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ASSESSMENT OF DEEP WELL DATA
BREVARD AND INDIAN RIVER COUNTIES
NOVEMBER 2003

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Prepared for

St. Johns River Water Management District
Palatka, Florida

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EXECUTIVE SUMMARY

The hydrogeologic information from ten (10) Class I Injection Well Systems in Brevard and Indian River counties was evaluated to identify areas suitable for disposal of potable water by-product. Potable water by-product is generated by municipal water suppliers during the desalination process. The results of this study are presented in this report.

Based on this evaluation the primary injection zone extends from the Sykes Creek site in Merritt Island in northern Brevard County to southern Florida. The northward extent beyond the Sykes Creek facility has not yet been determined due to a lack of available information. The westward extent of the primary injection zone beyond the Palm Bay exploratory well in Brevard County has not yet been determined due to a lack of available information.

There is a potential to use the zone directly below the middle confining unit for disposal of potable water by-product. This would be a less costly alternative for a utility than drilling to the primary injection zone. The areas around Merritt Island, Cocoa, Rockledge, and possibly Titusville in Brevard County, would have the highest potential, because water in excess of 10,000 mg/L TDS has been identified in the upper Floridan aquifer (McGurk et al. 1998) in this area. The Melbourne, West Melbourne, and Palm Bay areas would have a moderate potential, because there is some uncertainty regarding the exact depth of the lowermost USDW.

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1.0 PURPOSE AND SCOPE

The purpose of this project is to delineate subsurface areas within the southern St. Johns River Water Management District (SJRWMD) that are potentially suitable for potable water by-product disposal. In accordance with Chapter 62-528 F.A.C., the ambient groundwater within the potential injection zones must have a TDS content greater than 10,000 mg/L. No upward fluid migration is permitted to impact groundwater with less than 10,000 mg/L [defined as an Underground Source of Drinking Water (USDW)] as a result of deep well injection. The vertical hydraulic conductivities of the overlying confining beds in the study area were tabulated from existing consulting reports on ten (10) injection well sites. Individual confining beds and producing zones were correlated using geophysical logs (gamma, acoustic, and electric) and lithologic logs. Maps and a cross section are presented that delineate the hydrogeologic units within the study area.

2.0 LOCATION OF STUDY AREA

The study area (Figure 1) is located in Brevard and Indian River counties, Florida, between longitude 80°42'20" and 80°25'20". A total of ten (10) injection wells are present within the study area. There are eight (8) facilities presently using injection wells for disposal of municipal or industrial waste in the area. Of these facilities, six (6) are owned by municipalities and use injection wells for disposal of treated domestic waste. The other two (2) facilities use injection wells for disposal of treated industrial waste. All these injection wells discharge effluent to the primary injection zone, which is located at depths between -1950 feet NGVD and -2600 feet NGVD in the study area. There is also one (1) inactive injection well system located at the D.B. Lee Wastewater Treatment Plant (WWTP) in Melbourne and an exploratory well site in Palm Bay that has not yet been permitted for use as an injection well. In addition to the injection well sites, data from the Upper Floridan aquifer water supply wells at the City of Melbourne Lake Washington well field site was evaluated during this study.

3.0 OTHER INVESTIGATIONS

The technical reports reviewed for this project were developed by the U.S. Geological Survey, Florida Geological Survey, SJRWMD, and private consultants. The U.S. Geological Survey reports include Brown et al. (1962), Miller (1986), and O'Reilly et al. (2003).

Brown et al. (1962) presents the first comprehensive report on the geology and water resources of Brevard County. Due to a lack of information, the report did not address the deeper portions of the FAS.

Miller (1986), working under the Regional Aquifer-System Analysis (RASA) program, presented results of a regional study of the FAS. Although no specific data was included for Brevard County, the report did present structure contours and isopach lines of various units in the FAS in the study area.

O'Reilly et al. (2003) completed a water resource investigation of the Lower Floridan aquifer in east-central Florida that included some wells in Brevard County, but none in Indian River County. The data points used for the O'Reilly study were primarily concentrated in Orange County. The O'Reilly study recognizes a middle semiconfining unit in Brevard County that separates the Upper from the Lower Floridan aquifer.

The Florida Geological Survey reports include Chen (1965), Vecchioli et al. (1986), Scott (1988), Scott et al. (1991) and Duncan et al. (1994). Chen (1965) published a report on the regional lithostratigraphy of the Floridan Peninsula. Vecchioli et al. (1986) established the current hydrostratigraphic nomenclature used in the State of Florida. Scott (1988) did a regional study on the Hawthorn Group in peninsular Florida. Although his study did not specifically address the FAS in Brevard County, it does evaluate the structural geology in the study area. Scott et al. (1991) presented the hydrogeologic framework of each water management district. Duncan et al. (1994) did a comprehensive study of the framework of the Lower Floridan aquifer in Brevard County using all the deep well data available at the time. The Duncan report is herein used as a guide for correlations.

SJRWMD has numerous technical publications on many aspects of the hydrogeology in Brevard and Indian River counties. SJRWMD reports for this area include Skipp (1988), Toth (1988), and McGurk et al. (1998). Skipp (1988) completed groundwater modeling of the FAS in east and central Florida. Toth (1988) investigated saltwater intrusion in the coastal areas of Brevard, Indian River, and Volusia counties. McGurk et al. (1998) constructed a contour map of the estimated altitude of water in the FAS having chloride concentrations exceeding 5,000 mg/L in east-central Florida.

Consulting reports reviewed for this project include; CH2M HILL (1979, 1986, and 1987), Dames & Moore (1985), Geraghty & Miller (1984, 1986, and 1988), HydroDesigns (1989,1989b, 1990, and 1991), L.S. Sims & Associates, Inc. (1998, 1999, and 2001), Montgomery Watson Harza (2003), and Hartman & Associates (2003).

The CH2M HILL reports are all construction and testing documents for injection wells drilled at Hercules (now Ocean Spray Cranberries, Inc.), the City of West Melbourne, and Port Malabar (now City of Palm Bay). The Geraghty & Miller reports are also construction and testing reports for injection wells in the area. They include Harris (now Intersil) (1984), Merritt Island (now Brevard County Sykes Creek Regional WWTP) (1986), and the City of Melbourne D.B. Lee WWTP (1988). The HydroDesigns construction reports are for the City of Melbourne Grant Street WWTP (1989) and the City of Rockledge (1991). The HydroDesigns 1989b report describes testing procedures to determine possible mechanisms for vertical fluid movement in the D.B. Lee injection well. The 1990 report describes testing of a 1200 foot deep exploratory well at the Lake Washington Reverse Osmosis Plant. The L.S. Sims & Associates, Inc. reports are for the City of Melbourne Grant Street WWTP (1998) and the City of Melbourne D.B. Lee WWTP (1999 and 2001). The 1998 and 1999 reports are assessments of the hydrogeology at the two sites.

The L.S. Sims & Associates 2001 report is a document that was attached to a petition for a minor aquifer exemption for a portion of the FAS around the D.B. Lee injection well. As a part of the petition, a deep exploratory well was drilled at the D.B. Lee site to determine the base of the USDW. Montgomery Watson Harza (2003) presented a report on a deep exploratory well at the Sykes Creek site. The intention of the exploratory well was to determine the base of the USDW. Hartman & Associates (2003) reported on the construction of an exploratory well for the City of Palm Bay. The purpose of the well was to determine if zones were available for injection in southwestern Palm Bay.

4.0 METHODOLOGY

Geophysical and lithologic logs were obtained for all of the injection wells in Brevard and Indian River counties. The lithology of the wells was determined by comparing lithologic, gamma, acoustic, and induction logs. The criteria used for unit designation were generally taken from Duncan et al. (1994) and are discussed in the geology and hydrogeology sections of this report. Other logs (caliper, temperature, short/long normal resistivity, and flowmeter) were also considered.

The lithologic logs were available from the Florida Geological Survey for nearly all of the deep wells. The logs contain information on rock type, color, porosity, texture, matrix, induration, accessory minerals, and fossils content. During review of the lithologic logs, particular attention was paid to the benthonic foraminifera assemblages if identified. The presence of Dictyoconus cookei and Dictyoconus americanus are good indicators that the rock is from the Avon Park Formation. Helicostegina gyralis commonly occurs near the top of the Oldsmar Formation.

The gamma ray log contains records of natural gamma radiation levels with depth within the cased and uncased portions of the injection wells. Higher gamma activity is associated with minerals that contain high percentages of potassium, uranium and thorium in their lattice structure. Higher gamma radiation levels can be associated with uranium and thorium concentrated in phosphorites, clays, dolostone and possibly chert.

There are several gamma ray marker beds that are used to differentiate hydrogeologic units within the study area. In some wells the gamma ray marker beds are distorted or not present. This is probably due to cavities or larger hole diameters.

The acoustic velocity log [Borehole Compensated Sonic (BHC)] records measurements of the sonic transit time between the acoustic logging sonde transmitter and receiver(s). The borehole wall geometry, formation bedding, fractures, porosity, formation matrix, and fluid properties all affect the transit time. Generally, the denser (dolomitic) formations have faster transit times than less indurated and more porous (limestone and clay) formations. Fractured zones sometimes exhibit "cycle skipping" on the acoustic logs making them easily identifiable. Cycle skipping is an attenuation of the first sound pulse followed by a subsequent pulse not attenuated (Keys and MacCary 1983). Attenuations (slower transit times) are also apparent in the water-filled cavernous zones. Acoustic logs can be used to evaluate formation lithology and porosity. Duncan et al. (1994), utilizes calculated porosity values from these logs as a criterion for identifying potential confining beds.

The induction log is a record of the electrical conductivity (reciprocal of resistivity) of the formation and fluids within the radius of the sonde. An alternating electrical current is transmitted into the formation by the logging sonde. The transmitted current induces the flow of eddy currents, which set up secondary magnetic fields that induce voltage in the receiving coil. The magnitude of the signal received by the recording instrument is proportional to the conductivity or inversely proportional to the resistivity, of the formation. In general, dolostones and denser rocks are less conductive than limestones and poorly indurated sediments. Therefore, the denser rocks give lower deflections on logs. Groundwater with a higher TDS concentration is more conductive than fresher, less saline groundwater and can dominate the influence on conductivity in highly porous or permeable rocks. For this reason, highly fractured, dense dolostones saturated with high TDS waters can appear as conductive units. Electric logs are sometimes run in the open borehole to evaluate borehole fluid salinity variation with depth.

Cassettes containing wire line video surveys and written descriptions of the boreholes and casings with depth are available for all of the deep wells considered in this document. The video surveys are useful in identifying vertical lineaments, cavities, flow zones, and confining zones. Limestones are generally whiter than dolomites, which tend to be grayish to brownish on the color surveys. Also limestone tends to have a larger hole diameter. The recent video surveys of the Intersil injection wells showed density differences at the base of injected effluent on the top of the high TDS formation water. Horizontal flow was also noted in the primary injection zone. The Sykes Creek exploratory/monitor well video survey shows water entering the borehole from highly porous limestone and causing vortex eddies.

Temperature logs are the continuous records of fluid temperature immediately surrounding a sensor in the borehole. They can be used to determine inner borehole flow, temperature gradients, static water levels, correction of resistivity measurements, and to locate cement behind casings. In southern Florida the temperature survey can be used to locate the boulder zones by the presence of much colder water. In Brevard and Indian River counties the temperature survey normally shows an abrupt cooling at the top of the injection zones followed by a return to a normal temperature gradient with fluctuations at major cavities.

The caliper log is a record of the average borehole diameter. It is used to evaluate the output of other geophysical tools (borehole compensation) and to calculate hole volume. The caliper log can also be utilized to evaluate lithology. Soft limestones tend to be washed out (larger hole diameter) and hard crystalline limestone and dolostone have gauge holes (smaller hole diameter). Cavities are easily discerned on caliper logs by abrupt increases followed by abrupt decreases in hole diameter.

Long and short normal electric logs measure the apparent resistivity of a volume of rock surrounding the electrodes on the borehole geophysical tool. Short normal measurements record the apparent resistivity of the invaded zone (borehole in most cases). Long normal measurements are more indicative of the apparent resistivity away from the invaded zone.

The measured resistivity is affected by lithology, pore water quality, and pore geometry. The resistivity logs show no or very little response in the saline portion of the Lower Floridan aquifer in Brevard and Indian River counties. Resistivity approaches zero in saline water and loses bed definition.

5.0 DESCRIPTION OF DEEP WELLS IN THE AREA

Data from the following wells were used to construct the maps and cross section presented in this report. Information on the location of the base of the USDW was derived from the consulting reports associated with these deep wells. Figure 2 is a contour map depicting the base of the USDW. Appendix A contains relevant construction data on the deep wells.

5.1 Ocean Spray Injection Well System

The Ocean Spray Cranberries, Inc., injection well is located at latitude 27˚ 35' 07" and longitude 80˚ 29' 05". The well was originally owned by Hercules, Inc., and was constructed in 1986. The Ocean Spray facility is approximately nine (9) miles east of the barrier island and near Interstate 95. The injection well is 3005 feet deep with 2378 feet of 10-inch steel casing and 2355 feet of 6-inch FRP inner injection tubing. A multi zone monitor well at the site monitors intervals at 880 to 931 feet bls, 1387 to 1451 feet bls, and 1905 to 1963 feet bls. Technical information acquired during the drilling of the exploratory well indicated that the base of Upper Floridan aquifer is approximately 1400 feet bls. The TDS concentrations in samples collected from the 1387 to 1451 feet bls monitor zone are consistently over 10,000 mg/L.

5.2 South Beaches Injection Well System

The Brevard County South Beaches injection well is located at the South Beaches Regional Water Reclamation Facility just off of State Road A1A in Melbourne Beach near latitude 28˚ 4' and longitude 80˚ 32'. The permit to drill the well was issued by the then Florida Department of Environmental Regulation in 1982 and the well was completed in early 1985. The injection well is 2916 feet deep and has 2080 feet of 20-inch casing. There are three monitor wells at the site with monitor zone intervals from 300 to 350 feet bls, 1200 to 1320 feet bls, and 1550 to 1700 feet bls. Data collected during the drilling of the injection well indicates that the base of the Upper Floridan aquifer is located at a depth of approximately 1200 feet bls. The TDS data from the 1200 to 1320 foot monitor zone was initially about 10,000 mg/L. The TDS concentrations from the 1550 to 1700 foot monitor zone were initially greater than 15,000 mg/L. Since the injection well began operation, TDS in the 1200 to 1320-foot zone has increased, and the TDS in the 1550 to 1700-foot zone has decreased to approximately 4000 mg/L. FDEP has advised the county that vertical migration of effluent has occurred and the well is not in compliance with the permit to operate the system. This injection well system could be in an area where there is poor confinement overlying the primary injection zone. However, the lithologic and geophysical logs indicate that this should be an area suitable for injection. The vertical migration of fluids may be related to the well’s construction.

5.3 Palm Bay Injection Well System

The Palm Bay injection well is located approximately ten (10) miles east of the barrier island at latitude 28˚ 01' 35" and longitude 80˚ 35' 57". Construction began on the well in June of 1986, and was completed in January of 1987. The injection well is 3000 feet deep and contains 2050 feet of 20-inch inner casing. A multi-zone monitor well at the site monitors intervals from 400 to 472 feet bls and 1534 to 1650 feet bls. The base of the USDW has been identified at a depth of 1450 feet bls as determined by water quality testing during well construction. The TDS of the lower monitor zone is consistently greater than 10,000 mg/L. The exact position of the depth to the base of the USDW at this site is not certain. The nearby Intersil and Grant Street injection wells show the base of the USDW at depths ranging from 1200 to 1250 feet bls.

5.4 Palm Bay Exploratory Well

The City of Palm Bay recently drilled a 2600 foot deep exploratory well near Interstate 95 at latitude 27˚ 55' 49" and longitude 80˚40' 9". The base of the middle confining unit was identified at a depth of approximately 1280 feet bls. The borehole geophysical logs (resistivity and conductivity) showed dramatic shifts at approximately 1400 feet bls, indicative of more saline water. Drill stem water samples analyzed for chlorides only, showed a moderate increase at this depth. The TDS of the drill stem water samples was greater than 10,000 mg/L at depths below 1580 feet bls.

5.5 Intersil Injection Well System

The Intersil injection well system is located just off Palm Bay Road near latitude 28˚ 2' 33" and longitude 80˚ 36' 27". Construction of the injection well system commenced in October 1985 and was completed in April 1986. There are two injection wells at the site. They are both approximately 2300 feet deep with 2020 feet of 8-inch inner casings. There is one multi-zone monitor well with monitor zone intervals at 430 to 550 feet bls and 1488 to 1527 feet bls. The base of the USDW was identified at a depth of approximately 1200 feet bls during well construction. The TDS of the deep monitor zone is consistently greater than 20,000 mg/L.

5.6 West Melbourne Injection Well System

The West Melbourne injection well system is located just south of Highway 192 at latitude 28˚ 4' 14" and longitude 80˚ 38' 42". The well was drilled between January and July of 1986. The injection well is 2409 feet deep with 1980 feet of 14-inch inner casing. There are two (2) annular monitor tubes at depths of 1234 to 1306 feet and 1410 to 1450 feet. The base of the lowermost USDW was identified at a depth of approximately 1450 feet bls during construction of the well. The placement of the base of the USDW at 1450 feet bls at this site is suspect. Groundwater quality data from nearby deep wells (Grant Street and D.B. Lee) consistently demonstrate that the USDW occurs between 1100 and 1250 feet bls at these locations. Groundwater produced from the deep annular monitor tube initially contained TDS concentrations of approximately 1500 mg/L. The consulting report (CH2M HILL 1986) indicated that fresh water might have been trapped in this interval during a period of low sea level (Pleistocene). Since injection began, the lower monitor zone has continued to increase in TDS. It is presently above 10,000 mg/L TDS. Therefore, data from the West Melbourne monitor tubes is not considered representative of ambient conditions and this site was not used on Figure 2 for depiction of the USDW.

5.7 Grant Street Injection Well System

The Grant Street injection well system is located just south of Crane Creek at latitude 28˚ 04' 25" and longitude 80˚ 36' 35" in Melbourne. Construction began on the Grant Street injection well system in April 1988, and was completed in January 1989. The injection well is 2700 feet deep with 2035 feet of 24-inch inner casing. The two (2) monitor wells at the site monitor intervals from 1100 to 1150 feet bls and 1594 to 1644 feet bls. The base of the USDW was identified at a depth of 1250 feet bls during construction of the well. The shallow monitor well was rehabilitated in 1991, using a coiled tubing device. Immediately after rehabilitation the well began producing water with TDS concentrations greater than 10,000 mg/L. The lower monitor well has shown a gradual decrease in TDS concentrations over time.

5.8 D.B. Lee Injection Well System

The D.B. Lee injection well system is located south of Sarno Road at latitude 28˚ 07' 15" and longitude 80˚ 38' 10" in Melbourne, Florida. Construction began on the injection well in May 1986. Difficulties arose during the construction of the well (highly fractured formation, large cavities, cement loss, lost bits, etc.) and the well was not completed until March 1988. The injection well is 2440 feet deep with a 24-inch inner casing set at 1995 feet bls. Originally, there were three (3) monitor wells drilled at the site. The monitored intervals were at 1164 to 1208 feet bls, 1487 to 1527 feet bls, and 1794 to 1844 feet bls. All of these wells have been plugged. The D.B. Lee injection well system began showing signs that vertical migration of effluent was occurring soon after it went into operation. Injection was terminated at the site in March 1989. A subsequent testing program was performed by HydroDesigns (1989) to investigate the cause of the vertical migration of effluent in the well. The testing program consisted of radioactive tracer surveys, injection of Rodamine WT dye, and aquifer testing. It was concluded that the most probable cause of upward leakage was a lack of suitable confinement, a possible leak in the injection well annulus, and/or a possible leak in the annulus of the deep Floridan monitor well. The presence of the large cavities and possible fracturing in this area appears to be a localized phenomenon. Similar conditions were not encountered at other deep wells in the study area.

5.9 D.B. Lee Exploratory Well

The City of Melbourne drilled a deep exploratory well near the shut in injection well in order to determine the depth where the TDS concentration of ambient groundwater is between 3000 mg/L and 10,000 mg/L. The testing program was conducted between April 2000 and September 2000. Based on chemical analysis of water samples collected during the testing program, the 3000 mg/L TDS interface occurs at a depth of approximately 1017 feet bls. The 10,000 mg/L TDS interface occurs at a depth of approximately 1131 feet bls at this site. L.S. Sims & Associates (2001) used data from this exploratory well and the existing injection well to construct a groundwater density model (SWIFT 98) simulating the affects of injecting brine down the existing injection well. Leakance zones were calculated around the injection well and a 30-year and 100-year simulation was performed at 3.3 million gallons per day (MGD). The model results showed that the 10,000 mg/L TDS line, which corresponds to the lowermost USDW aquifer, was unaffected.

5.10 Lake Washington Exploratory Well

A 1204 foot deep exploratory well was drilled near Lake Washington at latitude 28˚ 09' 00" and longitude 80˚ 43' 45". A confining zone (middle confining unit) was penetrated at a depth 860 feet bls to total depth. The TDS concentrations across the zone did not exceed 1200 mg/L.

5.11 Rockledge Injection Well System

The Rockledge injection well system is located just west of U.S. Highway 1 at latitude 28˚ 00' 00" and longitude 80˚ 00' 00". The construction and testing of the well took place between October 1990 and April 1991. The injection well is 2720 feet deep with 1955 feet of 20-inch inner casing. The two (2) monitor wells at the site monitor zones at 901 to 951 feet bls and 1338 to 1388 feet bls. The base of the USDW was identified at a depth between 1133 feet bls and 1200 feet bls during construction of the well. The initial samples from the deep monitor zone contained TDS concentrations greater than 20,000 mg/L.

5.12 Sykes Creek Injection Well System

The Sykes Creek injection well system is located in Merritt Island just east of the North Courteney Parkway at latitude 28˚ 25' 20" and longitude 80˚ 42' 17". An exploratory well was constructed and tested at this site in 1983. Construction of the injection wells began at the site in December 1985 and was completed by August 1986. There are two (2) 2500-foot deep injection wells with 1850 of 18-inch casing inner casing in each well. There is a multi-zone monitor well monitoring intervals at 128 to 340 feet bls and 1418 to 1501 feet bls. The base of the USDW was estimated to be between 340 and 950 feet bls during construction of the wells.

5.13 Sykes Creek Exploratory Well

In 2001, an exploratory/monitor well was drilled at the site to determine the base of the USDW. The well is located at latitude 28°25'20" and longitude 80°42'17". Water in excess of 10,000 mg/L TDS was encountered at a depth of 804 feet bls.

6.0 GEOLOGY

The geologic units underlying Brevard and Indian River counties are summarized below and outlined in Table 1. Lithologic descriptions from area wells and information presented by L. S. Sims & Associates (2001) and Duncan et al. (1994) were used to determine the stratigraphic position of the individual rock units.

THICKNESS OF STRATIGRAPHIC UNITS

THICKNESS (feet)	**UNIT**
90 to 160	**Undifferentiated**
0 to 50	**Tamiami Formation**
20 to 250	**Hawthorn Group**
100 to 150	**Ocala Limestone**
1500 to 1600	**Avon Park Formation**
1900 to 2440	**Oldsmar Formation**

6.1 Pleistocene to Recent Series, Undifferentiated and Anastasia Formation

These deposits vary in thickness throughout Brevard and Indian River counties. The Anastasia Formation (Sellards 1912) is normally composed of a sandy coquina of mollusk shells held loosely together by calcareous cement. The unit can, however, be moderately to well indurated depending upon the quantity and composition of the cementing material. Undifferentiated deposits blanket all of Florida resulting from sea level fluctuations and terracing during the Pleistocene age.

6.2 Pliocene to Pleistocene Series, Tamiami Formation

Mansfield (1939) proposed the term “Tamiami Limestone” for a fossiliferous sandy limestone approximately 25 feet thick, which was penetrated in shallow ditches along the Tamiami Trail (U.S. Highway 41) in southern Florida. The formation lithology has been recognized in several of the deep wells in the study area. It lies directly below the undifferentiated deposits and above the Hawthorn Group.

6.3 Miocene Series, Hawthorn Group

Dall and Harris (1892) first used the term "Hawthorn beds" for Miocene Age phosphate laden sediments being quarried near the town of Hawthorne in Alachua County, Florida. Due to its economic importance, this unit has been studied, mapped, and evaluated by Florida geologists since the early 1900's. The formation was upgraded to 'Group' status by Scott (1988) and into two formations (Peace River Formation and Arcadia Formation) in Brevard and Indian River counties. The Hawthorn Group is dominated by the presence of olive green silts and clays intermixed with phosphate and quartz sand.

6.4 Upper Eocene Series, Ocala Limestone

Dall and Harris (1892) first used the term "Ocala Limestone" for limestone being quarried near the town of Ocala in Marion County, Florida. Applin and Applin (1944) recognized two distinct units within the Ocala Limestone, an upper coquinoid member, and a lower more fine-grained micritic member. Duncan et al. (1994) described the Ocala Limestone in Brevard County as a "white to very light orange, medium-grained, poorly to rarely moderately indurated, interbedded packstone and wackestone with occasional grainstone and mudstone". The top of the unit is easily discernable from the overlying Hawthorn Group by very low radioactivity on gamma ray logs and the presence of a distinct benthonic foraminiferal assemblage (Lepidocyclina ocalana, Opersulinoides sp., Heterestegina sp., Gypsina globula, and Amphistegina pinnareensis cosdeni) in the rock samples. The top of the Ocala Limestone normally marks the top of the FAS in Brevard and Indian River counties. The top of the Ocala Limestone dips from north to south. It occurs at –104 feet NGVD in the Sykes Creek well to –200 feet NGVD at Rockledge and finally, just below –425 feet NGVD at Ocean Spray. The thickness averages approximately 130 feet over the study area, although the new Palm Bay exploratory well only contained 50 feet of this formation.

6.5 Middle Eocene Series, Avon Park Formation

Applin and Applin (1944) used the terms "Avon Park Limestone" and "Lake City Limestone" for rocks of early-middle Eocene and late-middle Eocene Age, respectively, in Florida. In the type area the Lake City Limestone is described as a “gray brown, dense, microcrystalline dolomite with occasional thin beds of limestone, chert, and carbonaceous material” (Ceryak et al. 1982). The Avon Park Limestone is described as, “cream colored, chalky, limestone that contains distinct fauna” from a type well located at the Avon Park bombing range in central Florida (Vernon 1951). Away from the type areas, the two units are very similar lithologically and for the most part can only be separated by the type fossils present within them. Miller (1986) recognized the similarity of these two units and combined them to form the Avon Park Formation. Duncan et al. (1994) also used these criteria in constructing geologic cross sections in Brevard County. The top of the Avon Park Formation is marked by an increase in radioactivity on the gamma ray logs and the first occurrence of the benthonic foraminifera Dictyoconus sp. Duncan et al. (1994) delineate two marker beds (A and B) within the Avon Park Formation based on gamma ray signatures. The “A” marker bed is an increase in radioactivity followed by a decrease over a 20 to 40 foot interval usually at around 600 foot bls in the upper portion of the Avon Park. The “B” marker bed occurs approximately mid-way through the Avon Park Formation and according to Duncan et al. (1994), “separates the more thinly-bedded strata of the upper Avon Park Formation from more thickly-bedded and massive units of the lower Avon Park Formation.” The “B” marker signature on the gamma ray log is an increase in radioactivity followed by a decrease and then another increase over a 20 to 30 foot interval normally between 1100 feet and 1200 feet bls.

6.6 Lower Eocene Series, Oldsmar Formation

Applin and Applin (1944) applied the name “Oldsmar Limestone” to a series of faunal zones overlying the Cedar Keys Formation. Chen (1965) described the unit in peninsular Florida as being predominantly dolomite (dolostone) and limestone with gypsum and anhydrite as minor components. Duncan et al. (1994) conformed to Miller (1986) and used the term Oldsmar Formation to describe the unit. They defined the top of the Oldsmar Formation as, “a white to light gray, glauconitic, moderately indurated wackestone or packstone, which contrasts with the cherty, brown dolostones of the overlying Avon Park Formation.” The benthonic foraminifera Heliocostegina gyralis normally occurs somewhere within the glauconitic marker bed near the top of the Oldsmar Formation. Duncan et al. (1994) recognized a “C” marker bed that denoted the top of the lower Oldsmar Formation. This marker horizon occurs below the boulder zone and is associated with an increase in radioactivity below it.

7.0 HYDROGEOLOGY

There are four (4) major hydrogeologic units that occur in peninsular Florida (Vecchioli et al. 1986). These are the surficial aquifer system (SAS), the intermediate aquifer system (IAS) (also referred to as imtermediate confining unit), the FAS, and the sub-Floridan confining beds. Miller (1986) divides the FAS into two major zones separated by a confining zone in Brevard and Indian River counties. Duncan et al. (1994) recognize distinct zones in the Upper and Lower Floridan aquifer separated by a middle confining unit. They also include a lower Avon Park confining zone and glauconitic marker bed in the Lower Floridan aquifer . In this report, FAS has been divided into separate hydrogeologic units including the Upper Floridan aquifer , the middle confining unit, the secondary injection zone, the lower Avon Park confining zone, and the primary injection zone. Figure 3 is a cross section illustrating the position of the hydrogeologic units in the study area. Cross section line A – A’ is shown on Figure 1. Figure 4 is a gamma ray cross section of the wells used on Figure 1. Appendix D contains hydrogeologic diagrams of the injection wells and the new deep exploratory well in Palm Bay.

7.1 Surficial Aquifer System

SAS in the study area is composed of sands, shell beds, and sandy limestones of Pliocene to Recent age. The thickness of the system varies across the study area with the top of the Hawthorn Group. The upper portion of SAS is an unconfined, non-artesian aquifer. The lower portion of SAS responds to pumping as a leaky-artesian aquifer. The Cities of Palm Bay and Mims use the lower portion of SAS for water supply.

7.2 Intermediate Aquifer System or Intermediate Confining Unit

IAS is contained wholly within the Hawthorn Group. The overall lithology of the Group is characterized by interbedded sequences of sand, silt, phosphate, and clay. In some areas of Florida, the Hawthorn Group contains limestone, sandstone, and dolostone beds that are capable of producing large quantities of water. Sometimes these beds are in hydraulic contact with the underlying FAS and actually are included within that system. In Brevard and Indian River counties, the Hawthorn Group does not generally contain beds that are capable of producing large quantities of water for public water supply. Approximately 120 feet of limestone and dolostone was identified at the Ocean Spray well in the base of the Hawthorn Group. This interval may be hydraulically connected with the FAS.

7.3 Floridan Aquifer System

FAS is divided into an upper and lower aquifer system by a dolomitic confining sequence in Brevard and Indian River counties. Duncan et al. (1994) designated these beds the “middle confining unit.” The thickness of FAS normally increases from north to south ranging from 2300 feet in the northern portion of the study area to 2900 feet in the southern portion (Scott et al. 1991). The elevations and thickness of the hydrogeologic units are depicted in Appendix B.

7.4 Upper Floridan Aquifer System

The Upper Floridan aquifer in this area of Florida can be subdivided into several zones (Brown et al. 1962, Toth 1988, Skipp 1988, HydroDesigns 1990, and L.S. Sims & Associates 2001). These zones include an upper producing zone, middle semi-confining zone, and a lower producing zone. Although these zones are documented at several locations in Brevard County, the aerial extent is uncertain. Nearly all of the Floridan aquifer wells drilled in Brevard and Indian River counties are completed in the upper producing zone. L.S. Sims & Associates (2001) tested an exploratory well near the D.B. Lee Wastewater Treatment Plant in Melbourne, Florida, to determine water quality degradation with depth in the Upper Floridan aquifer. Water quality samples collected during drill stem and straddle packer tests indicated that the TDS content of the water was less than 3000 mg/L for all three (3) of the zones in the Upper Floridan aquifer and increased abruptly to over 10,000 mg/L within the underlying middle confining unit. HydroDesigns (1990) conducted testing on a 1200-foot deep exploratory well near Lake Washington in central Brevard County. At this site, the TDS concentrations of groundwater samples collected within the Upper Floridan aquifer ranged from 1000 and 1150 mg/L.

7.5 Middle Confining Unit (mcu)

Duncan et al. (1994) define the middle confining unit in Brevard and Indian River counties as “a zone of slightly lower permeability separating two zones of higher permeability.” It is easily recognized on geophysical logs by a slight increase (B marker bed) in gamma ray activity and a decrease in transit time on acoustic logs. All of the acoustic logs, with the exception of the log of the Sykes Creek well, show varying degrees of “cycle skipping” within this unit. The unit is highly fractured at the D.B. Lee site. The unit is primarily composed of highly recrystallized and dense dolostones. These dolostones are characterized by a gauge hole with some cavities on the caliper log. The middle confining unit dolostones also show high resistivity on induction logs. Only four (4) wells in this area had hydraulic values (Appendix C) available for the middle confining unit. The Sykes Creek and Rockledge wells both reported K_Z in the 1 X 10^{-8} centimeters per second (cm/sec) range for this interval. A K_Z value of 2.4 X 10^{-3} cm/sec was reported for this interval at the Intersil well site. A horizontal hydraulic conductivity value (K_X) of 1.64 X 10^{-3} cm/sec was reported for this interval at the South Beaches site.

The top of the middle confining unit (Figure 5) occurs at –916 feet NGVD at the Sykes Creek site, and at –1320 feet NGVD at the Ocean Spray site. Figure 3 shows the unit dipping to the southeast, which is consistent with cross sections presented by Duncan et al. (1994). The thickness of the middle confining unit (Appendix B) varies between 110 feet and 170 feet south of the D.B. Lee site and between 200 and 360 feet to the north of D.B. Lee. It appears that the middle confining unit is a controlling mechanism for water quality. All of the wells, with the exception of the new Palm Bay exploratory well, penetrate groundwater in excess of 10,000 mg/L TDS (Figure 2) within the confining unit or just below it.

7.6 Lower Floridan Aquifer System

According to Duncan et al. (1994), the top of the Lower Floridan aquifer occurs at the base of the middle confining unit, or if that unit is missing, it occurs where the TDS in groundwater equals or exceeds 10,000 mg/L. The Lower Floridan aquifer is composed of highly recrystallized limestone and dolostone from the Avon Park and Oldsmar formations. Duncan et al. (1994) describe two well-defined and readily correlative confining zones within the Lower Floridan aquifer . These are the glauconitic marker bed and lower Avon Park confining zone.

7.6.1 Lower Avon Park Confining Zone

The glauconitic marker bed occurs at the very top of the Oldsmar Formation. It is a glauconitic and micritic limestone. The Avon Park confining zone, a zone of cherty dense dolostones, lies just above the glauconitic marker bed. In this study these two zones are combined into the lower Avon Park confining zone. As shown on Figure 6, this unit dips in a southeasterly direction. The thickness of the combined zones is shown in Appendix B and at the well sites on the contour map. The thickness varies between 230 feet at the new Palm Bay exploratory well, to 450 feet at the Rockledge injection well. The average thickness is between 230 and 350 feet. K values (Appendix C) of this zone are given for all of the injection wells, with the exception of the Ocean Spray well in Indian River County. The lowest conductivity ($K_Z = 1 \times 10^{-9}$ cm/sec) was measured for a core collected at the Rockledge injection well. For the other wells, K_Z values ranged between 2.5×10^{-5} cm/sec (South Beaches) to 1.8×10^{-8} cm/sec (Intersil).

The Ocean Spray data includes transmissivity values for individual zones (Appendix C) within the lower Avon Park confining zone. Transmissivities ranged from < 5 gallons per day per foot (gpd/ft) to 80 gpd/ft within this interval. Porosities calculated by sonic transit times in the glauconitic section of this confining zone range between 10 and 37 percent. Duncan et al. (1994) noted the absence of fracturing and/or vuggy lithology within this zone at the Ocean Spray site.

7.6.2 Primary Injection Zone

The primary injection zone, also known as the "boulder zone" (Kohout 1965), is a highly permeable zone located within the lower Oldsmar Formation in Brevard and Indian River counties. The injection zone occurs within highly transmissive dolostones with vertical and horizontal fracturing and large cavities. It is believed that the zone resulted from karst processes (Vernon 1970). Miller (1986) only shows the boulder zone extending into the southern portion of Brevard County. His report pre-dates most of the injection well construction activity in Brevard County, so he did not have access to deep well data for this area.

Figure 7 shows the configuration of the top of the primary injection zone in Brevard and Indian River counties. The Sykes Creek injection wells in Merritt Island are the farthest north of all the injection wells on the east coast of Florida. There have been no efforts to identify the primary injection zone north of the Sykes Creek wells. The top of the primary injection zone in the Sykes Creek wells occurs at –1950 feet NGVD and the cavities comprising this zone occur over an interval of 90 feet. Just to the south at the Rockledge site, the top of the primary injection zone was encountered at a similar depth (–1977 feet NGVD) and was 230 feet thick. The zone dips to the southeast and occurs at –2600 feet NGVD at the Ocean Spray well in Indian River County.

The thickness of the primary injection zone (Appendix B) varies between 87 feet (Grant Street) to 439 feet (South Beaches). The transmissivity of the primary injection zone (Appendix C) in Brevard County varies between 216,650 gpd/ft (Palm Bay) to 3,000,000 gpd/ft (Grant Street).

7.6.3 Secondary Injection Zones

Figure 8 is a structure contour map showing the top of the Lower Floridan aquifer and/or the base of the middle confining unit. The top of the unit dips to the southeast from approximately -1100 feet NGVD near Rockledge in Brevard County to approximately -1600 feet NGVD near Ocean Spray in Indian River County. The thickness of the interval between the top of the Lower Floridan aquifer and the top of the lower Avon Park confining zone are shown in Appendix B and at the individual well sites on the contour map. The thickness over most of the area is between 200 and 400 feet. K_Z values range between 1.5 X 10^{-4} cm/sec at West Melbourne to 1.89 X 10^{-6} cm/sec at Sykes Creek. K_X values were approximately 1 X 10^{-3} cm/sec at West Melbourne and Intersil. K_X values were approximately 1 X 10^{-5} cm/sec at the Palm Bay injection well.

Depending on the site-specific hydrogeologic conditions, this interval could potentially be utilized for brine disposal. The water in the upper portion of the Lower Floridan aquifer is less saline than in the lower portion, so density differences between resident and injected fluids would not be as great. Therefore, there would be less of a driving force for the injected fluids to rise. The middle confining unit would fit the regulatory requirement for confinement above the injection zone and the groundwater quality in this interval, typically, is greater 10,000 mg/L TDS.

8.0 DISCUSSION

Miller (1986), Duncan et al. (1994) and O'Reilly et al. (2003) present information on the FAS in east-central Florida. Miller has a more regional view of the FAS, O'Reilly et al. a sub regional view, and Duncan et al. assess the aquifer system in only Brevard and Indian River counties. In addition, O'Reilly et al. (2003) do not recognize the "middle confining unit" as defined by Duncan et al. (1994) and use only limited data from Brevard County injection wells.

The units identified by Duncan et al. (1994) include the middle confining unit, Avon Park confining zone, glauconitic marker bed, and primary injection zone and can all be correlated southward into the Palm Beach County area (Duncan et al. 1994b). The addition of more deep wells after the Duncan et al. (1994) report has assisted in drawing the maps and cross section in this report. The Sykes Creek and D.B. Lee exploratory wells were drilled specifically to identify the base of the USDW at those sites. The Rockledge injection well and Palm Bay exploratory well provided new information on the placement of hydrogeologic units and the base of the USDW.

The middle confining unit separates the Upper from the Lower Floridan aquifer throughout the eastern portion of Brevard and Indian River counties. The transition from relatively fresh (<10,000 mg/L TDS) to saline (>10,000 mg/L TDS) water occurs within or just below this confining unit. The upper portion of the middle confining unit contained significant cavities at the D.B. Lee site (L.S. Sims & Associates 2001), but still acted as a confining layer to the underlying Lower Floridan aquifer. The middle confining unit is in part the same unit that O'Reilly et al. (2003) refer to as the "middle semiconfining unit" in east-central Florida. The primary difference is that Duncan et al. (1994) do not include a limestone sequence just above the middle confining unit dolostone within the unit.

The Avon Park confining zone and glauconitic marker bed were present in all of the injection wells and the Palm Bay exploratory well. The combined zone is the major confining sequence within the Lower Floridan aquifer above the primary injection zone. The glauconitic marker bed has K_Z in the 10^{-5} to 10^{-8} cm/sec range and does not show evidence of fracturing where cores are available for analysis. Unfortunately, the unit rarely exceeds 50 feet in thickness. The cherty dolostone comprising the overlying Avon Park confining zone is normally more than 150 feet thick, however, samples from the zone show some evidence of fracturing (Duncan et al. 1994).

The primary injection zone extends from the Sykes Creek location in northern Brevard County to southern Florida. The northward extent beyond the Sykes Creek facility has not yet been determined. The westward extent beyond the Palm Bay exploratory well has not yet been determined. The Palm Bay exploratory well penetrated cavities at –2055 feet NGVD, but was not drilled deep enough to fully penetrate the primary injection zone.

There is a potential to use the zone directly below the middle confining unit for disposal of potable water by-product. This would be a less costly alternative for a utility, than drilling to the primary injection zone. The areas around Merritt Island, Cocoa, Rockledge, and possibly Titusville in Brevard County, would have the highest potential, because water in excess of 10,000 mg/L TDS has been identified in the upper Floridan aquifer (McGurk et al. 1998) in this area. The Melbourne, West Melbourne, and Palm Bay areas would have a moderate potential, because there is some uncertainty regarding the exact depth of the lowermost USDW.

9.0 RECOMMENDATIONS

1) The maps presented in this report should be further refined to identify the middle confining unit, primary injection zone, the base of the USDW, and the secondary injection zone. All of the available information has been evaluated and new data is needed to make the maps more accurate.

2) The existence of the boulder zones and the middle confining unit in the western portion of Brevard and Indian River counties is uncertain. These areas should be considered for more exploratory drilling to fill in data gaps. This information would also be helpful in correlating the key marker beds defined by the U.S. Geological Survey and Florida Geological Survey.

3) The middle confining unit exhibits a structural control over the saline water of the Lower Floridan aquifer in eastern Brevard and Indian River counties. An investigation should be performed to determine the western and northern lateral extents of the middle confining unit and its effect on water quality in those areas.

4) It is uncertain if the boulder zone or secondary injection zones are present in northern Brevard and Volusia counties. These areas should be considered for exploration in the future.

5) Any drilling of exploratory wells should be done totally without the use of salt as a weighting additive to control flow. It is difficult to identify the exact base of the USDW after salt has been added to a well.

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FIGURES

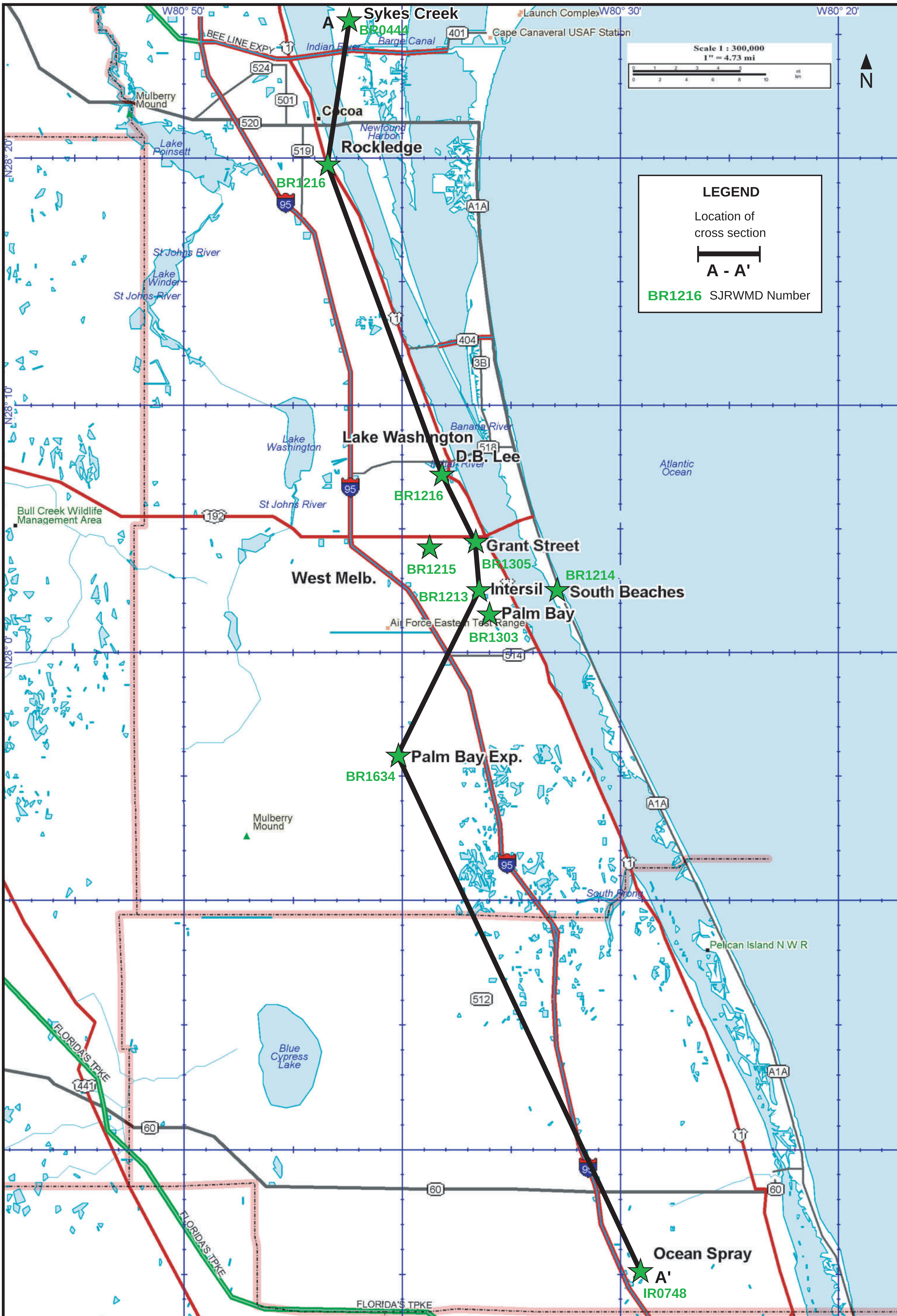

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FIGURE 1
LOCATION OF THE STUDY AREA

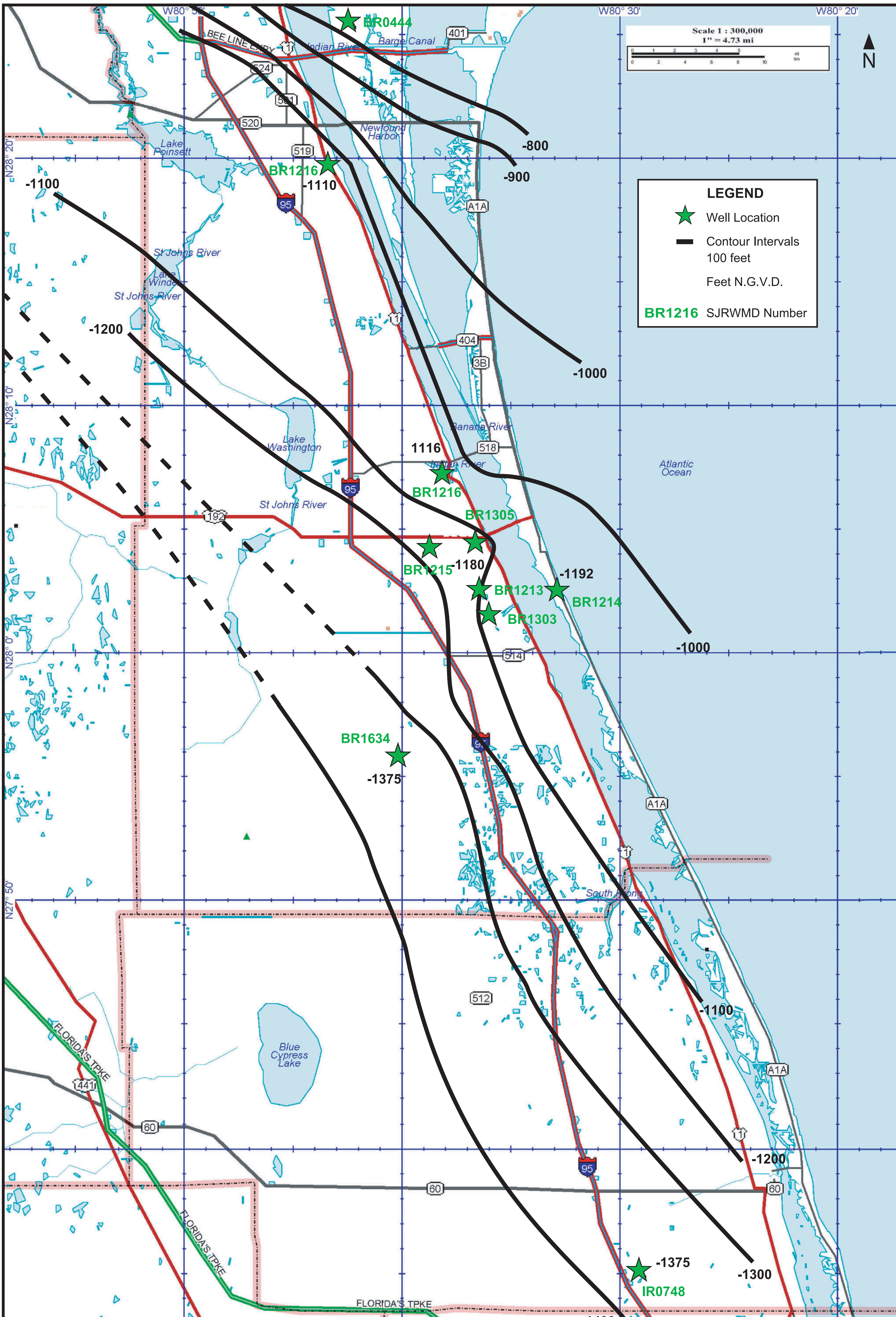

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FIGURE 2
ELEVATION OF THE BASE OF THE UNDERGROUND SOURCE OF DRINKING WATER (USDW)

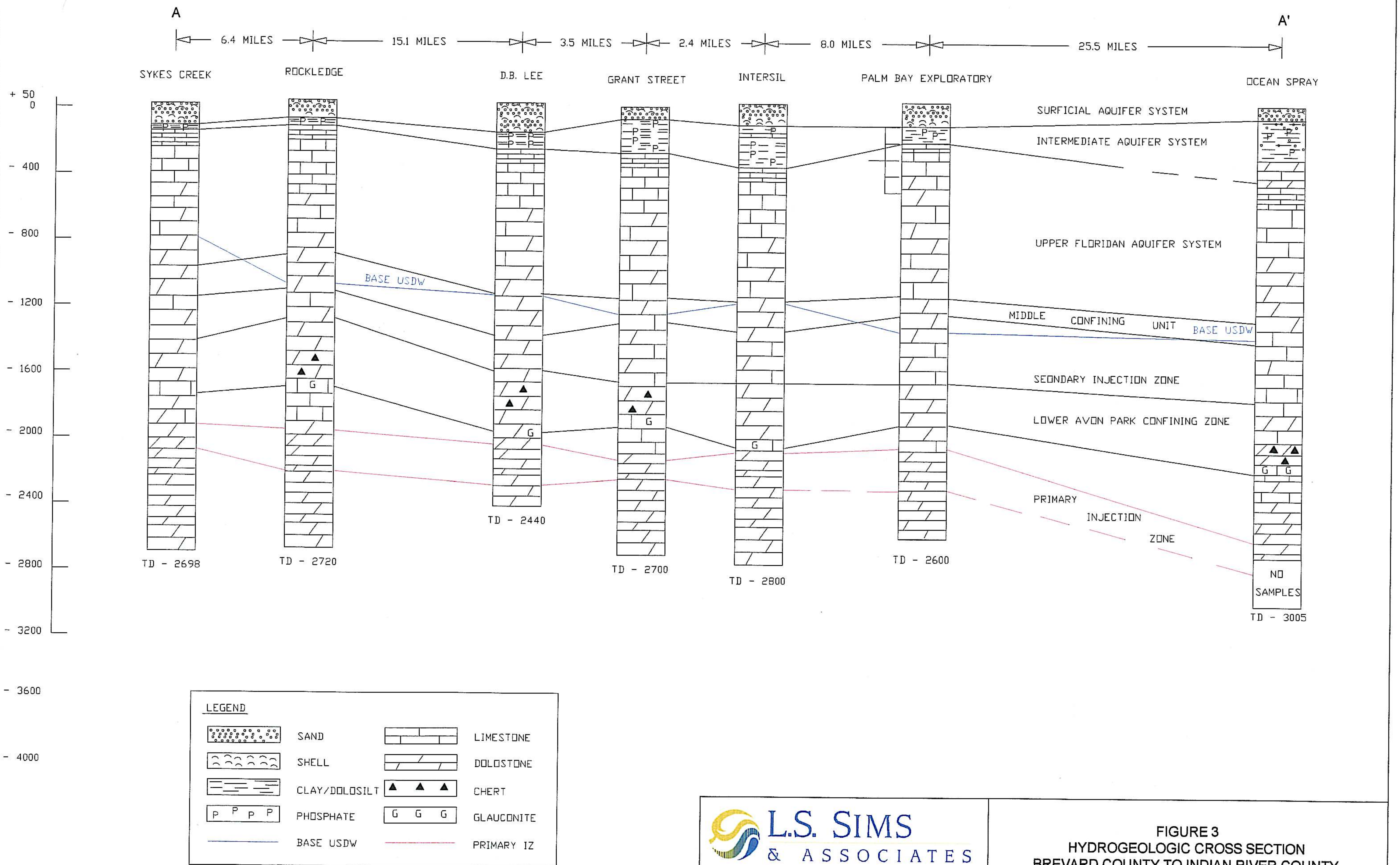

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FIGURE 3
HYDROGEOLOGIC CROSS SECTION
BREVARD COUNTY TO INDIAN RIVER COUNTY

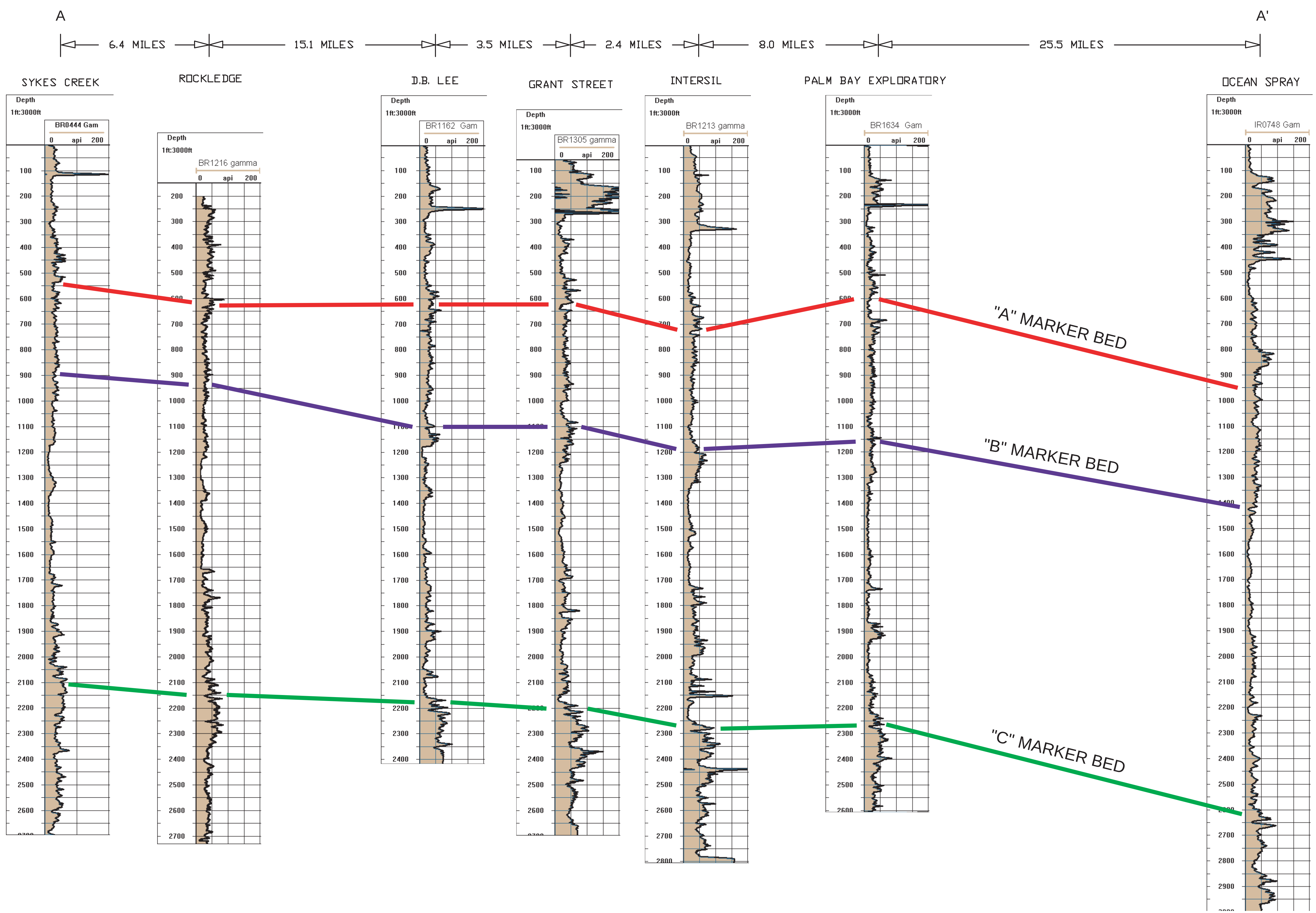

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FIGURE 4
GAMMA RAY CROSS SECTION
BREVARD COUNTY TO INDIAN RIVER COUNTY

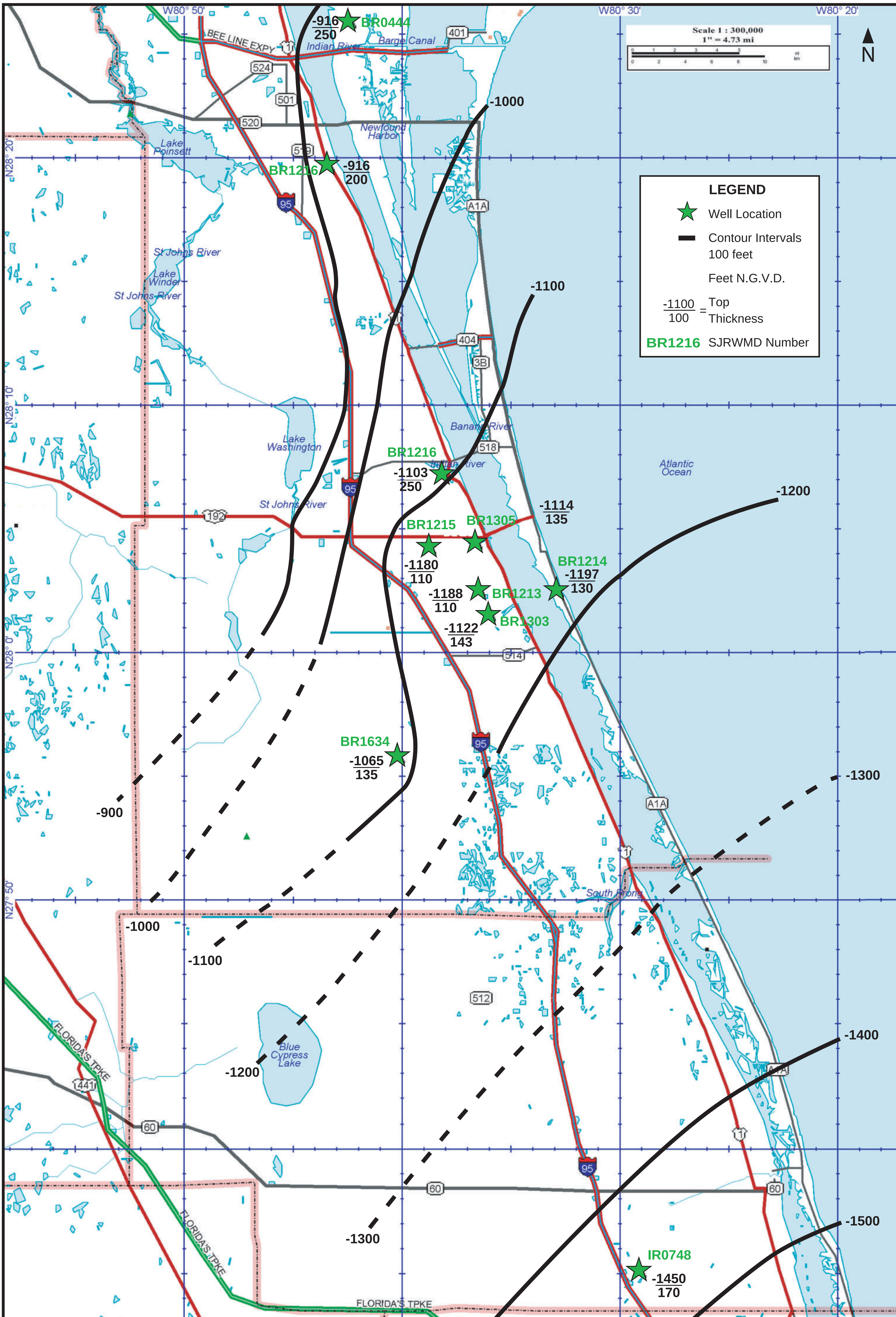

FIGURE 5
THE TOP OF THE MIDDLE CONFINING UNIT

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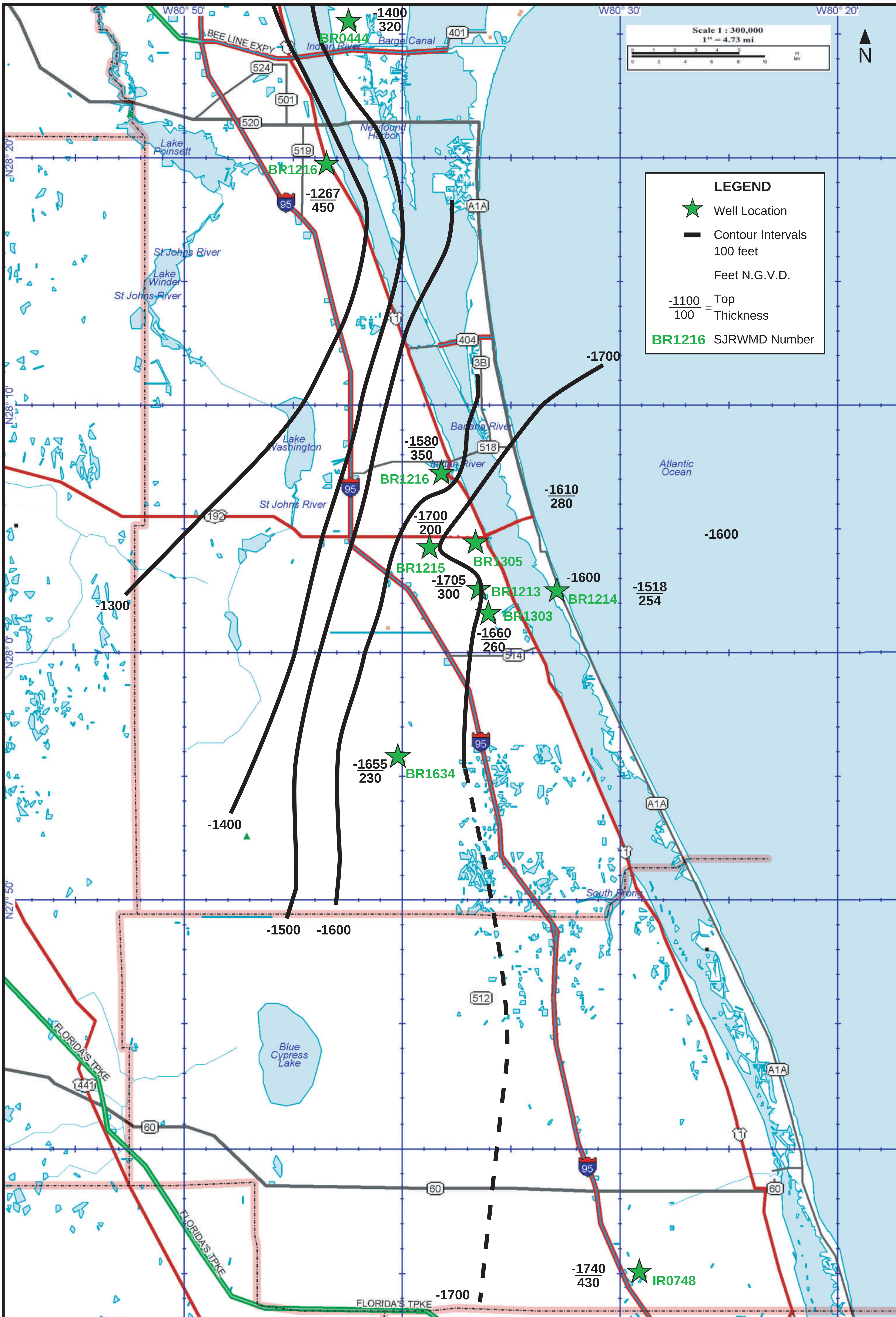

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FIGURE 6
THE TOP OF THE AVON PARK CONFINING ZONE

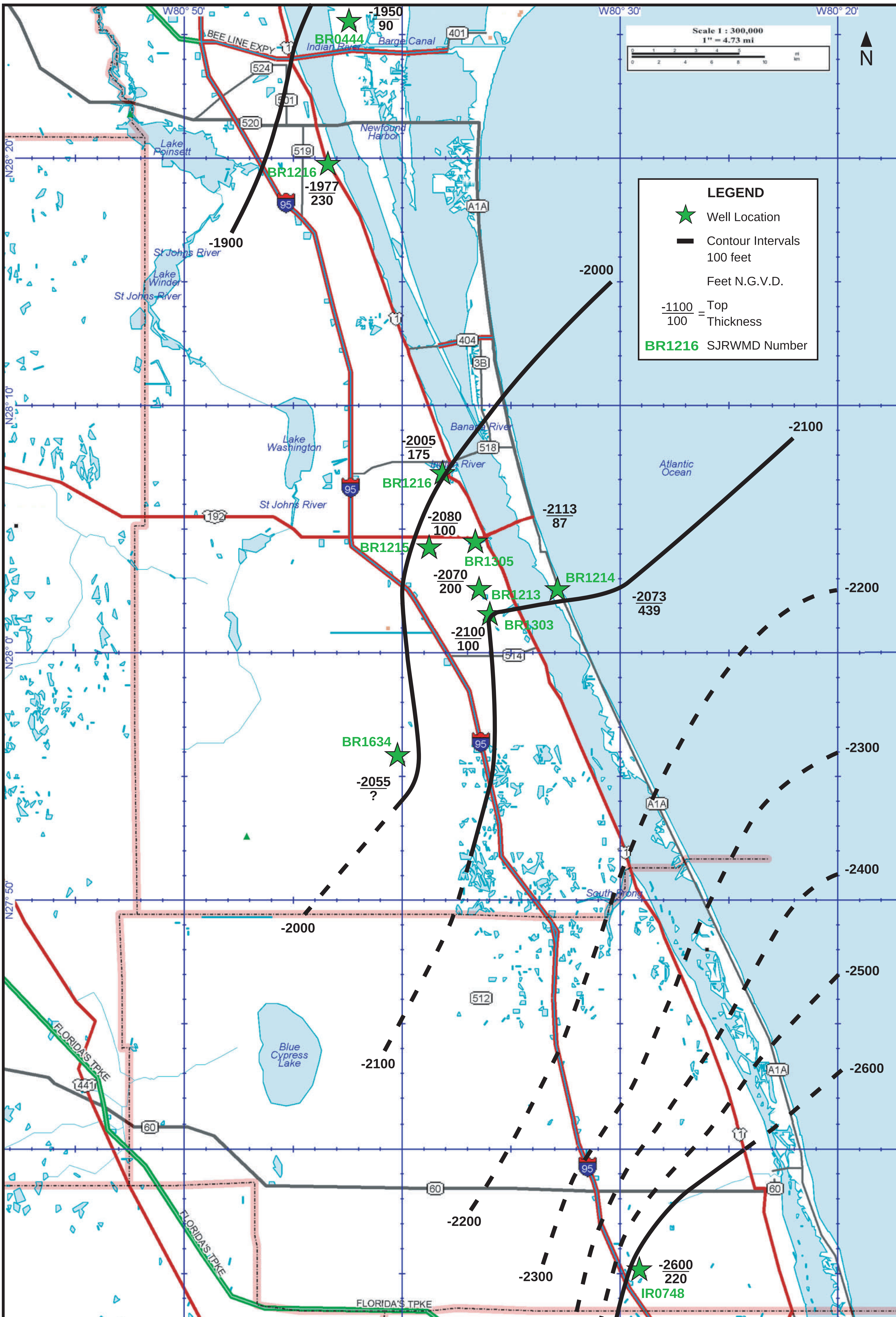

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FIGURE 7
THE TOP OF THE PRIMARY INJECTION ZONE

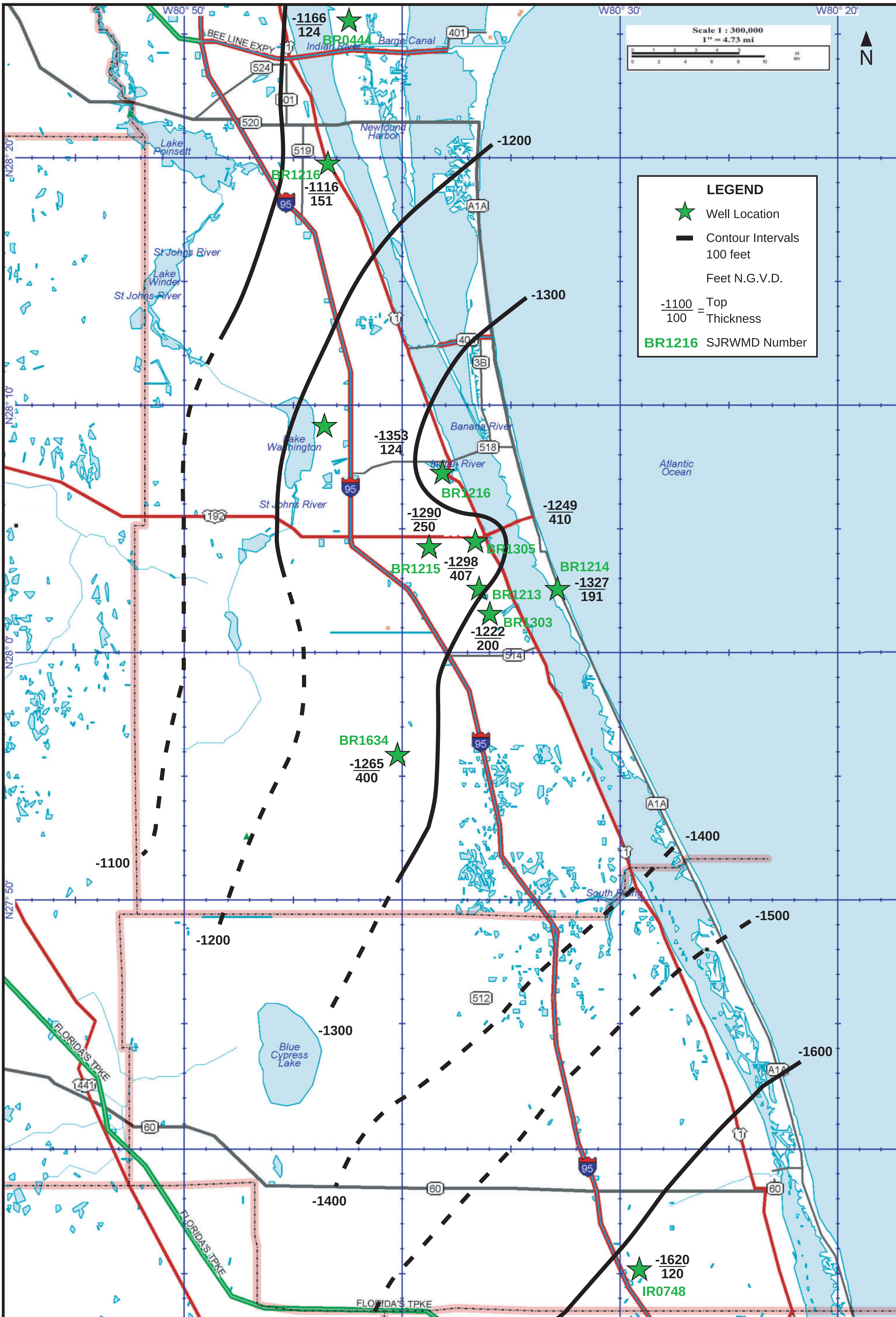

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FIGURE 8
THE TOP OF THE LOWER FLORIDAN AQUIFER SYSTEM
(SECONDARY INJECTION ZONE)

APPENDIXES

APPENDIX A

APPENDIX A

DEEP WELL
GENERAL INFORMATION

Well ID	Well Name	Latitude Longitude	Land Surface Elevation in feet (NGVD)	Well Depth		Casing		
				Depth in feet (bls)	Elevation (NGVD)	Diameter (inches)	Depth in feet (bls)	Elevation (NGVD)
BR0444	SYKES CK. DEEP EXP.	282533 804223	5 MON. WELL	2698 1501	-2693 -1496	18" 2 3/8"	1845	-1840
BR1217 BR1217A	SYKES CK. INJ. WELLS		5	2504 2500	-2499 -2495	18" 18"	1850 1850	1845 1845
BR1643	SYKES CK. EXPLOR/MON.	282520 804217	5	963	-958	6"	885	-880
BR1162	D.B. LEE INJ. WELL	280713 803807	15	2440	-2425	24"	1985	-1970
BR1594	D.B. LEE EXPLOR/MON.	280713 803807	15	1201	-1186	12"	279	-264
BR1213	INTERSIL INJ. WELL	280233 803627	20	2800 2333	-2780 -2313	8"	2000 (2 WELLS)	-1980
BR1214	SO.BEACHES INJ. WELL	280230 803250	8	2916	-2908	20"	2072	-2064
BR1215	W.MELB INJ.WELL	280414 803842	29	2409	-2380	14"	1932	-1903
BR1216	ROCKLEDGE INJ.WELL	281945 804321	23	2720	-2697	20"	1955	-1933
BR1303	PALM BAY INJ.WELL	280135 803557	18	3000	-2982	20"	2032	-2014
BR1634	PALM BAY EXPLOR/MON	275549 804009	25	2600	-2575			
BR1305	GRANT ST. INJ.WELL	280425 803635	6	2700	-2694	24"	2029	-2023
IR0748	OCEAN SPR. INJ.WELL	273507 802905	20	3005	-2985	6"	2335	-2315
IR0024	VERO BCH. GOLF COURSE	274206 802255		1969	-1964			

(NGVD) National Geodetic Vertical Datum of 1929
(bls) Below Land Surface
(ft) Feet

APPENDIX B

APPENDIX B

DEEP WELL
HYDROGEOLOGIC UNITS

Well ID	Middle Confinfing Unit			Secondary Injection Zone			Lower Avon Park Confining Zone			Primary Injection Zone		
	Top Elevation (NGVD)	DEPTH (ft bls)	Thickness (ft)	Top Elevation (NGVD)	DEPTH (ft bls)	Thickness (ft)	Top Elevation (NGVD)	DEPTH (ft bls)	Thickness (ft)	Top Elevation (NGVD)	DEPTH (ft bls)	Thickness (ft)
BR0444	-916	921	250	-1166	1171	234	-1400	1405	320	-1950	1955	90
BR1643	-900	905										
BR1162	-1103	1118	250	-1353	1368	227	-1580	1595	350	-2005	2020	175
BR1594	-1083	1098										
BR1213	-1188	1208	110	-1298	1318	407	-1705	1725	300	-2070	2090	200
BR1214	-1197	1205	130	-1327	1335	191	-1518	1526	254	-2073	2081	439
BR1215	-1180	1209	110	-1290	1319	410	-1700	1729	200	-2080	2109	100
BR1216	-916	939	200	-1116	1139	151	-1267	1290	450	-1977	2000	230
BR1303	-1102	1120	120	-1222	1240	438	-1660	1678	260	-2100	2118	100
BR1634	-1122	1147	143	-1265	1290	400	-1655	1680	230	-2055	2080	
BR1305	-1114	1120	135	-1249	1255	361	-1610	1616	280	-2113	2119	87
IR0748	-1320	1340	170	-1620	1640	120	-1740	1760	430	-2600	2620	220
IR0024*												

* Sonic and lithology logs unavaible-unable to correlate
Measured in feet NGVD (National Geodetic Vertical Datum of 1929)
bls (Below Land Surface)

APPENDIX C

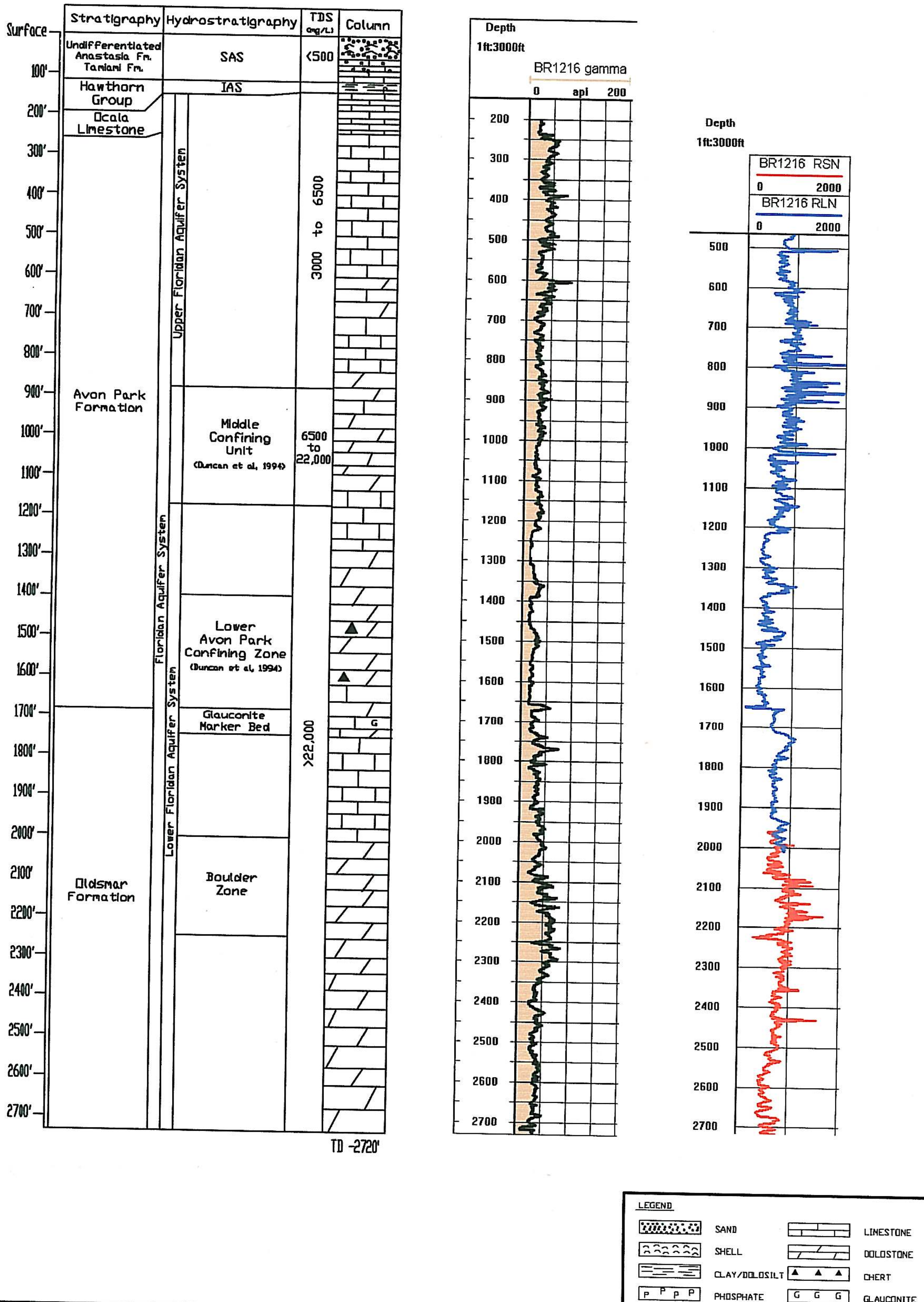
APPENDIX C

DEEP WELL
HYDRAULIC VALUES

Well ID	Middle Confining Unit		Secondary Injection Zone		Lower Avon Park Confining Zone		Primary Injection Zone	
	K_r=cm/sec. n=%porosity	K_z=cm/sec T=gpd/ft	K_r=cm/sec. n=%porosity	K_z=cm/sec T=gpd/ft	K_r=cm/sec. n=%porosity	K_z=cm/sec T=gpd/ft	K_r=cm/sec. n=%porosity	K_z=cm/sec T=gpd/ft
BR0444	2.7 X 10-4 n = .076	1.9 X 10-8 T=603	n = .258	1.89 X 10-6	5.0 X 10-4 n = .27	4.5 X 10-6 T=474		T = 1,000,000
BR1643								
BR1162						1.9 X 10-6		T = 2,100,000
BR1594								
BR1213	9.4 X 10-3 n = .245	2.4 X 10-3	1.8 X 10-3 n = .287	6.0 X 10-5	n = .261	1.8 X 10-8		T = 1,700,000
BR1214	1.64 X 10-3				1.85 X 10-4	2.5 X 10-5		T = 1,000,000
BR1215			3.1 X 10-3 n = .15	1.5 X 10-4 T=154	3.1 X 10-3 n .27	1.3 X 10-6		
BR1216	n = .14	1.3 X 10-8				1.1 X 10-9		2.4 X 10-3 T = 500,000
BR1303			2.9 X 10-5 n = .31	2.5 X 10-5	6.2 X 10-8 n = .22	2.9 X 10-6		T = 216,650
BR1634								
BR1305						5.03 X 10-7		2.1 X 10-6 T = 3,000,000
IR0748								T = 970
IR0024								

T = Transmissivity
n = Total Porosity
K_r = Hydraulic Conductivity (horizontal)
K_z = Hydraulic Conductivity (vertical)

APPENDIX D



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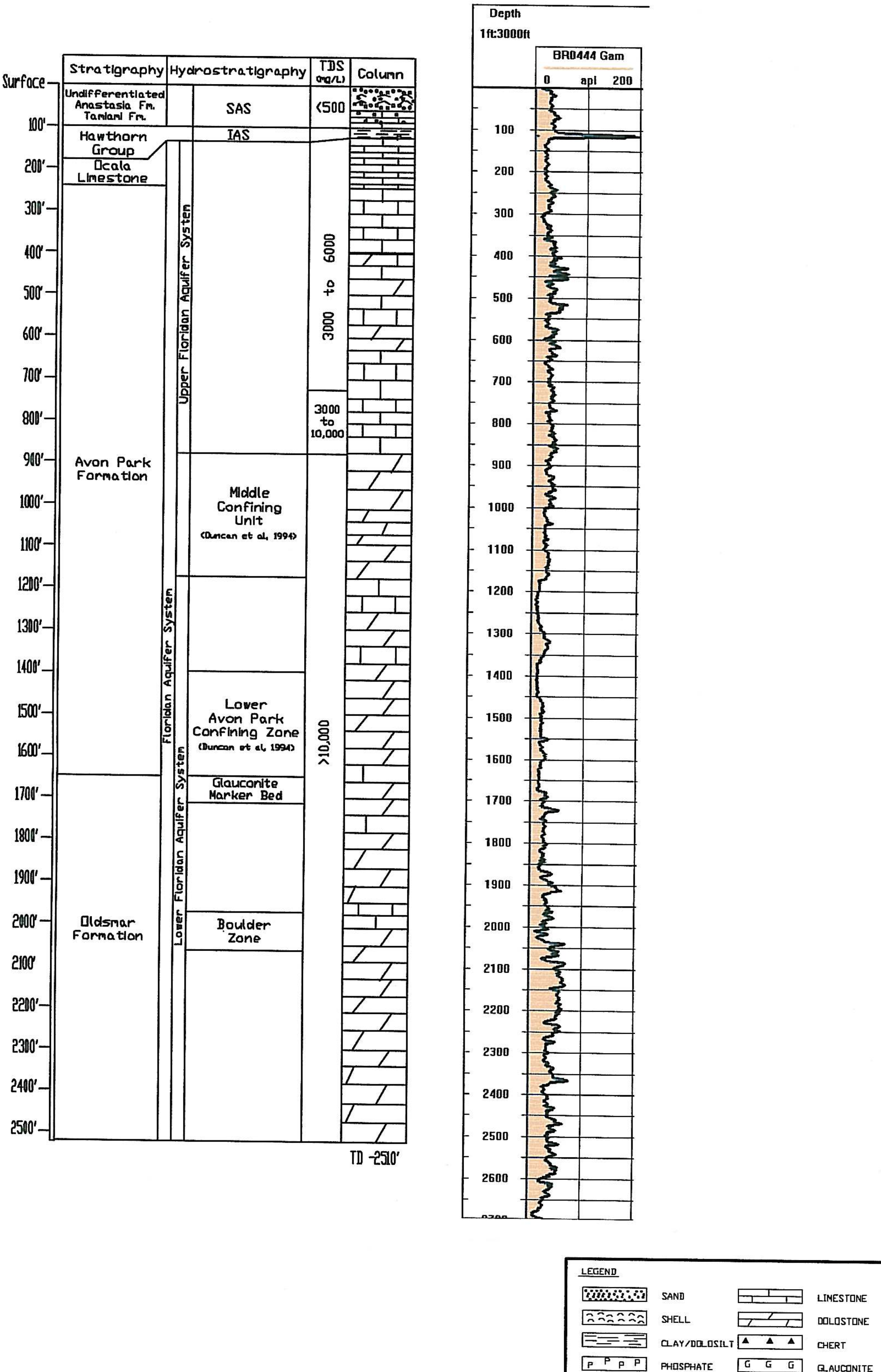
HYDROGEOLOGIC COLUMN
ROCKLEDGE INJECTION WELL (BR1216)



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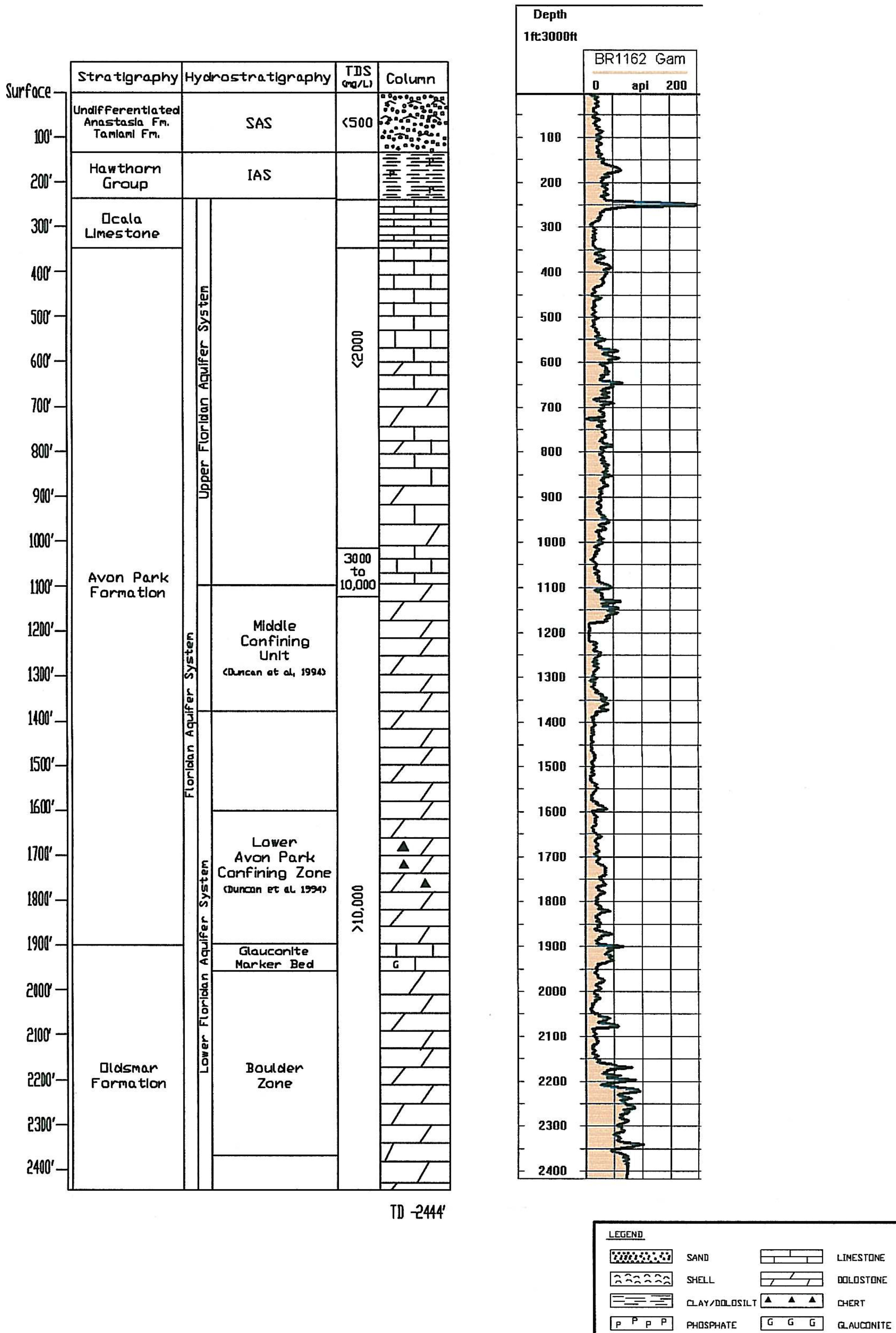
HYDROGEOLOGIC COLUMN
SYKES CREEK INJECTION WELL (BR0444)



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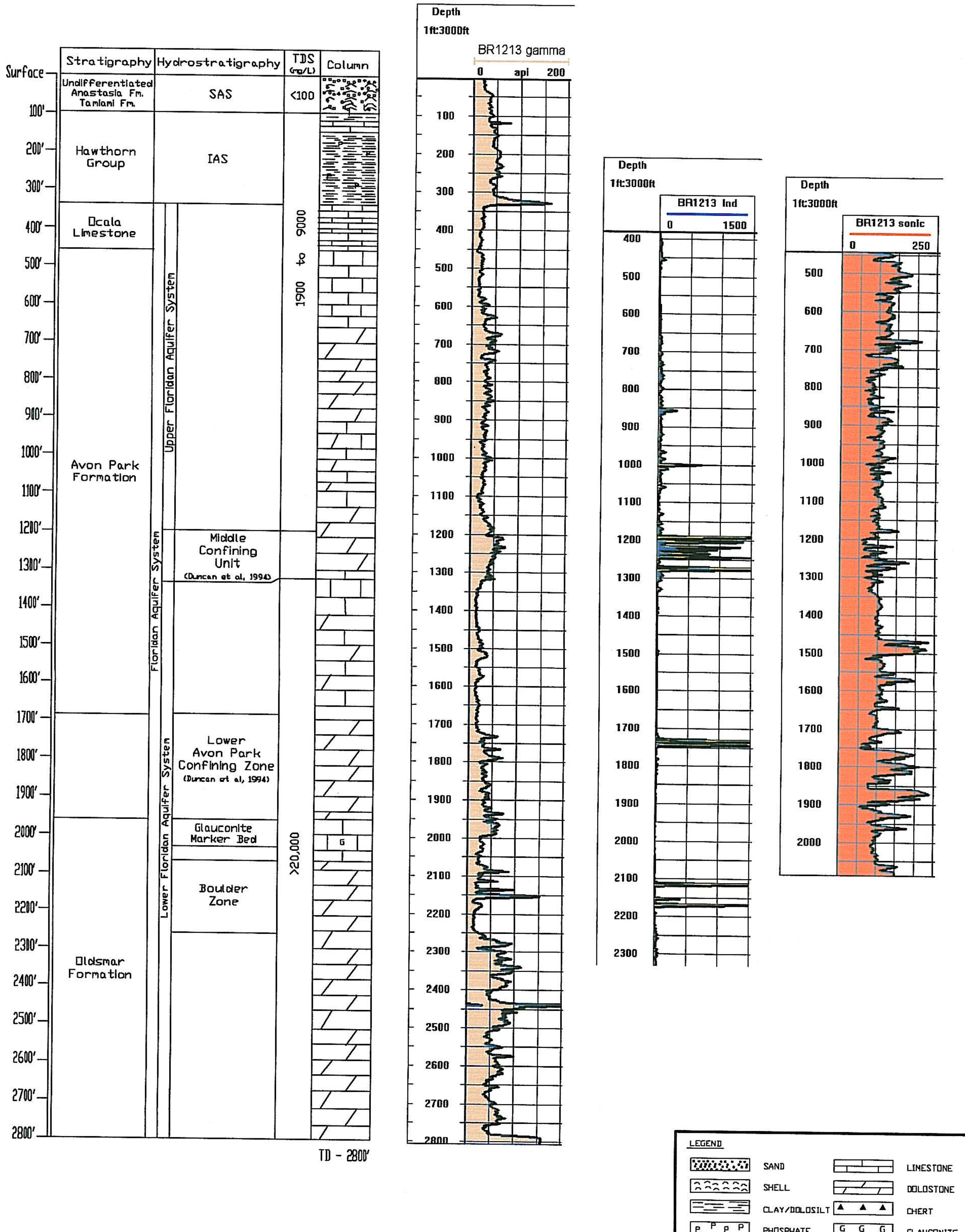
HYDROGEOLOGIC COLUMN
D.B. LEE INJECTION WELL SYSTEM (BR1162)



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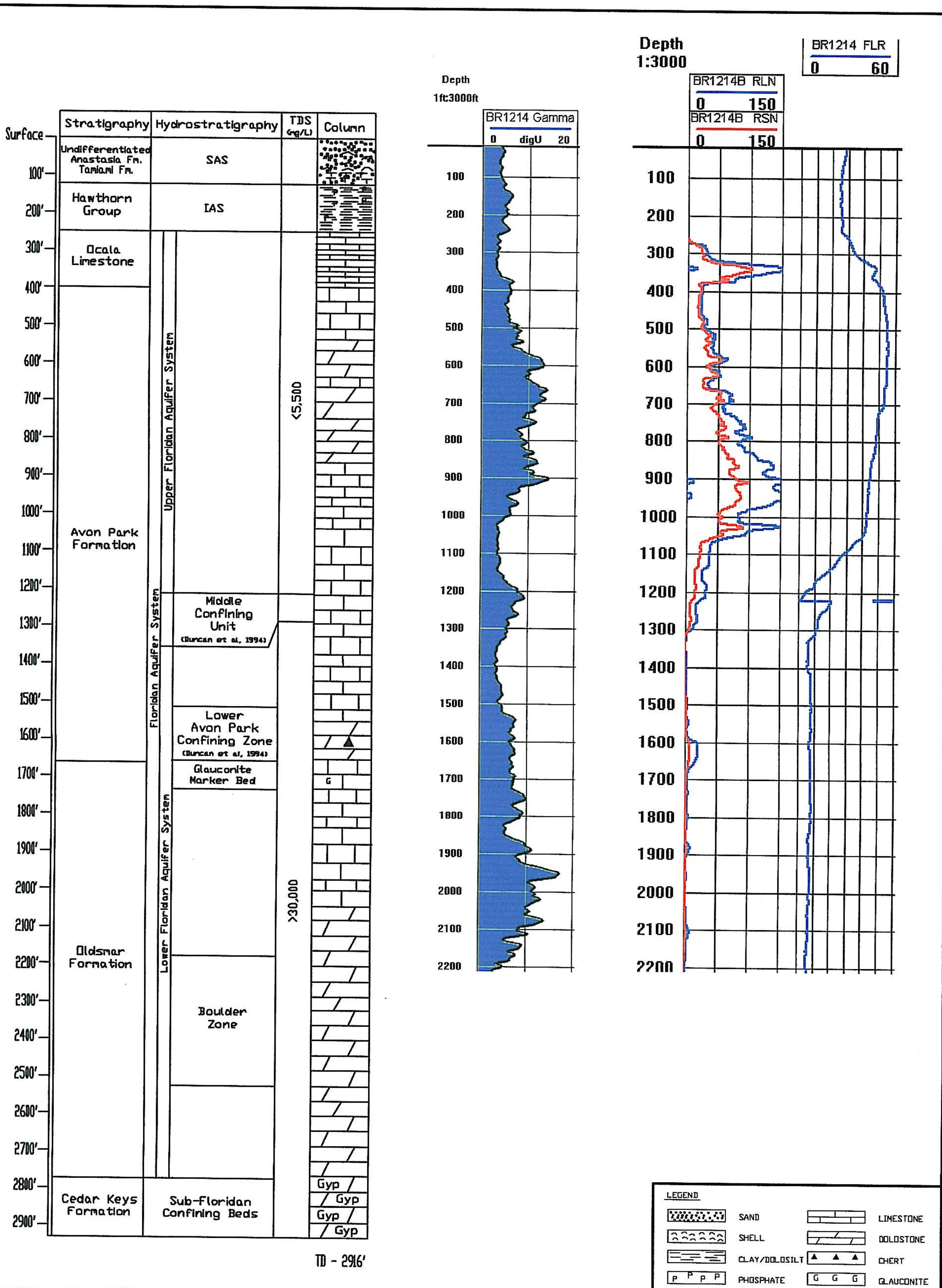
HYDROGEOLOGIC COLUMN
INTERSIL INJECTION WELL SYSTEM (BR1213)



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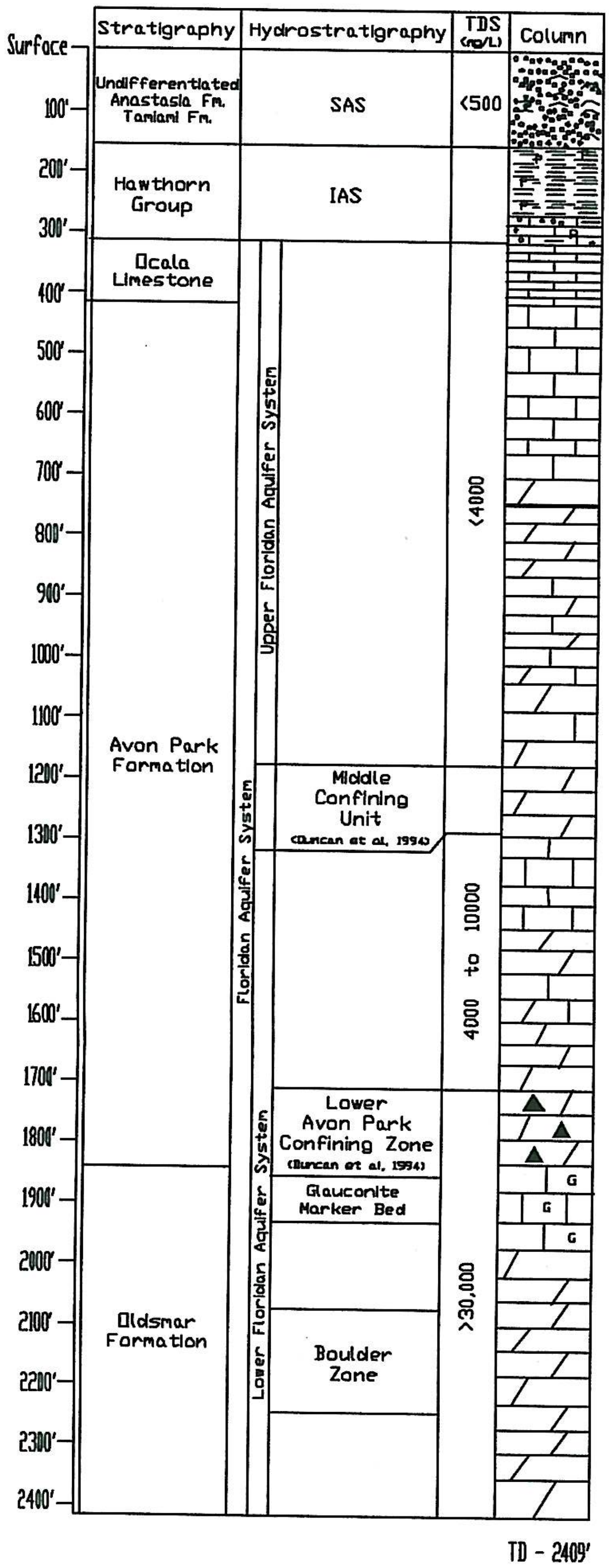
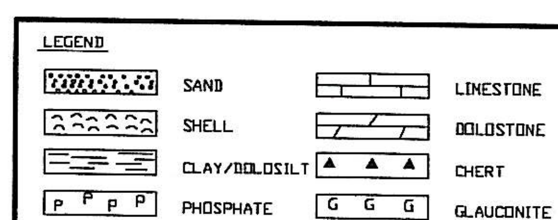
HYDROGEOLOGIC COLUMN
SOUTH BEACHES INJECTION WELL (BR1214)





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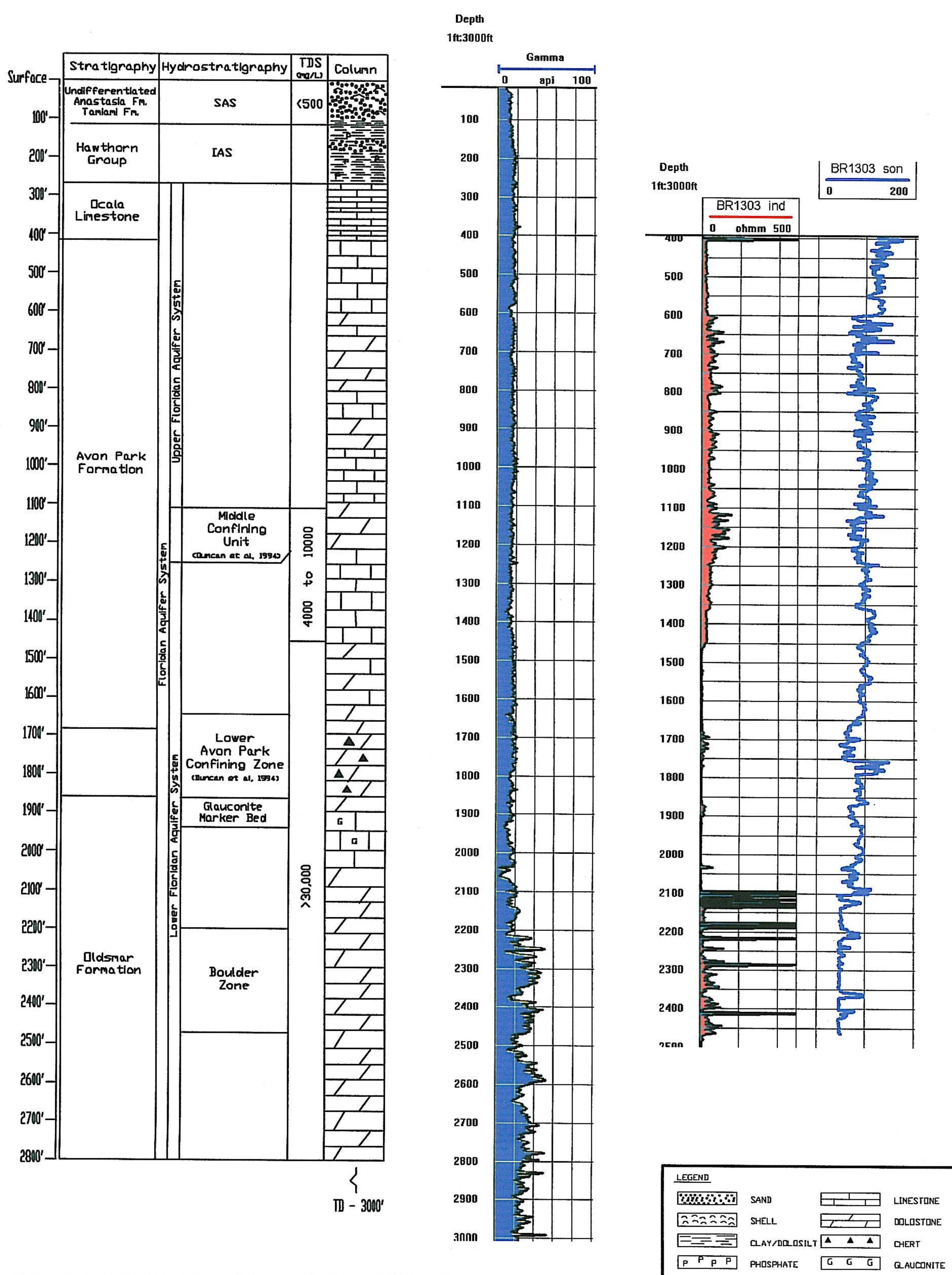
HYDROGEOLOGIC COLUMN
WEST MELBOURNE INJECTION WELL (BR1215)



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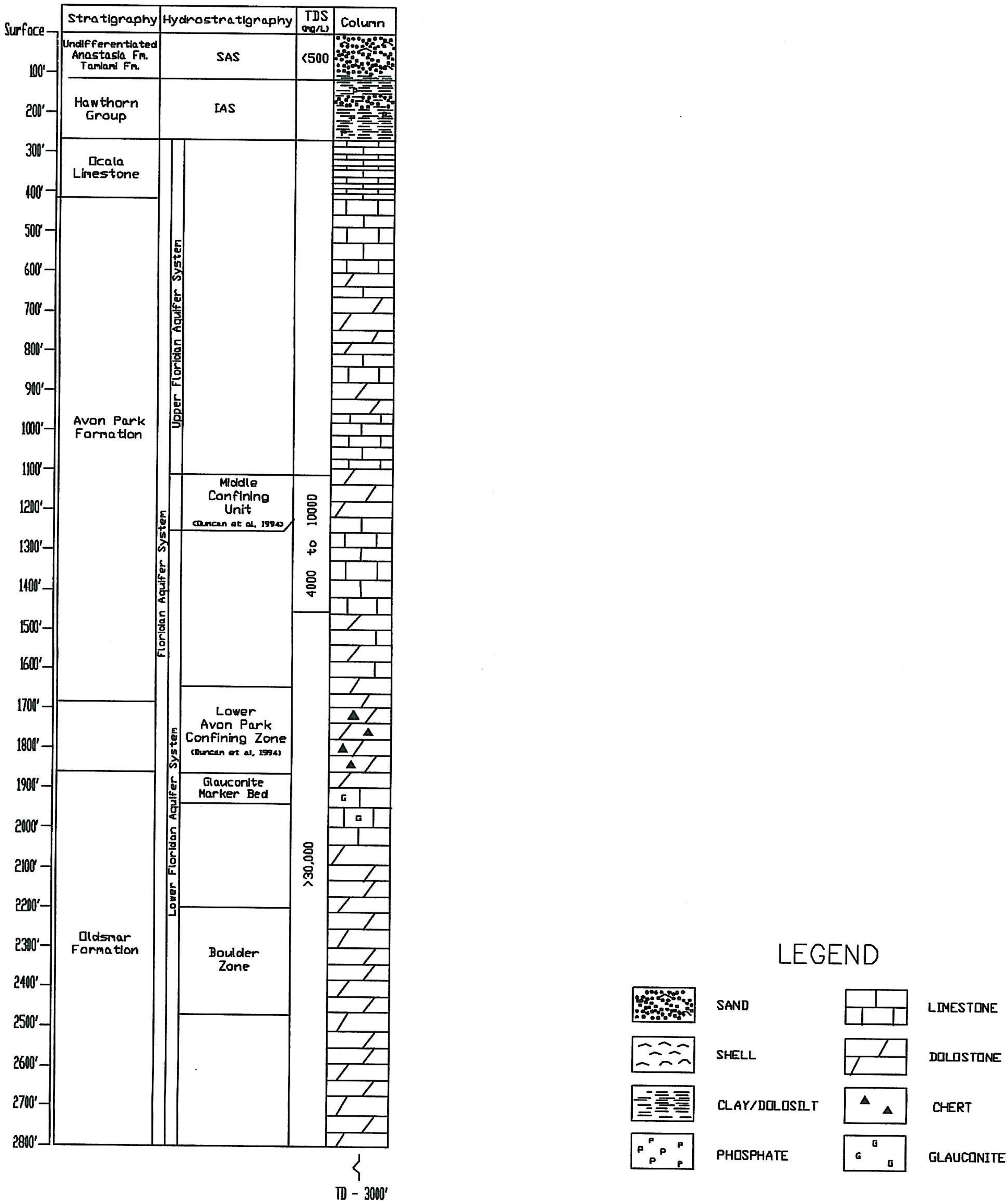
HYDROGEOLOGIC COLUMN
PALM BAY INJECTION WELL (BR1303)



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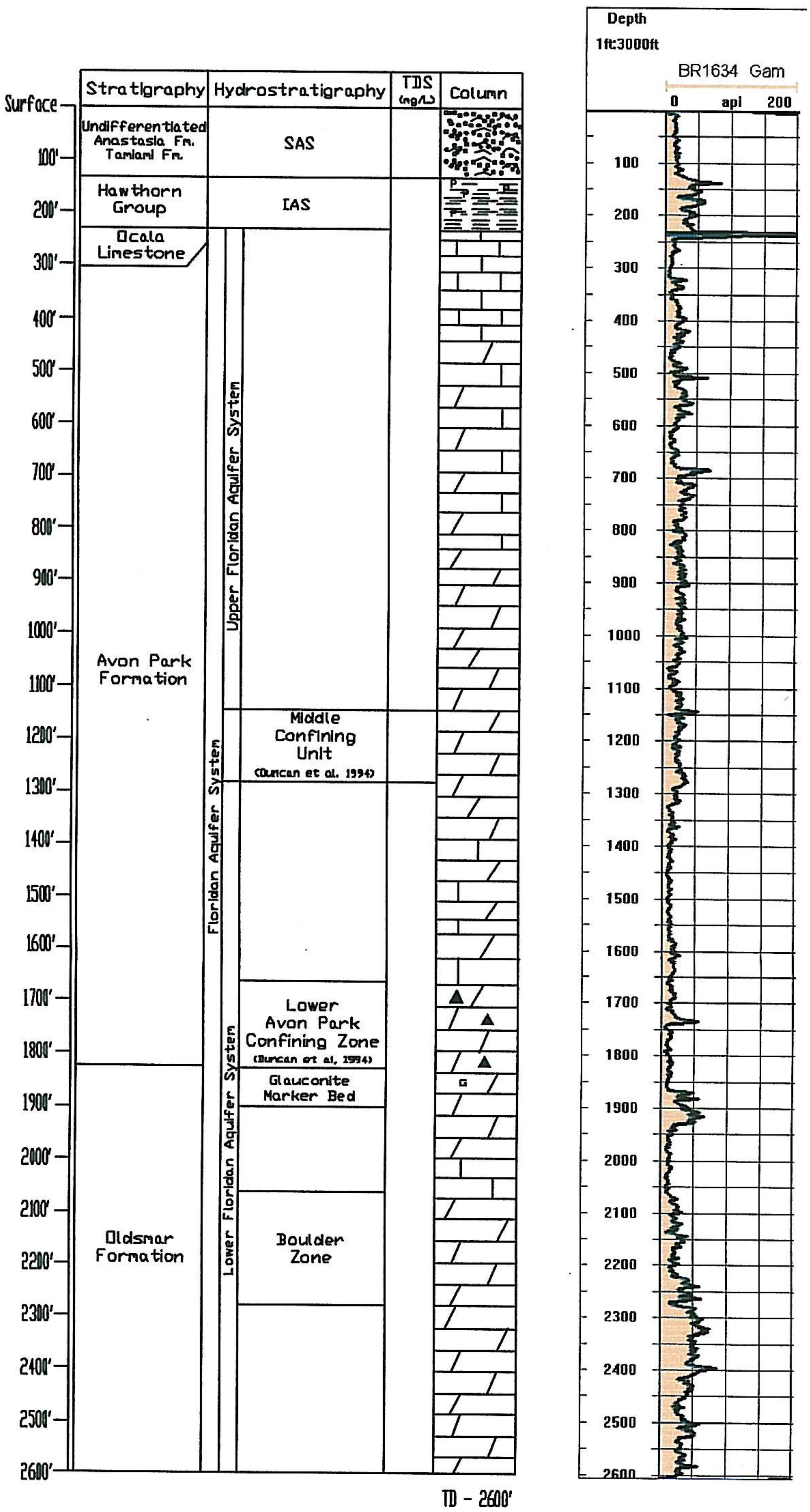
HYDROGEOLOGIC COLUMN
PALM BAY INJECTION WELL (BR1303)



LEGEND

SAND	LIMESTONE	SHELL	DOLOSTONE
CLAY/DOLOSILT	CHERT	PHOSPHATE	GLAUCONITE

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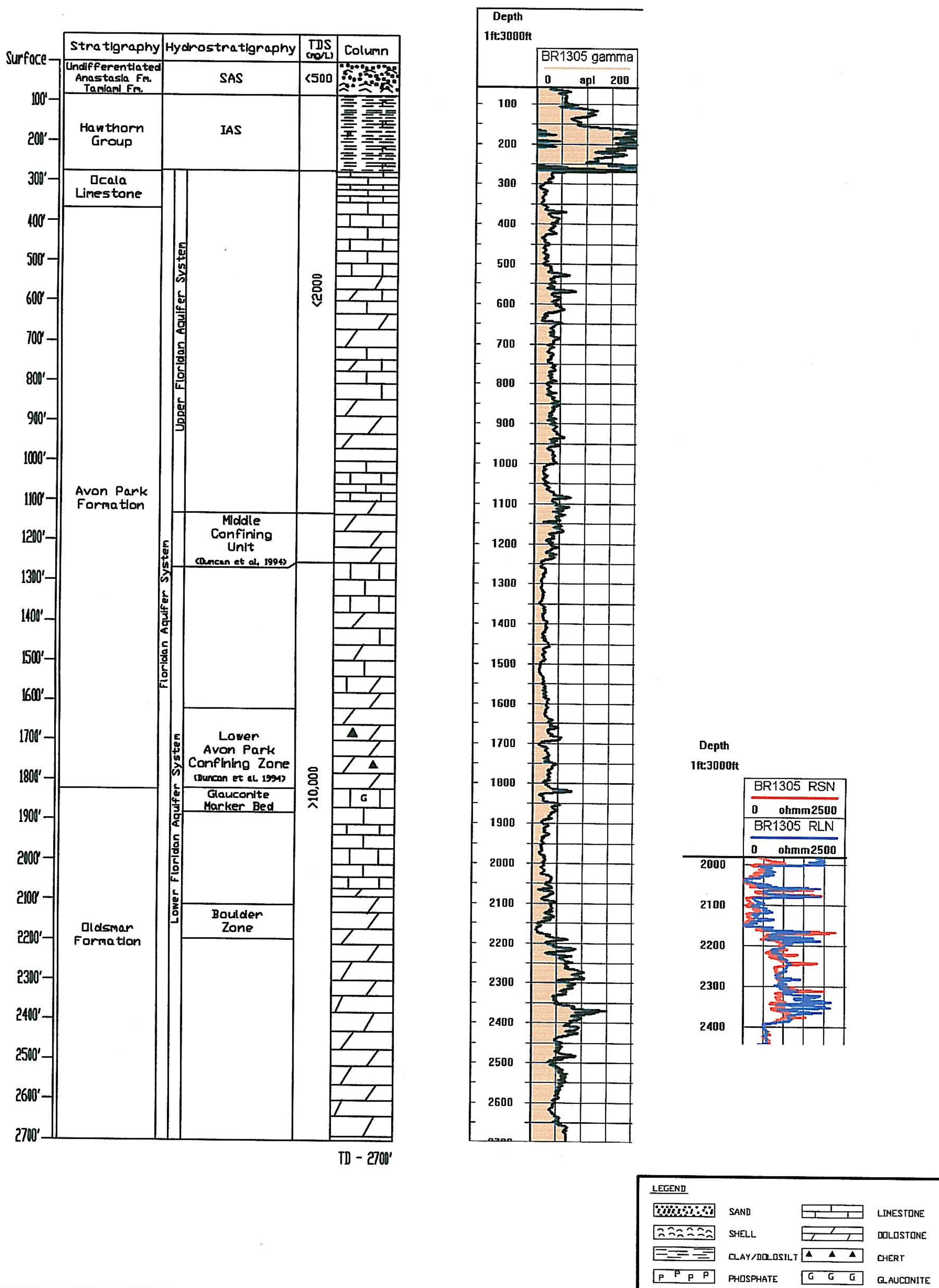
HYDROGEOLOGIC COLUMN
PALM BAY EXPLORATORY WELL (BR1634)



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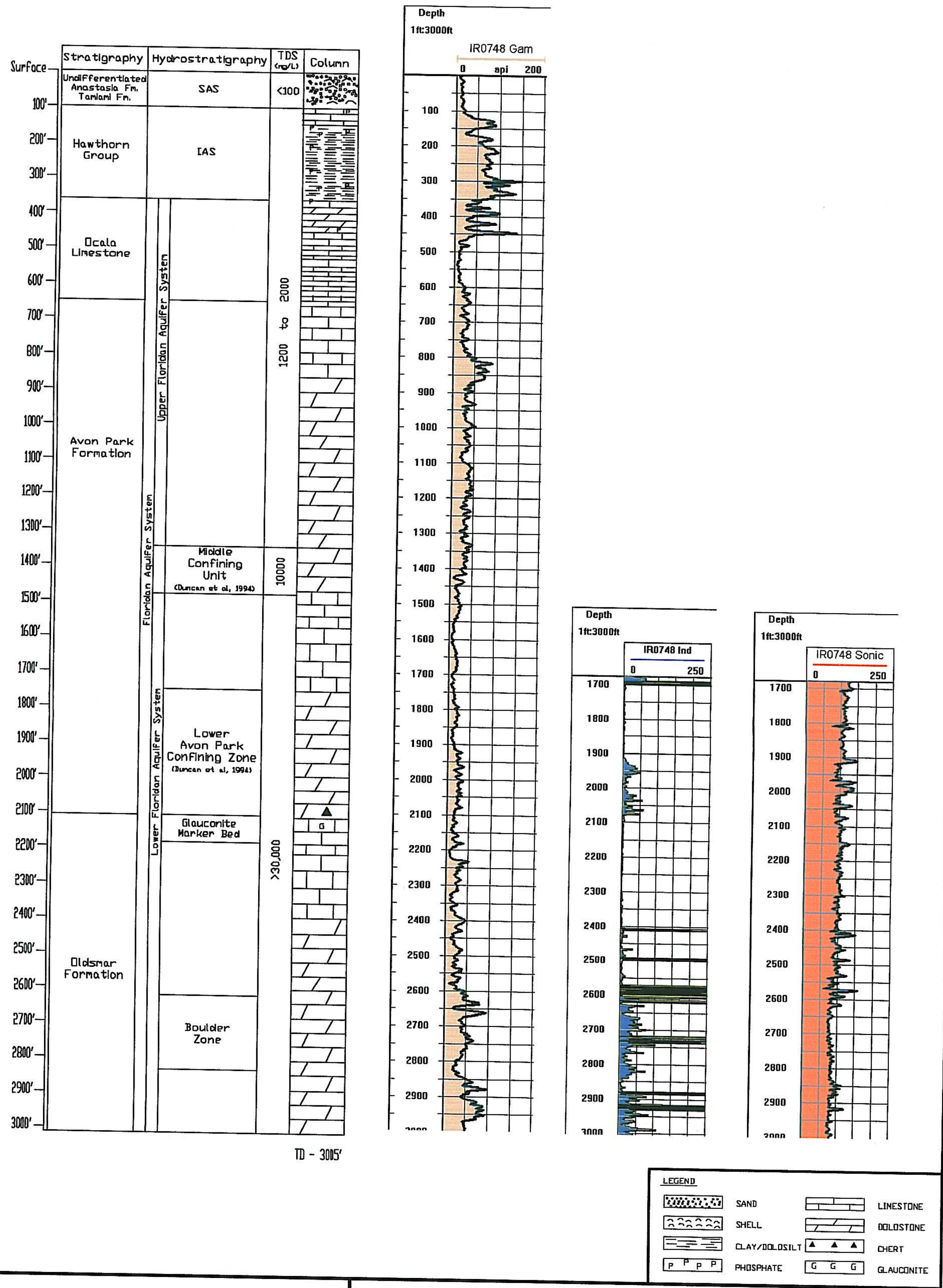
HYDROGEOLOGIC COLUMN
GRANT STREET INJECTION WELL SYSTEM (BR1305)



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HYDROGEOLOGIC COLUMN
OCEAN SPRAY INJECTION WELL SYSTEM (IR0748)