Salt-Water Intrusion Potential For Camden County, Georgia

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DEPARTMENT OF NATURAL RESOURCES

ENVIRONMENTAL PROTECTION DIVISION

GEORGIA GEOLOGIC SURVEY

Technical Completion Report
Contract Number 701-990099

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PROJECT REPORT 49

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Performed as part of the Georgia Environmental Protection Division's Interim Strategy to protect coastal Georgia from salt-water intrusion

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Executive Summary

The objective of this project was to assess the susceptibility of the Upper Floridan aquifer below Camden County, Georgia to salt-water intrusion. This assessment incorporated relevant geologic, hydrologic, and water quality data from neighboring Glynn County, Georgia and Nassau and Duval counties in northeastern Florida. Hydrogeological conditions below Camden County are similar to the three other counties; and, therefore, the occurrence and persistence of a salt-water plume below Brunswick in Glynn County is cause for concern. Ground-water utilization in Camden County is relatively low and this county has not experienced salt-water intrusion problems to date. There are no known Upper Floridan aquifer wells in Camden County in which chloride concentrations exceed the drinking water maximum concentration limit of 250 mg/L.

This report summarizes information derived from recently drilled wells in Glynn, Camden, and Nassau counties as well as time domain electromagnetic (TDEM) survey data for the study area. This new information confirmed the presence of salt water in the Fernandina Permeable Zone that occurs at depths of ~2,400-2,700 feet below mean sea level, immediately above the base of the Floridan aquifer. Several samples from recently drilled wells completed in Camden and Nassau counties indicate that salt water may not yet have contaminated much of the Lower Floridan aquifer in southeastern Georgia.

The most likely pathway for salt-water intrusion to occur involves the movement of salt water from the Fernandina Permeable Zone through conduits of enhanced permeability to the Upper Floridan aquifer. The lateral encroachment of seawater into the Upper Floridan aquifer is not a likely consideration for Camden County. The vertical migration of salt water is believed to be responsible for the "chloride plume" that has existed within the Floridan aquifer below Brunswick. The most probable pathways for the upconing of saltwater are a combination of high angle faults, fractures, and paleo-solution features such as buried sinkholes. The ultimate cause of salt-water upconing is the over-exploitation of ground water within the Upper Floridan aquifer. This lowers the potentiometric surface which in turn creates an upward vertical hydraulic gradient between the Upper and Lower Floridan aquifers.

Several wells exist in Duval and Camden counties where low levels ($50<Cl<250$ mg/L) of chloride contamination have been reported, likely indicating the mixing of small volumes of salt water with large volumes of fresh water. Slightly elevated chloride concentrations are reported for one well location at the Durango-Georgia Co. paper processing facility near St. Marys in Camden County where a steep but localized cone of depression exists. The St. Marys-Kingsland area within Camden County is where the Upper Floridan aquifer is most intensively utilized and, therefore, most vulnerable to salt-water upconing.

Two recommendations are offered if additional ground water is to be withdrawn from the Upper Floridan aquifer: 1) future allocations from the Floridan aquifer be spread over as large as an area as economically possible to prevent excessive hydraulic head reductions and 2) a monitoring well network be constructed within the pumping center as to provide an effective "early detection" system for the movement of chloride from the Lower Floridan aquifer to the Upper Floridan aquifer.

Project Overview and Objectives

The primary objective of this project was to synthesize the available geologic, hydrologic, and water quality information necessary to assess the potential for salt-water intrusion within the Floridan aquifer system in Camden County, Georgia. The project was commissioned by the Georgia Geologic Survey (GGS) [Environmental Protection Division (EPD), Department of Natural Resources (DNR), State of Georgia] and a contract was awarded to Georgia State University for the period between April, 1999 and June, 2002. This project is a part of the EPD's Interim Strategy to protect coastal Georgia's ground-water resources from salt-water intrusion. The primary focus of this study involves the vertical intrusion (upconing or upwelling) of salt water into the Upper Floridan aquifer from the Lower Floridan aquifer. This is a process that has likely been occurring below Brunswick, Georgia for the past five or six decades. To best make assessments for Camden County, the study area (Figure 1) was expanded to include hydrogeologic and water quality data from Glynn County in Georgia and Nassau and Duval counties in northeastern Florida.

Data Collection and Methods

Literature Review: "GEOBASE" and "GEOREF" were used as the primary electronic databases for the literature search. The search was enhanced by reviewing the literature collection of the Georgia Geological Society and by inspecting United States Geological Survey (USGS) data files. The results of these searches are summarized by keyword in Table 1 and the literature sources are given within the List of References.

Well Log, Water Level, Water Quality and TDEM Data: The St. Johns River Water Management District (SJRMWD, Palatka, Fla.) and the Florida Geological Survey (FGS, Tallahassee, Fla.) provided lithologic and geophysical logs, hydrographic data (water level) and water quality (chloride and specific conductance) information for Nassau and Duval counties. The USGS (Atlanta, Ga., Jacksonville, Fla., and Orlando-Altamonte Springs, Fla.) also provided water level, lithological, geophysical and other data for the four-county study area. Lithologic, hydrographic, and water quality information pertaining to wells that were drilled into the Lower Floridan aquifer in Nassau Co., Glynn Co., and Camden Co. during the course of this project was obtained from the SJRWMD, USGS-GA and USGS-SC offices. Time Domain Electromagnetic (TDEM) survey data were obtained for the study area from the Georgia Geologic Survey. Key agency contact personnel for this project are given in Table 2.

Map Preparation: A base map of the four-county study area was traced upon Mylar film from 1:100,000 series USGS topographic maps. The map was digitally enhanced and recorded by Southeastern Reprographics Incorporated (SRI) in Alpharetta, Georgia. All locations where data were recorded on the base map were hand-plotted using overlays that were eventually digitally recorded. Latitude and longitude data were plotted on the degree-minute-second scale by manual interpolation using a grid system. The well locations where lithological and geophysical data used for this report are shown on Plate 1. The well data are unevenly dispersed in that well locations are predominantly concentrated within the Brunswick and Jacksonville regions. Data are particularly

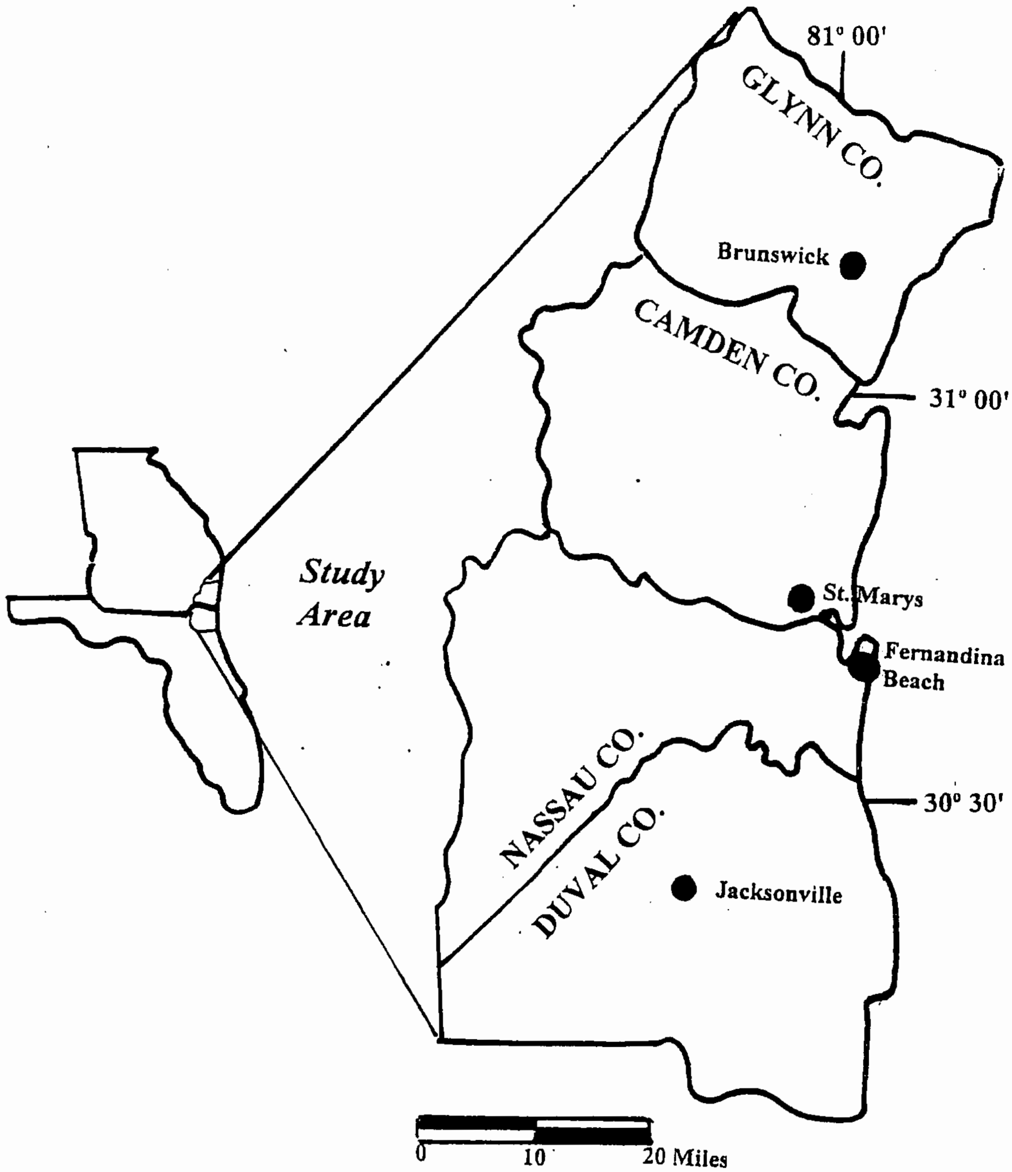

Figure 1: Map of the study area

Table 1:
Search of Databases

Database	Keywords	No of References
GEOREF	Saltwater Intrusion	240
GEOBASE	Saltwater Intrustion	80
GEOREF	Chloride Contamination	22
GEOBASE	Chloride Contamination	6
GEOREF	Salt Water Contamination	6
GEOBASE	Salt Water Contamination	1
GEOREF	Salt Water Upwelling	0
GEOBASE	Salt Water Upwelling	0
GEOREF	Glynn County	102
GEOREF	Camden County	198
GEOREF	Nassau County	365
GEOREF	Duval County	239

Table 2
Key Agency Contact Personnel

Agency	Contact Person	Phone	E-mail
USGS-GA	John Clarke	770-903-9170	jsclarke@usgs.gov
USGS-GA	Mike Peck	770-903-9122	mfpeck@usgs.gov
USGS-SC	Fred Falls	803-750-6100	wffalls@usgs.gov
USGS-FL -Orlando	Rick Spechler	407-865-7575	rspechler@usgs.gov
USGS-Fl-Orlando	Trudy Phelps	407-865-7575	tgphelps@usgs.gov
SJRWMD	Jeffrey Davis	904-329-4183	jeff_davis@district.sjrwmd.state.fl.us
SJRWMD	Glenda McDermont	904-329-4508	not known
SJRWMD	Doug Durden	904-329-4193	not known
SJRWMD	Don Boniol	904-329-4188	not known
SJRWMD	Bill Osburn	904-329-4188	Bill_Osburn@district.sjrwmd.state.fl.us
GGS-EPD-DNR-GA	William McLemore	404-656-3214	Bill_McLemore@mail.dnr.state.ga.us
EPD-DNR-GA	Bill Frechette	404-657-6010	Bill_Frechette@mail.dnr.state.ga.us
FGS	Jonathan Arthur	805-488-9380	jonathan.arthur@dep.state.fl.us
FGS	Paulette Bond	805-488-9380	paulette.bond@dep.state.fl.us

scarce for Camden County other than within the St. Marys area in the very southeastern portion of the county. Isopach, structural contour, isochlor, and potentiometric surface contour maps were prepared by manual interpolation and were digitally enhanced and then recorded by SRI as overlays to the base map. Color cross sections were drawn by hand and then digitally enhanced.

Overview of Camden County: Population and Water Use

The population of Camden County for the year 2000 was approximately 48,000 (http://www.gate.net/~billwl/general.html). The population has grown 45% in the ten-year period between the 1990 and 2000 census (*Atlanta Journal Constitution*, 3/23/01). Of Georgia's six coastal counties, Camden County ranks third and is smaller than Chatham (233,000) and Glynn (68,000) counties. Fifty-three percent of all people in Camden County reside within the St. Marys and Kingsland municipalities in the southeastern portion of the county. The cities of Kingsland and St. Marys grew at rates of 124% and 68% respectively during the period between 1990 and 2000 (*Atlanta Journal Constitution* listing of census figures; 5/20/2001). These represent the first and third highest growth rates for all cities in Georgia between the past two census counts. Many appealing factors including transportation access (I-95), employment opportunities (tourism, military, and paper processing industry), warm climate, and its coastal location suggest that the population of Camden County will continue to grow at a high rate.

Camden County withdrew 40 million gallons of ground water per day (Mgal/day) as of 1997 which comprises 84% of its total water use (Figure 2; Fanning, 1999). Most all of this ground water comes from the Upper Floridan aquifer. The cities of St. Marys and Kingsland combined ground-water withdrawal was only 2.5 Mgal/day. The paper manufacturing industry is the major ground-water user accounting for 77% of the permitted water use (Fanning, 1999). Most all of the ground-water withdrawal comes from industrial wells in the extreme southeastern portion of the county, in and near the city of St Marys.

Camden County's ground water use is best contrasted to Glynn County, its northern neighboring county, and site of the most significant salt-water intrusion problem in Georgia. The city of Brunswick, the major municipality in Glynn County, withdrew 5.24 Mgal/d ground water as of 1997 (Fanning, 1999); approximately twice that of St. Marys and Kingsland in Camden County. Glynn County as a whole withdrew a total 65.33 Mgal/d of ground water in 1997, most of which is used by the paper industry (Fanning, 1999). The Brunswick Peninsular is the site of most of the paper and chemical plants in Glynn County and industrial users withdrew 44.12 Mgal/d in 1997 (Fanning, 1999). These data indicate that far more ground water has been withdrawn from the Upper Floridan aquifer below Brunswick than within Camden County. This high withdrawal rate from a limited area (~5 square miles) with accompanying declines in the potentiometric surface is the most important factor contributing to the salt-water intrusion problem in Glynn County. The Glynn County problem serves as a model for what Camden County must strive to avoid as its population grows.

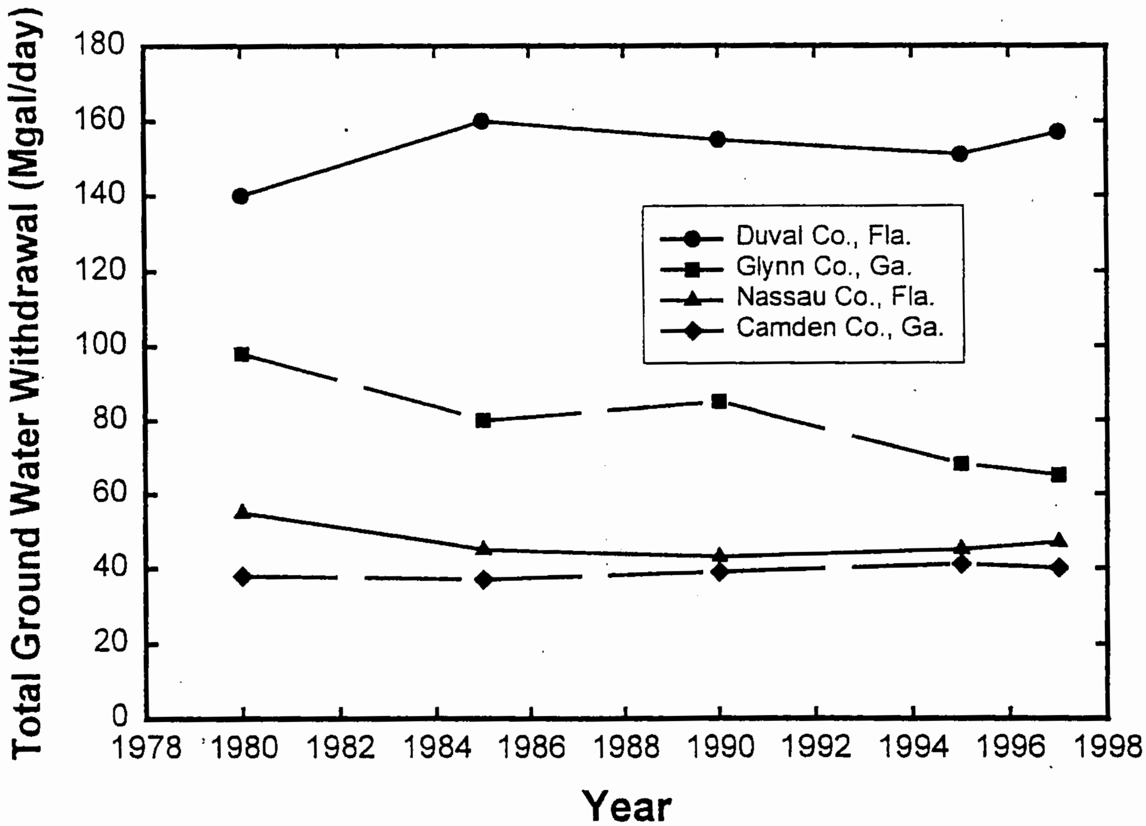

Figure 2: Ground-water withdrawals in the four-county study area

It is also useful to compare Camden and Glynn counties' water use with that of Nassau and Duval County in northeastern Florida (Figure 2). Ground-water withdrawal rates for the coastal counties have more or less remained constant during the past 20 years with the exception of Glynn County where withdrawal rates have declined by approximately 20% during the past decade. Camden County's withdrawal rate is comparable to that of neighboring Nassau County which has remained rural with the exception of the Fernandina Beach area. Camden County uses only approximately 25% of the ground water that is withdrawn from Duval County (Jacksonville, Fla.).

Hydrogeology of the Study Area

Hydrostratigraphic Framework: Camden County, like much of the southeastern Coastal Plain, is underlain by a thick sequence of Tertiary rocks (limestone, dolomite, and unconsolidated clay and sand) that form a regional aquifer system (Figure 3). Eocene to Oligocene age rocks are predominantly carbonate, whereas the younger overlying rocks are mostly semi-consolidated sands and clays (Miller, 1986; Clarke et al., 1990). The principal water-bearing unit in this area is the Upper Floridan aquifer which predominantly consists of the Upper Eocene Ocala Limestone. This is a massive fossiliferous chalky to granular marine limestone characterized by local high permeability solution features (Spechler, 1994). The Upper Floridan aquifer is overlain by the "intermediate confining unit" within the Miocene Hawthorn Formation. This consists of phosphatic clay and serves as the principal confining unit that hydrologically separates the Upper Floridan aquifer from the overlying surficial aquifer. The surficial aquifer is 400-450 feet thick within Camden County and is comprised of Upper Miocene to Holocene age sediment (Plate 2).

The top of the Floridan aquifer is approximately 400 feet below mean sea level (bmsl) in western Camden County and then dips to greater than 500 feet bmsl in eastern Camden County (below St. Marys and Cumberland Island; Plate 3). The limestone units comprising the Floridan aquifer generally thicken in the direction of dip in the southeastern Coastal Plain. In western Camden County the Floridan aquifer is 500 feet thick while in eastern Camden it is greater than 700 feet thick (Plate 4). The top of the Lower Floridan dips between -1,100 and -1,300 ft msl and is between 1,200 to 1,500 thick in Camden County (Plate 5 and Plate 6).

The Lower Floridan aquifer is comprised predominantly of the Middle and Lower Eocene Avon Park and Oldsmar formations. These are alternating units of granular and chalky limestone and dense dolomite (Spechler, 1994; Miller, 1986). The Upper Floridan aquifer is to a degree hydrologically separated from the Lower Floridan aquifer by the "middle semi-confining unit" which consists of relatively impermeable dolomite bed(s) within the Middle Eocene Avon Park Formation. The Lower Floridan aquifer like the Upper Floridan aquifer thickens in the direction of dip or towards the southeast. The base of the Floridan aquifer [i.e. those units below the Oldsmar Formation or the Fernandina Permeable Zone, Figure 3] is between -2,400 and -2,800 ft msl (Plate 7).

The "Fernandina Permeable Zone" of the Lower Floridan aquifer is named after a zone tapped at a depth of >2,000 feet by a test well in Fernandina Beach, Fla. The zone consists of pelletal

Series	Formation	Approximate thickness (feet)	Lithology	Hydrogeologic unit	Hydrologic properties
Holocene to Upper Miocene	Undifferentiated surficial deposits	20-120	Discontinuous sand, clay, shell beds, and limestone	Surficial aquifer system	Sand, shell, limestone, and coquina deposits provide local water supplies.
Miocene	Hawthorn Formation	100-500	Interbedded phosphatic sand, clay, limestone, and dolomite	Intermediate confining unit	Sand, shell, and carbonate deposits provide local limited water supplies. Low permeability clays serve as the principal confining beds for the Floridan aquifer system below.
Eocene	Upper: Ocala Limestone	100-350	Massive fossiliferous chalky to granular marine limestone	Floridan aquifer system: Upper Floridan aquifer	Principal source of ground water. High permeability overall. Water from some wells shows increasing salinity.
	Middle: Avon Park Formation	700-1,100	Alternating beds of massive granular and chalky limestones, and dense dolomites	Floridan aquifer system: Middle semiconfining unit	Low permeability limestone and dolomite.
				Floridan aquifer system: Lower Floridan aquifer: Upper zone	Principal source of ground water. Water from some wells shows increasing salinity.
	Lower: Oldsmar Formation	300-500		Floridan aquifer system: Lower Floridan aquifer: Semiconfining unit	Low permeability limestone and dolomite.
				Floridan aquifer system: Lower Floridan aquifer: Fernandina permeable zone	High permeability; salinity increases with depth.
Paleocene	Ceder Keys Formation	about 500	Uppermost appearance of evaporites; dense limestones	Sub-Floridan confining unit	Contains highly saline water; low permeability.

Figure 3: Generalized geology and hydrogeology of the study area (from Spechler, 1994)

limestone, recrystallized limestone, and finely crystallized dolomite. It is locally cavernous and therefore it is hydrologically designated upon the basis of its relatively high permeability (Krause and Randolph, 1989). The Fernandina Permeable Zone is overlain by a local confining unit termed the "lower semi-confining unit" (Krause and Randolph, 1989). The Floridan aquifer in Camden County is 500-800 less thick than within neighboring Glynn County, probably because Eocene age sediment in Glynn County accumulated in a relatively deep depositional center (graben?) (Plate 7).

Hydrogeologic Properties: The most important factors creating permeability within the Upper Floridan aquifer are moldic porosity and secondary karstic solutional features (Miller, 1986). In general, the hydraulic conductivity of the Lower Floridan aquifer (Avon Park Formation) is lower than the Upper Floridan aquifer due to the abundance of dolomite within the lower units. The dolomite is in places sufficiently thick and relatively impermeable such that it serves as local confining units.

Table 3 summarizes transmissivity [hydraulic conductivity x aquifer thickness (l^2/t)] values and storage values (dimensionless) for the Upper Floridan aquifer that have been published in various GGS, USGS and SJRWMD sources (Wait, 1965; Wait and Gregg, 1973; Gregg and Zimmerman, 1974; Frazee and McClaugherty, 1979; Miller, 1986; Randolph and Krause, 1990; Randolph et al., 1991; Jones and Maslia, 1994; Motz et al., 1997; and Durden, 1997). Transmissivity values range between 19,000 and 202,000 ft^2/day and storage values range between 3.75×10^{-4} and 9.9×10^{-3}. The geometric mean for the data shown in Table 3 is 33,000 ft^2/day. Few if any geographic trends are apparent for the transmissivity values representative of the Upper Floridan aquifer (Plate 8). Reported transmissivity values for the Upper Floridan aquifer in southeastern Camden County vary between 19,000 and 170,000 ft^2/day, closely resembling the range of variation reported for the four-county study area (Plate 8). The order-of-magnitude variation for transmissivity is probably the result of local secondary permeability features, variable pumping test methodology and interpretation artifacts.

Water Levels in the Upper Floridan Aquifer: The potentiometric surface of the Upper Floridan aquifer in western Camden County is between 30-40 feet above mean sea level and has remained at much the same level since the early 1980s (Plates 9-14). These are representative of regional water levels for the study area that have not been perturbed by excessive ground-water pumping. Such pumping occurs below the Brunswick Peninsula where the potentiometric surface of the Upper Floridan aquifer has declined to 10-20 feet bmsl and also below Fernandina Beach (Amelia Island, Fla.) where water levels have declined to ~100 feet bmsl. Ground-water flow in the Upper Floridan aquifer is from west to east as can be inferred from the potentiometric surface maps shown on Plates 9-14 and the regional hydraulic gradient is approximately 1 ft/10 miles (2×10^{-5}). The most notable feature affecting ground-water flow in Camden County is the steep and extensive cone of depression resulting from ground-water pumping at Fernandina Beach. Both Kingsland and St. Marys are within the outer periphery of this pumping center and ground water is likely drawn to the Fernandina Beach cone of depression from an area encompassing many square miles (Plates 9-14).

Table 3

Summary of Transmissivity and Storage Coefficient Data by County, Latitude and Longitude Upper Floridan Aquifer[1]

County/State	Latitude	Longitude	Transmissivity (Ft^2/day)	Storage Coefficient (dimensionless)
Camden/GA	30D 43M 13S	81D 33M 00S	110,000	1.4×10^{-3}
Camden/GA	30D 45M 12S	81D 34M 36S	98,000	1.7×10^{-3}
Camden/GA	30D 47M 56S	81D 31M 11S	130,000	9.9×10^{-3}
Camden/GA	30D 49M 39S	81D 31M 26S	170,000	2.4×10^{-3}
Camden/GA	30D 45M 00S	81D 28M 40S	19,000	
Camden/GA	30D 47M 02S	81D 29M 40S	43,000	
Glynn/GA	31D 10M 08S	81D 30M 58S	82,000	5.24×10^{-3}
Glynn/GA	31D 09M 53S	81D 28M 47S	64,000	2.05×10^{-3}
Glynn/GA	31D 09M 02S	81D 28M 43S	28,000	3.75×10^{-4}
Glynn/GA	31D 10M 35S	81D 28M 57S	57,000	1.02×10^{-3}
Nassau/Fl	30D 40M 55S	81D 28M 40S	21,000	
Duval/Fl	30D 23M 09S	81D 23M 17S	28,000	
Duval/Fl	30D 18M 16S	81D 30M 48S	130,000	
Duval/Fl	30D 18M 35S	81D 37M 42S	130,000	
Duval/Fl	30D 19M 53S	81D 38M 05S	22,000	
Duval/Fl	30D 23M O9S	81D 42M 14S	27,000	
Duval/Fl	30D 14M 21S	81D 40M 04S	202,000	
Duval/Fl	30D 16M 04S	81D 23M 46S	37,800	
Duval/Fl	30D 13M 17S	81D 50M 10S	29,000	

[1]See text for data sources

Ground-water pumping that occurs below the Durango-Georgia Co. (formerly Gilman Paper Co.) paper plant and processing facility in southeastern Camden County also results in a steep cone of depression. Ground-water levels below this facility immediately north of St. Marys, Georgia, declined to nearly 200 feet bmsl (Plates 10, 11, and 12). This, however, is only a highly localized cone of depression primarily associated with ground-water withdrawal from only a few wells on this property and does not have a regional influence.

Ground-water levels in the Upper Floridan aquifer within Nassau and Duval counties in Florida are typically 30-40 feet above sea level. The hydraulic gradient is very low (with the exception of the area near Fernandina Beach) and ground water in the Upper Floridan aquifer flows in a general west-to-east direction in northeastern Florida. There are no prominent cones of depression within this region including the Jacksonville, Florida area which is significant in that Duval County withdraws two to four times as much ground water as the other counties in this study area (Figure 2).

Changes in the Potentiometric Surface of the Upper Floridan Aquifer from Pre-Development: Ground-water withdrawal is the most significant factor affecting water levels in the four-county study area. USGS (Krause and Randolph, 1989) ground-water modeling results estimate that the "pre-development" potentiometric surface for the study area was between 70 and 60 feet above mean sea level (Plate 15). The pre-development gradient dips eastward or southeastward at a moderate rate of 1 foot per 3-4 miles and is more or less uniform throughout the study area (Plate 15).

Ground-water withdrawal from the Upper Floridan aquifer has resulted in an average potentiometric surface decline of 30 feet with respect to the pre-development surface in most of the western and central part of the study area (Plates16-20). Most of the decline has occurred prior to 20 years ago. Ground-water levels have declined by approximately 60-70 feet below Brunswick in Glynn County. The most dramatic declines with respect to the pre-development surface are associated with the steep cone of depression below Fernandina Beach. Here ground water levels in the Upper Floridan aquifer have declined by as much as 100-170 feet. Ground-water levels in the Upper Floridan aquifer throughout most of Camden County have declined by a comparatively modest 20-30 feet with respect to the modeled pre-development surface.

A comparison of the potentiometric surface of the Upper Floridan aquifer between May, 1980 and May, 1998 (Plate 21) indicates that water levels have generally stabilized during this period. Most notably, the potentiometric surface has risen by +20 to +80 feet in the vicinity of Fernandina Beach on Amelia Island, Florida. This is likely attributed to reduced ground-water pumping and water conservation in this coastal area. Water levels within the Upper Floridan aquifer below Brunswick, Georgia have only risen modestly, if at all, during the past 20 years. Likewise, the potentiometric surface of the Upper Floridan aquifer below most of Camden County has not changed appreciably during the past two decades (Plate 21).

Comparative Water Levels in the Upper and Lower Floridan Aquifer There have been only a relatively few wells completed within the Lower Floridan aquifer in the four-county study area. Therefore assessing the comparative water levels between the Upper and Lower Floridan aquifers is difficult. The highest density of deep wells is within the Brunswick region where a sufficient number of USGS monitoring wells exist such that potentiometric surface contours for the Lower Floridan aquifer can be drawn (see Plate 22). There are scattered monitoring wells completed in other locations than those shown on Plate 22; however, there are insufficient data for a contour map to be drawn for the four-county area. The potentiometric surface of the Lower Floridan aquifer in southeastern Glynn County is similar to that of the Upper Floridan aquifer and there is generally less than 5-10 feet of head difference between the two hydrostratigraphic units (Plate 23). Hydraulic head values are likely similar in both aquifers throughout most of the study area including Camden County.

In December, 1999 the USGS, as part the State of Georgia's coastal ground-water monitoring program, completed Well #33D073 to a depth of 1,500 feet below land surface in downtown St. Marys (Fred Falls, USGS-SC, written communication). This well was designed to monitor water levels and chloride concentrations within the Lower Floridan aquifer in southeastern Camden County. Fortunately, two previously existent wells (D-69 and D-04) were completed within the Upper Floridan aquifer (at depths of 575 and 600 feet) and are located within a mile of D-73 (Figure 4). The proximity of these three wells relative to each other offers the best opportunity for analyzing the relative difference between the potentiometric surfaces of the Lower and Upper Floridan aquifers in southeastern Camden County. However, this analysis is non-definitive in that these three wells, located thousands of feet from one another, do not constitute a true vertical monitoring well array.

Nonetheless, these data from the period between March and October, 2000 indicate that water levels within the Lower Floridan aquifer are approximately five feet greater than in the Upper Floridan aquifer (Figure 5). This represents only a modest head difference which suggests that the "middle semi-confining unit" between the Upper and Lower Floridan aquifers is moderately permeable and there is the potential for hydraulic communication between the two aquifers. The comparatively higher hydraulic heads within the Lower Floridan aquifer indicate that salt water, if present, can flow vertically upward and thereby contaminate the Upper Floridan aquifer in this region. This is not to say that upconing is in fact occurring here; only that the potential exists for it to occur (based upon the analysis of limited water-level data from these three wells).

Chloride Concentrations in the Floridan Aquifer

Background Conditions: Chloride concentrations within the Upper Floridan aquifer throughout most of the four-county study area are well below the safe drinking water limit of 250 mg/L (Appendix 1 and Clark et al., 1990). In fact, chloride concentrations in most wells throughout the study area are typically between 35-50 mg/L and this can be regarded as the "background" (i.e. uncontaminated) range for the Upper Floridan aquifer. One of the objectives of this project was to provide an isochlor map of the Upper Floridan aquifer for the four-county study area. There are only sparse well-control data; and therefore the 1,000 mg/L chloride isochlor can be constructed for a small area only below Brunswick in Glynn County (Plate 24).

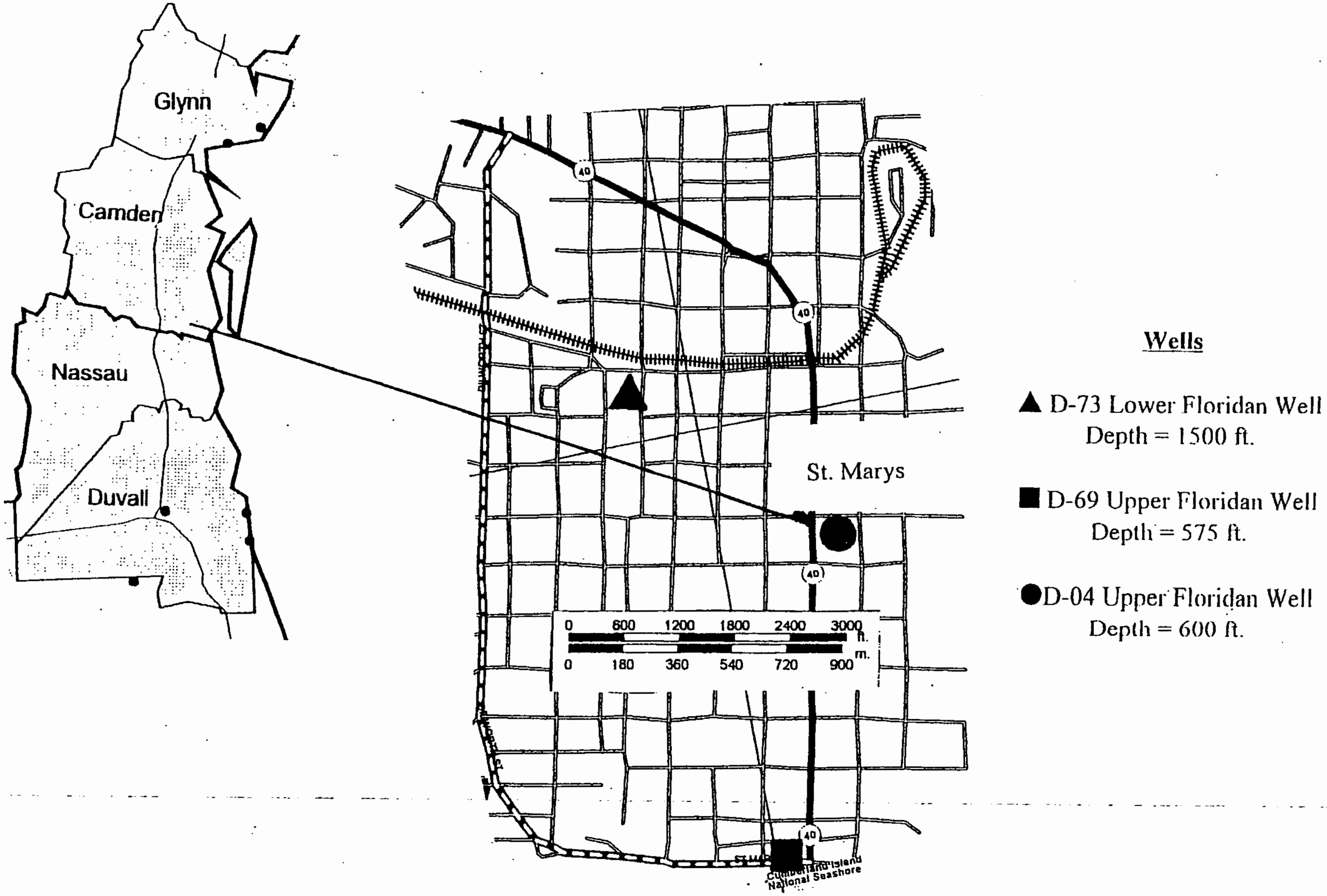

Figure 4: Location of Upper and Lower Floridan aquifer wells in St. Marys

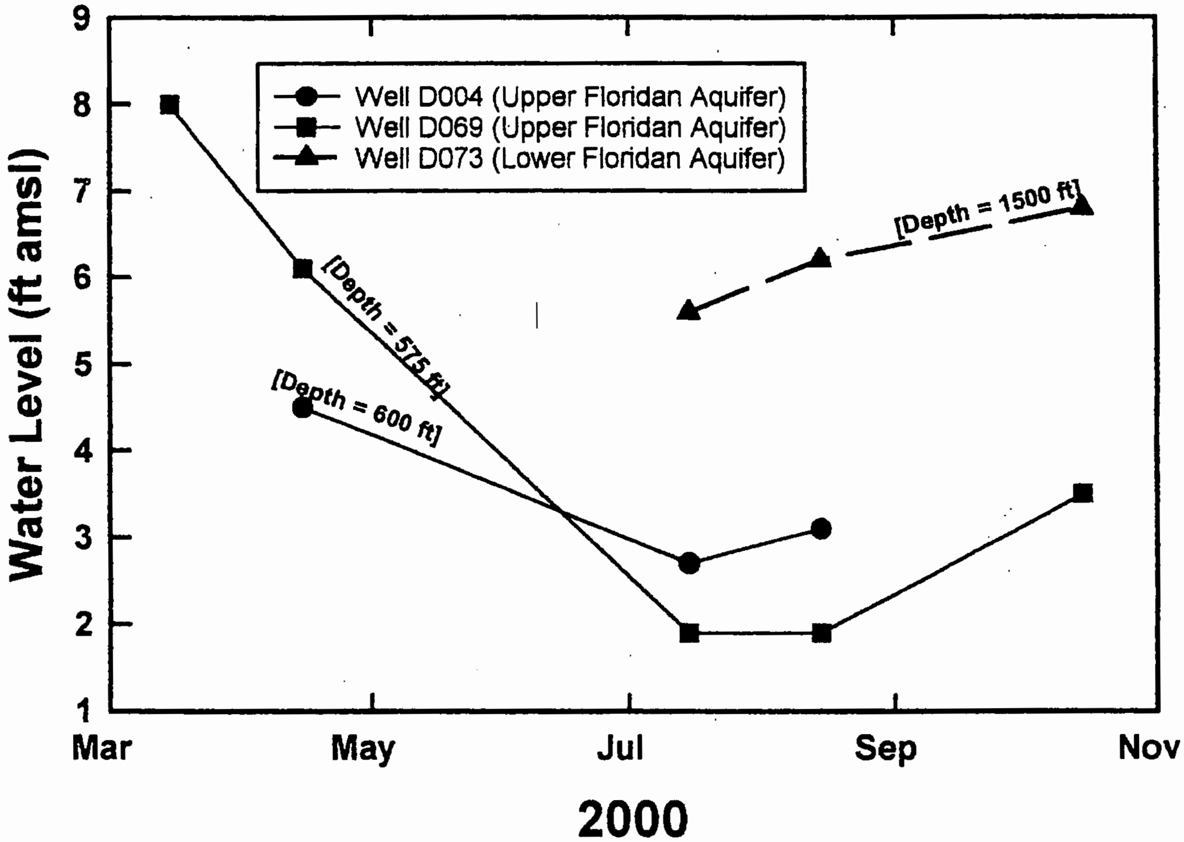

Figure 5: Water level comparison: Upper Floridan vs. Lower Floridan aquifer wells in St. Marys, Camden County

Brunswick Chloride Plume: The "chloride plume" within the Upper Floridan aquifer below the Brunswick Peninsula is characterized by chloride concentrations that are locally greater than 2,000 mg/L (Peck et al., 1992). This plume (Figure 6) has persisted for at least the past five decades (Stewart, 1960; Wait and Gregg, 1973; Maslia and Prowell, 1990) and is the result of intensive ground-water pumping in the Brunswick region. The potentiometric surface of the Upper Floridan aquifer has been drawn down by an estimated 50-60 feet from its pre-development level (Plate 20). This cone of depression has reversed the natural downward hydraulic gradient allowing the upward migration of salt water from the Fernandina Permeable Zone at the base of the Lower Floridan aquifer. Water-level trends in the Lower Floridan aquifer are nearly identical to those in the Upper Floridan aquifer, indicating a hydraulic connection between the aquifers (Clarke et al., 1990).

Various conduits for the upward movement of salt water below the Brunswick have been proposed. One of the most cited hypotheses involves the presence of high angle normal faults that breach the confining units above the Lower Floridan aquifer (Maslia and Prowell, 1990). Increased fracturing (and/or dissolution) at the intersection of these faults enhances the permeability of these localized zones, allowing the upward migration of salt water (Clarke et al, 1990). Recent seismic studies by the USGS in Florida strongly evidence the presence of deep karst features (i.e. "paleo-sinkholes") within the Floridan aquifer as likely vertical conduits (Spechler, 1996 and Spechler, USGS-Fla., oral communication); however, the presence of such features below Brunswick has not yet been confirmed.

The Lower Floridan Aquifer and Fernandina Permeable Zone (Data from Recent Test Wells): Water quality data are relatively sparse; however, from the data that are available it is apparent that much of the Lower Floridan aquifer within the four-county study area, and particularly in Camden County, contains fresh water. In late 1999, a test well (USGS No. 33D073) was drilled for the Georgia Department of Natural Resources within the Lower Floridan aquifer below St. Marys. This well produced fresh water (chloride = 31 mg/L) at a depth of 1,500 feet and similar chloride concentrations were observed between the Upper and Lower Floridan aquifers at this Camden County location (Table 4 and Plate 25).

A St. John Water Management District test well (N-236) was completed in November, 2000 at the Callahan Fairgrounds in northern Nassau County, Florida. This well produced fresh water (chloride = 39 mg/L) at the bottom hole depth of 2,114 feet (Table 5). Very low concentrations (<40 mg/L) of chloride were encountered at all depths within both the Upper and Lower Floridan aquifer at this location (Bill Osburn, SJWRMD, written communication, 2000). In contrast, brackish water (chloride concentrations ranging from194-1,926 mg/L) was encountered near the base of another recent SJRWMD test hole (the Ralph Simmons WMA site; N-222) drilled to a depth of 1,912 feet near Boulogne, Florida (Bill Osburn, SJRWMD, written communication, 2000). This well is located in northwestern Nassau County within a mile of the Florida-Georgia border near the St. Marys River.

The Fernandina Permeable Zone (FPZ) at the base of the Floridan aquifer has been identified as the primary source of salt water within the Floridan aquifer. The evidence for this comes primarily from a series of deep test wells drilled in the late 1970s and early 1980s by the USGS in coastal

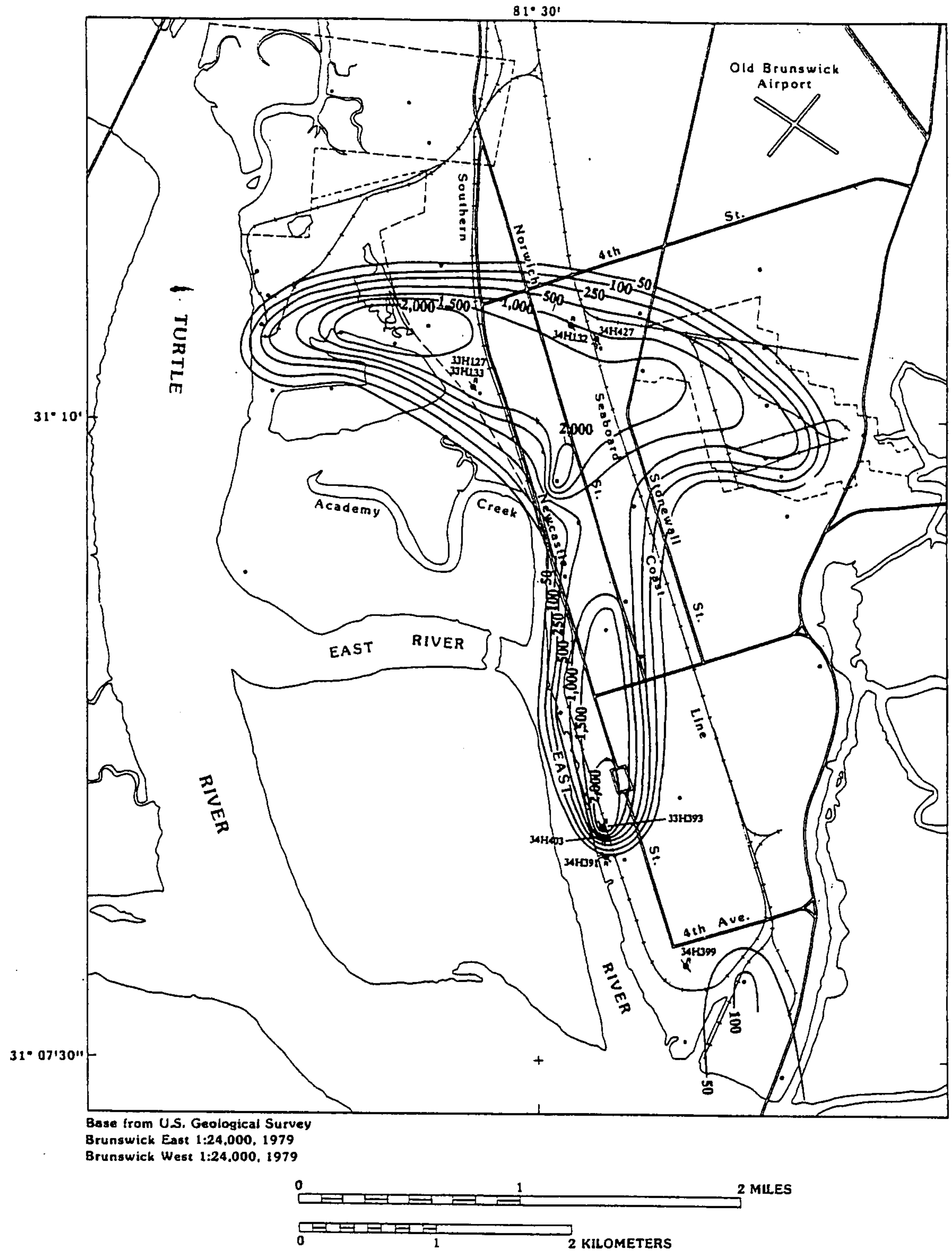

Figure 6: Chloride plume within the Upper Floridan aquifer below Brunswick, Georgia (after Peck et al., 1992)

Table 4
Chloride and Specific Conductance Concentrations for Well 34H495 (Brunswick) and Well 33D73 (St. Marys)
(all data from USGS communications)

Well 34 H495: Brunswick; Glynn Co.; Total Depth = 2,720 feet. Drilled: 10/00. Coordinates: 31 08 35; 81 29 44; Fernandina Permeable Zone Test Well				**Well 33 D073:** St. Marys; Camden Co. Total Depth = 1,500 feet. Drilled: 12/99. Coordinates: 30 44 06; 81 33 05; Lower Floridan Aquifer Test Well			
Depth in feet	**Chloride (mg/L)**	**Specific Conduct. (µS/cm)**	**Hydrogeol. Unit[1]**	**Depth in feet**	**Chloride (mg/L)**	**Specific Conduct. (µS/cm)**	**Hydrogeol. Unit[1]**
658-668	1,500	5,882	UFA	523-533		410	UFA
880-890	1,800	6,863	"	683-693		727	"
1,006-1,016	1,700	6,604	"	745-757	34	717	"
1,069-1,079	1,400	5,392	"	869-879	35	710	MSCU
1,101-1,111	2,800	9,528	"	1,009-1,019	32	686	"
1,196-1,206	2,200	7,692	LFA	1,039-1,048	34	660	"
1,301-1,313	2,300	8,018	"	1,139-1,149	36	686	
1,393-1,405	2,000	7,013	"	1,189-1,199		735	LFA
1,418-1,426	36	425	"	1,219-,1229	40	708	"
1,647-1,657	12	657	"	1,309-1,319	35	724	"
1,707-1,717	100	1,228	"	1,425-1,435	33	769	"
1,805-1,880	310	2,632	"	1,485-1,500	31	850	"
1,930-1,940	340	2,632	"				
2,050-2,060	210	1,908	"				
2,098-2,092	1,100	6,060	FPZ				
2,143-2,153	1,400	7,020	"				
2,173-2,186	2,000	9,060	"				
2,207-2,217	17,000	45,560	"				
2,661-2,671	17,000	47,860	"				
2,681-2,669	27,000	68,370	"				
2,709-2,720	27,000	67,440	"				

[1]UFA = Upper Floridan aquifer; LFA = Lower Floridan aquifer; FPZ = Fernandina Permeable Zone; MCSU = middle semi-confining unit

Table 5
Chloride Data for Newer Wells and Key Wells in Four County Study Area

County/ST	USGS Well No.	Latitude	Longitude	Date	Depth (ft.)	Chloride (mg/L)	Description/Comments/ Significance
Nassau, Fl	N-236	30D 35M 43S	81D 49M 48S	9/21/00	2,114	39	Callahan Well in Nassau County; newer SJRWMD Lower Floridan Aquifer/ Fernandina Permeable Zone well; fresh water found at great depth.
Nassau, Fl	N-237	30D 24M 09S	81D 55M 24S	5/7/98	500	20	Newer SJRWMD Upper Floridan Aquifer monitor well drilled in Cary State Forest; fresh water.
Nassau, Fl	N-222	30D 47M 00S	81D 57M 10S	6/00	1,912	1,912	New "Ralph Simmons WMA" SJRWMD monitor well completed near St. Marys River at Boulogne, Fl.; brackish water found in Lower Floridan aquifer.
Nassau, Fl	N-117	30D 40M 01S	81D 28M 03S	1979	2,094	7,800	USGS Fernandina Beach test well; Brackish water in the Fernandina Permeable Zone (FPZ) of the Lower Floridan Aquifer (LFA). Chlorides increase from 240 to 7,800 mg/L between 1,9076 and 2,094 feet.
Nassau, Fl	N-68	30D 38M 05S	81D 27M 39S	5/5/77 10/19/92	1,050	40 440	Upper Floridan Aquifer well near Fernandina Beach in which chloride concentration increased with time.
Duval, Fl	D-2386	30D 21M 59S	81D 23M 56S	1981	2,204	3,303	USGS Test Well: Kathryn Hanna Abbey Park; Brackish water in the FPZ of the Lower Floridan Aquifer LFA. Chlorides increase from 300 to 5,370 mg/L between 1920-2112 feet.

Table 5 (continued)							
County/ST	USGS Well No.	Latitude	Longitude	Date	Depth (ft.)	Chloride (mg/L)	Description/Comments/ Significance
Duval, Fl	not known	not known	not known	~1966	2,458	7,320	Early USGS test well in Jacksonville
Duval, Fl	not known	30D 20M 50S	81D 32M 40S	2/83	2,112	5,370	USGS test well in east-central Duval Co. Brackish water in the FPZ of the LFA. Chlorides increase from 320-2,112 between 1,640-2,112 feet.
Duval, Fl	D-425T	30D 18M 17S	81D 37M 49S	5/5/98	1,895	100	Fresh water at depth in the Lower Floridan Aquifer in Duval County.
Duval, Fl	D-262	30D 26M 08S	81D 35M 49S	1952 1990	1,237	21 50	Upper/Lower Floridan Aquifer well in Duval County showing increasing chloride concentrations with time.
Duval, Fl	D-275	30D 17M 40S	81D 36M 10S	1962 7/17/98	1,234	25 200	Upper/Lower Floridan Aquifer well in Duval County showing increasing chloride concentrations with time.
Duval, Fl	D-484	30D 17M 04S	81D 23M 34S	1974 1990	1,181	90 180	Upper/Lower Floridan Aquifer well in Duval County showing increasing chloride concentrations with time.
Duval, Fl	D-3060	30D 20M 52S	81D 32M 32S	5/8/90	2,122	2,100	USGS test well in Duval County showing brackish water in the FPZ of the LFA.
Glynn, GA	33H130	31D 10M 21S	81D 30M 31S	6/3/98	700	2,590	Upper Floridan Aquifer well within the Brunswick chloride plume showing with upper range of chloride concentrations.

Table 5 (continued)							
County/ST	USGS Well No.	Latitude	Longitude	Date	Depth (ft.)	Chloride (mg/L)	Description/Comments/ Significance
Glynn, GA	33H133	31D 10M 07S	81D 30M 17S	1969 1998	30 1,950	790	Upper Floridan Aquifer well within the Brunswick chloride plume showing increasing concentrations of chloride with time.
Glynn, GA	33H399	31D 07M 50S	81D 29M 20S	1969 1998	4,000 7,200	1,218	Brackish zone of the Lower Floridan Aquifer within the Brunswick chloride plume showing increasing concentrations of chloride with time.
Glynn, GA	34H495	31D 08M 35 S	81D 29M 45S	Oct,2000	1,333 1,426 1,940 2,123 2,281 2,671 2,720	2,200 36 340 1,200 17,000 17,000 27,000	Recently drilled test well completed within the FPZ below Brunswick. This well produces a very high chloride concentration (> seawater) of 27,000 mg/L @2,720 feet. There are also zones of fresh water below brackish water within the LFA.
Camden, GA	33D073	30D 44M 06S	81D 3M 05 S	Dec,1999	1,500	35	Recently drilled test well completed within the Lower Floridan Aquifer below St. Marys. Well shows fresh water @ 1,500ft.
Camden, GA	Well No. 11 (Gilman/Durango Well #)	not known	not known	9/24/99	not known	150	Durango (formerly Gilman Paper Co.) production well completed within the Floridan aquifer showing increased chloride concentration within localized steep cone of depression (may be only well in Camden Co. with elevated chloride concentrations).

locations in Glynn, Nassau and Duval counties (Brown, 1980; Brown et al., 1984; Brown et al., 1985; and Krause and Randolph, 1989). A deep USGS test well (33H225) drilled in the late 1970s at Colonel's Island near Brunswick encountered brine (chloride = 30,000 mg/L) within the FPZ (Krause and Randolph, 1984).

Water samples from a recently drilled USGS/GGS test well (34 H495) in Brunswick were characterized by chloride concentrations ranging from 1,100-27,000 mg/L (Tables 4 and 5) through the Fernandina Permeable Zone (Fred Falls, written communication, 2001). This corresponds to depths of 2,098-2,720 feet below land surface. Salt water and brines were also observed in test wells drilled by the USGS during the 1970s and 1980s in northeastern Florida. The chloride concentration sampled through a drill stem of a USGS test well (N-32) at Fernandina Beach in coastal Nassau County was 8,100 mg/L (Brown, 1980). This chloride concentration was encountered at a depth of 2,084 feet within the Lower Floridan aquifer (Appendix 3).

Similar chloride concentrations (3,300-5,370 mg/L) were encountered at depths of 2,000 - 2,100 feet in USGS test wells drilled in coastal Duval County, Florida (Appendix 4; Brown et al., 1984 and Brown et al., 1985). Collectively, these deep test well data indicate that the FPZ contains salt water with chloride concentrations varying between 5,000 - 30,000 mg/L. However, it should not be inferred from these limited set of deep wells that the FPZ is a source of salt water at all locations within the four-county study area.

Higher than Background Chloride Concentrations Within the Upper Floridan Aquifer: Data from several wells completed within the Upper Floridan aquifer indicate the presence of "above background" concentrations of chloride at several locations. Chloride concentrations at these locations are generally less than 250 mg/L; however, they are greater than the 35-50 mg/L range considered in this report as "background" or "normal" chloride for the non-contaminated Floridan aquifer (Appendix 1). Several wells completed within Duval County, in the Jacksonville area, show that chloride concentrations have increased from near background levels to 90 and 175 mg/L during the 1980s and 1990s (Figures 7 and 8 and Table 5). Chloride concentrations appear to be leveling off in these wells (particularly at the City of Jacksonville site, Well No. N-450, Figure 7) and it is not likely that the drinking water standard maximum concentration limit of 250 mg/L will be exceeded. Nonetheless, these data do indicate that at least small amounts of chloride have migrated upward to the Upper Floridan aquifer in select locations. Furthermore these data suggest that chloride can contaminate the Upper Floridan aquifer in other locations where ground-water pumping has adversely affected the vertical hydraulic gradient.

The intensive withdrawal of ground water for paper processing has caused a localized cone of depression in the St. Marys area below the Durango-Georgia Co. (formerly Gilman Paper Co.) site. As previously mentioned, the paper processing industry is permitted to withdraw greater than 70% of the ground water that is used in Camden County. In several Durango-Georgia Co. wells the potentiometric surface of the Upper Floridan aquifer has declined to elevations of approximately 100 feet below sea level (Figure 9). Drawdown from Durango-Georgia Well #11 is apparently most problematic. At this well location chloride concentrations are consistently greater than background

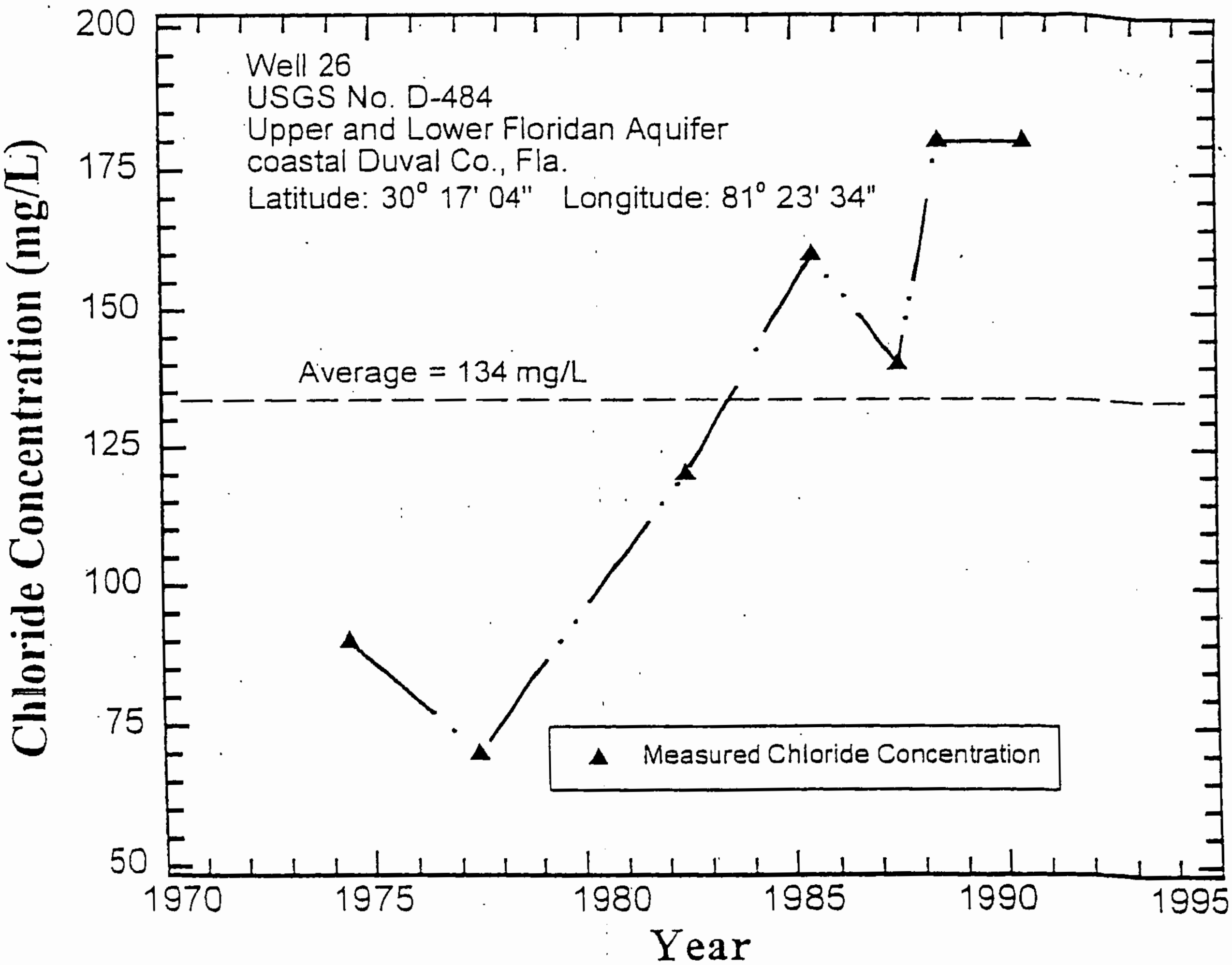

Figure 7: Chloride trends in an Upper Floridan aquifer well (D-484), Duval County, Florida

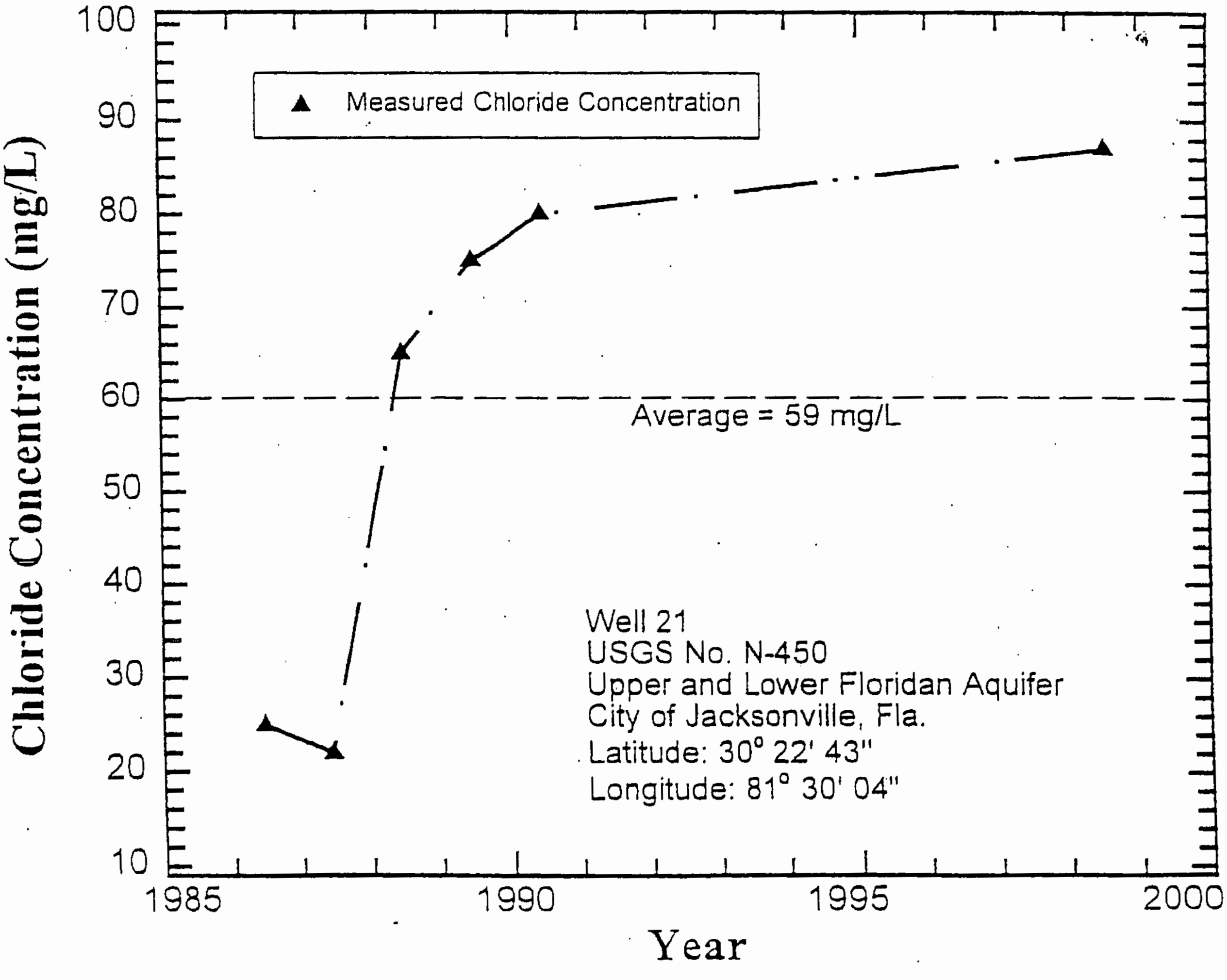

Figure 8: Chloride trends in an Upper Floridan aquifer well (N-450), Duval County, Florida

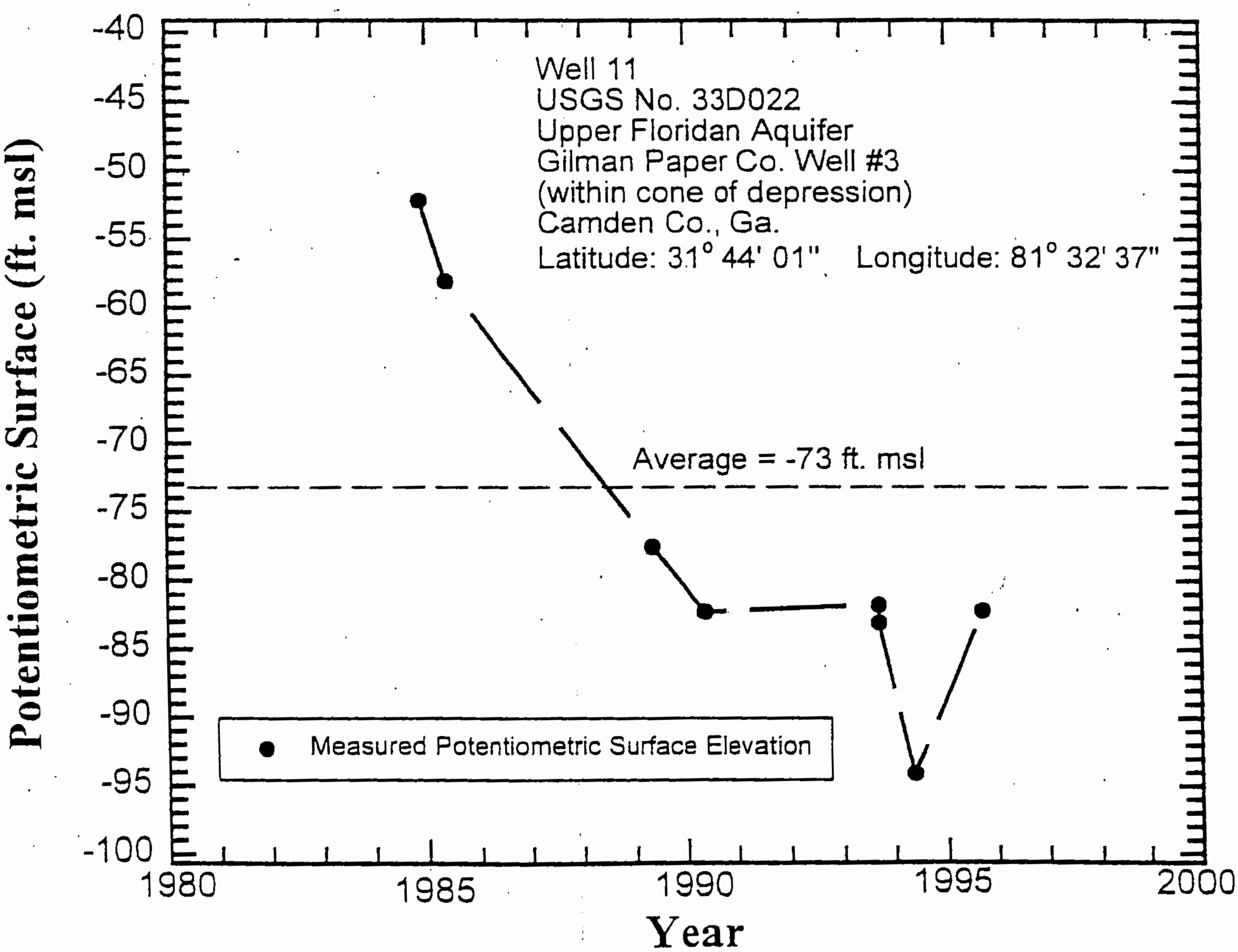

Figure 9: Potentiometric surface trends in an Upper Floridan aquifer well, Durango-Georgia Paper Company, Camden County, Georgia

ranging from 100-150 mg/L (Figure 10) (Durango-Georgia Co., written communication, 2002). Other wells completed within the Upper Floridan aquifer below this site produce ground water in which chloride concentrations are no greater than 40 mg/L (i.e. "background" levels).

The restricted areal extent of these "higher-than-background" chloride concentrations (Plate 26) likely indicates that the sources of chlorides are limited to fractures, solution features, or some other localized zones of high permeability that provide conduits for the vertical migration of salt water to the Upper Floridan aquifer. It is apparent from this Camden County example and from the limited extent of "above-background" chloride concentrations in Duval County that relatively small volumes of salt water that might have migrated vertically upward from the Lower Floridan aquifer have mixed with relatively large volumes of ambient fresh water within the Upper Floridan aquifer. The nature of this hypothesized mixing (i.e. whether it is purely diffusive or advective-dispersive-diffusive) is not understood.

TDEM Results: Time domain electromagnetic (TDEM) surveys have been conducted within the study area for the Georgia Geologic Survey and the St. Johns River Water Management District. Most of this work was done during the early1990s and was supplemented with additional more recent surveys conducted for the GGS within Camden and Glynn counties. Briefly, a TDEM sounding involves the application of an electrical current into the subsurface from a survey point on the earth's surface. Unfortunately, the presence of power lines, electrical generators and other artifacts can reduce the effectiveness of a TDEM survey by limiting the loop size and eventual depth within the subsurface that can be penetrated by current.

The electrical current used in TDEM is generated from a wire loop and the apparent resistivity of the subsurface is measured at continuous depth as the current spreads downward and outward from the survey point. The apparent resistivity is then inverted to produce a conductivity reading for a given depth. Conductivity is a function of many factors that include rock type, depth, water content (porosity), and the salinity of the water. The most important of these, however, is water chemistry and therefore the TDEM results can be used to infer the chloride concentration at a given depth. These particular survey results were stated in terms of depth to the inferred 5,000 mg/L chloride isochlor (i.e. 5,000 mg/L chloride was chosen as the indicator concentration of the salt water).

The TDEM results (Table 6 and Plates 27-37) indicate that chloride concentrations of 5,000 mg/L are found throughout the four-county study area at depths between approximately 2,200 and 3,800 feet. The depth to the inferred 5,000 mg/L chloride isochlor was greater than 3,000 feet for three of the ten survey points. Brackish water is typically encountered within well bores at depths of approximately 2,500 feet below land surface. Therefore some of the TDEM results may reveal depths that are greater than actual depths to salt water. Nonetheless, the TDEM survey data indicate that brackish water is present at depth throughout most of the study area at or near the base of the Floridan aquifer. Deep well data and TDEM survey results are still not adequate to permit the delineation of regional isochlors within the Lower Floridan aquifer as can be inferred from the cross sections shown as Plates 29-37.

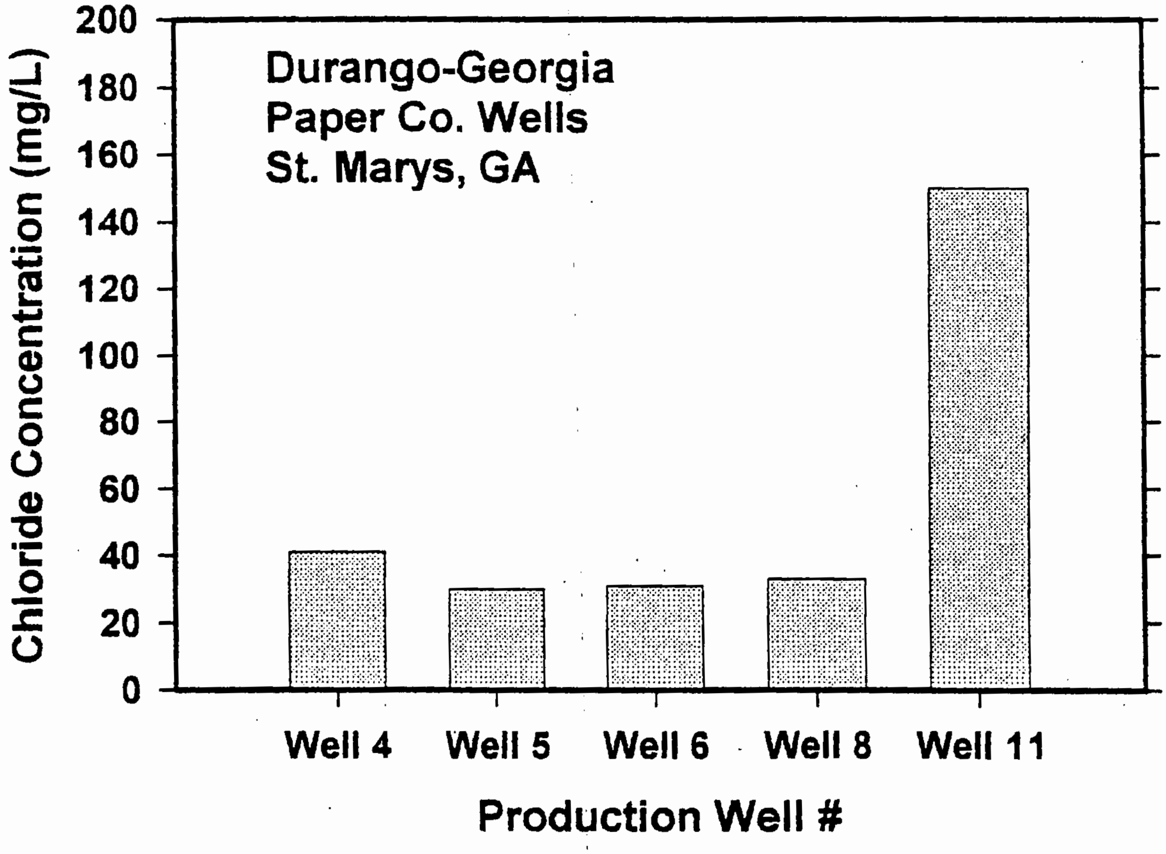

Figure 10: Chloride concentrations in selected wells, Durango-Georgia Co., St. Marys, Georgia

Table 6
Time Domain Electromagnetic (TDEM) Survey Data
Four-County Study Area

Site	County/St.	Latitude	Longitude	Estimated Depth to 5,000 mg/L Chloride Isochlor (ft. bmsl)
Cecil Field	Duval, Fla.	30D 11M 34S	81D 33M 06S	3,264
Garden Street	Duval, Fla.	30D 23M 50S	81D 51M 25S	3,102
Hillard	Nassau, Fla.	30D 43M 52S	81D 56M 28S	2,500
Nassau Co.	Nassau, Fla.	30D 35M 40S	81D 27M 22S	2,427
Silico Tract	Camden, Ga.	30D 55M 05S	81D 46M 45S	2,618
Cumberland Is.	Camden, Ga.	30D 48M 24S	81D 27M 22S	>2,200
Coffin Park, Brunswick	Glynn, Ga.	31D 08M 24S	81D 28M 46S	Not Determinable
Colonels Island	Glynn, Ga.	31D 06M 14S	81D 32M 11S	3,800
Jekyll Island Pine Lk. Golf Course	Glynn, Ga.	31D 04M 32S	81D 25M 04S	1,762
Gilman Paper - west Camden	Camden, Ga.	31D 03M 13S	81D 51M 31S	1,536
Gilman Paper - MSW Landfill	Camden, Ga.	30D 50M 19S	81D 51M 27S	2,710
All data are from the Georgia Geologic Survey				

Possible Mechanisms for Salt-water Intrusion in Camden County

Spechler (1994) provided a thorough review of the possible mechanisms of salt-water intrusion within coastal aquifers of northeastern Florida and southeastern Georgia. Briefly, the major mechanisms that were considered include:

- the lateral migration of sea water from the Atlantic Ocean
- the presence of residual sea water or brackish water in the Upper Floridan aquifer
- the upconing of salt water from the Lower Floridan through unplugged production wells
- the upconing of salt water from the Lower Floridan aquifer through natural zones of enhanced permeability such as faults, fractures, and paleo-karst features (or combinations of these three)

The lateral encroachment of modern sea water is not considered likely in Camden County in that earlier offshore drilling determined that the depth to the salt-water interface is ~ 2,000 feet below sea level (Figure 11) off southeastern Georgia and northeastern Florida. Ground water is actively moving through the Upper Floridan aquifer and it appears to be well-flushed of "residual" salt water throughout the study area. Therefore, the presence of paleo-sea water in the Upper Floridan aquifer below Camden County seems very unlikely. Likewise, the upconing of salt water through unplugged wells also does not appear to be a viable mechanism because there are few if any unplugged wells that penetrate the Lower Floridan aquifer in Camden County.

The upconing of fresh water from the Lower Floridan aquifer through unspecified natural features is considered the only viable mechanism of salt-water intrusion below Camden County. In this scenario, natural features such as faults, fractures or vertical solution cavities provide a pathway for the upward migration of salt water from the Lower Floridan aquifer (most likely from the Fernandina Permeable Zone) to the Upper Floridan aquifer. The migration can occur only if the hydraulic head values representative of the Upper Floridan aquifer are lower than respective hydraulic heads in the Lower Floridan aquifer. In a careful analysis of this type, corrections for salinity and specific gravity differences must be made (these corrections are typically stated as "*equivalent fresh water head*" values). There also must exist a pathway for vertical salt water transport. This is the model shown on Figure 12 (from Spechler, 1994) which has been developed by the United States Geological Survey to explain the long-acknowledged salt-water intrusion problem within the Upper Floridan aquifer below Brunswick, Georgia. No serious objection has been given to this model and it is presently well-accepted as "the working hypothesis" by hydrogeologists within the southeastern United States.

There is substantial evidence to indicate that the Lower Floridan aquifer, particularly the Fernandina Permeable Zone, contains salt water. The base of the aquifer is approximately 2,400-2,700 feet below sea level in Camden County (see Plate 7). Relatively impermeable dolomite and dolomitized limestone beds within the Floridan aquifer [i.e. the lower and middle semi-confining units (Figure 3)] are thought to provide a reasonably effective barrier for the vertical upconing of salt water to the Upper Floridan aquifer. Higher hydraulic head in the Upper Floridan than the Lower

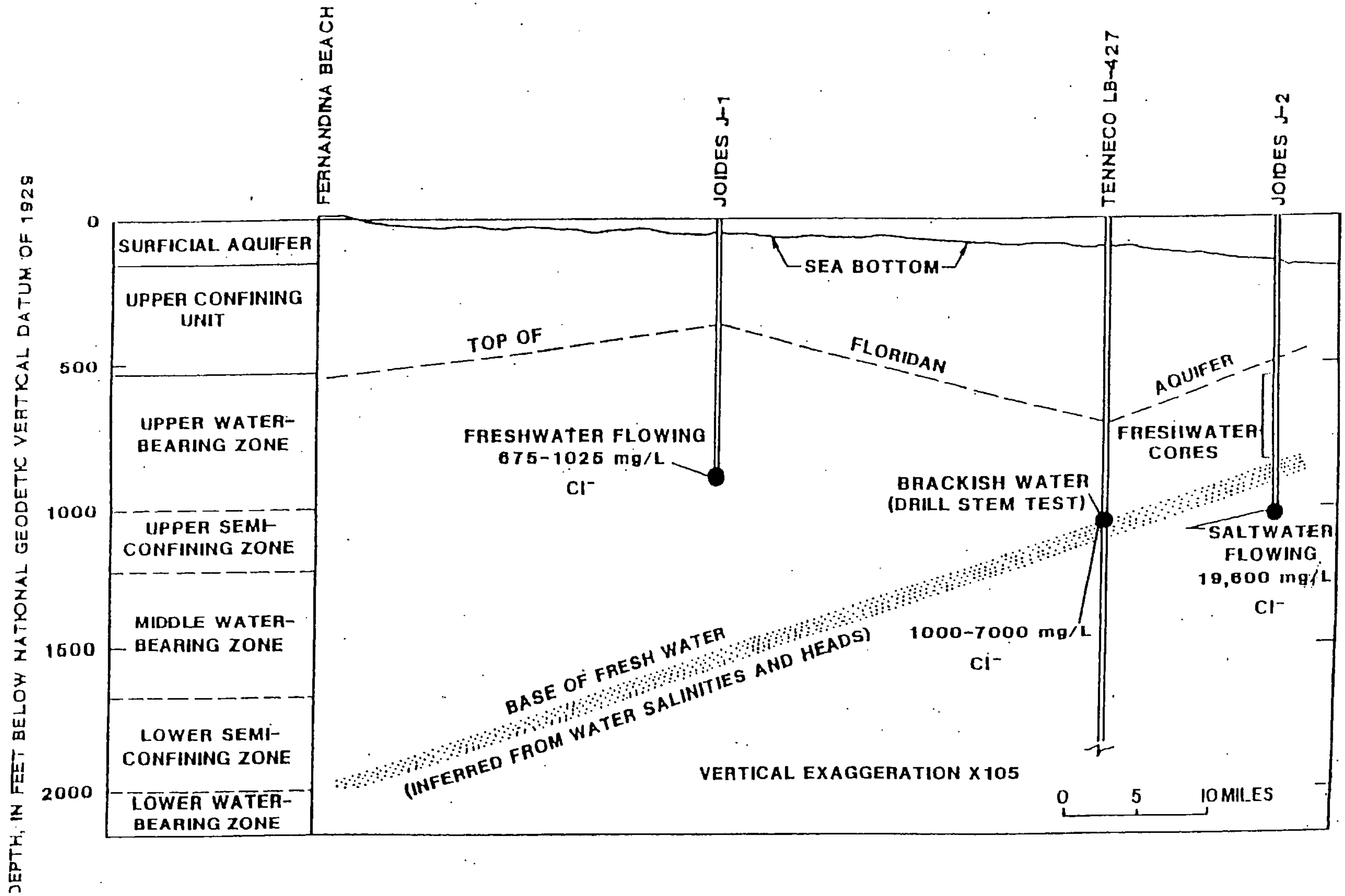

Figure 11: Inferred position of the saltwater-freshwater interface offshore Fernandina Beach, Fla. (from Brown, 1984)

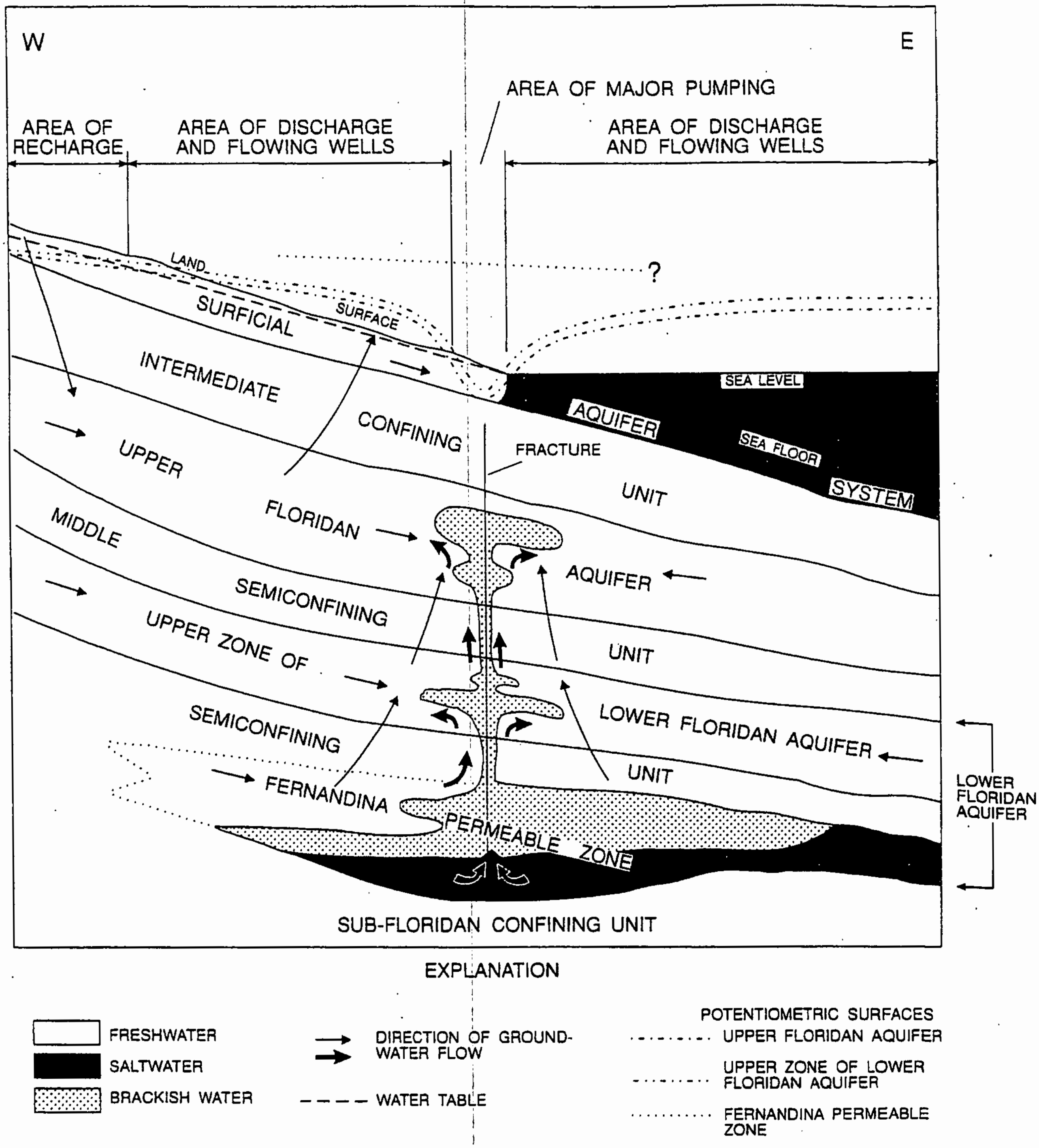

Figure 12: Model for the upconing of brackish water in the Floridan aquifer system (after Spechler, 1994)

Floridan aquifer would also provide a hydraulic barrier to upconing. However, the previously discussed chloride plume within the Upper Floridan aquifer below Brunswick, Georgia suggests that:

1) pathways for the vertical migration of brackish water do exist within the Floridan aquifer in southeastern Georgia and

2) large withdrawals of ground water from a small area can lead to reversal of the vertical hydraulic gradient and upward movement of brackish water from the Lower Floridan aquifer.

Numerous pathways have been proposed which potentially breach the middle semi-confining unit separating the upper and lower units of the Floridan aquifer. Two buried high-angle normal faults have been hypothesized from well data from central Duval County in Florida. These faults have been proposed as conduits for the movement of brackish water from a depth ~1,800 feet to the Upper Floridan aquifer (Leve, 1983). However, in recent years the existence of these fault has been questioned by USGS personnel in northeastern Florida (Spechler, oral communication, 2002).

Four major northeast-southwest trending buried faults have been hypothesized to occur within the Brunswick area in Glynn County, Georgia (Maslia and Prowell, 1990). These proposed faults along with an accompanying increase in fracturing may provide the conduits for the upconing of salt water responsible for the chloride plume below Brunswick (Maslia and Prowell, 1990). Recent seismic and sonic televiewer studies in northeastern Florida have identified paleo-karst features such as solution cavities (connected by fractures), buried solution pipes and/or paleo-sinkholes as conduits that breach the middle semi-confining unit within the Floridan aquifer system (Phelps and Spechler, 1997 and Odum et al., 1997).

There are no buried faults or other related features below Camden County that have been identified to this point. Paleo-solution features may likely be inferred by land based high resolution seismic studies; however, there has been no systematic seismic coverage of Camden County to this date. It is my opinion that although such studies would undoubtedly be interesting and useful, it is reasonable to make the *a priori assumption* that paleo-karst features do exist within the Camden County subsurface based upon the geological similarity with northeastern Florida.

The second prerequisite for the vertical upconing of salt water from the Lower Floridan aquifer is reduced hydraulic head (pressure reduction) in the Upper Floridan aquifer. Such pressure reduction is a direct result of excessive pumping within a geographically limited area. Significant withdrawal of ground water from the Upper Floridan aquifer in Camden County is limited to paper production within the extreme southeastern portion of the county. As previously mentioned, there also exists a small area within southeastern coastal Camden County that is affected by the cone of depression associated with ground-water withdrawal in the Fernandina Beach (Nassau Co., Fla.) area. The withdrawal of ground water below the Durango-Georgia Paper Co. property has resulted in higher than background concentrations at one localized well location (Figure 10).

Due to the historically limited population growth in Camden County, ground-water levels have declined less here than in the Brunswick region of Glynn County. Ground-water levels in the Upper Floridan aquifer throughout most of Camden County are 30-40 feet above mean sea level (see the potentiometric surface maps shown on Plates 9-14). The estimated decline in the potentiometric surface from pre-development levels for the Upper Floridan aquifer in Camden County has been 30 feet or less (Plates 16-20). This stands in contrast with Glynn County where the estimated decline in the potentiometric surface from pre-development levels has been between 40-60 feet. Currently there are insufficient data to evaluate potentiometric surface differences between the Upper and Lower Floridan aquifer in Camden County. However, limited data indicate that the potentiometric surface of the Lower Floridan aquifer is a few feet greater than the Upper Floridan aquifer within the St. Marys region of Camden County (Figures 4 and 5).

The estimated 30-foot estimated decline in the potentiometric surface from pre-development levels (Plates 16-20) is significant in that is very similar to that which is estimated for Duval County where selected wells have experienced low levels of salt-water contamination during the past several decades (see Figures 7 and 8). Ground-water extraction from the St. Marys - Kingsland region in the southeastern portion of the county is problematic in that this is not only the population center of the county but also is the site of the Durango-Georgia Co. paper processing plant which is the main user of ground water in the county. This is the area that should be monitored most closely within Camden County. The reduction or elimination of future water level declines is the most important factor in forestalling or preventing the upconing of salt water into the Upper Floridan aquifer in Camden County. This may or may not require continuing water restrictions placed upon ground-water withdrawal from the Upper Floridan aquifer in coastal Georgia.

A Proposed Monitoring Scheme for Camden County

Objective: Monitoring systems for salt-water intrusion typically involve the emplacement of a line of wells between the ocean and the production wells in order to detect the lateral encroachment of sea water. Such an approach is not useful for Camden County. The major objective of a proposed salt-water intrusion monitoring system for Camden County should be to provide an accurate indication of the vertical upconing of salt water into both the upper zone of the Lower Floridan aquifer and the lower portion of the Upper Floridan aquifer (Figure 13).

The monitoring well system should serve as an "early warning system" for the upward movement of chloride and other solutes within the Floridan aquifer system. The system should be placed within the St. Marys-Kingsland region which is most impacted by ground-water utilization for both municipal use and paper production (i.e. within the pumping center). The system should be designed to quantify changes in hydraulic head (water levels), temperature, salinity, and chloride concentrations on an in situ and continuous basis in both aquifers. One further design option that should be considered involves the possibility of recovering water samples from both aquifers such that the major ion and isotope chemistry of the ground water can be analyzed. The following design considerations are of a generalized nature and more rigorous specifications would be needed for actual design of the monitoring wells.

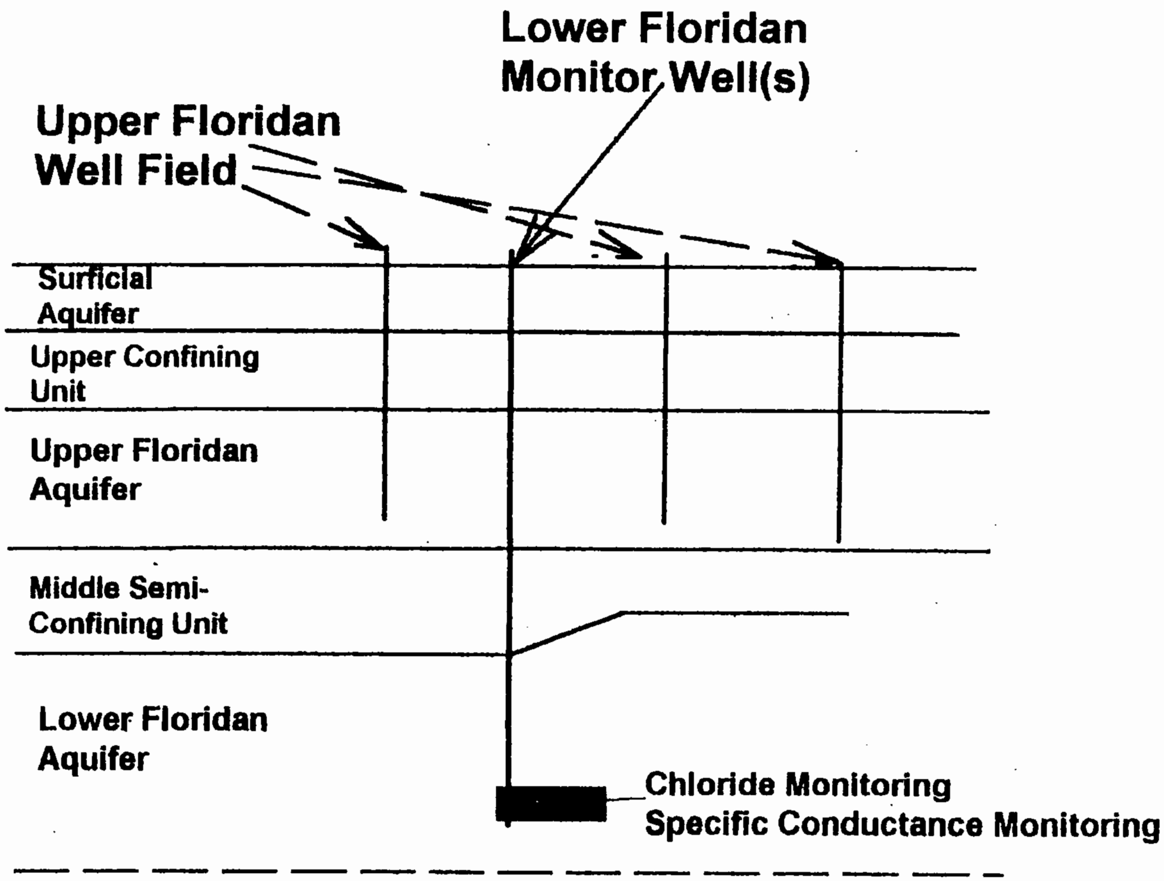

Figure 13: Conceptual model of a proposed monitoring system for the vertical migration of salt water in the Floridan aquifer system

General Design Considerations: The major design considerations are as follows:

1) Monitoring wells should be completed at two locations in the St. Marys-Kingsland area. These wells can complement the recently completed "Ball Park" monitoring well (USGS D-073) in St. Marys. Appropriate methods should be used such that drilling or other fluids are not introduced into the aquifer. One well at each location should be completed approximately 200-300 feet below the top of the Floridan aquifer (approximate depth = 1,000 feet below land surface) and another well should be completed approximately 100 feet below the top of the Lower Floridan aquifer or below the base of the middle semi-confining unit (approximate depth = 1550 feet below land surface). If funds permit, additional monitoring wells can be completed approximately 100 feet above the base of both the Lower and Upper Floridan aquifers. An alternative scheme would be to complete monitor wells near the middle of both aquifers.

2) The monitoring zone of both aquifers should be approximately 25 feet long and 6 inches in diameter, designed with an appropriate stainless steel well screen coupled to a steel casing. The casing should be grouted up to the earth's surface with cement. The upper portion of the well penetrating the surficial and Miocene aquifers should be cased with steel pipe and grouted with cement. This typically requires three steel casings of 24", 18" and 12" diameter for the lower Floridan aquifer (in these wells the Upper Floridan aquifer should also be cased) and two steel casings (18" and 12" diameter) for the Upper Floridan aquifer (Bill Osborne, SJRWMD, written communication, 2001). The annulus above the sampling interval should be grouted with cement as to insure a discrete sampling zone and to avoid "cross-contamination" of the different aquifers.

3) The monitoring zone for both wells (Upper Floridan and Lower Floridan aquifers) should be equipped with an in situ chloride electrode sensing device and temperature sensor (usually standard with all other devices). An accompanying salinity or total dissolved solids (TDS) sensor is an optional probe that may also be placed within the monitoring zone of both wells. All sensors should be precalibrated before being placed downhole and then periodically recalibrated. If funds are available, the chloride and salinity data should be recorded on a continuous basis. A less expensive alternative to continuous monitoring would be to monitor the aquifer on a periodic basis for chloride, salinity and TDS concentrations.

4) A pressure transducer should be placed in each well such that it is capable of resolving water level changes of ~0.1 foot or less. Such resolution is necessary to insure that potentially small hydraulic head differences between the Lower and Upper Floridan aquifer can be differentiated. The transducers should be precalibrated before being placed downhole and then periodically recalibrated. The water level data should be recorded on a continuous basis and then either relayed remotely or recorded on site such that the data are readily retrievable from the well location.

5) All methods of data gathering should be consistent with USGS specifications such that these wells could be used as part of their ground-water monitoring network. Taking this action would insure that the Camden County data can be used with other data in the official USGS data base. The USGS would likely be responsible for these monitoring activities.

6) A final optional design consideration would involve equipping the wells with a submersible pump capable of transporting small volumes of water (i.e. ~1-10 liters) to the surface through a small diameter (nominal 2" dia.) PVC sampling pipe. Retrieval of actual water samples (if funds are available) would allow a complete chemical and isotopic analysis to be made. This in turn might assist in better understanding the origins of ground water in each aquifer and mixing processes that might occur between the aquifers.

General Recommendations

The susceptibility of the Floridan aquifer underlying Camden County to salt-water intrusion does not imply that it must or will necessarily become contaminated in the future. Wise water management and ground-water monitoring practices can be used to forestall possible chloride contamination of the Upper Floridan aquifer in Camden County. The following recommendations are given for future consideration:

1) Take preemptive actions to minimize the decline of the potentiometric surface within the Upper Floridan aquifer. This is the ultimate means of preventing the upconing of salt water from the Lower Floridan aquifer to the Upper Floridan aquifer. Preemptive action schemes can take these forms:

a) limit the volume of water pumped from the Upper Floridan aquifer

b) develop water resources other than those of the Floridan aquifer (if available, practical, and environmentally feasible)

c) initiate conservation methods and incentives designed to reduce water demand

d) develop a plan for decentralized ground water-pumping in Camden County (see elaboration given below)

A decentralized ground-water pumping scheme in which production wells are spaced as far apart laterally as possible might allow for the continued or even expanded utilization of ground water from the Upper Floridan aquifer while minimizing potentiometric surface declines. The main drawback of this scheme is that it would involve a large capital expenditure in terms of well drilling, pipelines and pumps. However, by optimally spreading the pumping center from an area of a few square miles to possibly tens of square miles, potentiometric surface declines can likely be minimized. This in turn would favor retention of the hydraulic barrier posed by higher heads within the Upper Floridan aquifer relative to the Lower Floridan aquifer.

Alternative pumping scenarios can be tested using numerical ground-water modeling techniques capable of simulating solute transport between the Upper and Lower Floridan aquifers. Engineering estimates of pipeline and related infrastructure costs can accompany ground-water pumping scenarios that have been determined favorable by ground-water modeling. The cost of the proposed well field will undoubtedly be high and probably more than most cities in southeastern Georgia are willing to pay. However, this cost must always be weighed against that of losing a poorly designed well field to salt-water intrusion. Implementation of a pumping scheme that makes increased demands upon the Floridan aquifer should be accompanied by a ground-water monitoring scheme capable of detecting the vertical movement of salt water in the impacted zone.

2) Continued efforts should be given to using geophysical techniques to find the depth of salt water below Camden County and the surrounding region. The data gathered to date have been useful in better understanding the extent of salt water in the Lower Floridan aquifer; however, more data are required for a meaningful depiction of regional conditions. The safe working assumption is that the Fernandina Permeable Zone at the base of the Lower Floridan aquifer contains brackish to salt water on a regional basis. Efforts to find locations where the Lower Floridan aquifer is fresh throughout its vertical extent will be costly and are probably not justified.

3) Lower priority should be given to studies designed to find subsurface faults, fractures, solution features, or zones of enhanced permeability below Camden County. Although these studies certainly have merit, the ultimate cause of the vertical intrusion is not the "conduit"; rather it is pressure reduction within the Upper Floridan aquifer. To reiterate, conduits can exist and not result in salt-water intrusion if the *downward hydraulic gradient* between the Upper and Lower Floridan aquifers is maintained through wise water management and ground-water exploitation practices.

Summary and Conclusions

1) Camden County has not yet experienced a costly and problematic salt-water intrusion problem as has neighboring Glynn County. This is because the population of Camden County is relatively low as are accompanying ground-water demands. The population of Camden County has grown by 45% during the past decade and there will undoubtedly be increased pressures on the Floridan aquifer within the future. It is by no means certain whether increased water demands will result in salt-water intrusion within Camden County; however, the possibility needs to be seriously addressed before, rather than after, the problem exists.

2) Geological and hydrological conditions underlying Camden County are similar to Nassau, Duval, and Glynn counties in coastal Floridan and Georgia. Therefore, our knowledge of the Floridan aquifer system in these more developed locations can be applied to Camden County with some certainty. The fact that the Upper Floridan aquifer below Brunswick has experienced a persistent and a relatively extensive salt-water intrusion problem suggests that Camden County should take extreme caution in stressing the Floridan aquifer with increased ground-water withdrawals. Various low-level chloride problems (e.g. 50mg/L < [Cl] < 250mg/L) exist locally (i.e. confined to a few wells) within Duval County where ground-water use is extensive. These problems also suggest caution should be taken in Camden County.

3) The most likely mechanism for salt-water intrusion to occur within Camden County involves the vertical upconing of salt or brackish water from the Fernandina Permeable Zone at the base of the Lower Floridan aquifer. This is the same mechanism that is believed to be responsible for the Brunswick chloride plume which has contaminated the Upper and Lower Floridan aquifer in Glynn County. In order for the upconing (vertical migration) of salt water to occur, a vertical

hydraulic gradient must exist with higher hydraulic heads in the Lower Floridan aquifer than in the Upper Floridan aquifer. There also must be some form of conduit (i.e. relatively high permeability pathway) for the vertical migration of salt or brackish water to occur. The most likely pathways involve subsurface faults, fractures, and/or paleo-solution features such as buried sinkholes. The lateral migration of modern seawater into the Floridan aquifer in southeastern Georgia and northeastern Florida is not likely in that previous studies indicate that the freshwater/seawater interface is approximately 2,000 feet below sea level.

4) There are no known Upper Floridan aquifer wells in Camden County in which chloride concentrations presently exceed the drinking water standard of 250 mg/L. There is at least one well at the Durango-Georgia Co. facility near St. Marys in which chloride concentrations exceed 100 mg/L (chloride concentrations above 50 mg/L are considered above "background" for the Upper Floridan aquifer in this region). This well produces a >100-foot cone of depression and therefore the upconing of brackish water is apparently occurring at this location. Salt water at this location is highly mixed with fresh water in the Upper Floridan aquifer as evidenced by chloride concentrations that are only slightly above background. Similar processes are believed to be occurring elsewhere in the study area, notably at several well sites in Duval County, Florida.

5) Data from recently drilled deep wells in Camden and Nassau counties indicate that much of the Lower Floridan aquifer above the Fernandina Permeable Zone has not yet been contaminated by salt water. However, preliminary data indicate that hydraulic head values within the Lower Floridan aquifer are a few feet higher than within the Upper Floridan aquifer below St. Marys in southeastern Camden County. This indicates that the upward movement of salt water is possible in this region.

6) Numerous options can be explored to prevent or forestall the upconing of salt water into the Floridan aquifer below Camden County. One of the most important is to spread additional ground-water withdrawal demands over as large a geographic area as possible. This would have the effect of reducing future declines in the fresh water hydraulic head of the Upper Floridan aquifer. Such scenarios are costly and sophisticated modeling approaches need be employed to explore how various pumping schemes might affect the hydraulic gradient between the Upper and Lower Floridan aquifers.

7) New ground-water monitoring programs should accompany the increased withdrawal of ground water from the Floridan aquifer (if increased demands are such that more well fields need be drilled in Camden County). Monitoring wells should be placed in the both the Lower and Upper Floridan aquifers in the pumping center, thereby facilitating the collection of ground-water level and chloride data on a continuous basis. Such a system should be capable of providing an "early warning" detection system at the onset of salt-water upconing. Pumping schemes might then be modified accordingly to prevent the occurrence of a persistent contaminant plume such as the one created below Brunswick in Glynn County.

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Appendix 1

Chloride Concentration for Selected Wells in Duval, Nassau, and Camden Counties

(Wells are completed in the Upper Floridan aquifer unless otherwise stated)

County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Duval, Fl	D-46A	9/27/97	30D 21M 30S	81D 41M 18S	14	1234	
Duval, Fl	D-46A	7/15/98	"	"	13		
Duval, Fl	D-75	7/17/98	30D 15M 37S	81D 44M 19S	7.5	1302	
Duval, Fl	D-77	5/1/79	30D 30M 15S	81D 34M 33S	25	706	
Duval, Fl	D-90	9/8/92	30D 20M 03S	81D 38M 40S	17	1297	
Duval, Fl	D-94	1955	30D 19M 00S	81D 32M 28S	18	635	Upper Floridan well showing increasing chloride with time
		1973	"	"	18	"	
		1980	"	"	25	"	
		1986	"	"	30	"	
		1988	"	"	40	"	
		1989	"	"	55	"	
Duval, Fl	D-103	7/16/98	30D 16M 48S	81D 43M 18S	9.3	1332	
Duval, Fl	D-160	5/4/90	30D 18M 52S	81D 23M 42S	14	550	
Duval, Fl	D-176	9/29/97	30D 20M 22S	81D 39M 35S	13	1280	
Duval, Fl	D-176	7/16/98	"	"	12	"	
Duval, Fl	D-224	4/24/98	30D 17M 43S	81D 30M 47S	110	1179	
Duval, Fl	D-225	10/28/98	30D 17M 43S	81D 36M 23S	58	1277	
Duval, Fl	D-225	7/6/98	"	"	230	"	
Duval, Fl	D-228	10/30/97	30D 25M 02S	81D 33M 30S	28	850	
Duval, Fl	D-228	7/21/98	"	"	28	"	
Duval, Fl	D-262	1952	30D 26M 08S	81D 35M 49S	21	1237	Lower Floridan aquifer well showing increased chloride with time
Duval, Fl	D-262	1960	"	"	25	"	
Duval, Fl	D-262	1965	"	"	21	"	
Duval, Fl	D-262	1970	"	"	23	"	
Duval, Fl	D-262	1975	"	"	30	"	
Duval, Fl	D-262	1980	"	"	35	"	
Duval, Fl	D-262	1985	"	"	35	"	
Duval, Fl	D-262	1986	"	"	40	"	
Duval, Fl	D-262	1987	"	"	42	"	

Appendix 1

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County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Duval, Fl	D-262	1988	"	"	50	"	
Duval, Fl	D-262	1989	"	"	43	"	
Duval, Fl	D-262	1990	"	"	50	"	
Duval,Fl	D-263	1/22/98	30D 26M 08S	81D 35M 49S	19	1025	
Duval, Fl	D-275	1962	30D 17M 40S	81D 36M 10S	25	1234	Upper/Lower Floridan aquifer well showing increasing chloride with time
Duval, Fl	D-275	1970	"	"	50	"	
Duval, Fl	D-275	1975	"	"	70	"	
Duval, Fl	D-275	1980	"	"	90	"	
Duval, Fl	D-275	1982	"	"	140	"	
Duval, Fl	D-275	1985	"	"	150	"	
Duval, Fl	D-275	1987	"	"	160	"	
Duval, Fl	D-275	1988	"	"	200	"	
Duval, Fl	D-275	9/27/97	"	"	200	"	
Duval, Fl	D-275	7/17/98	"	"	200	"	
Duval, Fl	D-291	8/7/92	30D 15M 22S	81D 33M 13S	125		
Duval, Fl	D-296	7/16/98	30D 08M 20S	81D 35M 40S	17	487	
Duval, Fl	D-313	9/27/97	30D 19M 57S	81D 34M 23S	100	1150	
Duval, Fl	D-313	7/20/98	"	"	130	"	
Duval, Fl	D-329	10/28/97	30D 39M 25S	81D 39M 25S	20	1209	
Duval, Fl	D-329	7/15/98	"	"	19	"	
Duval, Fl	D-335	7/15/98	30D 20M 15S	81D 38M 45S	15	1286	
Duval, Fl	D-336	10/27/97	30D 22M 36S	81D 40M 15S	13	1303	
Duval, Fl	D-336	7/15/98	"	"	13	"	
Duval, Fl	D-348	5/10/90	30D 24M 16S	81D 52M 26S	9	708	
Duval, Fl	D-349	7/24/90	30D 24M 16S	81D 52M 26S	6	2165	
Duval, Fl	D-360	1976	30D 22M 43M	81D 30M 04S	170	665	Upper Floridan well showing increasing chloride with time
Duval, Fl	D-360	1980	"	"	210		
Duval, Fl	D-360	1984	"	"	220		

Appendix 1
Chloride Concentration for Selected Wells in Duval, Nassau, and Camden Counties
(Wells are completed in the Upper Floridan aquifer unless otherwise stated)

County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Duval, Fl	D-360	1986	"	"	250		Upper Floridan well
Duval, Fl	D-360	1989	"	"	260		showing increasing
Duval, Fl	D-360	1990	"	"	270		chloride with time
Duval, Fl	D-395	9/30/97	30D 27M 24S	81D 24M 28S	20	Unknown	
Duval, Fl	D-395	7/15/98	"	"	20	"	
Duval, Fl	D-398	6/5/97	30D 21M 32S	81D 52M 26S	15.4	1216	
Duval, Fl	D-401	4/30/79	30D 32M 16S	81D 43M 33S	25	Unknown	
Duval, Fl	D-411	5/2/79	30D 34M 58S	81D 36M 40S	24	1000	
Duval, Fl	D-425	3/18/98	30D 18M 17S	81D 37M 49S	15	1895	
Duval, Fl	D-450	1986	30D 16M 08S	81D 36M 28S	25	1297	Upper/Lower
Duval, Fl	D-450	1987	"	"	22	"	Floridan aquifer
Duval, Fl	D-450	1988	"	"	65	"	well showing
Duval, Fl	D-450	1989	"	"	75	"	increasing
Duval, Fl	D-450	1990	"	"	80	"	
Duval, Fl	D-450	7/21/98	"	"	87	"	
Duval, Fl	D-464A	7/29/97	30D 23M 39S	81D 25M 47S	15	1000	
Duval, Fl	D-464A	7/16/98	"	"	14		
Duval, Fl	D-479	7/15/98	30D 20M 07S	81D 35M 22S	140	1350	
Duval, Fl	D-483	9/19/95	30D 16M 57S	81D 23M 33S	144	1200	
Duval, Fl	D-484	1974	30D 17M 04M	81D 23M 34S	90	1181	Upper/Lower
Duval, Fl	D-484	1977	"	"	70	"	Floridan aquifer
Duval, Fl	D-484	1982	"	"	120	"	well showing
Duval, Fl	D-484	1985	"	"	160	"	increasing
Duval, Fl	D-484	1987	"	"	140	"	chloride
Duval, Fl	D-484	1988	"	"	180	"	concentration
Duval, Fl	D-484	1990	"	"	180	"	with time
Duval, Fl	D-535	8/12/96	30D 10M 44S	81D 37M 18S	16	542	
Duval, Fl	D-538	7/16/98	30D 11M 57S	81D 37M 43S	51	1000	

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(Wells are completed in the Upper Floridan aquifer unless otherwise stated)

County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Duval, Fl	D-547	9/21/92	30D 17M 10S	81D 32M 36S	15	740	
Duval, Fl	D-547	6/7/95	"	"	16	"	
Duval, Fl	D-547	5/4/98	"	"	15	"	
Duval, Fl	D-578	9/5/79	30D 32M 44M	81D 43M 43S	23	450	
Duval, Fl	D-591	3/20/96	30D 23M 53S	81D 43M 10S	15	1020	
Duval, Fl	D-592	10/28/97	30D 22M 27S	81D 43M 50S	12	1326	
Duval, Fl	D-592	7/16/98	30D 22M 27S	81D 43M 50S	11	"	
Duval, Fl	D-606	4/3/92	30D 21M 34S	81D 28M 27S	21	804	
Duval, Fl	D-642	5/7/92	30D 22M 35S	81D 35M 16S	17	1041	
Duval, Fl	D-642	9/7/95	"	"	13	"	
Duval, Fl	D-649	7/17/98	30D 17M 52S	81D 36M 05S	27	1005	
Duval, Fl	D-672	7/7/94	30D 12M 53S	81D 26M 56S	17	1014	
Duval, Fl	D-673	1/30/90	30D 32M 09S	81D 37M 18S	29	814	
Duval, Fl	D-673	4/10/90	"	"	34	"	
Duval, Fl	D-673	7/10/90	"	"	28	"	
Duval, Fl	D-673	10/2/90	"	"	24	"	
Duval, Fl	D-673	9/9/92	"	"	21	"	
Duval, Fl	D-673	6/5/95	"	"	21	"	
Duval,Fl	D-753	4/30/79	30D 31M 04S	81D 28M 44S	23	600	
Duval, Fl	D-909	7/17/98	30D 06M 22S	81D 28M 47S	19	500	
Duval, Fl	D-913	11/1/90	30D 25M 57S	81D 25M 31S	15	556	
Duval, Fl	D-913	10/30/97	"	"	380	"	
Duval, Fl	D-913	7/15/98	"	"	380	"	
Duval, Fl	D-1149	10/30/97	30D 25M 03S	81D 33M 20S	21	1104	
Duval, Fl	D-1149	7/21/98	"	"	26	"	
Duval, Fl	D-1150	10/30/97	30D 25M 05S	81D 33M 10S	31	1104	
Duval, Fl	D-1150	7/21/98	"	"	28	"	

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County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Duval, Fl	D-1151	7/21/98	30D 25M 11S	81D 33M 12S	21	1104	
Duval, Fl	D-1152	10/30/97	30D 25M 19S	81D 33M 15S	22	1104	
Duval, Fl	D-1155	1976	30D 16M 39S	81D 33M 08S	50	1170	Lower Floridan well
Duval, Fl	D-1155	1980	"	"	70	"	showing increasing
Duval, Fl	D-1155	1985	"	"	80	"	chloride with time
Duval, Fl	D-1155	1987	"	"	130	"	
Duval, Fl	D-1155	10/29/97	"	"	250	"	
Duval, Fl	D-1155	7/7/98	"	"	120	"	
Duval, Fl	D-1196	3/19/90	30D 30M 49S	81D 27M 20S	24	532	
Duval, Fl	D-1220	10/30/90	30D 17M 58S	81D 30M 39S	460	1185	
Duval, Fl	D-1220	7/9/96	"	"	839	"	
Duval, Fl	D-1220	7/11/96	"	"	852	"	
Duval, Fl	D-1220	7/15/96	"	"	752	"	
Duval, Fl	D-1220	7/19/96	"	"	806	"	
Duval, Fl	D-1271	6/2/95	30D 18M 52S	81D 37M 04S	4	577	
Duval, Fl	D-1292	4/21/92	30D 11M 57S	81D 46M 52S	57	621	
Duval, Fl	D-1298	8/12/96	30D 08M 40S	81D 35M 12S	99	704	
Duval, Fl	D-1342	3/3/92	30D 18M 02S	81D 58M 50S	10	764	
Duval, Fl	D-1342	9/12/95	"	"	10	"	
Duval, Fl	D-1342	6/3/98	"	"	10	"	
Duval, Fl	D-1359	8/19/91	30D 26M 31S	81D 31M 25S	21	733	
Duval, Fl	D-2386	1981	30D 21M 59S	81D 23M 56S	7.6	691	USGS TEST WELL
Duval, Fl	D-2386	1981	"	"	8	1007	Kathryn Hanna
Duval, Fl	D-2386	1981	"	"	50	1194	Abbey Park
Duval, Fl	D-2386	1981	"	"	33	1381	Jacksonville, Fl
Duval, Fl	D-2386	1981	"	"	21	1605	
Duval, Fl	D-2386	1981	"	"	28	1802	
Duval, Fl	D-2386	1981	"	"	75	1918	
Duval, Fl	D-2386	1981	"	"	300	1922	

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County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Duval, Fl	D-2386	1981	"	"	300	1973	USGS TEST WELL
Duval, Fl	D-2386	1981	"	"	1600	1980	Kathryn Hanna
Duval, Fl	D-2386	1981	"	"	3200	2000	Abbey Park
Duval, Fl	D-2386	1981	"	"	3300	2024	Jacksonville, Fl
Duval, Fl	Test Well	1966 circ	not given	not given	16	763	USGS TEST WELL
Duval, Fl	Test Well	1966 circ	"	"	14	1260	Jacksonville
Duval, Fl	Test Well	1966 circ	"	"	30	2175	
Duval, Fl	Test Well	1966 circ	"	"	7320	2458	
Duval, Fl	Test Well	Feb-83	30D 20M 50S	81D 32M 40S	110	711	USGS TEST WELL
Duval, Fl	Test Well	Feb-83	"	"	132	1014	East-Central Duval
Duval, Fl	Test Well	Feb-83	"	"	140	1274	County
Duval, Fl	Test Well	Feb-83	"	"	25	1306	
Duval, Fl	Test Well	Feb-83	"	"	45	1616	
Duval, Fl	Test Well	Feb-83	"	"	320	1638	
Duval, Fl	Test Well	Feb-83	"	"	680	1741	
Duval, Fl	Test Well	Feb-83	"	"	700	1863	
Duval, Fl	Test Well	Feb-83	"	"	345	1937	
Duval, Fl	Test Well	Feb-83	"	"	586	2071	
Duval, Fl	Test Well	Feb-83	"	"	3360	2081	
Duval, Fl	Test Well	Feb-83	"	"	4830	2095	
Duval, Fl	Test Well	Feb-83	"	"	5370	2112	
Note: Latitudes and Longitudes for USGS TEST WELL are approximate to seconds							
Duval, Fl	D-3060	5/8/90	30D 20M 52S	81D 32M 32S	80	800	USGS Monitor
Duval, Fl	D-3060	5/8/90	"	"	25	1400	Well
Duval, Fl	D-3060	5/8/90	"	"	30	1600	
Duval, Fl	D-3060	5/8/90	"	"	800	1630	
Duval, Fl	D-3060	5/8/90	"	"	300	2000	
Duval, Fl	D-3060	5/8/90	"	"	2100	2122	
Duval, Fl	D-3060	5/8/90	30D 20M 52S	81D 32M 32S	6,060	2112	
Duval, Fl	D-425T	2/5/92	30D 18M 17S	81D 37M 49S	14	1895	
Duval, Fl	D-425T	6/7/95	"	"	16	"	
Duval, Fl	D-425T	5/5/98	"	"	100	"	
Duval, Fl	D-2193	9/28/97	30D 17M 44S	81D 36M 33S	140	1304	
Duval, Fl	D-2193	7/16/98	"	"	140	"	

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County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Duval, Fl	D-4591	9/18/91	30D 13M 46S	81D 37M 18S	22	645	
Duval, Fl	D-4609	9/8/92	30D 12M 27S	81D 44M 11S	7.2	950	
Nassau, Fl	B-7	1952	30D 38M 23S	81D 27M 33S	420	1826	Fernand. Perm.Zone
Nassau, Fl	B-7	1955	"	"	600	"	"
Nassau, Fl	B-7	1957	"	"	1000	"	"
Nassau, Fl	B-7	1960	"	"	1600	"	"
Nassau, Fl	B-7	1962	"	"	1800	"	"
Nassau, Fl	B-7	1963	"	"	<100	1100*	
Nassau, Fl	B-7	1965	"	"	<100	"	
Nassau, Fl	B-7	1970	"	"	<100	"	
Nassau, Fl	B-7	1975	"	"	<100	"	
Well B-7 was plugged from 1826 to 1100 feet in 1962							
Nassau, Fl	B-10	1952	30D 39M 02S	81D 27M 39S	100	1820	Fernandina -LF
Nassau, Fl	B-10	1955	"	"	100	"	"
Nassau, Fl	B-10	1960	"	"	170	"	"
Nassau, Fl	B-10	1965	"	"	210	"	"
Nassau, Fl	B-10	1967	"	"	200	"	"
Nassau, Fl	B-10	1970	"	"	390	"	"
Nassau, Fl	B-10	1972	"	"	580	"	"
Nassau, Fl	B-10	1975	"	"	910	"	"
Nassau, Fl	B-11	1952	30D 39M 33S	81D 27M 46S	78	1840	Fernandina -LF
Nassau, Fl	B-11	1955	"	"	90	"	"
Nassau, Fl	B-11	1960	"	"	120	"	"
Nassau, Fl	B-11	1965	"	"	220	"	"
Nassau, Fl	B-11	1970	"	"	340	"	"
Nassau, Fl	B-11	1975	"	"	520	"	"
Nassau, Fl	B-15	1953	30D 39M 47S	81D 27M 54S	38	1700	"
Nassau, Fl	B-15	1955	"	"	42	"	"
Nassau, Fl	B-15	1958	"	"	50	"	"
Nassau, Fl	B-15	1965	"	"	75	"	"
Nassau, Fl	B-15	1970	"	"	95	"	"
Nassau, Fl	B-15	1972	"	"	125	"	"
Nassau, Fl	B-15	1975	"	"	135	"	"

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County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Nassau, Fl	Test Well	Mar-79	not given	not given	31	632	USGS TEST WELL
Nassau, Fl	Test Well	Mar-79	"	"	30	977	Fernandina Beach
Nassau, Fl	Test Well	Mar-79	"	"	47	1102	East bank of
Nassau, Fl	Test Well	Mar-79	"	"	120	1133	Amelia River
Nassau, Fl	Test Well	Mar-79	"	"	700	1290	
Nassau, Fl	Test Well	Mar-79	"	"	61	1600	
Nassau, Fl	Test Well	Mar-79	"	"	360	1819	
Nassau, Fl	Test Well	Mar-79	"	"	50	2008	
Nassau, Fl	Test Well	Mar-79	"	"	912	2071	
Nassau, Fl	Test Well	Mar-79	"	"	4800	2084	
Nassau, Fl	Test Well	Mar-79	"	"	7800	2094	
Nassau, Fl	N-2	4/4/78	30D 35M 19S	81D 27M 53S	25	580	
Nassau, Fl	N-8	5/2/79	30D 32M 44S	81D 26M 37S	24	680	
Nassau, Fl	N-9	5/5/77	30D 34M 57S	81D 27M 15S	29	586	
Nassau, Fl	N-12	12/5/75	30D 38M 01S	81D 27M 37S	30	640	
Nassau, Fl	N-16	12/26/75	30D 38M 20S	81D 26M 15S	30	630	
Nassau, Fl	N-19	10/4/77	30D 42M 13S	81D 27M 08S	31	710	
Nassau, Fl	N-20	5/4/77	30D 39M 39S	81D 31M 26S	23	567	
Nassau, Fl	N-22	5/13/75	30D 39M 40S	81D 28M 18S	28	1100	
Nassau, Fl	N-24A	4/5/78	30D 40M 20S	81D 27M 20S	25	1215?	
Nassau, Fl	N-28	4/11/78	30D 37M 34S	81D 29M 00S	30	578	
Nassau, Fl	N-30	4/5/78	30D 39M 21S	81D 27M 46S	109	750	
Nassau, Fl	N-31	5/13/75	30D 38M 12S	81D 27M 37S	32	1000	
Nassau, Fl	N-35	4/6/78	30D 39M 35S	81D 28M 37S	44	1062	
Nassau, Fl	N-43	10/7/91	30D 39M 40S	81D 28M 18S	36	1100	

Appendix 1
Chloride Concentration for Selected Wells in Duval, Nassau, and Camden Counties
(Wells are completed in the Upper Floridan aquifer unless otherwise stated)

County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Nassau, Fl	N-44	9/7/77	30D 37M 54S	81D 36M 27S	26	1000	
Nassau, Fl	N-45	4/10/78	30D 39M 45S	81D 31M 25S	28	500	
Nassau, Fl	N-46	4/4/78	30D 34M 35S	81D 27M 14S	24	1016	
Nassau, Fl	N-46	2/28/80	"	"	24	"	
Nassau, Fl	N-46	6/26/95	"	"	26	"	
Nassau, Fl	N-46	7/15/98	"	"	23	"	
Nassau, Fl	N-53	5/1/79	30D 40M 02S	81D 38M 12S	28	500	
Nassau, Fl	N-54	5/4/77	30D 37M 22S	81D 27M 14S	29	482	
Nassau, Fl	N-54	3/4/93	"	"	123	"	
Nassau, Fl	N-57	5/3/78	30D 35M 22S	81D 35M 14S	24	550	
Nassau, Fl	N-62	circa 198	30D 38M 23S	81D 27M 33S	26	1130	USGS TEST WELL
Nassau, Fl	N-62	circa 198	"	"	62	1410	at Fernandina Bch.
Nassau, Fl	N-62	circa 198	"	"	70	1564	
Nassau, Fl	N-62	circa 198	"	"	57	1860	
Nassau, Fl	N-62	circa 198	"	"	120	2130	
Nassau, Fl	N-68	5/5/77	30D 39M 58S	81D 28M 04S	40	1050	
Nassau, Fl	N-68	10/19/92	"	"	440	"	
Nassau,Fl	N-72	5/5/77	30D 35M 57S	81D 27M 27S	30	610	
Nassau, Fl	N-76	5/7/77	30D 39M 40S	81D 28M 57S	21	1065	
Nassau, Fl	N-76	11/7/91	"	"	32	"	
Nassau, Fl	N-100	9/7/77	30D 34M 03S	81D 31M 13S	22	672	
Nassau, Fl	N-102	4/5/78	30D 36M 55S	81D 26M 54S	33	1200?	
Nassau, Fl	N-106	9/11/75	30D 38M05S	81D 27M 39S	80	600	
Nassau, Fl	N-106	9/11/75	"	"	245	925	
N-106 was sampled with a downhole sampler							
Nassau, Fl	N-113	7/8/75	30D 34M 44S	81D 34M 31S	22	1016	

Appendix 1
Chloride Concentration for Selected Wells in Duval, Nassau, and Camden Counties
(Wells are completed in the Upper Floridan aquifer unless otherwise stated)

County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Nassau, Fl	N-117	1979	30D 40M 01S	81D 28M 03S	31	710	USGS
Nassau, Fl	N-117	1979	"	"	30	1006	TEST WELL
Nassau, Fl	N-117	1979	"	"	120	1133	
Nassau, Fl	N-117	1979	"	"	620	1195	
Nassau, Fl	N-117	1979	"	"	710	1460	
Nassau, Fl	N-117	1979	"	"	320	1756	
Nassau, Fl	N-117	1979	"	"	240	1976	
Nassau, Fl	N-117	1979	"	"	912	2071	
Nassau, Fl	N-117	1979	"	"	4800	2084	
Nassau, Fl	N-117	1979	"	"	7800	2094	
Nassau, Fl	N-117	5/13/90	30D 40M 01S	81D 28M 03S	11,800	1007	
Nassau, Fl	N-117	11/30/94	"	"	8,300	"	
Nassau, Fl	N-117	12/1/94	"	"	9,660	"	
Nassau, Fl	N-117	12/8/94	"	"	24,500	"	
Nassau, Fl	N-117	3/30/95	"	"	1,470	"	
Nassau, Fl	N-117	3/30/95	"	"	751	"	
Nassau, Fl	N-117	4/6/95	"	"	344	"	
Nassau, Fl	N-117	4/7/95	"	"	508	"	
Nassau, Fl	N-117	4/7/98	"	"	590	"	
Nassau, Fl	N-128	10/7/91	30D 39M 48S	81D 27M 52S	40	1693	
Nassau, Fl	N-190	10/23/91	30D 38M 23S	81D 27M 33S	616	1020	
Nassau, Fl	N-193	10/17/91	30D 39M 35S	81D 28M 37S	58	1062	
Nassau, Fl	N-195	10/7/91	30D 38M 46S	81D 27M 36S	34	888	
Nassau, Fl	N-199	9/14/92	30D 41M 20S	81D 55M 09S	28	521	
Nassau, Fl	N-199	11/9/95	"	"	27		
Nassau, Fl	N-204	1/12/93	30D 40M 35S	81D 27M 15S	71	976	
Nassau, Fl	N-220	9/19/94	30D 35M 43S	81D 49M 48S	32	650	
Nassau, Fl	N-220	9/22/94	"	"	113	"	
Nassau, Fl	N-220	9/22/94	"	"	241	"	
Nassau, Fl	N-220	9/28/94	"	"	32	"	
Nassau, Fl	N-220	10/5/94	"	"	49	"	
Nassau, Fl	N-220	10/5/94	"	"	70	"	

Appendix 1
Chloride Concentration for Selected Wells in Duval, Nassau, and Camden Counties
(Wells are completed in the Upper Floridan aquifer unless otherwise stated)

County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Nassau, Fl	N-220	9/7/95	"	"	27	"	
Nassau, Fl	N-220	11/9/95	"	"	26	"	
Nassau, Fl	N-220	12/6/95	"	"	26	"	
Nassau, Fl	N-220	3/13/96	"	"	28	"	
Nassau, Fl	N-220	6/12/96	"	"	28	"	
Nassau, Fl	N-220	9/18/90	"	"	27	"	
Nassau, Fl	N-220	3/12/97	"	"	29	"	
Nassau, Fl	N-220	6/18/97	"	"	33	"	
Nassau, Fl	N-221	11/9/94	30D 47M 00S	81D 57M 10S	36	820	
Nassau, Fl	N-221	6/22/95	"	"	30	"	
Nassau, Fl	N-221	9/7/95	"	"	30	"	
Nassau, Fl	N-221	11/8/95	"	"	29	"	
Nassau, Fl	N-221	12/6/95	"	"	31	"	
Nassau, Fl	N-221	3/13/96	"	"	29	"	
Nassau, Fl	N-221	6/12/96	"	"	29	"	
Nassau, Fl	N-221	9/18/96	"	"	31	"	
Nassau, Fl	N-221	12/11/96	"	"	32	"	
Nassau, Fl	N-221	6/18/97	"	"	28	"	
Nassau, Fl	N-222	6/30/00	30D 47M 00S	81D 57M 10S	1,775	1956	
Nassau, Fl	N-228	12/6/95	30D 38M 09S	81D 30M 08S	1,670	320	
Nassau, Fl	N-228	3/13/96	"	"	970	"	
Nassau, Fl	N-228	6/12/96	"	"	1,560	"	
Nassau, Fl	N-228	6/18/96	"	"	1,220	"	
Nassau, Fl	N-234	3/12/96	30D 41M 05S	81D 27M 23S	124	953	
Nassau, Fl	N-234	3/13/96	"	"	131	"	
Nassau, Fl	N-235	7/15/96	30D 40M 01S	81D 28M 03S	153	1007	
Nassau, Fl	N-235	7/16/96	"	"	232	"	
Nassau, Fl	N-236	9/21/00	30D 35M 43S	81D 49M 48 S	25	2023	Fresh deep well
Nassau, Fl	N-237	3/18/97	30D 24M 09S	81D 55M 24S	23	500	
Nassau, Fl	N-237	5/7/98	"	"	20	"	
Camden, GA	D-061	9/3/99	30D 44M 01S	81D 32M 37S	150		Upper Floridan aquifer
Camden, GA	D-049	9/3/99	30D 44M 13S	81D 33M 25S	31		Gilman/Durango-GA
Camden, GA	D-048	9/3/99	30D 44M 01S	81D 32M 35S	48		Paper Co.

Appendix 1

Chloride Concentration for Selected Wells in Duval, Nassau, and Camden Counties

(Wells are completed in the Upper Floridan aquifer unless otherwise stated)

County/ST	USGS Well No.	Date	Latitude	Longitude	Chloride Concent. (mg/l)	Total Depth (feet)	Comments
Camden, GA	D-006	9/3/99	30D 44M 26S	81D 32M 34S	33		St. Marys GA
Camden	D-073	Dec-99	30D 44M 06S	81D 33M 05S	35	750	St. Marys Test Well
Camden	D-073	Dec-99	30D 44M 06S	81D 33M 05S	32	1,000	drilled for GDNR in
Camden	D-073	Dec-99	30D 44M 06S	81D 33M 05S	40	1,220	downtown St.Marys
Camden	D-073	Dec-99	30D 44M 06S	81D 33M 05S	33	1,344	on Gallop Rd. Well is
Camden	D-073	Dec-99	30D 44M 06S	81D 33M 05S	31	1500	completed to Lower Floridan aquifer at 1,189 feet

Appendix 2
Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Well No.	Date	Latitude	Longitude	Chloride Conc. in mg/l	Depth or Interval (in feet)	Aquifer Designation (if known)
33H113	1975	31D 09M 55S	81D 31M 17S	125	550-1076	Upper and Lower
33H113	1980	31D 09M 55S	81D 31M 17S	100	550-1076	Floridan Aquifer
33H113	1985	31D 09M 55S	81D 31M 17S	120	550-1076	
33H113	1990	31D 09M 55S	81D 31M 17S	160	550-1076	
33H113	1991	31D 09M 55S	81D 31M 17S	180	550-1076	
33H113	1992	31D 09M 55S	81D 31M 17S	200	550-1076	
33H113	1993	31D 09M 55S	81D 31M 17S	220	550-1076	
33H113	1994	31D 09M 55S	81D 31M 17S	360	550-1076	
33H127	Jun-69	31D 10M 07S	81D 30M 17S	250	823-925	Lower Water Bearing
33H127	Jun-70	31D 10M 07S	81D 30M 17S	300	823-925	Zone of the Upper
33H127	Jun-71	31D 10M 07S	81D 30M 17S	250	823-925	Floridan Aquifer
33H127	Jun-72	31D 10M 07S	81D 30M 17S	300	823-925	
33H127	Jun-73	31D 10M 07S	81D 30M 17S	300	823-925	
33H127	Jun-74	31D 10M 07S	81D 30M 17S	300	823-925	
33H127	Jun-75	31D 10M 07S	81D 30M 17S	325	823-925	
33H127	Jun-76	31D 10M 07S	81D 30M 17S	350	823-925	
33H127	Jun-77	31D 10M 07S	81D 30M 17S	400	823-925	
33H127	Jun-78	31D 10M 07S	81D 30M 17S	450	823-925	
33H127	Jun-79	31D 10M 07S	81D 30M 17S	425	823-925	
33H127	Jun-80	31D 10M 07S	81D 30M 17S	450	823-925	
33H127	Jun-81	31D 10M 07S	81D 30M 17S	450	823-925	
33H127	Jun-82	31D 10M 07S	81D 30M 17S	400	823-925	
33H127	Jun-83	31D 10M 07S	81D 30M 17S	550	823-925	
33H127	Jun-84	31D 10M 07S	81D 30M 17S	600	823-925	
33H127	Jun-85	31D 10M 07S	81D 30M 17S	550	823-925	
33H127	Jun-86	31D 10M 07S	81D 30M 17S	600	823-925	
33H127	Jun-87	31D 10M 07S	81D 30M 17S	550	823-925	
33H127	Jun-88	31D 10M 07S	81D 30M 17S	600	823-925	
33H127	Jun-89	31D 10M 07S	81D 30M 17S	650	823-925	
33H127	Jun-90	31D 10M 07S	81D 30M 17S	600	823-925	
33H127	Jun-91	31D 10M 07S	81D 30M 17S	700	823-925	
33H127	Jun-92	31D 10M 07S	81D 30M 17S	650	823-925	
33H127	Jun-93	31D 10M 07S	81D 30M 17S	680	823-925	
33H127	Jun-94	31D 10M 07S	81D 30M 17S	750	823-925	
33H127	Jun-95	31D 10M 07S	81D 30M 17S	800	823-925	
33H127	Jun-96	31D 10M 07S	81D 30M 17S	850	823-925	
33H127	Jun-97	31D 10M 07S	81D 30M 17S	880	823-925	
33H127	Jun-98	31D 10M 07S	81D 30M 17S	825	823-925	

Appendix 2
Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.
All data from USGS database/USGS Open File Reports

Well No.	Date	Latitude	Longitude	Chloride Conc. in mg/l	Depth or Interval (in feet)	Aquifer Designation (if known)
33H130	1961	31D 10M 21S	81D 30M 31S	<50	530-700	Upper Water Bearing
33H130	1965	31D 10M 21S	81D 30M 31S	200	530-700	Zone of the Upper
33H130	1970	31D 10M 21S	81D 30M 31S	500	530-700	Floridan Aquifer
33H130	1975	31D 10M 21S	81D 30M 31S	750	530-700	
33H130	1980	31D 10M 21S	81D 30M 31S	1300	530-700	
33H130	1985	31D 10M 21S	81D 30M 31S	1600	530-700	
33H130	1990	31D 10M 21S	81D 30M 31S	2100	530-700	
33H130	1992	31D 10M 21S	81D 30M 31S	2400	530-700	
33H130	1994	31D 10M 21S	81D 30M 31S	2500	530-700	
33H133	Sep-69	31D 10M 07S	81D 30M 17S	30	520-790	Upper Water Bearing
33H133	Jun-70	31D 10M 07S	81D 30M 17S	100	520-790	Zone of the Upper
33H133	Jun-71	31D 10M 07S	81D 30M 17S	175	520-790	Floridan Aquifer
33H133	Jun-72	31D 10M 07S	81D 30M 17S	225	520-790	
33H133	Jun-73	31D 10M 07S	81D 30M 17S	300	520-790	
33H133	Jun-74	31D 10M 07S	81D 30M 17S	275	520-790	
33H133	Jun-75	31D 10M 07S	81D 30M 17S	350	520-790	
33H133	Jun-76	31D 10M 07S	81D 30M 17S	450	520-790	
33H133	Jun-77	31D 10M 07S	81D 30M 17S	500	520-790	
33H133	Jun-78	31D 10M 07S	81D 30M 17S	550	520-790	
33H133	Jun-79	31D 10M 07S	81D 30M 17S	625	520-790	
33H133	Jun-80	31D 10M 07S	81D 30M 17S	900	520-790	
33H133	Jun-81	31D 10M 07S	81D 30M 17S	1075	520-790	
33H133	Jun-82	31D 10M 07S	81D 30M 17S	1050	520-790	
33H133	Jun-83	31D 10M 07S	81D 30M 17S	1250	520-790	
33H133	Jun-84	31D 10M 07S	81D 30M 17S	1300	520-790	
33H133	Jun-85	31D 10M 07S	81D 30M 17S	1300	520-790	
33H133	Jun-86	31D 10M 07S	81D 30M 17S	1400	520-790	
33H133	Jun-87	31D 10M 07S	81D 30M 17S	1500	520-790	
33H133	Jun-88	31D 10M 07S	81D 30M 17S	1400	520-790	
33H133	Jun-89	31D 10M 07S	81D 30M 17S	1550	520-790	
33H133	Jun-90	31D 10M 07S	81D 30M 17S	1600	520-790	
33H133	Jun-91	31D 10M 07S	81D 30M 17S	1750	520-790	
33H133	Jun-92	31D 10M 07S	81D 30M 17S	1750	520-790	
33H133	Jun-93	31D 10M 07S	81D 30M 17S	1800	520-790	
33H133	Jun-94	31D 10M 07S	81D 30M 17S	1700	520-790	
33H133	Jun-95	31D 10M 07S	81D 30M 17S	1850	520-790	
33H133	Jun-96	31D 10M 07S	81D 30M 17S	1800	520-790	
33H133	Jun-97	31D 10M 07S	81D 30M 17S	1800	520-790	
33H133	Jun-98	31D 10M 07S	81D 30M 17S	1950	520-790	

Appendix 2

Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Well No.	Date	Latitude	Longitude	Chloride Conc. in mg/l	Depth or Interval (in feet)	Aquifer Designation (if known)
33H154	1970	31D 10M 22S	81D 30M 29S	250	817-989	Lower Water Bearing
33H154	1974	31D 10M 22S	81D 30M 29S	400	817-989	Zone of the Upper
33H154	1978	31D 10M 22S	81D 30M 29S	300	817-989	Floridan Aquifer
33H154	1980	31D 10M 22S	81D 30M 29S	380	817-989	
33H154	1982	31D 10M 22S	81D 30M 29S	400	817-989	
33H154	1984	31D 10M 22S	81D 30M 29S	400	817-989	
33H154	1986	31D 10M 22S	81D 30M 29S	480	817-989	
33H154	1988	31D 10M 22S	81D 30M 29S	550	817-989	
33H154	1990	31D 10M 22S	81D 30M 29S	650	817-989	
33H154	1992	31D 10M 22S	81D 30M 29S	900	817-989	
33H154	1993	31D 10M 22S	81D 30M 29S	1000	817-989	
33H154	1994	31D 10M 22S	81D 30M 29S	1100	817-989	
34H112	1960	31D 08M 12S	81D 29M 41S	200	528-747	Upper Water Bearing
34H112	1964	31D 08M 12S	81D 29M 41S	500	528-747	Zone of the Upper
34H112	1968	31D 08M 12S	81D 29M 41S	900	528-747	Floridan Aquifer
34H112	1970	31D 08M 12S	81D 29M 41S	1200	528-747	
34H112	1974	31D 08M 12S	81D 29M 41S	1400	528-747	
34H112	1978	31D 08M 12S	81D 29M 41S	1800	528-747	
34H112	1980	31D 08M 12S	81D 29M 41S	2000	528-747	
34H112	1984	31D 08M 12S	81D 29M 41S	2200	528-747	
34H112	1988	31D 08M 12S	81D 29M 41S	2000	528-747	
34H112	1990	31D 08M 12S	81D 29M 41S	2000	528-747	
34H112	1991	31D 08M 12S	81D 29M 41S	2000	528-747	
34H112	1992	31D 08M 12S	81D 29M 41S	2000	528-747	
34H112	1993	31D 08M 12S	81D 29M 41S	2000	528-747	
34H112	1994	31D 08M 12S	81D 29M 41S	2000	528-747	
34H117	1967	31D 08M 52	81D 29M 54S	20	540-780	Upper Water Bearing
34H117	1970	31D 08M 52	81D 29M 54S	20	540-780	Zone of the Upper
34H117	1974	31D 08M 52	81D 29M 54S	20	540-780	Floridan Aquifer
34H117	1980	31D 08M 52	81D 29M 54S	20	540-780	
34H117	1982	31D 08M 52	81D 29M 54S	80	540-780	
34H117	1984	31D 08M 52	81D 29M 54S	220	540-780	
34H117	1986	31D 08M 52	81D 29M 54S	450	540-780	
34H117	1988	31D 08M 52	81D 29M 54S	750	540-780	
34H117	1990	31D 08M 52	81D 29M 54S	650	540-780	
34H117	1992	31D 08M 52	81D 29M 54S	600	540-780	
34H117	1994	31D 08M 52	81D 29M 54S	620	540-780	

Appendix 2
Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Well No.	Date	Latitude	Longitude	Chloride Conc. in mg/l	Depth or Interval (in feet)	Aquifer Designation (if known)
34H132	Jun-69	31D 10M 20S	81D 29M 52S	275	540-566	Upper Water Bearing
34H132	Jun-70	31D 10M 20S	81D 29M 52S	375	540-566	Zone of the Upper
34H132	Jun-71	31D 10M 20S	81D 29M 52S	425	540-566	Floridan Aquifer
34H132	Jun-72	31D 10M 20S	81D 29M 52S	500	540-566	
34H132	Jun-73	31D 10M 20S	81D 29M 52S	500	540-566	
34H132	Jun-74	31D 10M 20S	81D 29M 52S	900	540-566	Upper Water Bearing
34H132	Jun-75	31D 10M 20S	81D 29M 52S	1100	540-566	Zone of the Upper
34H132	Jun-76	31D 10M 20S	81D 29M 52S	1200	540-566	Floridan Aquifer
34H132	Jun-77	31D 10M 20S	81D 29M 52S	1375	540-566	
34H132	Jun-78	31D 10M 20S	81D 29M 52S	1525	540-566	
34H132	Jun-79	31D 10M 20S	81D 29M 52S	1675	540-566	
34H132	Jun-80	31D 10M 20S	81D 29M 52S	1700	540-566	
34H132	Jun-81	31D 10M 20S	81D 29M 52S	1800	540-566	
34H132	Jun-82	31D 10M 20S	81D 29M 52S	2000	540-566	
34H132	Jun-83	31D 10M 20S	81D 29M 52S	2200	540-566	
34H132	Jun-84	31D 10M 20S	81D 29M 52S	2000	540-566	
34H132	Jun-85	31D 10M 20S	81D 29M 52S	1850	540-566	
34H132	Jun-86	31D 10M 20S	81D 29M 52S	1600	540-566	
34H132	Jun-87	31D 10M 20S	81D 29M 52S	1500	540-566	
34H132	Jun-88	31D 10M 20S	81D 29M 52S	1450	540-566	
34H132	Jun-89	31D 10M 20S	81D 29M 52S	1450	540-566	
34H132	Jun-90	31D 10M 20S	81D 29M 52S	1500	540-566	
34H132	Jun-91	31D 10M 20S	81D 29M 52S	1500	540-566	
34H391	Jun-68	31D 08M 18S	81D 29M42S	1550	1070-1159	Brackish zone
34H391	Jun-69	31D 08M 18S	81D 29M42S	2400	1070-1159	Lower Floridan aquifer
34H391	Jun-70	31D 08M 18S	81D 29M42S	2350	1070-1159	
34H391	Jun-71	31D 08M 18S	81D 29M42S	2250	1070-1159	
34H391	Jun-72	31D 08M 18S	81D 29M42S	2300	1070-1159	
34H391	Jun-73	31D 08M 18S	81D 29M42S	2200	1070-1159	
34H391	Jun-74	31D 08M 18S	81D 29M42S	2600	1070-1159	
34H391	Jun-75	31D 08M 18S	81D 29M42S	2300	1070-1159	
34H391	Jun-76	31D 08M 18S	81D 29M42S	2550	1070-1159	
34H391	Jun-77	31D 08M 18S	81D 29M42S	2400	1070-1159	
34H391	Jun-78	31D 08M 18S	81D 29M42S	2400	1070-1159	
34H391	Jun-79	31D 08M 18S	81D 29M42S	2550	1070-1159	
34H391	Jun-80	31D 08M 18S	81D 29M42S	2450	1070-1159	
34H391	Jun-81	31D 08M 18S	81D 29M42S	2600	1070-1159	
34H391	Jun-82	31D 08M 18S	81D 29M42S	2250	1070-1159	
34H391	Jun-83	31D 08M 18S	81D 29M42S	2150	1070-1159	

Appendix 2
Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Well No.	Date	Latitude	Longitude	Chloride Conc. in mg/l	Depth or Interval (in feet)	Aquifer Designation (if known)
34H391	Jun-84	31D 08M 18S	81D 29M42S	2150	1070-1159	Brackish zone
34H391	Jun-85	31D 08M 18S	81D 29M42S	2200	1070-1159	Lower Floridan aquifer
34H391	Jun-86	31D 08M 18S	81D 29M42S	2150	1070-1159	
34H391	Jun-87	31D 08M 18S	81D 29M42S	2450	1070-1159	
34H391	Jun-88	31D 08M 18S	81D 29M42S	2500	1070-1159	
34H391	Jun-89	31D 08M 18S	81D 29M42S	2550	1070-1159	
34H391	Jun-90	31D 08M 18S	81D 29M42S	2800	1070-1159	
34H391	Jun-91	31D 08M 18S	81D 29M42S	2800	1070-1159	
34H391	Jun-92	31D 08M 18S	81D 29M42S	2400	1070-1159	
34H391	Jun-93	31D 08M 18S	81D 29M42S	2000	1070-1159	
34H391	Jun-94	31D 08M 18S	81D 29M42S	2100	1070-1159	
34H391	Jun-95	31D 08M 18S	81D 29M42S	2400	1070-1159	
34H391	Jun-96	31D 08M 18S	81D 29M42S	2800	1070-1159	
34H391	Jun-97	31D 08M 18S	81D 29M42S	2600	1070-1159	
34H391	Jun-98	31D 08M 18S	81D 29M42S	2700	1070-1159	
34H393	Jun-69	31D 08M 25S	81D 29M 42S	2400	615-723	Upper Water Bearing
34H393	Jun-70	31D 08M 25S	81D 29M 42S	2850	615-723	Zone of the Upper
34H393	Jun-71	31D 08M 25S	81D 29M 42S	1950	615-723	Floridan Aquifer
34H393	Jun-72	31D 08M 25S	81D 29M 42S	2150	615-723	
34H393	Jun-73	31D 08M 25S	81D 29M 42S	2250	615-723	
34H393	Jun-74	31D 08M 25S	81D 29M 42S	2700	615-723	
34H393	Jun-75	31D 08M 25S	81D 29M 42S	2350	615-723	
34H393	Jun-76	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-77	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-78	31D 08M 25S	81D 29M 42S	2450	615-723	
34H393	Jun-79	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-80	31D 08M 25S	81D 29M 42S	2550	615-723	
34H393	Jun-81	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-82	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-83	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-84	31D 08M 25S	81D 29M 42S	2300	615-723	
34H393	Jun-85	31D 08M 25S	81D 29M 42S	2250	615-723	
34H393	Jun-86	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-87	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-88	31D 08M 25S	81D 29M 42S	2350	615-723	
34H393	Jun-89	31D 08M 25S	81D 29M 42S	2500	615-723	
34H393	Jun-90	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-91	31D 08M 25S	81D 29M 42S	2400	615-723	
34H393	Jun-92	31D 08M 25S	81D 29M 42S	2450	615-723	

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Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Well No.	Date	Latitude	Longitude	Chloride Conc. in mg/l	Depth or Interval (in feet)	Aquifer Designation (if known)
34H393	Jun-93	31D 08M 25S	81D 29M 42S	2450	615-723	Upper Water Bearing
34H393	Jun-94	31D 08M 25S	81D 29M 42S	2350	615-723	Zone of the Upper
34H393	Jun-95	31D 08M 25S	81D 29M 42S	2300	615-723	Floridan Aquifer
34H393	Jun-96	31D 08M 25S	81D 29M 42S	2300	615-723	
34H393	Jun-97	31D 08M 25S	81D 29M 42S	2300	615-723	
34H393	Jun-98	31D 08M 25S	81D 29M 42S	2300	615-723	
34H399	Jun-69	31D 07M 50S	81D 29M 20S	4000	1075-1218	Brackish Zone of the
34H399	Jun-70	31D 07M 50S	81D 29M 20S	4600	1075-1218	Lower Floridan
34H399	Jun-71	31D 07M 50S	81D 29M 20S	3950	1075-1218	Aquifer
34H399	Jun-72	31D 07M 50S	81D 29M 20S	4700	1075-1218	
34H399	Jun-75	31D 07M 50S	81D 29M 20S	5250	1075-1218	
34H399	Jun-76	31D 07M 50S	81D 29M 20S	5450	1075-1218	
34H399	Jun-77	31D 07M 50S	81D 29M 20S	5700	1075-1218	
34H399	Jun-78	31D 07M 50S	81D 29M 20S	6200	1075-1218	
34H399	Jun-79	31D 07M 50S	81D 29M 20S	6400	1075-1218	
34H399	Jun-80	31D 07M 50S	81D 29M 20S	6550	1075-1218	
34H399	Jun-81	31D 07M 50S	81D 29M 20S	6600	1075-1218	
34H399	Jun-82	31D 07M 50S	81D 29M 20S	6800	1075-1218	
34H399	Jun-83	31D 07M 50S	81D 29M 20S	6500	1075-1218	
34H399	Jun-84	31D 07M 50S	81D 29M 20S	6600	1075-1218	
34H399	Jun-85	31D 07M 50S	81D 29M 20S	6400	1075-1218	
34H399	Jun-86	31D 07M 50S	81D 29M 20S	6400	1075-1218	
34H399	Jun-87	31D 07M 50S	81D 29M 20S	6700	1075-1218	
34H399	Jun-88	31D 07M 50S	81D 29M 20S	7100	1075-1218	
34H399	Jun-89	31D 07M 50S	81D 29M 20S	7500	1075-1218	
34H399	Jun-90	31D 07M 50S	81D 29M 20S	7800	1075-1218	
34H399	Jun-91	31D 07M 50S	81D 29M 20S	7500	1075-1218	
34H399	Jun-92	31D 07M 50S	81D 29M 20S	7800	1075-1218	
34H399	Jun-93	31D 07M 50S	81D 29M 20S	7500	1075-1218	
34H399	Jun-94	31D 07M 50S	81D 29M 20S	6900	1075-1218	
34H399	Jun-95	31D 07M 50S	81D 29M 20S	6900	1075-1218	
34H399	Jun-96	31D 07M 50S	81D 29M 20S	7100	1075-1218	
34H399	Jun-97	31D 07M 50S	81D 29M 20S	7000	1075-1218	
34H399	Jun-98	31D 07M 50S	81D 29M 20S	7200	1075-1218	
34H403	Dec-70	31D 08M 22S	81D 29M 42S	1000	788-892	Lower Water Bearing
34H403	Jun-72	31D 08M 22S	81D 29M 42S	1600	788-892	Zone of the Upper
34H403	Jun-73	31D 08M 22S	81D 29M 42S	2100	788-892	Floridan Aquifer
34H403	Jun-74	31D 08M 22S	81D 29M 42S	1650	788-892	

Appendix 2
Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Well No.	Date	Latitude	Longitude	Chloride Conc. in mg/l	Depth or Interval (in feet)	Aquifer Designation (if known)
34H403	Jun-75	31D 08M 22S	81D 29M 42S	2050	788-892	Lower Water Bearing
34H403	Jun-76	31D 08M 22S	81D 29M 42S	1650	788-892	Zone of the Upper
34H403	Jun-77	31D 08M 22S	81D 29M 42S	1700	788-892	Floridan Aquifer
34H403	Jun-78	31D 08M 22S	81D 29M 42S	1750	788-892	
34H403	Jun-79	31D 08M 22S	81D 29M 42S	1550	788-892	
34H403	Jun-80	31D 08M 22S	81D 29M 42S	1650	788-892	
34H403	Jun-81	31D 08M 22S	81D 29M 42S	1550	788-892	
34H403	Jun-82	31D 08M 22S	81D 29M 42S	1500	788-892	
34H403	Jun-83	31D 08M 22S	81D 29M 42S	1450	788-892	
34H403	Jun-84	31D 08M 22S	81D 29M 42S	1500	788-892	
34H403	Jun-85	31D 08M 22S	81D 29M 42S	1500	788-892	
34H403	Jun-86	31D 08M 22S	81D 29M 42S	1500	788-892	
34H403	Jun-87	31D 08M 22S	81D 29M 42S	1450	788-892	
34H403	Jun-88	31D 08M 22S	81D 29M 42S	1450	788-892	
34H403	Jun-89	31D 08M 22S	81D 29M 42S	1450	788-892	
34H403	Jun-90	31D 08M 22S	81D 29M 42S	1500	788-892	
34H403	Jun-91	31D 08M 22S	81D 29M 42S	1450	788-892	
34H403	Jun-92	31D 08M 22S	81D 29M 42S	1600	788-892	
34H403	Jun-93	31D 08M 22S	81D 29M 42S	1550	788-892	
34H403	Jun-94	31D 08M 22S	81D 29M 42S	1400	788-892	
34H403	Jun-95	31D 08M 22S	81D 29M 42S	1400	788-892	
34H403	Jun-96	31D 08M 22S	81D 29M 42S	1500	788-892	
34H403	Jun-97	31D 08M 22S	81D 29M 42S	1500	788-892	
34H403	Jun-98	31D 08M 22S	81D 29M 42S	1475	788-892	
34H427	Jun-71	31D 07M 50S	81D 29M 20S	150	500-640	Upper Water Bearing
34H427	Jun-72	31D 07M 50S	81D 29M 20S	250	500-640	Zone of the Upper
34H427	Jun-73	31D 07M 50S	81D 29M 20S	300	500-640	Floridan Aquifer
34H427	Jun-75	31D 07M 50S	81D 29M 20S	1200	500-640	
34H427	Jun-76	31D 07M 50S	81D 29M 20S	1300	500-640	
34H427	Jun-77	31D 07M 50S	81D 29M 20S	1400	500-640	
34H427	Jun-78	31D 07M 50S	81D 29M 20S	1600	500-640	
34H427	Jun-79	31D 07M 50S	81D 29M 20S	1775	500-640	
34H427	Jun-80	31D 07M 50S	81D 29M 20S	1850	500-640	
34H427	Jun-81	31D 07M 50S	81D 29M 20S	1800	500-640	
34H427	Jun-82	31D 07M 50S	81D 29M 20S	1800	500-640	
34H427	Jun-83	31D 07M 50S	81D 29M 20S	1600	500-640	
34H427	Jun-84	31D 07M 50S	81D 29M 20S	1500	500-640	
34H427	Jun-85	31D 07M 50S	81D 29M 20S	1200	500-640	
34H427	Jun-86	31D 07M 50S	81D 29M 20S	1150	500-640	

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Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Well No.	Date	Latitude	Longitude	Chloride Conc. in mg/l	Depth or Interval (in feet)	Aquifer Designation (if known)
34H427	Jun-87	31D 07M 50S	81D 29M 20S	1000	500-640	Upper Water Bearing
34H427	Jun-88	31D 07M 50S	81D 29M 20S	950	500-640	Zone of the Upper
34H427	Jun-89	31D 07M 50S	81D 29M 20S	1150	500-640	Floridan Aquifer
34H427	Jun-90	31D 07M 50S	81D 29M 20S	1000	500-640	
34H427	Jun-91	31D 07M 50S	81D 29M 20S	1100	500-640	
34H427	Jun-92	31D 07M 50S	81D 29M 20S	1250	500-640	
34H427	Jun-93	31D 07M 50S	81D 29M 20S	1200	500-640	
34H427	Jun-94	31D 07M 50S	81D 29M 20S	1250	500-640	
34H427	Jun-95	31D 07M 50S	81D 29M 20S	1350	500-640	
34H427	Jun-96	31D 07M 50S	81D 29M 20S	1425	500-640	
34H427	Jun-97	31D 07M 50S	81D 29M 20S	1400	500-640	
34H427	Jun-98	31D 07M 50S	81D 29M 20S	1300	500-640	
34H469	1966	31D 10M 20S	81D 29M 52S	120	540-566	Upper Water Bearing
34H469	1967	31D 10M 20S	81D 29M 52S	200	540-566	Zone of the Upper
34H469	1968	31D 10M 20S	81D 29M 52S	250	540-566	Floridan Aquifer
34H469	1969	31D 10M 20S	81D 29M 52S	250	540-566	
34H469	1970	31D 10M 20S	81D 29M 52S	300	540-566	
34H469	1971	31D 10M 20S	81D 29M 52S	300	540-566	
34H469	1972	31D 10M 20S	81D 29M 52S	400	540-566	
34H469	1973	31D 10M 20S	81D 29M 52S	480	540-566	
34H469	1974	31D 10M 20S	81D 29M 52S	1100	540-566	
34H469	1975	31D 10M 20S	81D 29M 52S	850	540-566	
34H469	1980	31D 10M 20S	81D 29M 52S	1600	540-566	
34H469	1981	31D 10M 20S	81D 29M 52S	1700	540-566	
34H469	1982	31D 10M 20S	81D 29M 52S	2050	540-566	
34H469	1983	31D 10M 20S	81D 29M 52S	2200	540-566	
34H469	1984	31D 10M 20S	81D 29M 52S	2050	540-566	
34H469	1985	31D 10M 20S	81D 29M 52S	1900	540-566	
34H469	1986	31D 10M 20S	81D 29M 52S	1700	540-566	
34H469	1987	31D 10M 20S	81D 29M 52S	1500	540-566	
34H469	1988	31D 10M 20S	81D 29M 52S	1400	540-566	
34H469	1989	31D 10M 20S	81D 29M 52S	1200	540-566	
34H469	1990	31D 10M 20S	81D 29M 52S	1500	540-566	
34H469	1991	31D 10M 20S	81D 29M 52S	1500	540-566	
34H469	1992	31D 10M 20S	81D 29M 52S	1200	540-566	
34H469	1993	31D 10M 20S	81D 29M 52S	1100	540-566	
34H469	1994	31D 10M 20S	81D 29M 52S	1100	540-566	
34H469	1995	31D 10M 20S	81D 29M 52S	1200	540-566	
34H469	1996	31D 10M 20S	81D 29M 52S	1300	540-566	
34H469	1997	31D 10M 20S	81D 29M 52S	1350	540-566	
34H469	1998	31D 10M 20S	81D 29M 52S	1280	540-566	

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Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Chloride Depth Profile: Well 34H495 (Well 197 of this study): Completed 10/10/00
Lower Floridan/Fernandina Permeable Zone Test Well
Georgia Ports Authority Well in downtown Brunswick
Glynn County: Latitude = 31D 08M 35S; Longitude = 81D 29M 44S

Depth in Feet	Chloride (mg/L)	Specific Cond. (us/cm)	Hydrogeol. Unit
658-668	1,500	5,882	Upper Floridan Aquifer
722-732	1,700	6,666	
763-775	1,700	6,635	
817-827	1,700	6,765	
880-890	1,800	6,863	
912-922	1,700	6,730	
943-953	1,700	6,730	
974-984	1,800	6,863	
1,006-1,016	1,700	6,604	
1,037-1,047	1,500	6,000	
1,069-1,079	1,400	5,392	
1,101-1,111	2,800	9,528	
1,154-1,164	2,900	9,615	
1,196-1,206	2,200	7,692	Lower Floridan Aquifer
1,227-1,237	2,400	8,823	
1,301-1,313	2,300	8,018	
1,393-1,405	2,000	7,103	
1,418-1,426	36	425	
1,477-1,487	13	419	
1,547-1,557	13	418	
1,647-1,657	12	611	
1,707-1,717	100	1,228	
1,805-1,815	170	1,754	
1,870-1,880	310	2,482	
1,930-1,940	340	2,632	
2,050-2,060	210	1,908	
2,089-2,092	1,100	6,060	Fernandina Permeable Zone
2,121-2,123	1,200	6,300	
2,143-2,153	1,400	7,020	
2,173-2,186	2,000	9,060	
2,207-2,217	17,000	45,560	
2,239-2,249	17,000	46,980	
2,271-2,281	17,000	47,010	
2,333-2,343	17,000	47,210	

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Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.

All data from USGS database/USGS Open File Reports

Chloride Depth Profile: Well 34H495 (Well 197 of this study): Completed 10/10/00
Lower Floridan/Fernandina Permeable Zone Test Well
Georgia Ports Authority Well in downtown Brunswick
Glynn County: Latitude = 31D 08M 35S; Longitude = 81D 29M 44S

Depth in Feet	Chloride (mg/L)	Specific Cond. (us/cm)	Hydrogeol. Unit
2,435-2,445	17,000	48,540	
2,501-2,511	17,000	48,680	
2,611-2,621	17,000	47,580	
2,661-2,671	17,000	47,860	
2,681-2,699	27,000	68,370	
2,709-2,720	27,000	67,440	

Chloride-Depth Profile: Well 33H188: Colonel's Island: Glynn County; Total Depth = 2,720
Circa 1978 Latitude = 31D 08M 09S Longitude = 81D 32M 35S

Depth in feet	Chloride (mg/L)
700	20
800	120
900	20
1000	180
1100	150
1200	200
1300	500
1400	200
1500	120
1600	50
1700	500
1800	380
1900	220
2000	380
2150	220
2000	380
2100	220
2150	2,800
2200	4,500
2300	9,000
2350	16,500
2400	16,800
2500	16,500
2600	16,500
2720	16,800

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Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.
All data from USGS database/USGS Open File Reports

Other Wells in Glynn County: Near-Background Chloride Concentrations
Most wells are likely completed in the Upper Floridan aquifer

Well No.	Latitude	Longitude	Period	Maximum Chloride (in mg/l)
33G005	Not Available	Not Available	11/84-5/90	41
33G006	Not Available	Not Available	11/84-5/90	41
33G008	31D 07M 01S	81D 32M 02S	3/67-10/93	25
33G026	Not Available	Not Available	Nov-84	28
33H103	31D 11M 04S	81D 30M 30S	11/84-5/90	23
33H106	31D 10M 46S	81D 31M 17S	3/81-3/83	22
33H038	31D 10M 03S	81D 41M 49S	11/84-5/90	21
33H101	31D 11M 17S	81D 30M 28S	2/76-5/89	28
33H102	31D 11M 11S	81D 01M 19S	12/75-4/93	30
33H103	31D 10M 04S	81D 30M 30S	8/75-10/93	28
33H104	Not Available	Not Available	10/75-10/93	30
33H105	Not Available	Not Available	10/75-10/93	28
33H111	31D 10M 07S	81D 31M 17S	Nov-75	20
33H112	31D 10M 07S	81D 31M 13S	Nov-75	42
33H119	Not Available	Not Available	7/66-3/83	27
33H135	31D 11M 00S	81D 10M 00S	Jun-66	24
33H139	31D 07M 38S	81D 07M 38S	11/84-5/90	19
33H141	31D 10M 44S	81D 32M 31S	11/66-10/88	24
33H164	Not Available	Not Available	Nov-84	18
33H173	31D 30M 09S	81D 30M 37S	8/81-3/83	28
33H175	31D 12M 55S	81D 31M 23S	4/75-11/84	36
33H178	31D 10M 36S	81D 31M 17S	4/81-10/93	23
33H179	Not Available	Not Available	11/84-5/90	21
33H180	Not Available	Not Available	4/75-3/83	24
33H183	Not Available	Not Available	4/81-10/93	25
33H190	Not Available	Not Available	5/90-10/93	23
33H193	Not Available	Not Available	May-90	19
33H207	31D 09M 25S	81D 31M 22S	2/83-10/93	26
33H209	31D 09M 12S	81D 31M 53S	Nov-84	19
33H210	Not Available	Not Available	Mar-83	18
33H211	31D 10M 27S	81D 31M 13S	4/85-10/93	21

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Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.
All data from USGS database/USGS Open File Reports

Other Wells in Glynn County: Near-Background Chloride Concentrations
Most wells are likely completed in the Upper Floridan aquifer

Well No.	Latitude	Longitude	Period	Maximum Chloride (in mg/l)
33H220	31D 07M 39S	81D 32M 31S	11/85-4/86	31
34G004	31D 03M 31S	81D 26M 47S	Nov-84	21
34G016	31D 06M 07S	81D 24M 15S	Oct-62	16
34G017	31D 06M 58S	81D 25M 01S	9/74-10/88	24
34G041	Not Available	Not Available	May-90	26
34H012	Not Available	Not Available	4/93-10/93	28
34H025	31D 13M 26S	81D 28M 26S	3/81-10/88	30
34H062	31D 10M 05S	81D 28M 27S	4/81-3/83	40
34H085	31D 09M 06S	81D 28M 24S	6/66-4/86	30
34H091	31D 07M 53S	81D 29M 01S	7/67-5/88	45
34H095	Not Available	Not Available	3/83-10/93	30
34H097	31D 07M 55S	81D 07M 55S	6/66-10/93	21
34H130	Not Available	Not Available	Apr-90	20
34H133	Not Available	Not Available	3/81-10/89	33
34H134	31D 10M 51S	81D 29M 55S	3/81-10/93	37
34H160	Not Available	Not Available	3/81-3/83	24
34H204	Not Available	Not Available	Nov-84	15
34H344	31D 09M 38S	81D 28M 53S	3/64-10/93	34
34H358	Not Available	Not Available	Nov-84	18
34H368	Not Available	Not Available	4/75-11/84	32
34H371	31D 08M 18S	81D 29M 36S	10/66-10/93	33
34H372	31D 08M 32S	81D 29M 21S	7/68-10/93	28
34H381	31D 09M 59S	81D 23M 25S	Nov-84	16
34H383	31D 11M 54S	81D 23M 00S	Nov-94	25
34H392	31D 10M 08S	81D 29M 10S	3/81-5/90	22
34H410	31D 12M 11S	81D 27M 46S	Nov-84	26
34H436	31D 09M 01S	81D 28M 44S	1/84-10/93	31
34H442	Not Available	Not Available	11/85-5/90	26
34H444	Not Available	Not Available	May-90	18
34H445	31D 09M 02S	81D 28M 43S	10/88-4/93	17
34H449	31D 10M 36S	81D 28M 57S	5/90-10/93	23
34H450	31D 09M 56S	81D 28M 31S	11/90-10/93	18

Appendix 2
Chloride Concentrations in Selected Floridan Aquifer Wells, Glynn Co., GA.
All data from USGS database/USGS Open File Reports

Well 33D073 (Well 198 of this study): St. Mary's Test Well
Drilled for GDNR drilled on Gallop Road in downtown St.Marys; completed 12/07/99
Latitude = 30D 44M 06S **Lower Floridan Aquifer Well**

Depth in Feet	Chloride (mg/L)	Specific Cond. (us/cm)	Hydrogeol. Unit
523-533		410	Upper Floridan Aquifer
613-623		727	
683-693		717	
745-757	34	717	
804-812		710	
869-879	35	710	Middle Semi Confining Unit
899-909	35	670	
969-969		684	
1,009-1,019	32	686	
1,039-1,048	34	660	
1,099-1,109	31	735	
1,129-1,139		696	
1,139-1,149	36	686	
1,189-1,199		689	Lower Floridan Aquifer
1,219-1,229	40	708	
1,269-1,279	34	673	
1,309-1,319	35	724	
1,344-1,354	33	705	
1,395-1,405	32	776	
1,425-1,435	33	769	
1,485-1,500	31	850	

Appendix 3

Additional Floridan Aquifer Well Locations Characterized by High Chloride Concentrations

1978-1988 (most are after 1995)

County/ST	Well No.	Date	Latitude	Longitude	Depth or Screened Interval (ft)	Chloride Concentration (mg/L)	Aquifer
Duval, Fl	D-94	1989	30D 19M 00S	81D 32M 28S	635	55	UFA
Duval, Fl	D-360	1990	30D 22M 43S	81D 30M 04S	665	270	UFA
Duval, Fl	D-1292	4/21/92	30D 11M 57S	81D 46M 52S	621	57	UFA
Duval, Fl	D-1298	8/12/96	30D 08M 40S	81D 35M 12S	704	99	UFA
Duval, Fl	D-913	7/15/98	30D 25M 57S	81D 25M 31S	556	380	UFA
Duval, Fl	D-262	1990	30D 26M 08S	81D 35M 49S	1237	50	UFA + some LFA
Duval, Fl	D-225	7/6/98	30D 17M 43S	81D 36M 23S	1277	230	UFA + some LFA
Duval, Fl	D-275	7/17/98	30D 17M 40S	81D 36M 10S	1234	200	UFA + some LFA
Duval, Fl	D-313	7/20/98	30D 19M 57S	81D 39M 25S	1150	130	UFA + some LFA
Duval, Fl	D-450	7/21/98	30D 16M 08S	81D 36M 28S	1297	87	UFA + some LFA
Duval, Fl	D-479	7/15/98	30D 20M 07S	81D 35M 22S	1350	140	UFA + some LFA
Duval, Fl	D-483	9/19/95	30D 16M 57S	81D 23M 33S	1200	144	UFA + some LFA
Duval, Fl	D-484	1990	30D 17M 04S	81D 23M 34S	1181	180	UFA + some LFA
Duval, Fl	D-1155	7/7/98	30D 16M 39S	81D 33M 08S	1170	120	UFA + some LFA
Duval, Fl	D-1220	7/19/96	30D 17M 58S	81D 30M 39S	1185	806	UFA + some LFA
Duval, Fl	D-3060	5/8/90	30D 20M 52S	81D 32M 32S	800	80	UFA + some LFA
Duval, Fl	D-2193	7/16/98	30D 17M 44S	81D 36M 33S	1304	140	UFA + some LFA
Nassau, Fl	N-30	4/5/78	30D 39M 21S	81D 27M 46S	750	109	UFA
Nassau, Fl	N-54	3/4/93	30D 37M 22S	81D 27M 14S	482	123	UFA
Nassau, Fl	N-228	6/18/96	30D 38M 09S	81D 30M 08S	1220	320	UFA
Nassau, Fl	N-68	10/19/92	30D 39M 58S	81D 28M 04S	1050	440	UFA + some LFA
Nassau, Fl	N-106	9/11/75	30D 38M 05S	81D 27M 39S	925	245	UFA + some LFA
Nassau, Fl	N-117	1979	30D 40M 01S	81D 28M 03S	1133	120	UFA + some LFA
Nassau, Fl	N-190	10/23/91	30D 38M 23S	81D 27M 33S	1020	616	UFA + some LFA
Nassau, Fl	N-234	3/13/96	30D 41M 05S	81D 27M 23S	953	131	UFA + some LFA
Nassau, Fl	N-234	7/15/96	30D 40M 01S	81D 28M 03S	1007	153	UFA + some LFA
Nassau, Fl	N-222	6/30/00	30D 47M 00S	81D 57M 10S	1912	1927	LFA
Glynn, GA	33H106	11/2/90	31D 10M 46S	81D 31M 17S	496-775	212	UFA
Glynn, GA	33H110	6/23/99	31D 10M 44S	81D 30M 46S	494-1050	455	UFA + some LFA
Glynn, GA	33H113	6/23/99	31D 09M 55S	81D 31M 17S	1076	337	UFA + some LFA
Glynn, GA	33H114	4/18/95	31D 10M 27S	81D 31M 06S	560-1006	179	UFA + some LFA
Glynn, GA	33H120	10/30/90	31D 10M 36S	81D 30M 26S	514-571	118	UFA
Glynn, GA	33H127	6/3/98	31D 10M 07S	81D 30M 17S	823-895	778	UFA
Glynn, GA	33H130	6/3/98	31D 10M 21S	81D 30M 31S	530-700	2590	UFA

UFA = Upper Floridan Aquifer; LFA = Lower Floridan Aquifer

Appendix 3

Additional Floridan Aquifer Well Locations Characterized by High Chloride Concentrations

1978-1988 (most are after 1995)

County/ST	Well No.	Date	Latitude	Longitude	Depth or Screened Interval (ft)	Chloride Concentration (mg/L)	Comments
Glynn, GA	3H133	12/12/98	31D 10M 07S	81D 30M 17S	520-790	1965	UFA
Glynn, GA	33H154	6/22/99	31D 10M 22S	81D 30M 29S	817-989	1850	UFA
Glynn, GA	33H189	4/18/95	31D 10M 14S	81D 31M 08S	540-900	802	UFA + some LFA
Glynn, GA	33H192	6/20/99	31D 34M 45S	81D 37M 04S		730	
Glynn, GA	33H206	6/23/99	31D 09M 25S	81D 31M 22S	1000-1100	335	LFA
Glynn, GA	33H212	6/3/98	31D 10M 08S	81D 30M 58S	870-1007	1230	LFA
Glynn, GA	33H214	4/13/95	31D 10M 20S	81D 30M 54S	895-920	2500	LFA
Glynn, GA	33H215	4/13/95	31D 10M 20S	81D 30M 54S	557-800	2450	UFA
Glynn, GA	33H216	4/13/95	31D 10M 18S	81D 30M 39S	1010-1030	2650	LFA
Glynn, GA	33H217	4/12/95	31D 10M 18S	81D 30M 39S	885-907	2650	LFA
Glynn, GA	33H218	4/12/95	31D 10M 18S	81D 30M 39S	557-800	2700	UFA
Glynn, GA	33H221	6/3/98	31D 10M 27S	81D 31M 04S	556-1006	1048	UFA + some LFA
Glynn, GA	33H222	6/23/98	31D 10M 38S	81D 30M 55S	546-1010	250	UFA + some LFA
Glynn, GA	33H250	5/13/91	31D 09M 14S	81D 35M 29S		510	
Glynn, GA	34G002	6/2/94	31D 07M 27S	81D 28M 53S	585-750	106	UFA
Glynn, GA	34G003	10/21/96	31D 07M 27S	81D 28M 53S	494-692	128	UFA
Glynn, GA	34G036	6/3/98	31D 06M 43S	81D 29M 20S	1062-1140	373	LFA
Glynn, GA	34H065	10/24/96	31D 09M 50S	81D 28M 51S	455-664	503	UFA
Glynn, GA	34H072	11/20/90	31D 09M 52S	81D 28M 43S	498-950	228	UFA + some LFA
Glynn, GA	34H073	6/23/99	31D 09M 51S	81D 28M 57S	1063	499	UFA
Glynn, GA	34H076	6/23/99	31D 09M 59S	81D 29M 01S	1015	472	UFA + some LFA
Glynn, GA	34H078	6/23/99	31D 09M48S	81D 28M 52S	545-890	259	UFA
Glynn, GA	34H112	6/21/99	31D 08M 12S	81D 29M 41S	528-747	1690	UFA
Glynn, GA	34H117	6/3/98	31D 08M 52S	81D 29M 54S	540-780	508	UFA
Glynn, GA	34H125	6/20/99	31D 09M 06S	81D 29M 31S	535-604	460	UFA
Glynn, GA	34H128	6/21/99	31D 09M 19S	81D 29M 35S	519-700	782	UFA
Glynn, GA	34H132	6/1/91	31D 10M 20S	81D 29M 52S	540-566	1500	UFA
Glynn, GA	34H334	10/23/96	31D 09M 19S	81D 28M 53S	800-980	995	LFA
Glynn, GA	34H348	4/20/95	31D 10M 55S	81D 28M 53S	536-787	440	UFA
Glynn, GA	34H354	6/22/99	31D 09M 24S	81D 29M 52S	804-1003	1284	LFA
Glynn, GA	34H355	6/22/99	31D 09M 24S	81D 29M 52S	523-785	1524	UFA
Glynn, GA	34H363	12/2/95	31D 08M 22S	81D 29M 58S	612-744	177	UFA

UFA = Upper Floridan Aquifer; LFA = Lower Floridan Aquifer

Appendix 3

Additional Floridan Aquifer Well Locations Characterized by High Chloride Concentrations

1978-1988 (most are after 1995)

County/ST	Well No.	Date	Latitude	Longitude	Depth or Screened Interval (ft)	Chloride Concentration (mg/L)	Aquifer
Glynn, GA	34H373	6/21/99	31D 09M 40S	81D 29M 33S	512-719	441	UFA
Glynn, GA	34H374	6/3/98	31D 09M 53S	81D 29M 59S	527-696	1355	UFA
Glynn, GA	34H391	6/3/98	31D 08M 18S	81D 29M 42S	1070-1159	2810	Brackish zone LFA
Glynn, GA	34H393	12/22/98	31D 08M 25S	81D 29M 42S	615-723	2315	UFA
Glynn, GA	34H398	6/22/99	31D 07M 49S	81S 29M 04S	622-720	134	UFA
Glynn, GA	34H399	6/21/99	31D 07M 49S	81D 29M 20S	1078-1250	6880	Brackish zone LFA
Glynn, GA	34H400	6/3/98	31D 09M 36S	81D 29M 40S	524-756	541	UFA
Glynn, GA	34H401	6/21/99	31D 09M 45S	81D 29M 55S	525-756	1940	UFA
Glynn, GA	34H402	6/22/99	31D 09M 45S	81D 29M 55S	815-946	2100	LFA
Glynn, GA	34H403	6/21/99	31D 08M 22S	81D 29M 42S	788-892	1480	UFA
Glynn, GA	34H411	10/12/93	31D 10M 03S	81D 28M 57S	540-698	950	UFA
Glynn, GA	34H413	6/13/98	31D 09M 51S	81D 28M 46S	550-838	656	UFA
Glynn, GA	34H416	6/21/99	31D 08M 27S	81D 29M 43S		140	
Glynn, GA	34H424	6/23/99	31D 10M 11S	81D 29M 31S	550-745	2115	UFA
Glynn, GA	34H425	6/23/99	31D 10M 16S	81D 28M 58S	550-700	340	UFA
Glynn, GA	34H427	6/22/99	31D 07M 50S	81D 29M 20S	500-640	1425	UFA
Glynn, GA	34H434	6/22/99	31D 09M 11S	81D 29M 41S	530-670	1720	UFA
Glynn, GA	34H438	6/21/98	31D 09M 01S	81D 28M 44S		1731	
Glynn, GA	34H443	10/22/96	31D 08M 28S	81D 29M 42S		1547	
Glynn, GA	34H446	6/3/98	31D 08M 29S	81D 29M 45S		445	
Glynn, GA	34H468	6/23/99	31D 09M 31S	81D 29M 10S	560-750	244	
Glynn, GA	34H469	6/21/99	31D 10M 20S	81D 29M 52S	540-566	1335	UFA
Glynn, GA	34H495	3/21/00	31D 08M 35S	81D 29M 45S	658-668	1,500	UFA
Glynn, GA	34H495	3/21/00	31D 08M 35S	81D 29M 45S	1,196-1,206	2,200	LFA
Glynn, GA	34H495	3/21/00	31D 08M 35S	81D 29M 45S	2,089-2,092	1,100	LFA-FPZ
Glynn, GA	34H495	3/21/00	31D 08M 35S	81D 29M 45S	2,207-2,217	17,000	LFA-FPZ
Glynn, GA	34H495	3/21/00	31D 08M 35S	81D 29M 45S	2,709-2,720	27,000	LFA-FPZ
Camden,GA	33D061	5/6/93	30D 44M 01S	81D 32M 37S		124	UFA
Camden,GA	33120E	10/7/99	30D 48M 07S	81D 32M 37S		570	Surficial Aquifer
Nassau/Fl	N-117	1979	30D 40M 01S	81D 28M 03S	2,100	9,600	USGS WRI 83-4190
Nassau/Fl	N-62	1962	30D 38M 23S	81D 27M 33S	1,826	1,600	USGS WRI 83-4190 plugged to 1,100'
Nassau/Fl	N-32	1979	30D 39M 58S	81D 28M 04S	2,094	8,100	USGS

UFA = Upper Floridan Aquifer; LFA = Lower Floridan Aquifer; FPZ = Fernandina Permeable Zone

Appendix 3

Additional Floridan Aquifer Well Locations Characterized by High Chloride Concentrations

1978-1988 (most are after 1995)

Chloride in Test Wells in USGS Test Wells/Nassau and Duval Counties

County/ST	Well No.	Date	Latitude	Longitude	Depth or Screened Interval (ft)	Chloride Concentration (mg/L)	Comments (data source)
Duval/Fl	D-2386	1981	30D 21M 59S	81D 23M 56S	2,026	3,300	USGS OFR 84-143
Duval/Fl	D-3060	1983	30D 20M 52S	81D 32M 32S	2,112	5,370	USGS OFR 84-143
Duval/Fl	test well	pre 1966	Jax near St. Johns River		2,485	7,320	The exact location of this well was never published

The location of this test well can only be deduced from Figs 2 and 3 of Leve, Ground Water v.6 1968; Chloride concentration given in a USGS Open File Report FL66001
See Cross section A-A' and Figures 2 and 3 of Leve, Ground Water v.6, 1968.

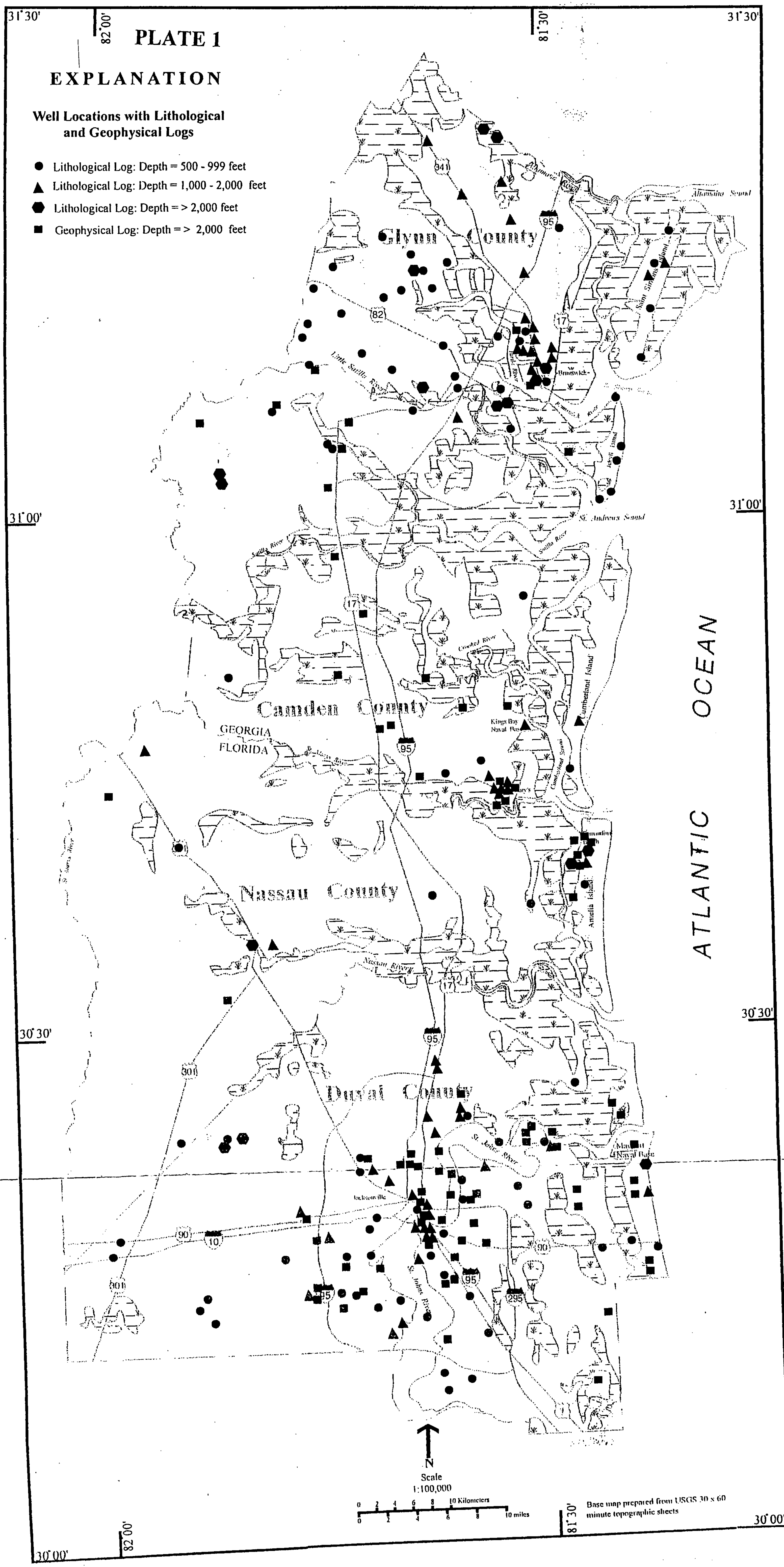


PLATE 1
EXPLANATION
Well Locations with Lithological and Geophysical Logs
Lithological Log: Depth = 500 - 999 feet
Lithological Log: Depth = 1,000 - 2,000 feet
Lithological Log: Depth = > 2,000 feet
Geophysical Log: Depth = > 2,000 feet
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Brunswick
St. Andrews Sound
Kings Bay Naval Base
Cumberland Island
Amelia Island
Nassau River
St. Johns River
Jacksonville
Mayport Naval Base
Little Satilla River
Satilla River
Crooked River
95
17
341
82
301
90
10
295
N
Scale 1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

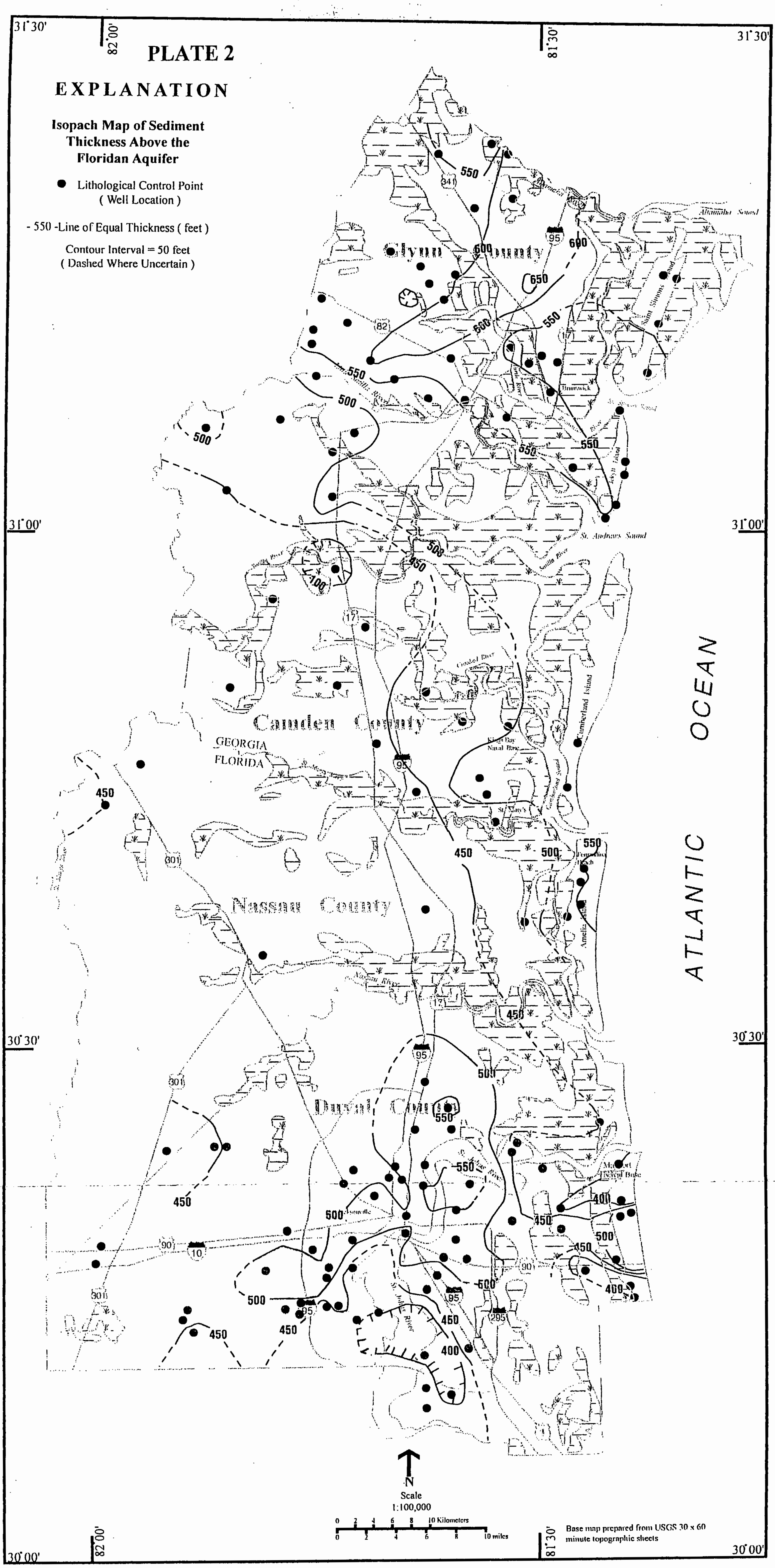
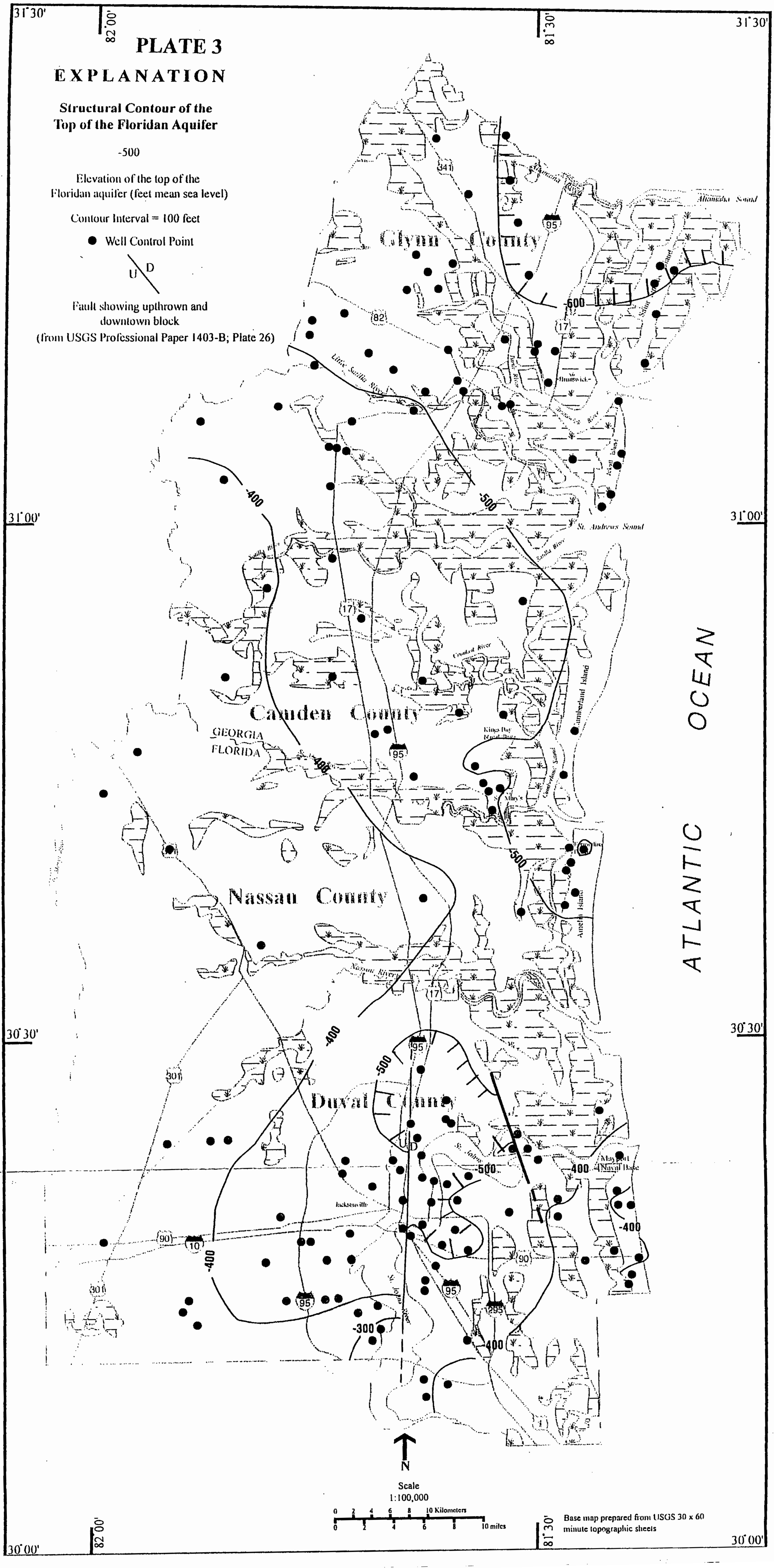


PLATE 2
EXPLANATION
Isopach Map of Sediment Thickness Above the Floridan Aquifer
Lithological Control Point (Well Location)
- 550 -Line of Equal Thickness (feet)
Contour Interval = 50 feet
(Dashed Where Uncertain)
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Altamaha Sound
St. Simons Sound
St. Andrews Sound
Brunswick
Cumberland Island
Kings Bay Naval Base
Cumberland Sound
Amelia Island
St. Johns River
550
600
650
500
450
400
N
Scale 1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets



31°30'
82°00'
81°30'
PLATE 3
EXPLANATION
Structural Contour of the Top of the Floridan Aquifer
-500
Elevation of the top of the Floridan aquifer (feet mean sea level)
Contour Interval = 100 feet
Well Control Point
U D
Fault showing upthrown and downtown block
(from USGS Professional Paper 1403-B; Plate 26)
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
St. Andrews Sound
Cumberland Island
Amelia Island
Jacksonville
Mayport Naval Base
-400
-500
-600
-300
31°00'
30°30'
30°00'
N
Scale 1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

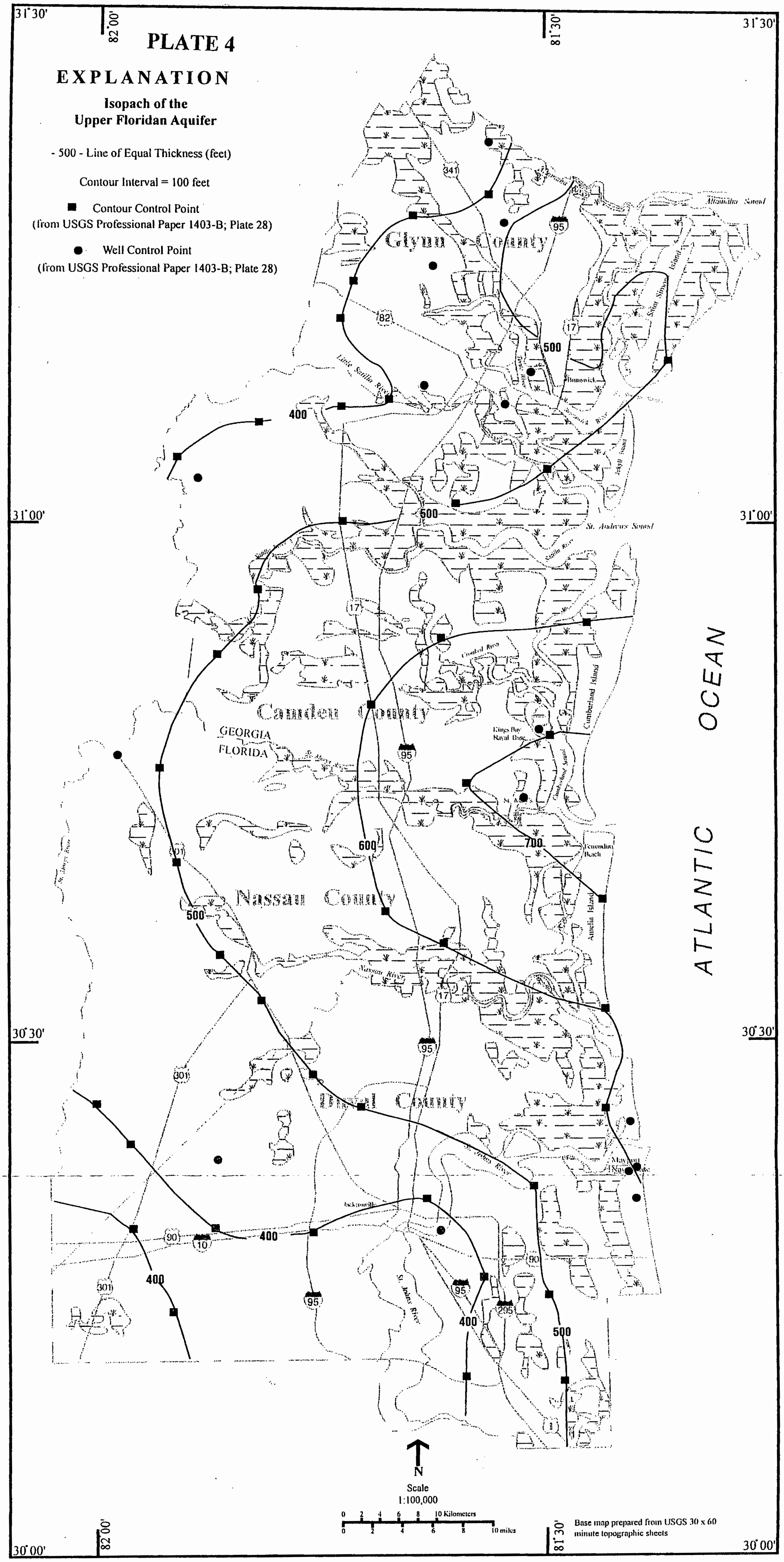
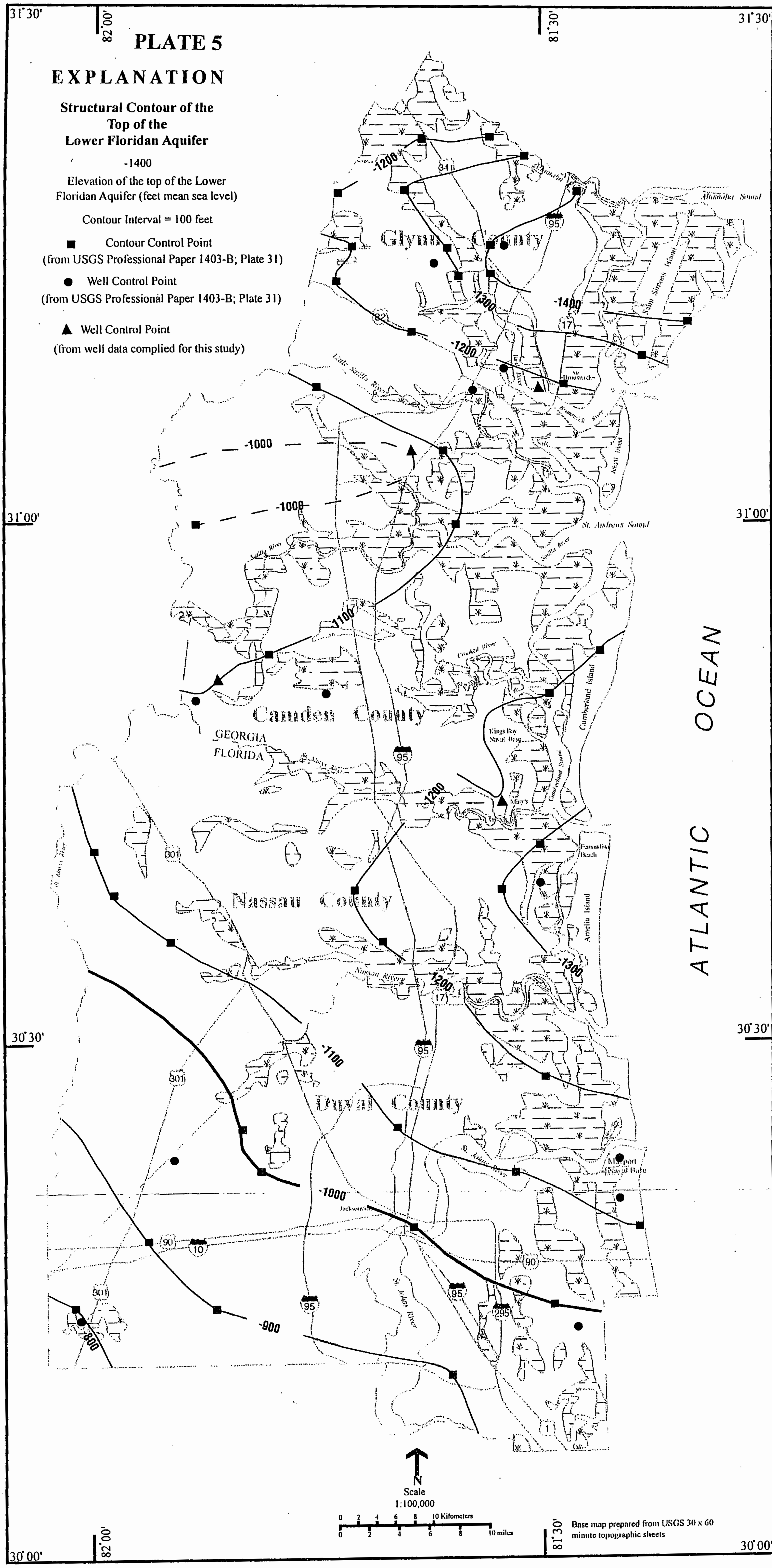


PLATE 4
EXPLANATION
Isopach of the
Upper Floridan Aquifer
- 500 - Line of Equal Thickness (feet)
Contour Interval = 100 feet
Contour Control Point
(from USGS Professional Paper 1403-B; Plate 28)
Well Control Point
(from USGS Professional Paper 1403-B; Plate 28)
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
400
500
600
700
St. Andrews Sound
Cumberland Island
Amelia Island
Kings Bay Naval Base
Nassau River
St. Johns River
N
Scale
1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

PLATE 5



31°30'
82°00'
81°30'
EXPLANATION
Structural Contour of the Top of the Lower Floridan Aquifer
-1400
Elevation of the top of the Lower Floridan Aquifer (feet mean sea level)
Contour Interval = 100 feet
Contour Control Point (from USGS Professional Paper 1403-B; Plate 31)
Well Control Point (from USGS Professional Paper 1403-B; Plate 31)
Well Control Point (from well data complied for this study)
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Cumberland Island
Amelia Island
Kings Bay Naval Base
St. Andrews Sound
Altamaha Sound
Mayport Naval Base
-1000
-1100
-1200
-1300
-1400
-900
-800
31°00'
30°30'
30°00'
N
Scale 1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

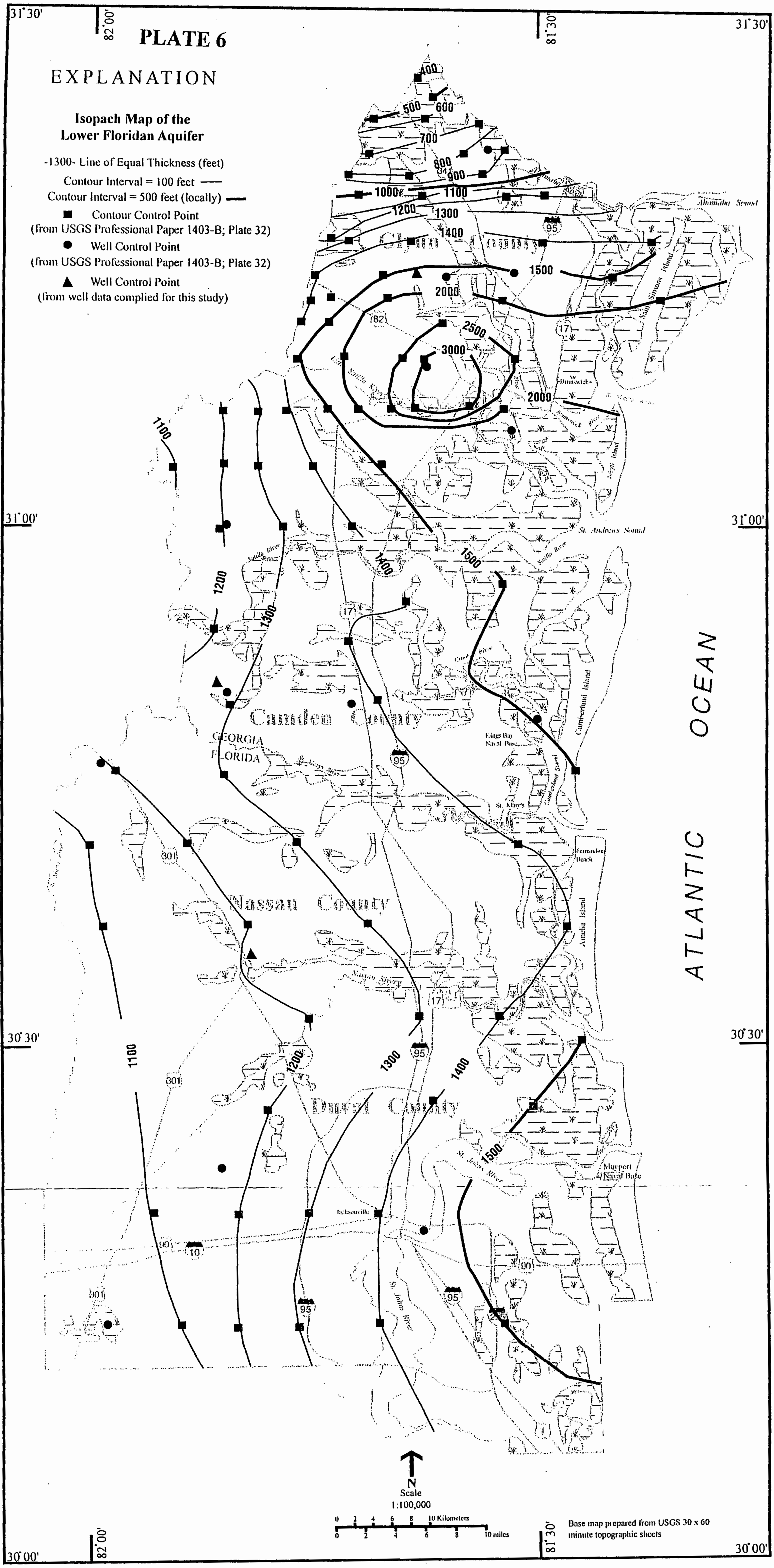


PLATE 6
EXPLANATION
Isopach Map of the
Lower Floridan Aquifer
-1300- Line of Equal Thickness (feet)
Contour Interval = 100 feet
Contour Interval = 500 feet (locally)
Contour Control Point
(from USGS Professional Paper 1403-B; Plate 32)
Well Control Point
(from USGS Professional Paper 1403-B; Plate 32)
Well Control Point
(from well data complied for this study)
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
2000
2500
3000
Camden County
GEORGIA
FLORIDA
Nassau County
Duval County
Kings Bay Naval Base
Cumberland Island
Amelia Island
Mayport Naval Base
ATLANTIC OCEAN
N
Scale
1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

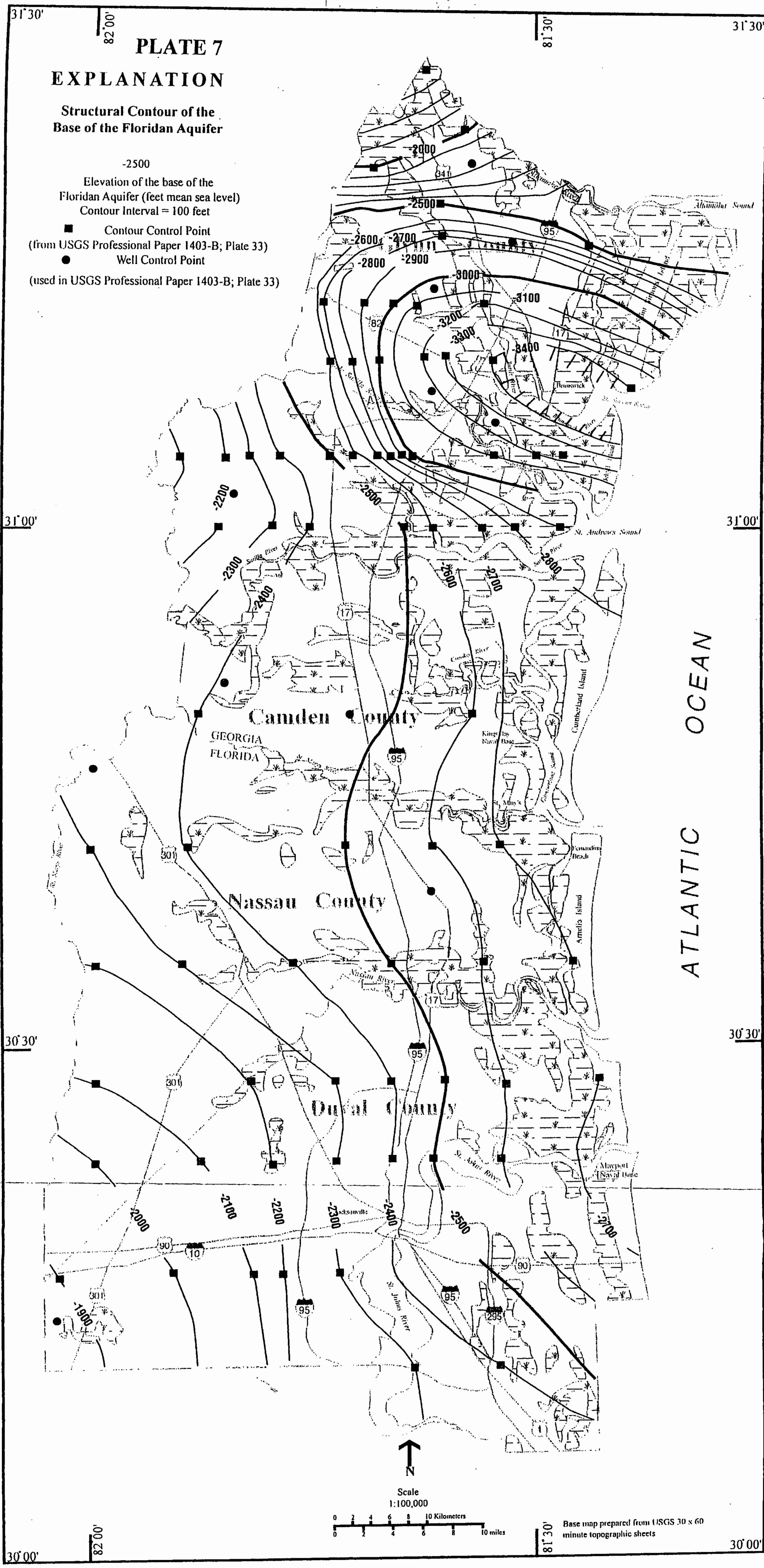
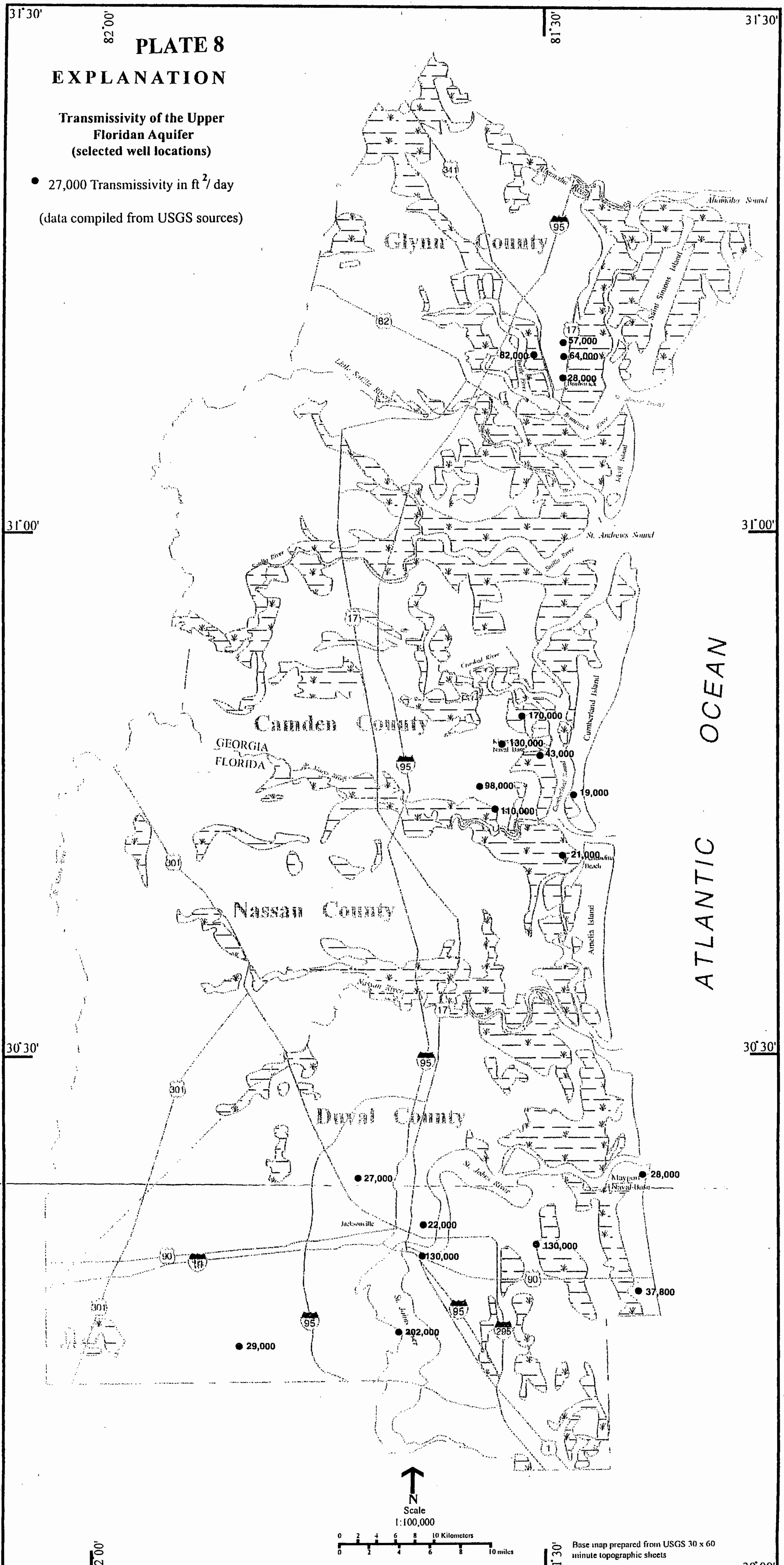


PLATE 7
EXPLANATION
Structural Contour of the Base of the Floridan Aquifer
-2500
Elevation of the base of the Floridan Aquifer (feet mean sea level)
Contour Interval = 100 feet
Contour Control Point (from USGS Professional Paper 1403-B; Plate 33)
Well Control Point (used in USGS Professional Paper 1403-B; Plate 33)
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
-1900
-2000
-2100
-2200
-2300
-2400
-2500
-2600
-2700
-2800
-2900
-3000
-3100
-3200
-3300
-3400
Altamaha Sound
St. Andrews Sound
Satilla River
Cumberland Island
Kings Bay Naval Base
Fernandina Beach
Amelia Island
Nassau River
St. Johns River
Mayport Naval Base
Jacksonville
Brunswick
Camden County
GEORGIA
FLORIDA
Nassau County
Duval County
ATLANTIC OCEAN
N
Scale
1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets



31°30'
82°00'
81°30'
31°30'
PLATE 8
EXPLANATION
Transmissivity of the Upper
Floridan Aquifer
(selected well locations)
27,000 Transmissivity in ft²/ day
(data compiled from USGS sources)
Glynn County
Saint Simons Island
St. Andrews Sound
Cumberland Island
57,000
82,000
64,000
28,000
31°00'
31°00'
Satilla River
Crooked River
Camden County
GEORGIA
FLORIDA
170,000
130,000
Naval Base
43,000
98,000
19,000
110,000
21,000
Nassau County
Amelia Island
Nassau River
ATLANTIC OCEAN
30°30'
30°30'
Duval County
St. Johns River
27,000
28,000
Mayport Naval Base
Jacksonville
22,000
130,000
130,000
37,800
202,000
29,000
N
Scale
1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60
minute topographic sheets
30°00'
82°00'
81°30'
30°00'

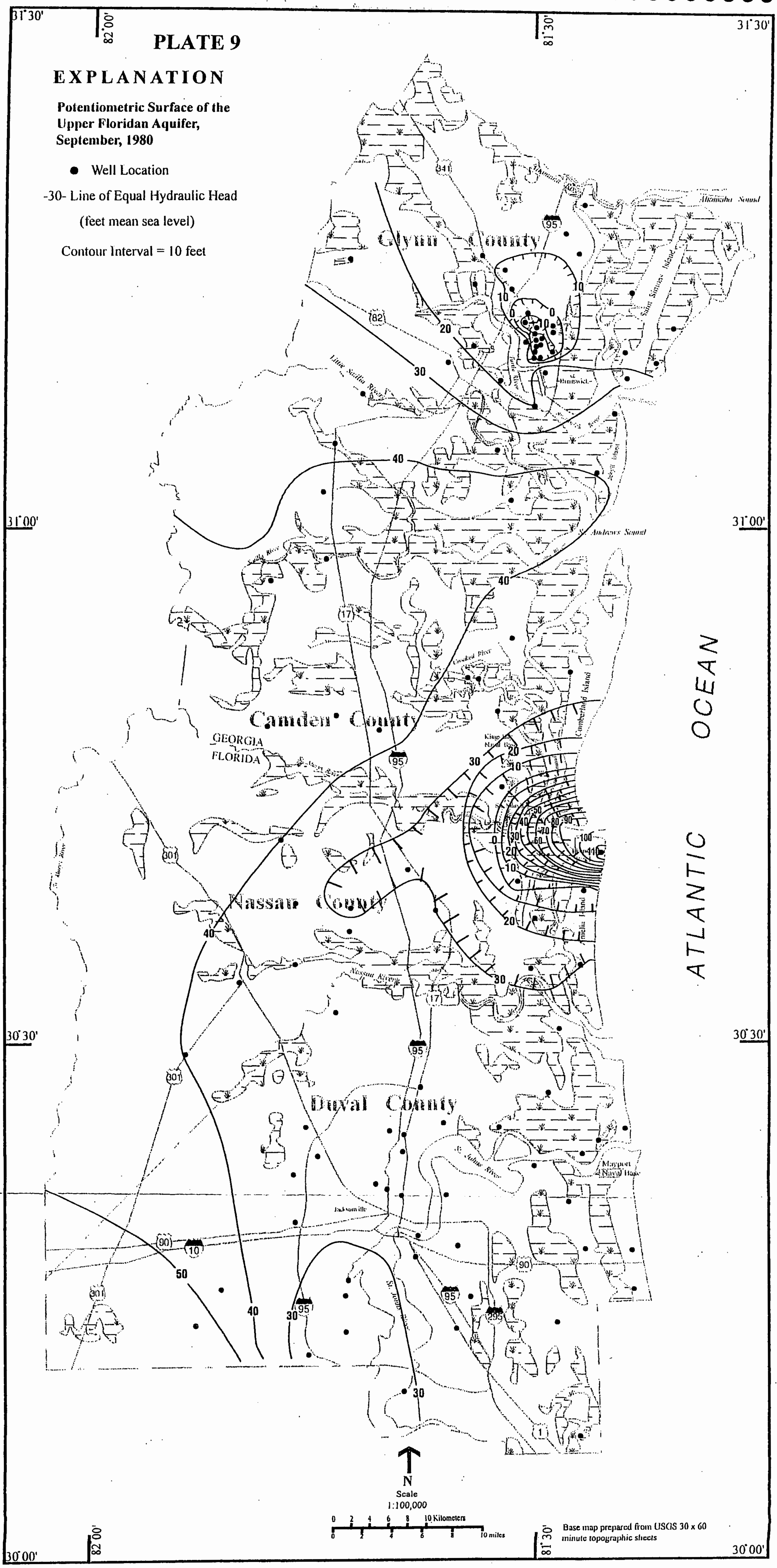


PLATE 9
EXPLANATION
Potentiometric Surface of the Upper Floridan Aquifer, September, 1980
Well Location
-30- Line of Equal Hydraulic Head
(feet mean sea level)
Contour Interval = 10 feet
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Jacksonville
Mayport Naval Base
Scale
1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets
31°30'
31°00'
30°30'
30°00'
82°00'
81°30'

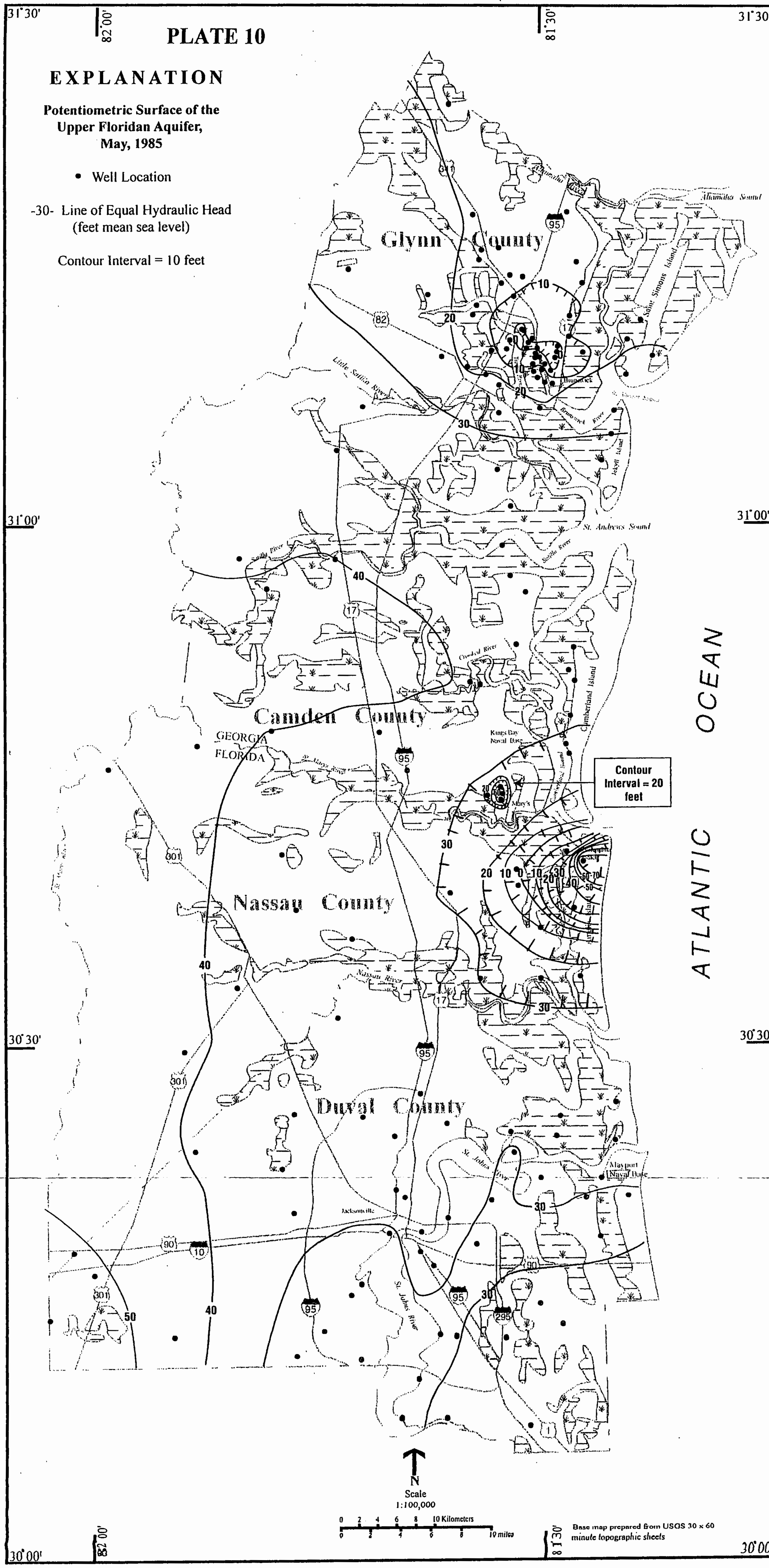


PLATE 10
EXPLANATION
Potentiometric Surface of the Upper Floridan Aquifer, May, 1985
• Well Location
-30- Line of Equal Hydraulic Head (feet mean sea level)
Contour Interval = 10 feet
Contour Interval = 20 feet
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
St. Andrews Sound
Altamaha Sound
Saint Simons Island
Little Satilla River
Satilla River
Crooked River
Cumberland Island
Kings Bay Naval Base
St. Marys River
Nassau River
St. Johns River
Mayport Naval Base
Jacksonville
31°30'
31°00'
30°30'
30°00'
82°00'
81°30'
N
Scale 1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

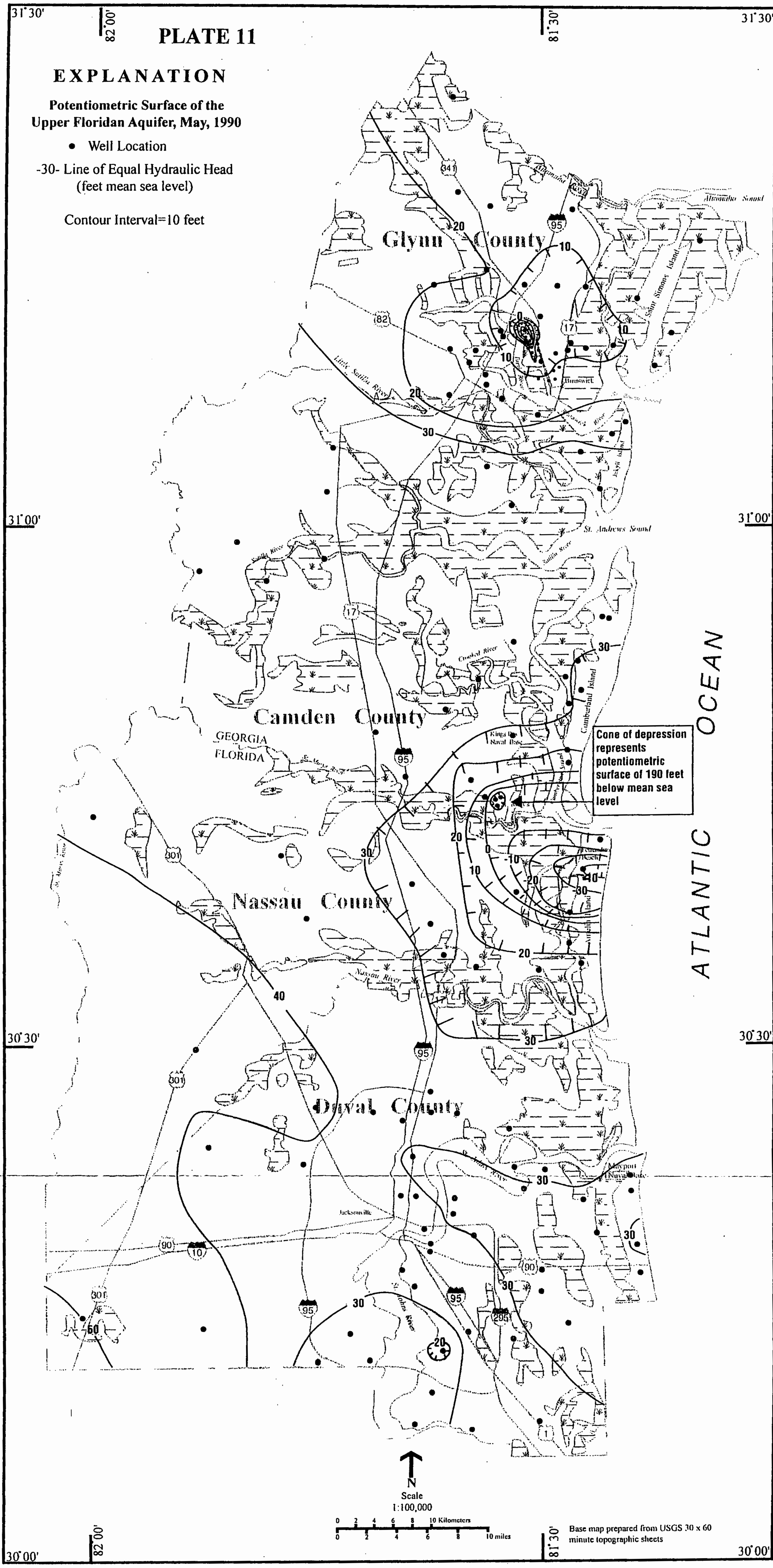


PLATE 11
EXPLANATION
Potentiometric Surface of the Upper Floridan Aquifer, May, 1990
• Well Location
-30- Line of Equal Hydraulic Head (feet mean sea level)
Contour Interval=10 feet
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
St. Andrews Sound
Cumberland Island
Saint Simons Island
Little Satilla River
Crooked River
Nassau River
Cone of depression represents potentiometric surface of 190 feet below mean sea level
Jacksonville
Scale
1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

PLATE 12

EXPLANATION

Potentiometric Surface of the Upper Floridan Aquifer, May 1995

• Well Location

-30- Line of Equal Hydraulic Head (feet mean sea level) Conour Interval = 10 feet

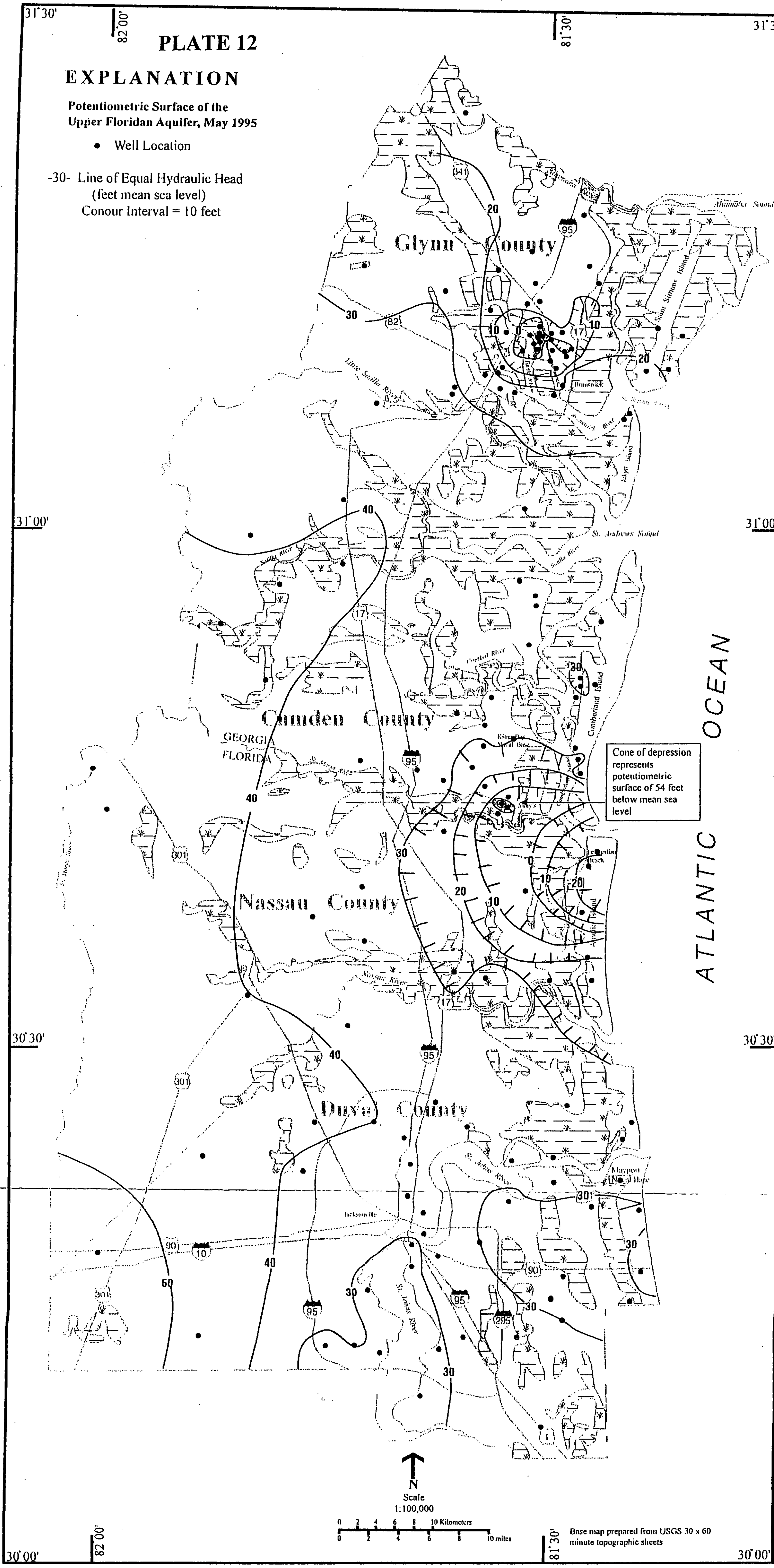


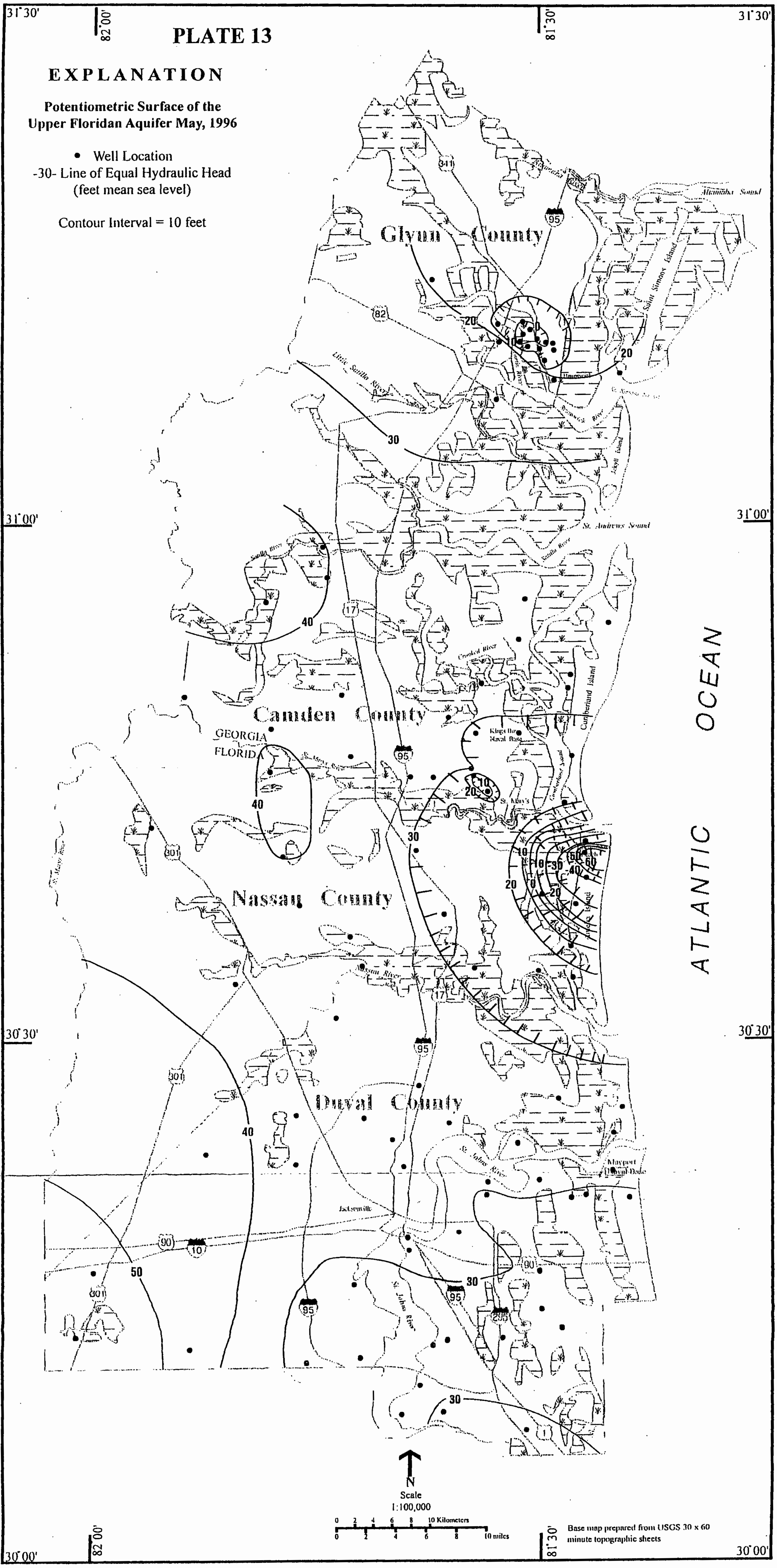
PLATE 13

EXPLANATION

Potentiometric Surface of the Upper Floridan Aquifer May, 1996

• Well Location
-30- Line of Equal Hydraulic Head (feet mean sea level)

Contour Interval = 10 feet



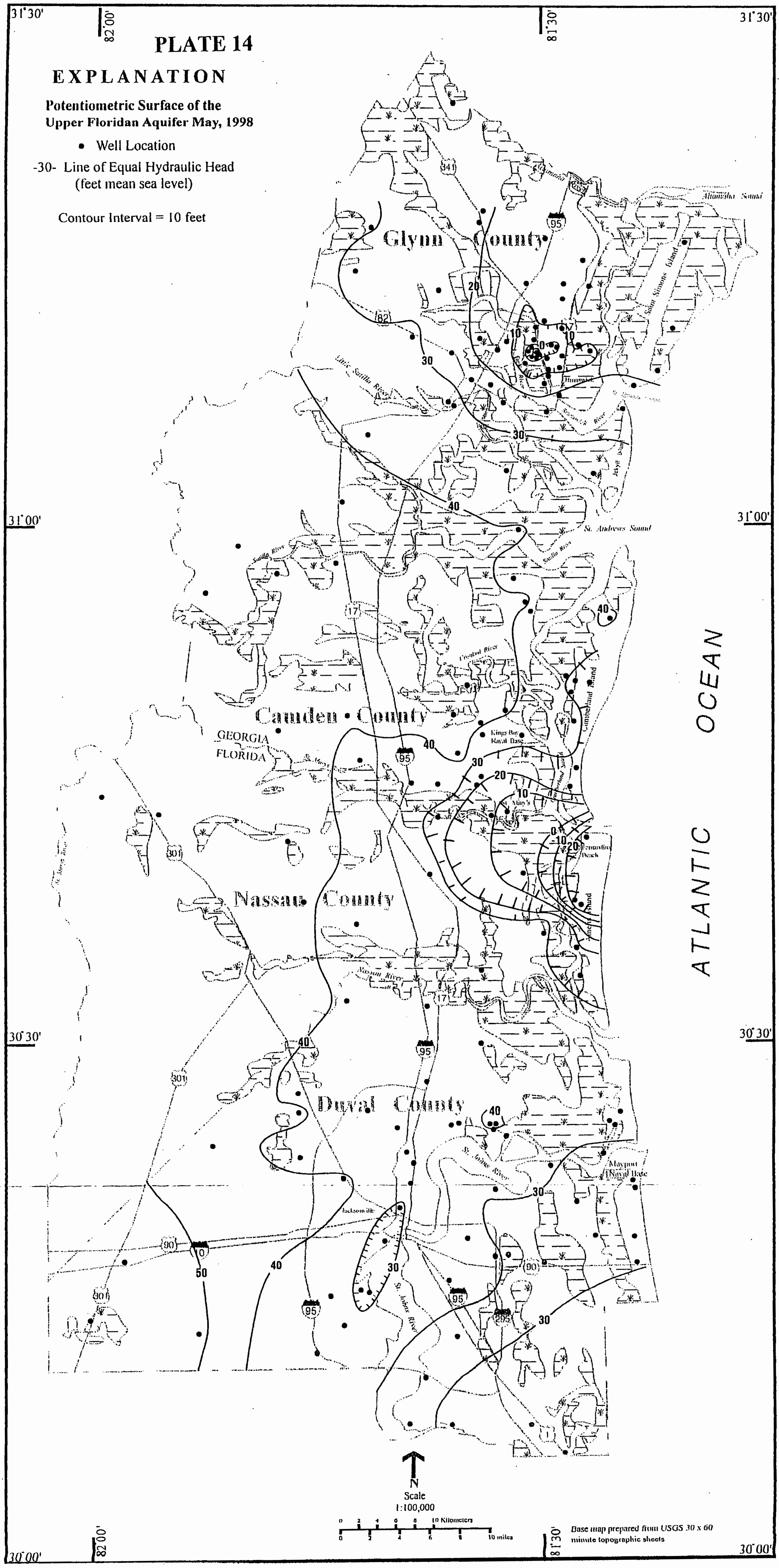


PLATE 14
EXPLANATION
Potentiometric Surface of the Upper Floridan Aquifer May, 1998
• Well Location
-30- Line of Equal Hydraulic Head (feet mean sea level)
Contour Interval = 10 feet
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
St. Andrews Sound
Kings Bay Naval Base
Mayport Naval Base
St. Johns River
Nassau River
Satilla River
Crooked River
Little Satilla River
Fernandina Beach
Jacksonville
Brunswick
Altamaha Sound
St. Simons Island
Cumberland Island
N
Scale 1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

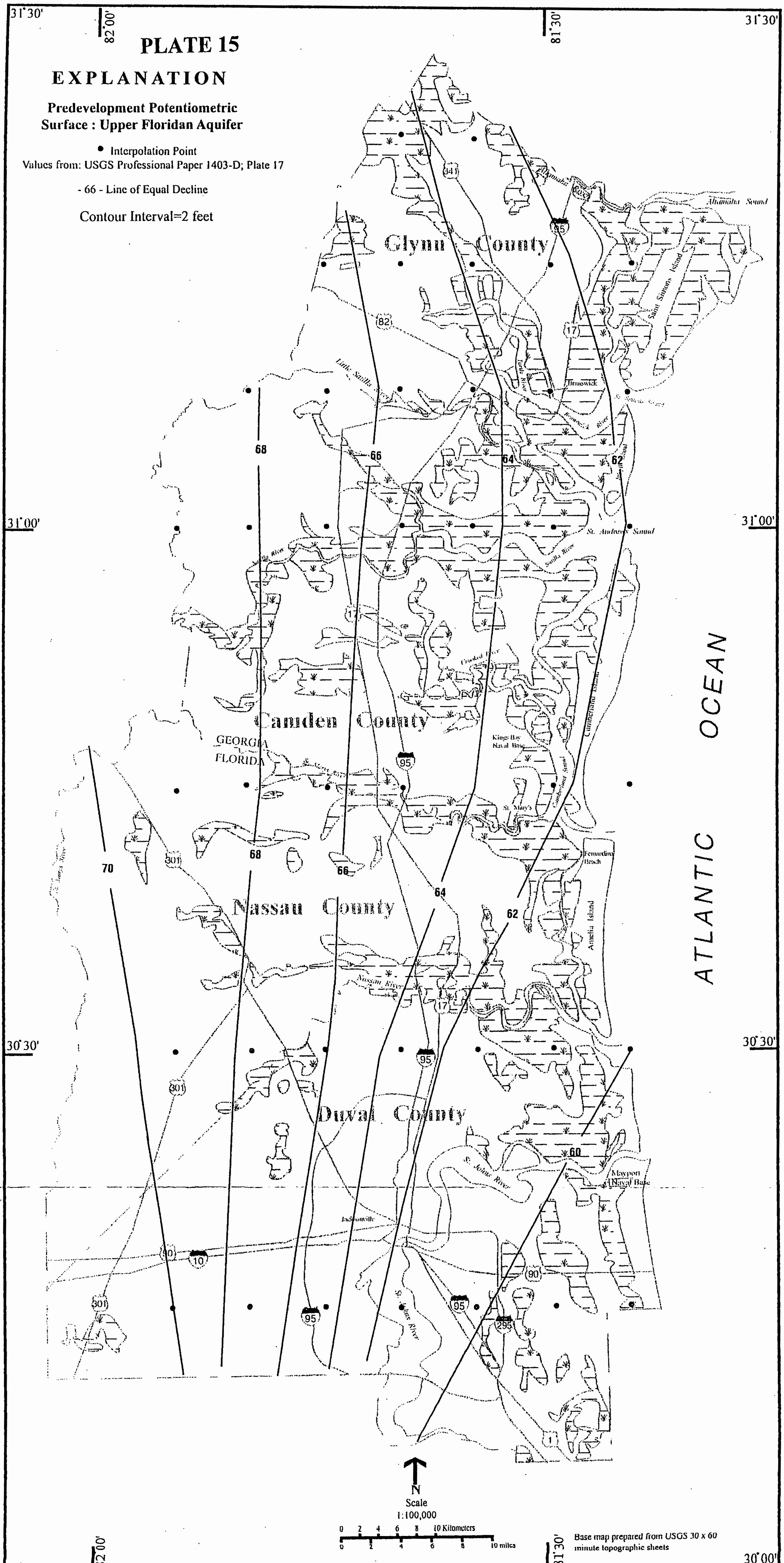


PLATE 15
EXPLANATION
Predevelopment Potentiometric Surface : Upper Floridan Aquifer
• Interpolation Point
Values from: USGS Professional Paper 1403-D; Plate 17
- 66 - Line of Equal Decline
Contour Interval=2 feet
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Altamaha Sound
Saint Simons Island
Brunswick
St. Andrews Sound
Cumberland Island
Kings Bay Naval Base
St. Mary's
Fernandina Beach
Amelia Island
Nassau River
St. Johns River
Mayport Naval Base
Jacksonville
70
68
66
64
62
60
N
Scale 1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

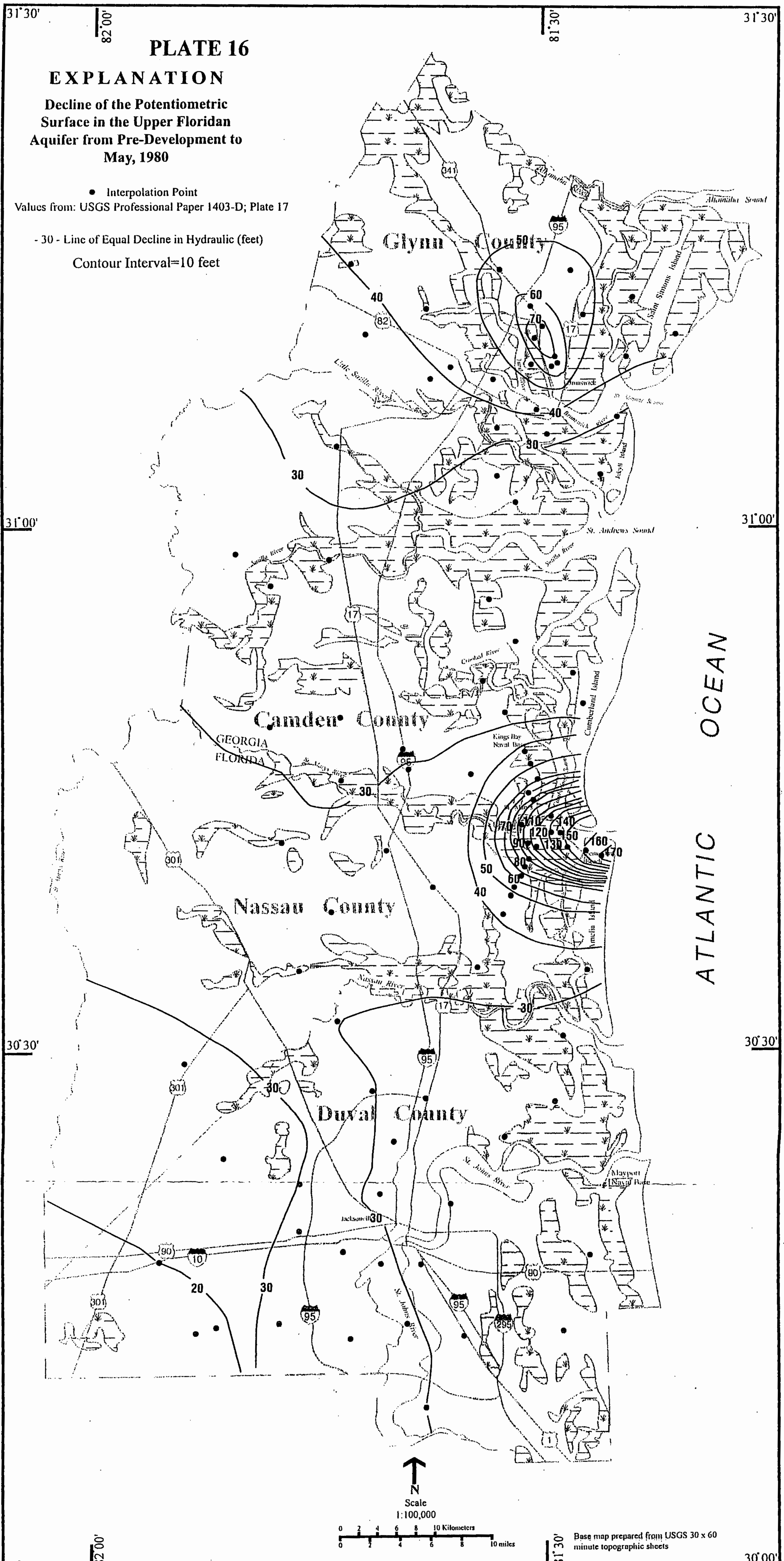
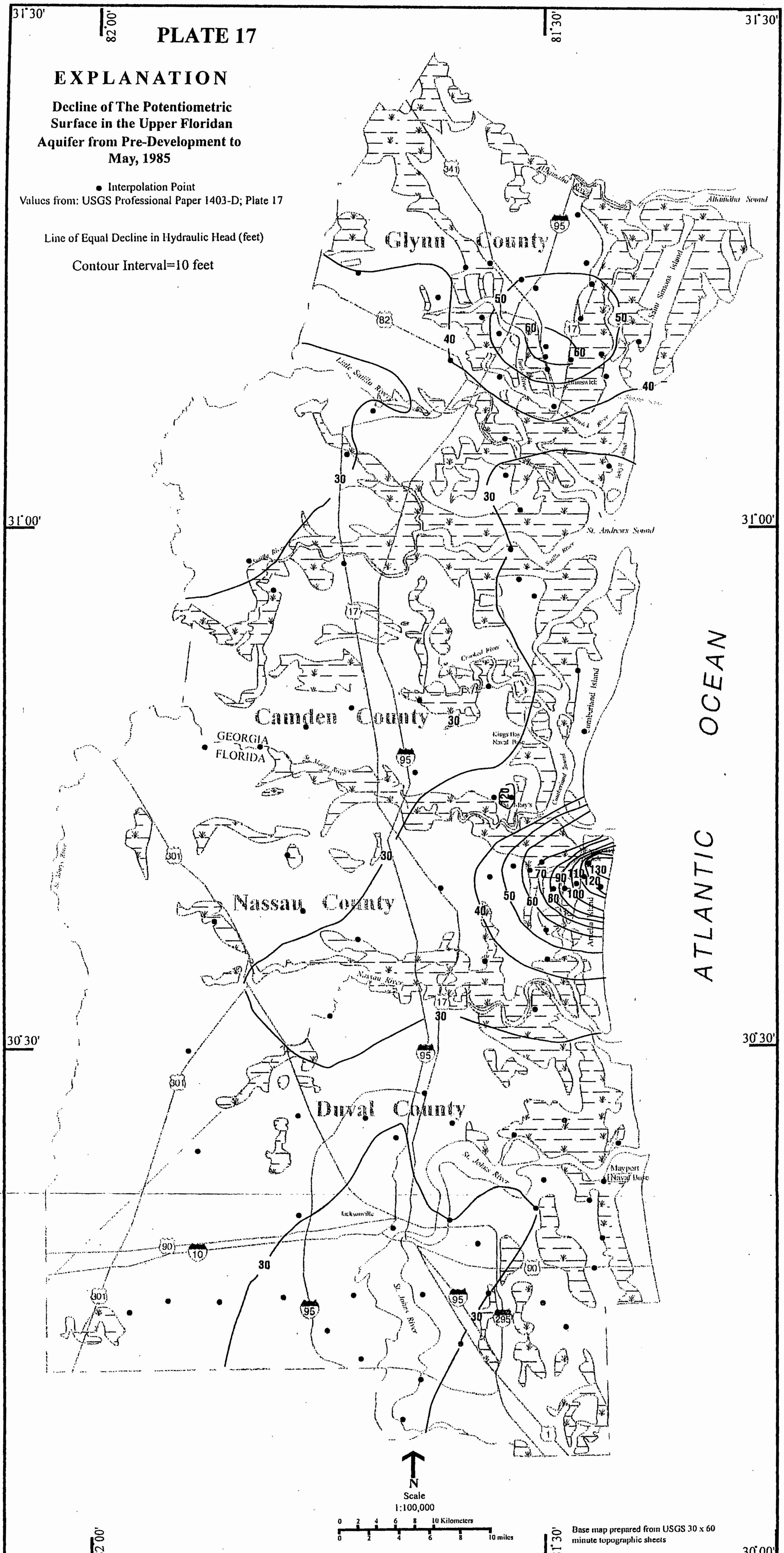


PLATE 16
EXPLANATION
Decline of the Potentiometric Surface in the Upper Floridan Aquifer from Pre-Development to May, 1980
• Interpolation Point
Values from: USGS Professional Paper 1403-D; Plate 17
- 30 - Line of Equal Decline in Hydraulic (feet)
Contour Interval=10 feet
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Cumberland Island
Amelia Island
Saint Simons Island
Jekyll Island
St. Andrews Sound
Kings Bay Naval Base
Mayport Naval Base
St. Johns River
Nassau River
Little Satilla River
Satilla River
Crooked River
Altamaha Sound
Jacksonville
Brunswick
20
30
40
50
60
70
80
90
110
120
130
140
150
160
170
N
Scale
1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

PLATE 17


EXPLANATION
Decline of The Potentiometric Surface in the Upper Floridan Aquifer from Pre-Development to May, 1985
Interpolation Point
Values from: USGS Professional Paper 1403-D; Plate 17
Line of Equal Decline in Hydraulic Head (feet)
Contour Interval=10 feet
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Altamaha Sound
St. Andrews Sound
Saint Simons Island
Cumberland Island
Kings Bay Naval Base
Mayport Naval Base
Jacksonville
St. Johns River
Nassau River
Little Satilla River
Satilla River
St. Marys River
Crooked River
Amelia Island
Brunswick
30
40
50
60
70
80
90
100
110
120
130
N
Scale
1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

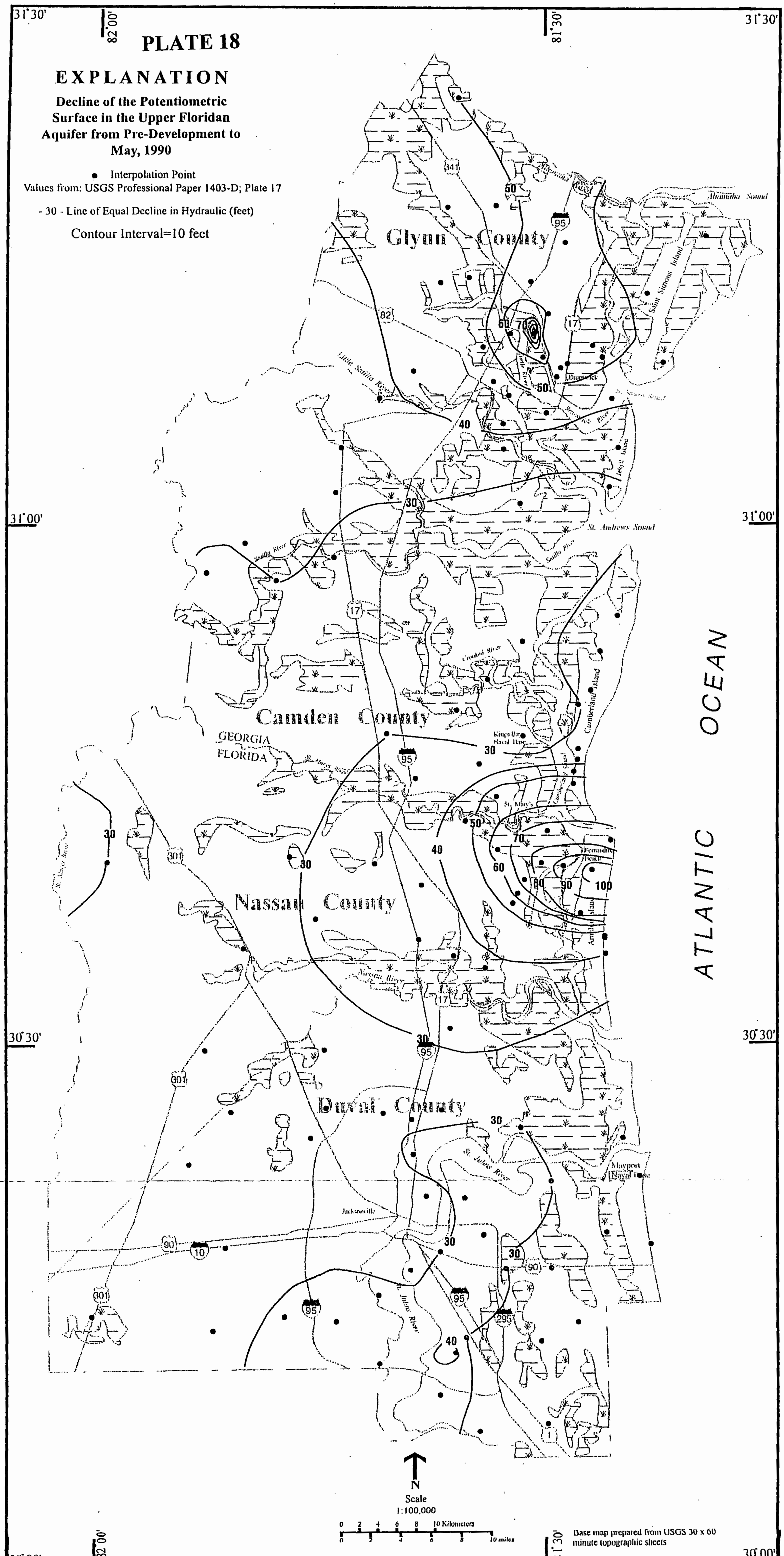


PLATE 18
EXPLANATION
Decline of the Potentiometric Surface in the Upper Floridan Aquifer from Pre-Development to May, 1990
• Interpolation Point
Values from: USGS Professional Paper 1403-D; Plate 17
- 30 - Line of Equal Decline in Hydraulic (feet)
Contour Interval=10 feet
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
St. Andrews Sound
Cumberland Island
Kings Bay Naval Base
Mayport Naval Base
Jacksonville
31°30'
31°00'
30°30'
30°00'
82°00'
81°30'
Scale
1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

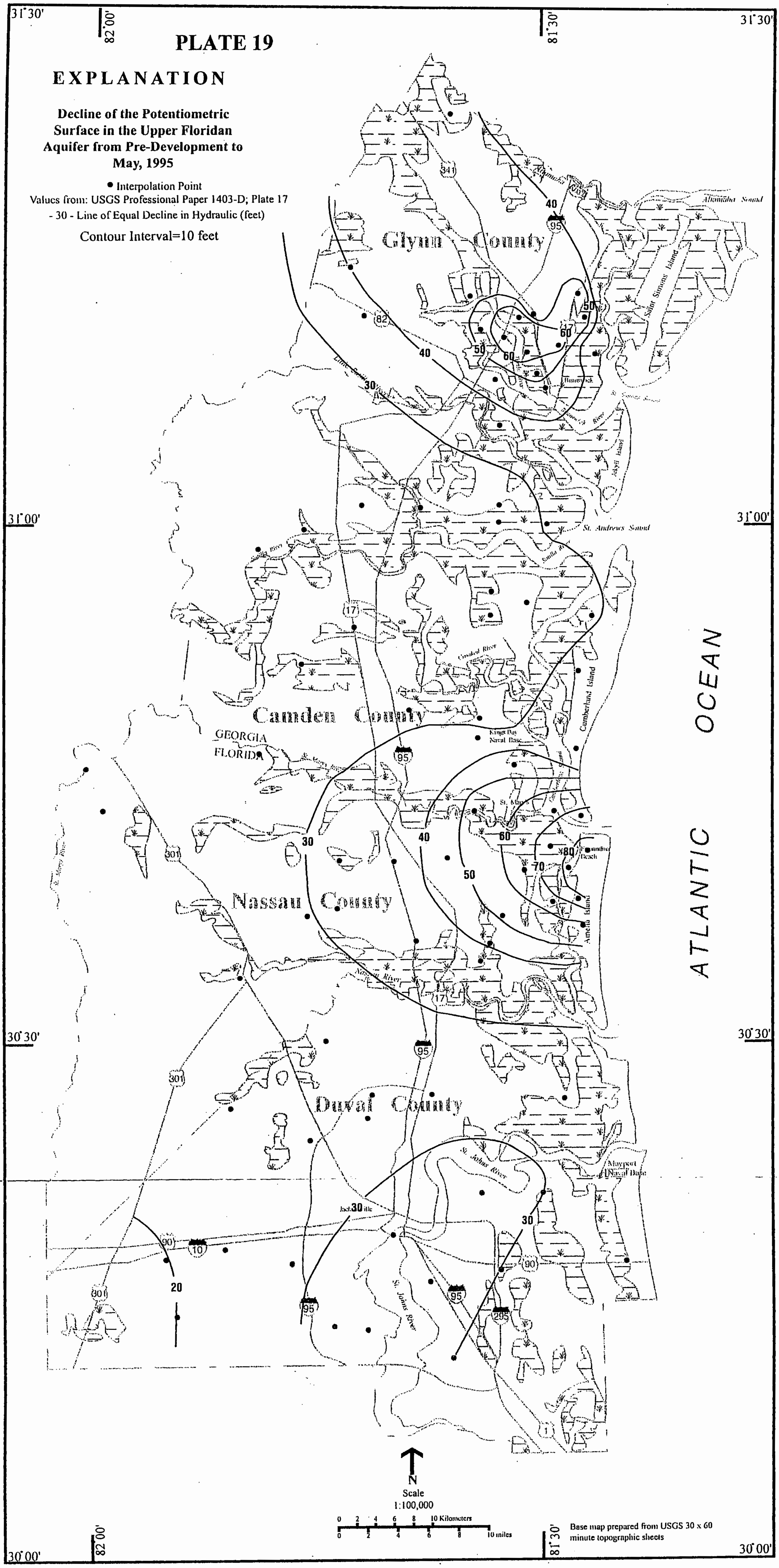


PLATE 19
EXPLANATION
Decline of the Potentiometric Surface in the Upper Floridan Aquifer from Pre-Development to May, 1995
• Interpolation Point
Values from: USGS Professional Paper 1403-D; Plate 17
- 30 - Line of Equal Decline in Hydraulic (feet)
Contour Interval=10 feet
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Altamaha Sound
Saint Simons Island
St. Andrews Sound
Jekyll Island
Cumberland Island
Kings Bay Naval Base
Crooked River
Amelia Island
Fernandina Beach
Nassau River
St. Johns River
Mayport Naval Base
St. Marys River
Jacksonville
Brunswick
20
30
40
50
60
70
80
N
Scale
1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

PLATE 20

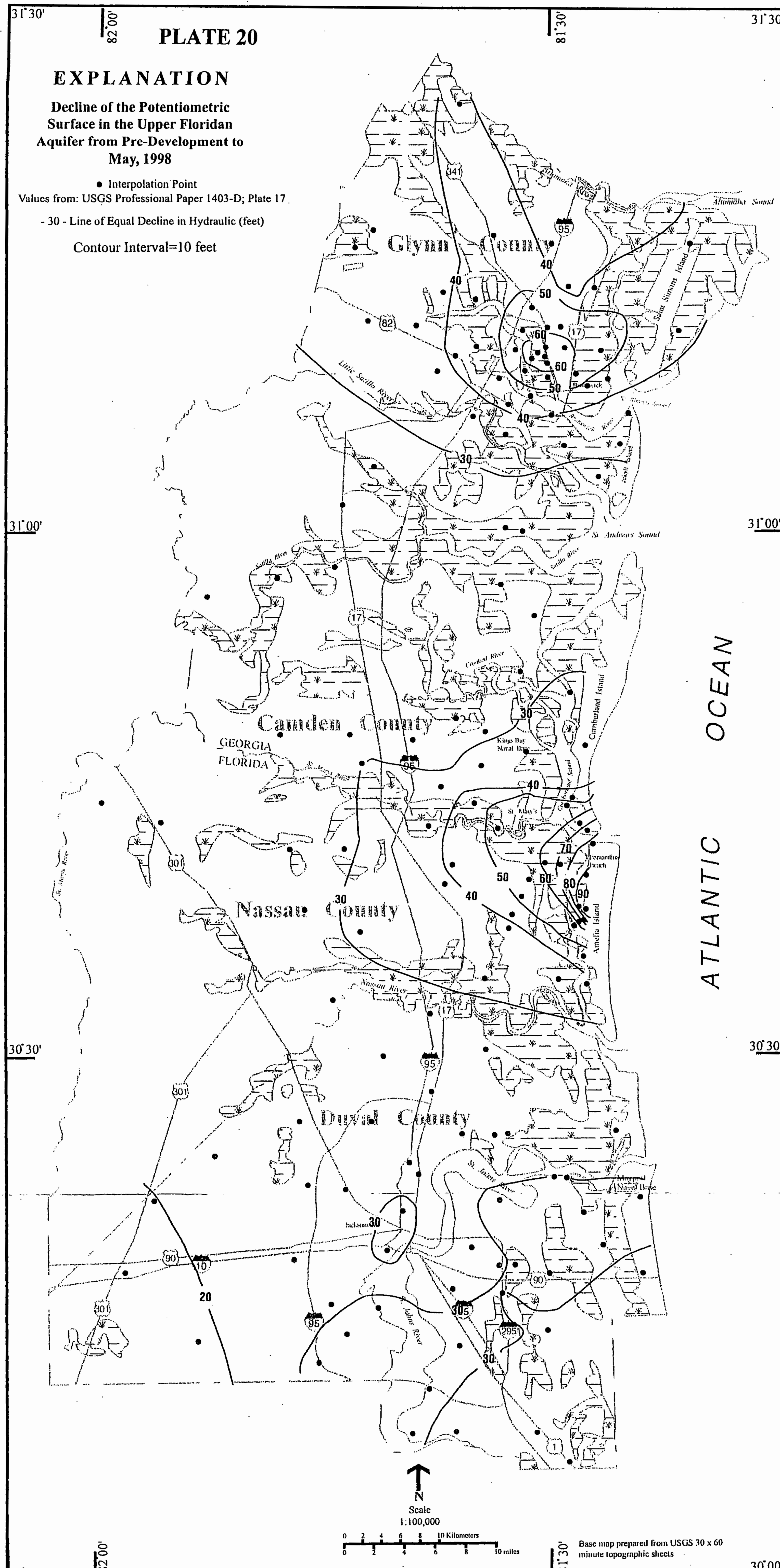
EXPLANATION

Decline of the Potentiometric Surface in the Upper Floridan Aquifer from Pre-Development to May, 1998

● Interpolation Point
Values from: USGS Professional Paper 1403-D; Plate 17

- 30 - Line of Equal Decline in Hydraulic (feet)

Contour Interval=10 feet



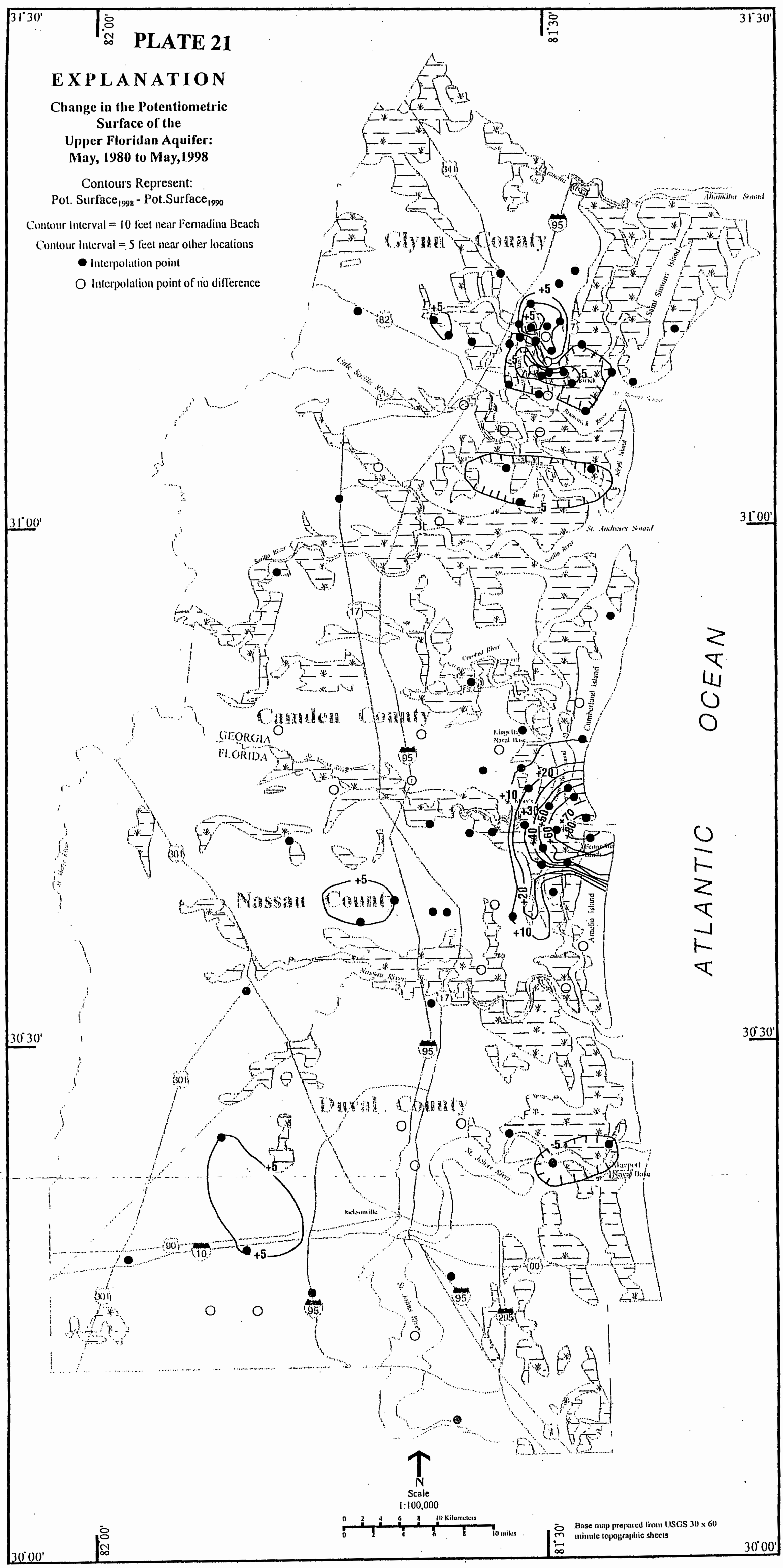


PLATE 21
EXPLANATION
Change in the Potentiometric Surface of the Upper Floridan Aquifer: May, 1980 to May, 1998
Contours Represent:
Pot. Surface1998 - Pot.Surface1990
Contour Interval = 10 feet near Fernadina Beach
Contour Interval = 5 feet near other locations
Interpolation point
Interpolation point of no difference
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Saint Simons Island
Cumberland Island
Amelia Island
St. Andrews Sound
Kings Bay Naval Base
Mayport Naval Base
Jacksonville
Little Satilla River
Satilla River
Crooked River
Nassau River
St. Johns River
+5
-5
+10
+20
+30
+40
+50
+60
+70
+80
N
Scale
1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

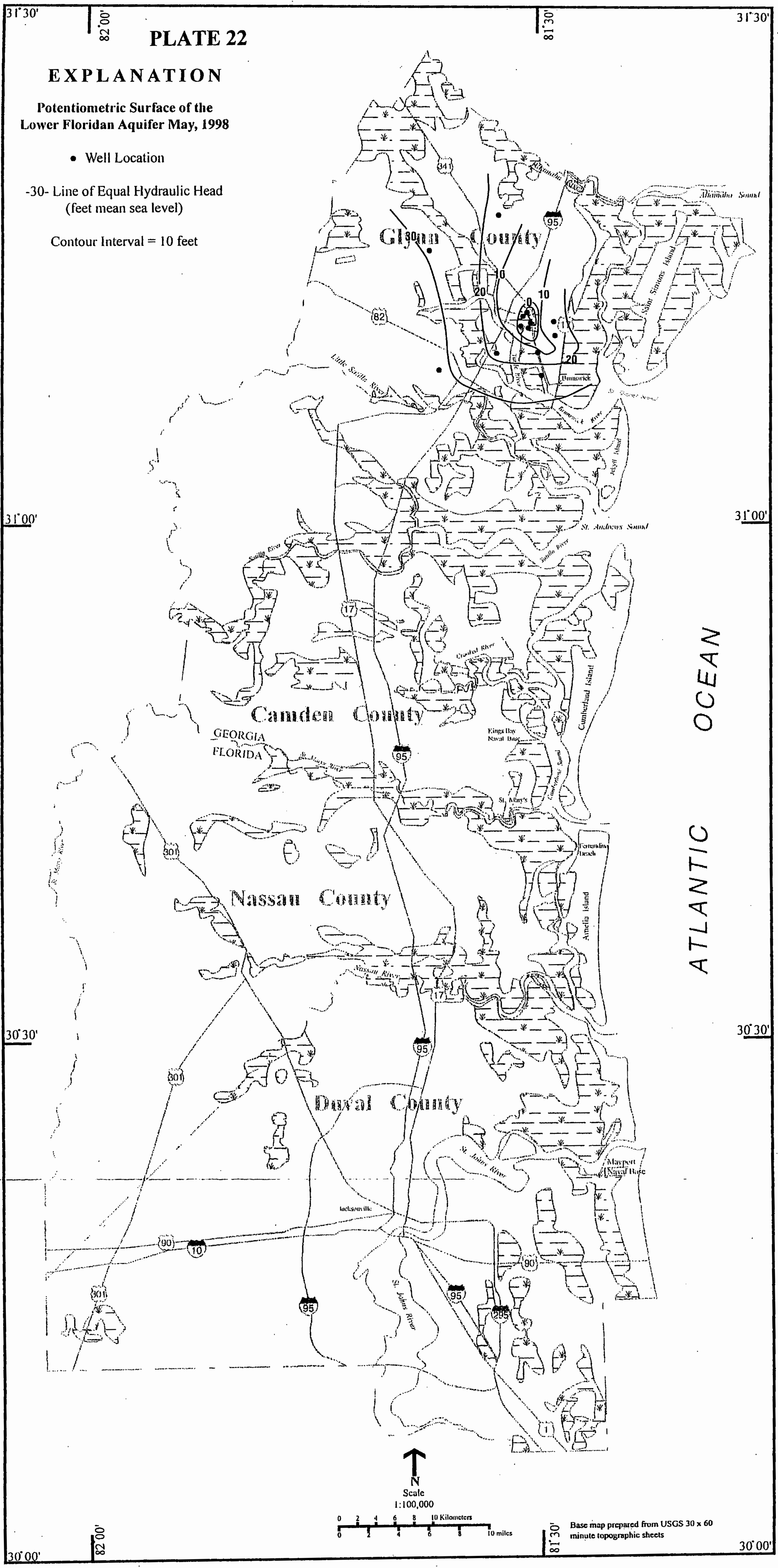
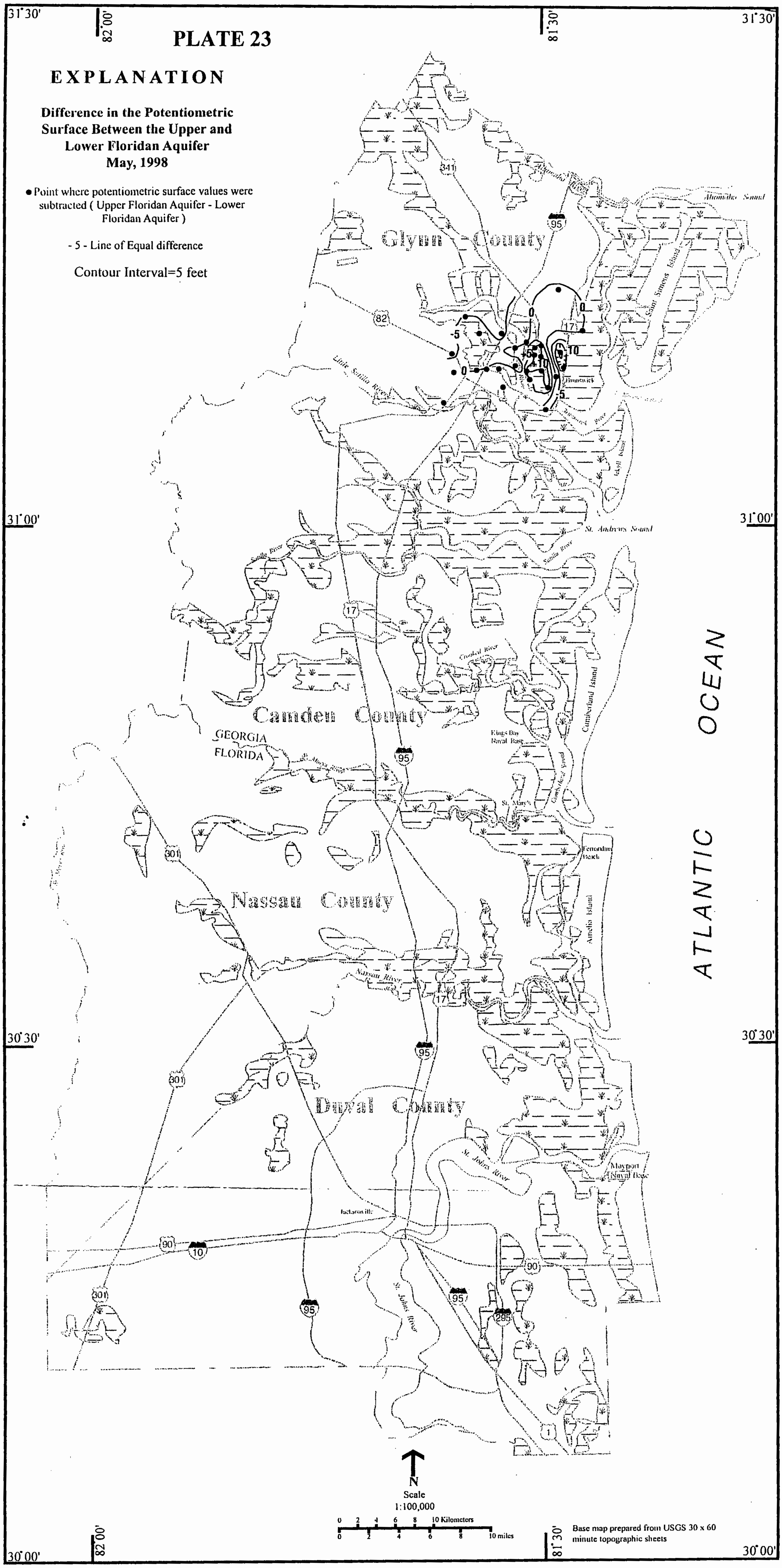


PLATE 22
EXPLANATION
Potentiometric Surface of the Lower Floridan Aquifer May, 1998
• Well Location
-30- Line of Equal Hydraulic Head (feet mean sea level)
Contour Interval = 10 feet
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Brunswick
Little Satilla River
Satilla River
Crooked River
Kings Bay Naval Base
St. Marys
Cumberland Island
Cumberland Sound
St. Andrews Sound
Jekyll Island
Saint Simons Island
Altamaha Sound
Fernandina Beach
Amelia Island
Nassau River
St. Johns River
Mayport Naval Base
Jacksonville
30
20
10
0
N
Scale 1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

PLATE 23



31°30'
82°00'
81°30'
31°30'
EXPLANATION
Difference in the Potentiometric Surface Between the Upper and Lower Floridan Aquifer May, 1998
• Point where potentiometric surface values were subtracted (Upper Floridan Aquifer - Lower Floridan Aquifer)
- 5 - Line of Equal difference
Contour Interval=5 feet
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Saint Simons Island
St. Andrews Sound
Cumberland Island
Kings Bay Naval Base
Fernandina Beach
Amelia Island
Mayport Naval Base
St. Johns River
Nassau River
Jacksonville
0
-5
10
5
31°00'
31°00'
30°30'
30°30'
N
Scale
1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets
30°00'
82°00'
81°30'
30°00'

PLATE 24

EXPLANATION

Isochlor Map of the Upper Floridan Aquifer

-1000- Line of Equal Chloride Concentration (mg/L)

● Well Control Point in which chloride>250 mg/L

Shaded Region: Chloride Concentration is between 1,000 and 2,700 mg/L

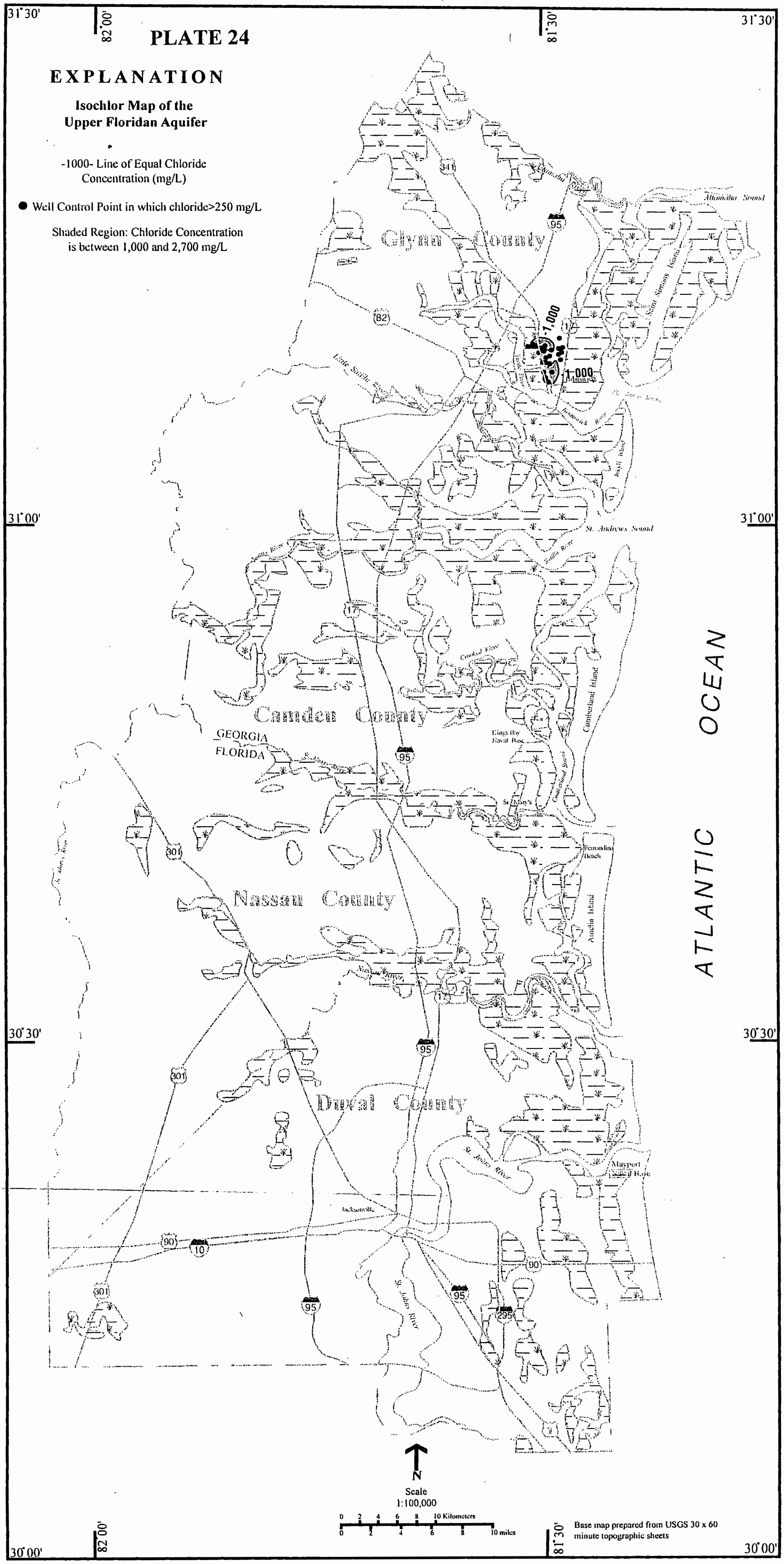
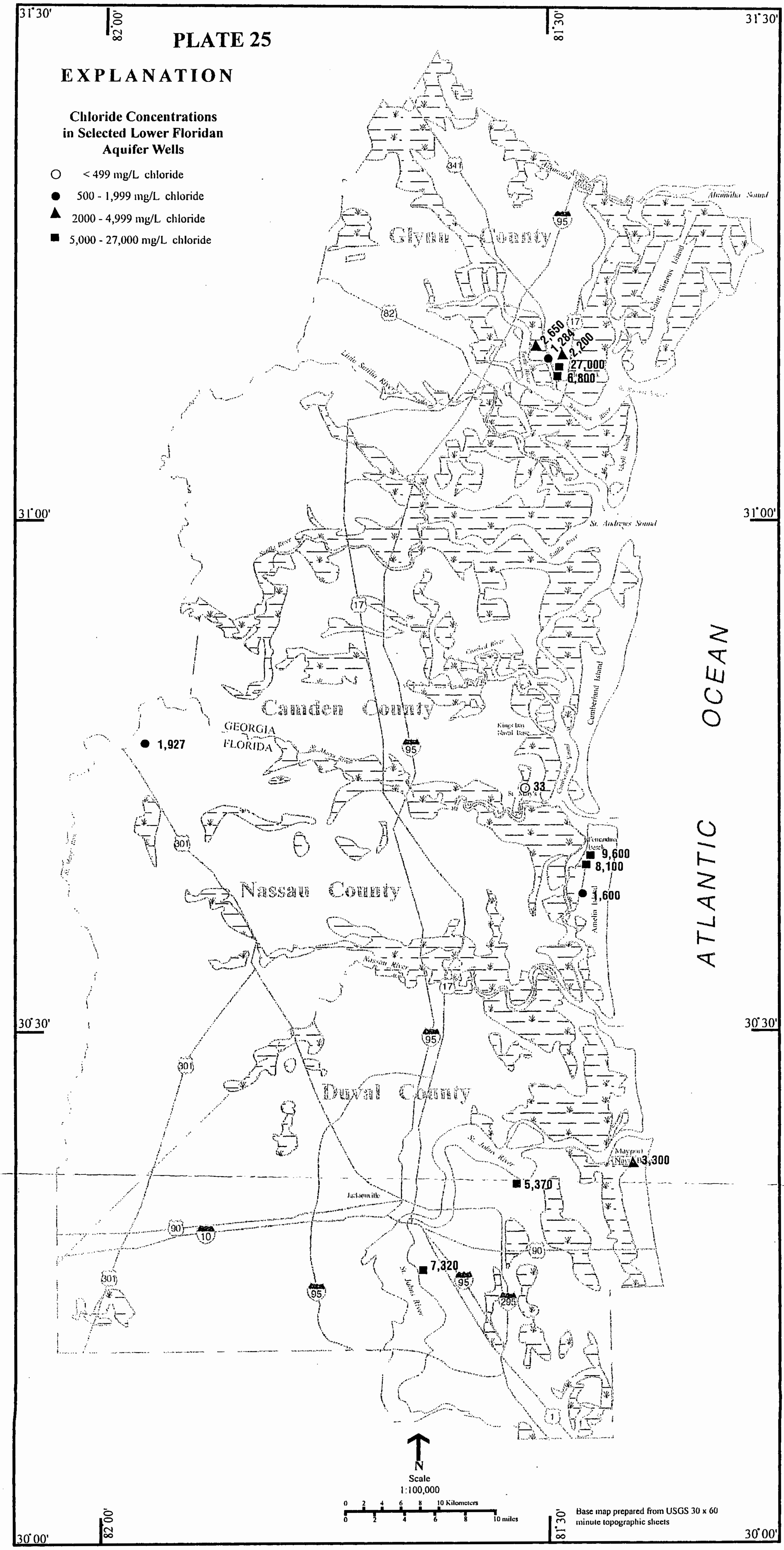


PLATE 25


EXPLANATION
Chloride Concentrations in Selected Lower Floridan Aquifer Wells
< 499 mg/L chloride
500 - 1,999 mg/L chloride
2000 - 4,999 mg/L chloride
5,000 - 27,000 mg/L chloride
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
Cumberland Island
Amelia Island
Jacksonville
2,650
1,284
2,200
27,000
6,800
1,927
33
9,600
8,100
1,600
3,300
5,370
7,320
341
95
17
82
301
10
90
295
1
N
Scale
1:100,000
0 2 4 6 8 10 Kilometers
0 2 4 6 8 10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

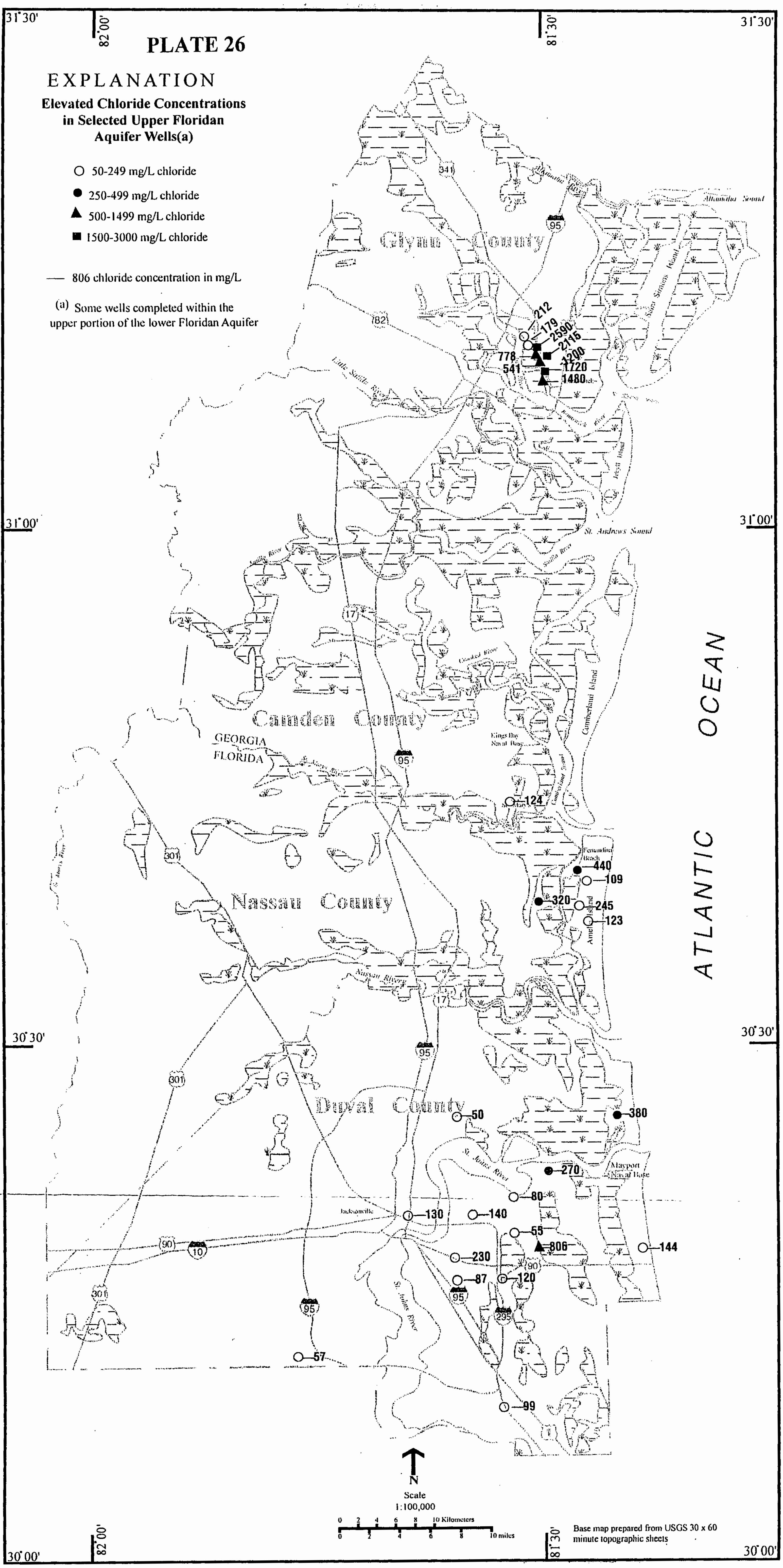


PLATE 26
EXPLANATION
Elevated Chloride Concentrations in Selected Upper Floridan Aquifer Wells(a)
50-249 mg/L chloride
250-499 mg/L chloride
500-1499 mg/L chloride
1500-3000 mg/L chloride
806 chloride concentration in mg/L
(a) Some wells completed within the upper portion of the lower Floridan Aquifer
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
St. Andrews Sound
Cumberland Island
Kings Bay Naval Base
Fernandina Beach
Amelia Island
Nassau River
St. Johns River
Mayport Naval Base
Jacksonville
212
179
2590
2115
1200
778
541
1720
1480
124
440
109
320
245
123
50
380
270
80
130
140
55
806
144
230
87
120
57
99
N
Scale
1:100,000
Kilometers
miles
Base map prepared from USGS 30 x 60 minute topographic sheets

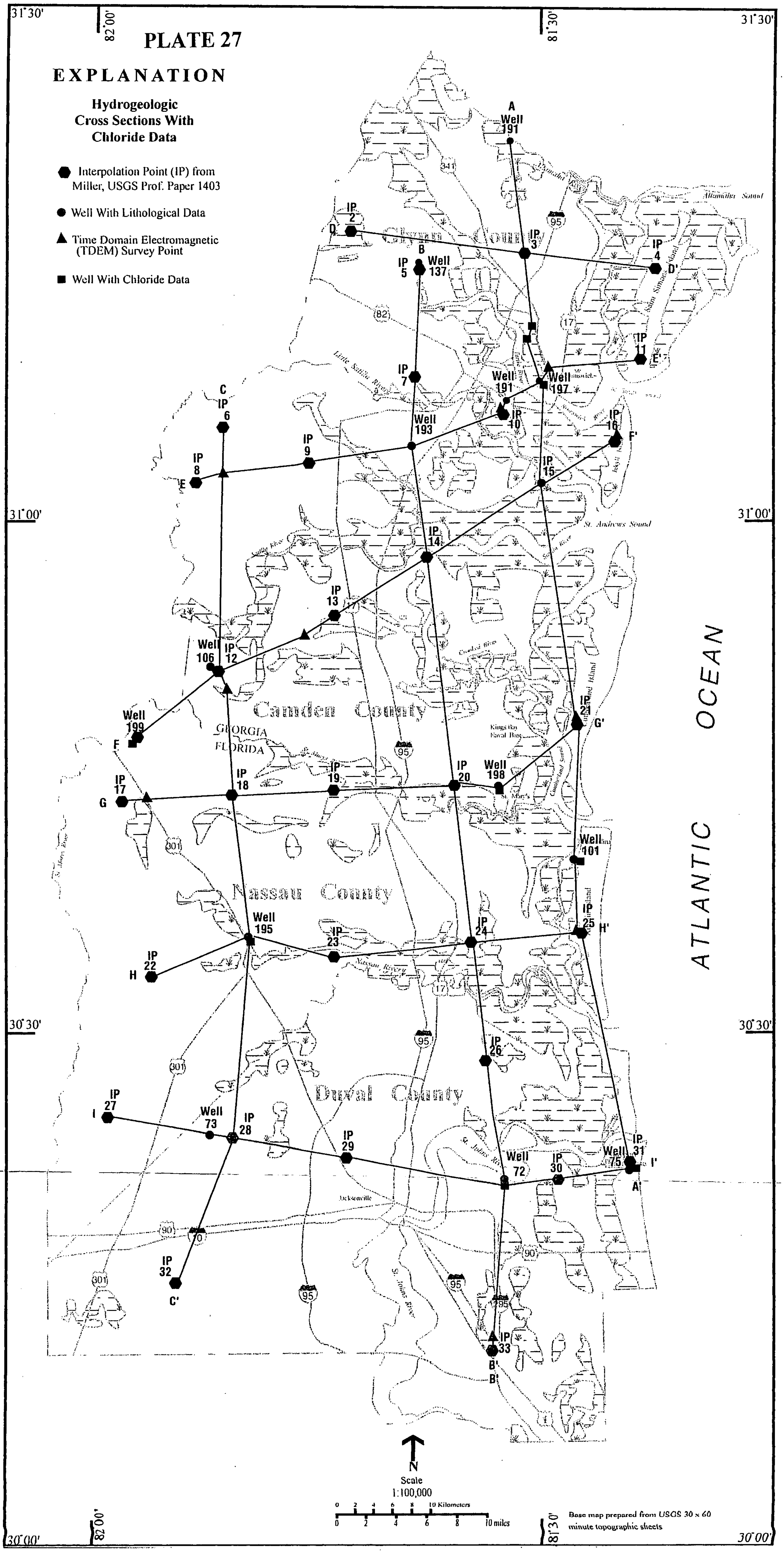


PLATE 27
EXPLANATION
Hydrogeologic Cross Sections With Chloride Data
Interpolation Point (IP) from Miller, USGS Prof. Paper 1403
Well With Lithological Data
Time Domain Electromagnetic (TDEM) Survey Point
Well With Chloride Data
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
N
Scale 1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

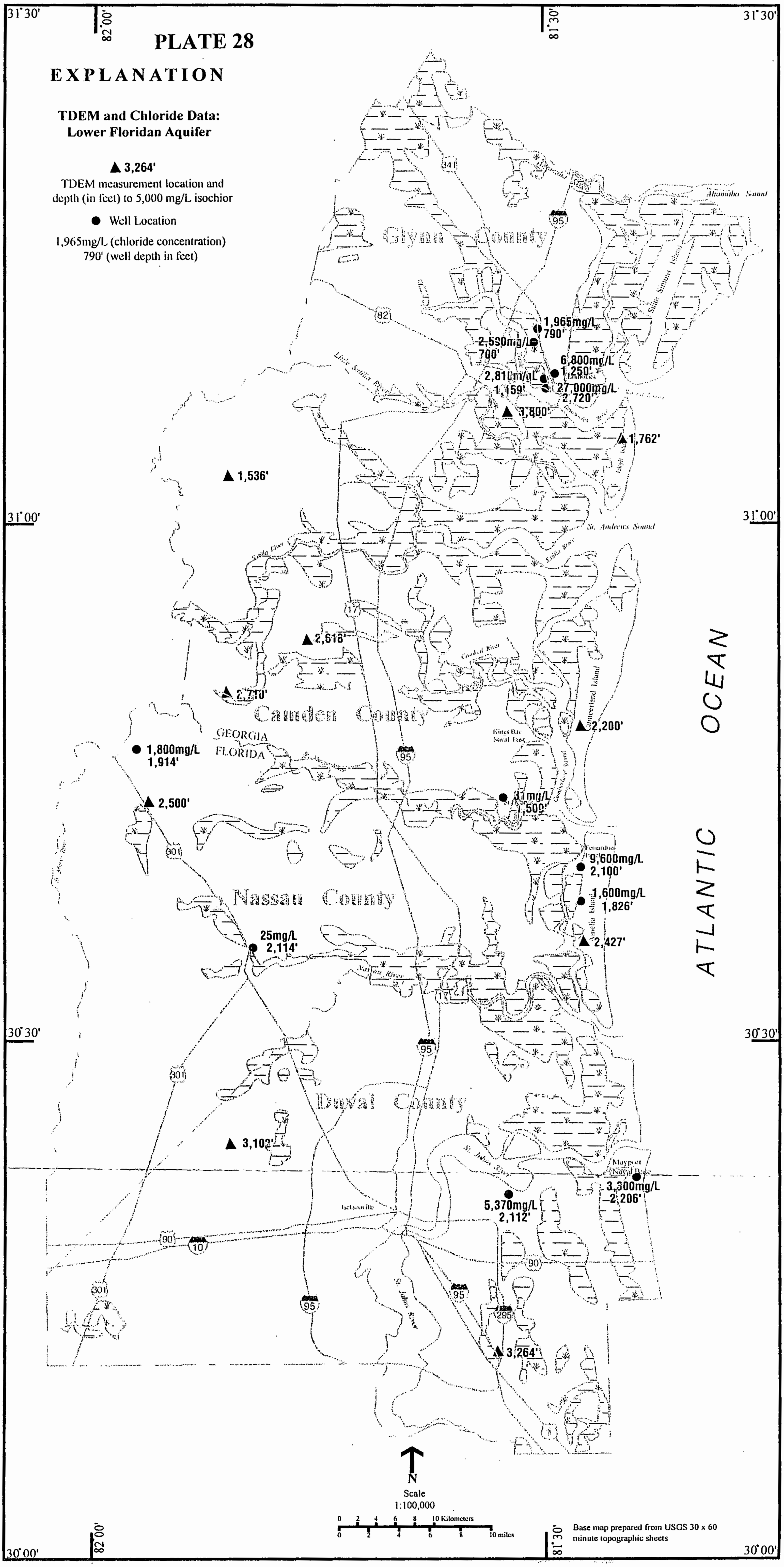
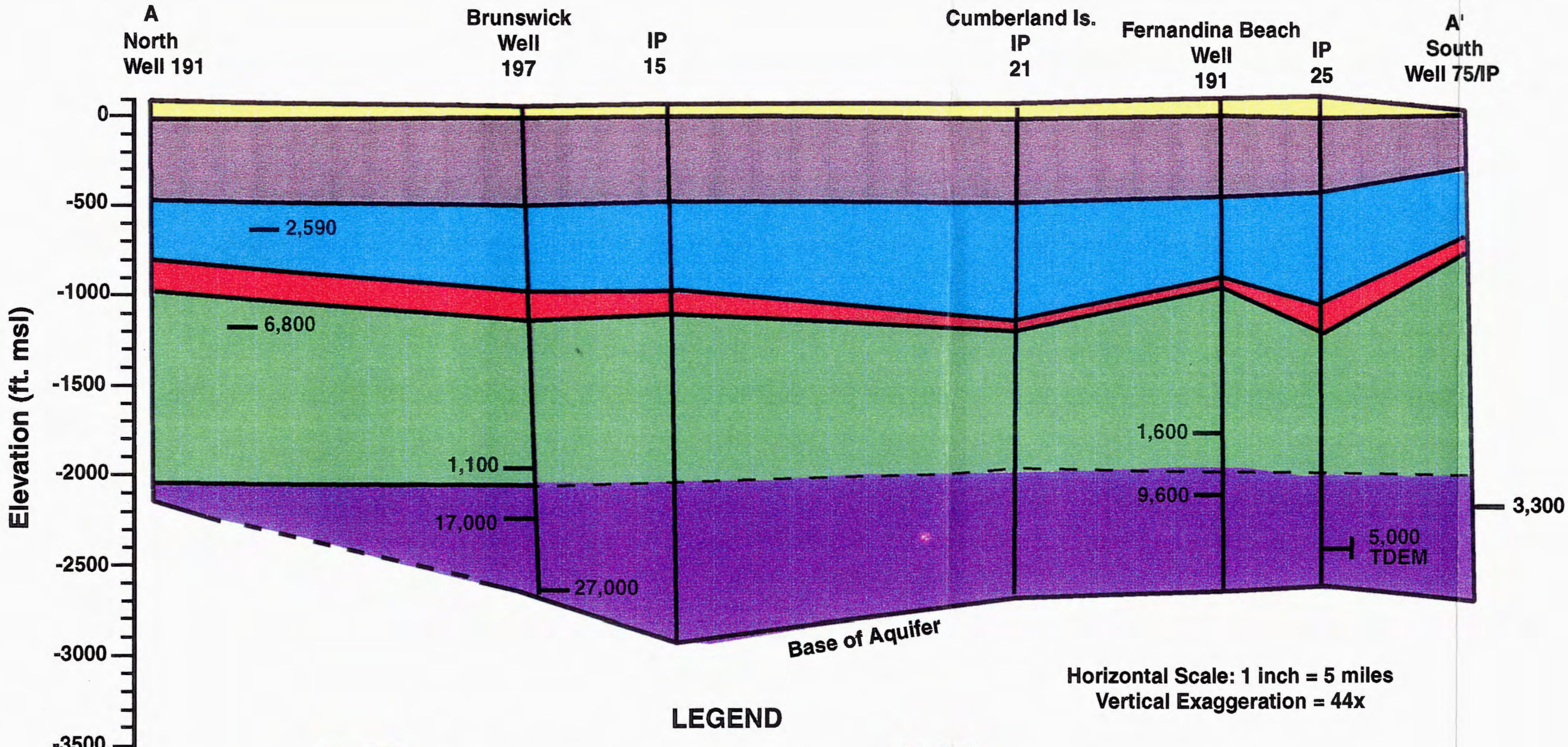


PLATE 28
EXPLANATION
TDEM and Chloride Data:
Lower Floridan Aquifer
▲ 3,264'
TDEM measurement location and depth (in feet) to 5,000 mg/L isochior
● Well Location
1,965mg/L (chloride concentration)
790' (well depth in feet)
31°30'
82°00'
81°30'
31°00'
30°30'
30°00'
Glynn County
Camden County
Nassau County
Duval County
GEORGIA
FLORIDA
ATLANTIC OCEAN
1,965mg/L
790'
2,550mg/L
700'
6,800mg/L
1,250'
2,810mg/L
1,159'
27,000mg/L
2,720'
3,800'
1,762'
1,536'
2,618'
2,710'
2,200'
1,800mg/L
1,914'
2,500'
31mg/L
1,500'
9,600mg/L
2,100'
1,600mg/L
1,826'
2,427'
25mg/L
2,114'
3,102'
3,300mg/L
2,206'
5,370mg/L
2,112'
3,264'
Scale
1:100,000
10 Kilometers
10 miles
Base map prepared from USGS 30 x 60 minute topographic sheets

Hydrogeologic Cross Section A-A' with Chloride Data



LEGEND

- Surficial Aquifer
- Upper Confining Unit (includes Miocene aquifer)
- Upper Floridan Aquifer
- Middle Semi-Confining Unit
- Lower Floridan Aquifer
- Fernandina Permeable Zone

IP = Interpolation Point (from Miller, USGS Prof. Pap. 1403)

— 1,600 refers to chloride concentration in mg/L measured at well location

5,000 TDEM: refers to the depth of 5,000 mg/L chloride concentration as inferred by time domain electromagnetic sounding measurement

PLATE 29

Hydrogeologic Cross Section B-B'
with Chloride Data

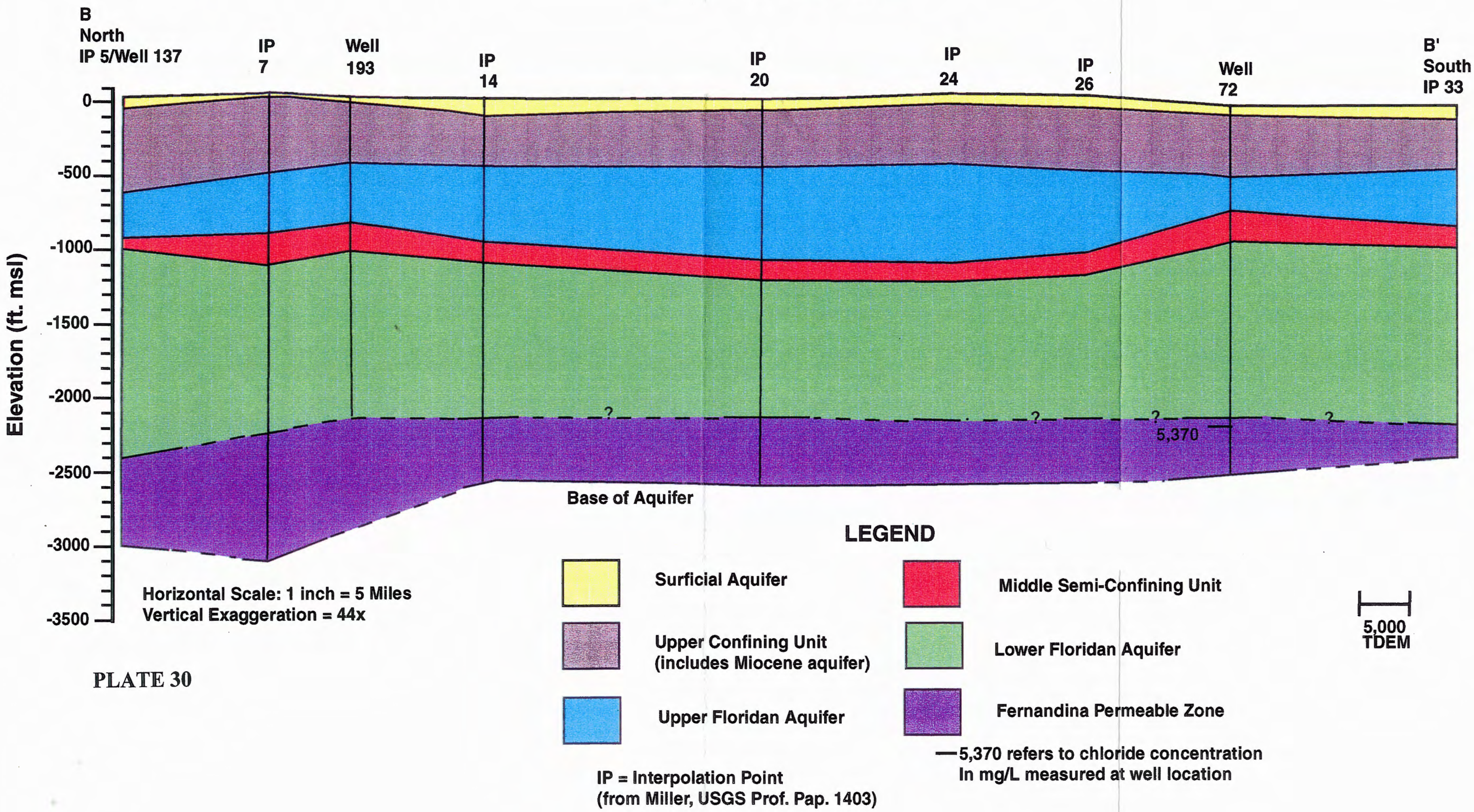
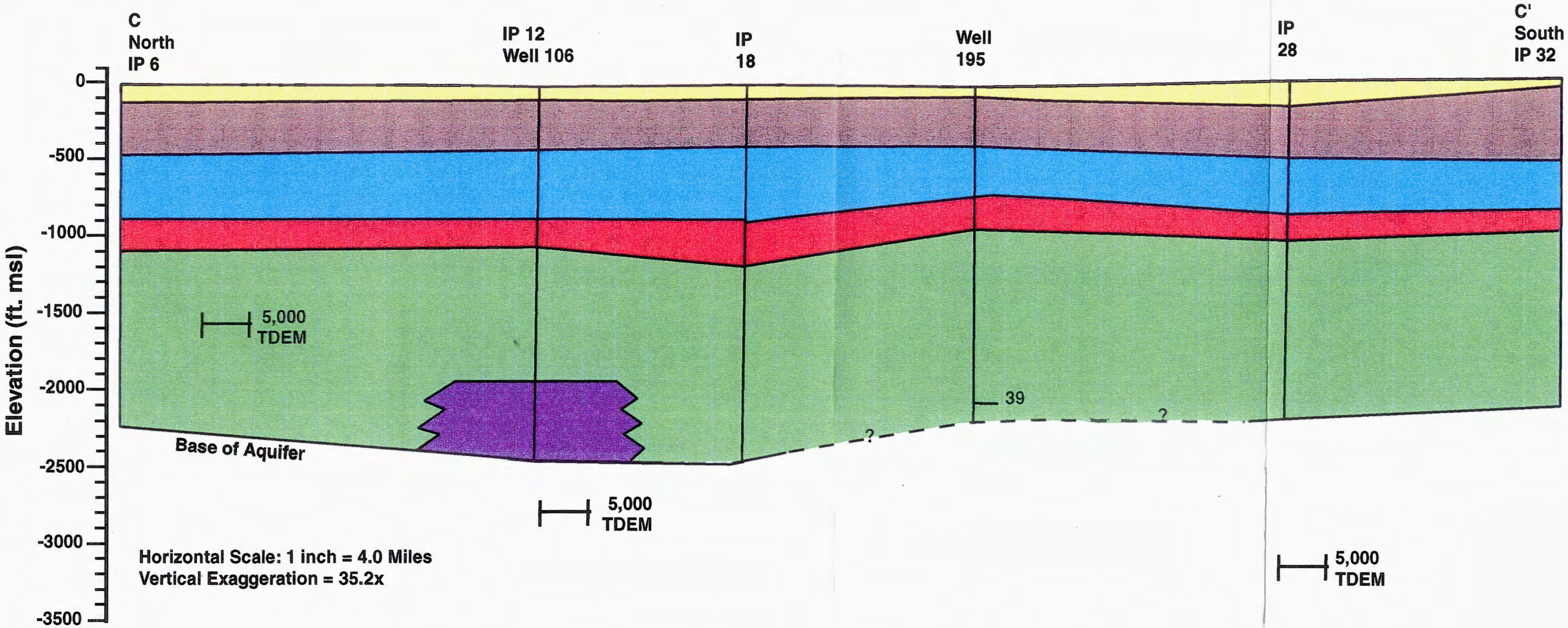


PLATE 30

Hydrogeologic Cross Section C-C'
with Chloride Data



LEGEND

- Surficial Aquifer
- Upper Confining Unit (Includes Miocene aquifer)
- Upper Floridan Aquifer
- Middle Semi-Confining Unit
- Lower Floridan Aquifer
- Fernandina Permeable Zone

5,000 TDEM: refers to the depth of 5,000 mg/L chloride concentration as inferred by time domain electromagnetic sounding measurement

IP = Interpolation Point (from Miller, USGS Prof. Pap. 1403)

—39 refers to chloride concentration in mg/L measured at well location

PLATE 31

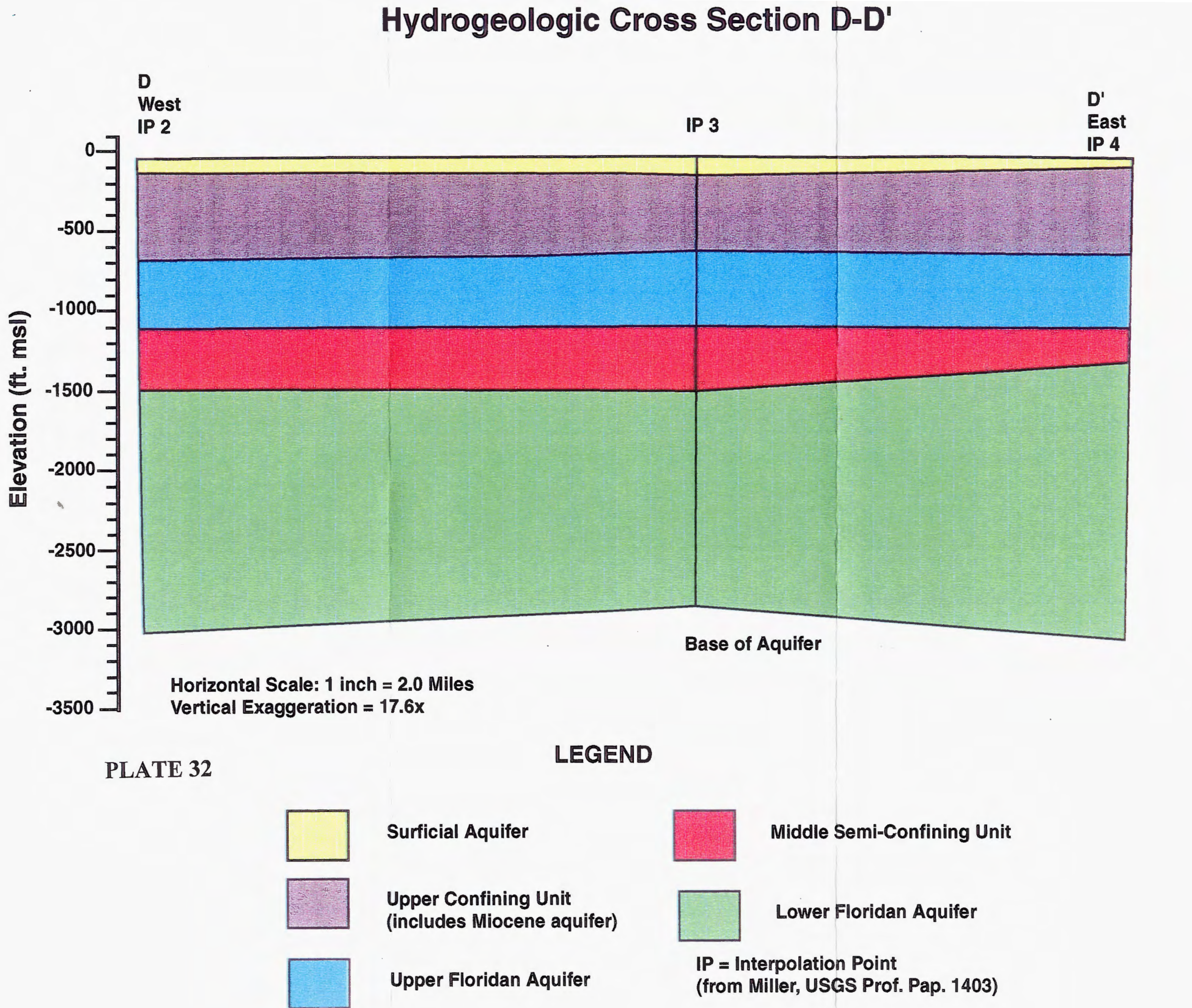

Hydrogeologic Cross Section D-D'
D
West
IP 2
IP 3
D'
East
IP 4
Elevation (ft. msl)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
Base of Aquifer
Horizontal Scale: 1 inch = 2.0 Miles
Vertical Exaggeration = 17.6x
LEGEND
Surficial Aquifer
Upper Confining Unit
(includes Miocene aquifer)
Upper Floridan Aquifer
Middle Semi-Confining Unit
Lower Floridan Aquifer
IP = Interpolation Point
(from Miller, USGS Prof. Pap. 1403)

PLATE 32

Hydrogeologic Cross Section E-E' with Chloride Data

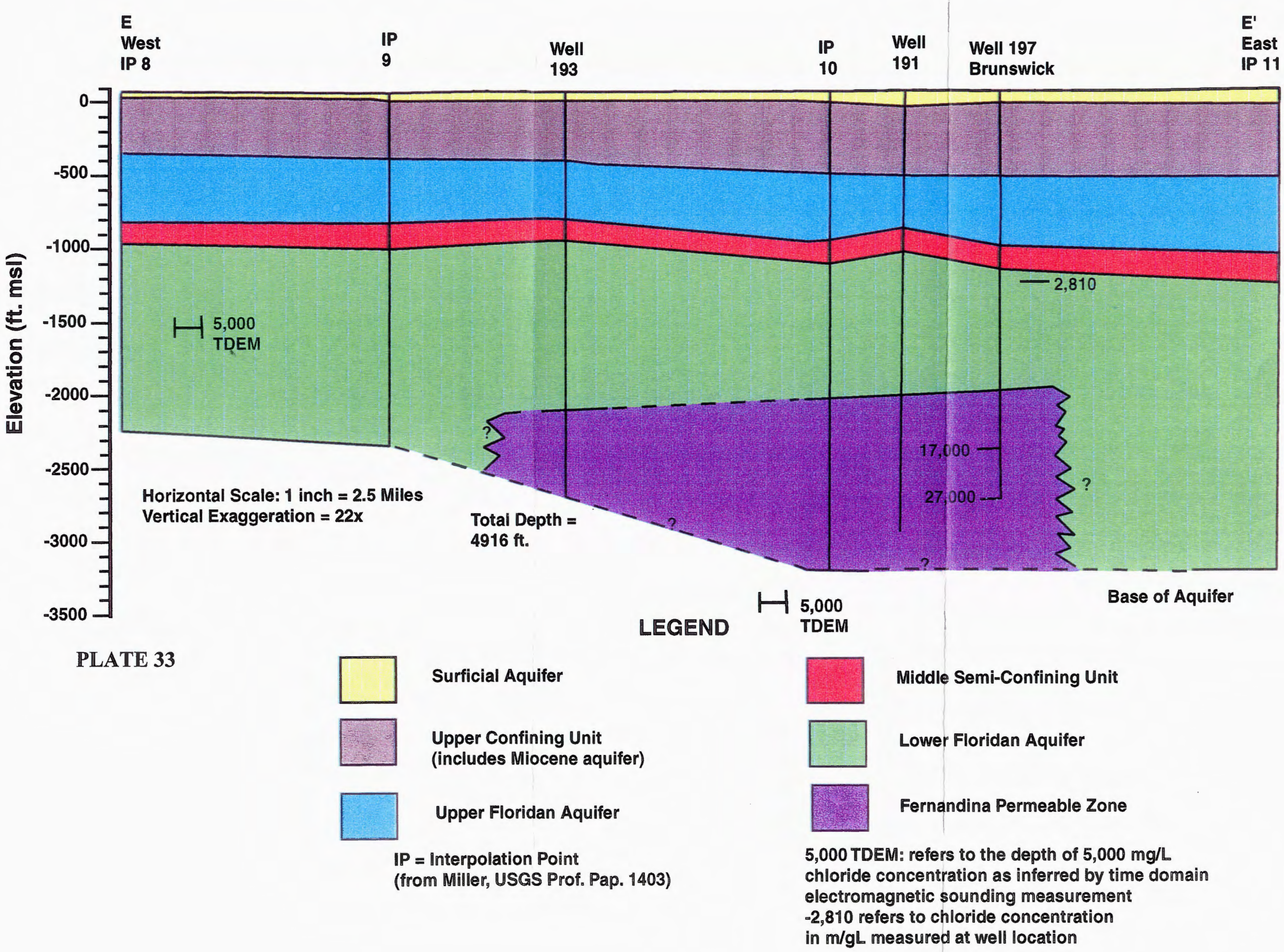
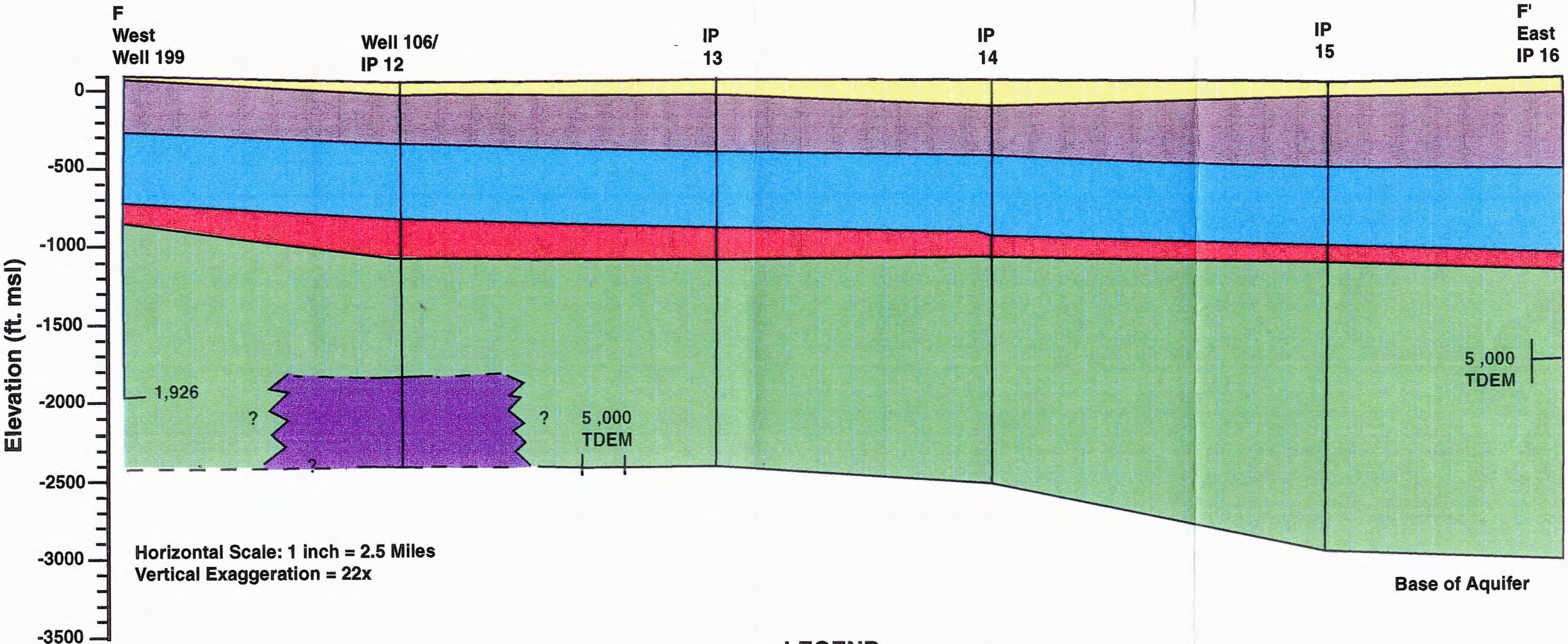


PLATE 33

Hydrogeologic Cross Section F-F' with Chloride Data



LEGEND

- Surficial Aquifer
- Upper Confining Unit (includes Miocene aquifer)
- Upper Floridan Aquifer
- Middle Semi-Confining Unit
- Lower Floridan Aquifer
- Fernandina Permeable Zone

IP = Interpolation Point
(from Miller, USGS Prof. Pap. 1403)

TDEM refers to the depth of 5,000 mg/L chloride concentration as inferred by time domain electromagnetic sounding measurement

PLATE 34

Hydrogeologic Cross Section G-G' with Chloride Data

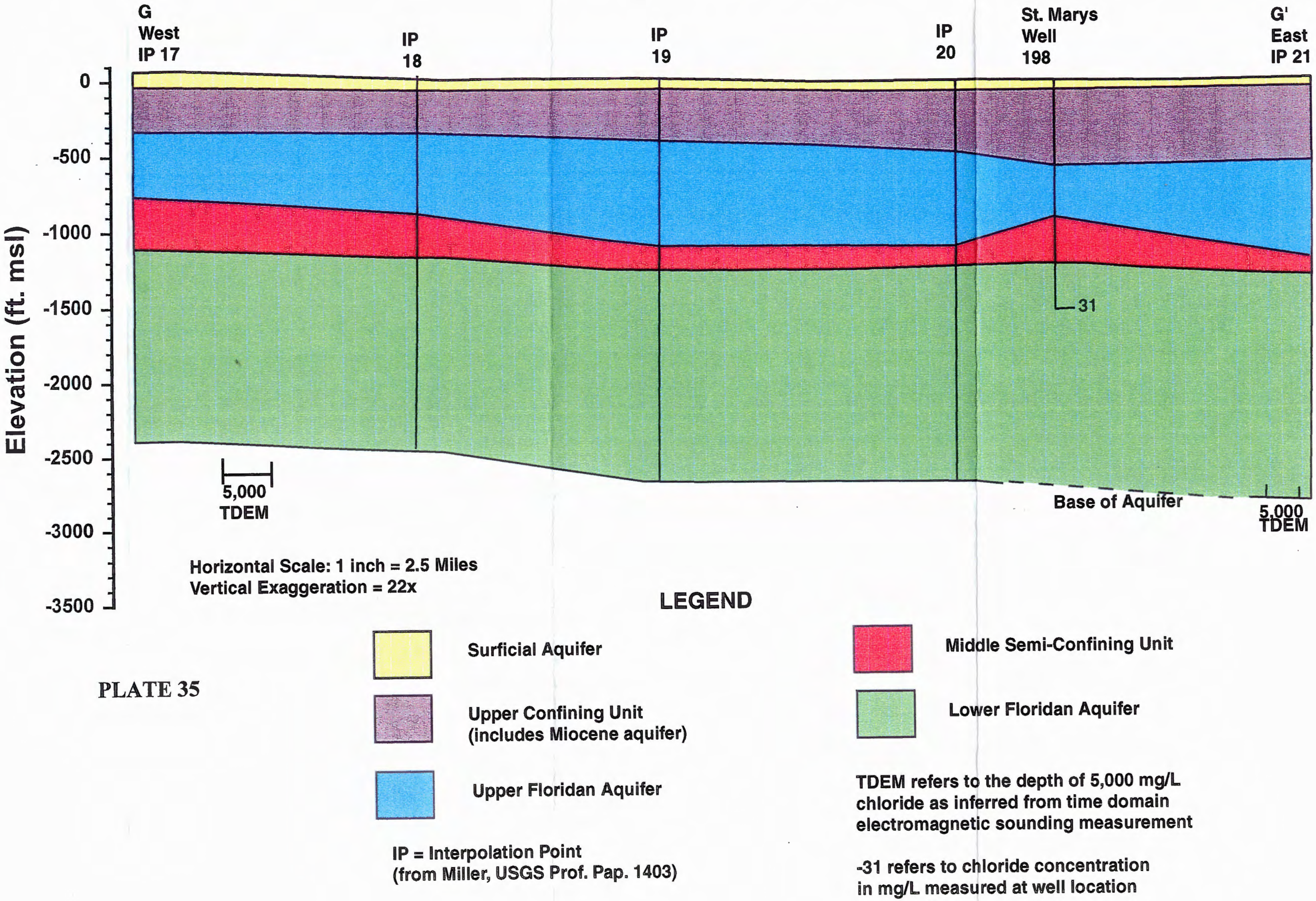


PLATE 35

Hydrogeologic Cross Section H-H' with Chloride Data

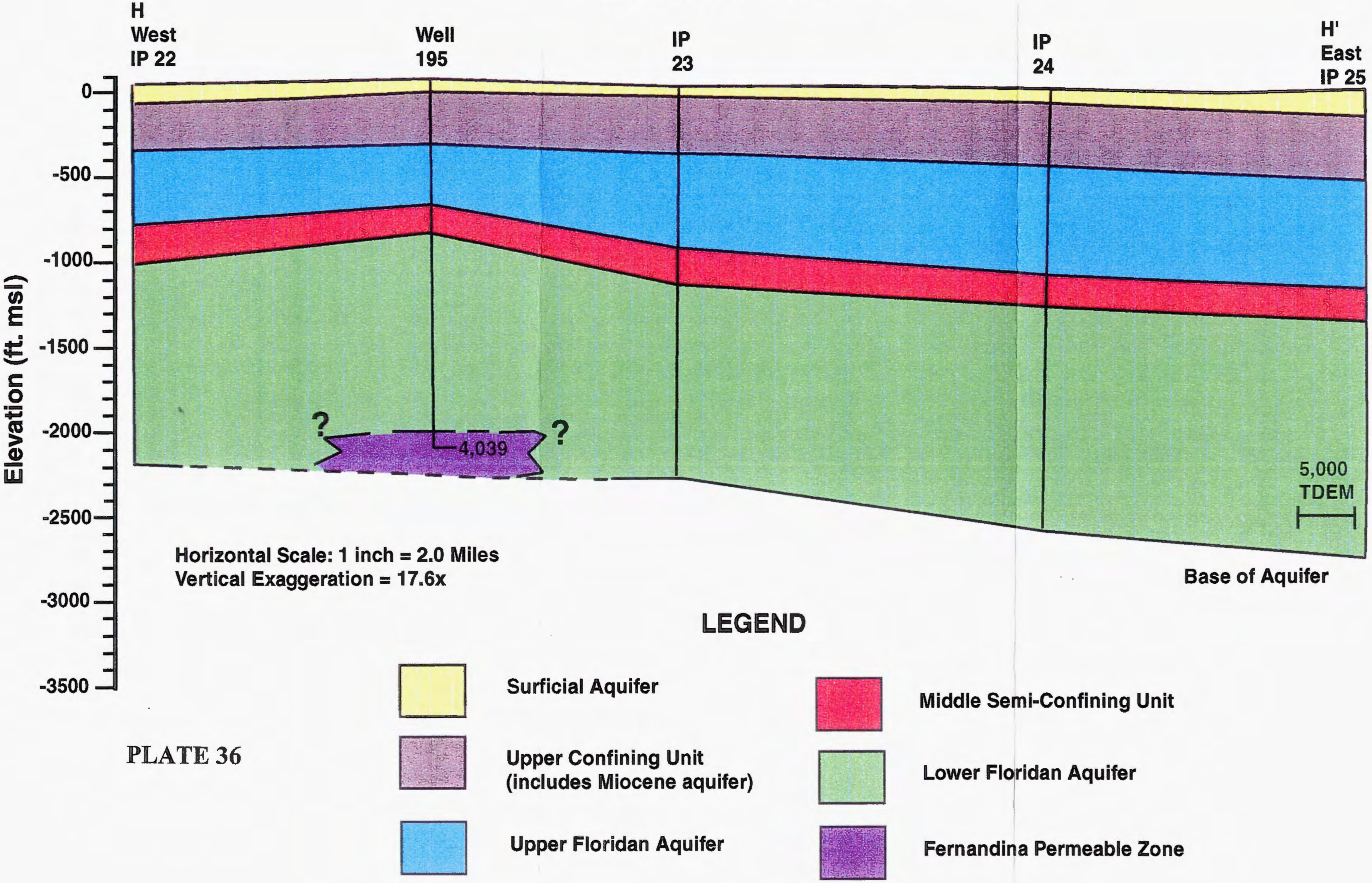


PLATE 36

IP = Interpolation Point
(from Miller, USGS Prof. Pap. 1403)

-4,039 refers to chloride concentration in mg/L measured at well location

5,000 TDEM : refers to the depth of 5,000 mg/L chloride concentration as inferred by time domain electromagnetic sounding measurement

Hydrogeologic Cross Section I-I' with Chloride Data

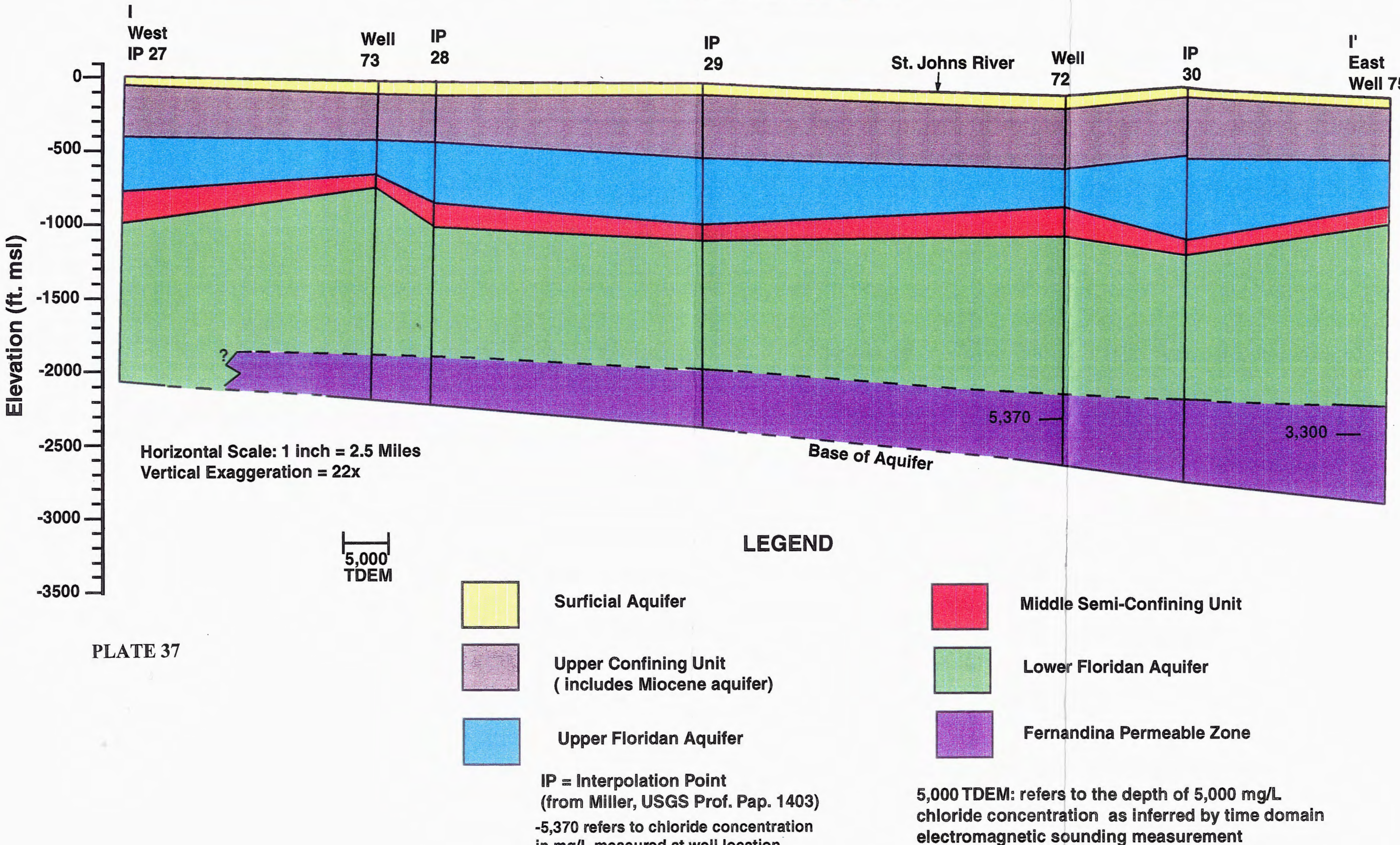


PLATE 37

Cost:$1860
Quantity: 100