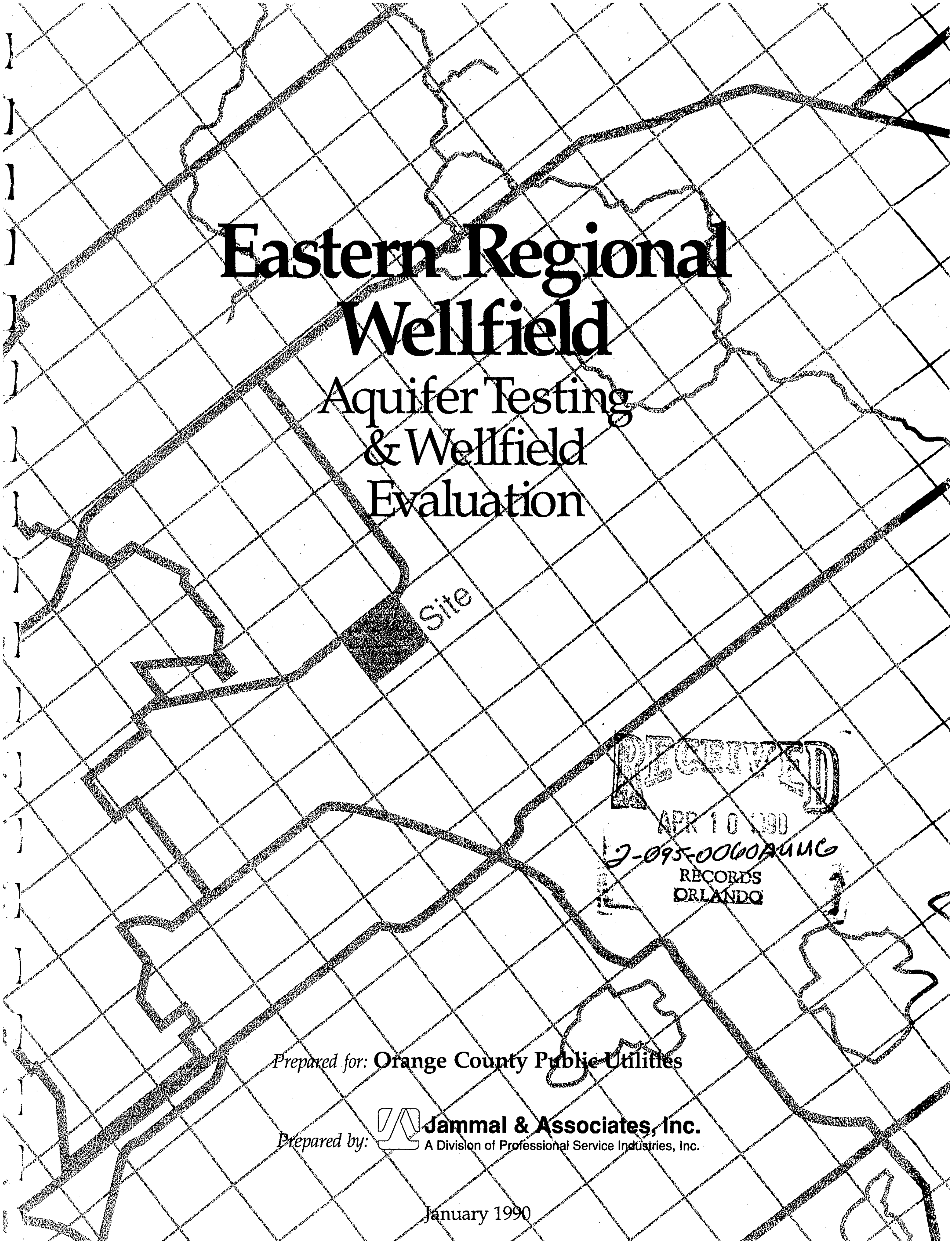

Eastern Regional Wellfield

Aquifer Testing & Wellfield Evaluation

Prepared for: **Orange County Public Utilities**

Prepared by: **Jammal & Associates, Inc.**
A Division of Professional Service Industries, Inc.

January 1990

LF Monitor = ER-LFMW

EASTERN REGIONAL WELLFIELD

AQUIFER TESTING AND WELLFIELD EVALUATION

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EXECUTIVE SUMMARY

Orange County Public Utilities has initiated an aquifer testing program designed to evaluate the feasibility of developing a potable water supply from the upper Floridan aquifer for the Orange County Eastern Region Service Area. The principal site under evaluation is located approximately seven (7) miles east of Orlando near the intersection of Econlockhatchee and Curry Ford Roads. Based on County's projections for water demands, an average daily flow rate of 28.8 MGD will be needed by the year 2010 from the combined discharges of its three (3) existing operating sites and the proposed Eastern Regional Wellfield (ERWF).

The aquifer testing program designed to evaluate the ERWF site included the construction of five (5) wells, step-drawdown testing, 72-hour aquifer performance testing, water quality testing, and computer based aquifer modeling. Aquifer testing activities designed to collect and evaluate geologic, hydrologic and geochemical characteristics of the surficial and Floridan aquifer systems indicate that the upper Floridan aquifer system extends from a depth of 198 to approximately 530 feet below land surface (bls) and has a transmissivity in excess of 2,000,000 gpd/ft. Calculated leakance characteristics from the pump test data indicate that the upper and lower Floridan aquifer horizons are well connected while vertical recharge rate from the surficial aquifer appears to be very low. It was determined that the proposed withdrawals will cause insignificant (if any) impact to the local surface water bodies.

Based on the results of our testing and regional modelling, it is our opinion that the selected ERWF site is located in an optimum area to create the least amount of impact to adjacent aquifer water users. We feel it is unlikely that a better site can be found in the Orange County Eastern Region Service area.

Results of groundwater flow model simulations indicate drawdown impacts on permitted adjacent Floridan aquifer users to be approximately 3.0 feet on the closest permitted user to less than 1.0 feet on the users located at distances of 13 to 16 miles. Those users located along the perimeter of the SJRWMD Zone II (area of potentially brackish water quality) are expected to observe less than 1.5 feet of drawdown. Saltwater intrusion evaluations performed by Dr. Charles Rowney indicate that in general the amount of impact to these users will be relatively minor as compared to the naturally occurring seasonal fluctuation of the saltwater/freshwater interface. However, those areas where the water quality has already been compromised by saltwater intrusion, the induced movement of the interface is more critical.

Several possible pollution sources to the water quality of the Floridan aquifer were identified. Among the sources identified were the Orange County Landfill, the Azalea Park Canal, the landfill canal, and a local drainage well. An investigation into each of these possible pollution sources failed to show a serious threat to the water quality. Furthermore, the proposed withdrawals would not significantly increase the potential for water quality degradation.

Based upon the testing and evaluation completed for this study, the projected withdrawals of 28.8 MGD for average daily withdrawals from the Orange County Eastern Regional facilities can be achieved without degrading the water quality and availability. Neither the saltwater intrusion nor the contamination from surface sources appears to be significant deterrent to the development of the proposed ERWF site. Furthermore, it appears that peak flow conditions of 48.8 MGD can be achieved with only minor increases to the local and regional drawdown effects.

The projected potable water demands of up to 28.8 MGD of Average Daily Flow (ADF) can be obtained by combining the existing three operating plants with the proposed ERWF site. The ERWF site can be designed to produce approximately 15.0 MGD with the remaining 13.8 MGD to be produced from the Econlockhatchee, Bonneville, Lake Nona and Conway water treatment plants. A total of six (6) production wells were conceptually designed for the ERWF site, each consisting of a 24-inch diameter well installed to a depth of approximately 550 feet bls. Expected yield from each well is approximately 3500 gpm.

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The Orange County Public Utilities Division (OCPUD) has initiated a program to evaluate the feasibility of developing a potable water supply from the upper Floridan aquifer in eastern Orange County, Florida. A specific wellfield site located approximately seven (7) miles east of Orlando has been selected to augment the currently existing water supply systems and to provide a large portion of the overall water demands. Based upon the results of an aquifer testing program, OCPUD intends to construct the new wellfield within and near the selected site to provide drinking water to the developments in the Eastern Orange County Region.

It is the intent of Orange County Public Utilities Division to renew and modify its existing Consumptive Use Permit for their Eastern Regional Service Area. Their existing water supply permit allows the withdrawal of groundwater from the upper Floridan aquifer from three existing sites until August of 1990. This permit allows for an annual allocation of 5,803.5 million gallons of water. It is the purpose of this report to evaluate the selected site and to address the hydrogeologic site conditions for the feasibility of withdrawing 10,512 million gallons annually from the Eastern Region Service Area.

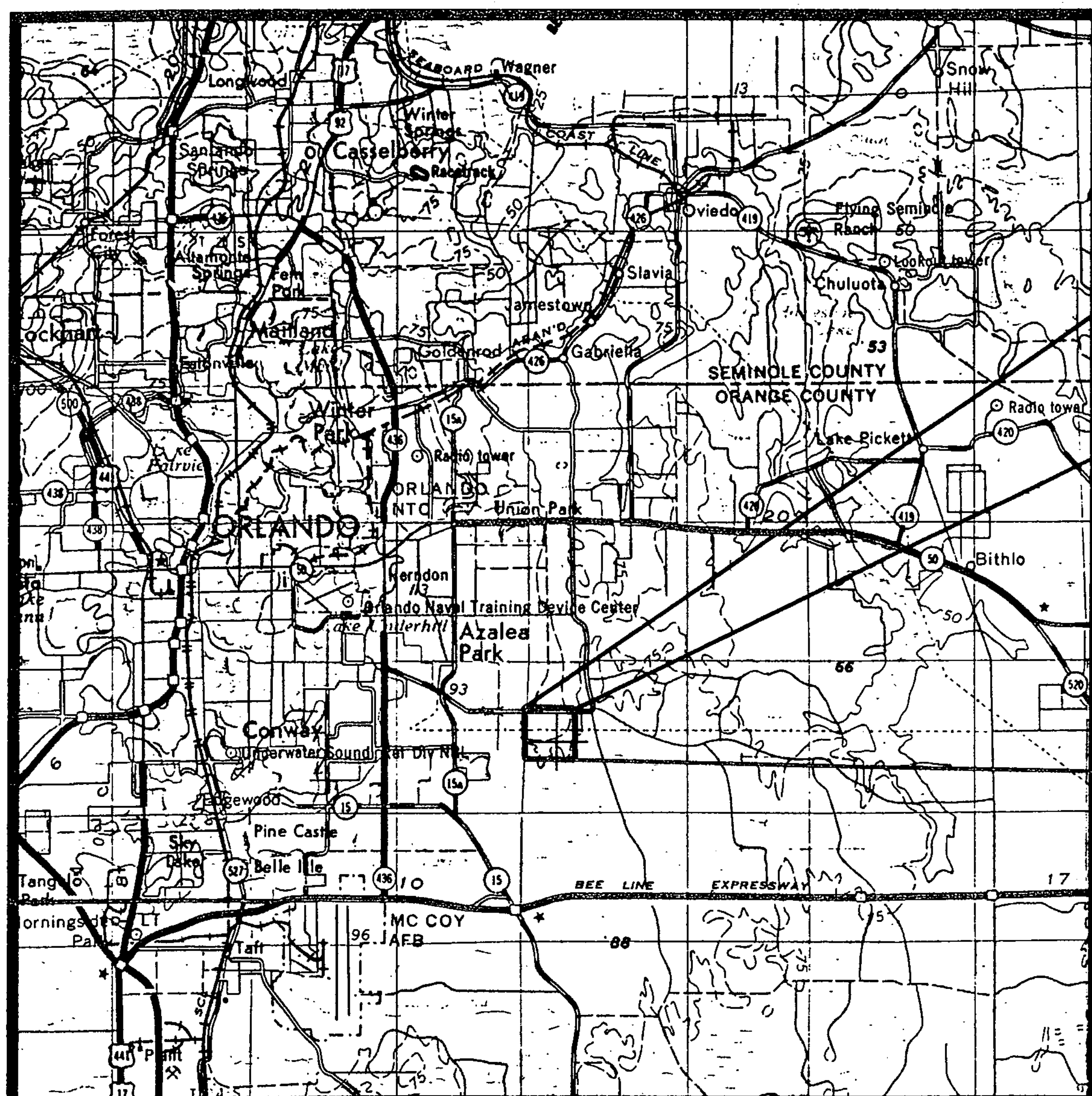
In support of the County's new Consumptive Use Permit, several wells were constructed and pumping tests completed to evaluate and hydraulically model the selected wellfield site. This report presents the results of the well construction, hydraulic testing, water quality testing and computer based modeling activities involved in evaluating the Eastern Regional Wellfield (ERWF) project. The contents of this report include well construction documentation; results of the aquifer performance test data analysis; numerical model construction and calibration documentation; results of groundwater flow model simulations for long term wellfield operation; and an assessment of withdrawals on water quality. Conclusions and recommendations concerning conceptual wellfield design, dependable yield and migration of the salt water-fresh water interface are also presented in this report.

1.2 PROJECT LOCATION

The proposed Eastern Region Wellfield Site is located in eastern Orange County, Florida, approximately 7 miles due east of Orlando. More specifically, the proposed site occupies approximately 160 acres within Section 7 of Township 23 South, Range 31 East. Figure 1 presents the location of the proposed wellfield site.

2.0 HYDROGEOLOGIC SETTING

The Eastern Regional Wellfield facility will be designed to utilize the Floridan aquifer to produce raw water for subsequent treatment and distribution. The Floridan aquifer is the primary source of drinking water in Central Florida and is one of the most productive aquifers in the country . The semi-artesian Floridan aquifer is composed of thick sequences of Eocene age limestones and dolomite. The aquifer is



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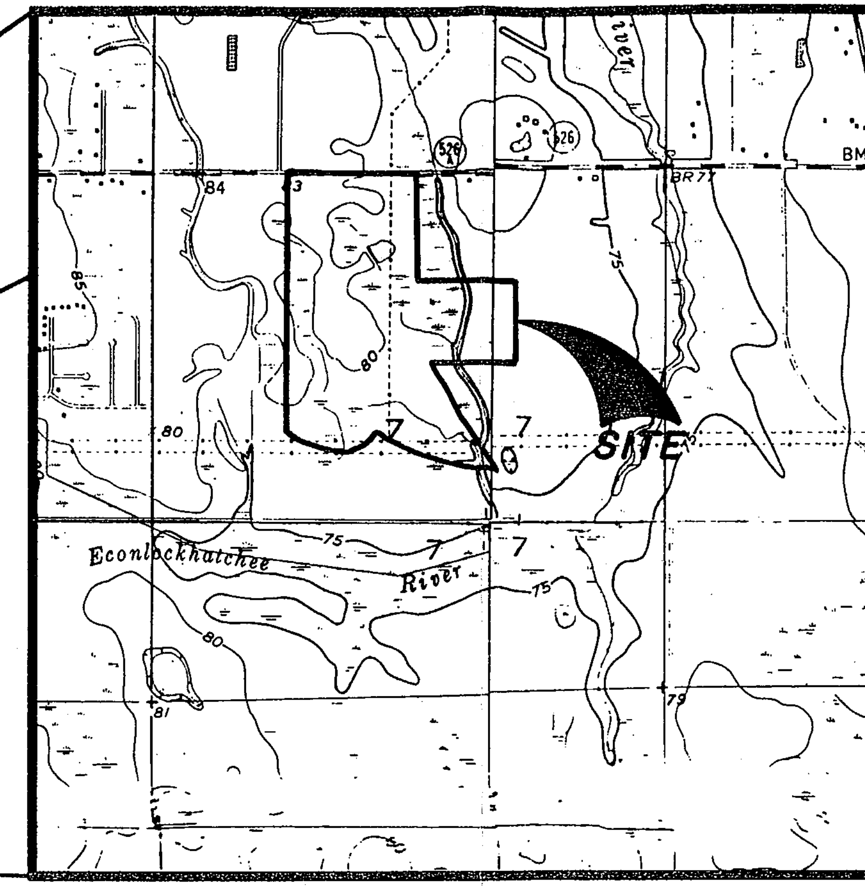
ISSUED: 1955
PHOTOREVISED: 1972
SCALE: 1" = 4 Miles



REFERENCE: U.S.G.S. "EAST ORLANDO, FLORIDA" QUADRANGLE MAP

SECTION:	7	ISSUED:	1962
TOWNSHIP:	30	PHOTOREVISED:	1980
RANGE:	23	SCALE:	1" = 2000'

DRAWN:	CFG
CHKD:	CLS
APPVD:	NEA
SCALE:	NOTED

SITE LOCATION
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DATE	PROJ NO	
2-12-90	88-03288	FIGURE 1

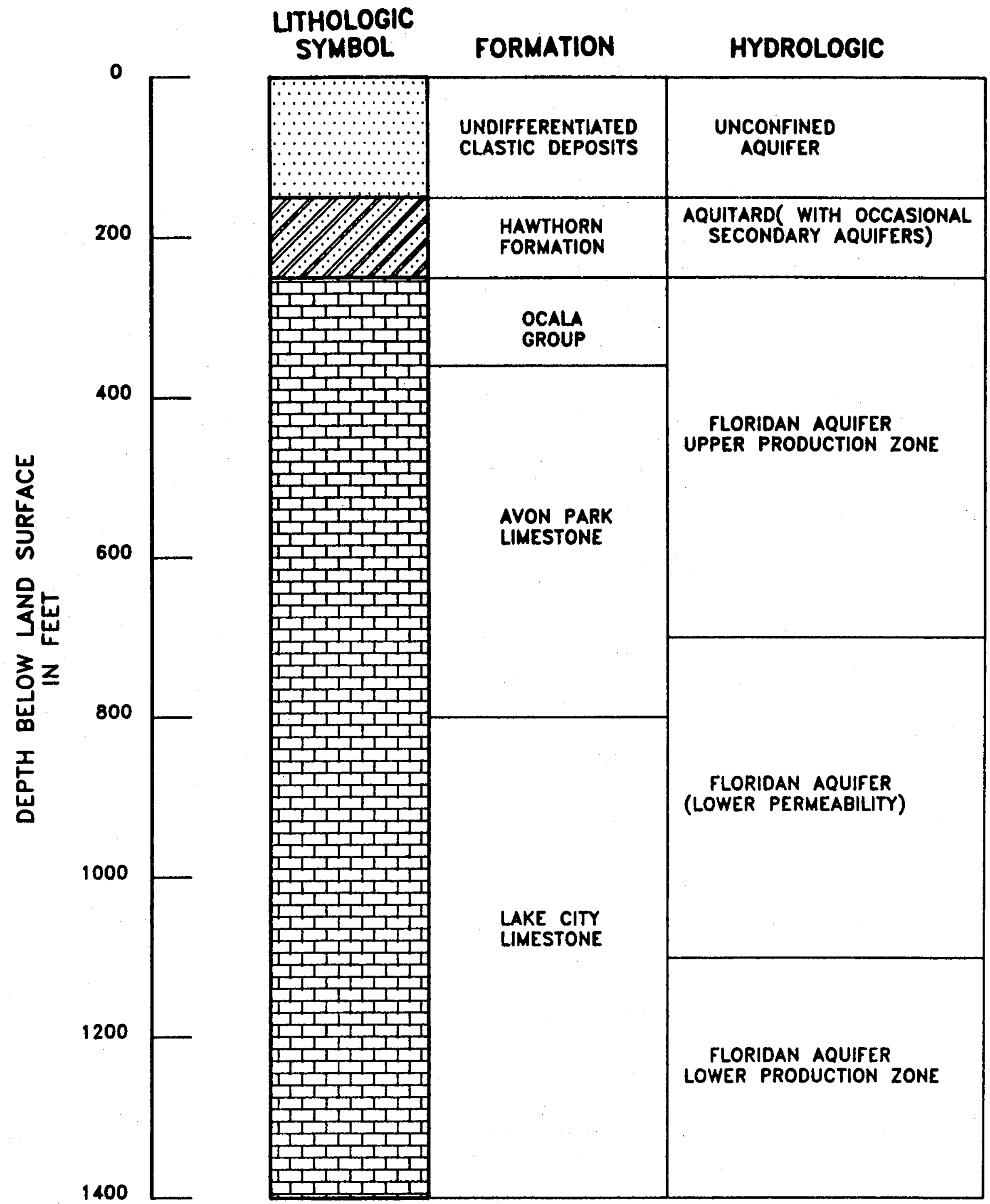
DRAPHIX #291020

considered to have two main production zones, referred to as the upper and lower Floridan, with an intervening, reduced transmissivity zone known as the intermediate Floridan aquifer. The ERWF facility proposes to produce the raw water from the upper production zone of the Floridan aquifer.

The regional hydrogeology has been previously described by numerous authors. The first comprehensive description of the regional hydrogeology was published by the United States Geologic Survey (U.S.G.S.), Lichtler,et al 1968. Based on the U.S.G.S. description, the hydrogeology of the area is divided into three (3) primary aquifers. These are the surficial unconfined aquifer and the upper and lower Floridan aquifers. Separating each aquifer is an aquitard or zone of lower permeability. These aquitard zones include the low permeability portions of the Hawthorn Formation and the intermediate Floridan aquifer. Figure 2 presents a generalized geologic section for the Central Florida area and the corresponding hydrologic function for each of these units.

2.1 SURFICIAL AQUIFER AND HAWTHORN FORMATION

The surficial aquifer, also called the non-artesian or unconfined aquifer, is comprised of a series of sand, shell and clay deposits. The total thickness of these deposits are approximately 80 feet in the area of the ERWF site, as shown by wells constructed within the wellfield area. The uppermost sand deposits of this aquifer are Pleistocene to Recent in age. Lower portions of this aquifer consisting of clayey sands and shell beds are likely part of the Miocene age Hawthorn Formation.



GENERALIZED GEOLOGIC SECTION

EASTERN REGIONAL WELLFIELD

ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN: CFG	SCALE N.T.S.	PROJ NO 88-03288
CHKD. CLS	DATE. 2-12-90	FIGURE 2

The bottom of the aquifer is marked by the thick clay deposits of the Hawthorn Formation. The sediments of the Hawthorn Formation act as a semi-confining layer retarding the vertical movement of water between the surficial aquifer and the underlying Floridan aquifer. Within the ERWF area, these sediments are believed to be approximately 105 feet thick, as interpreted from the well construction logs and the geophysical logs.

In the areas of the proposed wellfield, the surficial aquifer yields relatively small amounts of water. Effective use of this aquifer is generally limited to small domestic users. The surficial aquifer within the project area acts as a resevoir to hold water for later leakance into the Floridan aquifer below and slow lateral flow towards surficial lakes and rivers.

2.2 LIMESTONE AQUIFER SYSTEM

2.2.1 Upper Floridan Aquifer

In the Central Florida region, as in most parts of the state, Tertiary age limestones comprise the main aquifer system capable of producing significant sources of potable water. In the region of the proposed wellfield these limestones are divided into three (3) units based upon their hydraulic characteristics. These are the productive upper and lower Floridan aquifer and the low permeability intermediate Floridan aquifer.

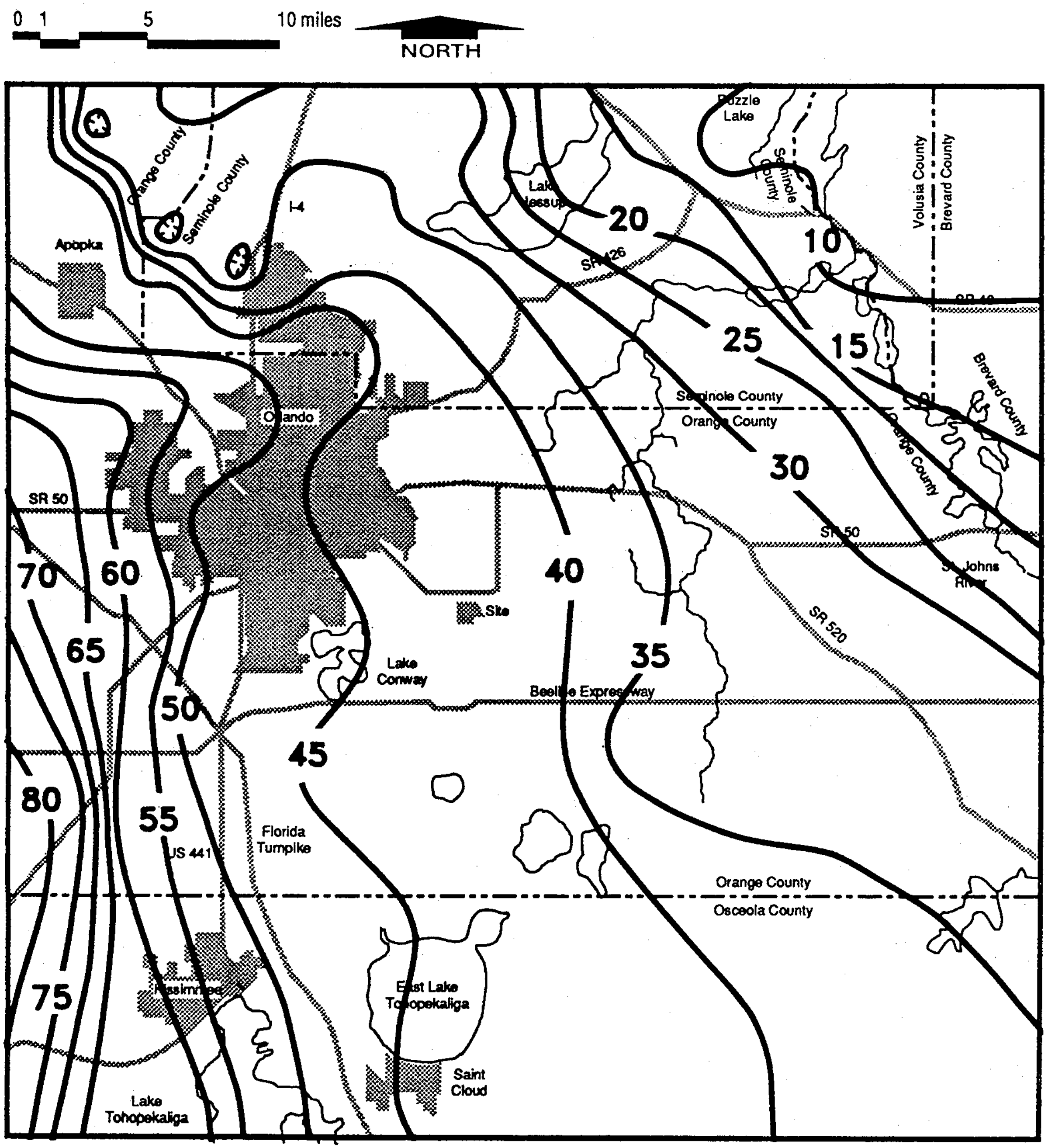
The upper Floridan aquifer is a semi-artesian aquifer comprised primarily of the Avon Park and the Ocala Group limestones. In some areas, as within the ERWF site, hydraulically connected limestones of the lower Hawthorn Formation are also part of the upper Floridan aquifer. Based on site specific well construction information and review of well logs from wells in the vicinity, the upper Floridan aquifer generally extends from a depth of approximately 185 feet bls to a depth of approximately 530 feet bls. Zones immediately below the 530 foot depth are generally less productive, as interpreted from geophysical flow logs. These zones of low productivity are considered to be a part of the intermediate Floridan aquifer system.

Recharge to the upper Floridan aquifer generally occurs through downward vertical leakance from the overlying units, lateral movement from areas of higher potentiometric elevations (high recharge areas), and from the lower Floridan aquifer in areas where the potentiometric head of the lower Floridan is elevated above that of the upper Floridan aquifer. Within the project vicinity, the majority of the recharge to the upper Floridan aquifer occurs from lateral movement within the aquifer system. Lichtler (1968) and Tibbals (1981) both suggest that vertical recharge from the overlying unconfined aquifer is 2 in/yr or less in the project vicinity. In contrast, the Lake Wales Ridge and the Orlando Ridge receive considerably higher vertical recharge (8 to 11 inches/year). Rutledge (1984) and German and Bradner (1988) both indicate that with the inclusion of drainage wells in the Orlando area, vertical recharge to the upper Floridan may be as high as 19 inches/year. The effects of this high recharge can be seen in the potentiometric surface maps for Orange County. Figure 3 presents the potentiometric surface in eastern Orange County for May 1988. As suggested by German and Bradner, (1988) the elevated potentiometric surface in the Orlando metropolitan area is considered to be related to high vertical recharge to the Floridan aquifer, which is believed to be substantially provided by the recharge through drainage wells.

Review of the potentiometric surface map presented on Figure 3 for the eastern Orange County indicates that the major flow direction of waters within the upper Floridan aquifer is mostly due east across the ERWF site. The potentiometric surface for September 1988 is presented on Figure 4. Review of the September, 1988 potentiometric surface (wet season conditions) indicates that the flow direction across the site remains relatively unchanged from dry season to wet season. Annual elevational changes of the potentiometric surface in the ERWF site vicinity fluctuates between approximately +42 feet and +48 feet NGVD for the years 1981 to 1989.

2.2.2 Intermediate and Lower Floridan Aquifers

Marking the base of the upper Floridan aquifer is a zone of lower permeability limestone formations, referred to as the intermediate Floridan aquifer. This zone of lower permeability extends from a depth approximately 530 feet bls in the ERWF area to approximately 1150 feet bls, at which point the Floridan aquifer becomes more permeable once again. In most areas of Central Florida this zone is thought to represent a poorly permeable aquifer or an aquitard between the upper and the lower Floridan aquifer units. The upper and lower boundaries for this unit are identified based upon the



Jammal & Associates, Inc.
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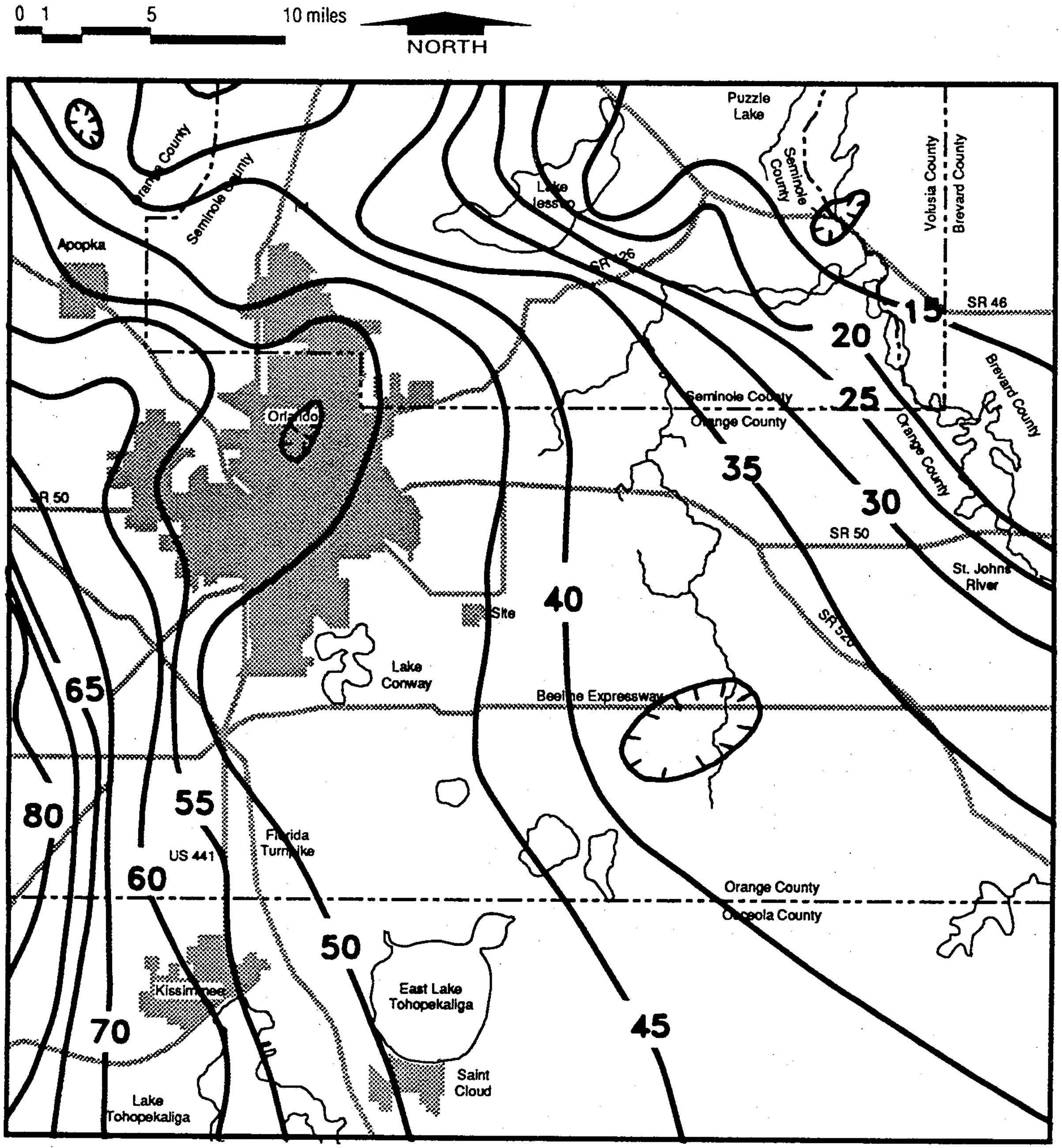
ELEVATION OF THE POTENTIOMETRIC SURFACE FOR THE UPPER FLORIDAN AQUIFER MAY, 1988

CONTOUR INTERVAL: 5.0 ft.

FIGURE 3



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ELEVATION OF THE POTENTIOMETRIC SURFACE FOR THE UPPER FLORIDAN AQUIFER SEPTEMBER, 1988

CONTOUR INTERVAL: 5.0 ft.

FIGURE 4

hydrologic properties of the limestones and not on a lithologic or chronologic division.

The lower Floridan aquifer, like the upper Floridan aquifer, is a known production zone for large quantities of water. The top of this hydrologic unit is marked by the base of the intermediate Floridan aquifer zone and extends down to an undetermined depth beyond 2,500 feet bls. The primary geologic unit comprising the lower Floridan aquifer is the Lake City Limestone. Tibbles, 1981, as well as others (Skipp, 1988; Lichtler, 1968), believe that the lower Floridan aquifer is generally much more transmissive than the upper Floridan aquifer system.

The potentiometric surface of the lower Floridan aquifer is much less defined than that of the upper Floridan aquifer. The primary reason for this is the reduced number of monitoring wells that penetrate the lower hydrologic unit. Tibbles (1981) and Skipp, 1988 believe that the potentiometric surface of the lower Floridan aquifer most likely mimicks that of the upper Floridan with minor differences in elevations. Observation wells in the downtown Orlando area indicate that the potentiometric surface of the lower Floridan is approximately 1 to 2 feet below that of the upper Floridan aquifer. At the ERWF area, this difference is approximately 0.14 feet with the lower Floridan aquifer being higher at the time of measurement (10/89). Further east, in areas of artesian flow, the potentiometric head of the lower Floridan aquifer is believed to be elevated above that of the upper Floridan aquifer.

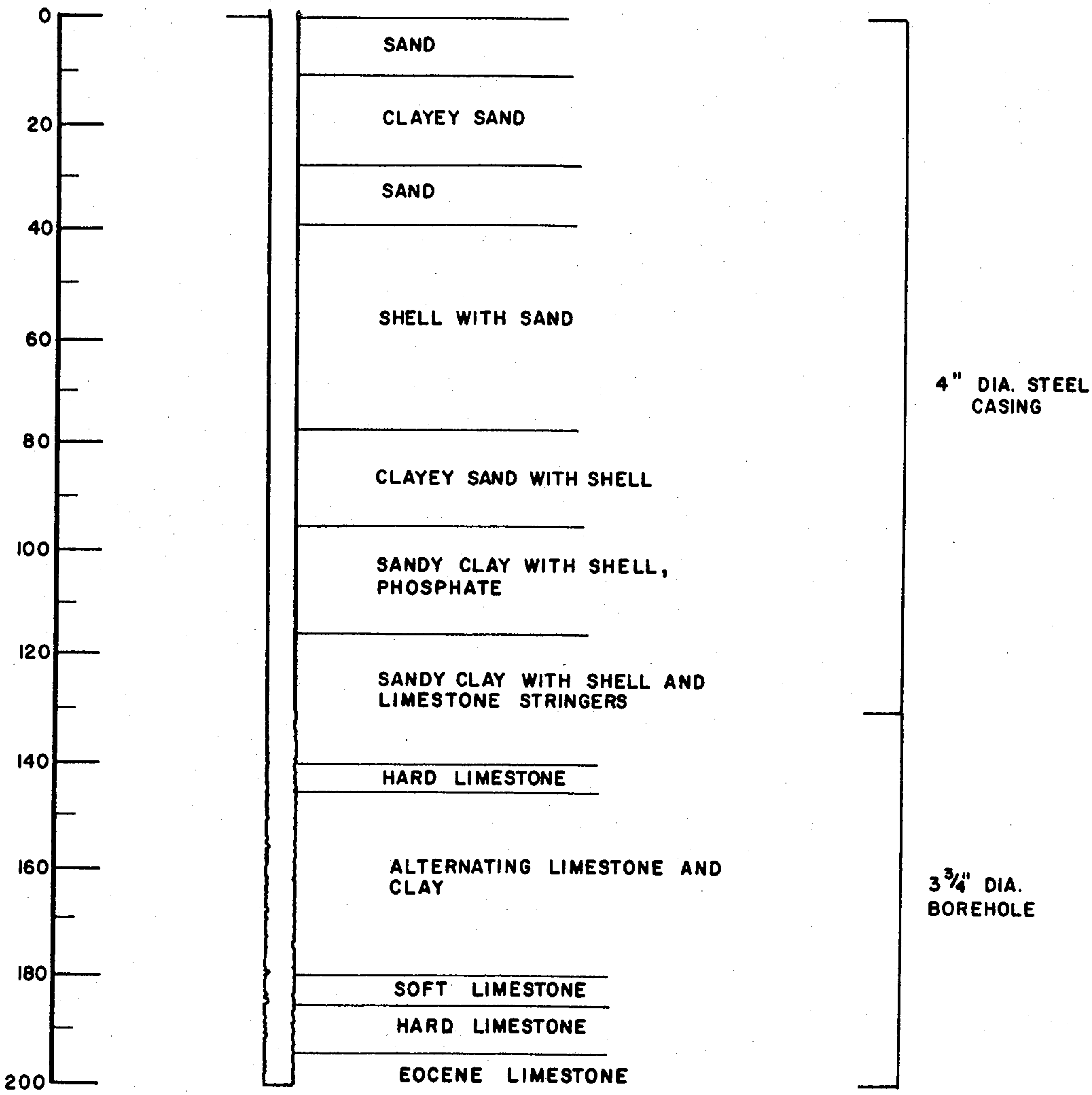
3.0 FIELD INVESTIGATIONS

3.1 WELL CONSTRUCTION

An aquifer testing program was developed to locate and provide essential hydrogeologic and geologic information on the most suitable groundwater production zones within the uppermost 700 feet of limestones at the ERWF site. The collected information was used to provide the basis for site evaluation and to project the potential impacts associated with the proposed future withdrawals. This testing program included the construction of one (1) Lower Floridan Exploratory Well (LFEW), one (1) Intermediate Floridan Monitoring Well (IFMW), one (1) Upper Floridan Production Well (UFPW), one (1) Upper Floridan Monitor Well (UFMW), and one (1) Shallow Piezometer (SP). One additional well (CSW), built primarily to provide well construction water, was also utilized during subsequent aquifer performance testing.

3.1.1 Construction Water Supply Well

On May 22, 1989 well construction began at the ERWF test site. The first well to be installed was the Construction Water Supply Well (CSW). The CSW was installed to provide a source of water for subsequent well construction activities. Upon completion the CSW had a string of 4 inch diameter steel casing extending from approximately one foot above land surface to 130 feet below land surface (bls). The open-hole section of the well extends from 130 feet bls to 201 feet bls and taps the uppermost contact of the Eocene age limestone. Figure 5 is a diagram of the CSW well and the type of sediments encountered during well drilling.



CSW WELL CONSTRUCTION DIAGRAM
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN: CFG	SCALE N.T.S.	PROJ NO 88-03288
CHKD. CLS	DATE. 2-12-90	FIGURE 5

DRAPHIX 290311

3.1.2 Lower Floridan Exploratory Well

Upon completion of the construction supply well, construction was begun on the Lower Floridan Exploration Well (LFEW). This well consists of a 6-inch diameter steel casing extending from one foot above land surface to a depth of 1,100 feet bls. Below this depth and extending to a total depth of 1,385 feet is a 12" diameter open borehole. Outside of the 6-inch diameter casing, varying lengths of 12-inch, 18-inch and 30-inch casings extend up to the ground surface. These additional diameter casings were specifically used to allow for the construction of this deep well and to allow for the subsequent installation of a 2-inch diameter annular piezometer screened in the intermediate Floridan aquifer zone. Each of these outer casings are constructed in a telescoping fashion with a minimum of 20 foot overlap between each.

During the construction of LFEW cuttings from the well were collected every 10 feet or at each lithologic change and four (4) core samples were obtained at selected intervals. The core samples were obtained at depth intervals of 737' to 747' bls, 950' to 960'bls, 1,040' to 1,050' bls and 1,070' to 1,080' bls. These core samples were evaluated and then submitted to the St. Johns River Water Management District (SJRWMD). The core samples were collected by Diversified Drilling with a special barrel bit.

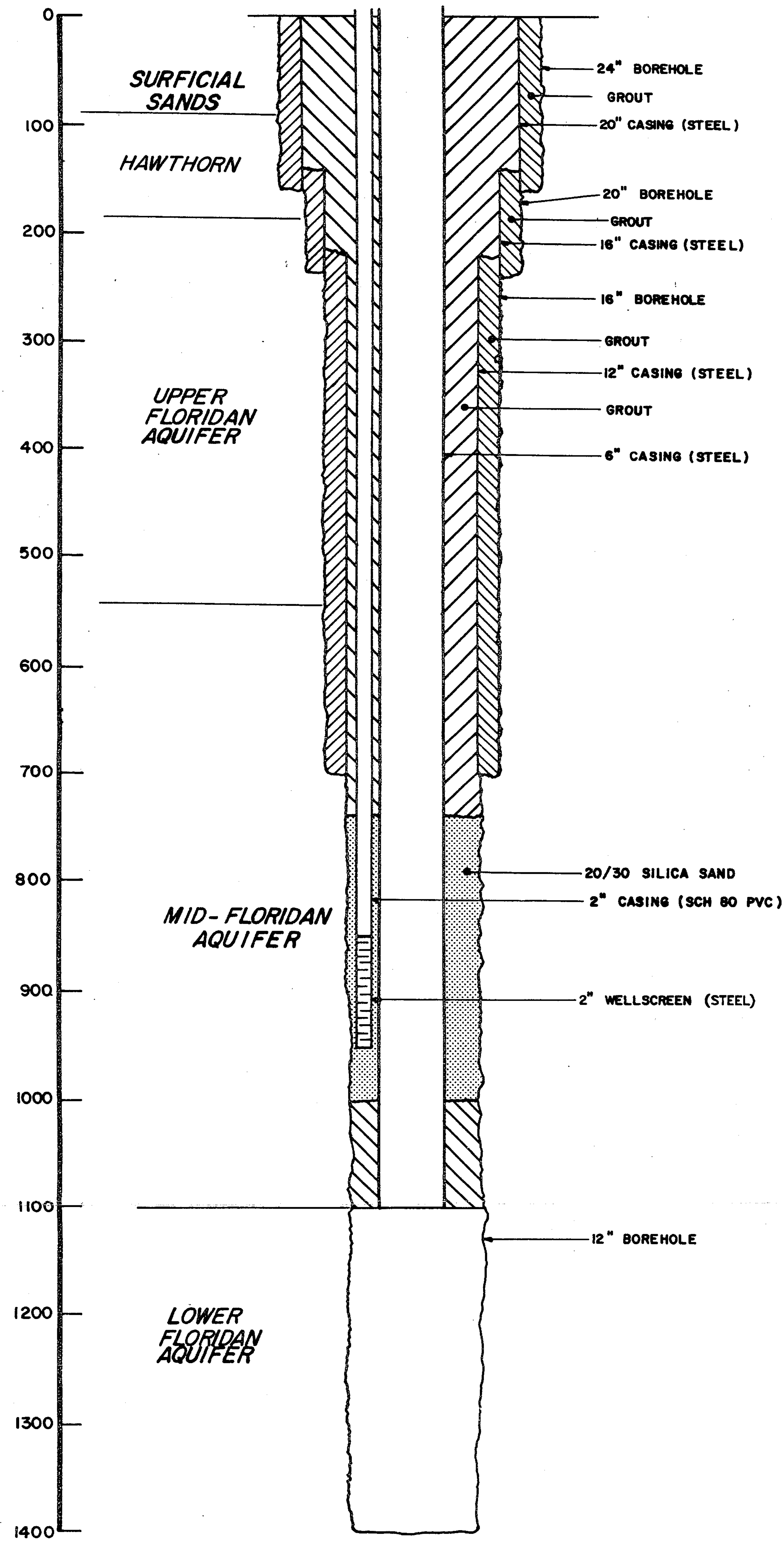
The Intermediate Floridan Monitor Well (IFMW) is a 2-inch diameter steel piezometer with a total depth of 950 feet bls. This piezometer has a casing extending from land surface to a depth of 850 feet. The lower 100 feet of this piezometer consists of 10/1000 slotted screen. The piezometer was installed in the annular spacing between the 12-inch open hole section and the 6-inch inner casing. Silica sand (20/30) was placed in the annular space surrounding the well screen to a depth of 50 feet below the base of the screen and 100 feet above the top of the screen. The upper 750 feet of the solid piezometer casing was grouted in place. Figure 6 presents a construction cross section of the Lower Floridan Exploratory Well and the associated 2-inch Intermediate Floridan Aquifer Monitor Well.

3.1.3 Upper Floridan Production and Monitor Wells

Coincidental with the construction of the Lower Floridan Exploratory Well, construction was begun on the Upper Floridan Production Well (UFPW). UFPW is a 24-inch diameter well with a total depth of 550 feet bls. This well has 210 feet of 24-inch diameter steel casing with 20 feet of 30-inch diameter steel casing as a pit casing. UFPW well was designed for production tests and for later use as a potable supply well. Figure 7 presents the recorded construction details of the UFPW well. The depth of casing, the diameter of the well, and the depth of the open hole section for the UFPW were initially selected based on the well construction records and geophysical logging data collected from the LFEW.

Subsequent to completion of well UFPW, work was begun on the Upper Floridan Monitor Well (UFMW). This well was constructed in a manner similar to that of the production well. This well was constructed using 210 feet of 6-inch steel casing and the open-hole was drilled to a total depth of 550 feet bls. Figure 8 presents the recorded construction details of the UFMW well.

DRAPHIX #279844

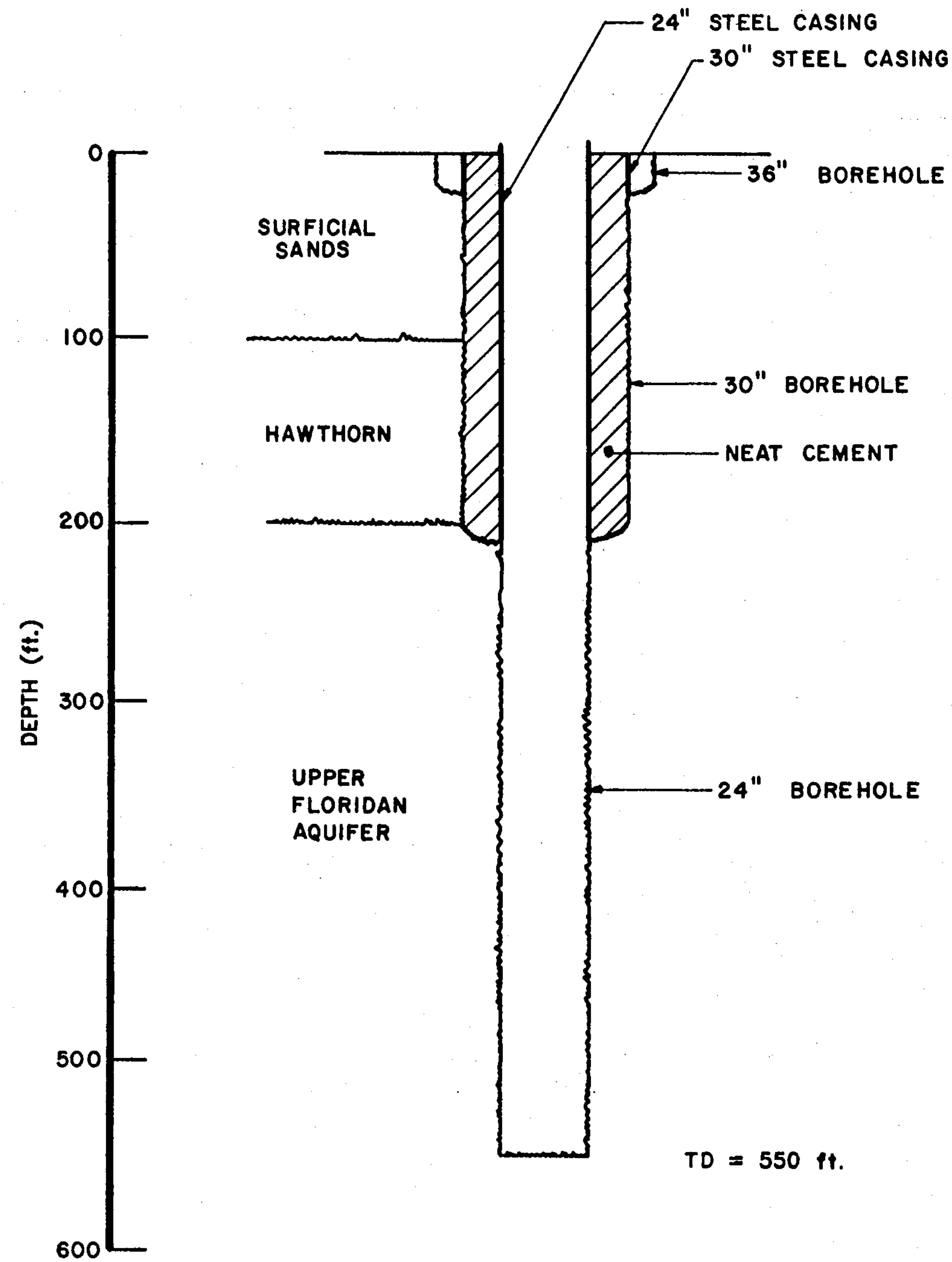


DRAWN: PS
CHKD: JJH
APPVD: NEA
SCALE:

LOWER FLORIDAN EXPLORATORY WELL
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DATE: 2-12-90 | PROJ. NO.: 88-03288 | FIGURE 6

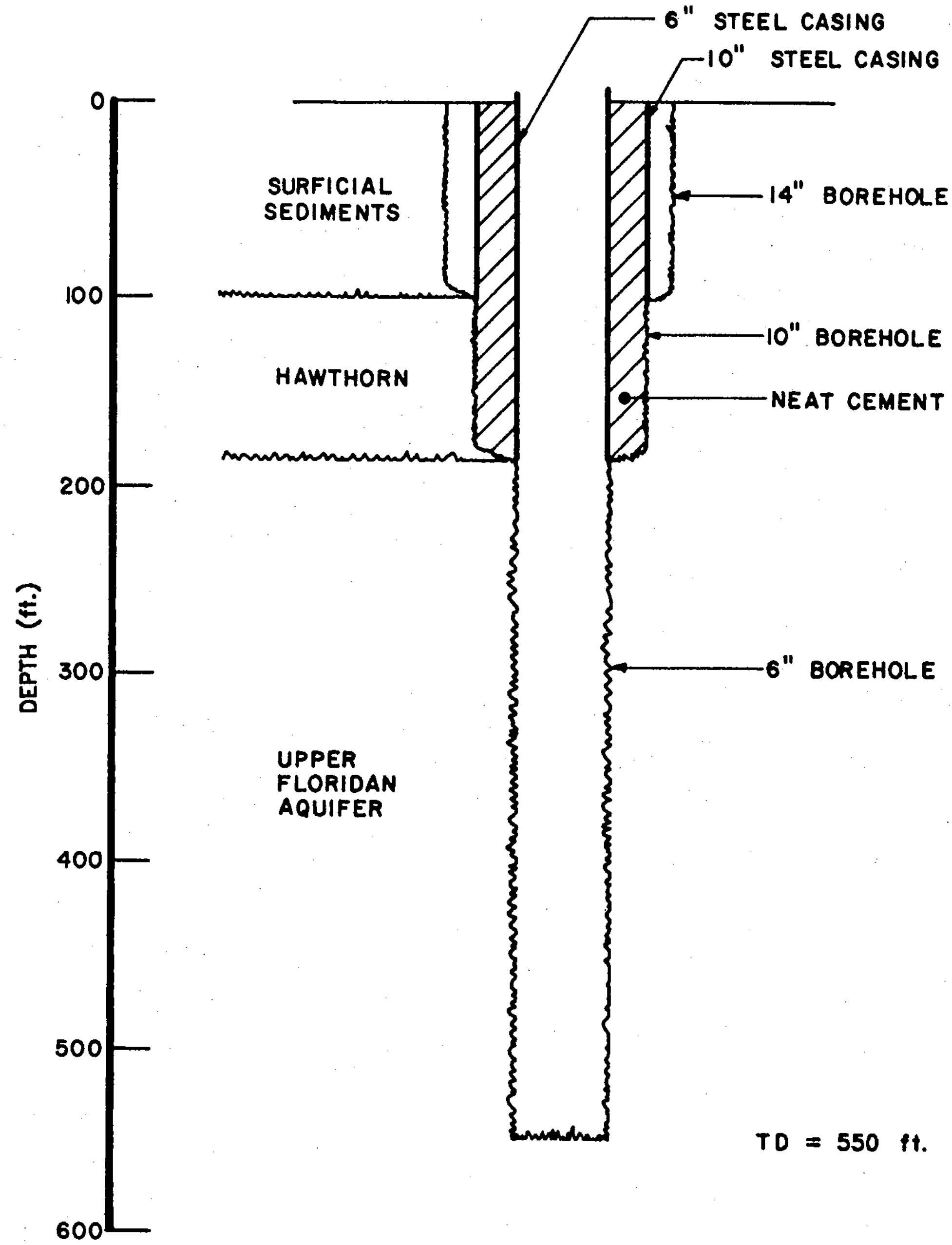


VERT. : 1" = 100'
HOR. : N.T.S.

UPPER FLORIDAN PRODUCTION WELL
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN: CFG	SCALE NTS	PROJ NO 8803288
CHKD. CLS	DATE. 2-12-90	FIGURE 7



UPPER FLORIDAN MONITOR WELL
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN: CFG	SCALE NTS	PROJ NO 88-03288
CHKD. CLS	DATE. 2-12-90	FIGURE 8

DRAPHIX 290311

In addition to the test wells, a shallow piezometer was installed into the surficial unconfined aquifer at a distance of 5.5 feet from the UFPW. This well was installed to a depth of 20 feet bls, having 10 feet of screen, and was designed to record water level fluctuations in the surficial aquifer during the 72 hour constant rate discharge test.

3.2 AQUIFER AND WATER QUALITY TESTS

3.2.1 Geophysical Logging

Upon completion and during construction of the five (5) wells, wells UFPW, UFMW and LFEW were geophysically logged. Table 1 below summarizes the type of logs run on each well.

TABLE 1

GEOPHYSICAL LOGS COMPLETED

Log Type	UFPW	UFMW	LFEW
Gamma Ray	X	X	X
Caliper	X	X	X
Spontaneous Potential (SP)		X	X
Single Point Resistivity		X	X
Temperature	X		X
Fluid Velocity			X
Fluid Resistivity	X		X
16 and 64 Normal Resistivity			X (701-1385 feet bls)

These geophysical logs were completed to gather information on the geology, relative water quality and the hydrogeology encountered in each well. Appendix A contains the results of the collected caliper, gamma, temperature, electrical resistivity and fluid velocity logs for each well.

Evaluation of the collected geophysical logs from the LFEW indicates the presence of five (5) distinctive production horizons within the penetrated 1,385 feet. The two (2) upper production zones are the surficial unconfined aquifer and the underlying Hawthorn Formation which acts as an aquitard. The base of the Hawthorn Formation is marked by a laterally extensive layer of limestones and clays. The base of this unit occurs at approximately 198 feet bls.

Between the depths of 198 and 530 are productive horizons of the Upper Floridan Aquifer. Gamma ray activity for this portion of the Floridan is relatively low, while caliper logs show numerous large cavaties to a depth of 530 feet. Fluid velocity logs show a sharp reduction in productivity of the formation at a depth of 530 feet.

Between the depths of 530 feet and 1,155 feet bls the Floridan aquifer appears to have reduced production capabilities as interpreted from the fluid velocity and 16-64 normal resistivity logs. This zone is therefore considered to be the intermediate Floridan aquifer. The lower extent of this horizon was primarily chosen based upon observations during the well construction and upon interpretation of the 16-64 normal resistivity log. Observed high productivity zones below the depth of 1,155 feet are believed to represent the lower Floridan aquifer.

3.2.2 Step Drawdown Testing

A step drawdown test was conducted on well UFPW in order to estimate the wells productivity and to determine the well's dynamic pumping water level at varying rates of discharge. The step drawdown test was conducted by pumping well UFPW at four (4) different rates and measuring the drop in water level within the pumping well with time. The average discharge rates for the test were 1,100 gpm, 3,500 gpm, 4,350 gpm, and 4,900 gpm. Each discharge rate was maintained until the measured water level approached a new stabilized level. Between each pumping step the well was allowed to recover to near its original static level. Figure 9 presents the results of the step drawdown test conducted on well UFPW. The projected total drawdown curve indicates the approximate amount of drawdown anticipated for any discharge rate between 0.0 and 5,500 gpm for well UFPW. Data collected during the step drawdown test is presented in Appendix B.

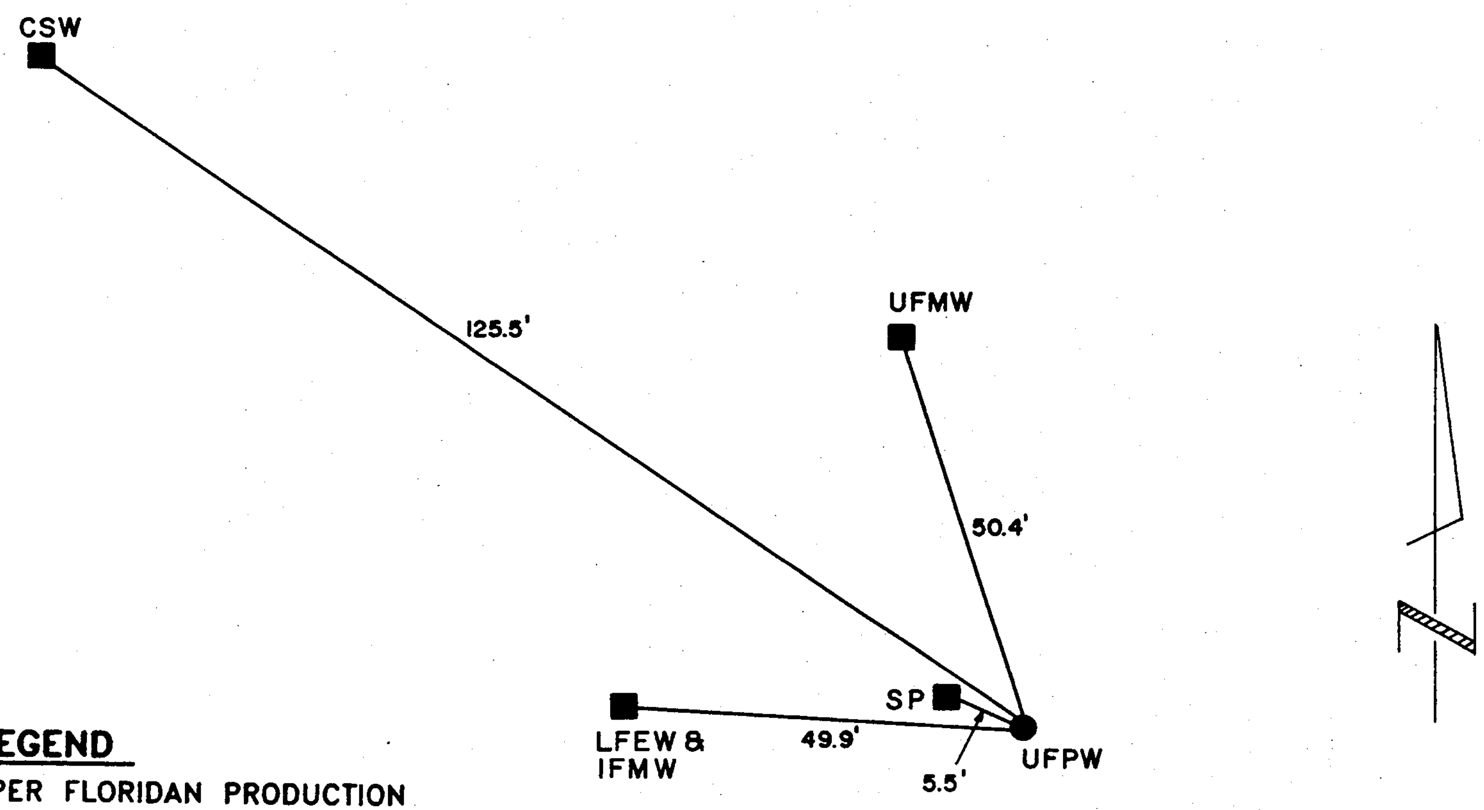
Based upon the test pumping rates, the well diameter and the recorded drawdown, both the well losses and the formation losses were calculated for each of the discharge rates of the step drawdown test. Our calculations indicate that the well losses account for less than 0.5 feet of the total drawdown at discharge rates of up to 5,000 gpm.

3.2.3 Constant Rate Pump Test

A 72-hour constant rate discharge test was conducted to estimate the aquifer hydraulic characteristics in the direct vicinity of the test/production well. This test utilized UFPW as a discharge point and wells UFMW, SP, LFEW, CSW and IFMW as observation points. The alignment of the wells and the distances between each well are presented on Figure 10.

The 72-hour constant rate discharge test or aquifer performance test (APT) consisted of continuously pumping well UFPW at a rate of 4,950.5 gpm for a period of approximately 72 hours while recording drawdown of the potentiometric surface and piezometric surface in the constructed wells. Continuous water level recorders were installed in all wells except the pumping well during the course of the test. Stevens-F Type Water Level Recorder, Stevens-A type Recorder, Thor Dataloggers and hand measurements were all used for the data collection. Machine collected water levels were periodically verified with manually collected readings to assure data accuracy. Water levels within wells LFEW and UFMW were recorded for a period of 18 days prior to the start of the test and for 18 days after completion of the test to record background water level fluctuations. Background recordings indicated that no significant long term recharge or discharge events were present during the pumping period. Tidal fluctuations recorded during the course of the APT did effect the measured water levels during the test. Amplitude of the tide effects were approximately 0.12 feet on the upper Floridan and 0.08 feet on the lower Floridan.

The discharge from well UFPW was produced using a diesel driven turbine pump. Measurements of discharge were made using a manometer for hourly readings and a flow meter with accumulated discharge for the total discharge volume. Total volume of water discharged from the well was approximately 21,609,000



LEGEND

UFPW UPPER FLORIDAN PRODUCTION WELL

UFMW UPPER FLORIDAN MONITORING WELL

LFEW LOWER FLORIDAN EXPLORATORY WELL

IFMW INTERMEDIATE FLORIDAN MONITORING WELL

CSW CONSTRUCTION SUPPLY WELL

SP SHALLOW PIEZOMETER

WELL LOCATION & DISTANCE
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN CFG	N.T.S.	PROJ NO 88-0328
CHKD CLS	DATE 2-12-90	FIGURE 10

DRAPHIX #267658

gallons in a period of 72 hours and 45 minutes. The APT test was begun at 6:05 p.m. on 9/11/89 and was stopped at 6:50 p.m. on 9/14/89.

Rainfall events before, during and after the course of the APT test were monitored by an on-site temporary rain gauge installed adjacent to the discharge well. Daily rainfall amounts on site were recorded throughout the course of the test. According to the on-site rain gauge monitoring data, a very small amount of rainfall was recorded several days prior to the start of the test and no rainfall was recorded during the course of the APT test. Recorded daily rainfall records are included in Appendix C.

In addition to the installation of an on-site rain gauge, a microbarograph was set up to record changes in atmospheric pressure. Large fluctuations in the atmospheric pressure during recording with pressure transducers may possibly influence the measured water level readings. The type of pressure transducers used in conjunction with the Thor Datalogger are barometrically compensated, however, suggesting that only very large and rapid changes in atmospheric pressure might effect the readings. Based on our barometric monitoring data, no significant atmospheric pressure changes were recorded.

3.2.4 Water Quality Tests

During the construction of well LFEW, groundwater samples were periodically collected and field tested for pH, temperature, electrical conductivity, chlorides and hydrogen sulfide. Field tests were conducted using HACH chloride and hydrogen sulfide test kits and a YSI temperature/conductivity meter. Water samples were collected by means of the discharge line during reverse-air drilling operations. Table 2 presents the water quality information collected (with depth) during drilling operations of well LFEW. Review of the collected water quality data indicates little change in the water quality with depth.

In addition to the field testing of water samples, representative water samples were collected at two separate intervals and analyzed for selected parameters by an independent chemical laboratory. These water samples were collected at depths corresponding to withdrawals from the upper Floridan aquifer (210'-707' bls) and from the lower Floridan aquifer (1,100'-1,385' bls). Appendix D presents the laboratory results of these water quality analyses. Review of this data indicates that waters from both the upper Floridan and the lower Floridan aquifers are chemically similar. The results indicate that none of the analyzed parameters of either water sample exceed the water quality parameters set forth by the State in Chapter 17-550 F.A.C. The measured chloride and total dissolved solids (TDS) concentrations were found to be low in both samples.

TABLE 2
EASTERN REGIONAL WELLFIELD
EXPLORATORY WELL WATER QUALITY DATA

DATE (1989)	DEPTH ft. bls	pH	TEMP. °C	COND. umhos	Chl[1]	HS[2]
06/06	275	9.25	23.7	185	18.8	1.0
06/07	340	8.45	24.9	220	20.6	5.0
	400	8.35	23.6	260	--	5.0
06/08	460	7.95	27.2	260	8.7	5.0
06/09	520	7.90	25.5	255	12.5	5.0
06/12	286	7.94	24.9	288	13.4	2.0-5.0
06/13	645	7.55	25.6	285	5.9	1.0-2.0
	706	8.06	24.6	280	8.1	2.0-5.0
07/05	800	9.45	27.4	210	19.3	1.0
	860	8.88	24.6	290	17.6	2.0
07/06	920	8.35	24.6	305	12.3	2.0-5.0
07/07						
07/10	980	8.22	25.3	310	16.8	1.0-2.0
07/11	1040	7.99	25.2	300	11.2	2.0-5.0
07/17	1110	8.25	25.9	300	11.3	1.0
	1170	8.16	24.8	275	12.8	1.0-2.0
07/18	1230	8.01	25.5	280	11.1	2.0
	1290	8.08	25.7	290	13.0	2.0
07/19	1345	7.94	26.0	305	13.0	2.0

1) Chl - Chlorides in mg/l

2) HS - Hydrogen Sulfide in mg/l

Water quality tests were also conducted on samples collected from Azalea Park Canal and Azalea Park well (a nearby lower Floridan aquifer well). Surface water samples from the Azalea Park Canal were tested for organochlorine pesticides and primary inorganics. A copy of the report evaluating the collected water samples and results of the analyses are provided in Appendix E. The results indicate that all analyzed parameters were below detection limits with the exception of sodium and floride which were well below the State quality standards. The water sample collected from the Azalea Park Well was tested for chlorides and TDS. The Azalea Park Well is a out-of-service lower Floridan well with an open borehole between the depths of 1,089 and 1,226 feet bls. This well is located approximately 2 1/2 miles northwest of the ERWF site. Analyzed concentrations of chlorides and TDS for the collected sample were 10 mg/l and 190 mg/l respectively.

In addition to the water quality tests conducted during the construction of the LFEW, water quality samples were taken and analyzed as part of the APT. Nineteen (19) water samples were collected from well UFPW and one (1) from well LFEW during the course of the APT. Each was analyzed for major ion constituents including calcium, magnesium, sodium, potassium, chlorides, sulfate, bicarbonate and carbonate alkalinity, TDS, total hardness, pH, sulfate, iron, and specific conductance. Table 3 below presents the time since the start of pumpage when each sample was taken. Results of the laboratory water quality analysis of these samples is included in Appendix F.

TABLE 3

APT WATER QUALITY SAMPLING TIMES

Well	Sample #	Time Since Start of Pumping
UFPW	1	3 minutes
UFPW	2	4 hours
UFPW	3	8 hours, 13 minutes
UFPW	4	12 hours, 3 minutes
UFPW	5	16 hours, 3 minutes
UFPW	6	20 hours, 3 minutes
UFPW	7	24 hours, 3 minutes
UFPW	8	28 hours, 5 minutes
UFPW	9	32 hours, 9 minutes
UFPW	10	36 hours, 5 minutes
UFPW	11	40 hours, 9 minutes
UFPW	12	44 hours, 7 minutes
UFPW	13	48 hours, 3 minutes
UFPW	14	52 hours, 15 minutes
UFPW	15	56 hours, 30 minutes
UFPW	16	60 hours, 3 minutes
UFPW	17	64 hours, 1 minute
UFPW	18	68 hours, 10 minutes
UFPW	19	71 hours, 53 minutes
LFEW	20	72 hours, 35 minutes

Water samples gathered from well UFPW were collected at the discharge orifice in the laboratory bottles. The water sample taken from well LFEW was collected by means of a downhole sampler connected to a geophysical logging unit. This sample was taken at a depth of approximately 1,300 feet. The last sample collected from well UFPW (UFPW-19) was analyzed for State Primary and Secondary Standards as outlined in Chapter 17-550 F.A.C., as well as priority pollutants and certain other parameters. Results of the chemical analysis indicate that none of the analyzed parameters exhibit concentrations in excess of those standards set by the State and Federal agencies.

Results of the time-related water samples were used to conduct a geochemical pattern analysis of the water source type as described by Frazee (1982). This method allows for the identification of the water source type based upon the key ion concentrations. Appendix G contains Plates 1 through 20 showing the plotted location of each analyzed water sample on the water type Piper diagram. Evaluation of the collected water quality data from both wells UFPW and LFEW indicates that the water source for both the upper and the lower Floridan aquifers is fresh water recharge types I and II. According to Frazee, (1982) these type waters represent the purest and youngest form of limestone waters.

3.3 WELL INVENTORY

A well inventory was conducted to identify permitted and non-permitted Floridan aquifer users within a two (2) mile radius surrounding the proposed site. The search was completed using U.S. Geologic Survey and FDER files as well as field survey methods. The results of this inventory show that within the two (2) mile radius several small diameter domestic supply wells and irrigation supply wells are present. One (1) U.S.G.S. monitor well and one drainage well are also present. Sheet 1, provided in Appendix H presents the approximate locations of the identified wells.

The domestic and irrigation wells existing in the site vicinity are concentrated along Curry Ford Road west of the site and near the intersection of Curry Ford Road and Dean Road. These locations are identified on Sheet 1 (Appendix H). Of these wells, those which withdrawal from the Floridan aquifer system have been designated with a well number between two (2) and eleven (11). A detailed description of each well is provided in Appendix H (letter dated August 21, 1989).

Two (2) permitted Orange County water supply plants, Azalea Park and Rio Pinar Plants are located just beyond a two mile radius of the proposed ERWF site. Both of these facilities are currently off-line and are scheduled for abandonment. The Orange County, Econlockahatchee water supply plant is located approximately 2 1/2 miles north of the ERWF and is currently operational.

The drainage well located in Section 2 of Township 23 south, Range 30 East, labeled as well #1 on Sheet 1 of Appendix H was investigated by Jammal & Associates, Inc. This well was found to be in a satisfactory condition and apparently functions as a lake level control system. Geophysical logging performed by the FDER indicates that this well is 472 feet deep with 196 feet of casing. Additional discussion is provided on this well under the pollution source inventory.

Within the predicted radius of impact caused by discharges at the ERWF, exist several large commercial Floridan aquifer users. Thirty-seven (37) of the largest facilities are included as part of the numerical modelling discussion of this investigation. Their names, locations and predicted impacts are discussed in length within this section.

3.4 POLLUTION SOURCE INVENTORY

An inventory of the potential contamination sources surrounding the project site was also conducted during early phases of this investigation by Jammal & Associates, Inc. and Brown and Caldwell, Inc.. Both surveys were designed to identify the locations of landfills, permitted dredge and fill sites, hazardous waste generators, septic tank users, domestic waste water facilities, drainage wells and industrial facilities. The Jammal & Associates, Inc. survey concentrated on identifying potential pollution sources on-site and in the direct vicinity of the subject site. The survey conducted by Brown and Caldwell covered a broader area and included identification of facilities within a two (2) mile radius of the proposed site. Jammal & Associates, Inc. survey identified the Orange County Landfill, the landfill outfall canal, Azalea Park Canal and the drainage well in Section 2 of Township 23 South, Range 30 East as potential sources of contamination. Data gathered during Jammal & Associates, Inc. contamination assessments of these sites are included in Appendix I.

Those items identified by Jammal & Associates, Inc. as potential pollution sources were field investigated and subsequent tests were performed to evaluate the potential contamination to the Floridan aquifer. Surface water quality samples are collected quarterly at four (4) stations along the landfill outfall canal and the East Orlando Canal. Results from the past three (3) quarterly sampling events for these stations were reviewed. Location and summary of these surface water quality results are provided in Appendix I as part of a report dated April 19, 1989. A review of the surface water quality data from these two canals indicate no significant undesirable characteristics.

During February, 1989 Jammal & Associates, Inc. collected surface water quality samples from the Azalea Park Canal in order to determine the canal's potential for causing pollution to the Floridan aquifer system. The collected samples were analyzed for Primary Inorganic Drinking Water Parameters and EPA method 608 parameters. Review of the collected surface water quality data indicated no undesirable water quality characteristics. This combined with the fact that the Azalea Park Canal acts to drain stormwater away from the ERWF site, make the potential for contamination minimal to the water supply of the upper Floridan aquifer.

In addition to the existing canals, a drainage well located in Section 2, of Township 23 south, Range 30 east was investigated. According to records this well was drilled in 1959 and extends to a depth of 472 feet. A sketch of the well is provided as Figure 1 in Jammal & Associates, Inc. letter-report dated January 23, 1989 included in Appendix I.

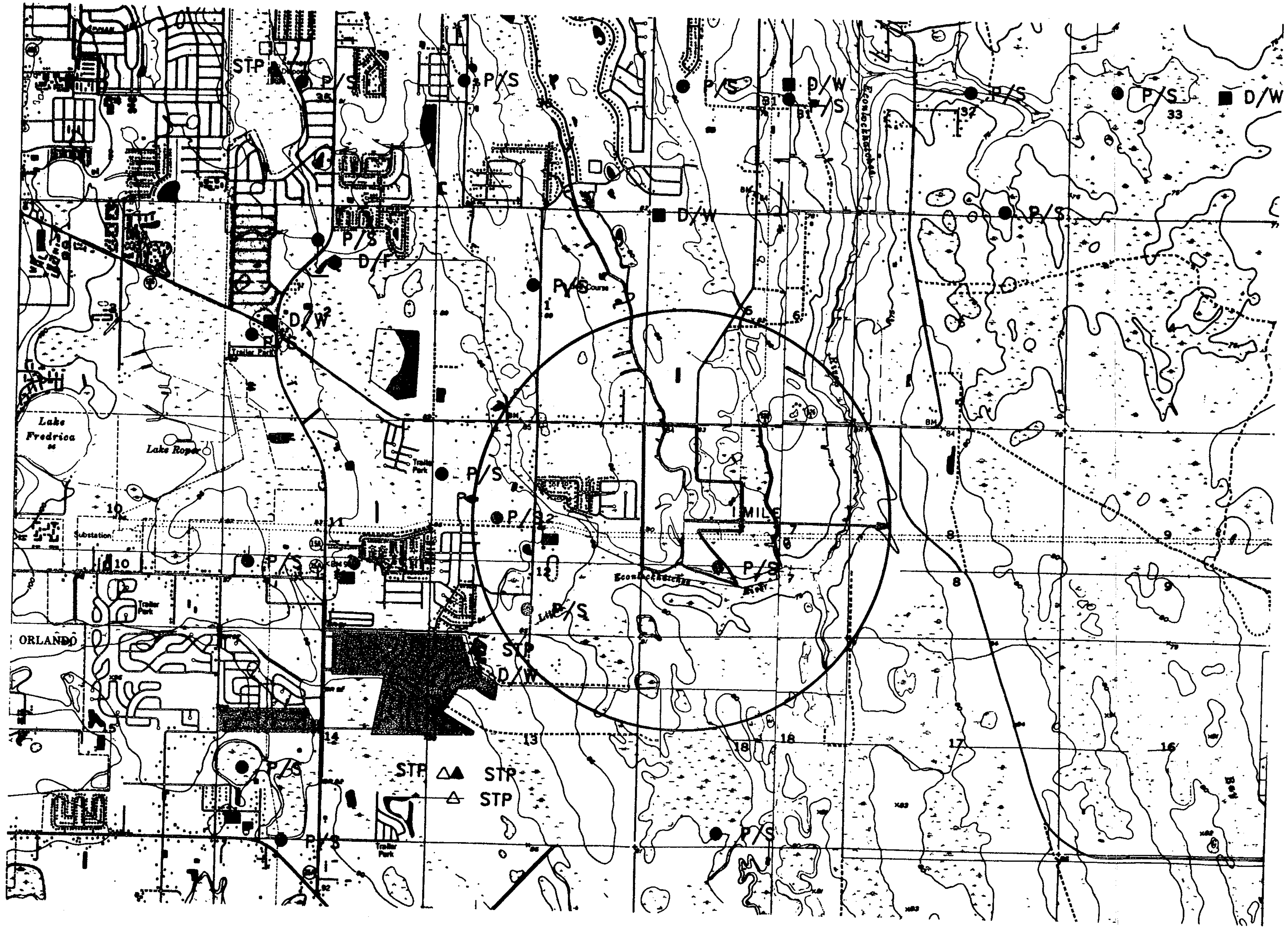
The purpose of the drainage well appears to be for water level control for the adjacent retention area and Azalea Park Canal. Water recieved by the well appears to originate as stormwater runoff to the canal and the retention pond. Water quality samples collected from the Azalea Park Canal, as discussed earlier, show no significant undesirable water quality characteristics. A copy of the January 23, 1989 Jammal & Associates, Inc. report is included in Appendix I.

In addition to the work performed by Jammal & Associates, Inc., a contamination survey conducted by Brown and Caldwell, 1988 identifies one (1) inactive sewage treatment plant, one (1) water treatment plant and three (3) areas identified as non-point source surface water discharge permits within a one (1) mile radius of the site. Figure 11 is adapted from the Brown and Caldwell report and indicates the identified location of the potential pollution sources. The water treatment plant facilities and surface water discharge facilities are believed to represent low risks for contamination to the Floridan aquifer system due to the thick sequence of clayey materials within the Hawthorn Formation.

4.0 DATA REDUCTION AND EVALUATION

The primary purpose for conducting the 72-hour constant rate pump test or APT was to collect information on water quality under stressed conditions and to obtain data useful in estimating the aquifer's hydraulic characteristics in the project vicinity. Raw data collected during this test was processed by both computer and graphical methods for this determination. The collected raw data is presented in Appendix J.

Data collected during the course of APT test was taken primarily using pressure transducers and electric recording devices. The recorded water levels in each well reflect the drawdowns caused by pumping and in part by natural fluctuations caused by tidal surges and recharge/discharge events. The natural tidal fluctuation and recharge/discharge events are



LEGEND

■	D/F	PERMITTED DREDGE/ FILL SITE
●	P/S	NON-POINT SOURCE SURFCE WATER PERMIT
▲	STP	INACTIVE SEWAGE/ WASTEWATER TREATMENT PLANT
△	STP	ACTIVE SEWAGE/ WASTEWATER TREATMENT PLANT
⬢	D/W	DRAINAGE WELL

NOTE:

LOCATIONS DETERMINED BY BROWN & CALDWELL, INC.

DRAWN:	CFG
CHKD:	CLS
APPVD:	NEA
SCALE:	N.T.S.

POTENTIAL SURFACE SOURCES OF COMTAMINATION

EASTERN REGIONAL WELLFIELD

ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DATE:	PROJ. NO:	
2-12-90	88-03288	FIGURE.11

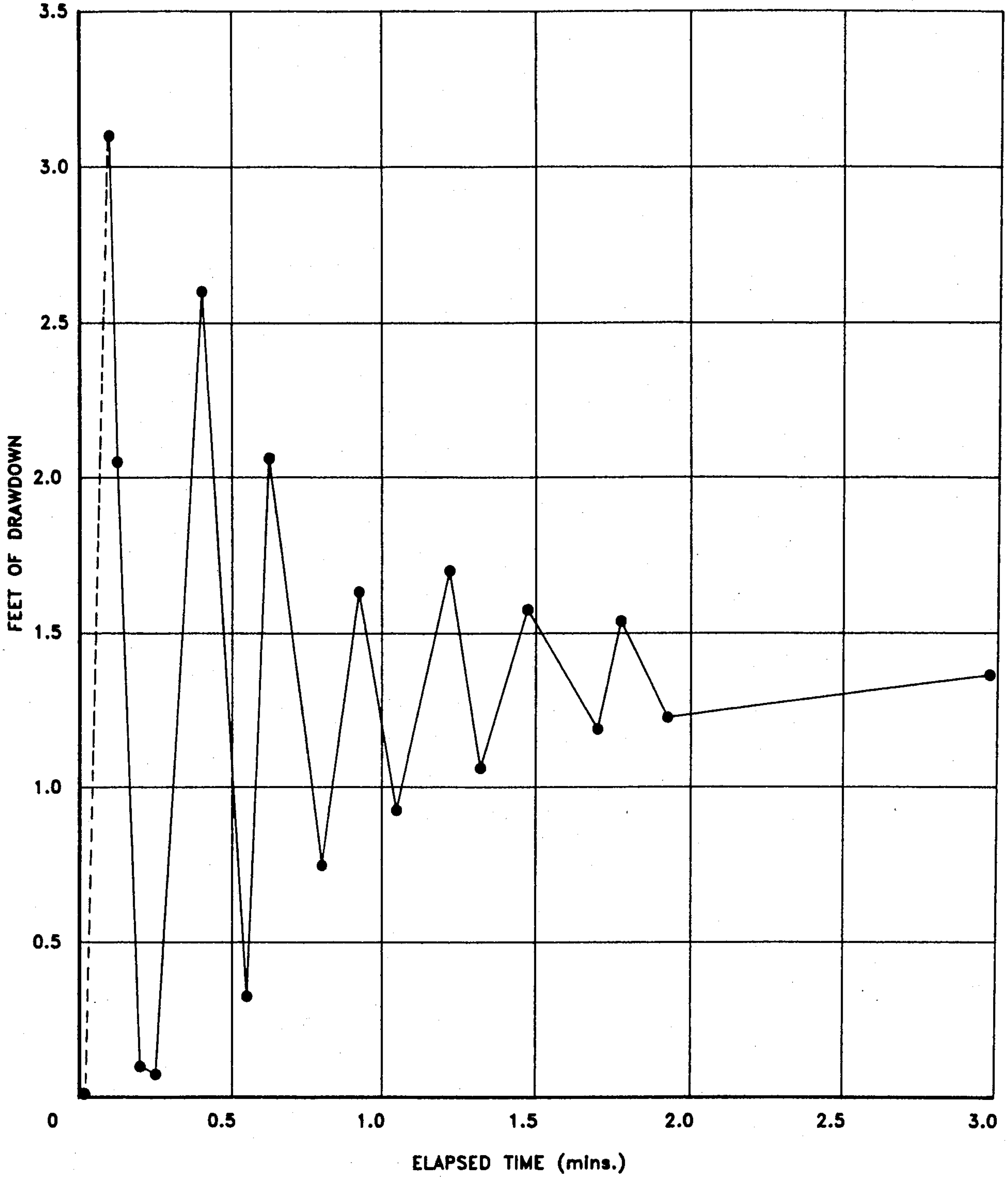
DRAPHIX #286975

unwanted noise data, typically termed as "background fluctuations". These background fluctuations were removed from the APT data utilizing water levels records collected prior to the start and after the conclusion of the test. Graphical methods and point by point subtraction were used to isolate the true drawdown curve for each well.

With the background noise removed from the drawdown response, the true drawdown impact caused by pumping well UFPW was isolated for each well. The early data response collected in wells tapping the upper Floridan aquifer showed an oscillating or rebounding effect in the potentiometric surface. Figure 12 presents the recorded water levels for well UFMW during the first three minutes of pumpage. Hydraulic engineers indicate that this type of response is similar to the flow in open pipes during rapid transmission of fluids.

Although this information suggests a very high level transmissivity between wells UFPW and UFMW, it also makes selection of accurate drawdown data during the first two minutes of pumpage nearly impossible. For this reason the first 2 minutes of recorded aquifer response was not used for hydraulic characterization of the upper Floridan aquifer.

Analysis of the corrected water level data was made by using graphical curve matching methods described by Lohman, 1972 for leaky artesian aquifers. The method requires matching a set of pre-defined curves to the collected time/drawdown and time/recovery water levels within the same aquifer. The technique specifies a match point used to calculate transmissivity, total leakance and storage.



RECORDED DRAWDOWN FOR FIRST 3 mins. IN WELL UFMW

NOTE: DASHED WHERE INTERPRETED

WELL UFMW
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

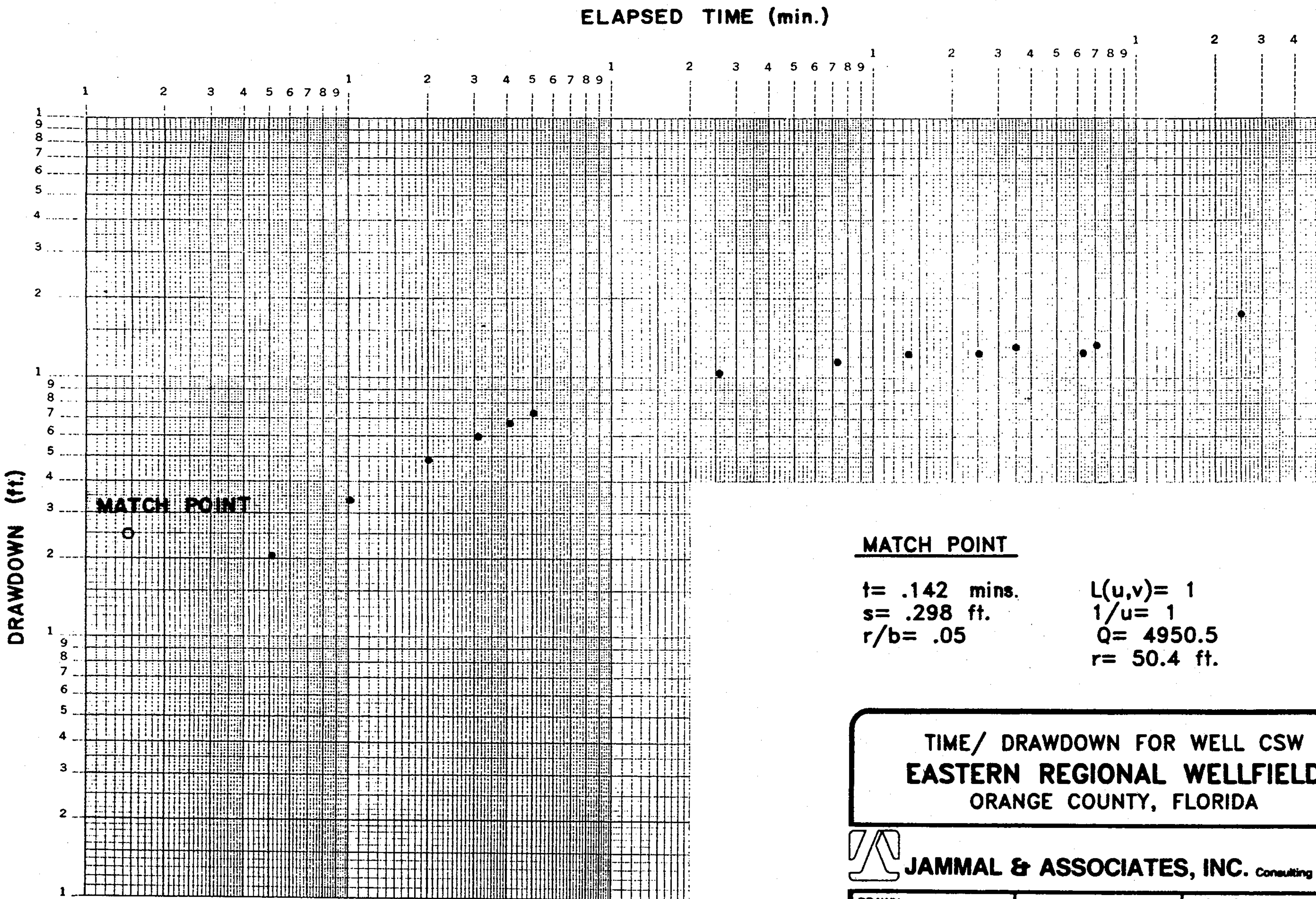
JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN: CFG	SCALE	PROJ NO 88-03288
CHKD. CLS	DATE. 2-12-90	FIGURE 12

DRAPHIX 290311

Due to the immediate response of the potentiometric surface within well UFMW and the oscillating nature of the water level time/drawdown data for this period from well UFMW gave inconclusive results. However, the time/recovery data for this well did provide reasonable results. Time/drawdown information collected from the CSW provided an addition point of reference for hydraulic parameter calculations. This well, however, suffers from the effects of partial penetration and provides an unreliable value of vertical leakance. Graphical representation of the reduced data are presented on Figure 13 through 15.

In addition to the graphical techniques employed, a numerical based computer model was devised to simulate the measured drawdown during the pumping test. The model used was the modular three-dimensional groundwater flow model written by McDonald & Harbaugh, 1984. The model was a simplified 2-layer simulation with a grid size extending approximately 2 miles in any direction from the wellfield area. The surficial aquifer and upper confining material were simulated as recharge input into the model. The confining unit between the upper and lower Floridan aquifers was simulated as leakance between the layers. An average recharge of 1.5 in/year from the surficial aquifer to the upper Floridan aquifer was used. Hydraulic constants estimated from the graphical interpretation were used as initial input. The model was used to estimate transmissivity and storage in the upper and lower Floridan aquifers as well as leakance between the two aquifers. The method employed to verify the correct selection of hydraulic constants attempted to reproduce the original time/drawdown curves recorded in wells UFMW and LFEW and reasonably simulated



MATCH POINT

t= .142 mins.
s= .298 ft.
r/b= .05

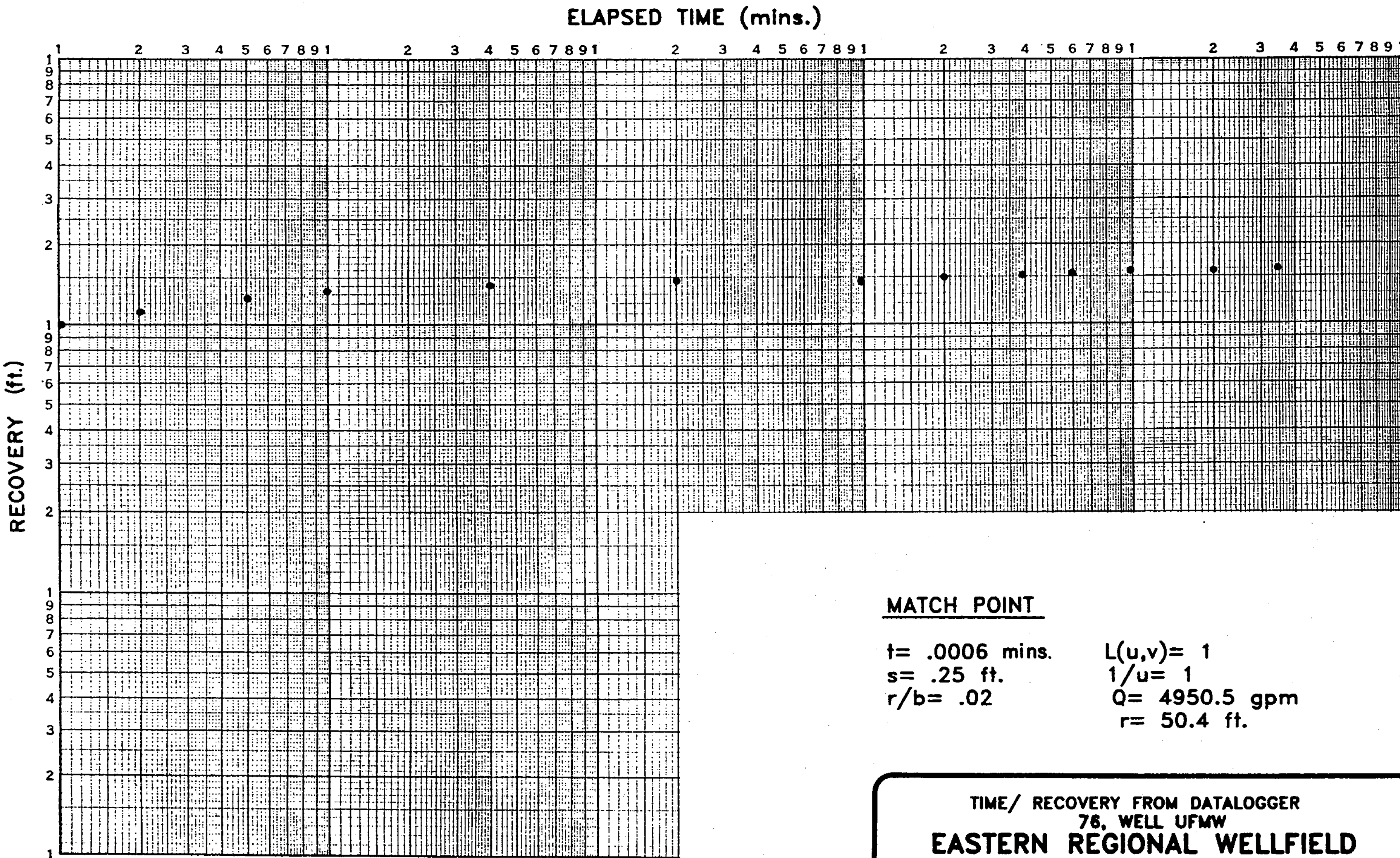
L(u,v)= 1
1/u= 1
Q= 4950.5
r= 50.4 ft.

TIME/ DRAWDOWN FOR WELL CSW
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN: CFG	NTS	PROJ NO 88-03288
CHKD: CLS	DATE: 2-12-90	FIGURE 13

DRAPHIX #267658



MATCH POINT

t= .0006 mins.
s= .25 ft.
r/b= .02

L(u,v)= 1
1/u= 1
Q= 4950.5 gpm
r= 50.4 ft.

TIME/ RECOVERY FROM DATALOGGER
76, WELL UFMW

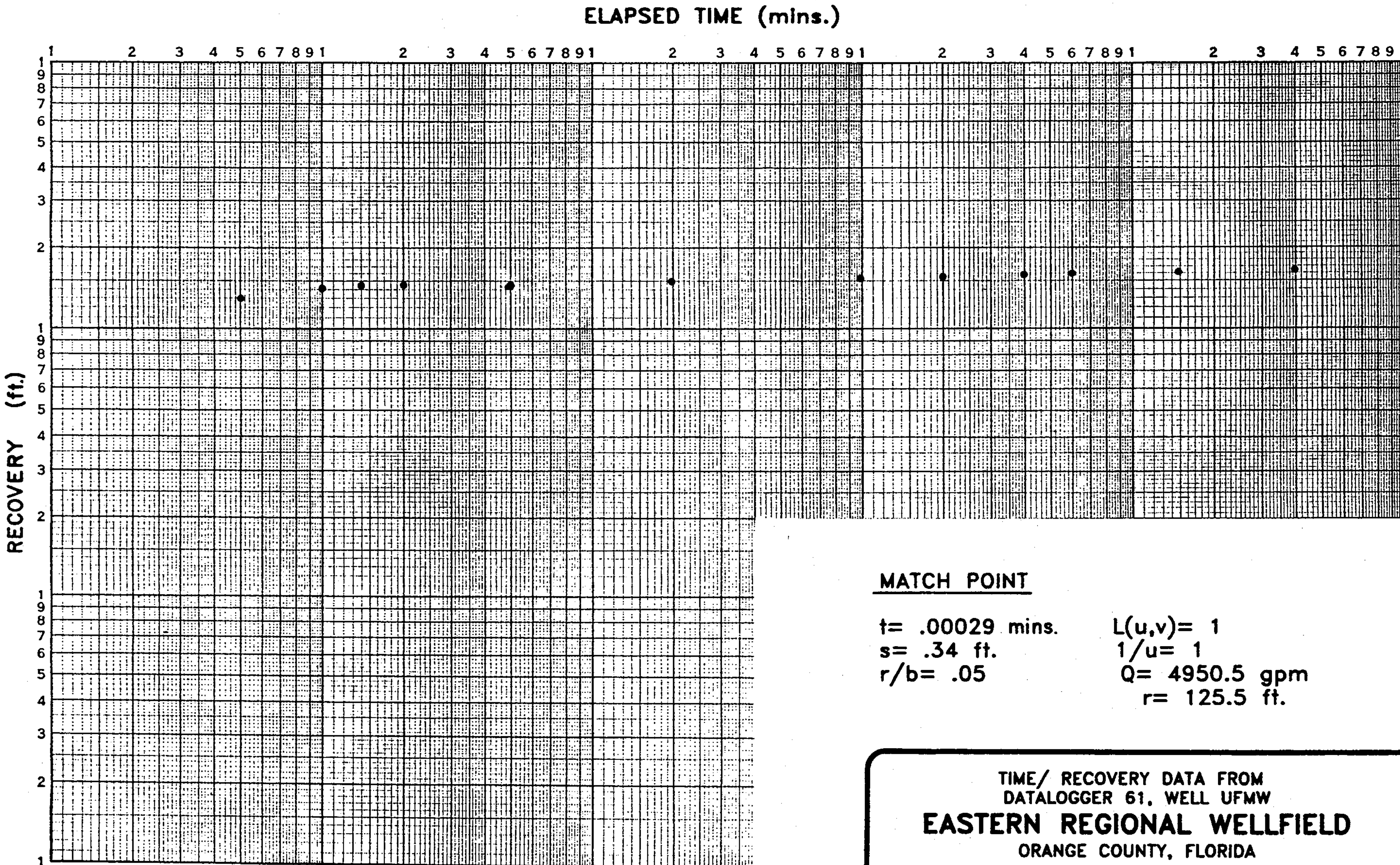
EASTERN REGIONAL WELLFIELD

ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN CFG	NTS	PROJ NO 88-03288
CHKD. CLS	DATE 2-12-90	FIGURE 14

DRAPHIX #267658



MATCH POINT

t= .00029 mins.
s= .34 ft.
r/b= .05

L(u,v)= 1
1/u= 1
Q= 4950.5 gpm
r= 125.5 ft.

TIME/ RECOVERY DATA FROM
DATALOGGER 61, WELL UFMW

EASTERN REGIONAL WELLFIELD

ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN CFG	NTS	PROJ NO 88-03288
CHKD CLS	DATE 2-12-90	FIGURE 15

DRAPHIX #267658

the drawdown observed in CSW. Table 4 indicates the hydraulic parameters for layer 1 determined from the model simulation and those determined from the graphical methods discussed earlier.

TABLE 4

Estimated Hydraulic Parameters for Upper Floridan Aquifer

	GRAPHICAL METHOD			
	Recovery		Drawdown	
Parameter	UFMW (Recorder 61)	UFMW (Recorder 76)	CSW	Computer Estimation
Trans-missivity (gpd/ft)	1,670,000	2,270,000	2,300,000	2,500,000
Storativity (dimensionless)	.007	.0002	.0077	.002
Leakance (gpd/ft)	.872[1/]	.179[1/]	.183[1/]	.64[3/]
Storativity[2/] (For Layer 2)	-----	-----	-----	.03

1) Represents total leakance from above and below aquifer
2) Storage coefficient for lower Floridan aquifer
3) Leakance coefficient between upper and lower Floridan aquifer only

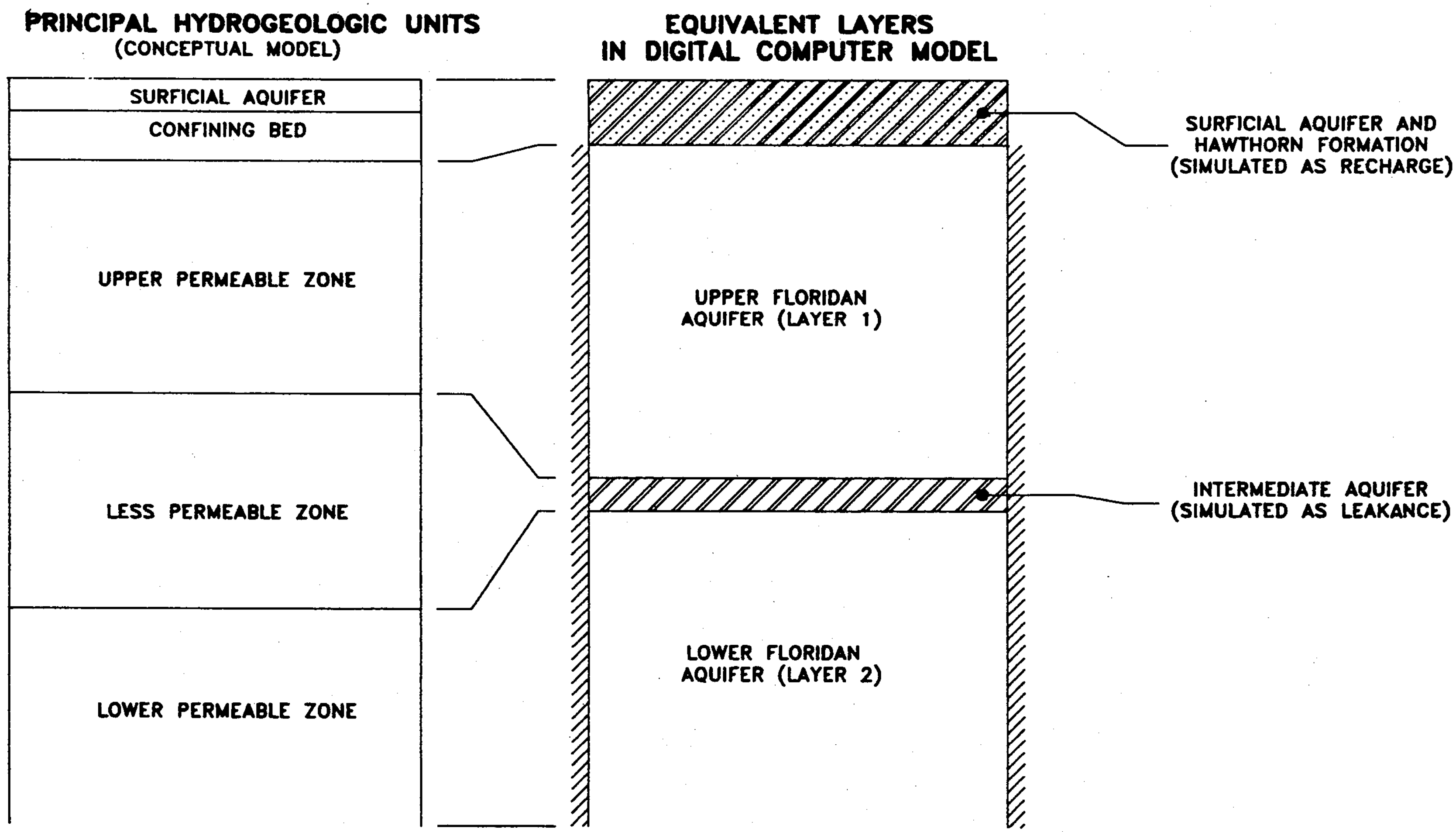
5.0 GROUNDWATER FLOW MODELING

An investigation into the potential impacts from the proposed ERWF withdrawals was initiated using the information obtained during the aquifer testing program and the use of numerical groundwater flow models. The groundwater flow modelling of the Orange County Eastern Region Wellfield consisted of utilizing two (2) separate computer models. The site was modelled for overall regional impact utilizing the U.S.G.S. 3-D groundwater flow model "MODFLOW". Local impacts at individual wells within the site and the determination of the optimum well spacing within the property boundaries were analyzed using the Hantush-Jacob computer model for leaky artesian aquifers.

5.1 REGIONAL MODEL CONSTRUCTION AND CALIBRATION

An analysis of the potential regional impacts on the water resources as a result of withdrawals from the upper Floridan aquifer at the Orange County Eastern Region Wellfield site was conducted utilizing the Modular three-dimensional groundwater flow model "MODFLOW". A model grid was set up to encompass the majority of Orange County and portions of Seminole, Brevard, Volusia and Osceola Counties. The regional model contains a uniform square mile grid system covering a total of 1,521 square miles. Plate 21 in Appendix K presents the 39 by 39 grid system used for this model.

The regional aquifer system was characterized within the model by two (2) semi-confined aquifers, namely the upper and the lower Floridan aquifers. The surficial aquifer was simulated



LEGEND

CONSTANT HEAD BOUNDARY

EASTERN REGIONAL WELLFIELD
HYDROGEOLOGIC UNITS AND EQUIVALENT
LAYERS USED IN COMPUTER SIMULATION
ORANGE COUNTY, FLORIDA

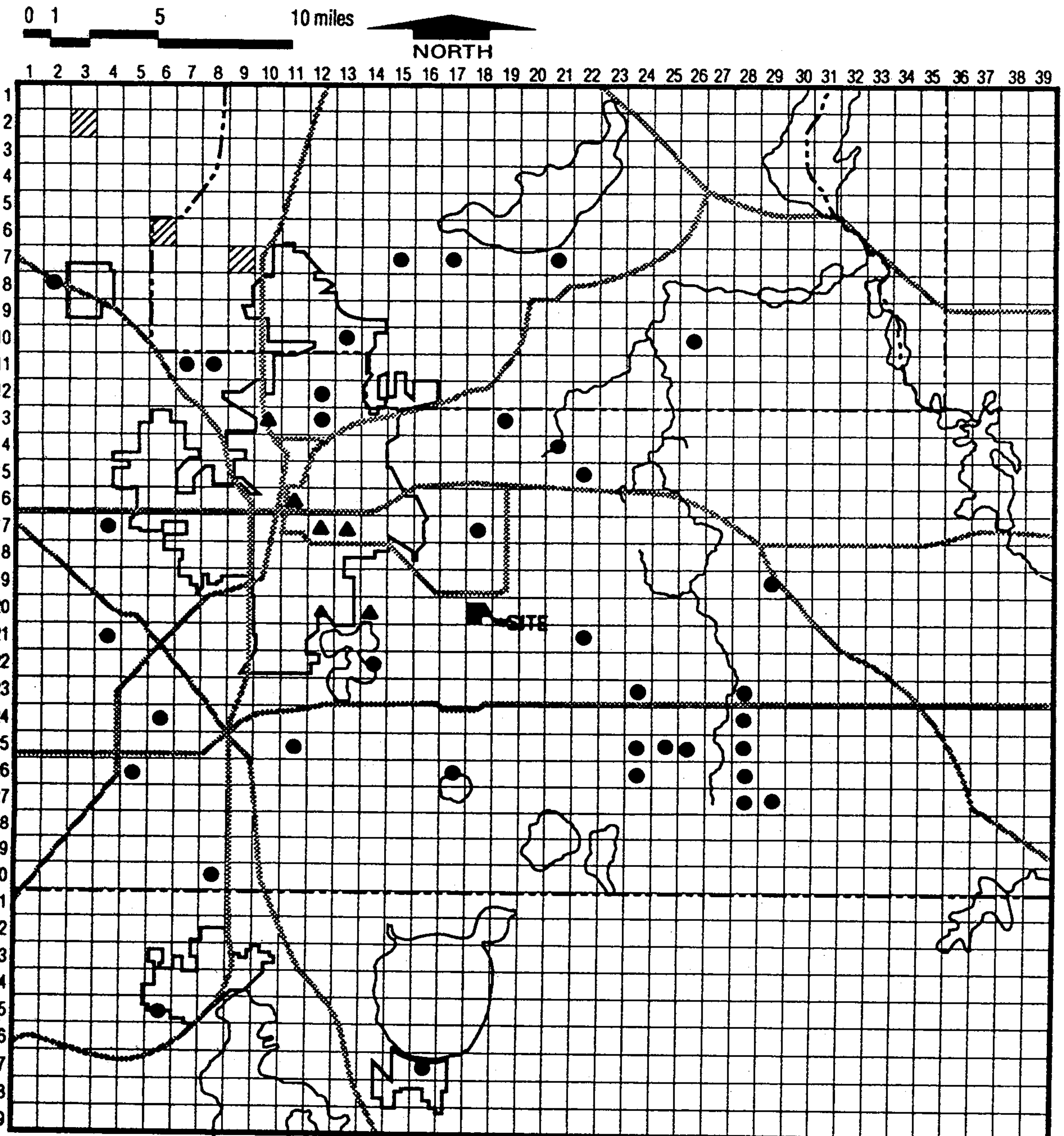
JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN CFG	N.T.S.	PROJ NO 88-03288
CHKD CLS	DATE 2-12-90	FIGURE 16

DRAPHIX #267658

To calibrate the computer model under current aquifer stress conditions, a search of major Floridan aquifer users in the modelled area was conducted. Our search consisted of obtaining records from the St. John's River Water Management Districts (SJRWMD) in Orlando and Palatka and information from our own files. In addition, we have contacted each city, county and municipality in the region to obtain information of water users not recorded in the Water Management Districts files. Based on this search, we have identified a total of 33 pumping centers with significant withdrawal rates. Table 5 identifies the pumping center name, grid locations and discharge rates associated with each modelled facility. Figure 17 shows the approximate location on the grid for the respective pumping centers. There are numerous other wells used for domestic and small industrial uses which likely have smaller radii of impact. The collective discharges of these smaller pumping wells were not incorporated directly into the model, but were instead included as part of the areal calibration of the recharge/discharge to the upper Floridan aquifer. Calibration of recharge in our model incorporates the discharge from small pumping wells.

In addition to the known pumping centers within the model area several natural springs exist. Among these springs are Wekiva Springs, Rock Springs, Sanlando Springs, Palm Springs, Starbuck Springs, Barrel Springs, Witherington Springs, Wekiwa Springs and Sulfer Springs. Current average discharge rates for each of these springs were unavailable. For this reason the model cells for each spring were set as constant heads and the aquifer transmissivity was back calculated to recreate the potentiometric surface in the vicinity of these springs. The distance of these springs from the ERWF site is sufficiently large for this modelled assumption to have minimal affect on the withdrawal impacts at the site.



PUMPING CENTER LOCATIONS

LEGEND

- ● LOCATION OF UPPER FLORIDAN AQUIFER WELL
- ▲ LOCATION OF LOWER FLORIDAN AQUIFER WELL
- ▨ LOCATION OF SPRINGS

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FIGURE 17

TABLE 5

Pumping Center Locations

Plant Name or Well	Discharge Rate (MGD)	Grid Location "i"	Grid Location "j"
Primrose (2)	7.8	13	17
Kuhl (2)	11.8	11	20
Navy Base (2)	4.0	12	17
Conway (OUC) (2)	4.3	14	20
Martin	8.5	6	24
Highlands (2)	10.5	11	16
Hidden Springs	2.7	4	21
Lake Nona	0.06	17	26
Bonneville	2.02	22	15
UCF & Central Florida Research Park	2.3	21	14
Econlockhatchee Plant	3.45	17	18
Stanton Energy	0.38	22	21
Econ. Utilities	1.5	29	19
Chuluota (Southern States Utilities)	0.19	26	10
City of Winter Springs #1	0.62	15	7
#2	0.62	17	7
City of Winter Park(2)(Wymore)	13.1	10	13
(Swoope Ave.)	7.4	12	13
Riverside	3.27	8	11
City of Maitland	3.3	12	12
Orange County Correctional Institute	0.44	24	23
Meadow Woods	0.123	11	25
Orangewood	1.94	5	26
Suncrest	1.7	19	13
Hunterfield	2.45	13	10
Oakmeadow	2.895	4	17
City of Belle Air	0.1	13	22
Hunters Creek	0.65	8	30
Conway (O.Co.)	3.55	14	21

TABLE 5 (cont.)

Pumping Center Locations

Plant Name or Well	Discharge Rate (MGD)	Grid Location "i"	"j"
Cocoa Wellfield[1/]			
18,19	3.6	24	26
15,16,17	9.80	24	25
13,14	4.03	25	25
7A	0.43	26	25
3,7	0.75	28	25
10	0.23	28	23
2,8,9	0.19	28	24
5	0.42	28	26
4,4A1,11,12B	2.13	28	27
12A	0.24	29	27
City of Oviedo	1.5	21	7
City of Apopka	12.8	2	8
City of Kissimmee	4.0	6	35
City of Longwood	2.1	11	7
City of St. Cloud	1.2	16	37

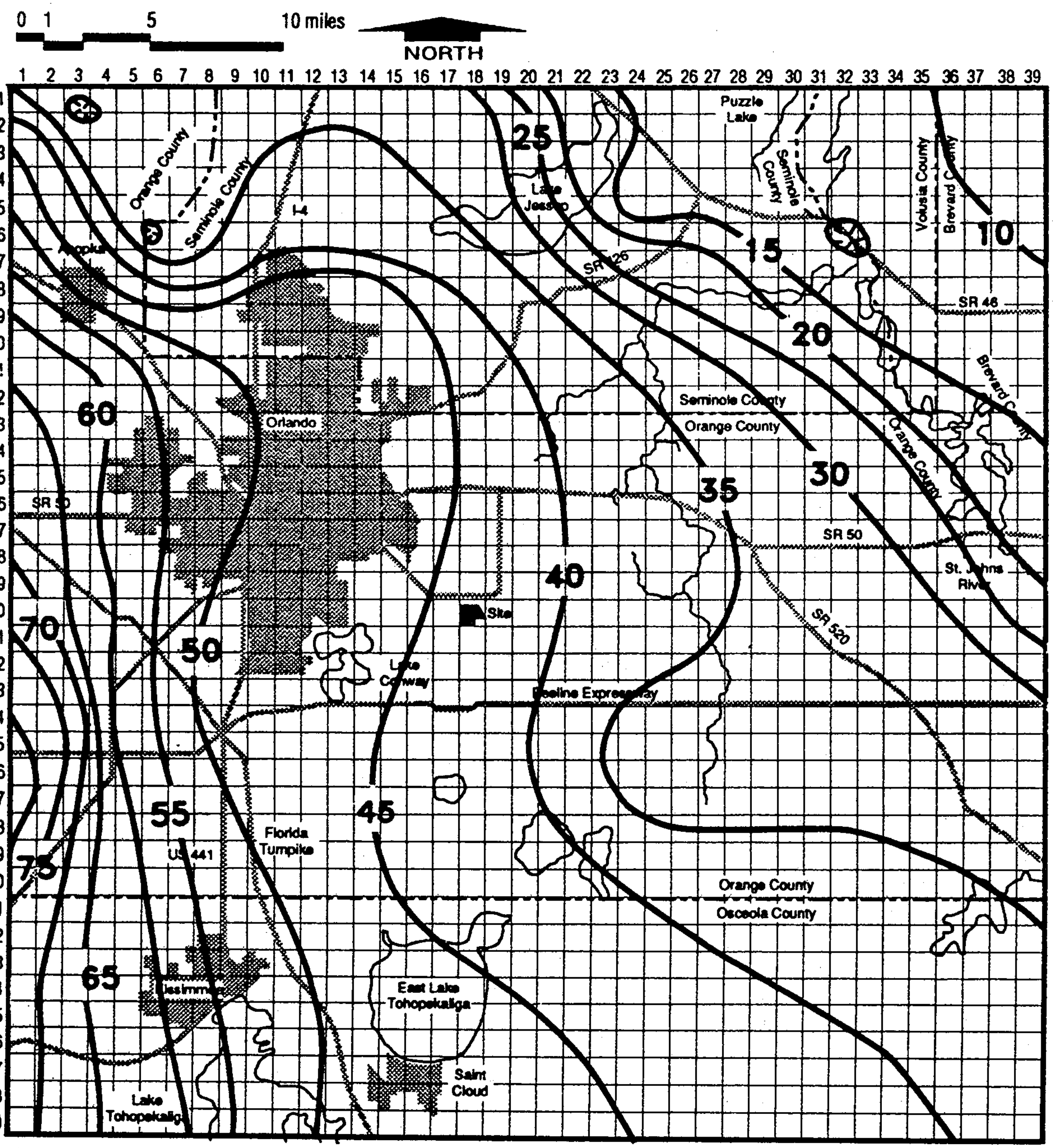
1/ Determined from 1987 average discharge rates.
(2) - Indicates lower Floridan pumping center

During calibration of the computer model, a stress period of one (1) year was selected starting with the initial potentiometric surface of average seasonal conditions and calculating the resulting heads at the end of one (1) year. The hydraulic parameters of the aquifer system (storage coefficient, transmissivity, leakance, and recharge) were adjusted during the numerous computer simulations in order to re-create the potentiometric surface conditions within the grid system reasonably close to the initial potentiometric levels input into the model. The initial hydraulic conditions and recharge conditions for the modelled area were obtained from

Tibbals, 1981 and Skipp, 1988 computer model calibration performed by U.S.G.S. and SJRWMD, respectively. The initially selected hydraulic parameters for this aquifer system were obtained from larger grid systems which did not account for minor local variations that we have considered in our model. Hydraulic parameters within the model were adjusted during the simulations until initial and computer generated potentiometric surfaces within an area of eight (8) mile radius around the ERWF were calibrated with generally less than one (1) foot head difference. The remaining portion of the grid system was also calibrated as much as possible (generally within 3 feet).

Figures 18 and 19 show the initial (average 1988) potentiometric surface and the computer generated potentiometric surface for the modelled area, respectively. In certain highly developed areas (Orlando and West Orlando area) a considerable amount of small withdrawals from individual wells could not be directly accounted by our computer model and effective recharge needed to be adjusted in order to achieve model calibration. Comparison of the two figures shows that effective calibration of the model has produced a good correlation between the two surfaces.

Calibrated hydraulic parameters within the grid system of the computer model are presented on Figures 20 through 25. With the exception of the recharge components, the hydraulic parameters presented on Figures 20 through 25, are considered effective calibrated values for the modelled area. The recharge rates presented on Figure 25 are considered accurate for the eastern portion of the grid system where the area is relatively undeveloped. In the western portion of the grid system, the recharge rate should be considered the effective



AVERAGE POTENTIOMETRIC SURFACE FOR 1988 UPPER FLORIDAN AQUIFER

CONTOUR INTERVAL: 5.0 ft.

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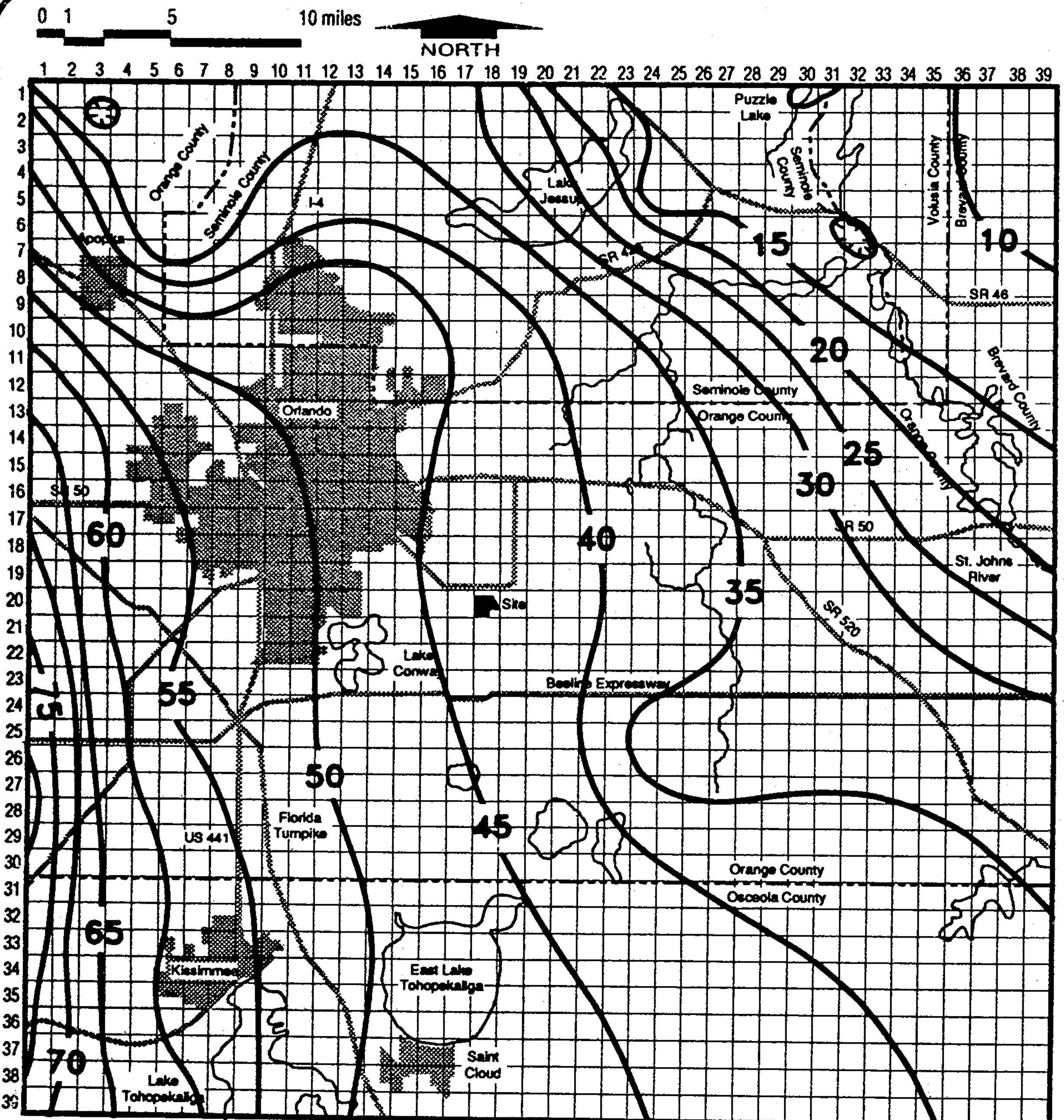
FIGURE 18



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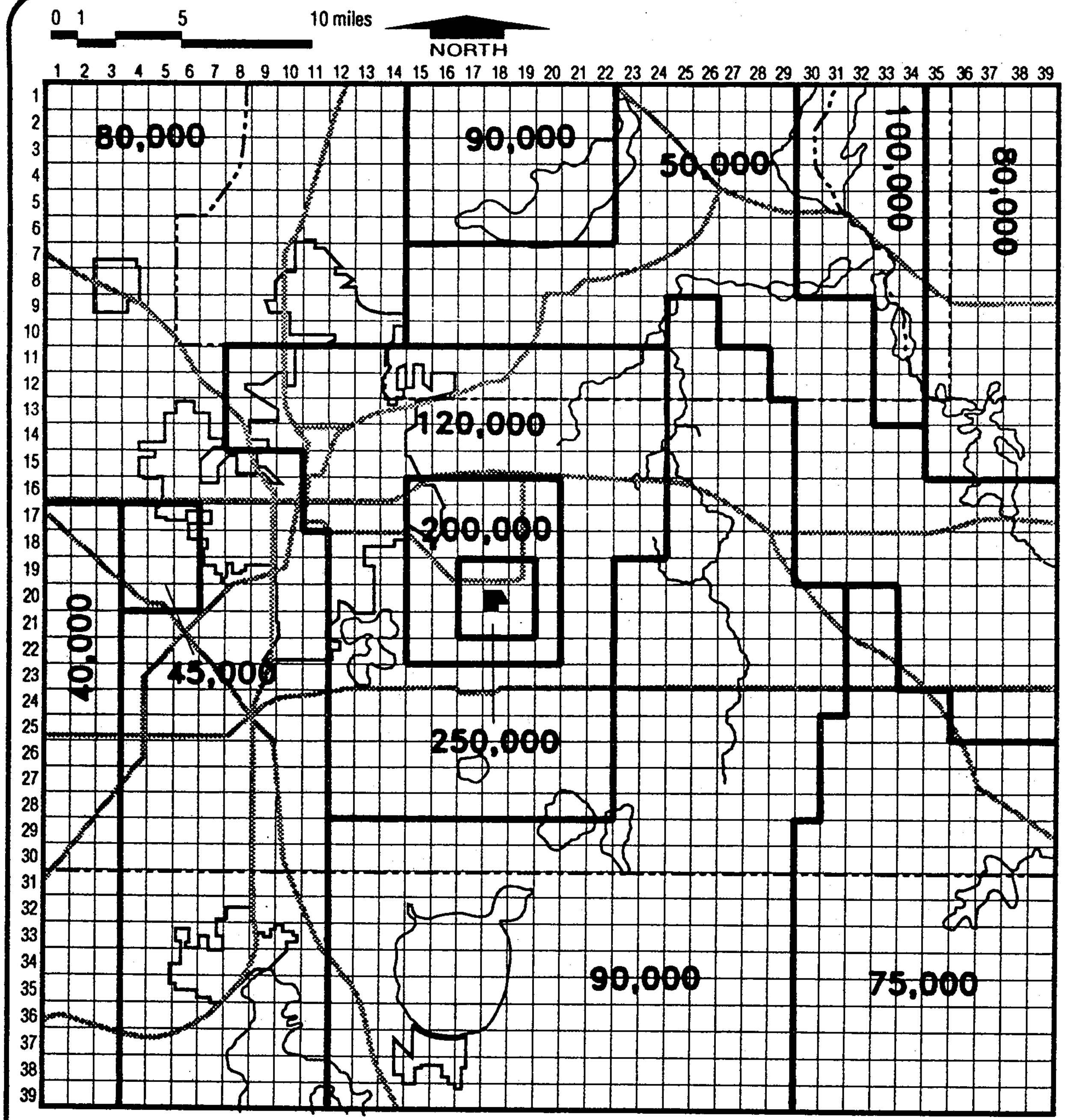
CALIBRATED POTENTIOMETRIC SURFACE FOR LAYER 1 UPPER FLORIDAN AQUIFER

CONTOUR INTERVAL: 5.0 ft.

FIGURE 19



AQUIFER TRANSMISSIVITY UPPER FLORIDAN AQUIFER (LAYER 1)

UNITS: Ft^2/ day

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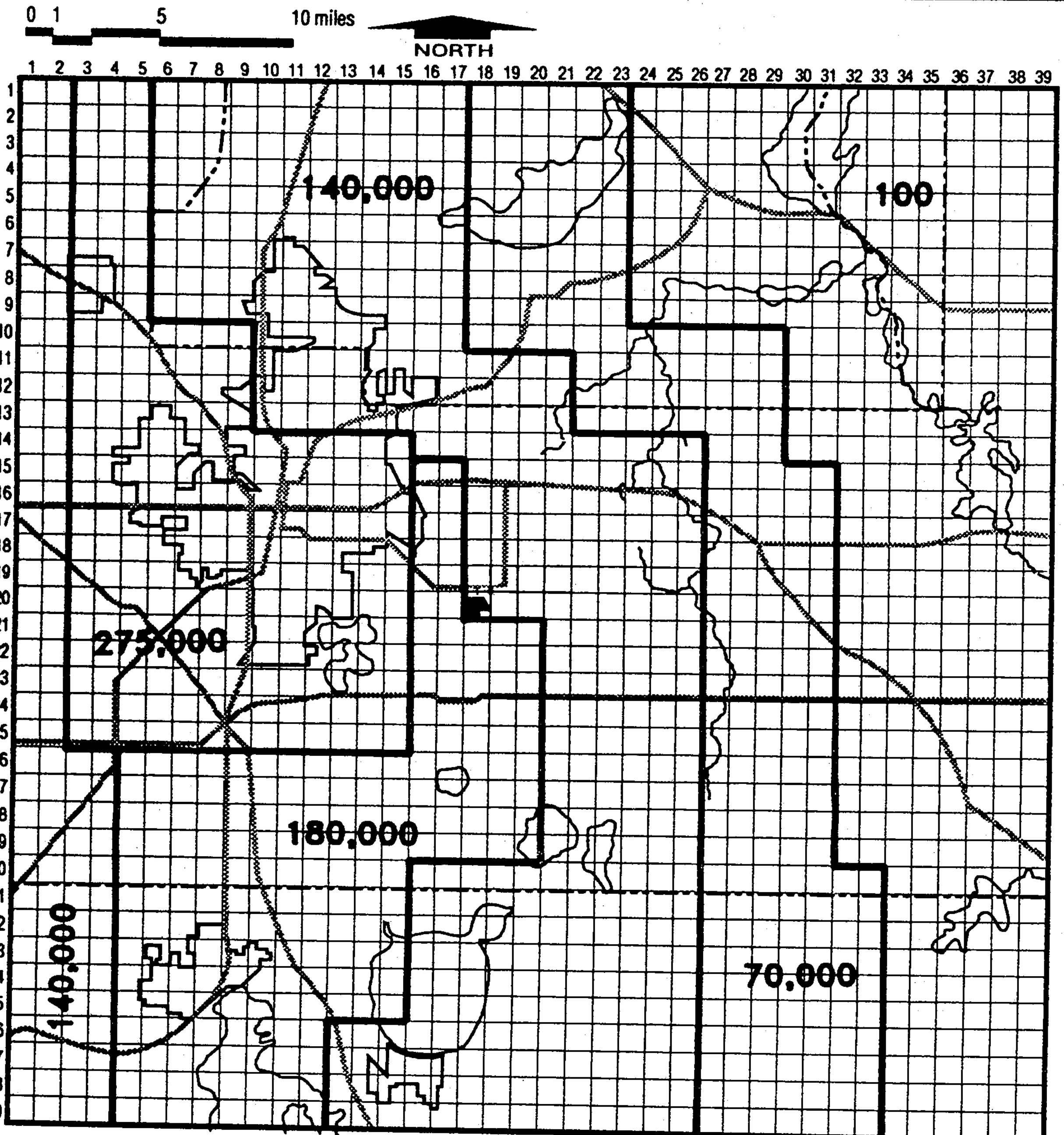
FIGURE 20



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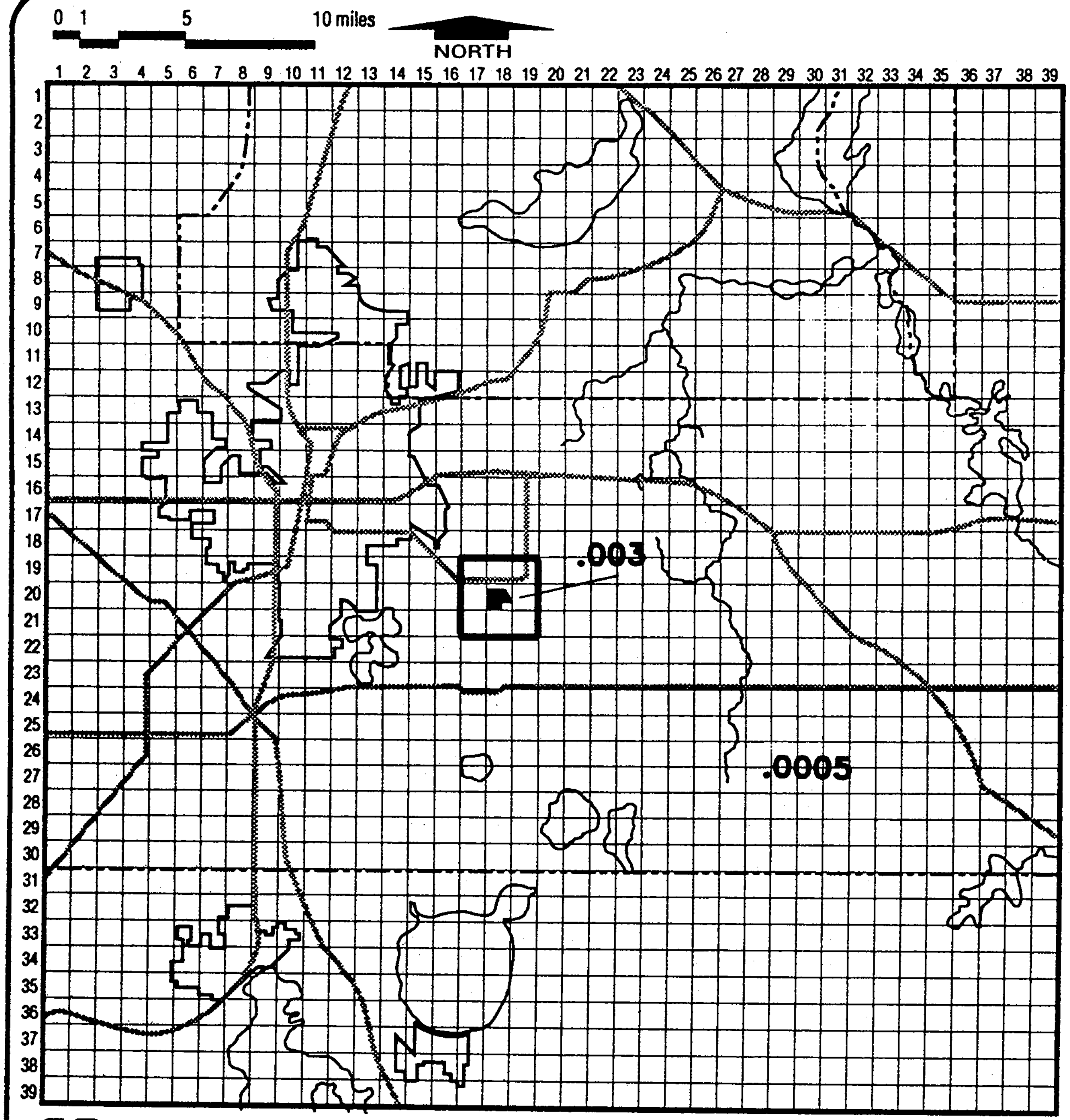
AQUIFER TRANSMISSIVITY
LOWER FLORIDAN AQUIFER
(LAYER 2)

UNITS: Ft^2/ day

■ SITE

FIGURE 21

STORAGE COEFFICIENTS FOR THE LOWER FLORIDAN AQUIFER (LAYER 2)



■ SITE

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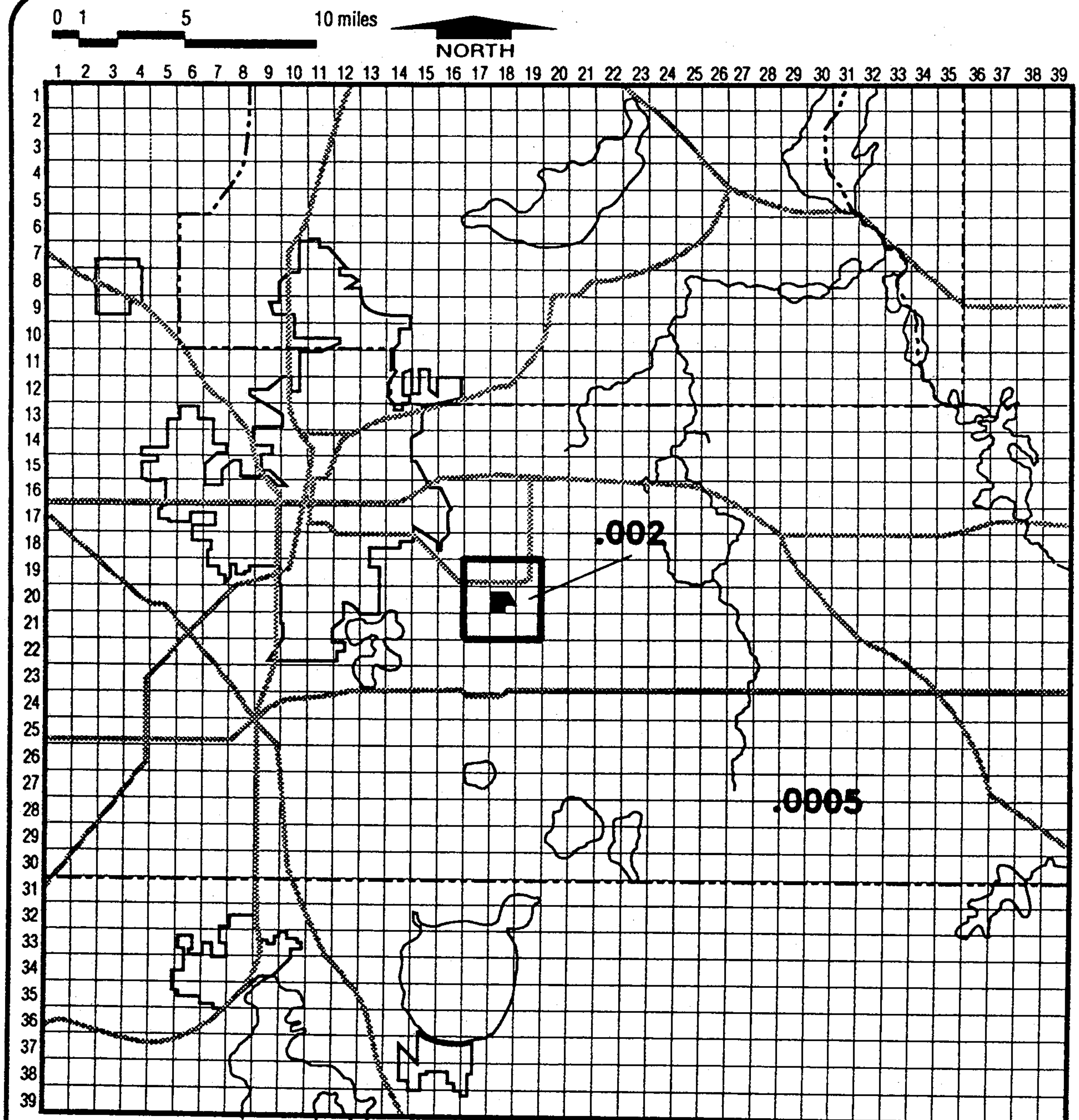
FIGURE 22



STORAGE COEFFICIENTS FOR THE UPPER FLORIDAN AQUIFER (LAYER 1)

SITE

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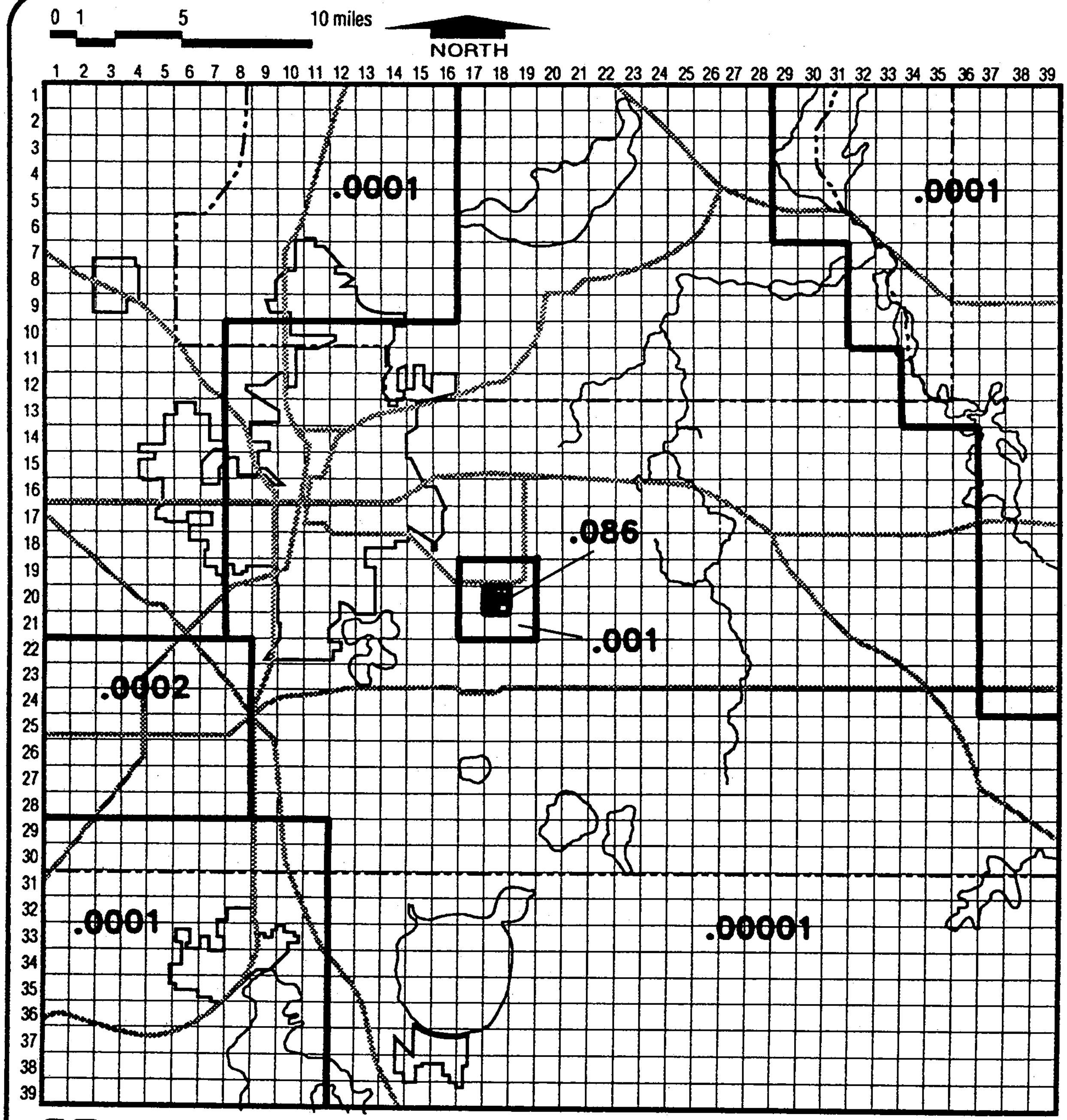
FIGURE 23



VERTICAL LEAKANCE BETWEEN LAYER 1 and 2

UNITS: Ft^2/day^{-1}

■ SITE

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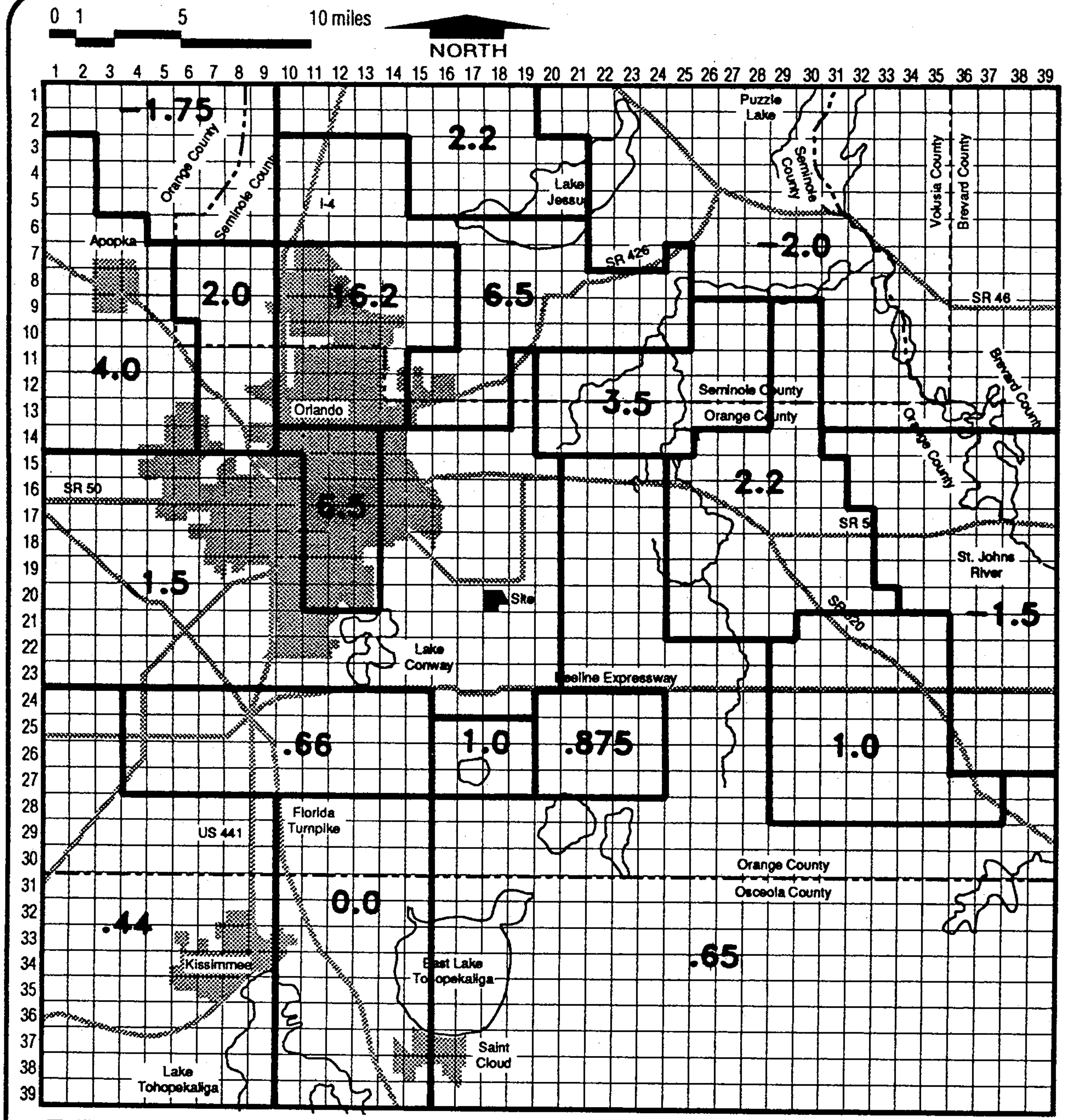
FIGURE 24



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RECHARGE TO LAYER 1 (UPPER FLORIDAN)

UNITS: inches/ yr.

■ SITE

FIGURE 25

recharge rate including the actual recharge rate minus withdrawal from numerous individual small wells which could not be directly inventoried and input into the model.

5.2 SENSITIVITY ANALYSIS

To evaluate the sensitivity of the calibrated hydraulic parameters for the regional MODFLOW computer model, the values of each of the following hydraulic parameters were increased and decreased by 20% and the change in drawdown caused by the proposed withdrawals from the upper Floridan aquifer were evaluated:

a. Storage coefficient of upper Floridan aquifer
b. Transmissivity of upper Floridan aquifer
c. Recharged into upper Floridan aquifer
d. Leakance between upper and lower Floridan aquifers
e. Storage coefficient of lower Floridan aquifer
f. Transmissivity of lower Floridan aquifer
g. Model Simulation Time

The resulting head difference in both the upper Floridan and lower Floridan aquifer for each of the sensitivity analysis parameters modelled is summarized in Table 6. Based on the evaluation of sensitivity analysis results, it is apparent that the most significant hydraulic parameters affecting the drawdown in the vicinity of the project site are the recharge to the upper Floridan aquifer and the transmissivity of the upper Floridan aquifer. However, when a calibrated computer model is used for the design modelling, the potential errors of one (1) of the calibrated hydraulic parameters will generally be compensated by the remaining hydraulic parameters to achieve an equivalent end result. For instance, if the calibrated transmissivity of the upper Floridan aquifer is in error by a certain percentage, the calibrated transmissivity of the lower Floridan aquifer may partially compensate for the error and vice versa. Perhaps the most significant verification of reasonable calibration is the fact that the currently existing Cocoa Wellfield withdrawal rates incorporated into the calibrated model resulted in excellent duplication of the potentiometric level in the upper Floridan aquifer. This suggests that the hydraulic parameters must be relatively accurate. Removal of the Cocoa Wellfield discharge from the model resulted in a potentiometric surface similar to that seen prior to its installation thus adding creditibility to the model calibration values.

TABLE 6

Summary of Key Elements of the Sensitivity Analysis Performed on Calibrated Model

Parameter Changed	Variation	Change in Drawdown at the ERWF Site (ft) Layer 1	Change in Drawdown at the ERWF Site (ft) Layer 2	Change in Drawdown at 1-Foot Drawdown Contour Layer 1	Change in Drawdown at 1-Foot Drawdown Contour Layer 2
Transmissivity in Layer 1	- 20%	+0.5	+0.6	+<.1	+<.1
Transmissivity in Layer 1	+ 20%	-0.4	-0.3	-<.1	-<.1
Recharge	+ 20%	+1.5	+1.4	+.7	+.3
Recharge	± 20%	-1.5	-1.4	-.7	-.3
Storage Layer 1	± 20%	N.C.	N.C.	N.C.	N.C.
Leakance between Layers 1 & 2	± 20%	N.C.	N.C.	<.1	<.1
Transmissivity Layer 2	- 20%	+0.1	+1.6	+0.3	+0.5
Transmissivity Layer 2	+ 20%	-0.5	-1.4	0.2	0.3
Storage Layer 2	± 20%	N.C.	N.C.	N.C.	N.C.
Model Stabilization Time (365 Days)	± 20%	N.C.	N.C.	N.C.	N.C.

Sensitivity analysis to eliminate constant head boundaries at the eastern and western perimeters of the grid system was not conducted due to the following reasons:

1) In a MODFLOW computer program, the grid system is modelled as a closed boundary box. In order to create inflow and outflow in this "box" modelling area, it is necessary to either set constant head boundaries or recharge/discharge the boundary cells. Without these conditions and given the fact that the transmissivity of the modelled aquifers is extremely high, the potentiometric level within the "box" will tend to equalibrate at a constant elevation, lacking the obvious presence of large quantities of groundwater inflow and outflow.

2) To set the initial minimum size of a computer grid system we have utilized the Hantush-Jacob method of wellfield modelling. For this purpose, we have utilized an average regional transmissivity of 850,000 gallons per day per square foot. A storage coefficient of 0.002 and a relatively low and relatively high leakance values. The computer program was then executed to calculate the extent of drawdown effect from a wellfield pumping at the potentially maximum rate of 30 million gallons per day. The minimum grid size was established based on this analysis using the criteria of zero drawdown radius as the outer boundaries of the computer grid system.

Based on this sensitivity analysis and computer model grid boundary selection criteria, we feel that the computer model for this site was sufficiently calibrated and the projected drawdown effects under long term operation are realistic for the purpose of regional wellfield design.

5.3 CONCEPTUAL WELLFIELD DESIGN

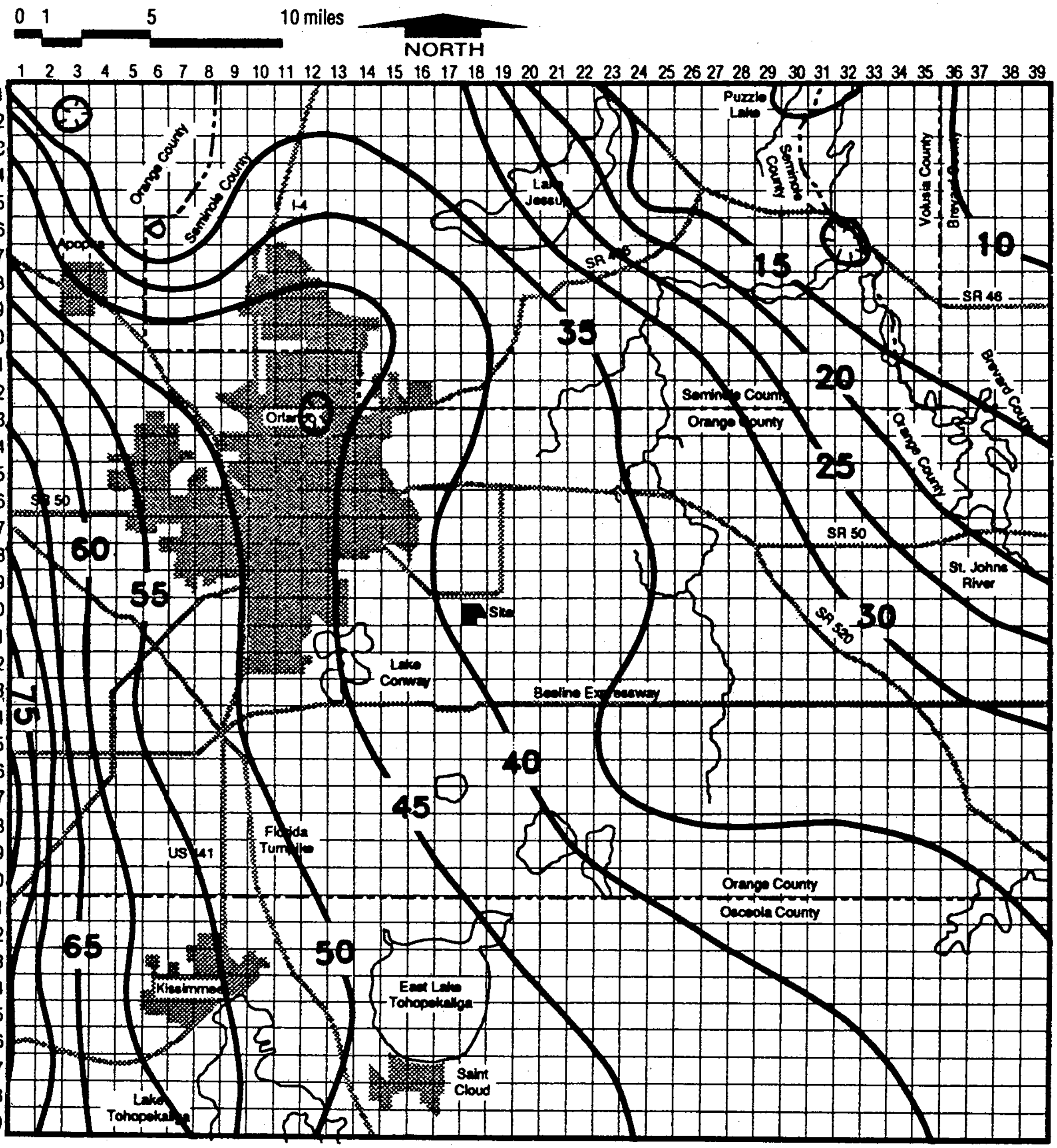
5.3.1 Regional Wellfield Modelling

Orange County has assessed its potential needs for water supply for its Phase I plans and has estimated an average daily demand of 28.8 MGD with peak flows of 48.8 MGD. Withdrawals under the County's existing CUP for the eastern service area allocate an ADF of 15.9 MGD which is obtained from four existing water plant facilities, namely the Bonneville, Econlockhatchee, Conway and Lake Nona plants. It is the County's desire to redistribute a portion of its existing withdrawals and obtain additional withdrawals from the centrally located site under investigation herein. Using the production capabilities of each existing facility, the calibrated regional model containing the four existing plants and the ERWF site was used to withdraw the total estimated water demand of 28.8 MGD.

Numerous pumping distribution scenarios were modelled using the four (4) largest pumping centers to obtain the desired 28.8 MGD at ADF. Each scenario was evaluated on its potential drawdown impacts on both the upper and lower Floridan potentiometric surfaces, and for its impact on adjacent Floridan aquifer users. Based upon these pumping distribution scenarios an optimum arrangement of wells were selected which minimizes the overall aquifer drawdown and minimizes the potential for saline water movement. The pumping distribution selected provides for discharges at the Bonneville and Conway plants to remain unchanged while discharge from the Econlockhatchee plant was increased by 4.8 MGD (8.25 MGD total) and the proposed ERWF site was modelled with an average withdrawal rate of 15.0 MGD. Discharges from the Lake Nona plant (.06 MGD) were not included as part of the 28.8 MGD as this plant is intended to be taken off-line as the new ERWF begins operations.

Figures 26 and 27 present the resulting potentiometric heads and the drawdown impacts on the upper Floridan aquifer with an additional discharge rate of 19.8 MGD (for a total of 28.8 MGD from the Orange County's four plant sites). Figure 26 shows the movement of potentiometric contours to the west as a result of the additional withdrawals. The model was run for a period of one year of average discharge. By the end of one year the aquifer drawdown has stablized. Discharge periods of greater than one year were also simulated, however no additional drawdown was observed. Discharge rates for the individual water plants are labeled on Figure 27. As indicated by Figure 27 the drawdown surrounding the ERWF and Econlockhatchee Plant sites is nearly circular on a regional scale.

Drawdown in the lower Floridan aquifer after one year of pumping at a total rate of 28.8 MGD of ADF is presented on Figure 28. As indicated in this figure, the drawdown impacts extend further eastward in the lower Floridan as compared to the upper Floridan. This is believed to result from the discontinuity of lateral flow in the lower Floridan aquifer as it approaches saltwater/freshwater interface. The contours become compressed near the St. Johns River because of the natural discharge and no-flow boundary of the saltwater interface in this area.



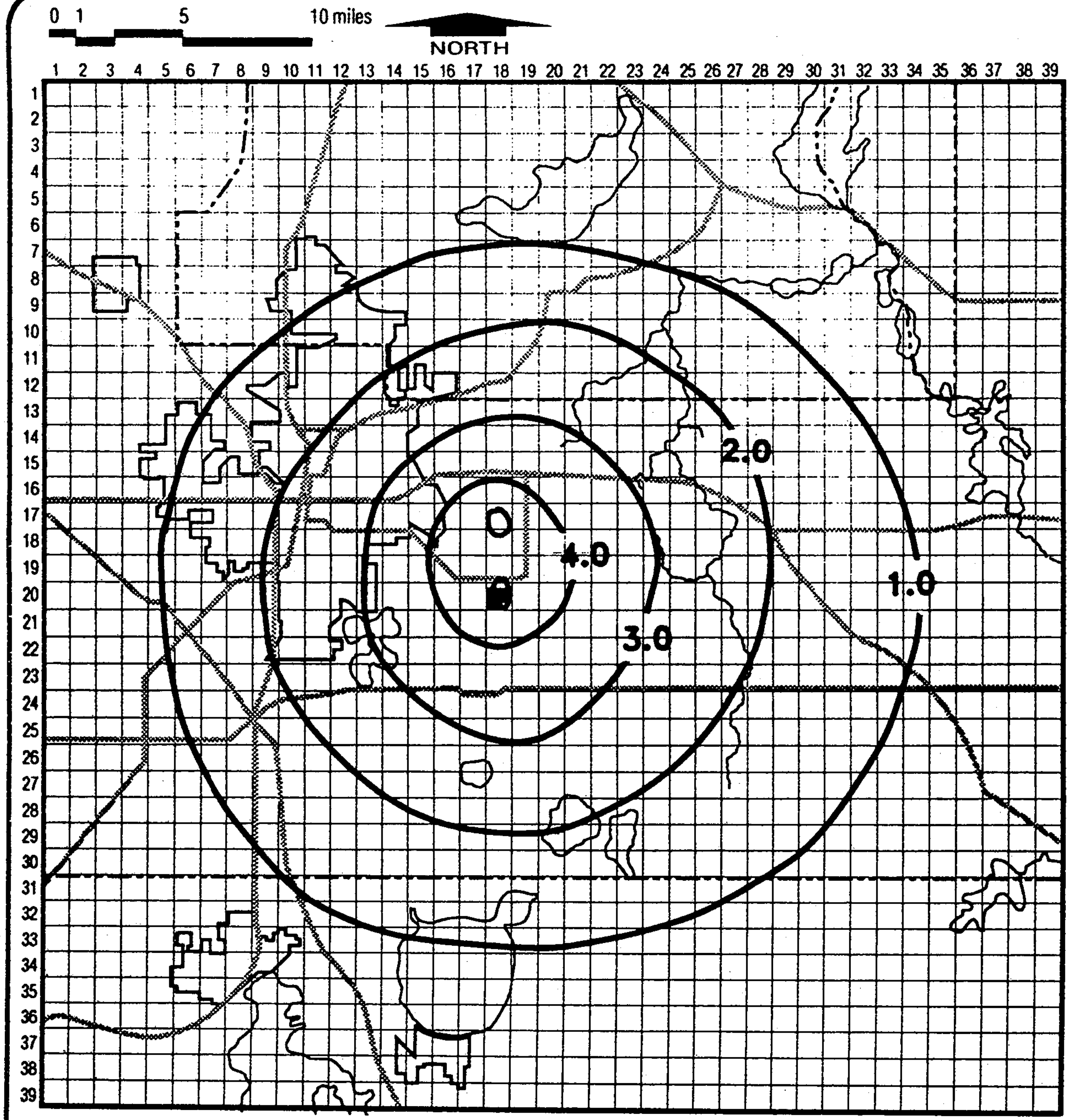
POTENTIOMETRIC SURFACE OF UPPER FLORIDAN AQUIFER

(AVERAGE DAILY FLOW)

DISCHARGE RATE:
28.8 MGD – 1 yr.

CONTOUR INTERVAL: 5.0 ft.

FIGURE 26



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DRAWDOWN ON THE UPPER FLORIDAN AQUIFER
(AVERAGE DAILY FLOW)

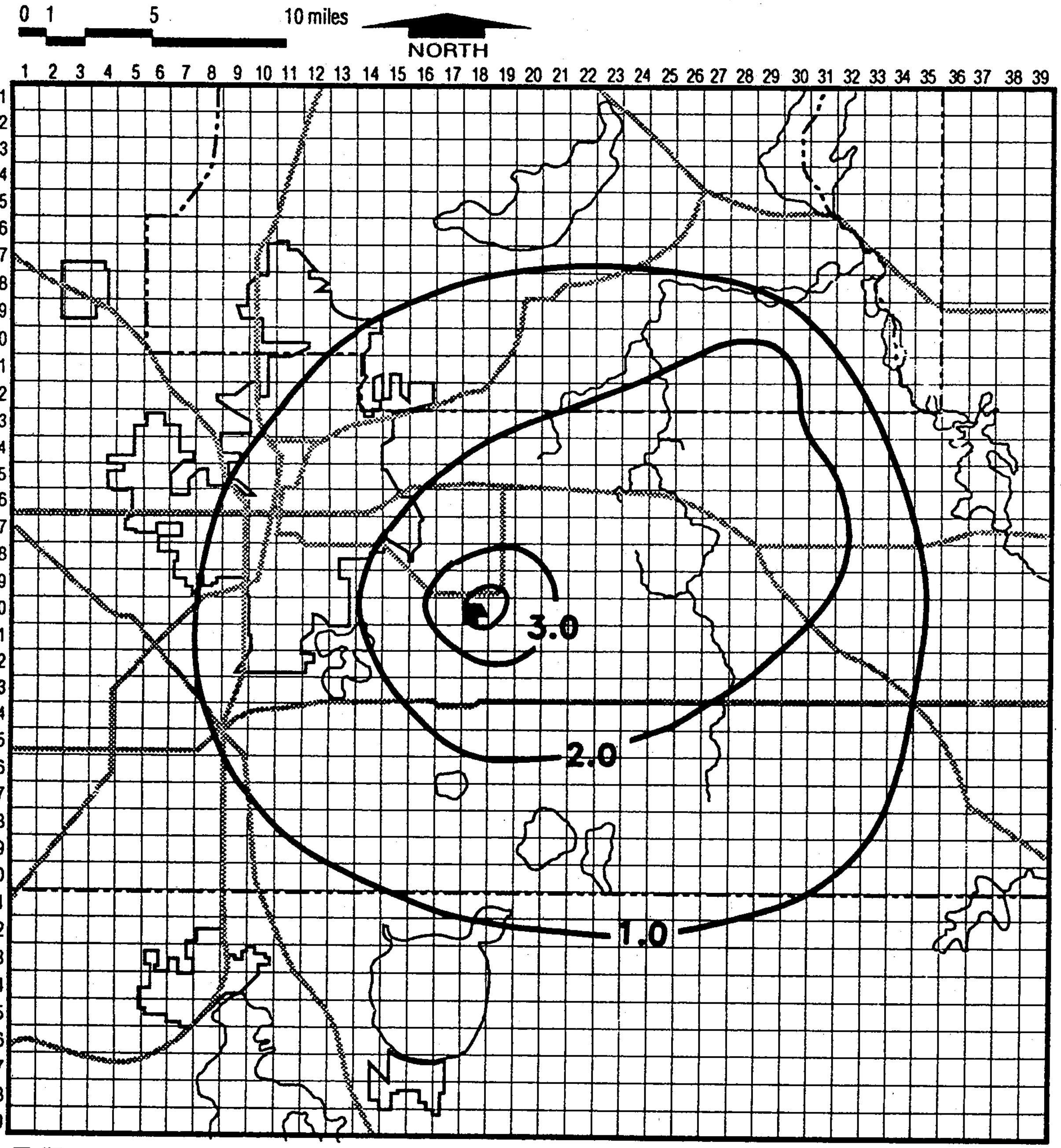
DISCHARGE:
28.8 MGD – 1 yr.

15 MGD ERWF SITE
8.25 MGD ECON PLANT
2.02 MGD BONNEVILLE
3.55 MGD CONWAY

SITE

CONTOUR INTERVAL: 1.0 ft.

FIGURE 27



DRAWDOWN ON THE LOWER FLORIDAN AQUIFER
(AVERAGE DAILY FLOW)

DISCHARGE RATE:
28.8 MGD – 1 yr.

CONTOUR INTERVAL: 1.0 ft.

■ SITE

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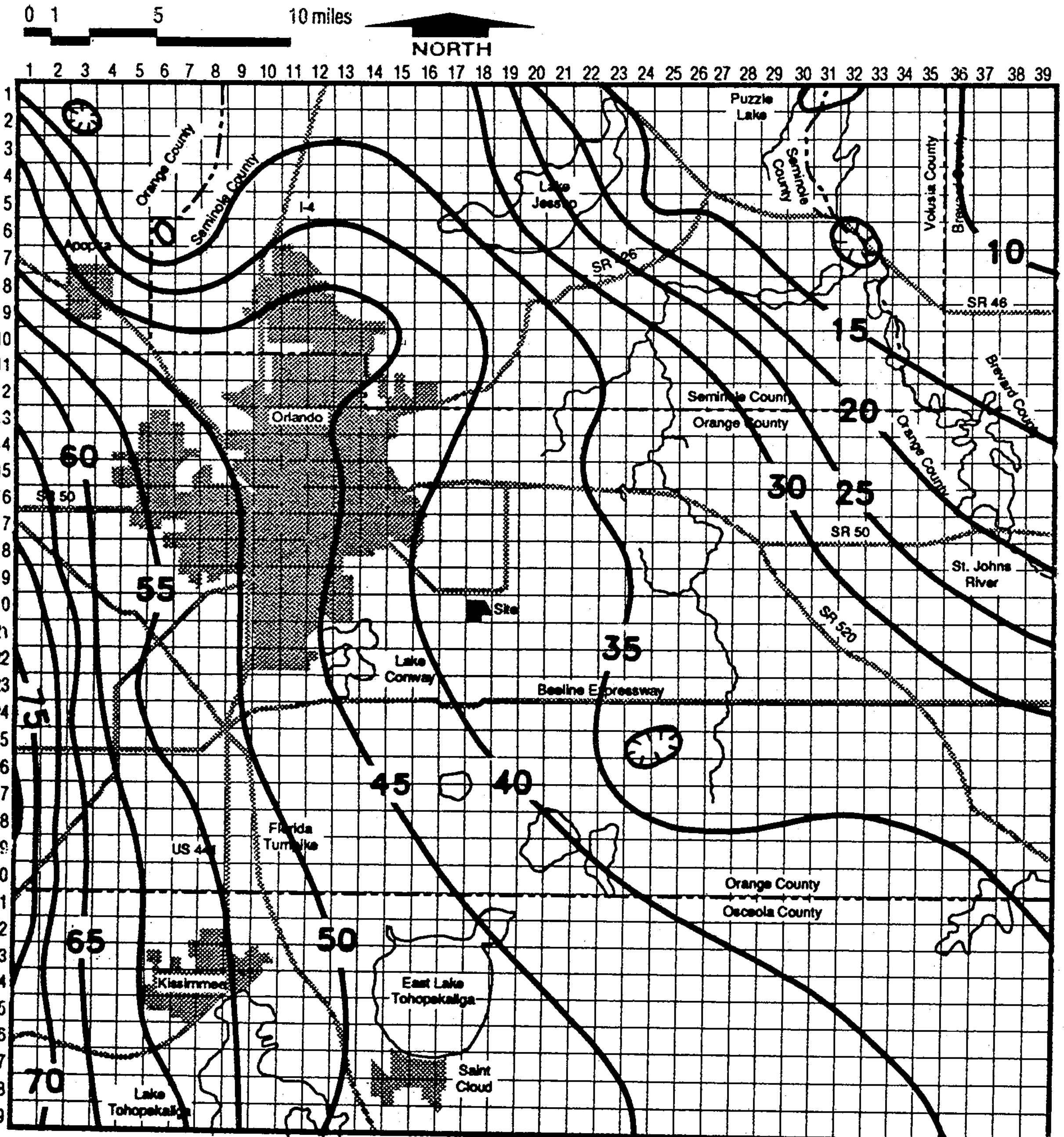
FIGURE 28

Upon completion of modelling the 28.8 MGD of ADF conditions, peak flow conditions of 48.8 MGD were modelled. For peak flow conditions, the model was executed with the 28.8 MGD of ADF conditions for a period of one (1) year and at the end of this period two (2) days of peak flow were modelled. Discharge rates for peak flow conditions were obtained by multiplying the ADF rates by a factor of 1.7. The results of this modelling scenario are presented on Figures 29, 30 and 31. Figure 30 shows the drawdown on the upper Floridan aquifer caused by worst case conditions of back to back days of peak flow at 48.8 MGD. Figure 29 shows the resulting potentiometric contours of the upper Floridan aquifer. Figure 31 presents the drawdown in the lower Floridan aquifer for the same pumping scenario. These contours appear only slightly changed in layer 1 where compared to the 28.8 MGD of ADF pumping scenario with the exception of the drawdown near the center which was inlarged as expected. Drawdown on layer 2 shows an additional two (2) feet of drawdown at the pumping center and an increased radius of the 2 foot contour line of 2.3 miles.

5.3.2 Impacts On Adjacent Users

The drawdown impacts to the potentiometric heads on the known adjacent Floridan aquifer users for each of the described commercial pumping centers has been tabulated in Table 7.



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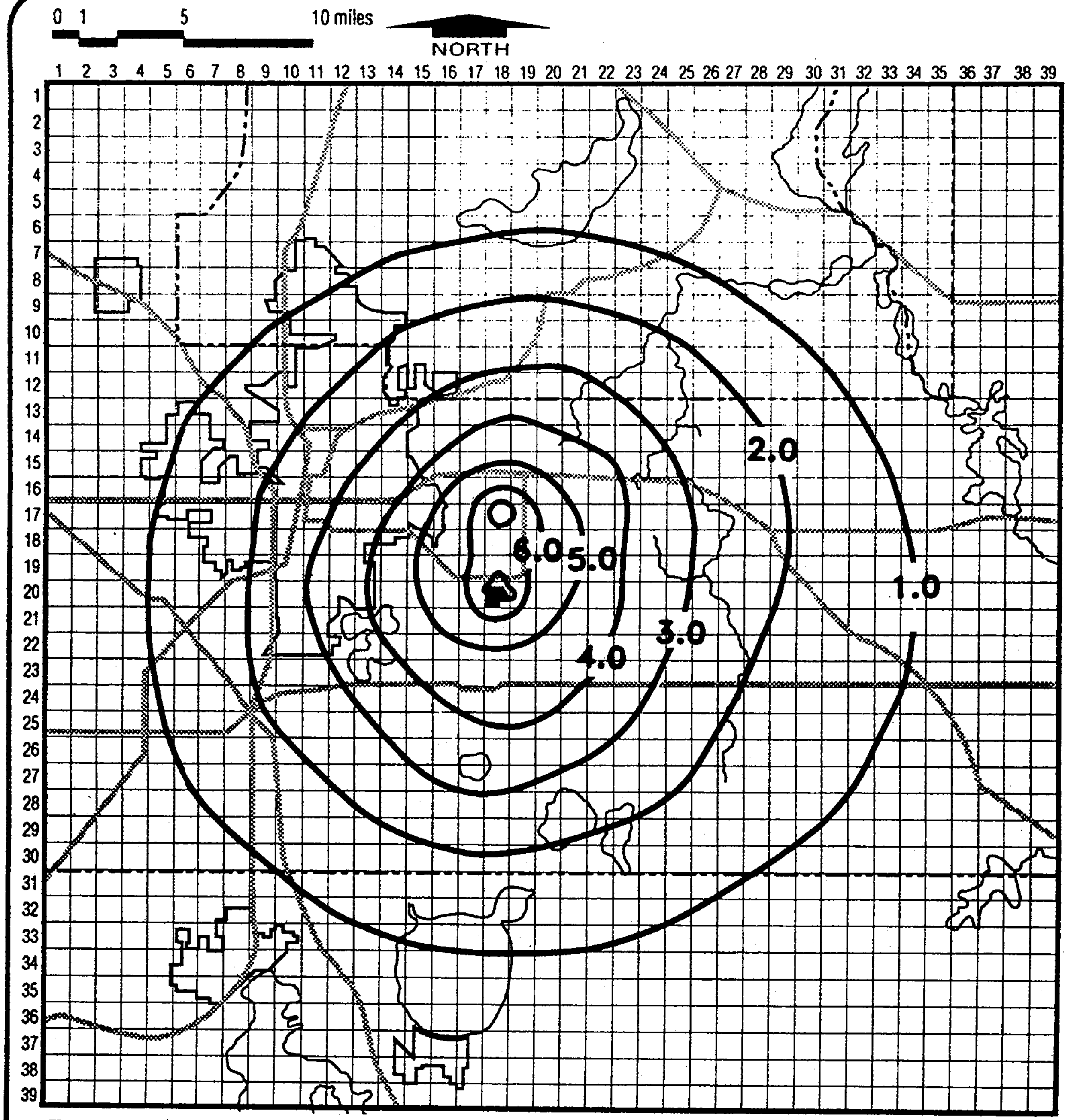
POTENTIOMETRIC SURFACE OF UPPER FLORIDAN AQUIFER
(PEAK FLOW CONDITIONS)

DISCHARGE RATE:
28.8 MGD – 1 yr.
48.8 MGD – 2 days

CONTOUR INTERVAL: 5.0 ft.

FIGURE 29



DRAWDOWN ON THE UPPER FLORIDAN AQUIFER

(PEAK FLOW CONDITIONS)

DISCHARGE:
1 yr @ 28.8 MGD
2 days @ 48.8 MGD

CONTOUR INTERVAL: 1.0 ft.

▶ SITE

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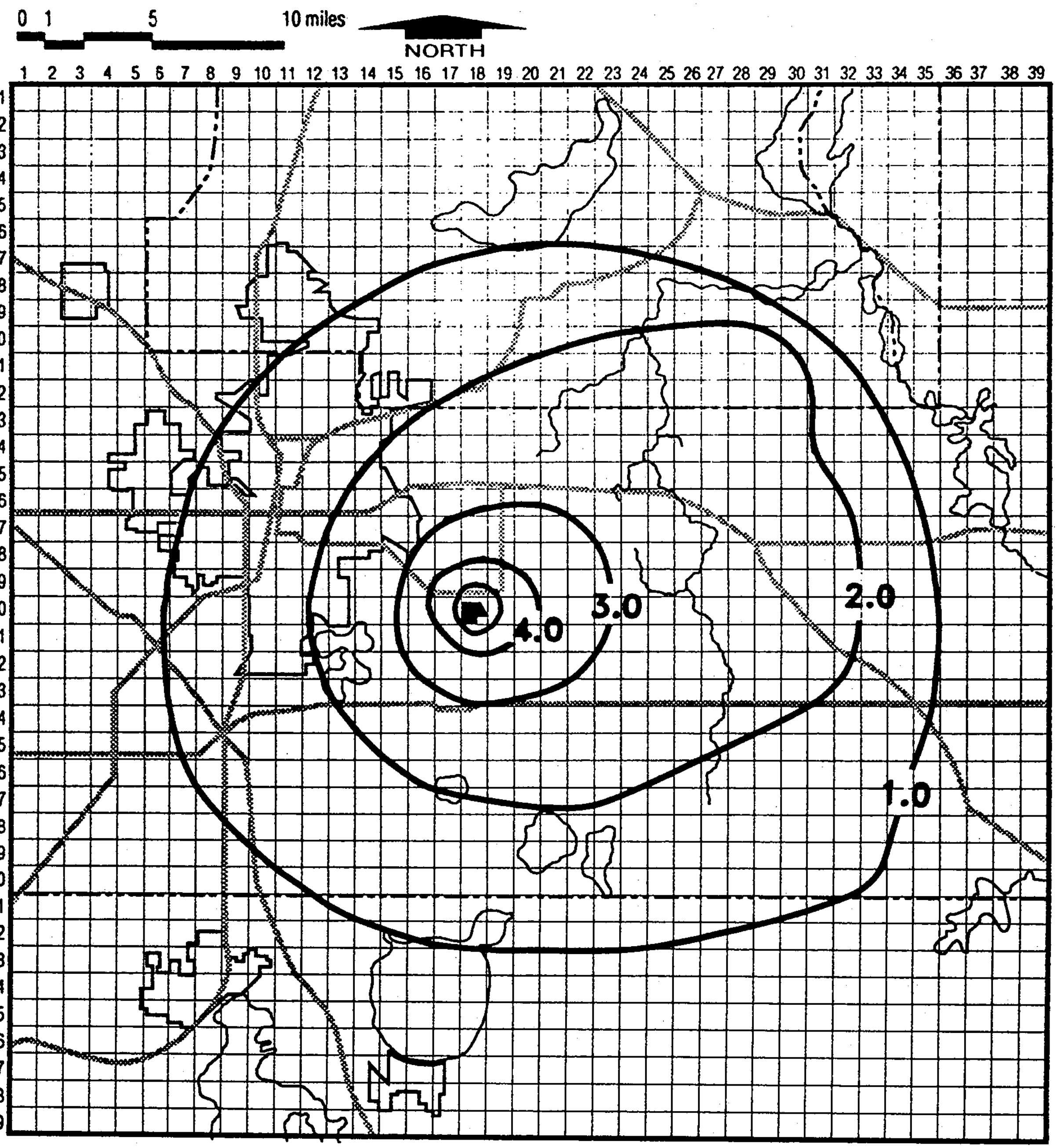
FIGURE 30



DRAWDOWN ON THE LOWER FLORIDAN AQUIFER (LAYER 2)

(PEAK FLOW CONDITIONS)

DISCHARGE RATE:
28.8 ADF – 1 yr.
48.8 PEAK FLOW – days

CONTOUR INTERVAL: 1.0 ft.

■ SITE

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FIGURE 31

TABLE 7

Predicted Drawdown Impacts to Adjacent Floridan Aquifer Users

Pumping Center/ User	Predicted Drawdown for ADF Pumping Scenario (ft)	Predicted Drawdown for Peak Flow Pumping Scenario (ft)
Primrose (OUC)(2)	1.6	2.0
Kuhl (OUC)(2)	1.4	1.7
Navy Base (OUC)(2)	1.5	1.8
Conway (OUC)(2)	2.0	2.5
Martin (OUC)	0.9	1.0
Highlands (OUC)(2)	1.2	1.5
Hidden Springs (O.Co.)	0.9	0.8
City of Apopka	----	----
City of St. Cloud	0.3	0.3
Lake Nona	2.6	3.0
Bonneville	3.0	4.2
UCF/Central Florida Business Park	3.0	3.7
Stanton Energy Plant	3.5	4.2
Econ Utilities	1.8	1.9
Chuluota (Southern States Utilities)	1.5	1.6
City of Winter Springs	0.9	1.0
City of Winter Park		
Wymore	1.5	1.7
Swoope	1.9	2.2
Riverside (O.Co.)	0.9	1.0
City of Maitland	1.7	2.0
O.Co.Correctional Inst.	2.6	3.0
Meadow Woods (O.Co.)	2.0	2.3
Orange Wood (O.Co.)	0.7	0.8
Suncrest	2.9	3.5
Hunterfield	1.5	1.6
Oakmeadow (O.Co.)	0.6	0.6
City of Belle Air (Southern States Utilities)	2.9	3.7

TABLE 7 (cont.)

Predicted Drawdown Impacts to Adjacent Floridan Aquifer Users

Pumping Center/ User	Predicted Drawdown for ADF Pumping Scenario (ft)	Predicted Drawdown for Peak Flow Pumping Scenario (ft)
Hunter's Creek (O.Co.)	0.8	0.9
Conway (O.Co.)	2.8	3.2
Cocoa Wellfield		
18,19	2.1	2.3
15,16,17	2.3	2.5
13,14	2.1	2.3
7A	2.0	2.1
3,7	1.6	1.7
10	1.8	1.8
2,8,9	1.7	1.8
5	1.5	1.6
4,4A1,11,12B	1.4	1.4
12A	1.3	1.3
City of Oviedo	1.0	1.0
City of Kissimmee	0.3	0.3
City of Longwood	0.5	0.6
Tuskawilla (18,8)	1.3	1.5
Lake Hayes (21,11)	2.3	2.7
Alafaya Woods (22,10)	2.0	2.2

(2) Lower Floridan Wells

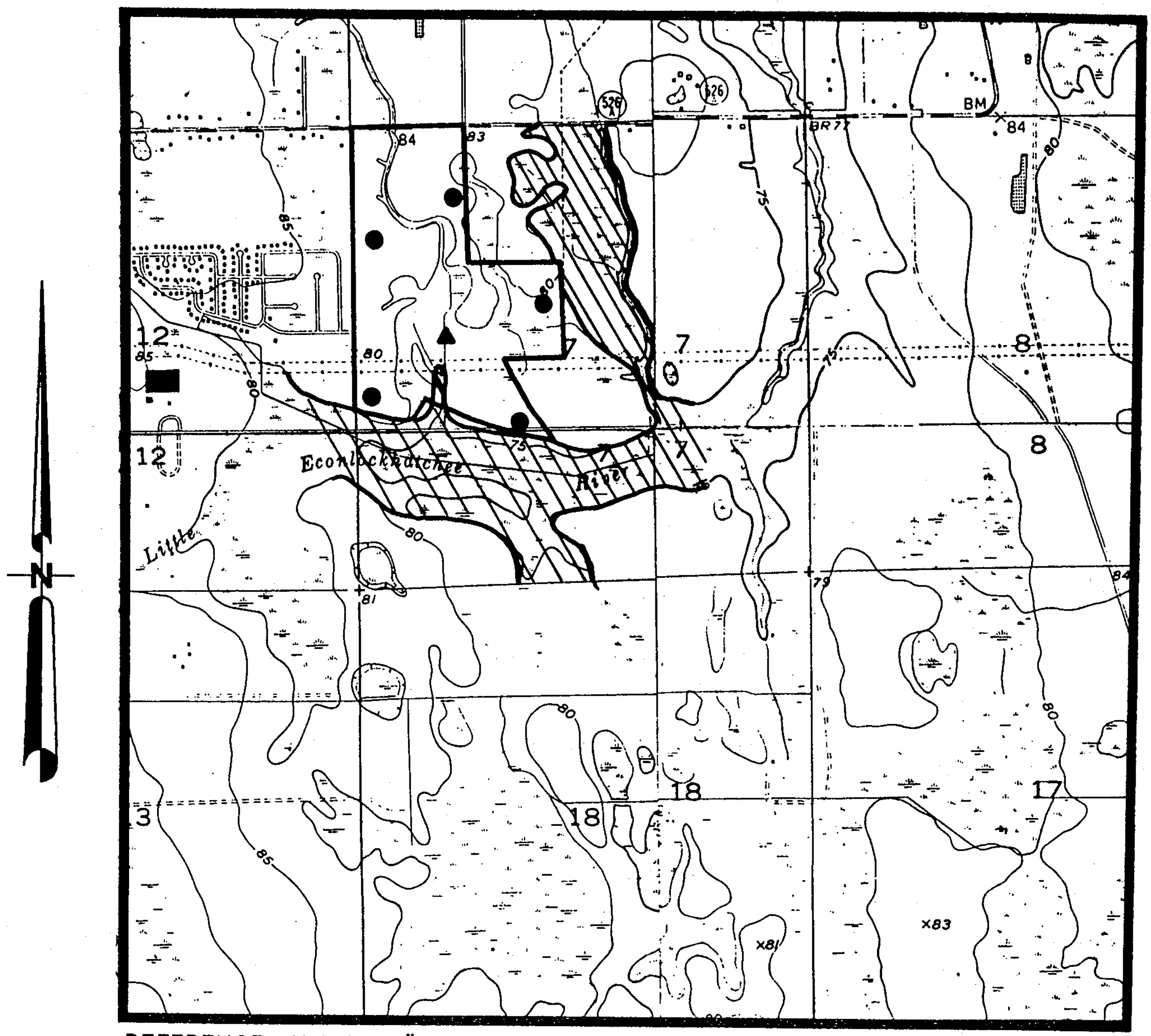
Based on our evaluation of the calculated drawdown affects on the adjacent Floridan aquifer users (Table 7), we estimated that approximately 0.0 feet to 3.5 feet of impact will be incured by the adjacent commercial users under average operating conditions.

5.3.3 Internal Wellfield Configuration and Modelling

Once the design discharge rates for each pumping center within the Orange County Eastern Service Area were defined using the regional model, the arrangement of individual wells within these sites was analyzed. Since no addition wells are proposed at the Conway, Bonneville and Econlockhatchee facilities, only the arrangement of wells within the ERWF site were modelled. It was determined during the course of the aquifer performance testing that wells installed within the ERWF site may be expected to achieve discharge rates between 3,000 and 4,000 gpm. From regional modelling design scenarios it was determined that approximately 15 MGD will be required from the ERWF site in order for the County to meet its anticipated demands of 28.8 MGD for Phase I. Using the design criteria of 15.0 MGD on this site and given the configuration of this site, approximately 6 wells were determined to be needed on the ERWF site to supply the desired 15 MGD of ADF and the estimated 25.5 MGD of peak flow.

The optimal arrangement of wells on the subject property would be to distribute the well locations as much as possible and to maintain maximum alignment of wells normal to the direction of groundwater flow. During wellfield design it is also necessary to maximize existing road use and to place wells out of flood prone areas. A preliminary arrangement of wells for this site was selected based on site conditions and the direction of aquifer water flow within the Floridan aquifer. Figure 32 presents the arrangement of wells we feel best fit the design criteria.

Analysis of the drawdown impacts within one (1) mile radius of the ERWF site was conducted using a Hantush-Jacob computer model for leaky artesian aquifers. This model is a simplified one layer simulation which assumes homogenous, isotropic conditions extending infinitely in each direction, except for transmissivity which is input for each individual well location. With the exception of vertical leakance, the hydraulic constants used for this model were the same as defined in the previous model in the area directly surrounding the ERWF site. The vertical leakance component used for this simulation was the determined median value between the local leakance value (approx. 0.0075 gpd/ft^3) and the regional calibrated value (0.000075 gpd/ft^3). The value selected was .00075 gpd/ft^3. Selection of this leakance valve was made because computer generated valves of drawdown produced by this model were simular to those predicted by the larger 3-D model. For the first scenario, the model was executed for a period of one (1) year, pumping the 6 wells on site at a rate of 3,500 gpm each for 12 hours a day (15.0 MGD total). Results of this model simulation predict drawdown at the individual wells to be approximate 6.0 feet.



REFERENCE: U.S.G.S. "ORLANDO EAST, FLORIDA" QUADRANGLE MAP

SECTION: 7
TOWNSHIP: 30
RANGE: 23

ISSUED: 1962
PHOTOREVISED: 1980
SCALE: 1" = 2000'

PROPOSED LOCATION of WELLS WITHIN
ERFW SITE

EASTERN REGIONAL WELLFIELD

ORANGE COUTNY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

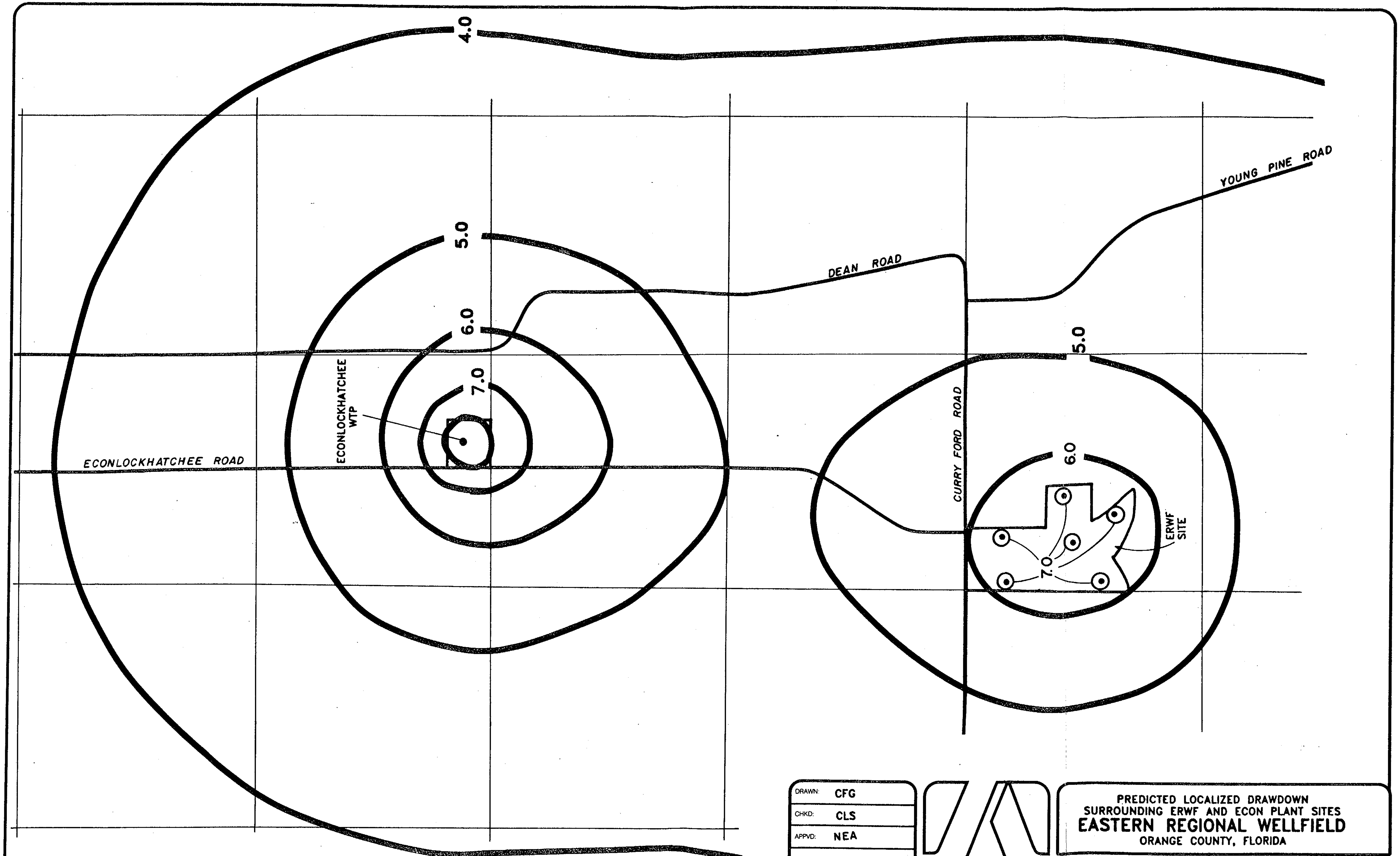
DRAWN: CFG	SCALE NOTED	PROJ NO 88-03288
CHKD. CLS	DATE: 2-12-90	Figure: 32

A second scenario was modelled to predict drawdown impacts caused by the withdrawals at the ERWF site (15.0 MGD) and the increased withdrawal rates from the Econlockhatchee facility (8.25 MGD). Figure 33 presents the predicted drawdown results for this withdrawal scenario. This simulation indicates a drawdown of 5.5 feet between the two facilities, approximately 8.5 feet drawdown surrounding the Econlockhatchee site wells and approximately 7.0 feet of drawdown at the ERWF site wells.

Based on the results of these site specific well withdrawal modelling, we conclude that the selected well configuration presented on Figure 32 is reasonable and provides near optimal location of wells within the ERWF site. Minor adjustments of these well locations can be made during final design and installation.

5.3.4 Proposed Well Construction

Each constructed production well is anticipated to consist of 24-inch casing and be drilled to a total depth of approximately 535 feet below ground surface. Based on the exploratory wells constructed at this site and geophysical logs collected from production well UFPW, information as to the productive formations at this site and the expected design for future well installation were determined. Construction details for the proposed production wells within this site are anticipated to be similar to that of well UFPW. Figure 7 provides brief construction details for well UFPW.



NOTE: TOTAL DISCHARGE RATE IS 28 MGD FOR A PERIOD OF 1 YEAR

DRAWN: CFG
CHKD: CLS
APPVD: NEA
SCALE: 1" = 200'

PREDICTED LOCALIZED DRAWDOWN
SURROUNDING ERWF AND ECON PLANT SITES
EASTERN REGIONAL WELLFIELD
ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DATE: 2-12-90 | PROJ. NO: 88-03288 | FIGURE 33

DRAPHIX #291020

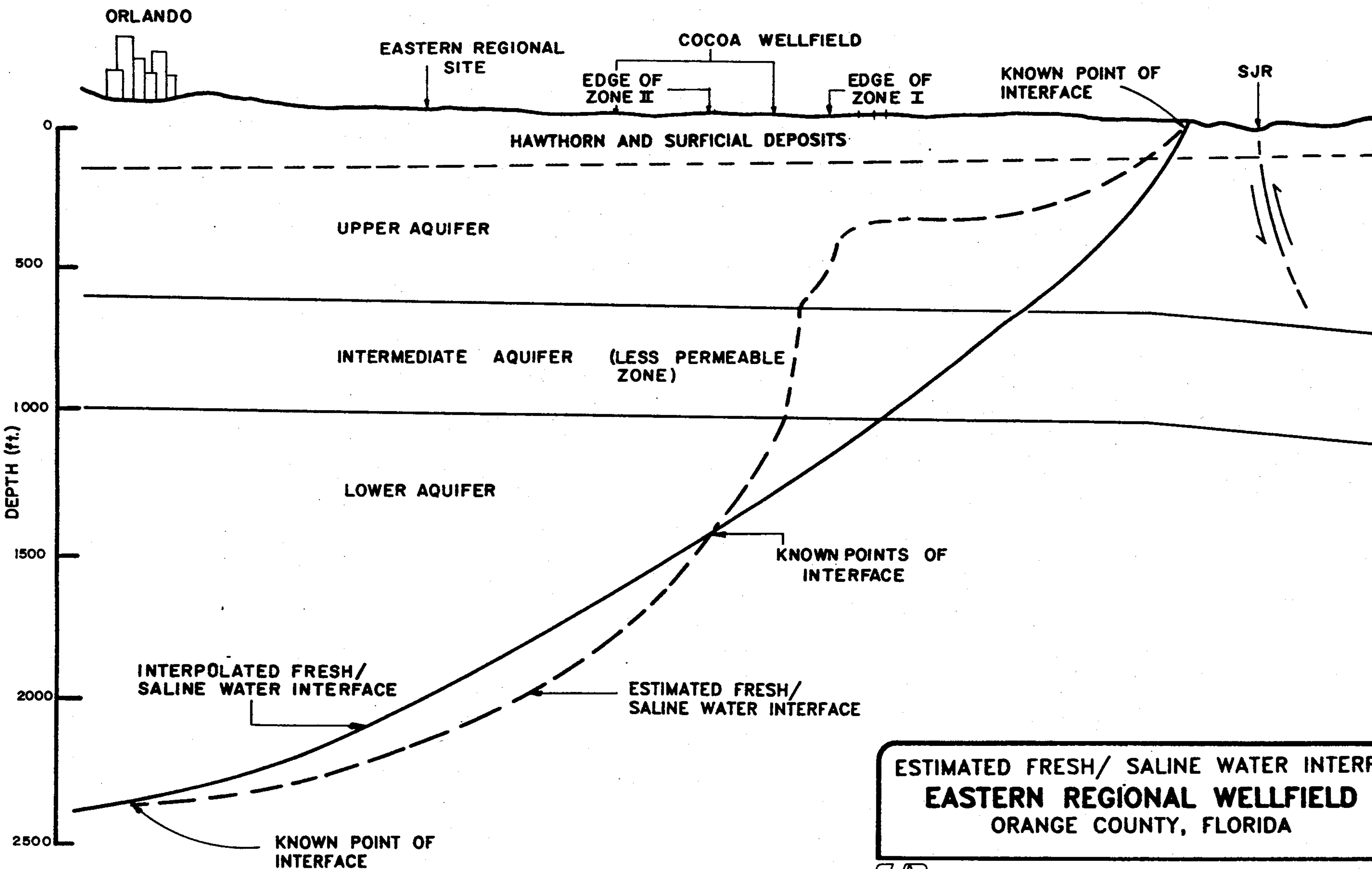
Once the conceptual design of this wellfield has been permitted, detailed construction specifications for each well will be developed for permitting at that time.

6.0 SALTWATER INTRUSION EVALUATION

6.1 FRESH/SALINE WATER INTERFACE DELINIATION

The extent and location of the fresh/saline water interface was difficult to determine within the modelled area. From the available literature, three (3) points of the interface within Orange County were identified. These three points include the St. Johns River with salt water occurring near the surface, the U. S. Geological Survey Well C at Cocoa wellfield with interface occuring at a depth of approximately 1,400 feet and in a deep well drilled in Orlando at Lake Ivanhoe with interface occuring at a depth of approximately 2,300 feet. A first approximation of the interface might be a line connecting the three (3) known points. This first approximation is presented on Figure 34 as the interpolated interface.

However, this direct interpolation of the fresh/saline interface does not compare well with the water quality information obtained from wells a few miles west of the St. Johns River (SJR). The SJRWMD has collected sufficient water quality data points in the areas surrounding and west of the SJR and has developed a map, identifying areas of poor water quality (Zone I) and transitional water quality (Zone II). Zone I areas are identified as often having potable water while Zone II areas generally have transitional water quality. By incorporating the observed water quality patterns for this area and the water quality zones established by the SJRWMD, a



SCALE: VERT. 1" = 500'
HORZ. 1" = 4 miles

ESTIMATED FRESH/ SALINE WATER INTERFACE

EASTERN REGIONAL WELLFIELD

ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN CFG	NOTED	PROJ NO 88-3288
CHKD CLS	DATE 2-12-90	FIGURE 34

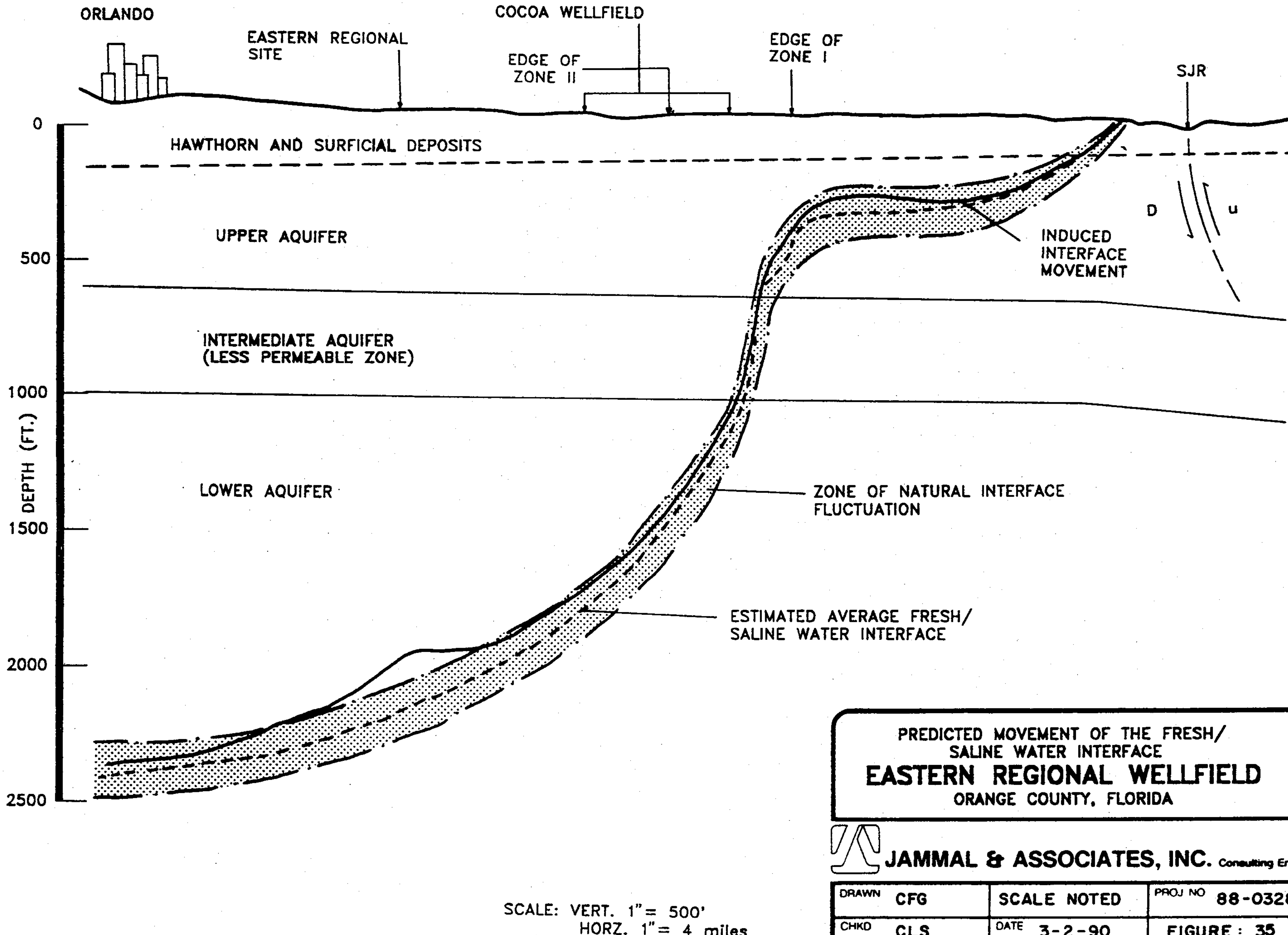
DRAPHIX #267658

new inferred fresh/saline water interface was estimated. This interface has been labeled as the estimated fresh/saline water interface on Figure 34. The position of the interface was used by Dr. Rowney in his analysis of the potential saltwater movement.

Using the Ghyben-Herzberg relationship and the seasonal fluctuation of the potentiometric head within the Floridan aquifer systems (taken as approximately 5 feet), the position of the fresh/saline interface was estimated to move vertically as much as 200 feet between wet and dry periods. The shaded area along the interface on Figure 35 shows the estimated zone of natural movement of the fresh/saline water interface.

6.2 SALTWATER INTRUSION ANALYSIS

A separate report addressing specific details of saltwater intrusion modelling for the regional and local effects was prepared by Dr. Charles Rowney and is included in Appendix L. Based on the saltwater intrusion analysis conducted by Dr. Rowney and as interpreted from our well construction data and water quality data gathered during the field program, it was determined that the proposed additional withdrawal rates of 19.8 MGD from the ERWF and Econlockhatchee sites will not pose an adverse saltwater intrusion or saltwater upconing problem in wells not already impacted by transitional type waters. Those wells on the fringe elements of the salt saline water edge are anticipated to inucur slight aggravation of their existing conditions. During this analysis effort, Dr. Charles Rowney utilized the results of the regional three-dimensional groundwater flow model and calculated the potential movement of fresh/saline water interface.



PREDICTED MOVEMENT OF THE FRESH/ SALINE WATER INTERFACE

EASTERN REGIONAL WELLFIELD

ORANGE COUNTY, FLORIDA

JAMMAL & ASSOCIATES, INC. Consulting Engineers

DRAWN CFG	SCALE NOTED	PROJ NO 88-03288
CHKD CLS	DATE 3-2-90	FIGURE: 35

DRAPHIX #267658

As presented in Dr. Rowney's analysis, the interface movement caused by withdrawals at the ERWF sites will be governed by the decrease in head in the aquifer and not the lateral groundwater flow velocity change. Therefore, the Ghyben-Herzberg relationship can be applied using the predicted drawdown amounts at given locations. Using the drawdown estimate predicted by the three-dimensional model the interface movement above the average background level was calculated. The resulting "induced" interface is presented on Figure 35, labeled as induced interface movement. This line represents the average stabilized interface after one year of withdrawals at 28.8 MGD. As shown by this figure, the new stabilized interface, with the exception of the area directly beneath the ERWF site, is within the area of natural interface fluctuation caused by seasonal potentiometric head variations.

Specific details of the saltwater intrusion analysis and associated estimates of fresh/saline water interface movement are included in Dr. Rowney's report (Appendix L). The major conclusion of Dr. Rowney's modelling efforts is that the proposed withdrawals from the Eastern Regional Service area pose a critical problem to only those wells which are currently compromised with saline water and to those nearest the fresh/saline water interface. Wells not currently exhibiting saltwater intrusion problem are expected to have minimal risk to adverse impacts due to the proposed withdrawals.

6.3 INDUCED SINKHOLE POTENTIAL

Sinkholes in Florida result from the State's underlying geologic and hydrogeologic conditions. The entire State is underlain, at various depths, by sedimentary carbonate deposits consisting primarily of limestone and dolomite which are susceptible to dissolution by groundwater and subsequent sinkhole formation. Where solution activity has become a significant process, the resulting topographic form is known as Karst. Karst is a comprehensive term applied to sedimentary areas possessing topography resulting primarily from underground solution activity and subsidence events.

Sinkholes generally result from one of two types of processes. The most common type is known as ravelling. The vast majority of sinkholes formed in Central Florida occur in this manner. A similar yet distinctive type of sinkhole formation activity is a collapse-type sinkhole which, while less common, does occur. Ravelling sinkholes originate within bedrock formations containing fractures or cavities at the upper surface of the formation. A ravelling sinkhole initially develops slowly as soil from the overlying unconsolidated strata erodes into the cracks within the bedrock limestone. This continual erosion and ravelling of the soil material into the bedrock formation creates a dome shaped cavity within the overlying sediments which, under favorable hydrogeologic conditions, enlarges until the dome can no longer support the weight of the overlying material, at which time collapse occurs. Collapse-type sinkholes result from the collapse of the roof of cavities within the limestone formation itself, followed by the subsequent subsidence of the overlying unconsolidated material. Sinkholes resulting from collapse are generally steeply sided while those resulting from ravelling are more often funnel shaped depressions that broaden outward.

Within Central Florida, ravel-type sinkholes are generally formed in an environment with the following physical characteristics:

1. The sedimentary formations (primarily in limestone) contain fractures which are overlain by unconsolidated sediments.

2. The cavity systems within the sedimentary formation extend upward and are in contact with the overlying unconsolidated sediments.

3. The shallow water table is considerably higher than the potentiometric surface of the Floridan aquifer.

4. There is high recharge to the Floridan aquifer resulting from breaches in the semi-confining beds overlying this aquifer system.

5. Sufficiently large cavities, fractures or other openings exist within the sedimentary formation. These cavities are capable of receiving the overlying eroded unconsolidated materials.

If the conditions described above prevail, water moving downward from the unconfined aquifer is able to transport large quantities of sediments into the cavernous limestone, thus creating voids within the overlying sediments (usually in the Hawthorn Formation). Portions of Central Florida where sinkhole formation is more frequent are generally found to have limestone cavity systems at depths in the range of approximately 50 to 150 feet below ground surface.

Certain topographic features, including the presence of closed depressions, lakes, lack of natural surface drainage patterns and areas of significant topographic relief, are all indicators that an area has a high sinkhole potential.

Four (4) general zones have been delineated in Florida which are classified according to the potential for sinkhole formation. The ERWF site is located in an area classified as stable sinkhole activity.

The relationship between the water table and the potentiometric surface elevation is important in evaluating the sinkhole potential of a particular site. High water tables and low potentiometric levels result in large vertical hydraulic gradients which increase downward movement of water and hence increase the probability of sinkhole formation.

Operating the proposed ERWF water supply system will result in an increase of hydraulic gradient due to the resulting drawdown in the Floridan aquifer. However, the estimated drawdown is relatively small when compared to existing head differential between the surficial aquifer and the Floridan aquifer.

Based on our evaluation, it is considered unlikely that sinkholes will form due to the operation of the proposed ERWF water supply system. No evidence was found during our field investigation which indicates any active subsidence (leaning trees, fences, etc.). The existing 40 to 45 feet of head difference between the surficial aquifer and the Floridan aquifer and the presence of cavernous limestone are the only conditions at this site that are working to potentially create a sinkhole. However, these conditions are compensated by a thick and competent confining unit (Hawthorn Formation) separating the limestones from the surficial unconsolidated deposits. The calibrated low vertical recharge in the site vicinity further supports the competancy of this unit.

6.4 POTENTIAL SURFACE WATER IMPACTS

The top of the Floridan aquifer exists at an average depth of 200 feet bls in the vicinity of the ERWF site. The overlying confining bed, the Hawthorn Formation, is approximately 120 feet thick with laterally continuous layers of relatively impermeable material separate the surficial aquifer from the Floridan aquifer within the project site and site vicinity. The presence of these poorly permeable clay beds (Hawthorn Formation) limit the hydraulic interaction between surface water bodies and the underlying Floridan aquifer. A hydraulic head difference of approximately 42 feet currently exists between the surface water bodies and the Floridan aquifer indicating the presence of competant confining beds. Estimated recharge values documented by Lichtler, 1968 and Tibbals, 1981 and work done at the Orange County landfield confirm this conclusion. Based upon this information, we conclude that surface water bodies will not be significantly affected by the proposed withdrawals at the ERWF site.

7.0 CONCLUSIONS AND RECOMMENDATIONS

An aquifer testing program was completed by Jammal & Associates, Inc. at the Eastern Regional Wellfield to evaluate the site suitability for regional water supply. The results of this study indicate that ample water quantity and suitable quality are available for the projected Orange County's daily water demands through Phase I development.

7.1 AQUIFER SYSTEMS

Wells constructed as part of the aquifer testing program have shown the existance of five (5) zones bearing different hydraulic characteristics. The zones include the surficial aquifer, the Hawthorn Formation as an aquitard, the upper Floridan aquifer, the intermediate Floridan aquifer and the lower Floridan aquifer. These hydraulic zones appear within the upper 1,385 feet penetrated during well drilling on-site. In the vicinity of the ERWF site, the surficial aquifer is contained between the water table and a depth of approximately 80 feet bls. The non-permeable clay layers of the Hawthorn Formation, which act to retard vertical water movement between the surficial aquifer and the underlying upper Floridan aquifer, are approximately 105 feet thick. Approximately 13 feet of a transitional zone between the Hawthorn Formation and the underlying limestones consist of soft limestone. The Eocene age limestones of the upper Floridan aquifer extend from the base of the Hawthorn Formation at a depth of 198 feet to a depth of approximately 530 feet bls. The lower extent of this aquifer was determined from geophysical logs collected during construction of the lower Floridan Exploration well. Between the depths of 530 feet and 1,155 feet exists the intermediate Floridan aquifer. This horizon, although referred to as an aquifer, behaves as an aquitard relative to the transmissive qualities of the upper and lower Floridan units. The relatively low transmissivity of the intermediate zone acts to retard vertical movement of water between the upper and lower Floridan aquifers. The vertical boundaries of this aquifer are not lithologic and can therefore only be recognized on geophysical logs and through production tests during drilling. The lower Floridan aquifer on the ERWF site extends from the base of intermediate horizon to an undetermined depth beyond 1,385 feet. This aquifer, although not completely penetrated, appears to contain potable water within the upper 200 feet.

7.2 WATER QUALITY

Water quality tests conducted during well construction and subsequent aquifer performance testing indicate that water quality from the upper and lower Floridan aquifer surpasses all State and Federal water quality standards. Iron, chloride and sulfate concentrations are considered very low. Total hardness values of approximately 115 mg/l to 120 mg/l are considered moderate. Water treatment for consumptive use at this site is expected to be minimal if any. Time related water samples collected during aquifer performance testing indicate that water quality from this wellfield may be identified as the fresh water recharge type.

7.3 WATER AVAILABILITY

Specific capacity tests conducted during well construction and at the end of well construction indicate that the most productive horizons within the upper Floridan aquifer occur between the interval of 390 and 495 feet bls. Wells constructed in a fashion similar to that of well UFPW are expected to create a drawdown of approximately 3 to 4 feet at the well when individually operating between 3,000 to 4,000 gpm.

Aquifer performance testing completed at the ERWF site indicates that the upper Floridan aquifer is extremely transmissive in the vicinity of the ERWF site. Drawdown reponses of the adjacent monitor wells to water withdrawals from UFPW were nearly immediate making the information collected during the course of the test difficult to evaluate. Analysis of the collected information indicates a transmissivity in excess of 2,000,000 gpd/ft^2 for the upper Floridan aquifer. Subsequent analysis also indicates that the upper and lower Floridan aquifers are relatively well connected at the ERWF site. Drawdown responses within the lower Floridan occurred within one (1) minute of the start of pumpage at the UFPW test well. The calibrated computer model was used to calculate the leakance between the upper and lower Floridan aquifers. An average value was estimated at 0.64 gpd/ft^3 using the calibrated model. Similar high leakance values were confirmed by the match point methods.

Aquifer hydraulic parameters determined from the aquifer preformance tests at the ERWF site and those obtained from literature were used to calibrate a regional aquifer model to predict the impacts from the proposed withdrawals. Calibration of the regional model simulation generally substantiates the findings of Rutledge, 1984 and German and Bradner, 1988 that recharge to the upper Floridan aquifer in the metropolitan Orlando area is in excess of 16 inches/year partially a result of existing drainage wells. Calibration of the model also indicates that the most transmissive portions of both the upper Floridan and the lower Floridan appear on the northwest portion of the modelled area.

Using the calibrated numerical model, the impacts due to the projected potable water demands of 28.8 mgd were analyzed. The model indicates that the radius of impact caused by the withdrawal extends for several miles. The predicted drawdown under steady state withdrawal of 28.8 MGD (ADF) conditions is expected to be approximately 5.5 feet within the site. Under worst case conditions of 48.8 MGD peak flow for two consecutive days, the drawdown is expected to reach 7.5 feet within the site. Figures 26 through 31 present the drawdown impacts within the modelled area for the upper Floridan aquifer.

7.4 POTENTIAL POLLUTION SOURCES

The potential pollution sources to the potable groundwater at the Eastern Regional Wellfield site have been evaluated as to the severity of each potential source. The identified pollution sources have been divided into surface water sources and drainage well categories. Indentified potential surface water contamination sources include the Orange County landfill, Azalea Park and landfill canals, and numerous small point-discharge sources. The potential for these sources to cause contamination to the Floridan aquifer system is considered to be small, due to the presence of thick sequence of clay sediments within the Hawthorn Formation separating the pollution sources and the upper Floridan aquifer. The identified drainage well in Section 2 of Township 28 south and Range 30 east could potentially pose a threat to water quality at the proposed wellfield. This drainage well functions to maintain water levels in the adjacent pond containing water from Azalea Park Canal. Water quality samples taken from the source canal indicates that no significant undesirable water quality characteristics are present in the canal waters. As long as the surface water directed to the drainage well is maintained at the present quality or better, the drainage well posses no significant contamination potential.

The amount of impact caused by the proposed withdrawals was estimated to be between 0.3 and 3.5 feet for the larger permitted water users in the regional area. Table 6 presented in this report provides the approximate total drawdown for each of the larger permitted users in the regional area. Those domestic users of the Floridan aquifer directly adjacent to the ERWF location may anticipate between 4 and 5 feet of drawdown during operational periods of the wellfield. From our well survey we did not find any information on nearby users indicating that they will be adversely affected by the estimated drawdown impacts.

7.5 SALTWATER INTRUSION

The extent of possible saline water intrusion and upconing was analyzed and addressed by Dr. Charles Rowney. The results of Dr. Rowney's investigation suggest that the movement of the saline water interface in the vicinity of this site may be estimated by applying the Ghyben-Herzberg relationship on hydrostatics. Using the drawdown calculated by the calibrated MODFLOW computer model and applying the Ghyben-Herzberg relationship the approximate movement of fresh/saline water interface was estimated. The results of this analysis indicate that the proposed withdrawal from the ERWF will somewhat augment the natural fluctuation of the fresh/saline water interface. However, this augmentation should not cause an imbalance of the interface or a significant saltwater encroachment into existing users in the area. However, wells installed to the depth of existing fresh/saline water interface may be impacted by the estimated movement of interface.

7.6 SUMMARIZATION

Based upon the results of this investigation and the subsequent analysis and evaluation, Jammal & Associates, Inc. has the following conclusions and recommendations:

1) The selected ERWF wellfield site was found to be located in a very productive aquifer zone with extremely high transmissivity and with high water quality. The site is in an optimal location from the geographic and hydrogeologic point of view and will create the least impact on the adjacent water users. It is our opinion that a better site will be difficult to find within the Orange County eastern region.

2) The upper and lower Floridan aquifer units appear to be well connected in the vicinity of the ERWF site. The similarities between the water quality and the potentiometric head for each horizon and the calculated leakance between the two units substantiate this hydraulic connection.

3) The upper Floridan aquifer in the vicinity of the ERWF site is extremely transmissive. Aquifer performance

test information and pipe flow conditions between wells on the site confirm this condition. However, calibration of the regional flow model suggests this high transmissive area may be limited to within one to two square miles of the ERWF site. The exact extent was difficult to determine from our modeling and testing efforts. A conservative area of only one (1) square mile was used for the simulation.

4) Water quality testing both in the upper Floridan and lower Floridan aquifers indicates that the water is of good quality for potable supply purposes. Minimal treatment is anticipated. Based on time-related water quality testing and geochemical pattern analysis, the water from both upper and lower Floridan aquifers can be classified as "fresh water recharge Type I and Type II" (Frazee, 1982).

5) Each well constructed on the ERWF site should be designed in such a manner that it will be capable of producing 3,500 to 4,000 gpm with drawdowns in the range of 5 to 8 feet. The best design for such a well would be a 24-inch diameter well cased between the depths of 0 and 210 feet and having an open hole section within the limestone unit between the depths of 210 and approximately 540 feet. Actual well construction should always be modified to fit specified field conditions. A conceptual layout for a total of 6 individual wells is presented on Figure 32 in this report. These locations can be modified during final design, but should be aligned in the north-south direction as much as possible.

6) A master wellfield model should be maintained. Information obtained from the installation and testing of each well should be used to update the model and to predict actual wellfield impacts. At the end of each year of wellfield use, updated hydrologic reports should be prepared to access water quality and drawdown trends and to evaluate actual impacts.

7) Modeling of the wellfield for regional impacts indicated that although conditions surrounding the Bonneville WTP are satisfactory for water production, reduction in daily withdrawals from this plant or removal of this plant from operation and redistribution of withdrawals elsewhere will be desirable. This will reduce the aquifer stresses in an area where production capabilites appear less favorable due to the proximity of the site to groundwater with questionable quality.

8) Due to the concerns of off-site impacts, we suggest a monitoring program be initiated to assess long-term withdrawal impacts and to assure the wellfield is operating as designed. Principal monitoring activities should consist of the measurement of water levels in the production wells and existing upper and lower Floridan aquifer monitoring wells, collection of on-site rainfall data and collection of water levels in nearby lakes and bayheads. Periodic water quality samples from the production wells and the lower Floridan monitoring well should be analyzed to assess long-term water quality trends. This monitoring

program should be initiated prior to initial withdrawals to provide baseline water level and water quality conditions.

9) The surficial aquifer in the vicinity of the ERWF site contributes very little to vertical recharge to the Floridan aquifer. Annual recharge values estimated by Tibbals, 1981, and Lichtler, 1968 as well as work done at the Orange County Landfill verify this conclusion. Measured water levels in the surficial aquifer at the ERWF site during aquifer testing (well SP) indicated no reduction in elevations during the 72-hour pump test. The low vertical leakance from the surficial aquifer should mitigate any impacts to surface water bodies in the ERWF vicinity.

10) It is recommended that the proposed six (6) wells (Figure 32) be utilized to achieve the 15.0 MGD of ADF allocated for the ERWF site. Each well should be designed to yield approximately 3,500 gpm for a 12-hour period each day. Modeling the proposed arrangement of the wells (Figure 33) indicates that the distribution of the individual wells is not critical at this site. The field restraints caused by flood plain areas and wetlands will most likely dictate the arrangement of wells on site. We do recommend, however, that the spacing of the wells be maximized on site in order to minimize the drawdown between each well within the wellfield area. The wellfield layout presented on Figure 32 optimizes the available spacing within the site.

11) Those users closest to the proposed pumping centers may be required to make minor pump setting adjustments to compensate for the imposed additional drawdowns. Although we feel this is unlikely we recommend monitoring water levels in those wells adjacent to the discharge facilities to study this possible problem.

12) Based on our groundwater flow modelling and subsequent saltwater intrusion analysis performed by Dr. Charles Rowney, it was determined that minor augmentation of fresh/saline water interface fluctuation will occur as a result of the ERWF operation. However, when compared to natural fluctuations due to seasonal fluctuation of potentiometric levels in the aquifers the effect of the ERWF will not be critical for water supply in the regional area. Wells located directly adjacent to areas already experiencing saline water problem will be most critically effected.

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