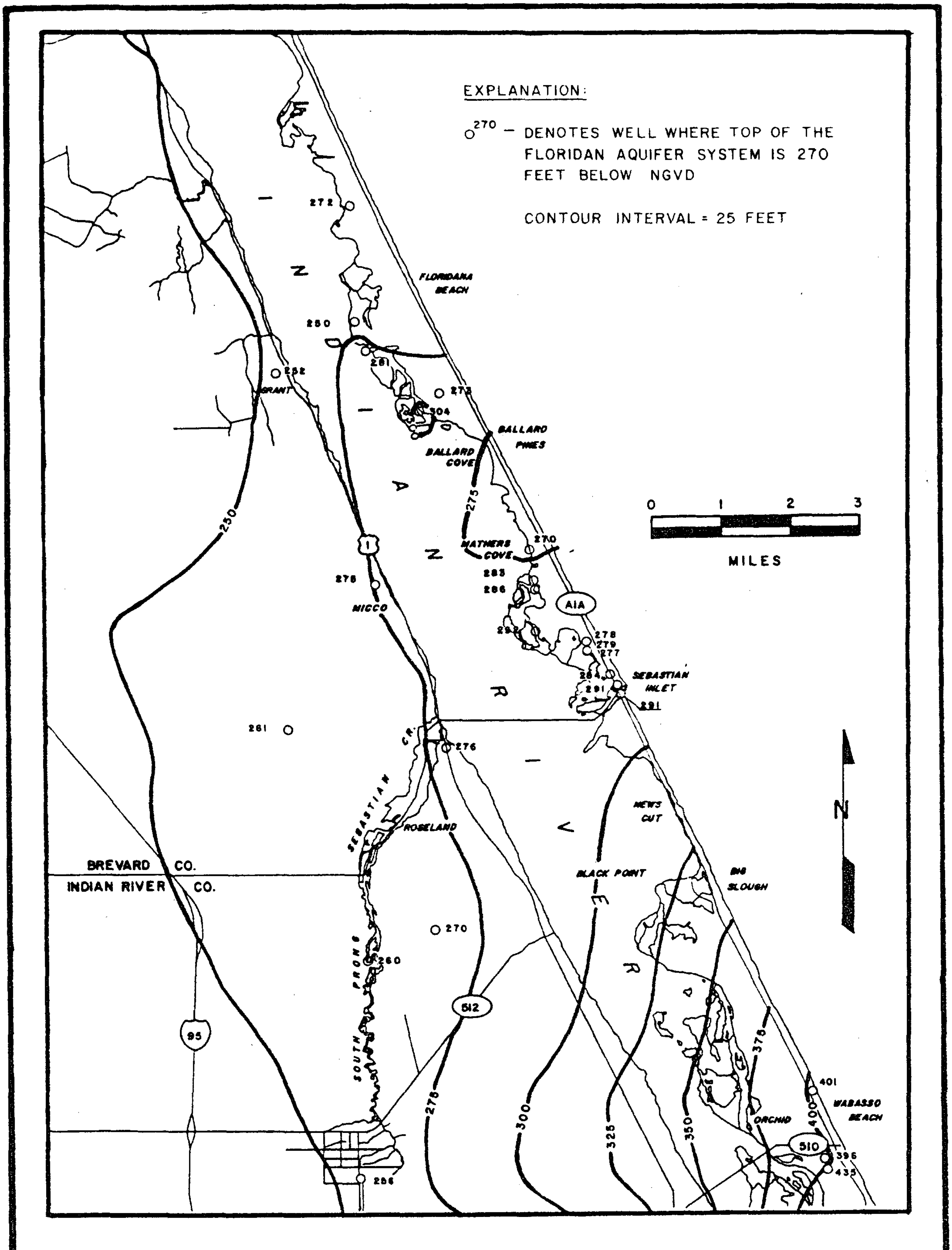

Figure 3. Depth below National Geodetic Vertical Datum (NGVD) to the top of the Floridan aquifer.

discussion is restricted to these strata and the overlying Hawthorn Formation. A more in-depth discussion on the geology can be found in Wyrick, 1960; Brown, et. al., 1962; and Bermes, 1958.

Figure 4 presents hydrogeologic and stratigraphic data for a test well at Sebastian Inlet (Toth, 1985). Divisions between units are based primarily on geophysical logs (Johnson, 1984) and are confirmed by drill cutting samples. The divisions are in general agreement with the literature cited above. Following is a description of the stratigraphic units discussed in order of decreasing age.

Avon Park Limestone

The Avon Park Limestone of Middle Eocene age consists of two distinct and correlatable lithologic zones; a basal, low porosity, dolostone zone and an upper, interbedded limestone and dolostone zone.

The lower zone is composed of very hard, low porosity, brown to dark brown, cavernous dolostone. Frequently, individual dolomite rhombs can be distinguished under low magnification. Because of the cavernous nature of the zone, permeability can be extremely high.

The upper zone occurs in the interval between the top of the Avon Park dolostone zone and the contact with the overlying Ocala Limestone. It is characterized by interbedded limestone and dolostone. The limestone is generally white to tan to light brown, hard and completely recrystallized to soft, and composed of weakly cemented, partially altered foraminiferal tests. The

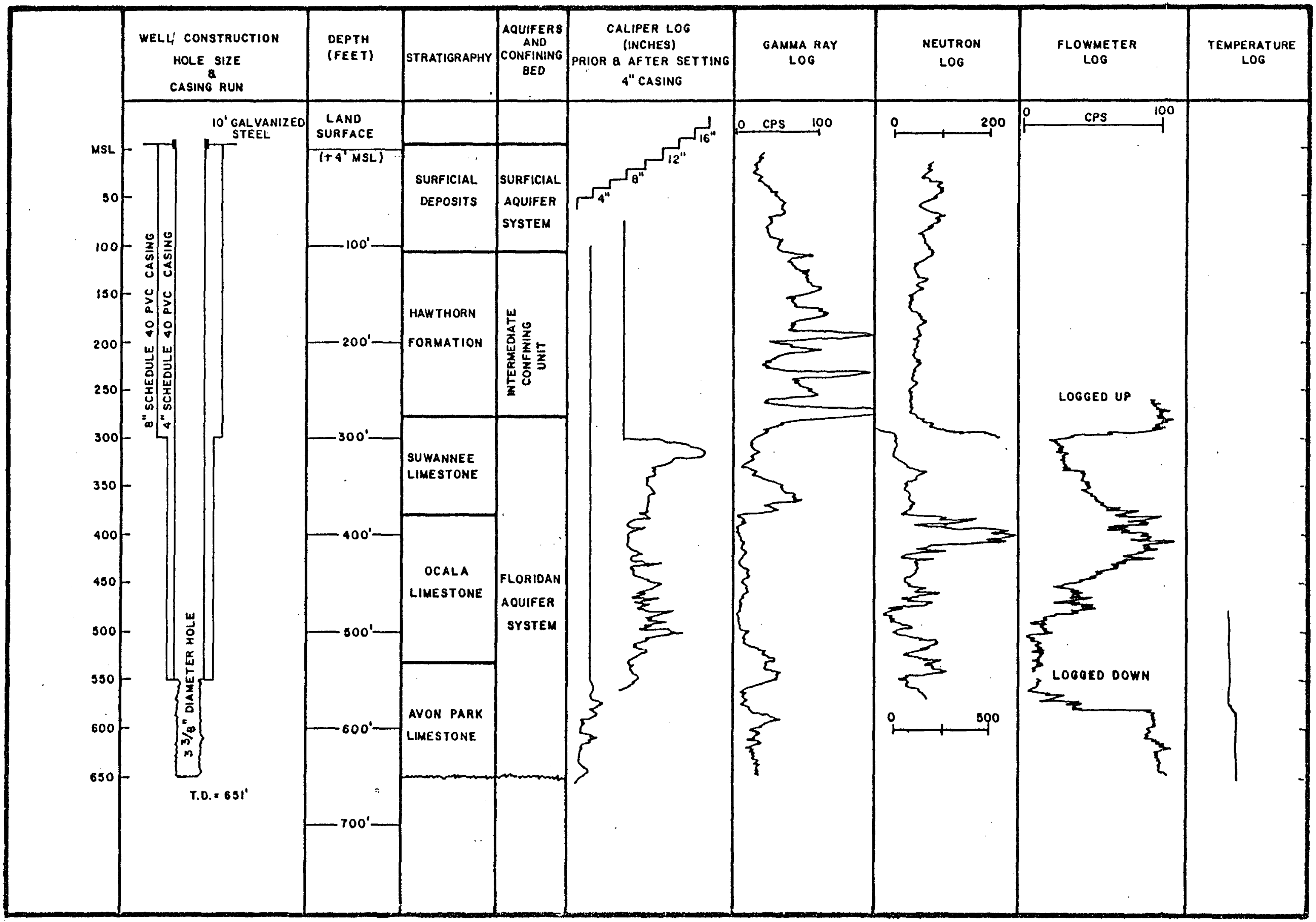

Figure 4. Hydrogeologic data for BR0624 at Sebastian Inlet (from Toth, 1985).

dolostone is dark brown to brown, hard and recrystallized (micrite-like) to a moderately well cemented calcarenite.

These depths to the top of the Avon Park increases toward the coast and from north to south in the study area. At Floridana Beach, it lies between 400 and 450 feet below NGVD, and at Wabasso Beach, it is encountered between 550 and 600 feet below NGVD, as inferred from 23 wells in south Brevard and northeast Indian River counties.

The thickness of the Avon Park also increases toward the coast and from north to south. In the few geophysically logged wells penetrating the Avon Park in the study area, its thickness increases from 400 feet near Melbourne to 600 feet near Wabasso Beach.

Ocala Limestone

The Ocala Limestone of late Eocene age consists of white to light tan, soft and very weakly cemented to hard and recrystallized, foraminiferal, coquinoid limestone. The coquina is composed of whole and fragmented foraminiferal tests with some intermixed echinoid, bryozoan, and other biological debris. Generally, two zones can be distinguished: a lower, more recrystallized micritic zone and an upper, less well-cemented zone of calcarenite.

The top of the Ocala is an unconformity and is typically karstic, with paleosinkholes exhibiting relief as great as 400 feet. The top of the Ocala increases in depth toward the coast (east) and to the south. Near Floridana Beach, the top of the

Ocala varies between 250 and 300 feet below NGVD. At Wabasso Beach, the top of the formation lies at 500-550 feet below NGVD. The above depths to the top of the Ocala are extrapolated from geophysical data collected in 45 wells from south Brevard and northeast Indian River counties.

The thickness of the Ocala ranges from 25 to over 150 feet throughout the study area (Figure 5). It is thinnest at Wabasso Beach and thickest near Sebastian Inlet.

Suwannee Limestone

The Suwannee Limestone of Oligocene age consists of white to light tan, slightly argillaceous to arenaceous to pure, bioclastic to chalky limestone. It lies between the Ocala Limestone and the Hawthorn Formation.

The thickness of the Suwannee Limestone increases to the south and east (Figure 6). It ranges from zero (0) feet near Floridana Beach to over 125 feet at Wabasso Beach on the barrier island.

Hawthorn Formation

The Hawthorn Formation of Middle Miocene age consists of interbedded clay, silt, sand, and carbonate beds, all of which contain varying amounts of black to brown phosphatic material. The carbonate beds consist of sandy, hard, recrystallized, phosphatic limestone with some brown dolostone, except at the base of the formation where hard, brown to dark blue, sandy,

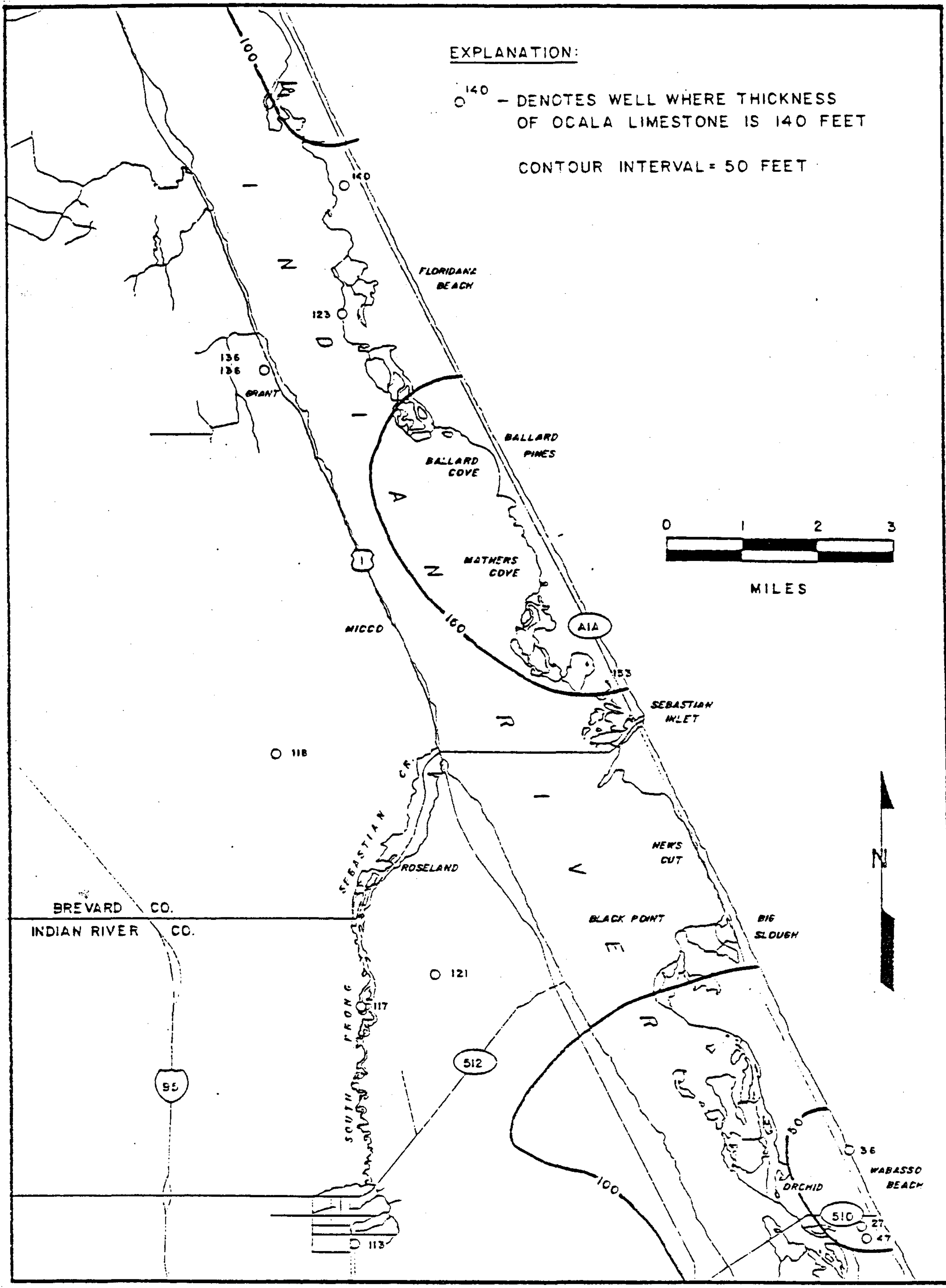

Figure 5. Thickness in feet of Ocala Limestone.

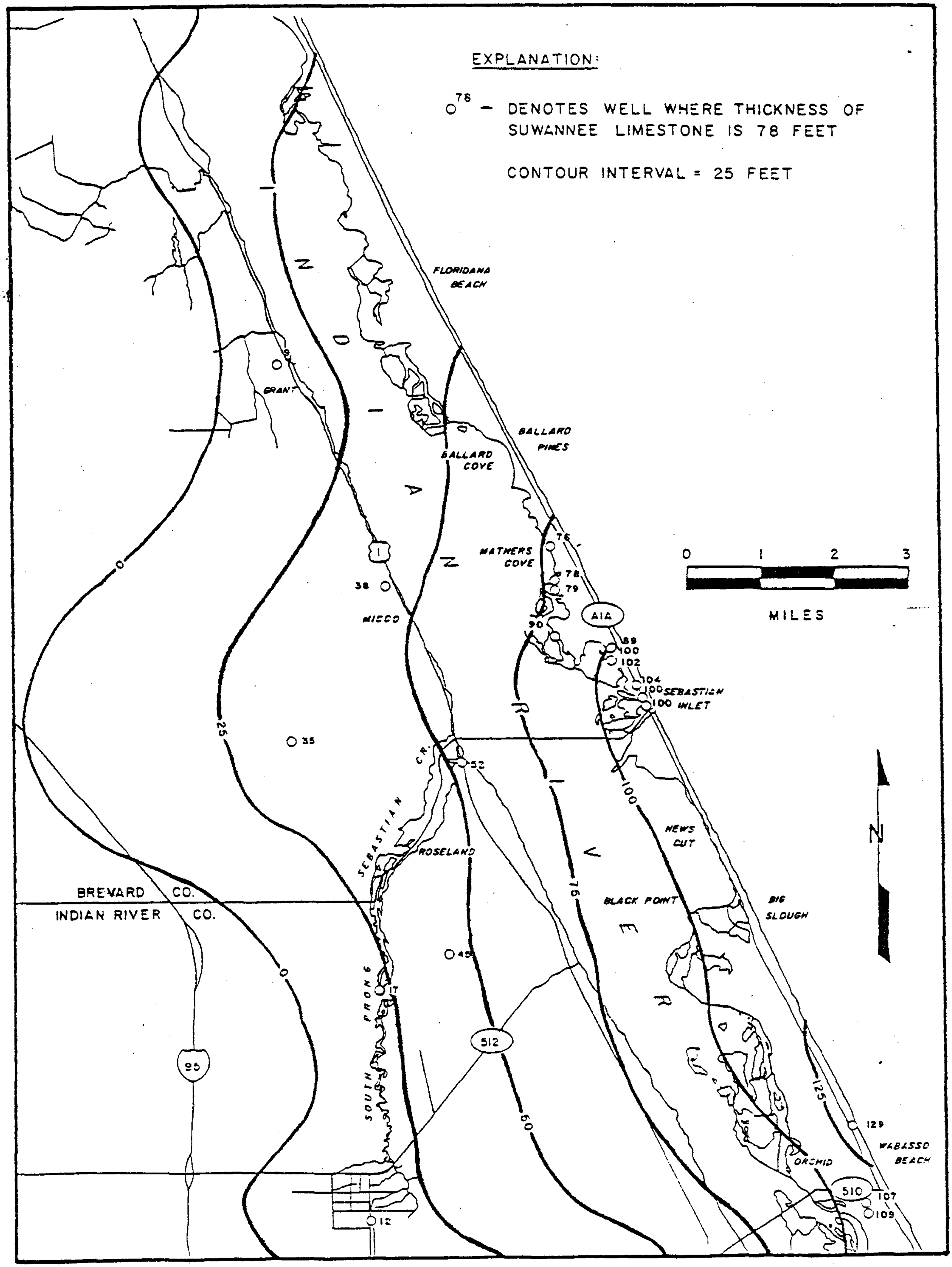

Figure 6. Thickness in feet of Suwannee Limestone.

phosphatic dolostone predominates. In Indian River County, the base of the formation is green to dark green, hard, phosphatic clay.

The Hawthorn Formation occurs throughout the study area and increases in thickness toward the southeast. Its thickness varies between 100 and 150 feet in the northeast portion of the study area to approximately 300 feet at Wabasso Beach (Figure 7).

Structure

Within the study area, Bermes (1958) postulated the existence of two vertical faults based upon (1) a change in the apparent dip of the Ocala Limestone from nearly horizontal "to more than 70 feet per mile," (2) the thickening of the Ocala Limestone, and (3) the presence of Suwannee Limestone, not found elsewhere in Indian River County. One of these two faults, as described by Bermes, strikes roughly parallel to the Indian River. The second strikes northeast through the barrier island near Wabsso (Figure 8). Subsequent work by Schiner et al (1986), personal communication, does not support the presence of these faults within the study area.

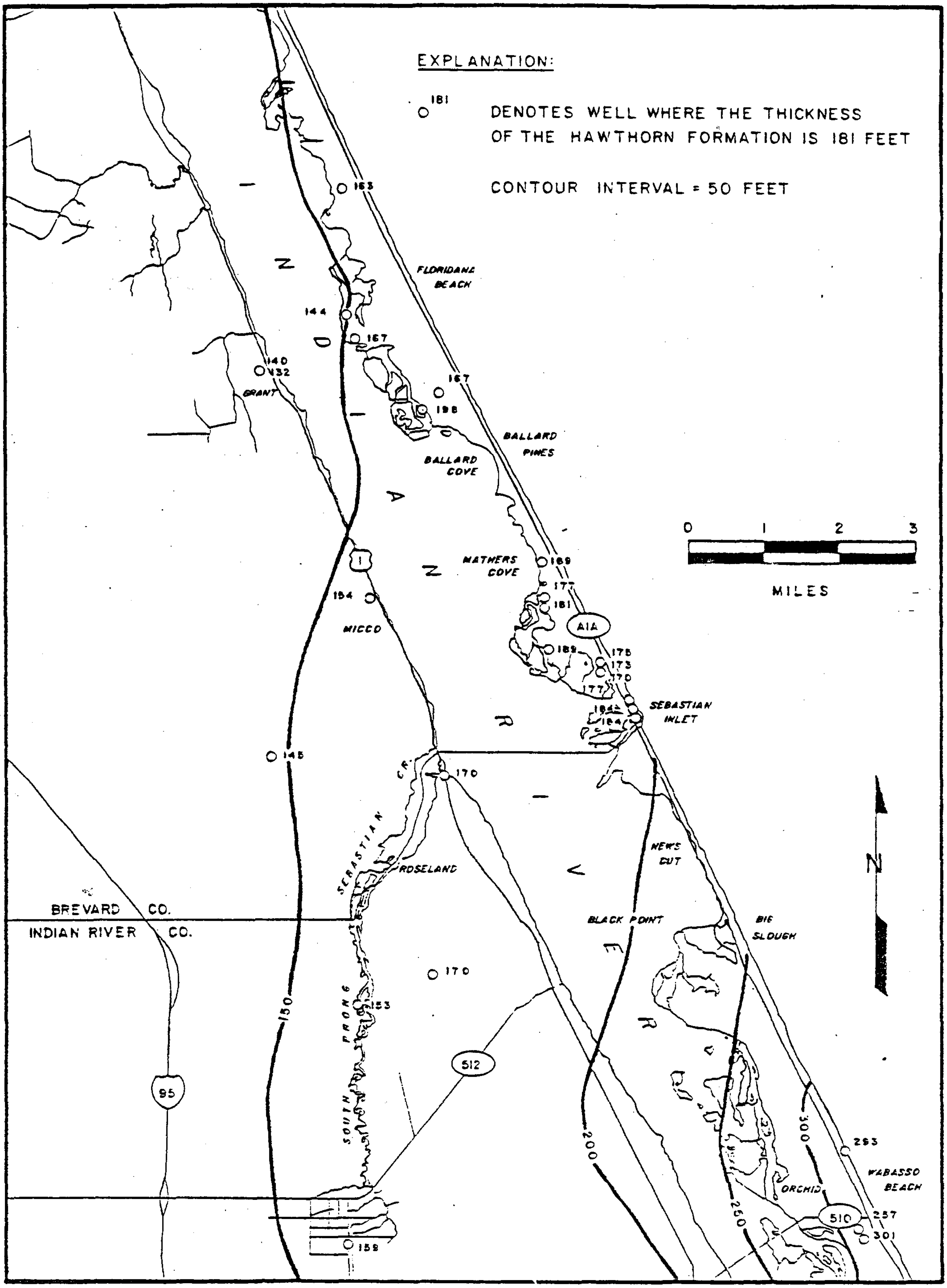

Figure 7. Thickness in feet of Hawthorn Formation.

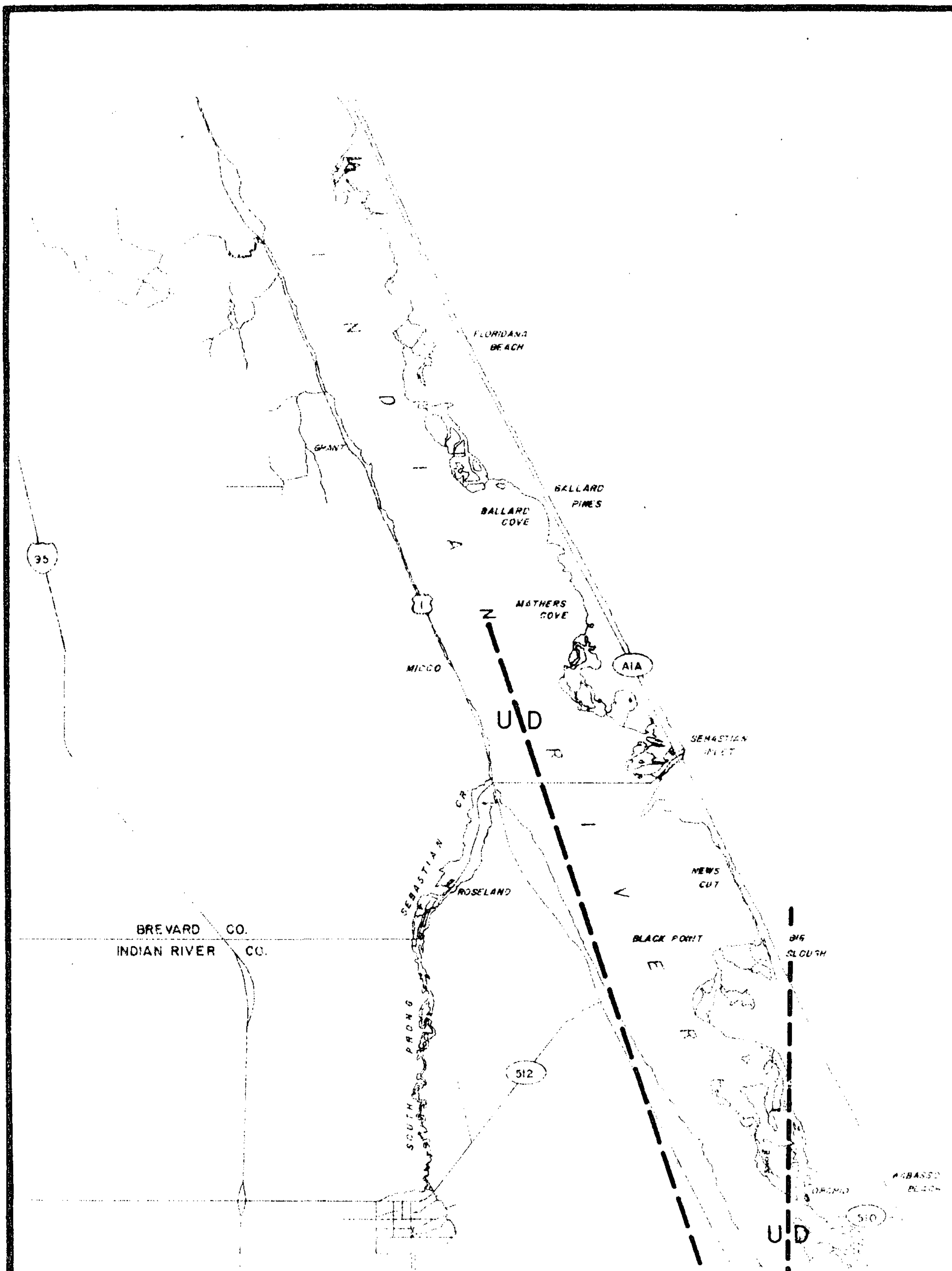

Figure 8. Location of faults inferred by Bermes (1958).

FLORIDAN AQUIFER POTENTIOMETRIC SURFACE FLUCTUATIONS

The potentiometric surface of an aquifer is the level to which water will rise in a well tightly cased into the aquifer. Fluctuations in the potentiometric surface are reflected as changes in water levels in such wells. In the study area water levels fluctuate seasonally and are affected by rainfall and ground water withdrawals.

Wells monitored in this study are completed in the upper Floridan aquifer. "The upper Floridan aquifer generally consists of all or part of rocks of Oligocene age (mostly the Suwannee Limestone), rocks of late Eocene age (mostly the Ocala Limestone), and rocks of middle Eocene age" (mostly the upper part of the Avon Park Limestone; Miller, 1986). The localized zonation of the upper Floridan divides it into an upper and lower zone as discussed below.

Upper Zone. The upper zone as addressed here consists of the Ocala and Suwannee limestones extending from about 300 to 500 feet below NGVD. In the mid 1930's, the potentiometric surface of the upper zone throughout the study area was estimated to be greater than 40 feet above NGVD (Johnson, et al., 1980). Prior to this time and through the early 1950's, ground water withdrawals from the Floridan aquifer were minimal. During the 1950's, the area began to experience increased development with associated population increases. (Dietrich, 1978). Since this time, water levels in the study area have decreased between 15 and 20 feet with the largest decrease occurring near Wabasso Beach (Figure 9).

Although no continuous measurement of water levels has occurred in the area, data for potentiometric maps (USGS) between 1974-85 (Appendix 1) indicates levels were lowest in the study area in May 1981 (Figure 10) following a period of below normal rainfall and increased ground water withdrawals.

Table 1 lists water levels from May 1979-1985 for eight wells in the study area (Figure 11). Inspection of the table reveals that levels averaged 32 feet above NGVD during the late 70's and 80's but annually fluctuated from between 28-36 feet above NGVD. The greatest change occurred at Sebastian Inlet, where a record low potentiometric surface elevation of 24 feet above NGVD was measured in a well during May 1985.

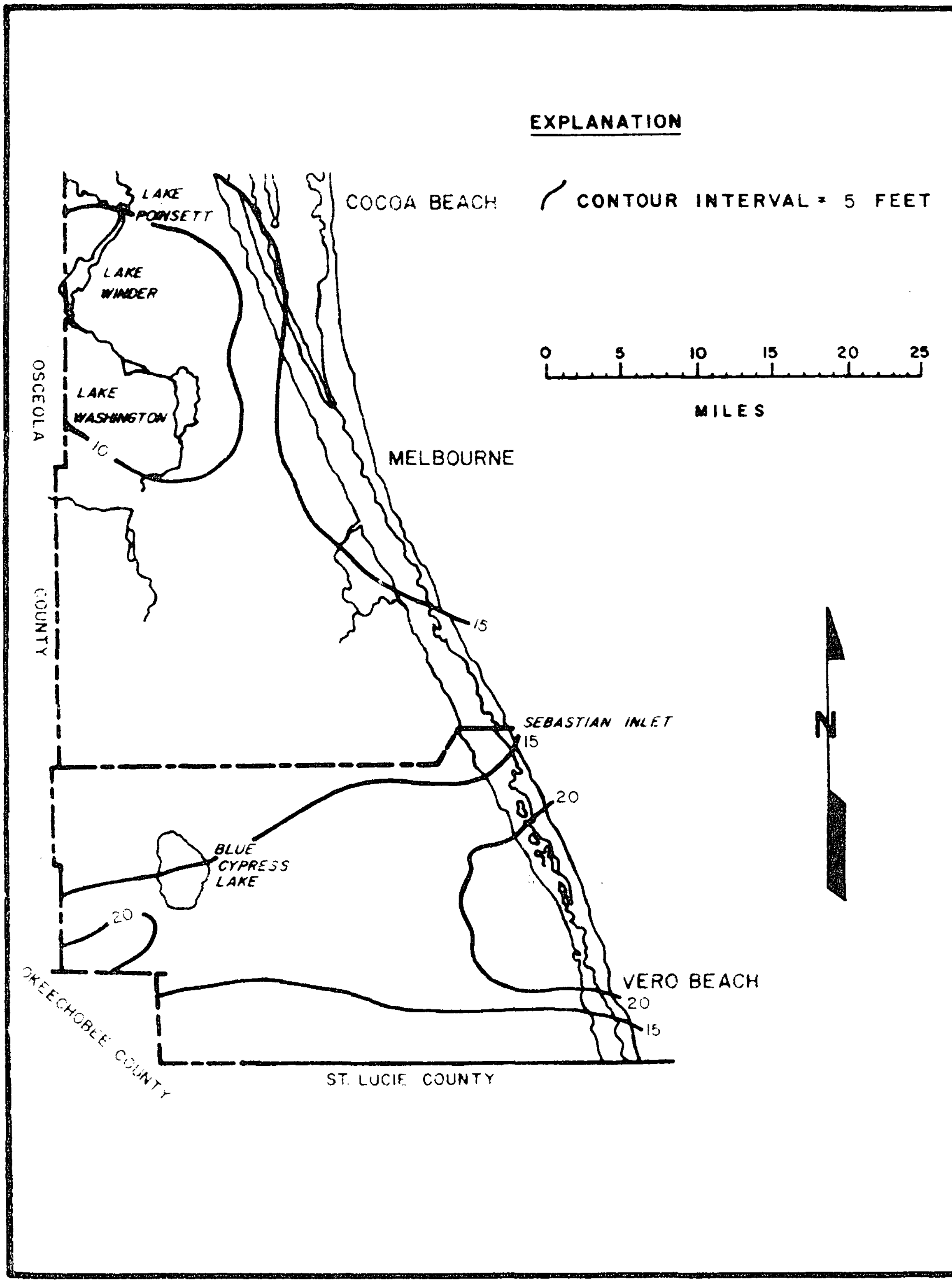

Figure 9. Decline in the potentiometric surface of the Floridan aquifer from 1936 to 1981 (data from Johnson et. al. 1980; Schiner and Hayes, 1981).

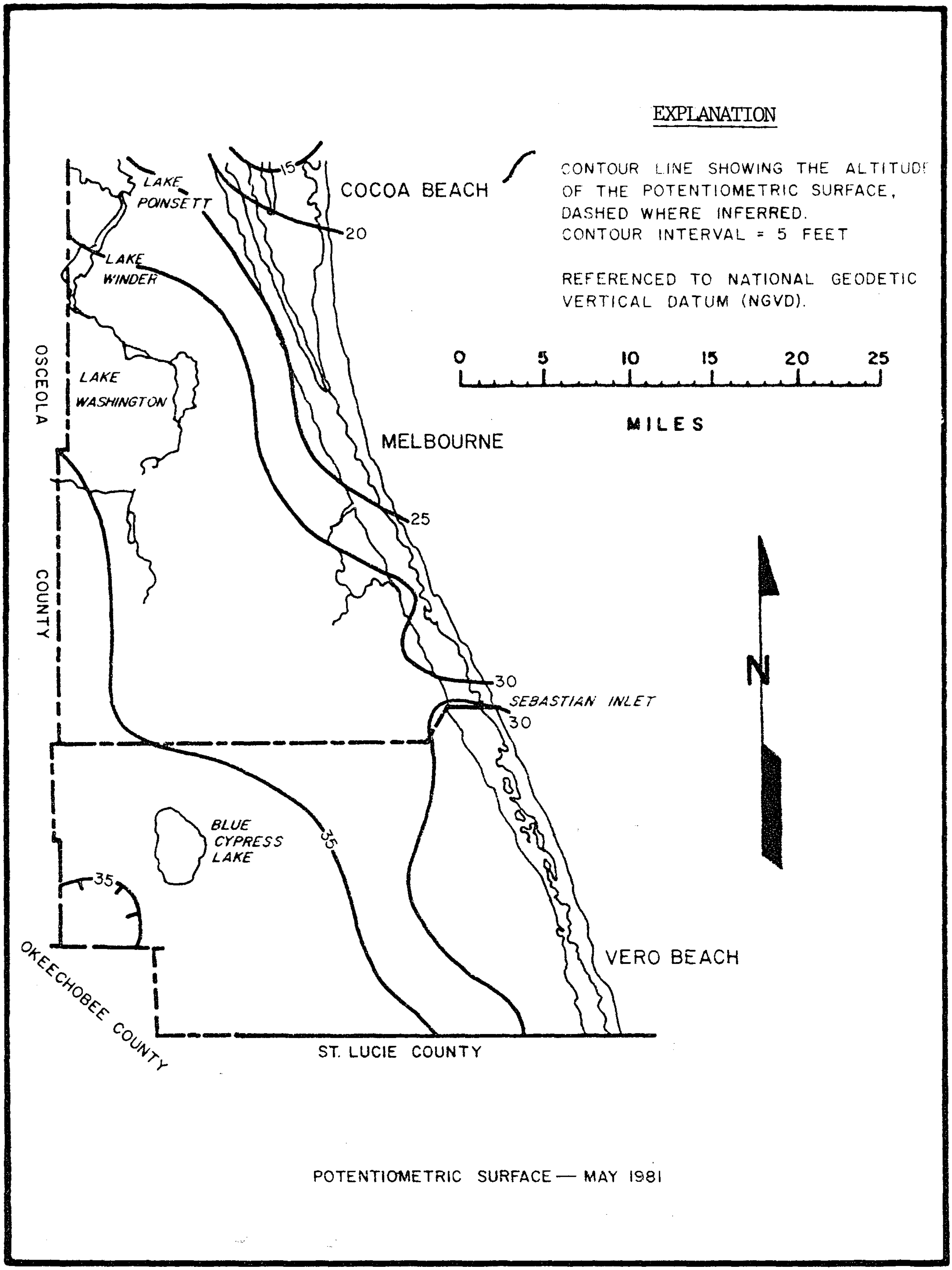

Figure 10. Potentiometric surface of the Floridan aquifer for May 1981. (from Schiner and Hayes, 1981)

Table 1.--May water level measurements in feet above NGVD for Upper Floridan aquifer wells in the study area between 1979 and 1985.

	Water Level							
Well	#1	#2	#3	#4	#5	#6	#7	#8
Well								
May 1985	33	34	32	24	29	31	31	29
May 1984	34	34	32	33	30	32	32	29
May 1983	35	34	33	33	32	35	31	
May 1982	35	35	33	31	35	34	36	36
May 1981	29	29	28	31	28	28	29	28
May 1980	34	35	34	34	28	31	32	32
May 1979	30	34		33	32	30	32	32
Average	33	34	32	31	31	32	32	31

Well locations are shown on Figure 11.

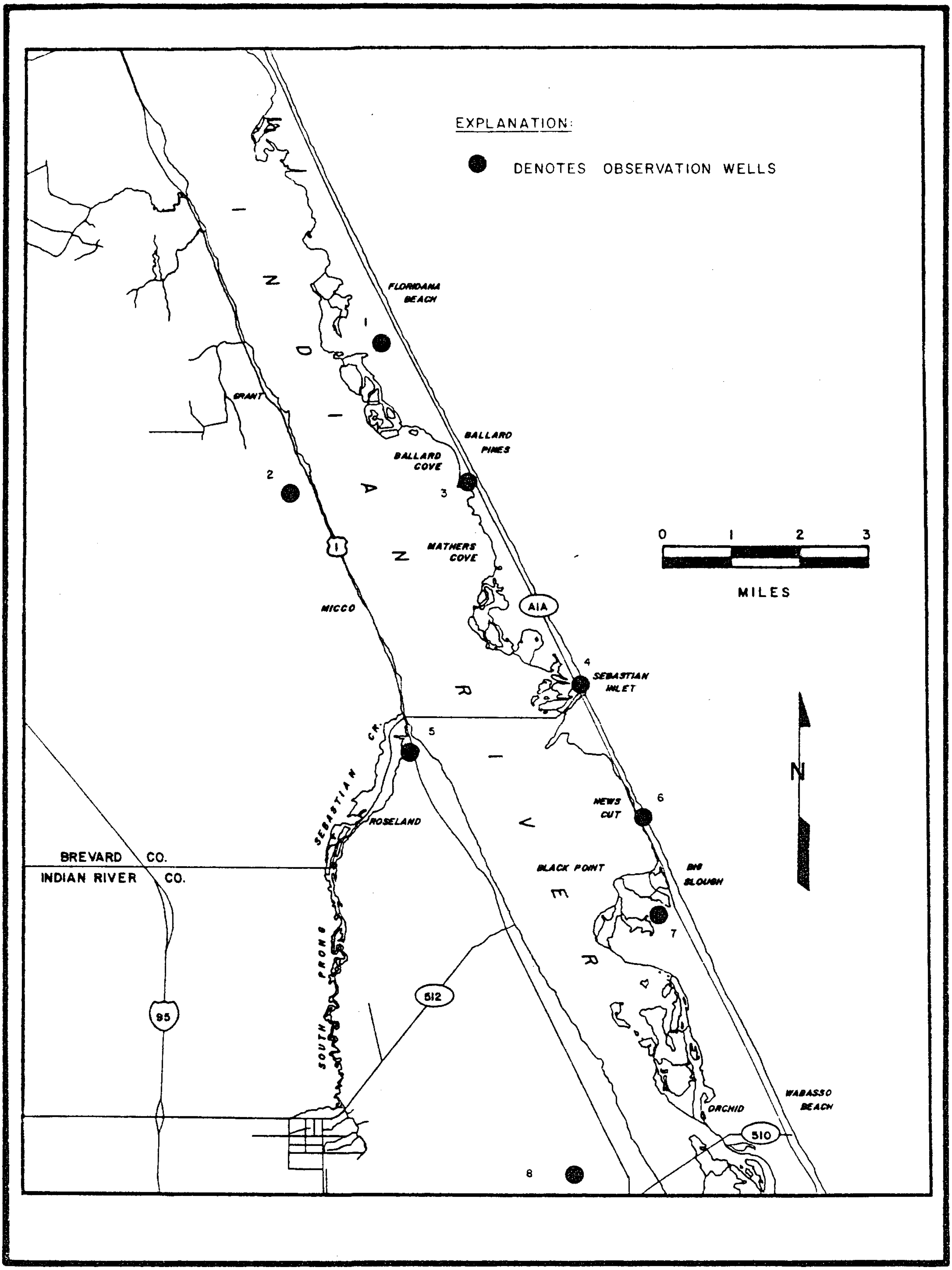

Figure 11. Location of Floridan observation wells referenced in Table 1.

Lower Zone

The lower zone as addressed here consists of the upper Avon Park Limestone which extends from about 500 to 800 feet below NGVD. The bottom of the lower zone is assumed to be the low porosity dolostone zone in the Avon Park Limestone. The dolostone zone occurs approximately halfway through the Avon Park Limestone, which is assumed to be 500 feet thick along the barrier island in southeast Brevard County. Regional studies by Miller (1986) indicate the lower zone could be much thicker and extend as far as 950 feet below NGVD in southeast Brevard County.

In the study area, not much is known about the lower zone. Most wells in this area do not penetrate the Avon Park Limestone. A test well drilled in 1981 at the residential development known as Aquarina (located about six miles north of Sebastian Inlet on U.S. Hwy. A1A) was one of the first wells in the area to penetrate the Avon Park Limestone. Although water quality differences between the upper and lower zones were documented as a result of the test well project, no difference in the potentiometric surfaces of the two zones was documented. In 1984, at Sebastian Inlet State Park, an observation well was drilled into this zone to monitor chloride concentration and potentiometric surface fluctuations (Toth, 1985). Information gained from this well substantiated the water quality findings at the Aquarina well. In addition, differences in potentiometric surface between upper and lower zones were noted.

Upper and Lower Zone Relationships

Hydrographs for two monitor wells drilled at Sebastian Inlet State Park (Toth, 1985) are shown in Figure 12. One well (BR0625) is 450 feet deep and monitors potentiometric surface fluctuations in the upper zone. The other well (BR0624) is 650 feet deep and monitors potentiometric surface fluctuations in the lower zone. Both hydrographs illustrate the variations in the potentiometric surface in the study area.

Mean water levels in the upper zone (BR0625 in Figure 12) oscillated between 29.9 and 33.8 feet above NGVD between May 5 and August 11, 1986. During that same period, mean water levels in the lower zone varied between 30.4 and 34.7 feet above NVGD. In each instance, water levels in the lower zone were 0.2-1.0 feet higher than in the upper zone. Hence, within the study area, the potential exists for the upward movement of water from the lower zone to the upper zone.

Because of the upwardly directed artesian pressure in the study area, recharge derived from overlying water bearing zones is unlikely as a replacement source for water withdrawn from the Floridan aquifer in this area.

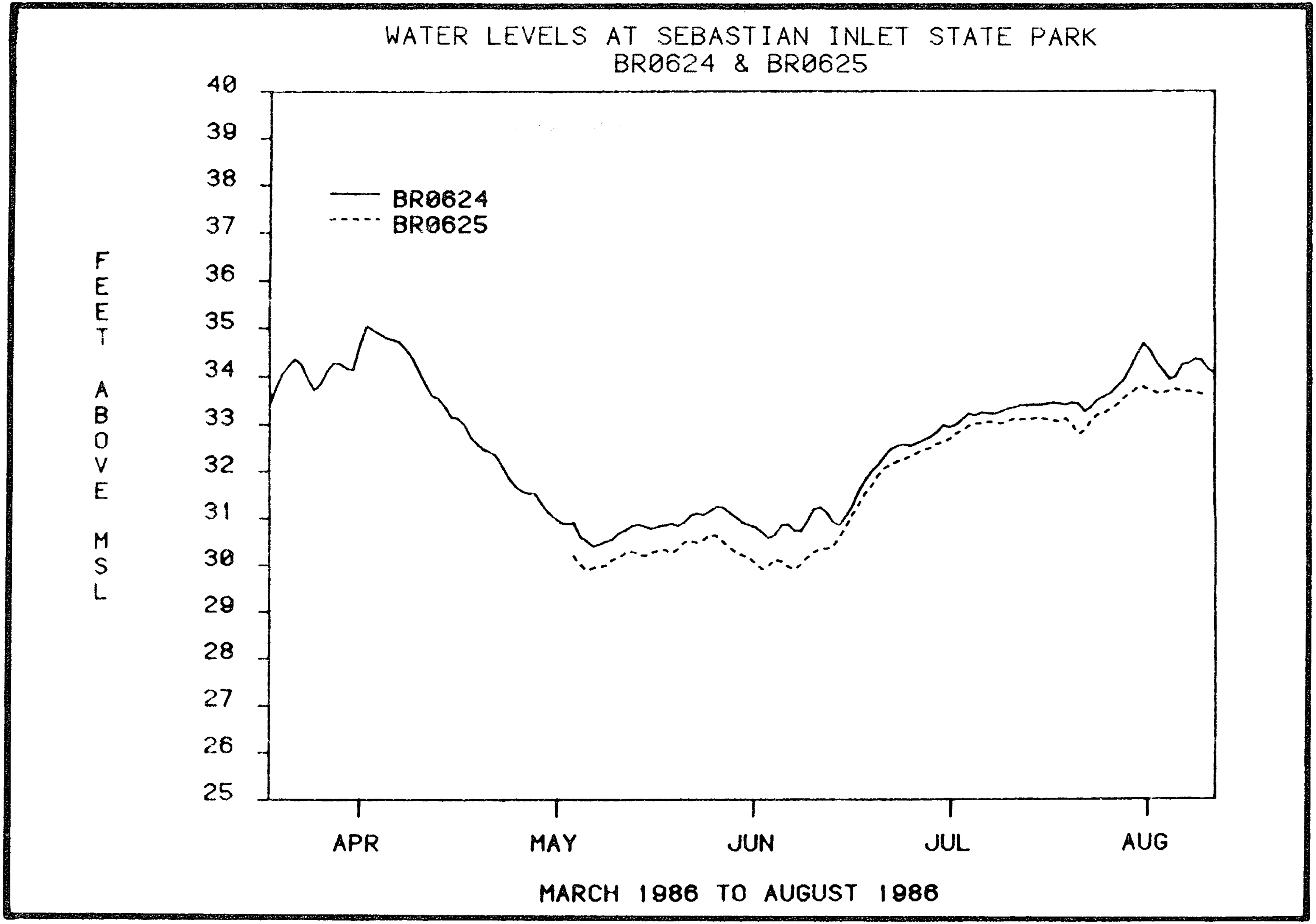

Figure 12. Hydrographs for wells BR0624 and BR0625 at Sebastian Inlet State Park.

WATER QUALITY

Ground water contains dissolved minerals that are derived from rainwater that enters an aquifer as recharge and from reactions between soil and rock particles through which ground water flows. The concentration of these dissolved minerals often depends on the water's duration of contact with the aquifer material. In coastal areas, salts within the ground water system may be derived from laterally intruded seawater or saline waters entrapped in rocks during deposition.

The mineral content of ground water primarily consists of Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, Sr^{+2}, Fe^{+2}, HCO^{-}_{3}, Cl^{-}, SO_4^{-2}, and SiO_2. Of these, chloride is the most useful for mapping the occurence of laterally intruded seawater and/or the mixing between waters of differing mineral content. This is because it generally does not enter into mineral or bacteriological reactions.

Brown et.al. (1962) documented the existence of fresh water (chloride concentration less than 250 mg/l) within the Floridan aquifer in the study area, but did not document the thickness and areal extent of this fresh water. Chloride concentration data examined as part of this study indicates that this body of fresh water is completely surrounded by water with chloride concentrations greater than 250 mg/l. This body of fresh water is referred to as the "Sebastian freshwater lens."

Upper Zone

Figure 13 shows chloride concentrations for the upper zone in the study area in 1985. The contours were generated using computer graphics with data collected by the District. Concentrations are below 200 milligrams per liter (mg/l) on the barrier island but increase to above 250 mg/l west of the Indian River. Currently the Sebastian freshwater lens consists of three lobes: a narrow north lobe, located south of Floridana Beach and extending to Ballard's Cove; an isolated central lobe situated between Ballard's and Mathers Cove; and a large south lobe stretching from Mathers Cove in Brevard County to News Cut in Indian River County. Each of these potable areas are confined to the barrier island and represent the areal extent of the Sebastian freshwater lens in 1985.

Throughout the study area, the upper zone is the source of most of the water withdrawn from wells. The largest concentration of these wells is located in the vicinity of the north lobe where population growth has been the greatest. Increased withdrawals from these wells for public supply, irrigation, and use for water source heat pumps has occurred concurrently with increased chloride concentrations, thus decreasing the amount of available potable water. The division of the lens into three distinct areas (the north, middle and south lobes) also occurred concurrently with increased withdrawals.

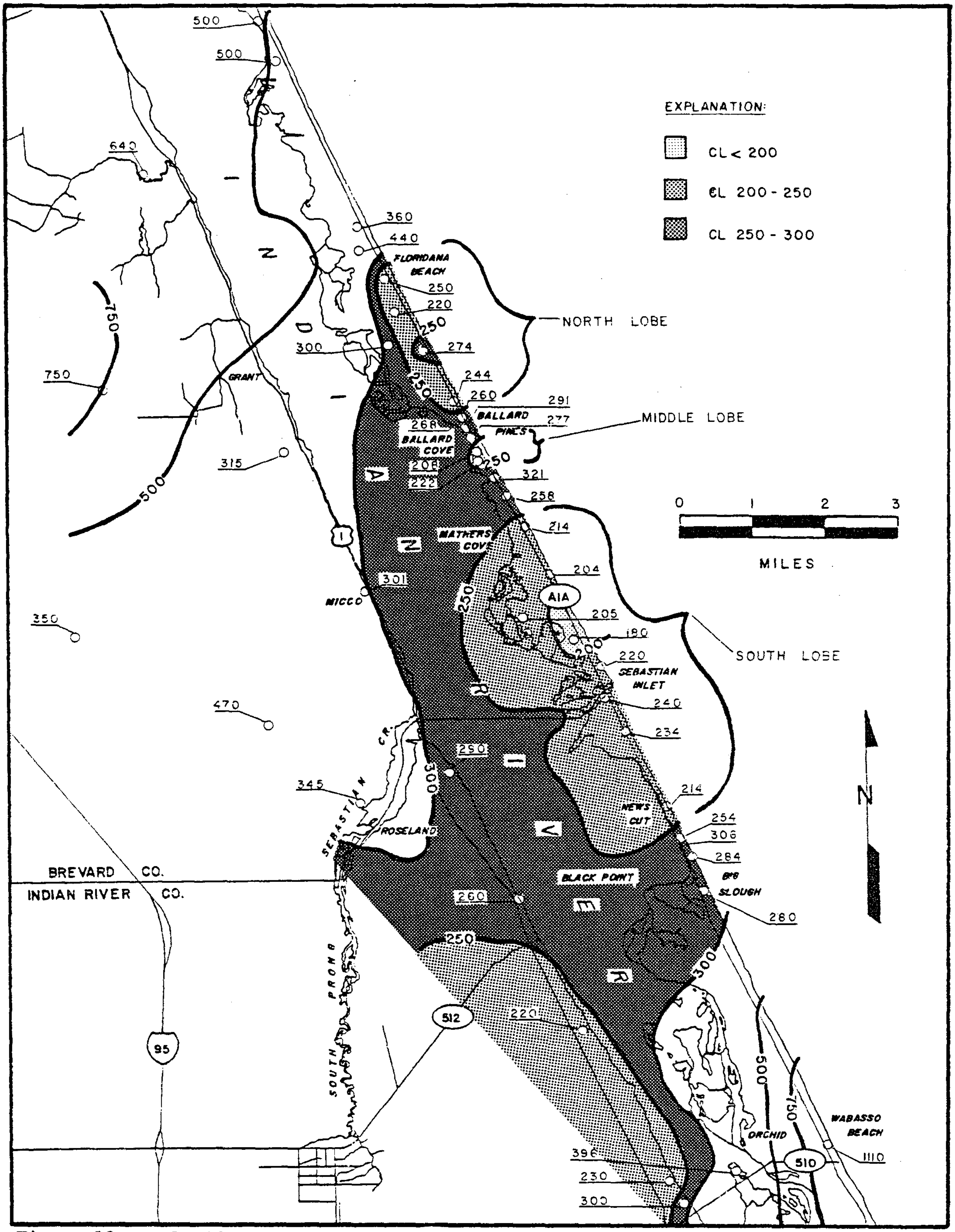

Figure 13. Chloride concentrations, in mg/l, for the upper zone in 1985.

Figures 14 through 17 show the areal extent of the Sebastian freshwater lens within the upper zone at four different time periods: 1983-84; 1979-82; 1975-78; and 1956. The contours were generated by computer graphics from data collected by the District, Brevard County, and the USGS. The confidence in lens definition improves as the number of wells sampled during each period increases. For each earlier period, the lens area appears larger. In 1956, it appeared to extend from Floridana Beach to Big Slough on the barrier island and west through Roseland and Sebastian in Indian River County. At that time it contained three lobes with chloride concentrations below 200 mg/l. In 1985 the chloride concentrations in these lobes were above 200 mg/l. This can be illustrated by comparing figures 13 and 17.

Using a classification of water types outlined by Frazee (1982), six water samples were collected and analyzed for major constitutents. As shown on the Piper diagram (Figure 18), lens water classifies as transitional and transitional connate water. It is underlain and surrounded by connate water with chloride concentrations of 300-500 mg/l. Connate waters are dominated by calcium-sulfate-chloride mixtures characteristic of long term storage in limestone and are the prevailing water type in south Brevard and Indian River counties.

Figure 19 shows a north-south cross-section through the lens

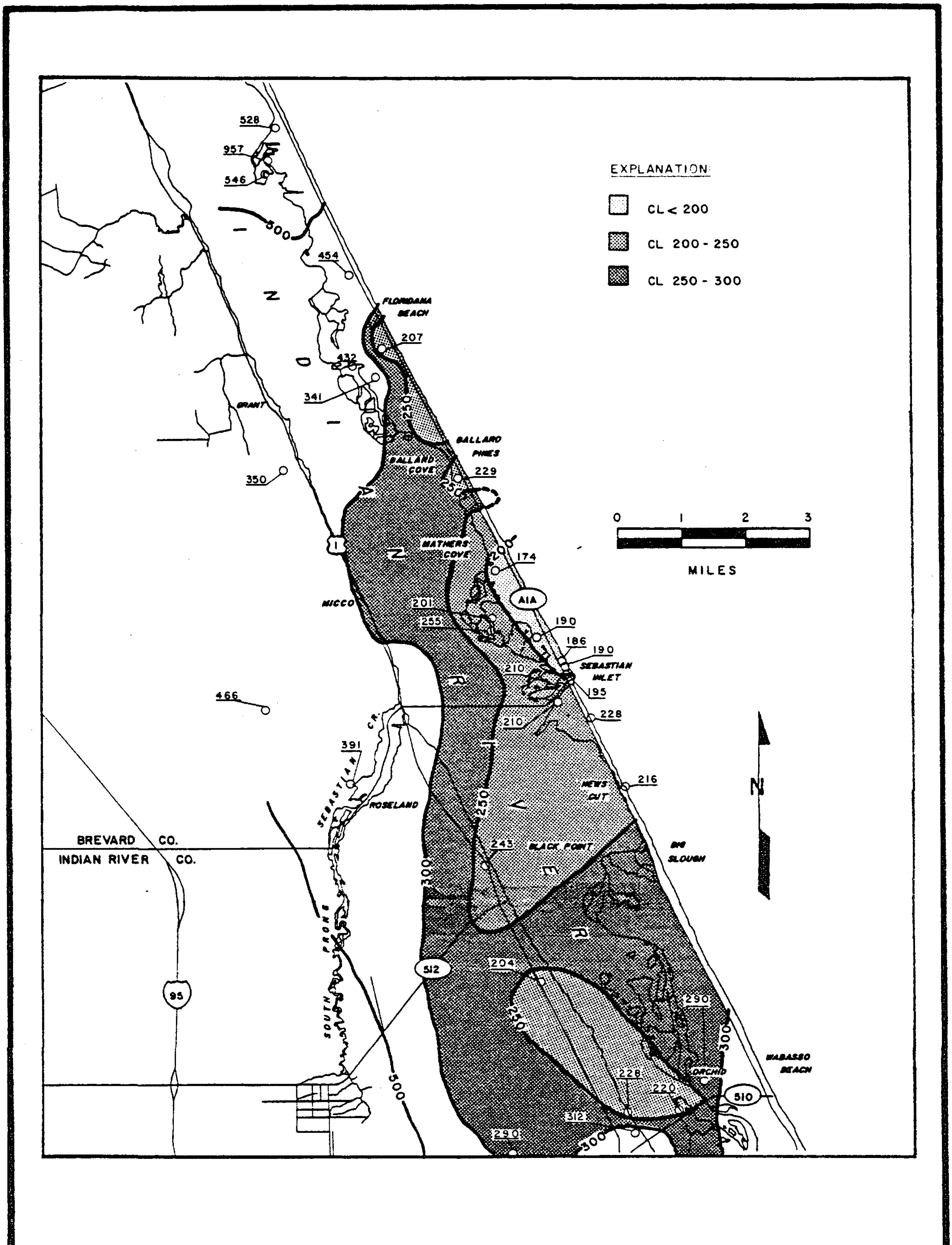

Figure 14. Chloride concentration, in mg/l, for the upper zone during 1983-1984.

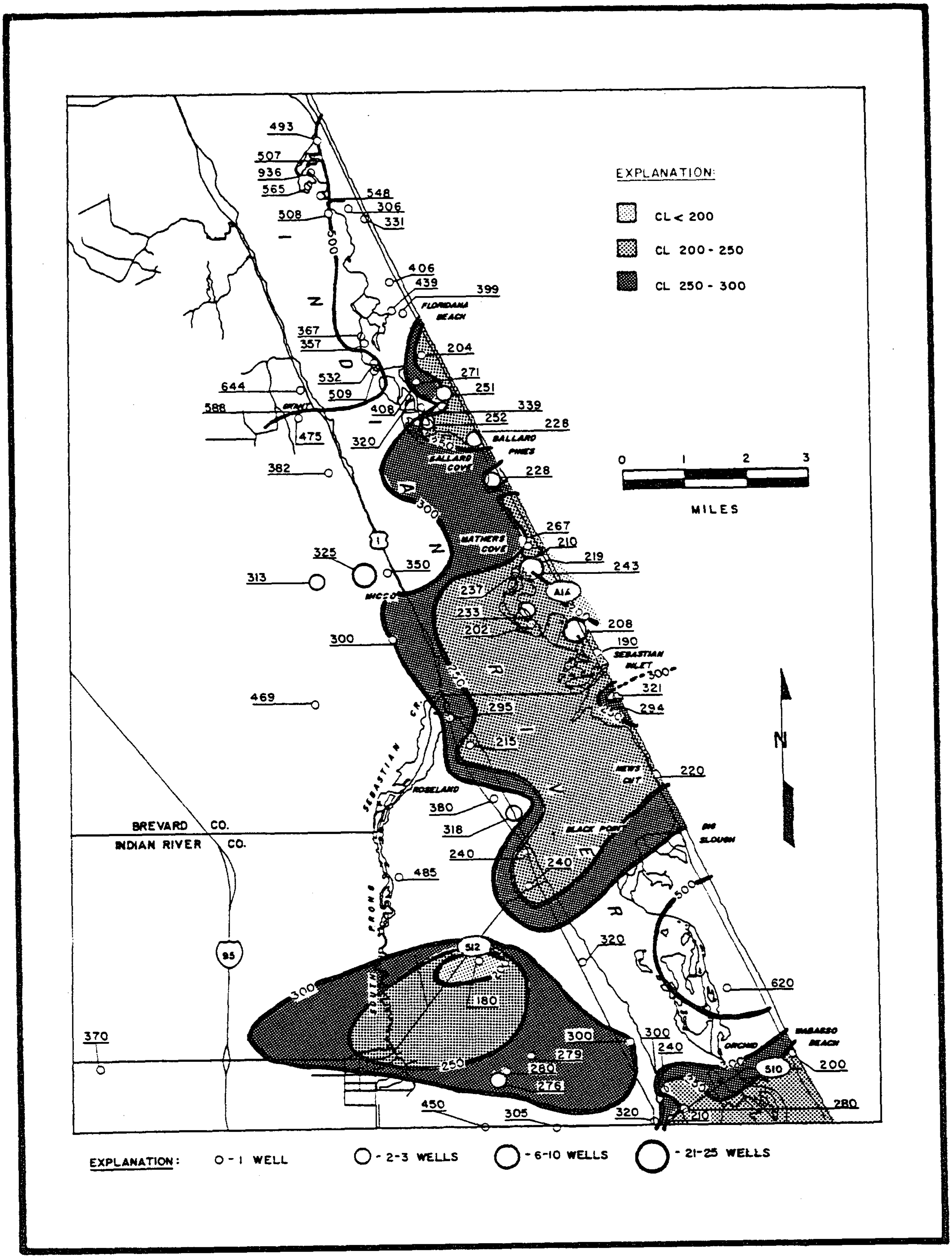

Figure 15. Chloride concentration, in mg/l, for the upper zone during 1979-1982.

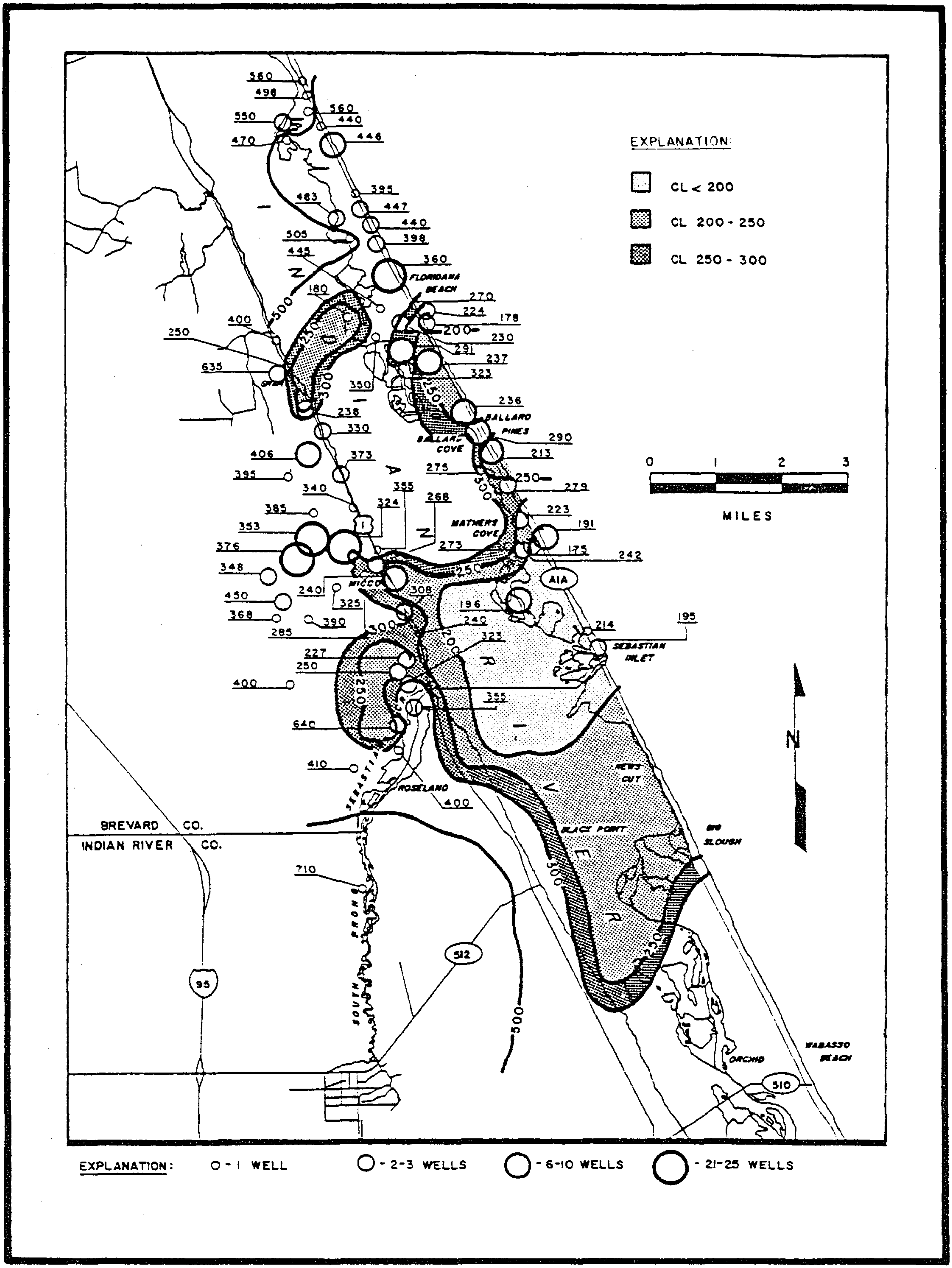

Figure 16. Chloride concentration, in mg/l, for the upper zone during 1975-1978.

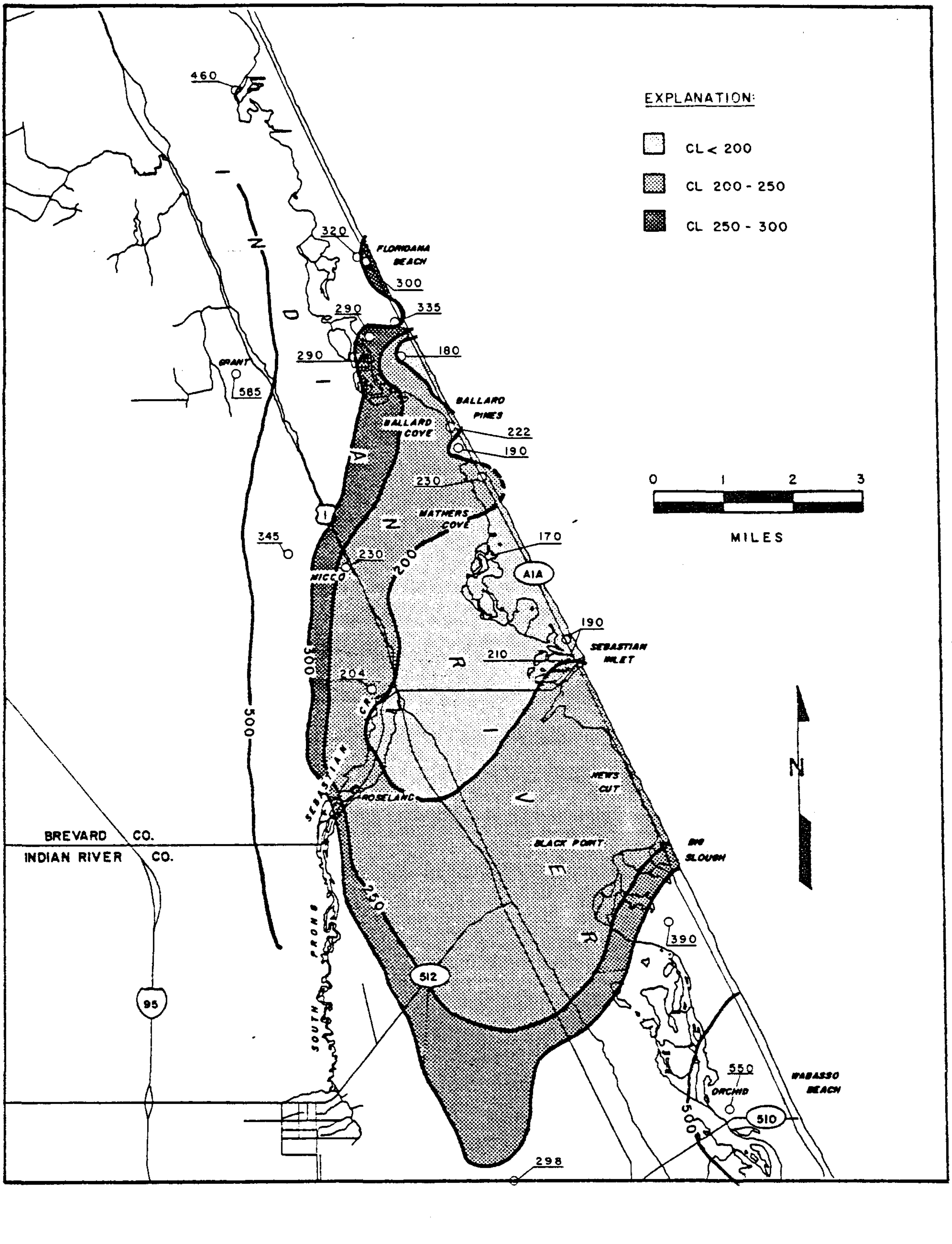

Figure 17. Chloride concentration, in mg/l, for the upper zone in 1956.

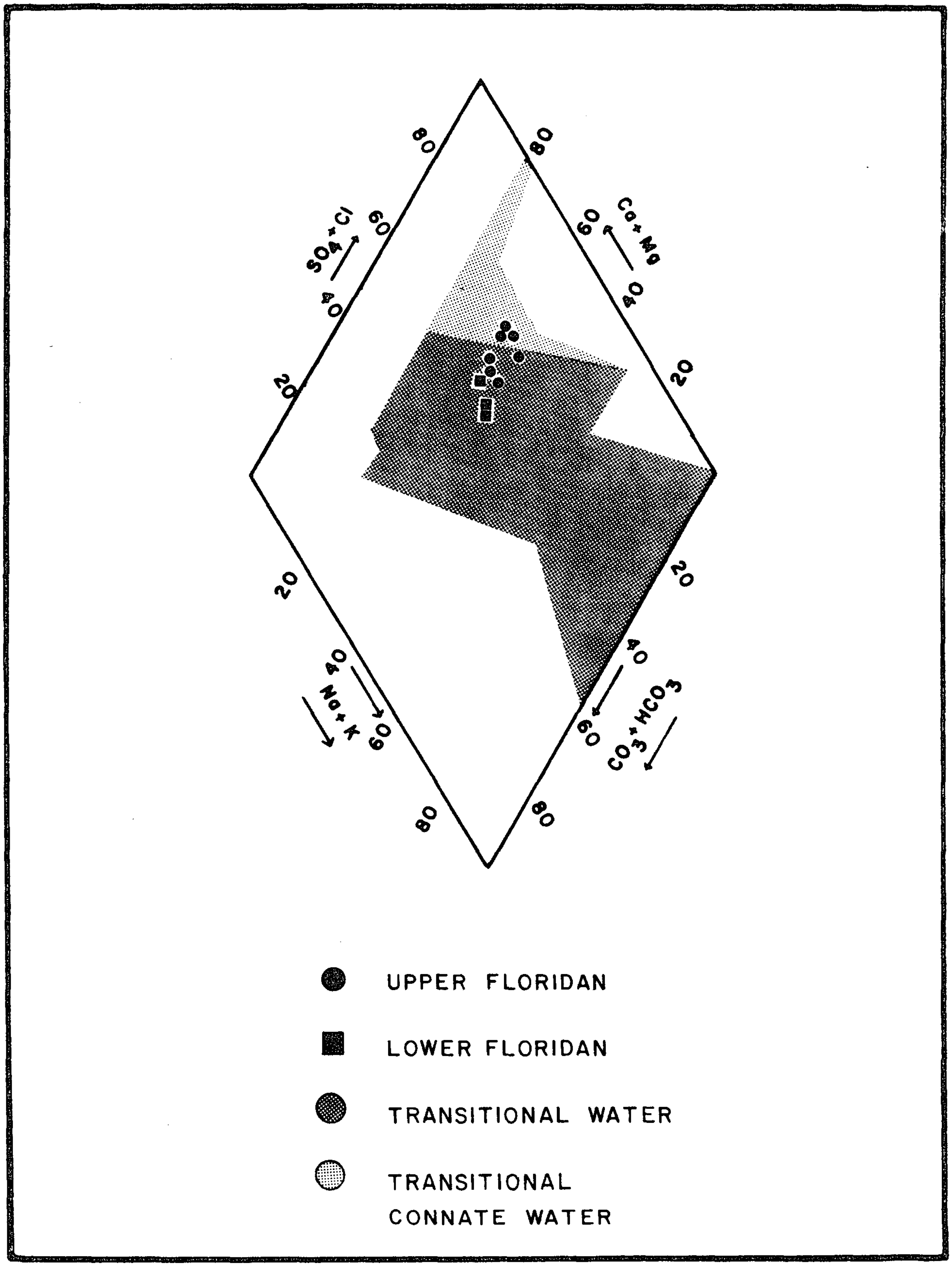

Figure 18. Water quality data from wells in the Sebastian freshwater lens plotted on the central field of the Piper diagram.

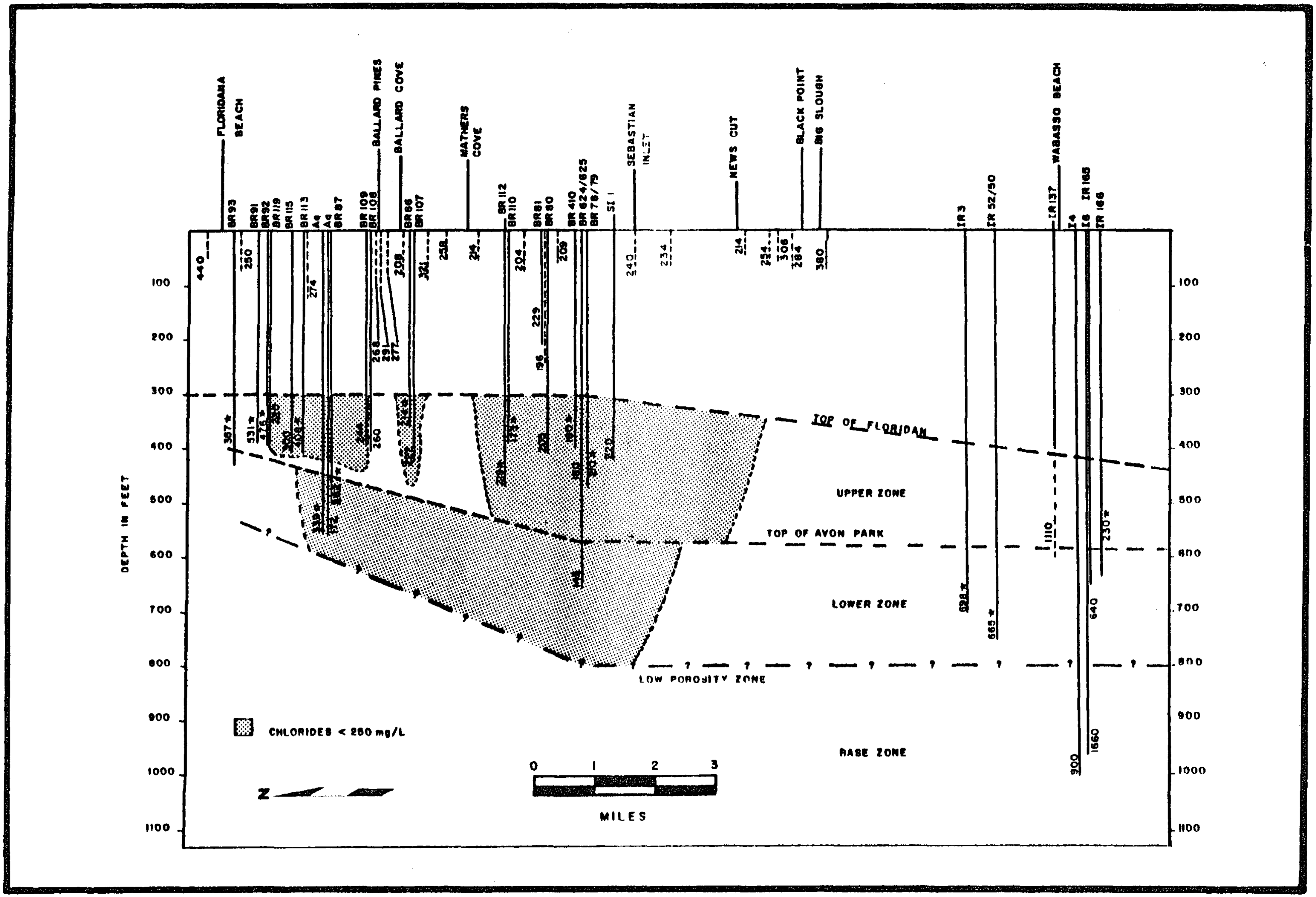

Figure 19. North-south cross-section through the Sebastian freshwater lens in 1985, indicating well depths and chloride concentration. Values with stars refer to samples collected prior to 1985 (between 1969 and 1984)

in 1985, indicating well depths and chloride concentration. At present, data indicates that three lobes of fresh water exist along the north-south axis of the lens. However, their lateral extent has not been defined in the area east of the barrier island. The lens increases in thickness to the south. The average thickness of the north lobe of the lens is 100 feet. At Sebastian Inlet, in the south lobe, lens thickness increases to approximately 250 feet. Therefore, 150 feet is taken as a conservative figure for the thickness of the middle/south lobe of the lens.

Lower Zone

Figure 20 shows the areal extent of the lower zone in the study area in 1985. Like the upper zone the potable water in the lower zone is confined to the Barrier Island and extends from south of Floridana Beach to Sebastian Inlet. It also contains chloride concentrations below 200 mg/l.

Figure 21 shows the chloride concentration in the lower zone of the lens for an earlier period (1969-84). A comparison of Figures 20 and 21 indicates that the areal extent of potable water in the lower zone has remained stable for the last 15 years.

Figure 22 shows a depth profile of chloride concentrations at Sebastian Inlet (Toth, 1985). Chloride concentrations increase from 150 to 204 mg/l as depth increased from 315 to 565 feet below land surface, but then decrease with depth to 152 mg/l at 640 feet. The decrease in chlorides is due to zones of low permeability which tend to isolate these low chloride waters from surrounding more mineralized waters. Similar findings were observed at Aquarina, approximately 5 miles north of the Sebastian Inlet well site during construction of a test production well. Here chlorides as high as 570 mg/l occurred at the base of the upper zone at a depth of 450 feet below land surface, but decreased to 220 mg/l at a depth of 550 feet (Pitt, 1981).

Four flow zones were detected in this well. These zones are at 457, 493, 540, and 578 feet. The first two zones occur within the lower Ocala Limestone. The third occurs at the

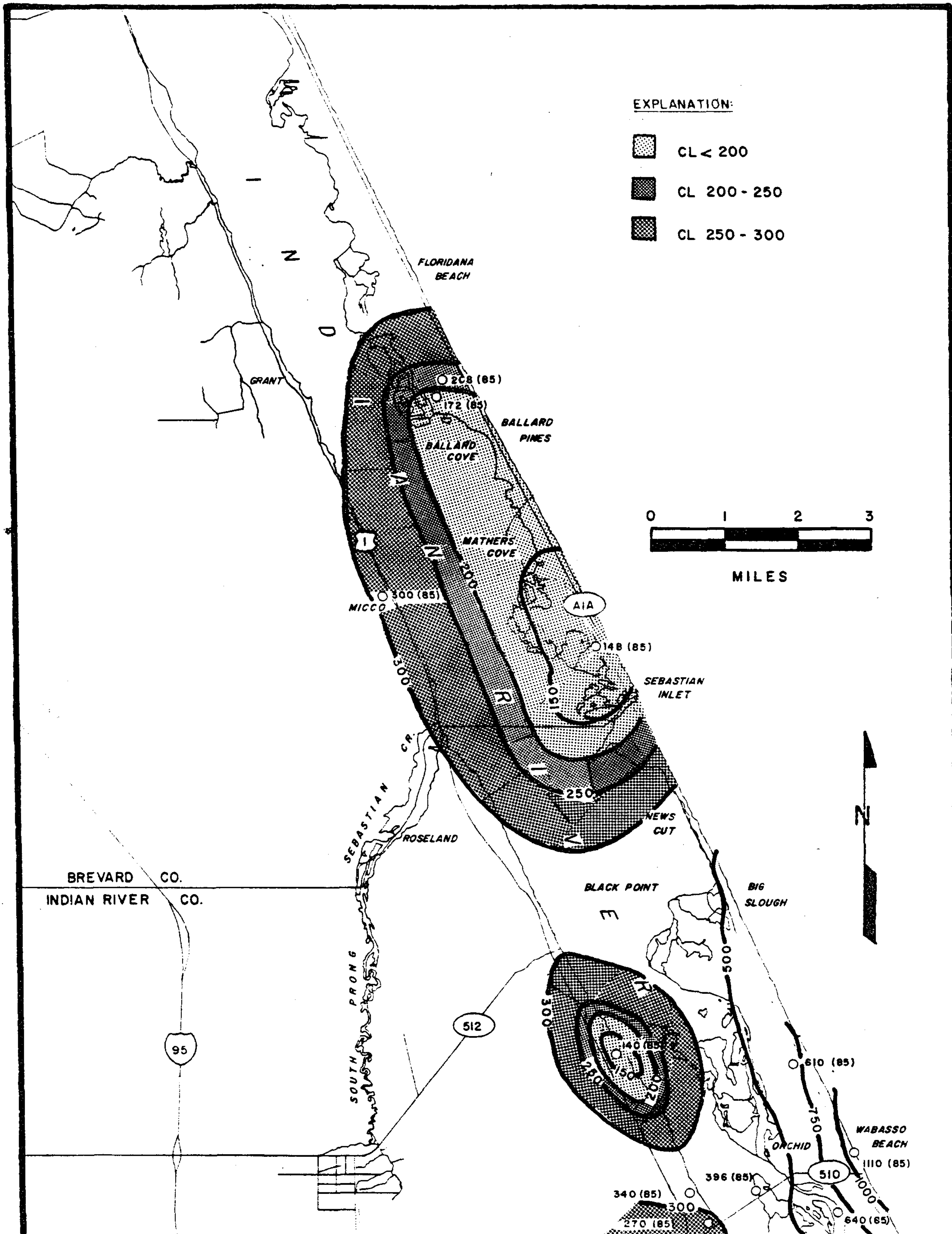

Figure 20. Estimated chloride concentration, in mg/l, for wells in the lower zone in 1985.

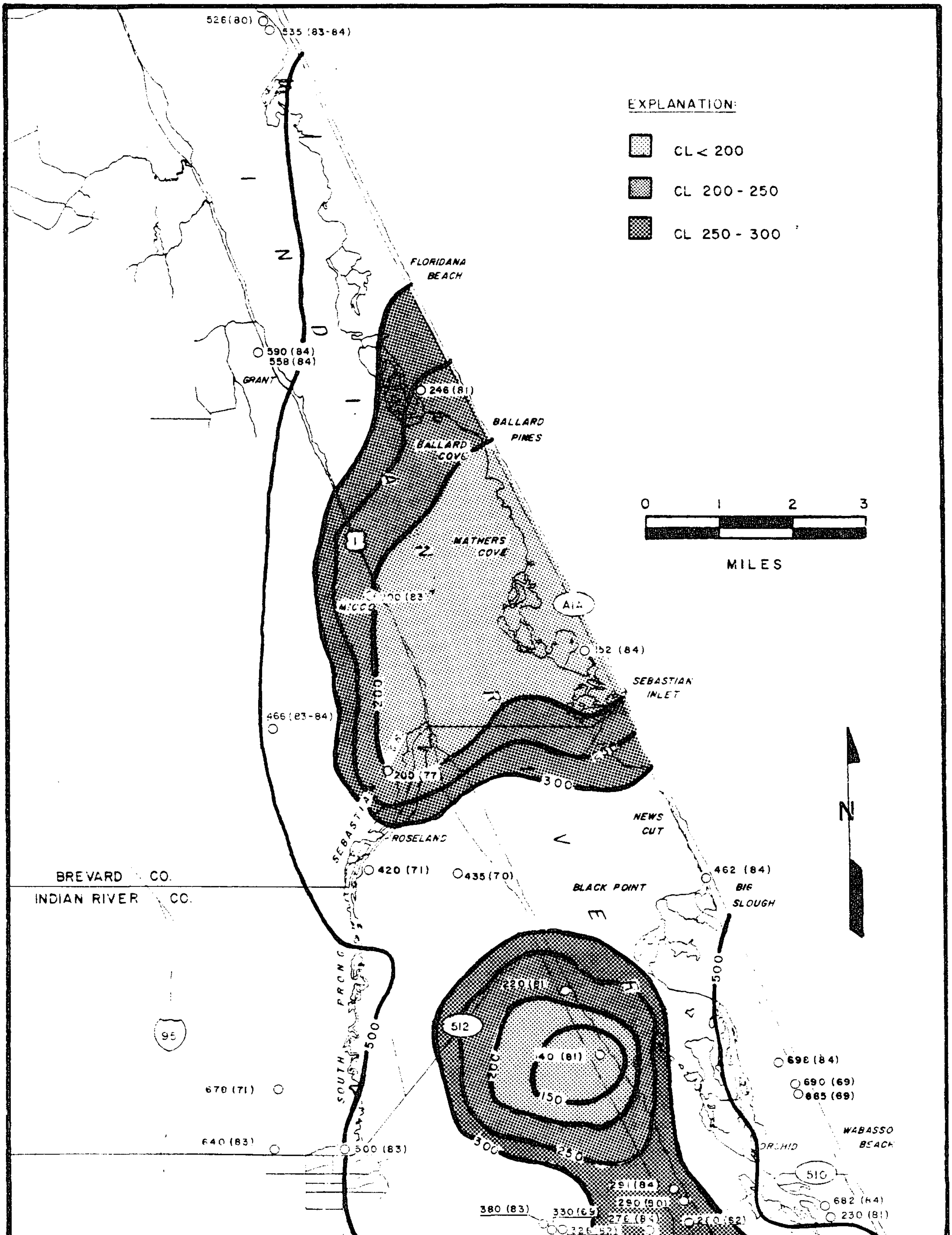

Figure 21. Estimated chloride concentration, in mg/l for wells in the lower zone during 1969-1984.

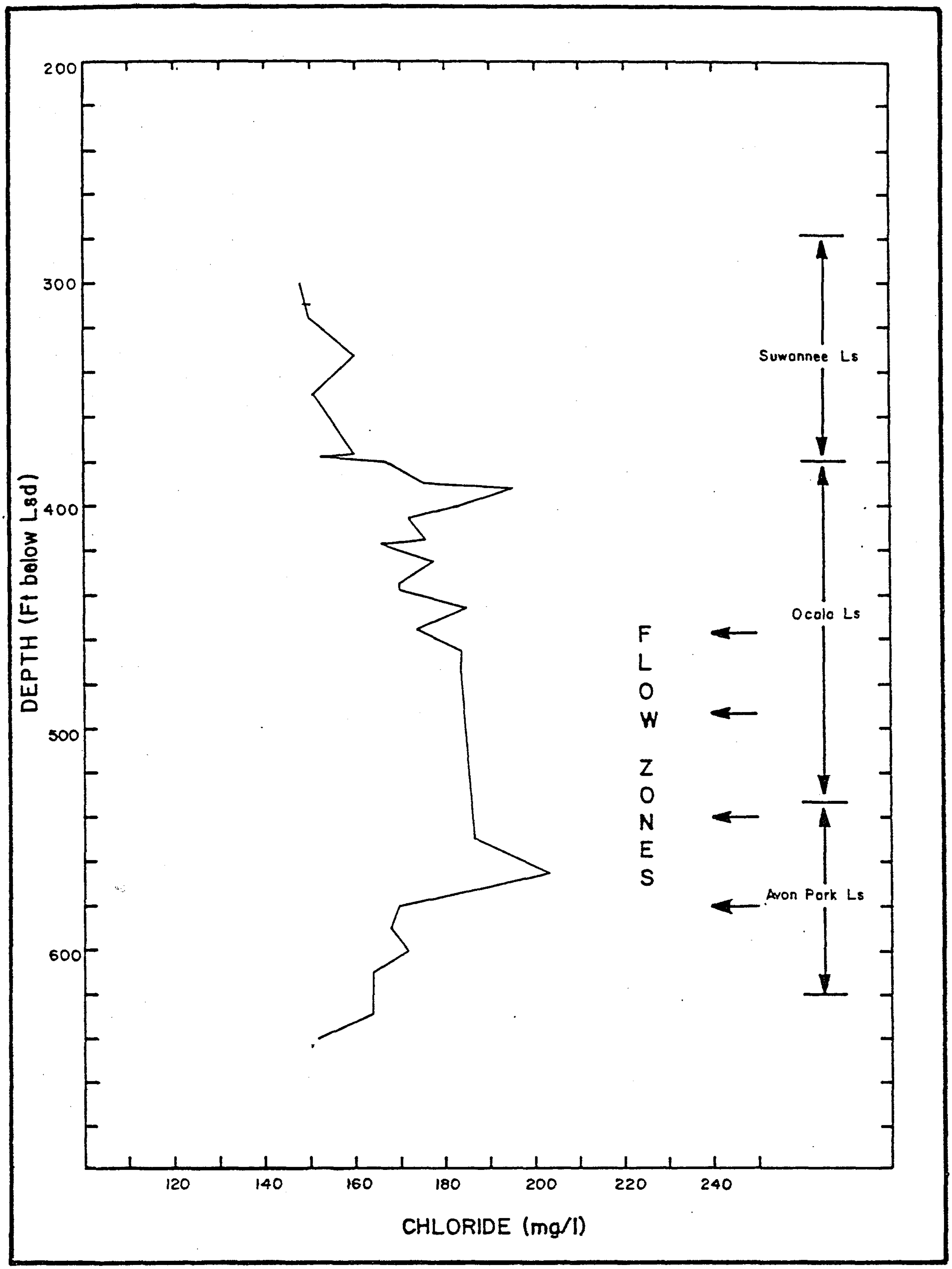

Figure 22. Change in chloride concentration with depth at BR0624 at Sebastian Inlet; from Toth (1985).

contact of the Ocala and Avon Park limestones. The fourth zone occurs within the upper part of the Avon Park Limestone. Inspection of figure 22 reveals that each of the first three zones contains water with similar chloride concentrations. The fourth zone, however, contains water with a lower chloride concentration.

Water quality data for three lower zone wells sampled in 1985 indicates the lower zone water is a transitional type (Figure 18), which in some areas , has lower chloride concentrations than the water in the upper zone. It is assumed that the quality of this water represents the original quality of water entrapped in the lens.

RADIOCARBON AGE DATING AND STABLE ISOTOPE RATIOS

Ground water samples were collected from six wells within the Sebastian freshwater lens for carbon 13/12 and oxygen 18/16 isotope ratio determinations and radiocarbon age dating. Four of the samples were from wells tapping the upper zone whereas two of the samples were from wells tapping the lower zone. In this study, radiocarbon dating is used as a technique to determine the age of potable waters within the Sebastian freshwater lens. From this analysis it may be possible to determine whether the lens receives any recharge from outside the immediate study area. In addition oxygen 18/16 stable isotope ratios are used to identify waters with different origins and to assess whether the upper and lower zones in the Sebastian freshwater lens are hydraulically connected.

Radiocarbon Dating

Radiocarbon dating is based on the formation of a radioactive isotope, carbon-14, by the reaction between cosmic rays and nitrogen in the atmosphere. The carbon-14 combines with oxygen to form radioactive carbon dioxide, which is taken up by living materials and adsorbed by rain and surface water bodies exposed to the atmosphere. After death or absence of exposure to the atmosphere, plants, animals, and ground water lose carbon-14 by radioactive decay.

The radiocarbon content of ground water decreases at a rate equal to the half-life of carbon-14. The half life is defined as the time it takes for the carbon-14 content of ground water to decrease to one-half of its initial concentration. By expressing the measured carbon-14 content of ground water as a percentage of the carbon-14 content of modern ground water, the age of the sample can be calculated. For this calculation a half-life value of 5,568 years, the Libby value, is used (Tamers, personal communication, 1985).

Radiocarbon dating has been applied to the study of recharge rates of ground water (Tamers, 1967), in calculations of ground-water flow rates (Hanshaw et al., 1983; and Pearson and White, 1983), and in determining safe yields for the Biscayne aquifer (Tamers et al., 1975). The results of radiocarbon dating of water samples from six different wells are summarized in Table 2.

The radiocarbon ages for the water samples from the lower zone are remarkably consistent and date 23,220 and 22,980 years before present. The radiocarbon ages for upper zone water samples are more variable and range from 20,890 to 25,910 years before present. The oldest water sample with an age of 25,910 years is from the north lobe of the lens. The middle lobe has an age of 24,220 years, and the age for samples from the south lobe are 20,890 and 22,740 years.

Planert and Aucott (1985) reported a radiocarbon age of 29,000 years before present for a water sample from the upper zone in the south lobe of the lens. A well with a total depth of 450 feet, cased to the top of the Hawthorn Formation was sampled. In contrast, water from two south lobe wells sampled in this study resulted in ages of 22,740 and 20,890 years before present.

TABLE 2. Radiocarbon ages and carbon 13/12 and oxygen 18/16 isotope ratios for water samples from the upper and lower zones of the Sebastian Freshwater Lens.

Location	Stn.	Lat.	Long.	Well Depth (ft)	Casing Depth (ft)	C-14 Age YrBP*	C13/C12 (ppt)	018/016 (ppt)	CL mg/1)
<u>Upper Zone</u>									
South Lobe:	IR-1	275003	802604			22,740	-4.70	-1.28	218
	BR0625	275210	802722	450	300	20,890	-2.91	-0.91	181
Middle Lobe:	BR107	275425	802831	420		24,220	-5.61	-1.63	228
North Lobe:	BR119	275616	802938	385		25,910	-4.15	-0.44	213
<u>Lower Zone</u>									
	BR0624	275210	802722	650	550	23,220	-5.19	-0.97	152
	Aquarina	275520	802937	550	450	22,980	-5.74	-1.29	176

*Years before present.

Both wells were cased to the top of the Floridan aquifer at approximately 300 feet. Differences in well construction may be responsible for the disparity in ages. Older waters from intermediate aquifers within the Hawthorn Formation may have mixed with upper zone water, yielding an older age in the former study. Hence, the ages reported here are considered more reliable.

Figure 23 shows the relation between radiocarbon age and chloride concentration. The age for water samples from the lower zone appears to be independent of their chloride content. This suggests that the measured ages for lower zone waters have not been appreciably altered by mixing with surrounding, more mineralized waters. In contrast, the age for samples from the upper zone is directly related to chloride concentrations. The age of samples from the south and middle lobe of the lens increases as chloride concentration increases. The sample from the north lobe of the lens, however, does not appear to follow this pattern. These findings suggest that the lens receives no recharge but the measured range in age for upper zone samples is due to mixing between lens water and older, surrounding and/or underlying mineralized water. By this reasoning, the "true" age for the upper zone of the lens would be represented by the sample with the lowest chloride concentration, or 20,980 years before present.

Radiocarbon age dating suggests that formation of the Sebastian freshwater lens was during glacial times. The last glacial advance began 26,000 years before present, peaked around 18,000 years before present, and ended approximately 11,000 years ago. During this time

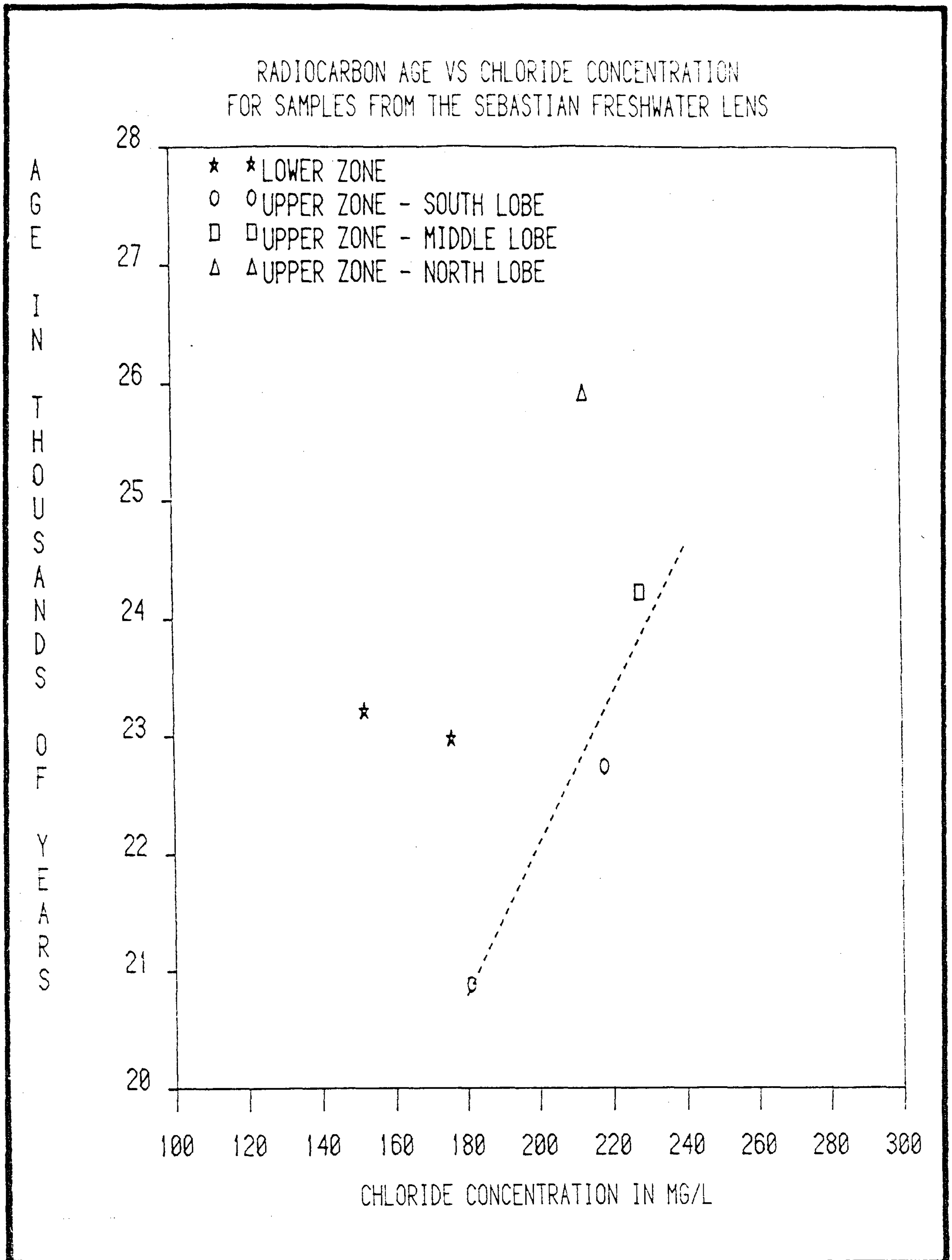

Figure 23. Relation between radiocarbon age and chloride concentration of ground water samples from the upper and lower zones of the Sebastian freshwater lens.

sea level was lowered by 100 meters (Turekian, 1968). Measured dates for lens water lie within this interval.

Stable Isotope Ratios

Stable isotope ratios reflect the relative occurrence of the same element in nature and these ratios are altered by different physical and chemical processes. Stable isotope ratios have been used as tracers to map ground water flow (Thatcher, 1967) and to identify the origin of waters with different chemical compositions (Hitchon and Friedman, 1983).

Figure 24 shows how the oxygen isotope content (O^{18}/O^{16}) of the samples varies with chloride concentration. The sample from the north lobe is anomalous and does not lie along the linear trend defined by the other samples. This data suggests that the water in the north lobe of the lens has a different mixing history from the water in the middle and south lobes.

Figure 24 also indicates that the oxygen isotope and chloride concentrations of water samples from the lower zone define a linear trend which parallels that of upper zone samples. This parallelism, coupled with different radiocarbon ages and chloride concentrations, indicates that the upper and lower zone of the Sebastian freshwater lens are not hydraulically connected.

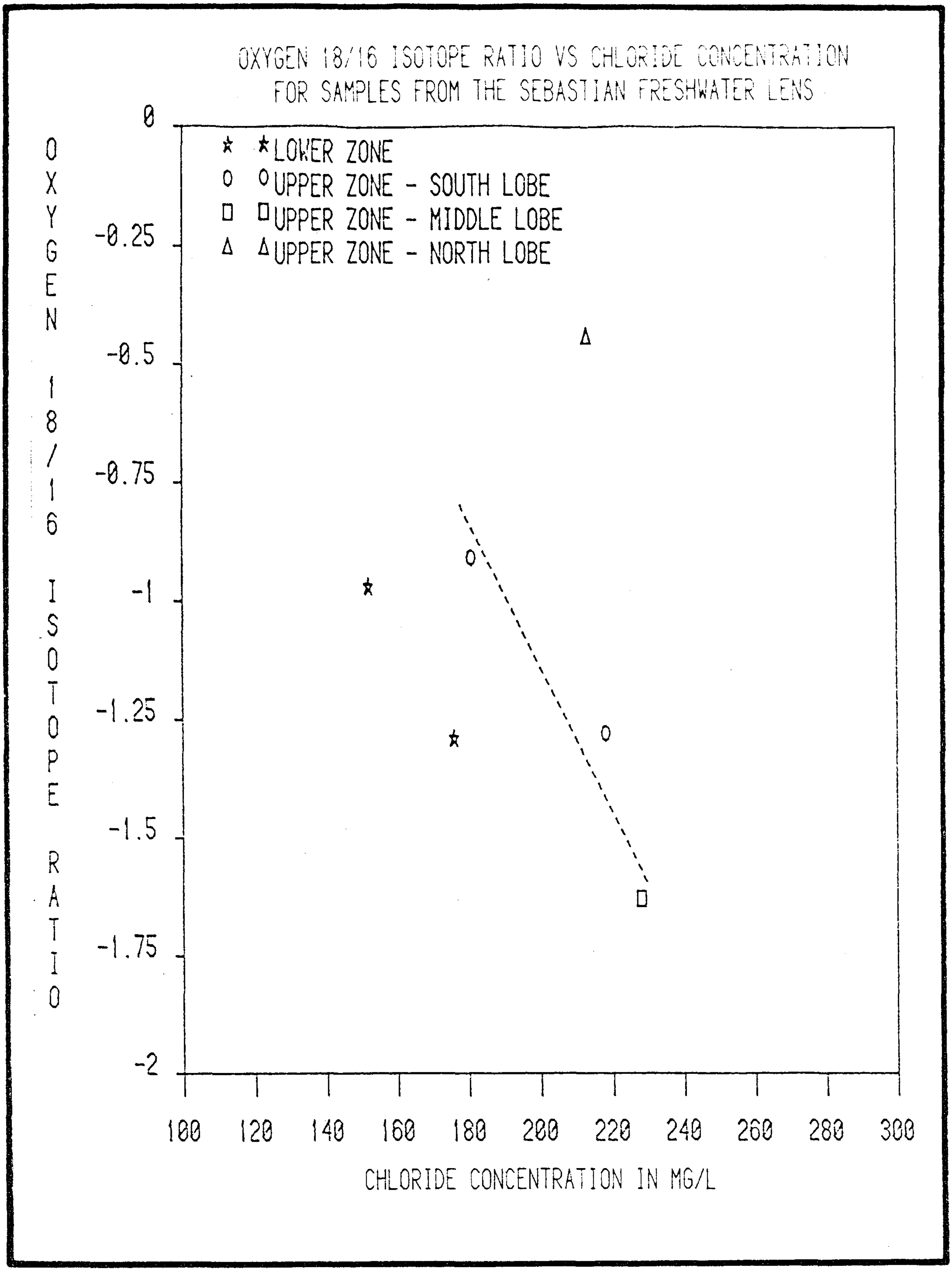

Figure 24. Relation between oxygen 18/16 isotope ratio and chloride concentration of ground water samples from the upper and lower zones of the Sebastian freshwater lens.

WATER USE

Water is withdrawn from the Floridan aquifer in the study area for domestic and public supply, lawn irrigation, and water source heat pumps. Prior to 1981, the dominant withdrawal in the study area was by free-flowing wells which discharged an estimated 6.7 million gallons per day (MGD). Withdrawals for domestic supply, lawn irrigation, and heat pump usage were secondary (Marella, 1982). In 1982, the District plugged 13 of these wells on the Barrier Island. This was done in an effort to conserve water within the lens and to retard its deterioration. Currently, the largest use of water in the study area is for water source heat pumps and is estimated to be 0.41 MGD. In 1984, state and county parks, utilities, and businesses in the study area withdrew 18.1 million gallons per year (MGYR) of water from wells in the upper zone and 2.2 MGYR from wells in the lower zone for public supply (Aquarina). These users are from south to north: Sebastian Inlet State Park (2.1 MGYR), Long Point County Park (1.65 MGYR), Chuck's Steak House (0.46 MGYR), Aquarina (2.2 MGYR), and Sunnyland Beach Utility Commission (13.9 MGYR).

Population density is largest in the northern portion of the study area where growth is rapid. Further south, the barrier island is very narrow. Long Point County Park and Sebastian Inlet State Park are located here. For this reason, the study area is divided at Ballard's Cove (see Figure 11) into a northern and southern section and water use for each section is discussed separately.

Area North of Ballard's Cove

In this region, a total of 80.1 MGYR of water is estimated to have been withdrawn from the upper zone aquifer in 1984. Sunnyland Beach Utility Commission is the principal supplier of water and withdrew 13.9 MGYR for public supply in 1984. In addition, about 20 homes have irrigation wells that withdraw approximately 50 gallons/minute or 15 MGYR if operated for 1 hour, 243 days a year.

There are 105 houses in Sunnyland. Of these it is estimated that at least 79 use a water source heat pump. These homes are generally 1,200 square feet or larger and require, as a minimum, a 2 1/2 ton air-conditioner (30,000 BTU/hr). A 2 1/2 ton water source heat pump uses 6.0 gallons of water per minute. Therefore, if all 79 heat pumps are operated for 1800 hours per year (Frazee, 1985) then a total of 51.2 MGYR is withdrawn.

Area South of Ballard's Cove

In this region, a total of 195.2 MGYR of water is estimated to have been withdrawn from wells in the upper zone in 1984. Of this total, an estimated 32 MGYR are withdrawn by public and domestic users, 66 MGYR for lawn irrigation, and 97.2 MGYR for water source heat pumps operating 1,800 hours/yr. The above estimates assume that there are 150 homes in the area with an average household population of 2.5, and a water use/capita/day of 200 gals. These homes are large and require a 2 1/2 ton or greater capacity air-conditioner as discussed previously. In addition, it is also assumed that each house irrigates for 1 hour, 243 days a year from wells that flow at 30 gal/min.

ESTIMATES OF LENS LIFE

Upper Zone

In 1985, the area of the upper zone of the Sebastian freshwater lens was 12 million square feet for the north lobe and 178 million square feet for the middle and south lobes. The portion of the lens that extends offshore, beneath the Atlantic Ocean, is not included in the above areas. The area offshore could be substantial. Therefore, the values above reflect minimum estimates of potable lens area in the upper zone.

Using these minimum areas, a porosity of 0.14 (Toth, 1985), and an average thickness of 100 and 150 feet for the north and middle-south lobes, respectively, within the upper zone, the volume of potable water in each lobe is:

Volume (gal) = Area (ft^2) x Thickness (ft) x Porosity x 7.48 gal/ft^3

= 1,290 Million gallons (Mgal) for the north lobe and

= 27,960 Mgal for the middle/south lobe.

Dividing these volumes by the 1984 water use estimates of 80.1 MGYR (north lobe) and 195 MGYR (middle/south lobe) yields an expected life of 16 and 143 years for the north and middle/south reservoirs of the lens, respectively.

Lower Zone

An estimate of the life of the lower zone was not made because the thickness of this zone is not known and its areal extent cannot be adequately defined by the nine wells which penetrate it. Hence, the volume of potable water in this zone cannot be accurately determined with available data.

CONCLUSIONS

Potable water occurs in two different depth zones within the Sebastian freshwater lens: an upper zone, which consists of Ocala and Suwannee limestones, and a lower zone, associated with the Avon Park Limestone. In 1985, the upper zone of the Sebastian freshwater lens consisted of three lobes of water with chloride concentration less than 250 mg/l and was confined to the Barrier Island. Between 1956-1985, the areal extent of the lens decreased. During the same period, population within the study area increased and resulted in increased withdrawals from the upper zone of the lens. Most wells in the area withdraw water from the upper zone for domestic supply, lawn irrigation, and water source heat pumps.

The thickness of the upper zone of the Sebastian freshwater lens increases to the south. In the area of the north lobe it averages 100 feet and consists almost entirely of Ocala Limestone. In the area of the middle and south lobes it averages 150 feet and consists of Ocala and Suwannee limestones. Hence, the average thickness of the middle/south lobe is at least 50 feet greater than that of the north lobe.

Radiocarbon ages for four samples from the upper potable zone of the Sebastian freshwater lens ranged between 20,890 and 25,910 years before present. The ages linearly increase with the chloride concentration of the samples and suggest that water from the lens has mixed with older, surrounding and/or underlying mineralized water. The ages also indicate that the lens is not being recharged with fresh water.

The north and middle/south lobes in the upper zone have minimum calculated volumes of 1,290 and 27,960 Mgal, respectively. Based on current water use practices they are expected to supply water for a minimum of 16 and 143 years if withdrawals average 80.1 and 195 MGYR (1984 water use), respectively.

The lower zone is tapped by few wells and is more stable. Its water quality is a transitional type, which in some areas has lower chloride concentrations than those in the upper zone. Withdrawals from this zone are small (2.2 MGYR at Aquarina in 1984) and have not significantly changed its background water chemistry.

Radiocarbon ages for two samples from the lower zone of the Sebastian freshwater lens are 23,220 and 22,980 years before present. The ages are independent of chloride concentration and suggest the chemical composition of lower zone samples represents the original chemistry of water entrapped in the lens. Little is known about the volume of potable water in this zone.

Radiocarbon ages of lens water support formation of the Sebastian freshwater lens during glacial times. The last glacial advance began 26,000 years before present (YRBP), peaked around 18,000 YRBP, and ended approximately 11,000 years ago. During this time sea level was lowered by 100 meters. The measured dates for lens water are within this interval.

Oxygen 18/16 isotope ratios of lens water were also measured. The oxygen isotope ratios indicate that the upper and lower zones of the lens are not hydraulically connected. They also indicate that water from the north lobe of the upper zone of the lens has a different mixing history than that of water in the upper zone of the middle and south lobes. In addition, water levels in the lower zones are higher than in the upper zone. This further indicates that there is no significant hydraulic connection between the two zones.

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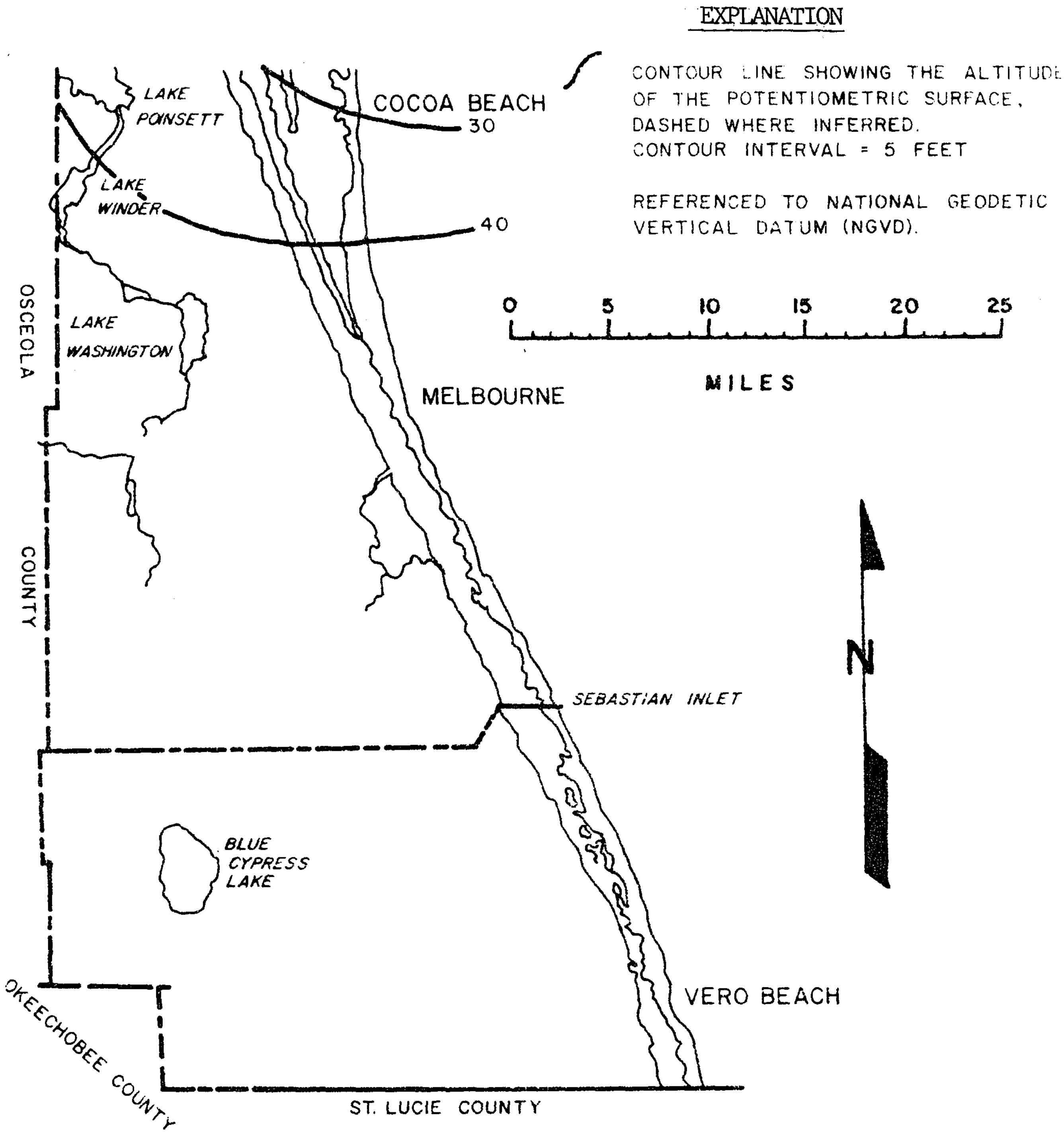
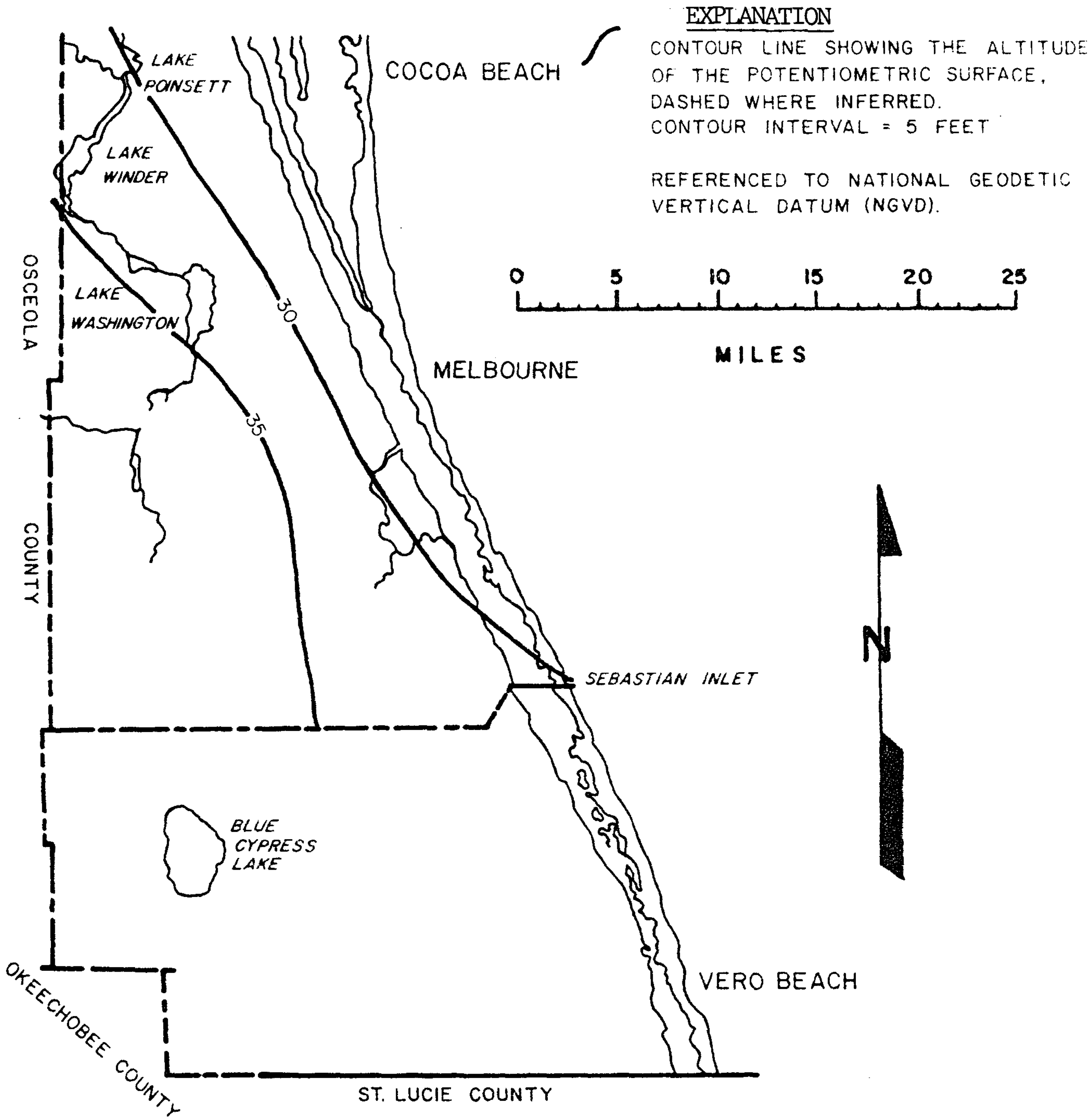
APPENDIX I

Potentiometric surface of the upper Floridan aquifer in South Brevard and Indian River counties for pre-development time and for May 1973-1984



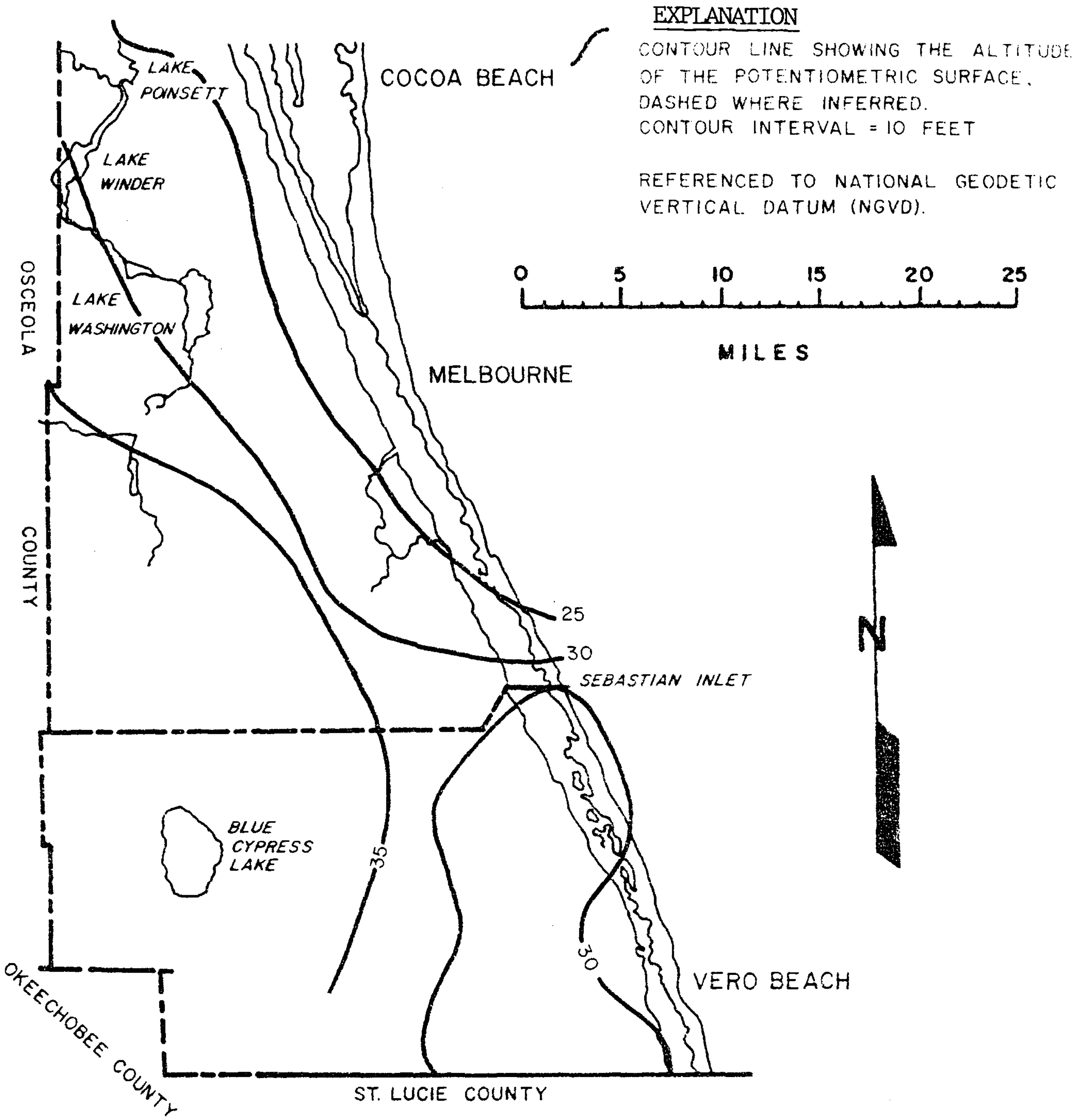
POTENTIOMETRIC SURFACE — PRE-DEVELOPMENT

From Johnston, R.H., et. al., 1980



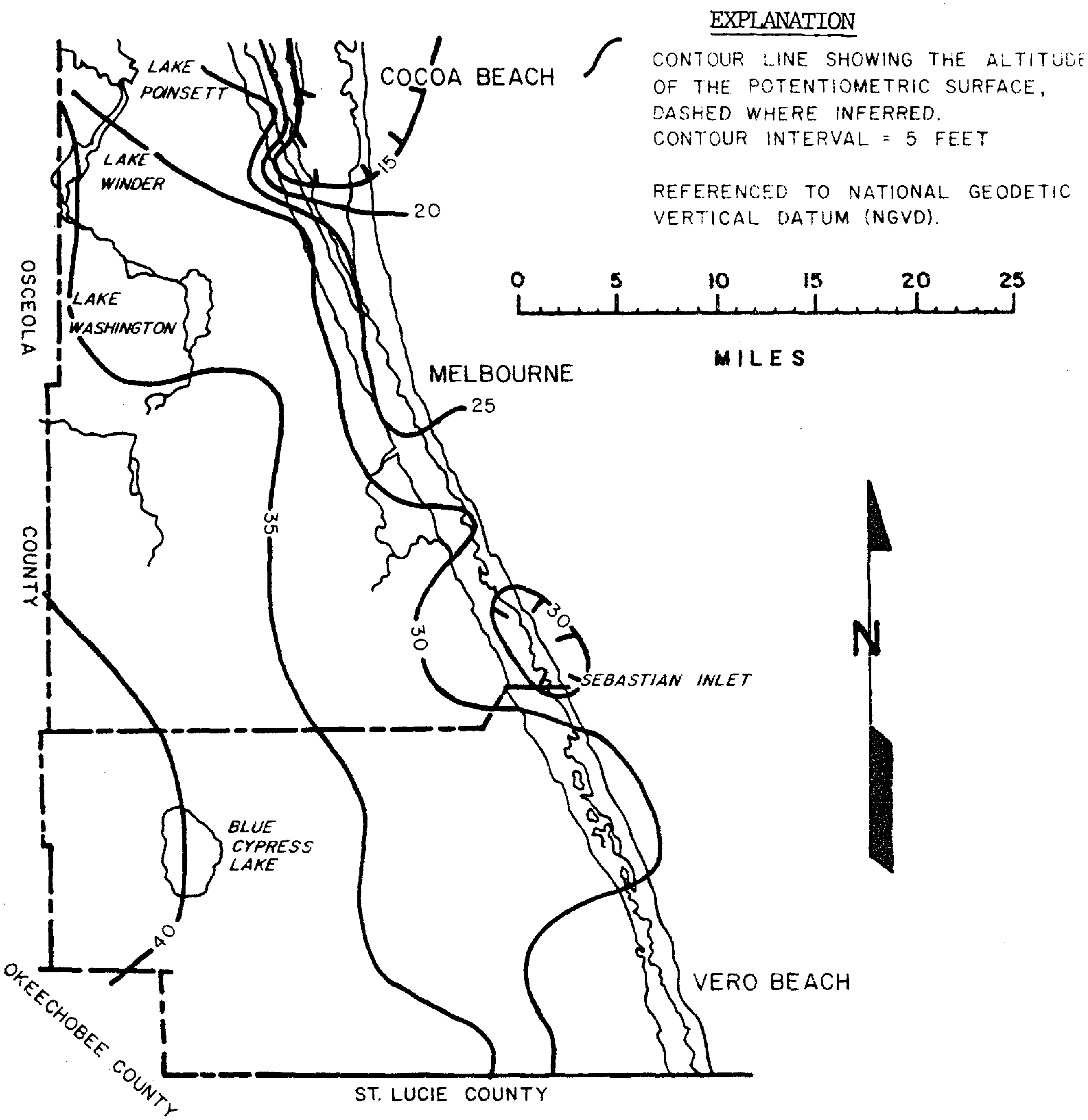
POTENTIOMETRIC SURFACE — MAY 1973

From Laughlin, C.P., 1973



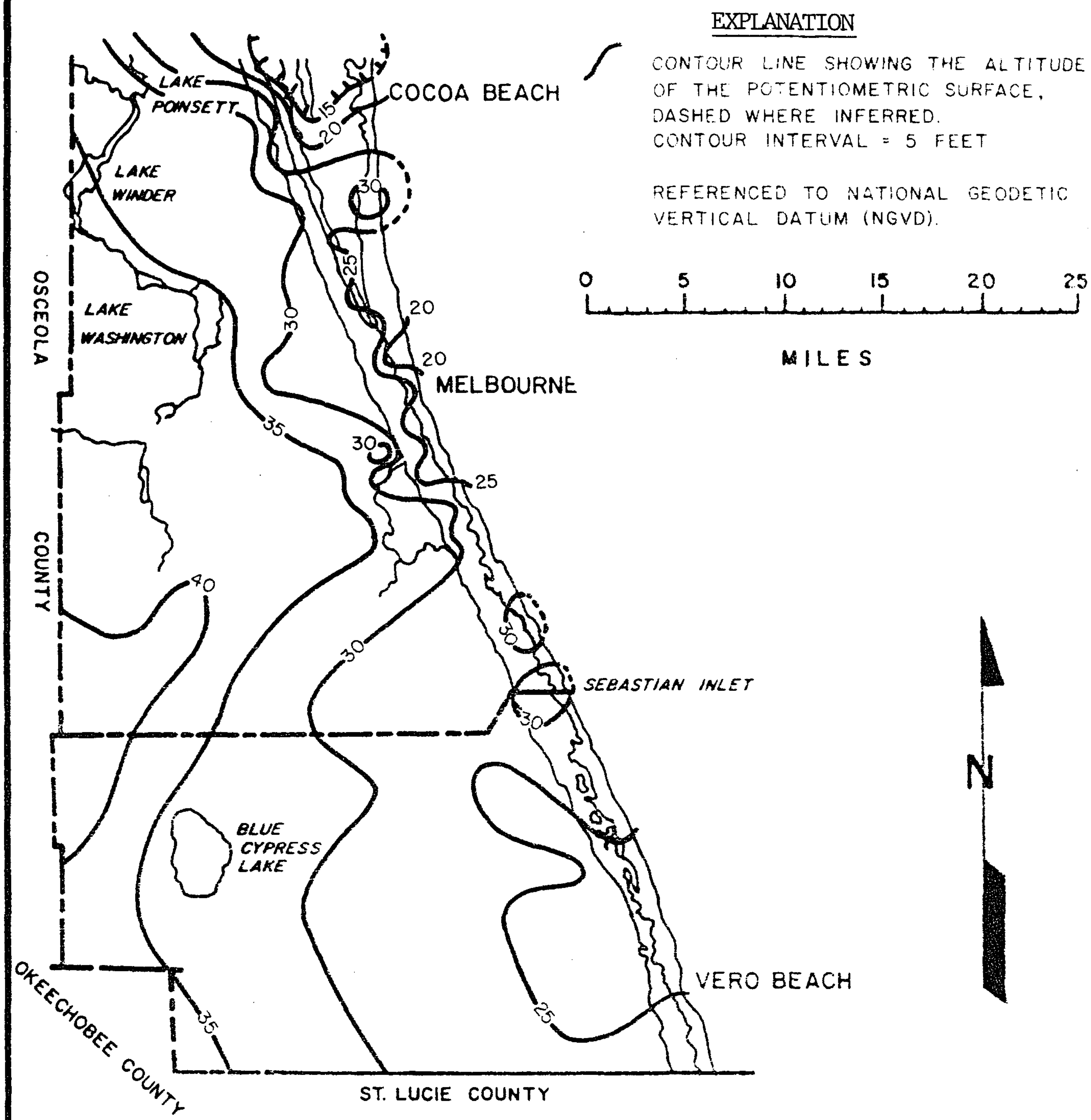
POTENTIOMETRIC SURFACE— MAY 1974

From Laughlin, C.P., 1974



POTENTIOMETRIC SURFACE—MAY 1975

From Laughlin, C.P., 1975



POTENTIOMETRIC SURFACE MAY 1976

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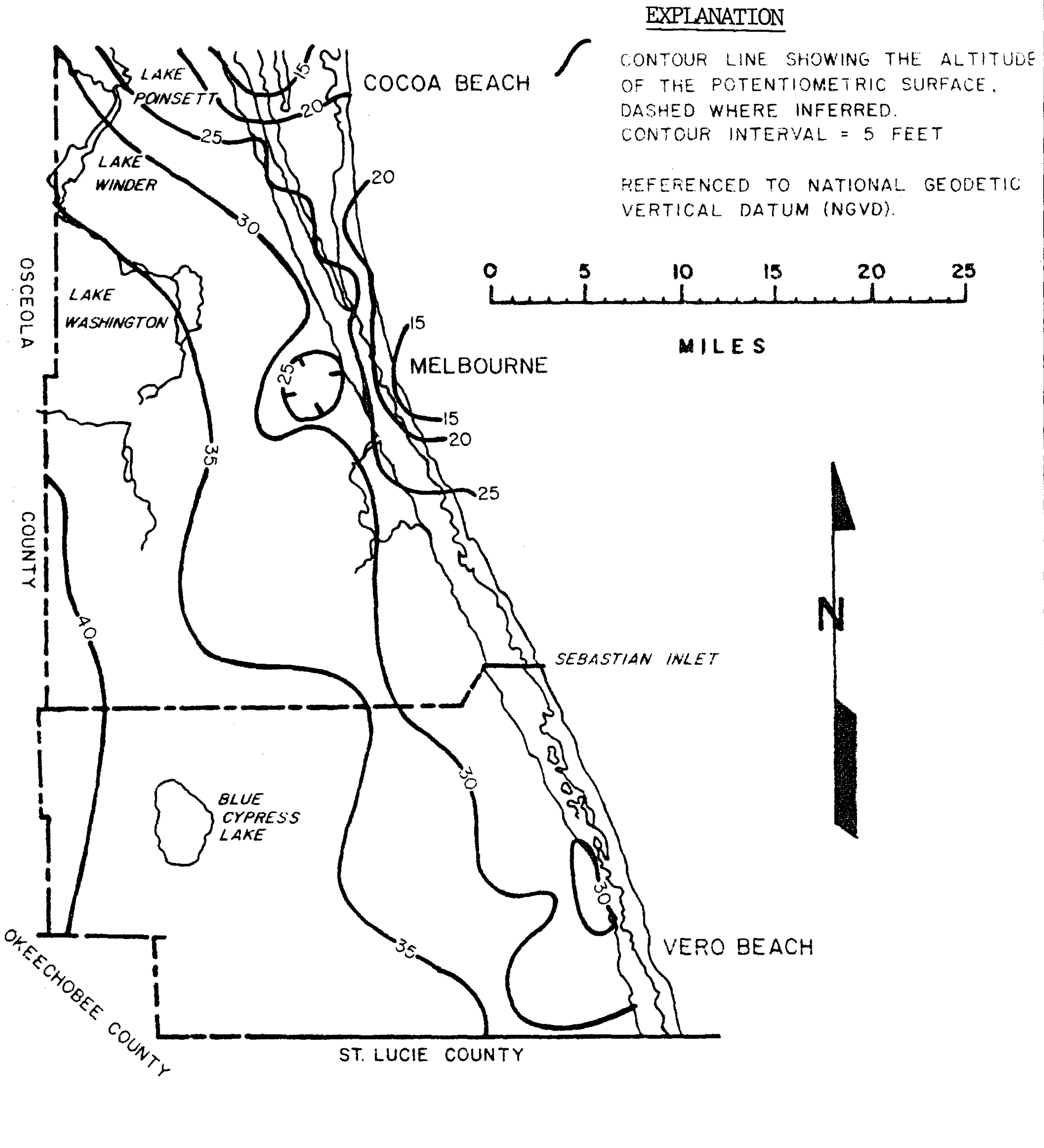
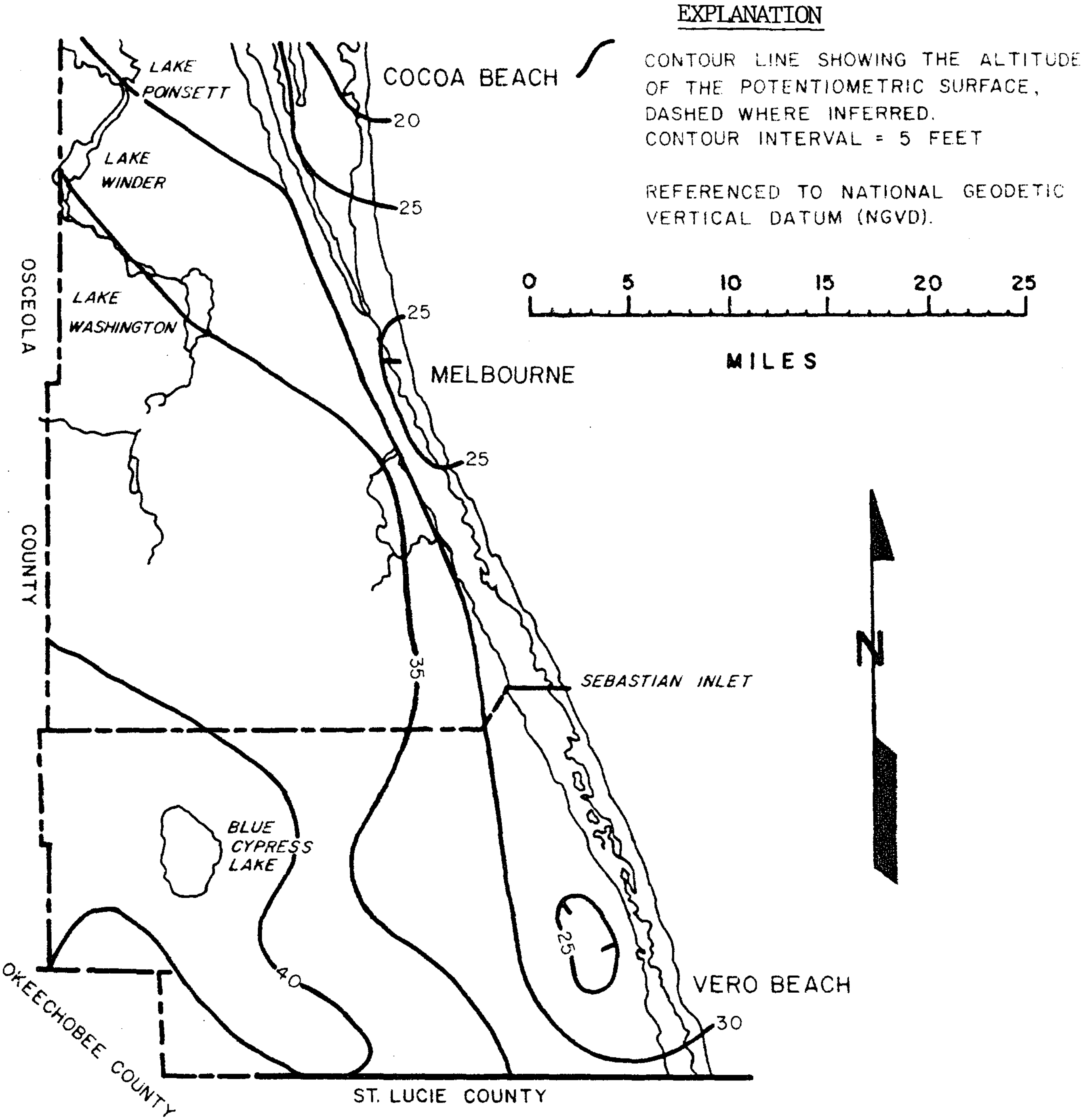


POTENTIOMETRIC SURFACE — MAY 1977

From Laughlin, C.P., and Hayes, E.C., 1977



POTENTIOMETRIC SURFACE — MAY 1978

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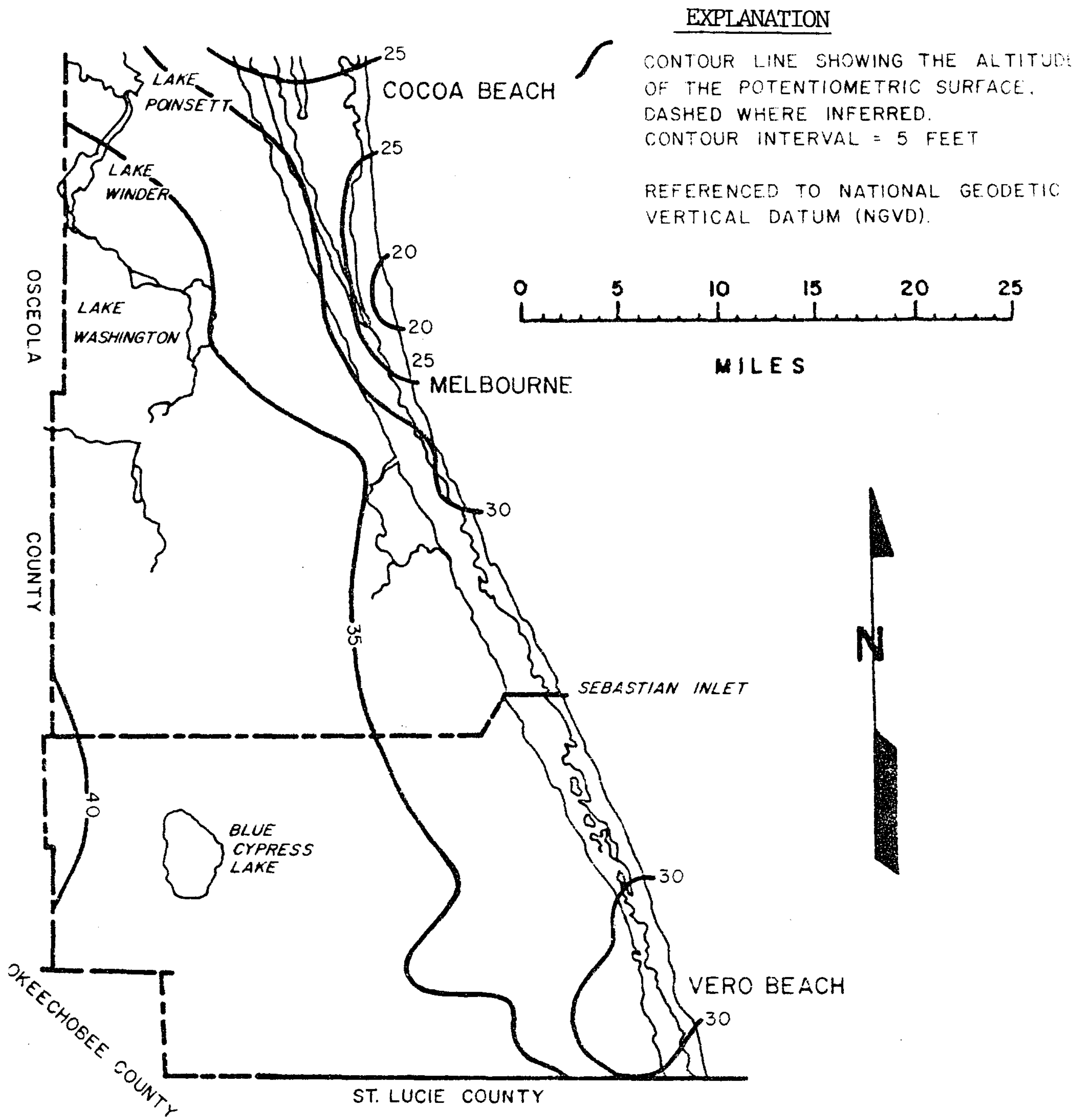

POTENTIOMETRIC SURFACE—MAY 1979

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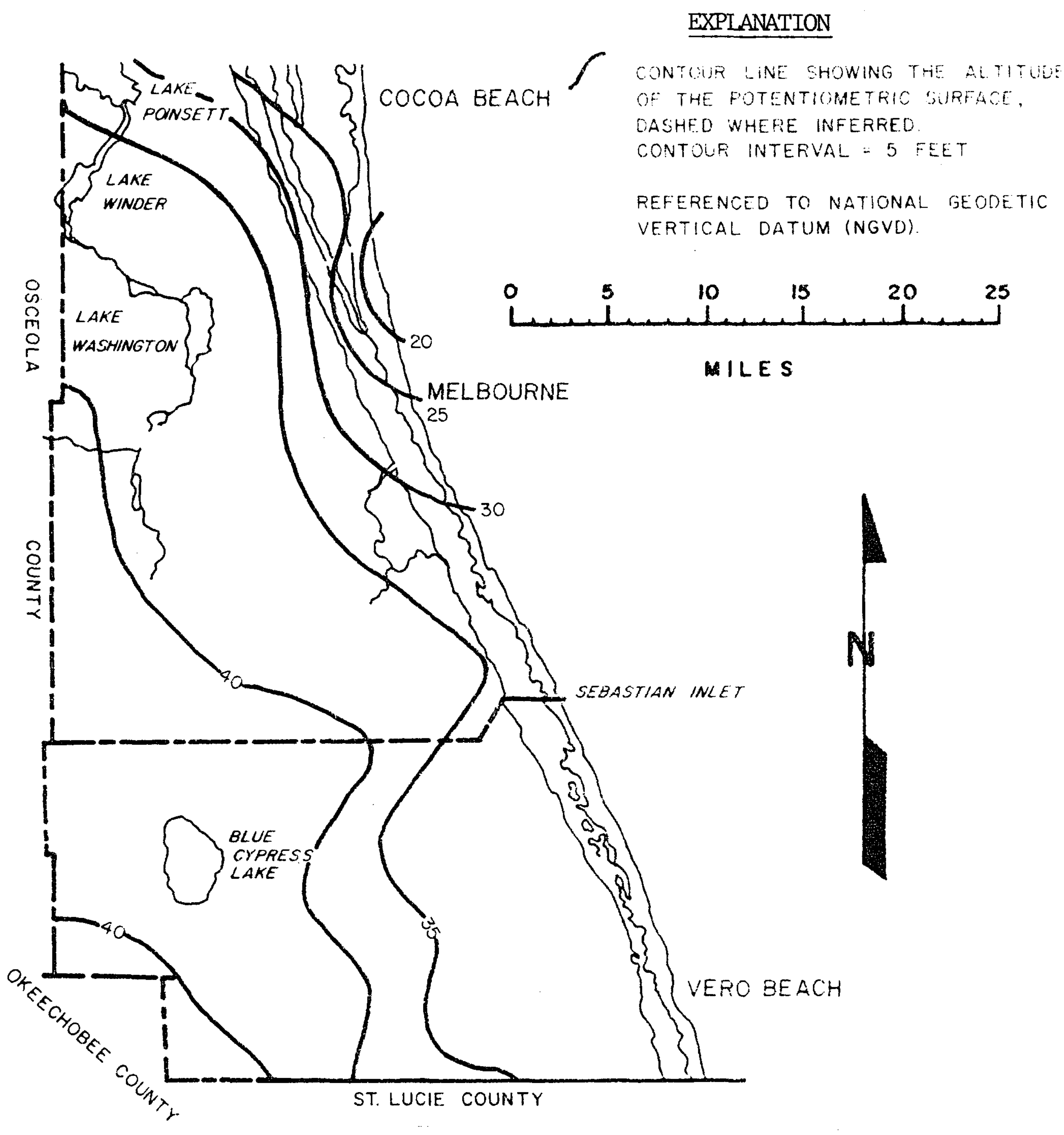

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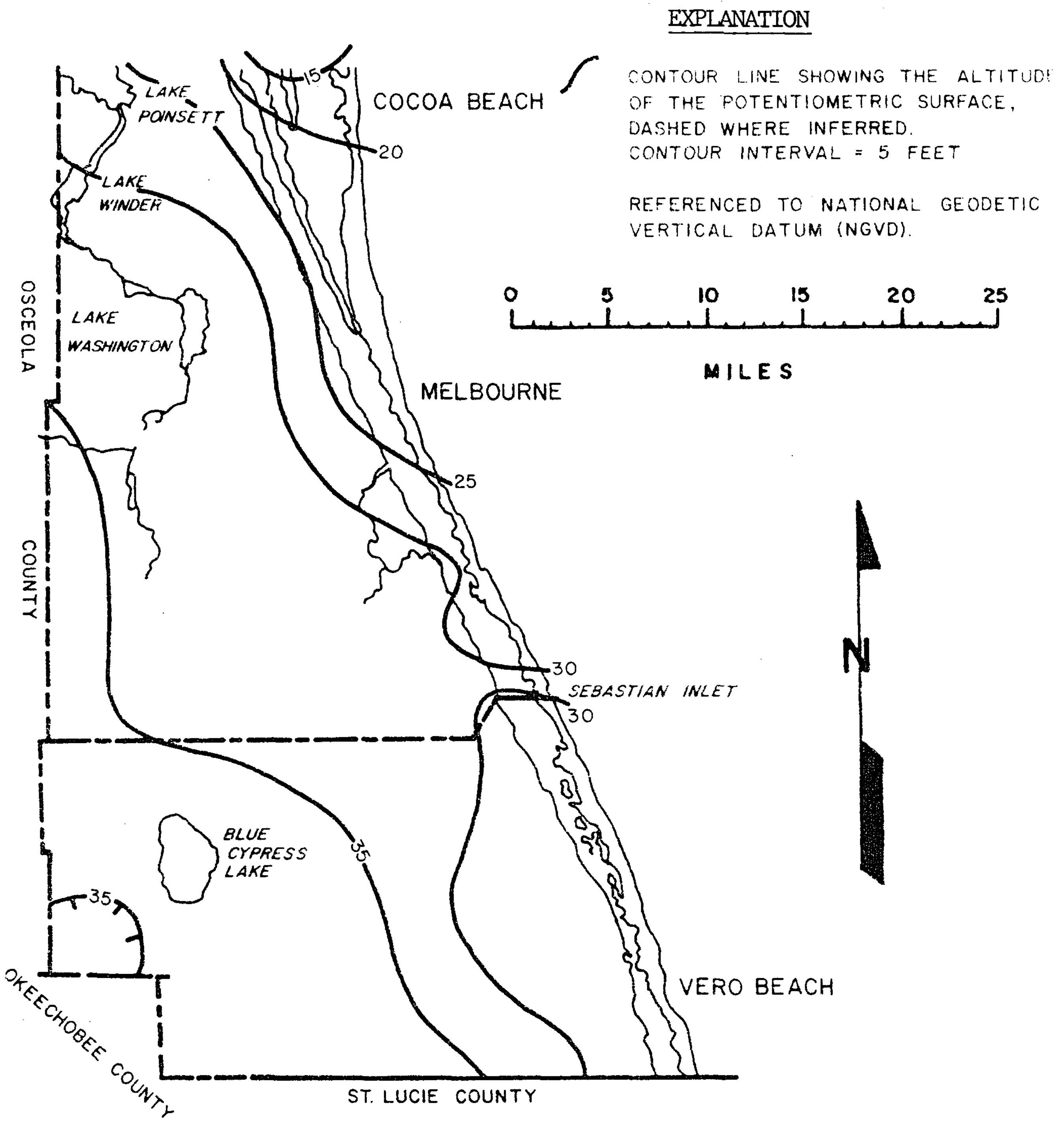

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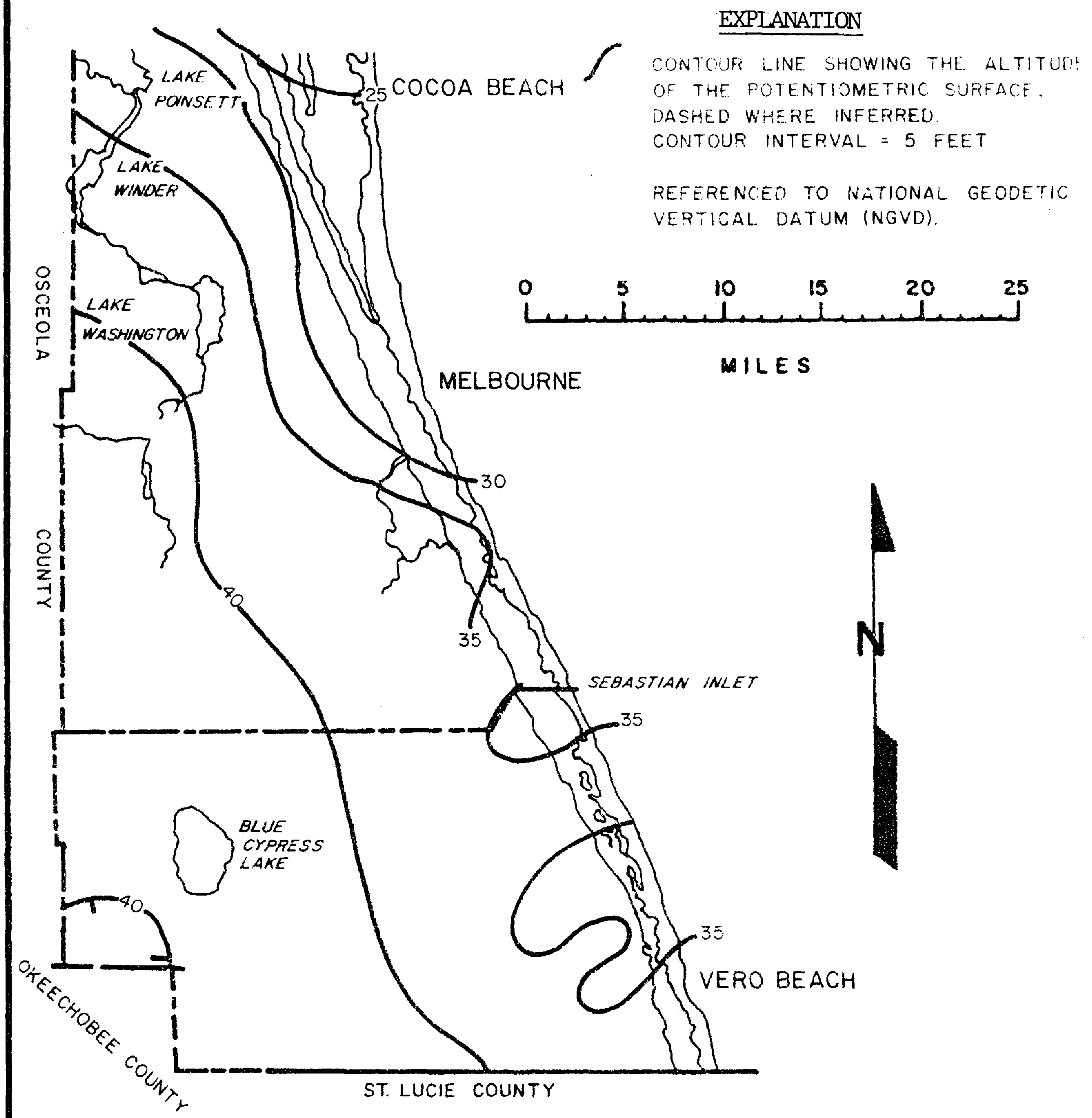

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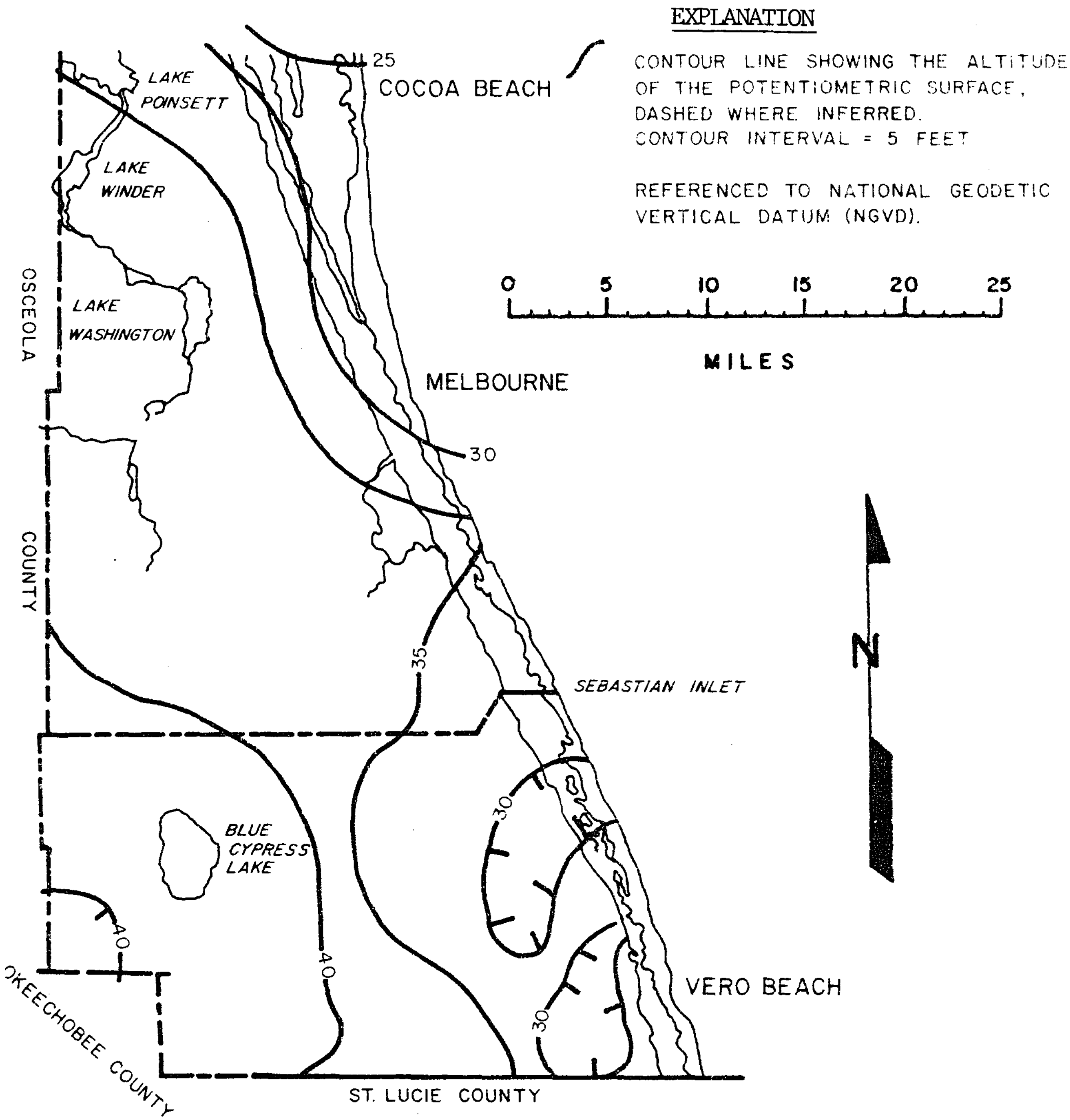
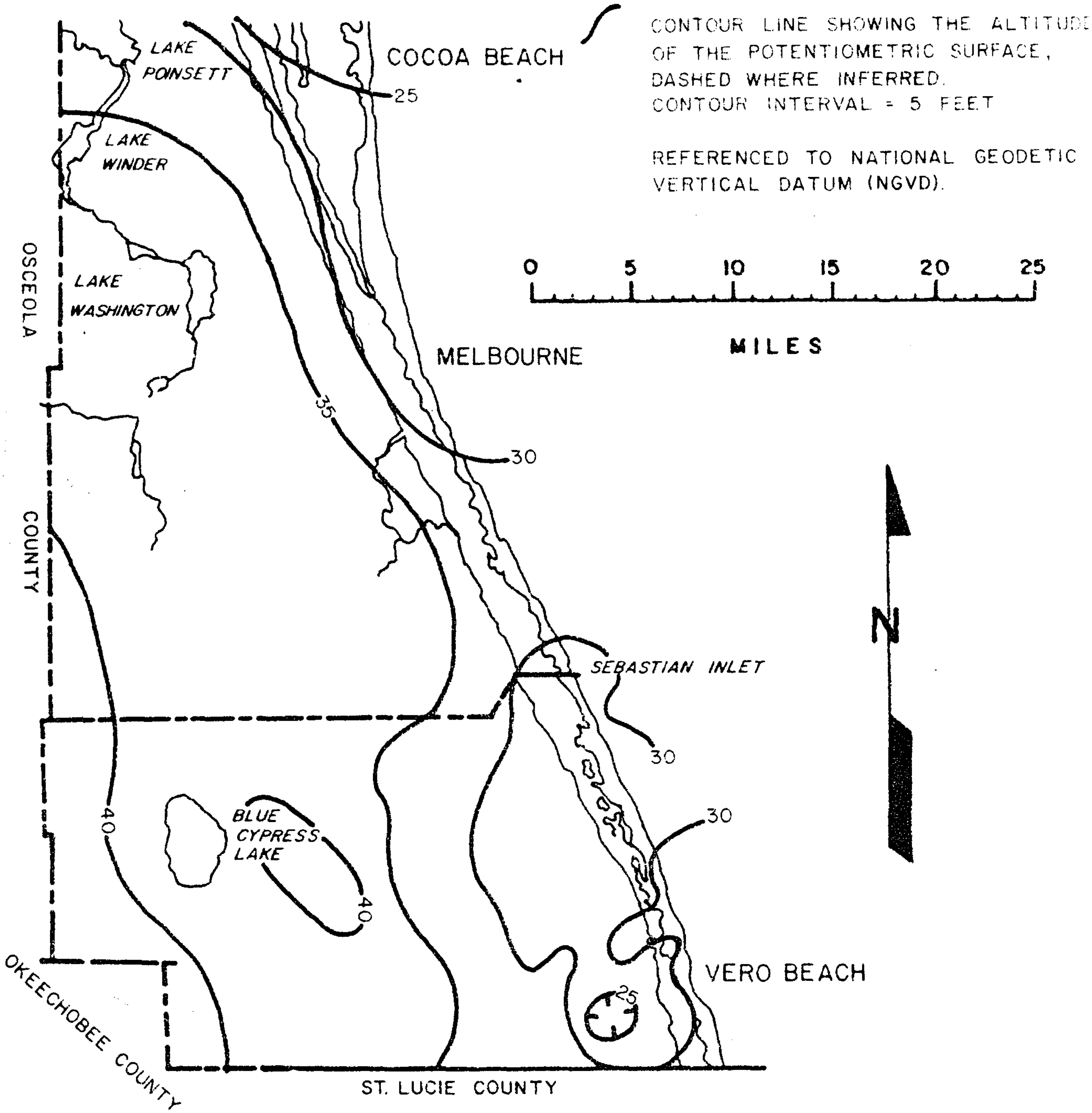


POTENTIOMETRIC SURFACE — MAY 1983

From Schiner, G.R., and Hayes, E.C., 1983



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