WELL FIELD EVALUATION
AND
NEW WELL SITE LOCATION STUDY
FOR THE CITY OF
CORAL SPRINGS, FLORIDA

January 1985

Camp, Dresser & McKee Inc.
Fort Lauderdale, Florida

CDM

environmental engineers, scientists, planners, & management consultants

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January 17, 1985

The Honorable Mayor
and Members of the City Commission
City of Coral Springs
9551 West Sample Road
Coral Springs, Florida 33065

RE: Coral Springs Well Field Evaluation

Dear Commissioners:

We are pleased to submit ten copies of the Well Field Evaluation and New Well Field Site Location Study. The study included an evaluation of the City's existing well field and determination of well sites for near term expansion of the City's potable water supply system.

The evaluation of the twelve City wells included review of the existing data and several field tests. Specific capacity tests were performed on all wells, and step drawdown and sand tests were performed on Wells 3, 8, and 10. These three wells were chosen for their geographical position, historical problems, and their method of construction. The test results indicate Wells 3 and 8 are producing sand but not at dangerous levels. However, Well 10 will produce 527 mg/l of sand when pumped at 800 gpm. Mechanical deterioration will occur as a result of sand production and therefore Well 10 must continue to be used at a controlled pumping rate of 500 gpm or less.

Evaluation of the wells concluded that the wells do not have provisions for replacing the gravel pack installed at the time of construction. The replacement of gravel is necessary as the wells continue to develop because voids in the formation are generated as long term pumping continues to remove sand from the well. Wells 1 through 8 cannot be economically modified to make these provisions. Wells 1 through 8 will eventually fail and should be phased out of primary service and placed in standby service to prolong their life expectancy. Wells 9 through 12 have similar construction restrictions as the other wells, but modification may be possible. The economic advantages to modification should be evaluated when the well field expansion program occurs. If the modifications cannot be made, Wells 9 through 12 will ultimately lose production capabilities and will have to be placed on standby capacity.

The present well field capacity is 4,820 gpm (6.93 MGD) under the present pumping scheme. In May 1984, the water demand was 5.13 MGD. The 1985 water demand projection is 7.09 MGD, and if the demand is factored by 4% plant losses and 20% standby capacity, the City's well field should have an installed capacity of 8.84 MGD. Therefore, the City's well field must be expanded immediately to meet the water demand for the upcoming year.

To meet this need, we recommend the City undertake an immediate expansion program to include the construction of eight wells over the next two years. They will be new production wells and allow the phasing of Wells 1, 4, 6, 8, and 10 to standby status. This phase will include standby power and transmission mains for a total estimated cost of $1.63 million. This value is escalated at an annual rate of seven percent per year. The projected eight wells are based on extremely conservative pumping rates per well. Field testing will determine actual production rates and predictable higher rates will reduce the actual number of wells from this worst case scenario.

The recommended area for expansion is along the north and east side of Forest Hills Drive and on the Broken Woods Golf Course. Expansion should continue in order to meet water demands through the year 2005, when a total of 32 wells would exist. At that time, all present wells would be on standby, and 20 new wells would have been constructed. The City's installed well field capacity would then be 16.75 MGD to meet a water use demand of 13.96 MGD.

We wish to thank the City's engineering, utility, and other City personnel who assisted in both data development and field testing. Their cooperation is sincerely appreciated. We are pleased to transmit this report to you and welcome the opportunity to again work with the City of Coral Springs.

Sincerely,

CAMP DRESSER & McKEE INC.

Bob Moresi

Robert J. Moresi, P.G.
Water Resources Manager

RJM/la

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1. INTRODUCTION

In 1984, the City of Coral Springs established record high water demands, encouraging the City Commission to authorize Camp Dresser & McKee Inc. (CDM) on June 12, 1984 to evaluate the City's water supply system. CDM undertook evaluation of the Coral Springs well field with several goals in mind. The first goal was to determine the cause of repeated well production problems including decreasing production rates, higher than anticipated drawdown levels, and the pumping of sand from several production wells. After review of the historical data and by study of newly acquired information from field testing selected wells, the next goal was to determine the cause for each problem and suggest corrective measures. The final goal was to design a well field expansion program, including recommended well sites and a schedule for implementation. This project included a modified application for a South Florida Water Management District (SFWMD) Water Use Permit under Chapter 40E-2, of the Florida Administrative Code (FAC).

These goals were outlined in five tasks:

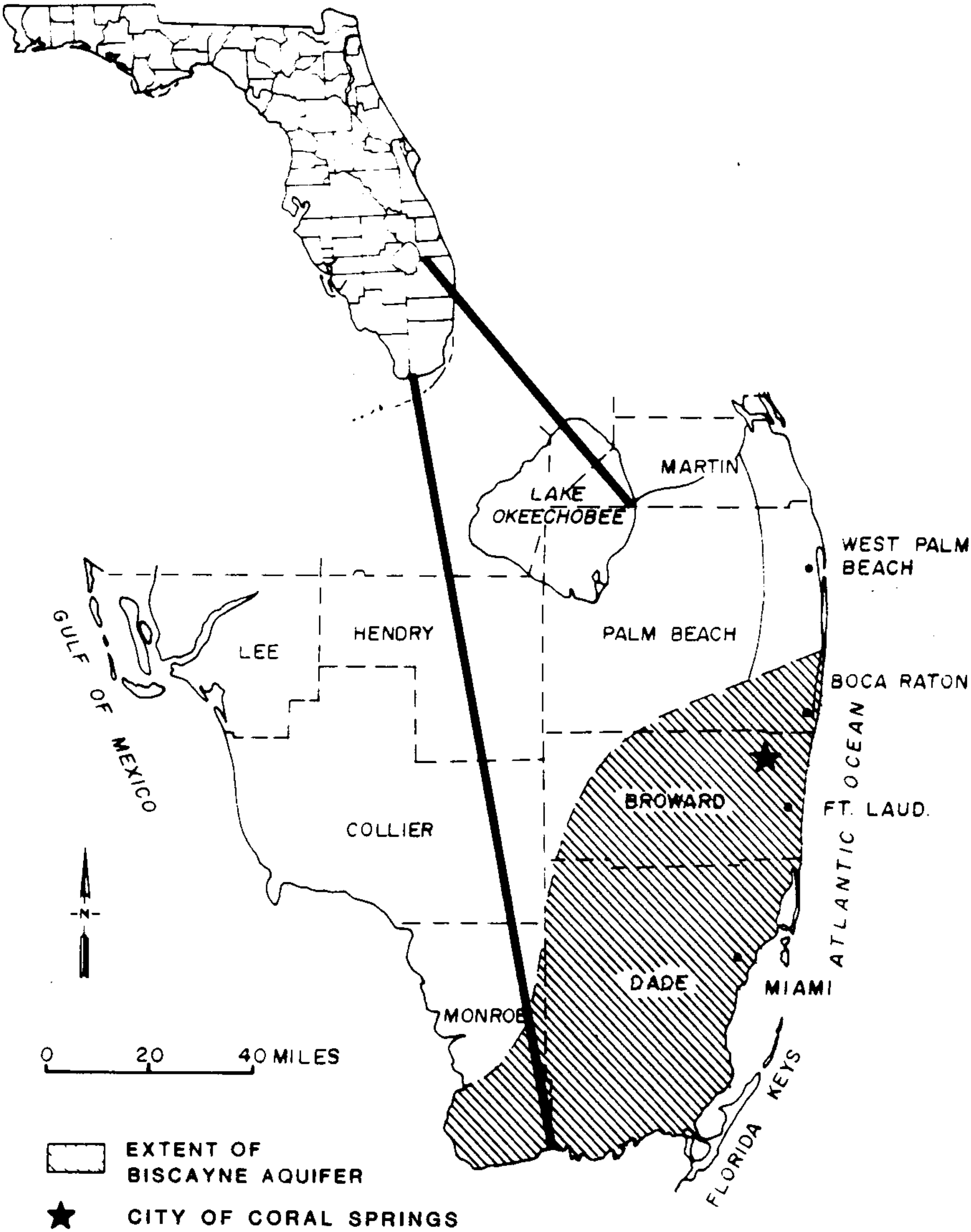
- Review existing data and expand on CDM's Master Plan Update prepared in 1984.
- Evaluate present well performance using step drawdown tests on three wells selected as representative of existing well field conditions.
- Evaluate and propose new well sites and a schedule for construction.
- Prepare a report describing the evaluation and recommendations.
- Prepare a Water Use Permit modification requesting a ten-year projected water use allocation.

2. HISTORY

The City of Coral Springs is located in northern Broward County, Florida (Figure 1) and was originally established under Chapter 298, of the Florida Statutes, known as the General Drainage Act of Florida. The City began in 1967 with 815 lots to be served by a groundwater supply system consisting of two production wells. Early population growth increased yearly at a rate of almost 50 percent. The number of annual water connections rose from 151 in 1968 to 4,711 in 1977. The City's population growth rate began to level off after 1977, increasing the number of water connections to 6,950 in 1984. The present population of the City of Coral Springs' service area is approximately 39,500. Potable water demands have consequently risen with the increasing population, forcing periodic expansions to the City's potable water system. The demand has continued to increase, reaching record levels in May 1984 of over four million gallons per day (MGD) average demand.

Coral Springs was originally provided water from two wells constructed near a 0.35-MGD water treatment plant. This treatment plant was enlarged in 1972 to a rated capacity of 1.05-MGD in preparation for adding production wells to the system. In 1973, two additional wells were drilled and in 1977, four more wells were added to the system. By the end of 1979, a total of 12 wells had been drilled with the last four wells not placed in service until 1981. The increasing demand for water also required additional expansion to the water treatment plant and by 1982 the plant was expanded to its present rated capacity of 8.3-MGD, based on 24 hours per day operation.

The City has had repeated problems in obtaining originally predicted production from its wells. Problems have included decreasing production rates, higher than expected drawdown levels and the pumping of sand. Consequently, several evaluations have been performed and reports prepared for the City. The most comprehensive well field study to date was prepared by Reynolds, Smith and Hills Inc. in September 1982 as the Phase II Well Field Analysis. A listing of the more pertinent water supply reports appears in Appendix A.



LOCATION MAP FOR THE CITY OF CORAL SPRINGS

Figure 1

environmental engineers, scientists, planners, & management consultants CDM

3. HYDROGEOLOGIC SETTING

Climate

The climate of southeast Florida is principally a result of its geographical position. The area is nearer to the equator than any other part of the continental United States and all parts of southern Florida are within 60 miles of either the Atlantic Ocean or the Gulf of Mexico. The climate of the area is characterized by warm weather, ample rainfall and a light persistent wind.

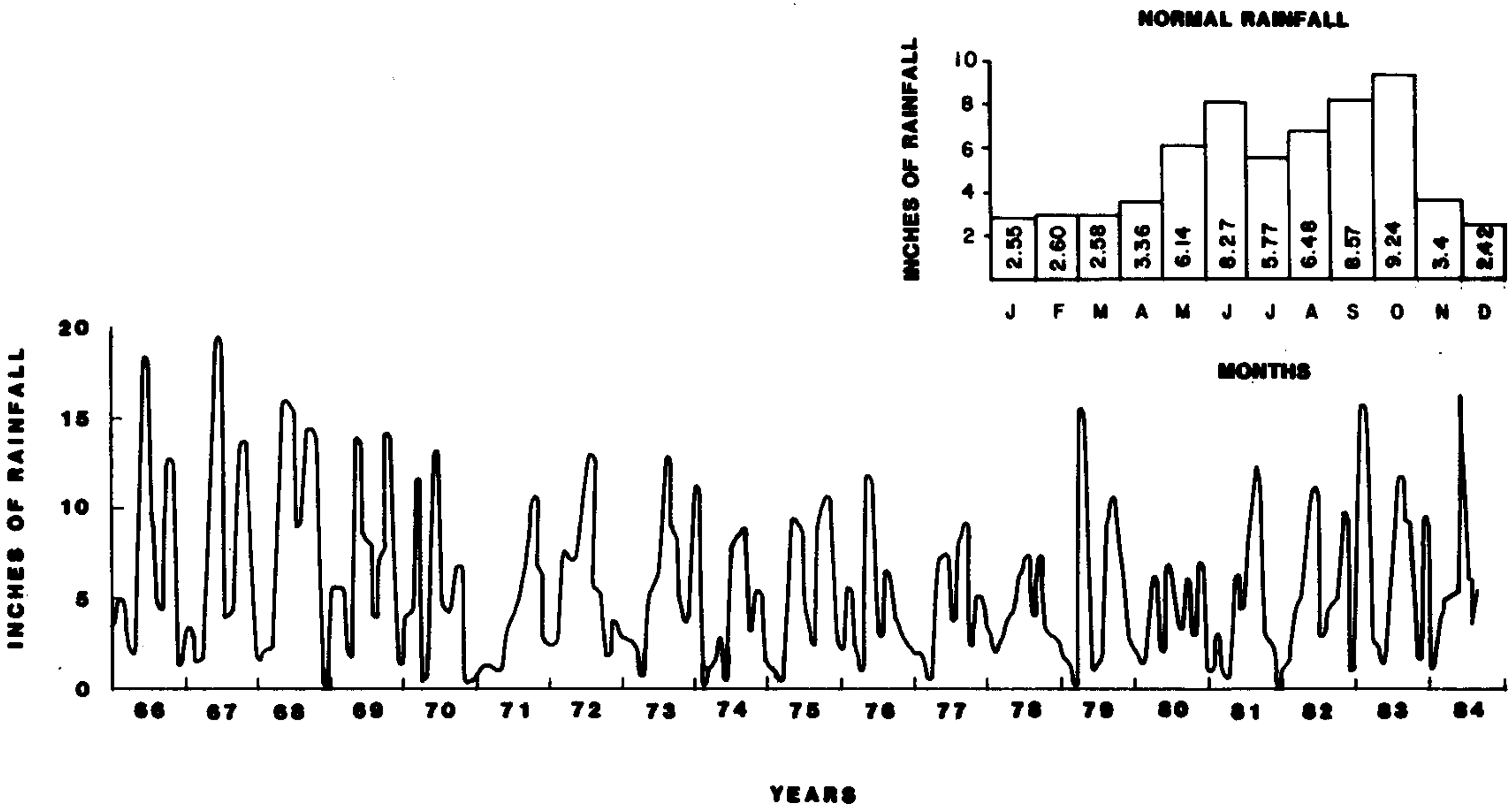
The annual rainfall in the Coral Springs area averages 60 inches. The rainy season, normally from June through October, brings approximately 70 percent of the total annual precipitation. The remainder of the rainfall occurs during the remaining seven month period. The nearest National Oceanic and Atmospheric Administration (NOAA) weather station is Pompano Beach. The total monthly precipitation since 1966 is shown in Figure 2.

Local temperatures range from extremes of approximately 29^{o} F to 96^{o} F. Usually, January is the coldest month and August is the hottest. The warm temperatures, along with relatively high humidity, results in high evapotranspiration rates. During the SFWMD Works Recharge Analysis performed by CDM in 1981, groundwater evapotranspiration rates were estimated to be 10.7 inches during wet years and 2.5 inches during dry years.

Topography and Drainage

Coral Springs is located west of the coastal ridge and east of the SFWMD's conservation area, which is part of a regional surface water management project. The City is in a relatively flat area with an average elevation of approximately 12 feet above mean sea level (msl).

Surface water drainage in Coral Springs is controlled by a series of canals that run north and south (lateral canals) and another series that runs east and west (drainage canals). The major canals that control the drainage for Coral Springs are the Cypress Creek (C-14) Canal to the south and the



TOTAL MONTHLY AND MONTHLY NORMAL PRECIPITATION. POMPANO BEACH STATION

FIGURE 2

CDM

Hillsboro Canal to the north which drains the area north of Wiles Road. Although the canal system's major function is drainage and flood control, it also influences groundwater levels and acts as a source of recharge to areas of depressed groundwater levels. This is usually the case when canals are in the cone of influence of a well field.

Regional Geology

The geology of south Florida consists of approximately 16,000 vertical feet of sedimentary rocks ranging in age from Holocene (recent) to Cretaceous (125 million years in age). Underlying the sedimentary rock unit is a complex sequence of much older rocks which make up the base for the Florida Peninsula. Since the geology occurring within 4,000 feet just below land surface is the unit of primary interest to the people in southeast Florida, this report briefly describes that geologic section.

Generally, the first 300 feet consists of a series of formations composed of limestone, sandstone, sand, and clay. The formations include the Key Largo limestone, the Miami oolite, the Fort Thompson formation, the Pamlico sand and the Anastasia formation. These formations comprise the Biscayne aquifer, which serves as the sole source of drinking water for the people of southeast Florida.

Underlying the Biscayne aquifer is the Hawthorn formation which consists of clay, marl, limestone and cherts from approximate depths of 300 feet to 950 feet. The major significance of this unit is that it is the confining bed which separates the Biscayne aquifer from the deeper Floridan aquifer.

The Floridan aquifer is made up of several geologic units, the most prominent being the Ocala Group, the Avon Park limestone and the Lake City limestone. The aquifer extends to a depth of approximately 2,300 feet. Underlying the Lake City limestone is the Oldsmar formation which consists of two units, the upper Oldsmar (2,300 to 2,800 feet) and the lower Oldsmar (from 2,800 to 4,000 feet). The upper Oldsmar formation is a confining unit which separates the Floridan aquifer and the lower Oldsmar formation. The lower Oldsmar unit is commonly called the Boulder Zone, which is highly transmissive, contains nonpotable water, and has been used for the disposal of waste products such as industrial by-products and treated wastewater.

Local Geology

The upper 300 feet of material consists of a complex series of limestone, sandstone, sand, shell and marl material. These units comprise the Biscayne aquifer in the area of Coral Springs. The units are inconsistent with interlacing facies changes, making delineation of these units impractical. Most units are unconsolidated or semi-consolidated. The semi-consolidated rock is highly porous and contains numerous sand-filled solutional cavities.

The upper unit is extremely porous, and in most places, close to and sometimes at the surface. It may be as much as 20 feet thick. Underlying the first unit is usually a unit of fine to medium grained quartz sand existing from approximately 20 to 60 feet. Beneath the sand unit is the production zone of the Biscayne aquifer which consists of medium to fine grained sandstone. The unit varies in rock-like nature from good to poor, with solution cavities generally filled with a fine sand. This zone varies from 80 to 100 feet in thickness.

The last unit of concern is the clay unit called the Hawthorn formation. This unit is at the base of the Biscayne aquifer. A generalized lithology of the local geology is shown in Figure 3.

Groundwater

Groundwater from the Biscayne aquifer is the sole source of drinking water for the City of Coral Springs. The Biscayne aquifer is wedge shaped, ranging from approximately ten feet thick at the western county boundary and dipping eastward to the thickest section of approximately 250 to 300 feet at the coast. The increased thickness to the east accounts for the generally higher transmissivity and productivity of wells drilled in this

FIGURE 3

GENERAL LITHOLOGY AT CORAL SPRINGS

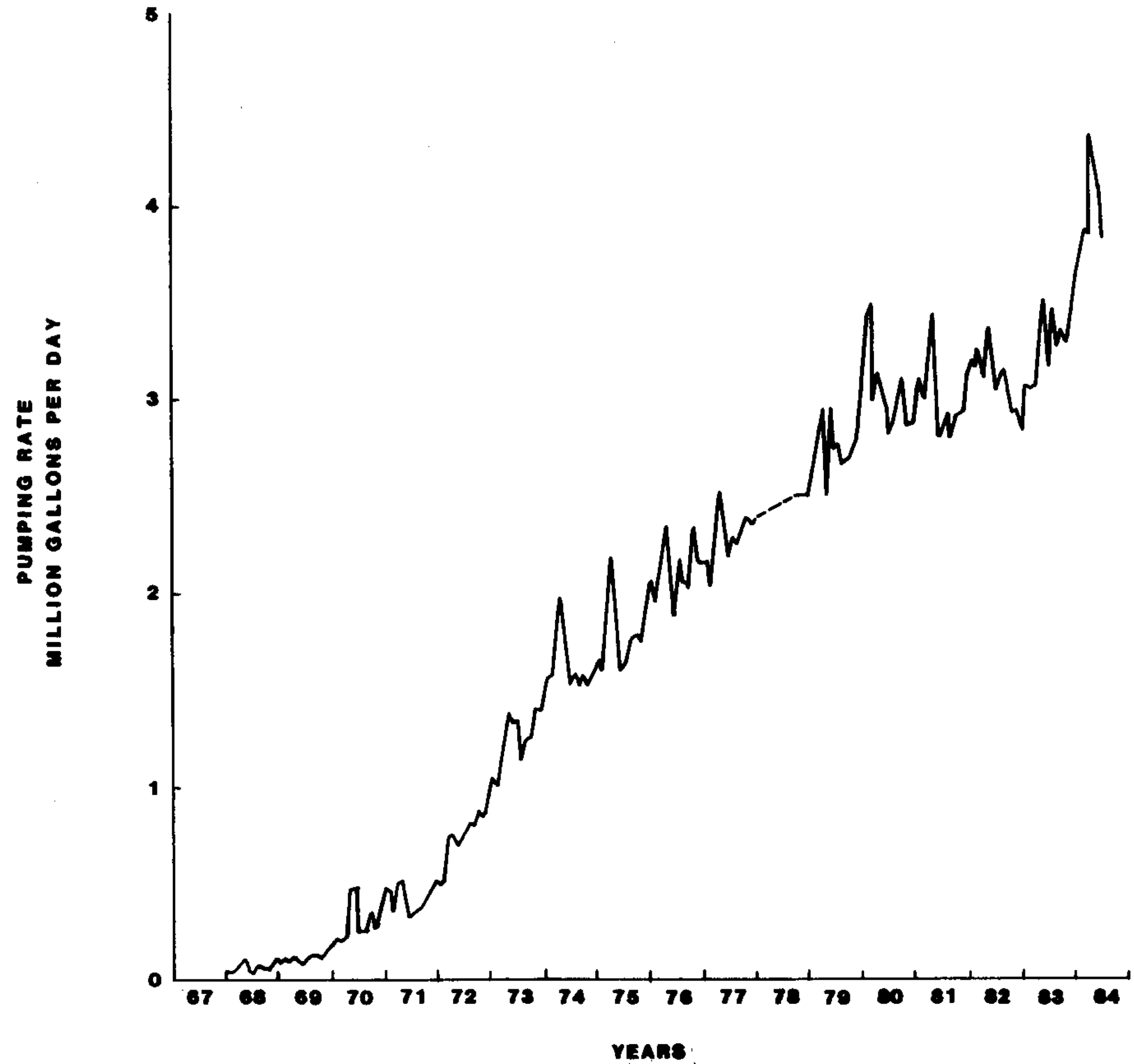
Feet Below Land Surface	
0-10	Sand and limestone - light grey, fine grained, quartz; with shell fragments.
10-35	Sand and limestone - brown, fine grained, quartz; with shell fragments.
35-50	Sand - brown, fine grained, quartz; with shell fragments, limestone and clay units.
50-70	Sand - light grey, fine grained, quartz; with limestone and shell fragments, hard and soft lenses.
70-100	Sand and sandstone - grey, fine grained, quartz; with limestone, cemented sands, shell fragments and fine shell inter-bedded sands and sandstone.
100-150	Sand and sandstone - grey, fine grained, quartz; with limestone, cemented sand and shell fragments, inter-bedded sand and sandstones.
150-180	Sand and sandstone - grey, fine grained, quartz; with limestone and shell fragments, inter-bedded sand and sandstones.
180-200	Sandstone shell and green clay - no grain size available; the clay would indicate transition zone toward the base of the aquifer.

section of the aquifer. Regional trends of the Biscayne aquifer show that both water quality and groundwater productivity decrease in the westward and northward directions.

Water quality usually deteriorates with depth. Connate water, which has high chloride concentrations, exists in isolated areas within the aquifer. The existance of connate water usually indicates restricted movement of groundwater through the aquifer due to an area of low permeability. In certain areas, the water is high in total hardness, iron and total dissolved solids concentrations. Water in certain areas may also be high in concentrations of chloride, hydrogen sulfide and have poor color quality. These parameters are the most objectionable naturally occurring constituents found in groundwater from this aquifer.

The portion of the Biscayne aquifer underlying Coral Springs is characterized by lower transmissivities and poorer groundwater quality than some other areas of the aquifer. The westward position of the City, however, reduces the threat of saltwater intrusion to the well field from lateral migration from the ocean. Although groundwater quality in Coral Springs is higher in total hardness, iron, color, chloride and hydrogen sulfide concentrations than other areas of the aquifer, they are not above drinking water standards.

Groundwater quality has remained stable, but groundwater levels have shown a steady decline in the Coral Springs area throughout the 1970's. Although this could be interpreted as reflecting an increase in groundwater pumpage, regional trends have shown similar declines. Therefore, increased groundwater pumping (Figure 4) from the City's well field is not the only influence. Regional increases in water use, increasing numbers of drainage programs, and lower than normal rainfall throughout the 1970's (Figure 2) all contribute to declining water levels.



MONTHLY RAW WATER PRODUCTION

FIGURE 4

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4. TESTING

Well Selection

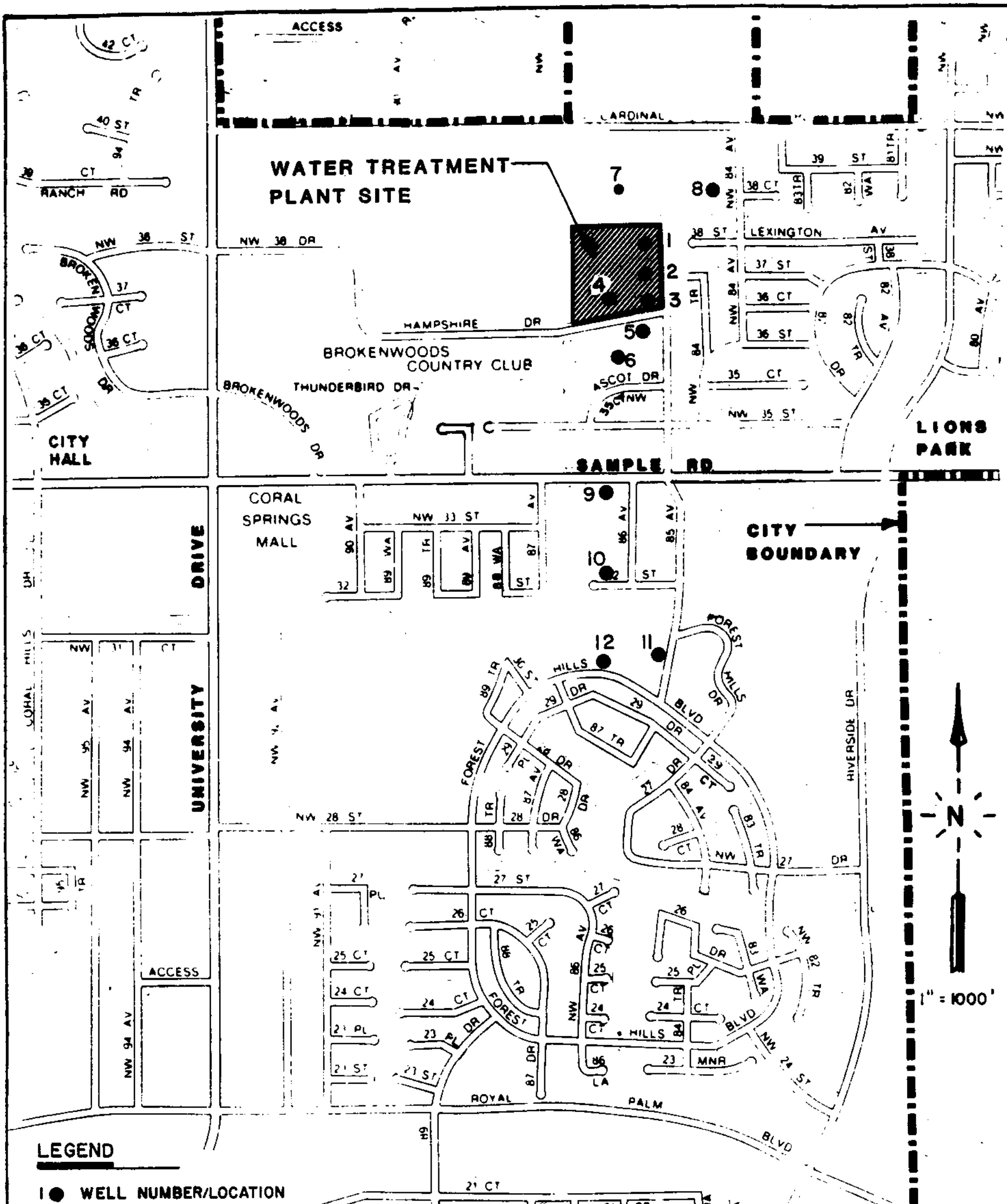
Wells 3, 8 and 10 were selected for field testing because of their particular location within the well field, their relative well construction and/or their history of problems. Figure 5 shows the location of production wells in Coral Springs.

Well 3 was constructed with design similar to Wells 1, 2 and 4 and is located near the center of the well field. Although Well 3 has not had a history of problems, its central location made it preferable for testing to the other three wells. Well 8 represents the second phase of well construction and is located in the northern extreme of the well field. The well also has had a history of problems, most prominently a continual decline in production rate and drawdown levels usually higher than those experienced in other wells. Well 10 represents the southern area of the well field, and a constructed method similar to Wells 9, 11 and 12. It produces sand of such volume that mechanical deterioration of the equipment is eminent. Appendix B contains a table of construction specifications for each well.

Testing of the three selected wells included a step drawdown test, a sand test and a test for specific capacity. A simple pump test was also performed on Well 8. A detailed methodology of the test procedures is included in Appendix C, Scientific Methods.

Step Drawdown Tests

Well 3 was pumped at 187 gpm, 280 gpm and 350 gpm (the maximum pumping rate). The measured drawdowns were 4.04 feet, 6.27 feet and 12.19 feet, respectively. Following the method of analysis outlined in Appendix C, the well appears to be unstable and that gravel pack stabilization is not finalized. This indicates that development at the time of construction was not adequate and that sand in the formation is still being shifted when



LOCATION OF PRODUCTION WELLS IN CORAL SPRINGS

FIGURE 5

CDM

significant changes in pumping rates occur. During testing, a hydrogen sulfide odor was also noticed and the possibility of algae in the well is supported by personal communication with the plant operator.

Well 8 was pumped at 95 gpm, 200 gpm, and 280 gpm (maximum pumping rate) with the drawdowns measured at 2.07 feet, 7.20 feet, and 11.62 feet, respectively. Analysis of the data indicates that the well is still developing. The data also indicates higher drawdown values than obtained in other wells with similar production rates.

Well 10 was pumped at 250 gpm, 500 gpm, and 720 gpm with the drawdowns being 5.16 feet, 12.52 feet, and 20.39 feet respectively. The analysis indicates that substantial development of the well is occurring during pumping.

Sand Tests

The methodology and equipment used in the sand test is also described in Appendix C. The results of the sand test, which was performed on Wells 3, 8 and 10, are listed in Table 1. The American Water Works Association standards suggest that wells should produce less than 5 milligrams per liter (mg/l) sand. As can be seen in the table, only Well 8 meets this standard.

The sand produced by Well 3 during pumping is an indication of two possible problems. Either the gravel pack and well screen were not properly selected to retain the sand and/or the well was not completely developed after construction.

The low amount of sand produced during pumping Well 8 may be attributed to the low pumping rate. If the pumping rate for Well 8 was increased, the amount of sand per liter of water may also increase. Review of the data indicates that the well screen is probably clogging, and significant increases in pumping rates cannot be obtained.

TABLE 1

RESULTS OF SAND TEST PERFORMED
ON WELLS 3, 8 AND 10

Well Number	Pumping Rate gpm	Sand Concentration mg/l
3	530	31
8	230	3.57
10	500	71
	800	527

Well 10 has produced large quantities of sand since it was rehabilitated in 1983. The process included injecting hydrochloric acid into the well and developing the well using compressed air. The reason for this excessive sand is probably twofold:

- o The well was not completely developed when originally constructed.

- o The gravel pack has dropped below the upper portions of the well screen, resulting in a void and allowing sand to freely enter the well.

Pump Tests

Regional aquifer performance tests evaluated by the United States Geological Survey (USGS) and others have resulted in estimates of transmissivity values ranging from about 350,000 gallons per day per foot (gpd/ft) to 150,000 gpd/ft. In order to predict well interference and estimate future well spacing, a better estimate of transmissivity was desired. Although final well field design will require site specific testing, a simplified pump test for comparison with regional transmissivity estimates was conducted. After the step drawdown test on Well 8, a 30 minute pump test was conducted using Well 8 as the production well and Well 7 as an observation well. The pumping rate was 280 gpm with the observation well 720 feet away. The field data is presented in Appendix D.

A computational assessment was made by using two simplified straight line techniques. Since the test and evaluations were conducted under simplified conditions, the values should only be used as generalities. The resulting transmissivity values were 211,000 and 171,000 gpd/ft. These values are at the lower end of the estimated regional range, but they are considered reasonable and conservative values for initial planning purposes. Using these values, a distance drawdown graph (Figure 6) was developed to estimate the interference between wells. Since well interference results in head losses, requiring greater energy to pump water, a maximum interference limit of only two feet would be perferred. At a rate of 500 gpm per production well, a well would create a one foot drawdown at 370 feet.

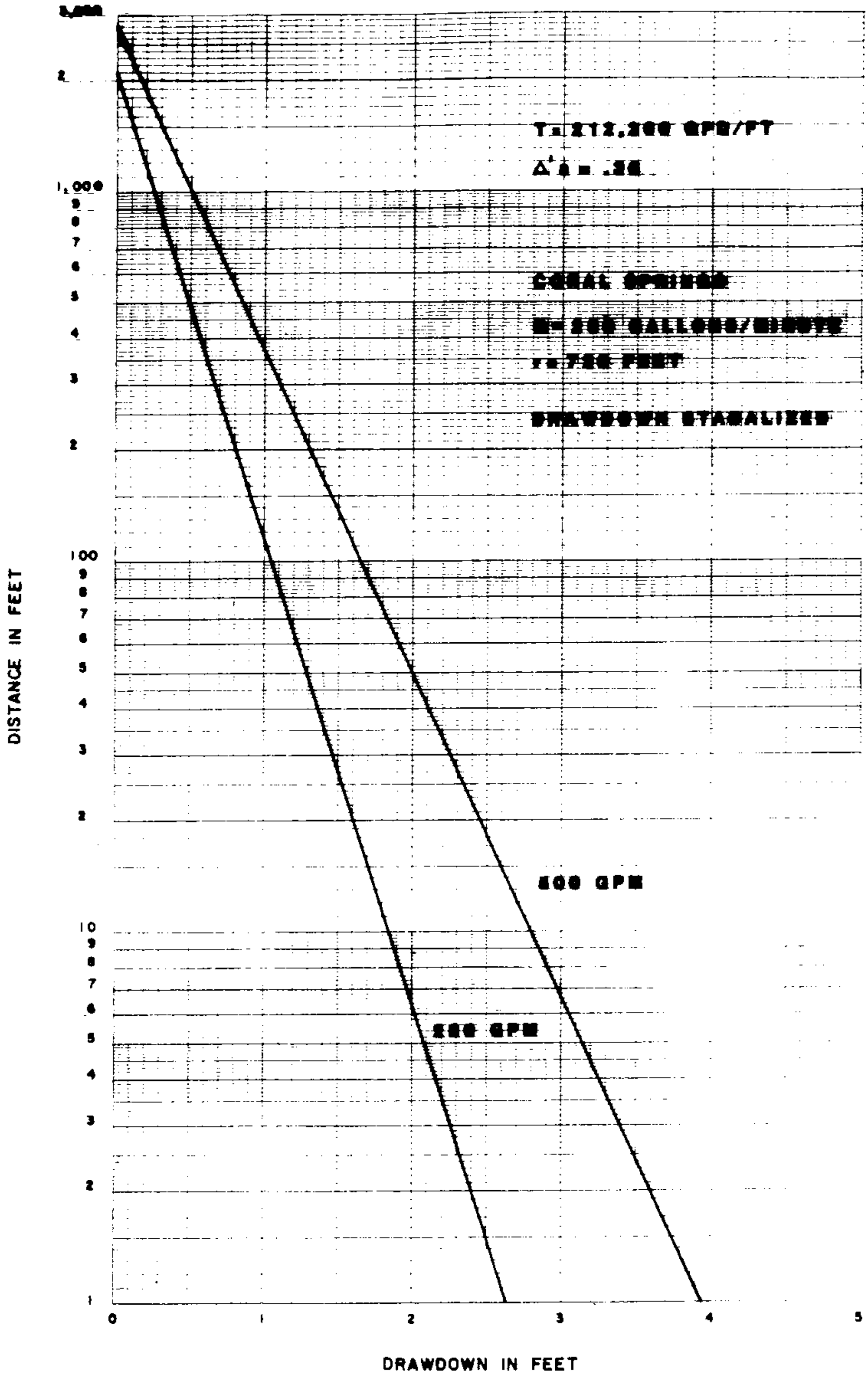


FIGURE 6 DISTANCE DRAWDOWN GRAPH

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Drawdowns are additive and therefore a well inside the cone of influence of many wells results in multiple well interference. Therefore, to plan well spacing, it is suggested to more than double the distance as a minimum, or attempt 1,000 foot spacing between wells to reduce well interference. Verification of these estimates should be made during the well field site testing and design phases of the City's expansion program.

Specific Capacity Tests

At the request of CDM, specific capacity tests were conducted on each well by the City's utility personnel in September 1984. The procedure requires determining the drawdown from static level to pumping equilibrium, and knowing the pumping rate during that time span. Specific capacity is measured in gallons per minute pumped per foot of drawdown and is used to correlate well efficiency. The higher the specific capacity, the more efficient the well, as long as all other factors are equal. Table 2 presents the results of the September 1984 tests.

TABLE 2

SPECIFIC CAPACITY OF WELLS

Well Number	Initial Pump Rate gpm	Installed Specific Capacity gpm/ft	Current Pump Rate gpm	Current Specific Capcity gpm/ft
1	670	51.54	330	13.33
2	650	40.63	370	139.58*
3	550	52.38	410	32.16
4	720	60.00	360	34.82
5	760	118.00	390	NR*
6	760	111.43	380	NR*
7	735	56.9	510	29.13
8	550	57.33	275	23.40
9	700	32.35	520	48.52
10	700	60.83	400	47.06
11	450	32.14	375	26.15
12	700	38.00	500	26.80

*NR = Not Reliable. Readings are questionable. Well 2 shows large increase in specific capacity. Wells 5 and 6 actually showed increase in water level, possibly due to water falling on top of probe.

5. ANALYSIS OF THE EXISTING WELL FIELD

Analysis of the existing well field and its history, assist in the design of the City's new well field. The City's utilities and engineering employees have maintained files on each production well and the data was used in a historical analysis of the wells. Included in Appendix E is a chronological history of each well. The following is a status summary of each well.

Well 1

Well 1 was designed and constructed in 1967 as an open hole well, although the geologic conditions did not support this type of construction (telephone conversation with Mr. Tiley of Morton Pump and Supply, August 1984). The well was modified to incorporate a telescoping well screen and a lead packer with no gravel pack. Presently, the major problems with this well are caused by well interference due to the close proximity of nearby wells. The pump was changed in 1979 to overcome back pressure in the transmission lines due to the addition of wells. The well's pumping rate has varied significantly but has been stable since 1979.

Well 2

Well 2 was constructed in 1967 in a similar manner as Well 1. The difference is that a gravel pack was installed between the well screen and the borehole. Both Wells 1 and 2 have 10 inch casings. Problems experienced by this well are the same as those for Well 1. The well pumping rate is higher than in the past but below early production rates following the September 1983 rehabilitation.

Well 3

Well 3 was installed in 1973. It was designed with a screen and gravel pack to prevent sand from entering the well. This well experiences interference due to its close proximity to Wells 2 and 4. The step drawdown test analysis conducted by CDM concluded that the well is still developing, and that the gravel pack is unstable. The well is constructed such that replenishment of the gravel pack is not feasible. Although the well presently pumps more than in 1980 when the pump was replaced, the well has been decreasing in capacity over the past two years, even with an additional pump replacement in 1983.

Well 4

Well 4 was constructed in 1973 with a screen and gravel pack to prevent sand from entering the well during pumping. Replenishment of the gravel pack, however, is not feasible. Well interference is caused by the close proximity of this well to Wells 2, 3, 5 and 6. Wells 3 and 4 both have 12 inch casings. Well 4, like Well 3, is declining in production rate.

Well 5

Well 5 was constructed in late 1973 with well screens, casing blanks, and a gravel pack designed to prevent sand production during pumping. There appears to be minor pumping interference problems in this well. However, the historical specific capacity reached 167 gallons per minute per foot of drawdown (gpm/ft), the highest of the entire well field. As with previous wells, this well cannot have the gravel pack replenished. Well 5, like all the following wells, has 16 inch casings. Its pumping rate has stabilized over the past eight years, but at a lower rate than when first constructed.

Well 6

Well 6 was constructed in late 1973 with screens and casing blanks, and included a gravel pack. The well does not allow for replenishment of the gravel pack. Although well interference also occurs in Well 6, the historical specific capacity reached 118 gpm/ft of drawdown which is the second highest in the well field. The production rate for Well 6 has continually declined but now appears to be stable.

Well 7

Well 7 was constructed in late 1973 with screens and casing blanks, and included a gravel pack. However, the well construction does not allow for replenishment of the gravel pack. This well is located at the north end of the well field, and has a lower specific capacity than wells to the south. The well experienced declining pumping rates until April 1983, at which time pumping rates were increased by installing a new pump and now appears to be stable.

Well 8

Well 8 was designed to be screened and gravel packed to prevent sand production during pumping. The well construction does not allow for replenishment of the gravel pack. Well 8 has had problems from the time it was constructed in 1974. When the original well was drilled, the well collapsed during well development. The present well was reconstructed 15 feet to the east, and may have been constructed in disturbed strata from the collapsing of the abandoned hole. The step drawdown test indicates the well is clogging and its specific capacity is decreasing. The rapid decline in production rates from 600 gpm to 150 gpm over a six year period supports this theory. The well is back in use after rehabilitation and new pump installation in September 1983, at a production rate of approximately 275 gpm.

Well 9

Well 9 was constructed in 1979 with a screen and gravel pack. The historic data indicate the well was developing from the time it was put in service in 1981 to 1983. Initial valve adjustment resulted in a pumping rate of over 700 gpm in 1983. The valve was later readjusted for a pumping rate of less than 500 gpm. Wells 9, 10, 11 and 12 were all drilled by the mud rotary method. The well's construction restricts gravel pack replenishment possibilities.

Well 10

Well 10 was also constructed in 1979 with a well screen and gravel pack, but again no provision was included to replenish the gravel pack. The specific capacity increase from the time it was placed in service in 1981 to 1982 indicates the well was developing during this time and that the decrease in pumping rate in 1982 may have resulted in clogging of the gravel pack. The data also indicate that the well has not yet sufficiently developed. The step drawdown test indicates that the rehabilitation effort in September 1983 to increase the specific capacity of this well was effective only for a short time. The amount of sand collected from the well during the sand test was 527 milligrams per liter (mg/l) at 800 gpm. It is theorized that the gravel pack does not exist in the top portion of the well screen, and therefore, the well will either produce sand indefinitely or the well screen will eventually clog. Like Wells 9, 11, and 12, production rates have been reduced from the original pumping rate (Table 2).

Well 11

Well 11 was also constructed in 1979 with a well screen and gravel pack and placed in service in 1981. Likewise, well construction will not allow the gravel pack to be replenished. The improved pumping rates from 1981 to 1982 indicate the well was being developed during this period of time. The decrease in the pumping rate in 1982 reduced groundwater velocity and the gravel pack probably clogged with sand. The clogging of the gravel pack caused water to enter the well screen in selected areas, exceeding the critical entrance velocity of 0.10 feet per second. The water quality is such that this velocity results in calcium carbonate incrustation on the well screen, as seen in the television surveys taken in 1983. Rehabilitation efforts followed in August 1983. Clogging of the gravel pack and well screen may explain why the calcium carbonate was deposited in selected areas of the well screen. The production rate is stable, but reduced from the original uncontrolled pumping rate of 450 gpm.

Well 12

Well 12 was constructed in 1979, and placed in service in 1981 with a well screen and gravel pack to prevent sand from entering the well. However, the design does not allow for the replenishment of the gravel pack. The well showed improvement in specific capacity between 1981 and 1982 and therefore suggests well development had occurred during this period. The specific capacity has decreased from March 1983 to June 1984 by 8 gpm/ft of drawdown and the well may be clogging. The production rate has been decreased to approximately 500 gpm.

Summary

Although all of the wells are functional, Wells 1, 2, 3, 8, 9, 10, 11, and 12 have problems that affect their operation. Wells 4, 5, 6, and 7 appear to have decreased pumping rates since other wells were put into operation. Most wells have serious problems concerning replenishment of the gravel pack, which cannot be easily corrected. The major well field problems are as follows:

- Wells 1 through 7 are spaced too close together, causing well interference.
- Wells 1 through 8 were not constructed to allow replenishment of the gravel pack. Therefore, further rehabilitative measures could cause early well failure and/or extensive sand production.
- Wells 9 through 12 may be rehabilitated if the gravel pack can be feasibly replenished. However, the methodology for gravel pack replenishment will be costly. A cost analysis of this work should be addressed when the future well field is evaluated.

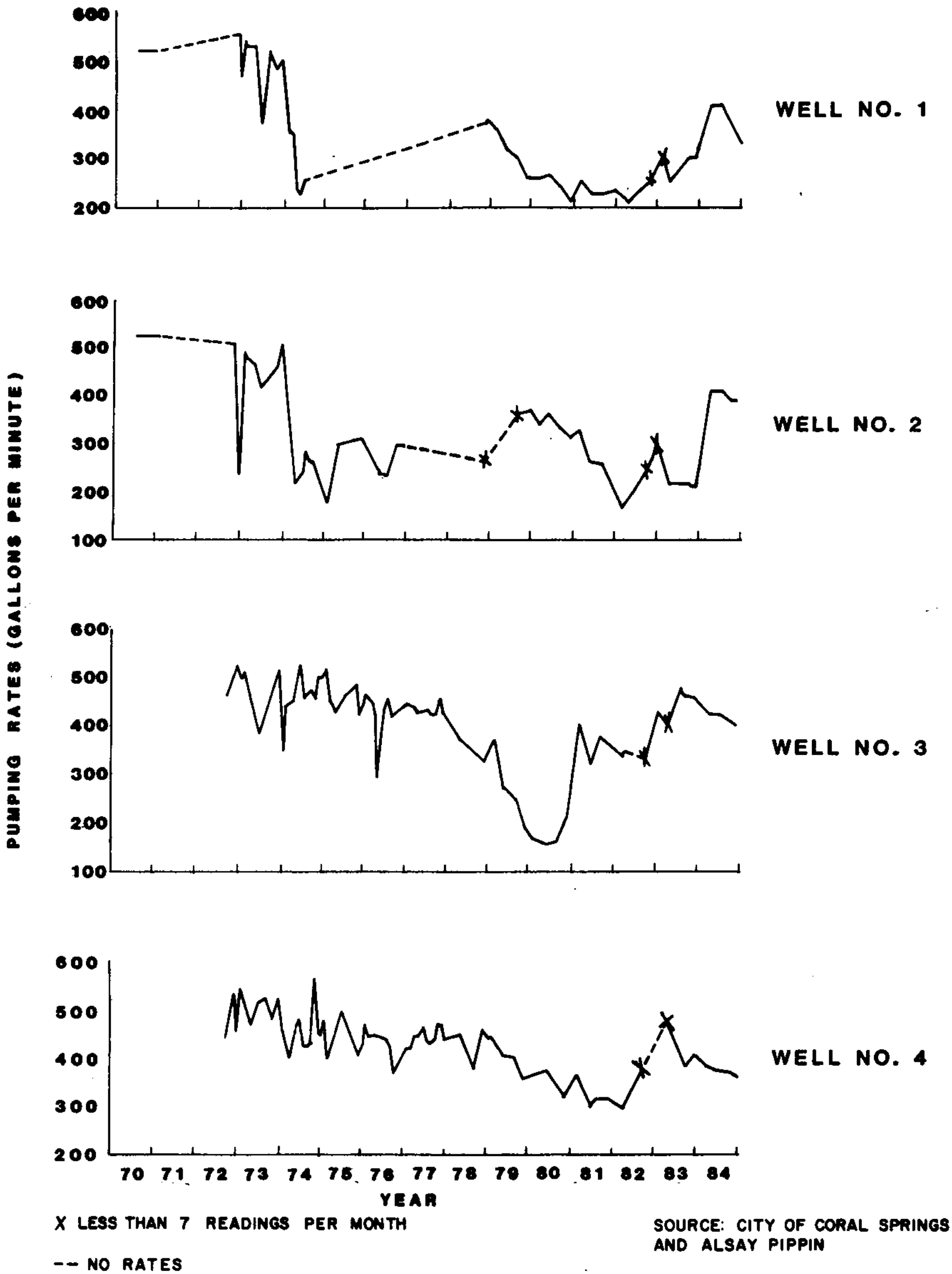
6. FUTURE WATER SUPPLY

Water Needs

By authority of Chapter 373 of the Florida Statutes, the SFWMD has issued the City of Coral Springs a Water Use Permit which is valid until March 10, 1987. The permit grants an average daily allocation of groundwater to the City of 6.58 million gallons (MG) with the maximum single day volume not to exceed 10.52 MG.

In the 1984 Master Plan Update developed by CDM, the projected water demands will be 16.75 MGD in the year 2005. This latest estimate takes into account available data including the fact that from December 1983 to May 1984, record high average daily demands were established. In the present Water Use Permit, the SFWMD projected the maximum per capita use to reach 140 gallons per capita per day (gpcd). Based on this gpcd figure, SFWMD issued the Water Use Permit allocating an average daily use of 6.58 MG and a yearly maximum of 2.4 billion gallons (BG). Under present projections, the present Water Use Permit allocates sufficient water through its expiration date. When present water use trends are forecast into the future, water use demands will meet the permit allocation near the year 1990.

The original well production rate was anticipated to be 550 gpm per well. However, production from the existing 12 wells has historically declined (Figure 7) and actual well field production is below the original design capacity of 6000 gpm (8.6 MGD). The maximum pumping rates were measured in each well in September 1984. The total pumping capacity is 4820 gpm (Table 3). Although some wells may be able to produce high volumes of water, the well design limits long term use of these wells at high pumping rates due to carbonate encrustation of well screens, sand production, and well interference. All wells have reducing mechanisms to maintain pumping rates at reduced limits. Therefore, increased well field production must be obtained by the installation of new wells.

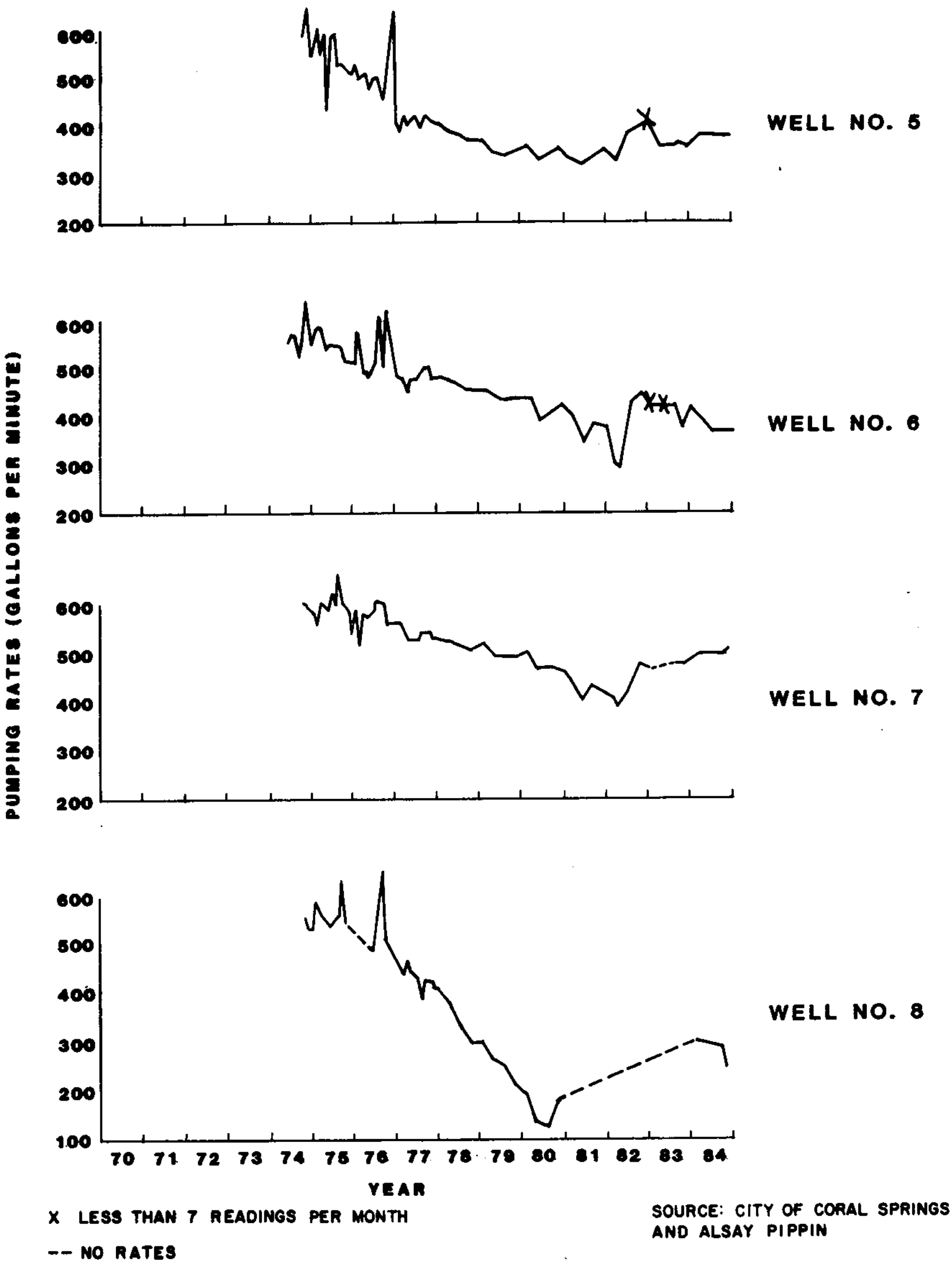


SOURCE: CITY OF CORAL SPRINGS AND ALSAY PIPPIN

HISTORICAL PUMPING RATES OF THE CORAL SPRINGS WELL FIELD

FIGURE 7

CDM



SOURCE: CITY OF CORAL SPRINGS AND ALSAY PIPPIN

FIGURE 7 (CONTINUED)

CDM

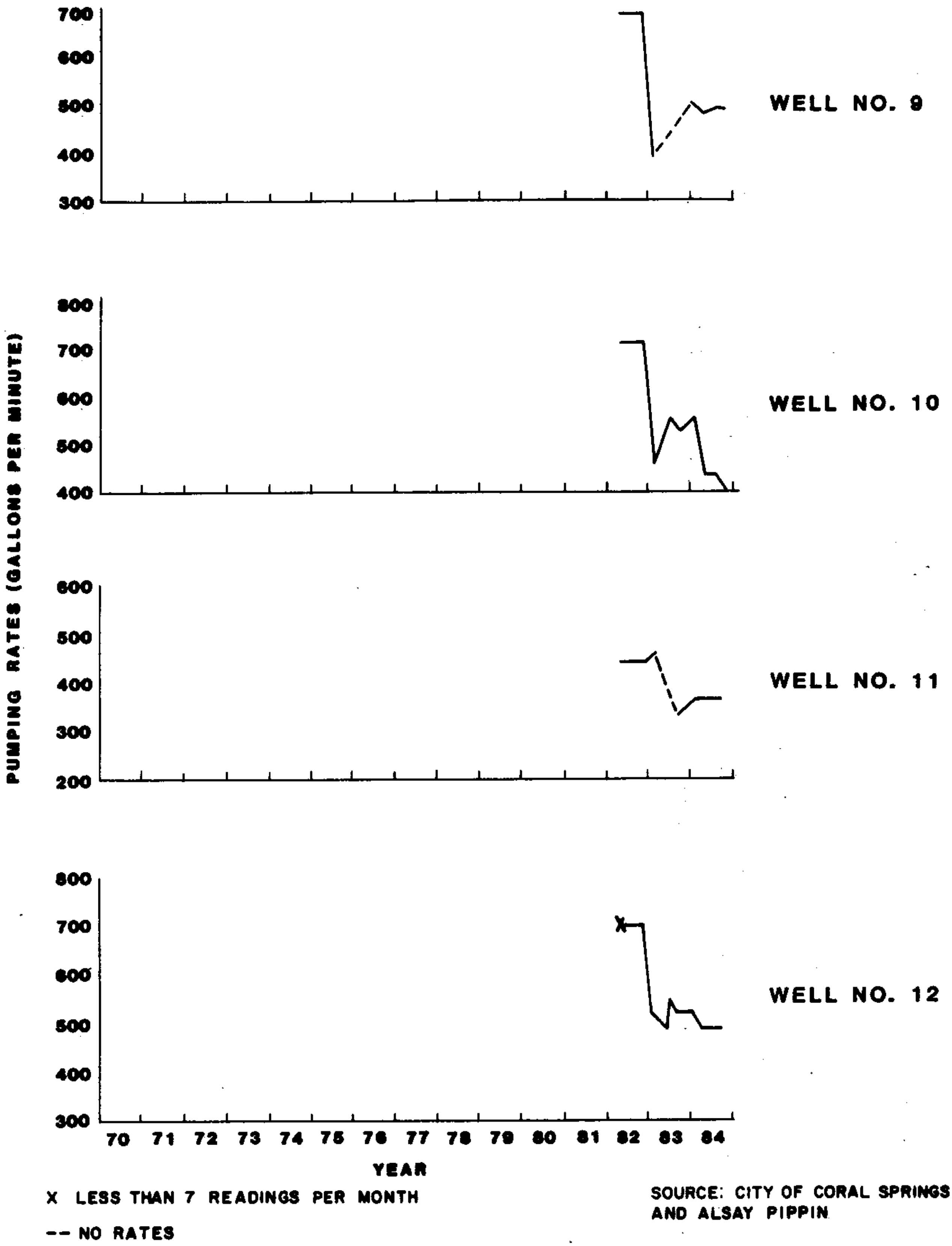


FIGURE 7 (CONTINUED)

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TABLE 3

EXISTING WELL CAPACITY

Well No.	Design Capacity[1] gpm	Actual Production[2] gpm
1	450	330
2[3]	450	370
3[4]	450	410
4[4]	450	360
5	550	390
6	550	380
7[4]	550	510
8[3][4]	550	275
9[3]	550	520
10[3]	550	400
11[3]	350	375
12	550	500
TOTAL	6,000	4,820

(1) Coral Springs Water and Wastewater Systems--Annual Review and Report, 1982.

(2) Based on City Quarterly Check List Records for August 1984.

(3) Wells rehabilitated in Fiscal Year 1983-84 based upon data provided by City.

(4) Pumps replaced.

In order to have standby capability and reduce well interference, usually eight wells are used at a time. By averaging the present pumping rates of the twelve wells and multiplying by eight, we obtain an average production rate for eight wells of 3213 gpm. The record pumping rate set in May 1984 of 3569 gpm is 111 percent (%) of this average capability. Therefore, present demand exceeds the preferred scheduling of the well field, and standby capabilities must be abandoned in order to meet present demands. The demand was 74 percent of the present well field's total production capacity of 4820 gpm for a 24 hour period.

The well field's present capacity is 6.93 MGD (4,820 gpm). Factoring the well field capacity by plant losses (4%) and emergency standby (20%), the maximum production from the well field in any one day should be only 4.14 MG. The existing safe well field capacity therefore is 4.14 MGD, which is .99 MGD below the record demand in early 1984 of 5.13 MGD. Using CDM's recent projection for maximum day pumpage, the well field must be capable of producing 8.84 mgd in 1985. This is 1.9 MGD more than the present capacity of 6.93 MGD. Table 4 shows the tabulation of these values through the year 2005. An increase in well field capacity is therefore an immediate need if the well field is to have the capability to produce sufficient water and still have standby capacity.

Water Quality

The water quality factor which may affect the future of the Coral Springs well field is saltwater intrusion since all coastal communities in Florida are subject to migration of saline water, both vertically and horizontally. As water demand increases and groundwater levels decline, the horizontal movement of saline water advances by replacing the fresh water. In Broward County, the horizontal saltwater wedge is approximately 8 miles to the east and poses no threat to the City of Coral Springs water supply in the foreseeable future. This assumption is based on water supplies to the east of Coral Springs remaining status quo. However, major water development to the east may increase the potential for horizontal saltwater migration. This would be caused by major withdrawal of fresh water, which would be

TABLE 4

WELL FIELD REQUIREMENTS THROUGH
THE YEAR 2005 (in MGD)

	1985	1990	1995	2000	2005
Raw Water	7.09	9.66	11.42	12.83	13.42
4% Plant Losses	0.28	0.38	0.46	0.51	0.54
20% Standby Factor	1.47	2.01	2.38	2.67	2.79
Total Well Field Requirement	8.84	12.05	14.26	16.01	16.75

replaced by advancing saltwater from the ocean. Vertical saltwater movement from deep zones is essentially prevented by the extensive confining bed beneath the Biscayne aquifer as described earlier, and therefore significant natural degradation of water quality in the City's well field is unlikely.

Review of the City's water quality history indicates that chloride levels (indicator of saline waters) are far below any level of concern. The standard for drinking water is 250 mg/l and no trend toward increasing chlorides is noted in the data. Another parameter tested by the City is hardness. Figure 8 shows water quality trends for these parameters, and as can be seen, no change has occurred over the past years. Therefore, water quality changes are not expected and present treatment processes should not have to be changed as a result of the City's well field expansion.

Predictive Groundwater Model

In order to evaluate the groundwater impacts by the City's well field, a groundwater computer simulation model was developed. A digital simulation model can predict the effects on groundwater levels due to seasonal variations in pumping, local canal levels, and climatic conditions. Water level changes predicted by the model can be used to analyze potential well field impacts. The model can also be used to determine the best well field design by analyzing the impacts of several different well field locations and layouts.

This modeling approach was chosen over ordinary analytical methods because of its versatility. Ordinary analytical methods cannot incorporate many of the hydrogeologic complexities such as canal recharge, pumping variations, evapotranspiration, and well location. In the City's well field area, some of these hydrogeologic complexities have a significant impact on the groundwater system.

The computer model used in the groundwater impact analysis is a modification of a computer model developed by T. Prickett and C. Lonnquist in 1971. The model uses advanced mathematical techniques to solve the partial

GROUNDWATER QUALITY TRENDS FOR HARDNESS AND CHLORIDE CONCENTRATIONS

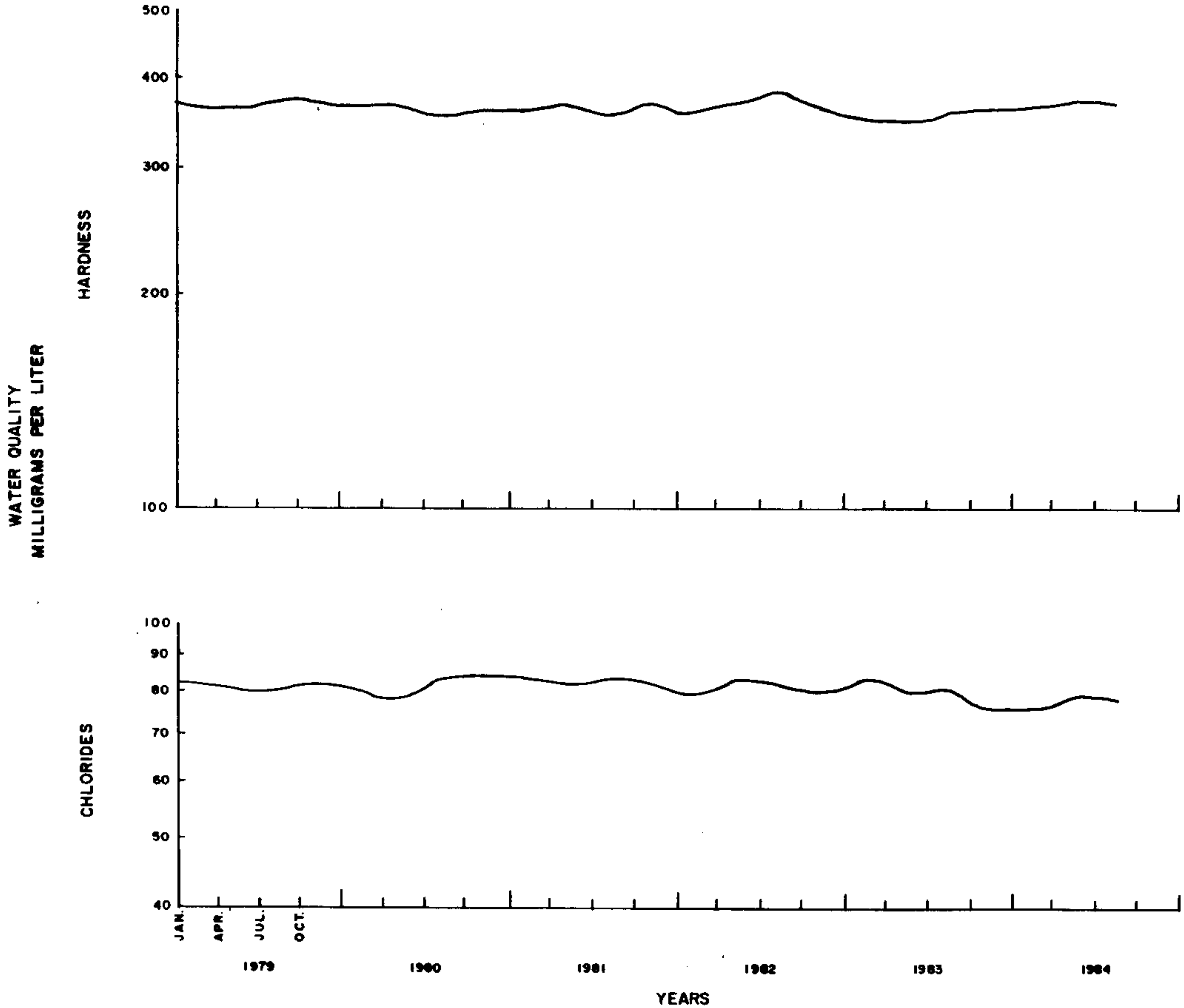


FIGURE 8

CDM

differential equation that describes transient, two-dimensional groundwater flow through a nonuniform aquifer. This approach involves replacing the continuous aquifer system parameters with an equivalent set of discrete values, and solving a large set of simultaneous equations. The solution technique is flexible enough to incorporate variations of transmissivity, storage coefficient, pumpage, rainfall recharge, evapotranspiration and canal leakage.

Model Setup

The computer model provides the mechanism for calculating aquifer water levels resulting from chosen well and well field pumping schemes. Regional impacts, well field cones of depression, and interference between wells are provided by analysis of the model results. Once water levels are produced, aquifer flow rates and canal seepage rates may also be calculated.

Many sources of existing data were investigated during this study in order to determine representative values for the parameters used in the model. These sources included USGS reports, other consulting firm reports, as well as CDM reports for studies involving the Biscayne aquifer. In addition, a simplified aquifer performance test was performed using Well 7 as an observation well to verify the applicability of some of the parameter values found in the literature. Based on the literature search and the aquifer performance test, the following values were selected to represent the Biscayne aquifer system in the Coral Springs well field area:

Transimissivity = 200,000 gpd/ft
Storage Coefficient = .004
Canal Recharge Factor = 1.0×10^8 gpd/sq.mile/ft
Rainfall Recharge Percentage = 50
Land Surface Elevation = 12 feet msl
Depth to Zero Evapotranspiration = 11.5 feet

These values are preliminary and development of future well fields should include hydrogeologic testing to refine the values. This will allow greater accuracy in predicting the best well field location and configuration.

Areas of Water Development

The Biscayne aquifer does not have an overlying confining bed, and consequently, surface water bodies act as sources of direct recharge to the aquifer. The drainage system throughout Coral Springs concentrates stormwater runoff, increasing recharge through the canal system. If the well field is located near a canal, the well field cone of influence can be reduced and well production increased due to recharge through the canal bottoms.

Geological constraints are also considered in well site location. The aquifer thickens and becomes less complex eastward. The increase in aquifer thickness provides greater storage and therefore increases the probability of successful long-term water production. However, wells constructed to the east increase the probability that saline water will either be encountered, or rates of intrusion will be increased due to the pumping. The existence of a major landfill, other potential contaminant sources, and future water supply conflicts also need to be considered before additional well fields are selected.

Development of a water supply to the distant west may be considered since little conflicting development can proceed in that direction due to limited land availability. However, the aquifer becomes thinner and more complex, and pumping rates will subsequently be reduced if moved far to the west. A well field location to the north will probably encounter more complex geology than one south of the existing well field and production rates have historically been higher to the south.

Well Field Site Selection

Selection of new well field sites is based on several factors including hydrogeologic parameters, transmission main costs, environmental and regulatory constraints, and operational costs. All of these factors are considered in the analysis of future well field sites for the City of Coral Springs.

Based on an analysis of the City's well field, and review of data, the best location for a new well field is to the south of the existing well field. In this vicinity, the geology of the aquifer becomes more consolidated and water quality predictably improves. Additionally, data obtained from the existing well field indicates that transmissivity increases to the south corresponding to the increasing thickness of the aquifer. However, other areas should be considered based on engineering factors, accessibility and the results of field tests for aquifer productivity.

The number of wells needed for the future was determined using water demand projections developed in CDM's Master Plan Update for Coral Springs, 1984 (Table 4). Assuming a pumping rate from future wells, based on the ability of the present wells near Forest Hills Boulevard, the number of wells needed through the year 2005 were projected. For planning purposes, 500 gpm was used but field testing may indicate higher pumping rates are possible. If higher pumping rates can be attained, the number of projected wells will be reduced accordingly. The projections also assume that the present well field will be converted to standby status. Variations in the present pumping rates and the phasing of new wells were considered in predicting future well requirements. Table 5 presents the phasing of additional wells based on the assumed production rate. This number may change depending on information gained during field testing in the proposed areas for well field expansion.

From Table 5, eight wells should be drilled in 1985 to meet demand and provide standby capacity. Of the eight, three would be considered new production wells while five would be replacement wells for five existing wells. The replaced wells would have emergency standby status. This procedure would continue as water demand increases until after the year 2005 when 20 production wells would exist with twelve standby wells.

Site selection for wells to meet the City's immediate needs was based on present transmission line access, site access and hydrogeologic constraints. Using the computer model developed for evaluating the well field, well spacings were evaluated at 500 and 1000 foot intervals. Wells

TABLE 5

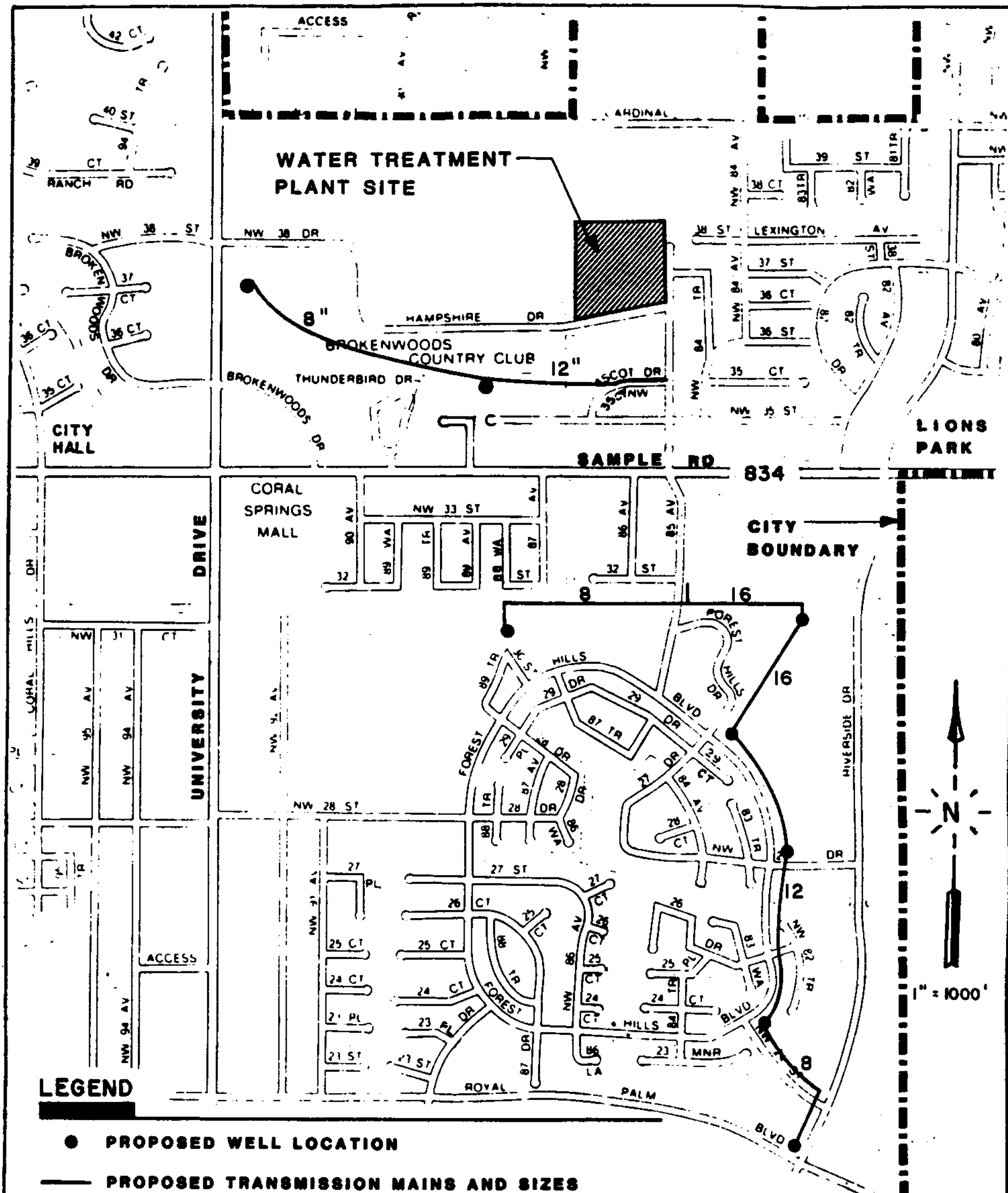
WELL CONSTRUCTION AND REPLACEMENT PHASES

By Year End	Number of Production Wells	Number of Standby Wells	Additional Wells[1]		Total Wells	Capacity In MGD	Old Well Replacement Schedule
			Replace Old Wells	New Production			
1984	12	0	--	--	12	6.93	--
1985	12	0	3	3	18	8.84	4, 8, 10
1990	15	3	3	4	25	12.05	1, 6, 3
1995	19	6	3	2	30	14.26	2, 5, 12
2000	21	9	3	2	35	16.01	7, 9, 11
2005	23	12	0	1	36	16.75	

[1] assuming 500 gpm

spaced at 500 foot intervals showed interference drawdowns of up to 8.7 feet as compared to 4.4 feet for 1000 foot spacings. Therefore, using 1000 foot well spacings wherever practical is recommended. Figure 9 shows the proposed well field sites to provide immediate water demands. Figure 10 shows the cone of influence developed by computer modeling to reflect pumping from the new well field, in conjunction with the existing well field. This assumes all wells are pumping except for those wells which are phased to standby status in order to predict worst possible effects. Although this cone of influence depicts all wells pumping, refinement of the effects should be undertaken when the future well field sites are tested. Long term consequences can then be predicted with the existing well field being phased out. Although immediate well field expansion is proposed to the south, consideration should be given to site testing on the Broken Woods Golf Course. The golf course's location adjacent to the treatment plant, transmission main accessibility and site easement possibilities could outweigh hydrogeologic considerations, whereupon possible lower production rates would be justified. The testing could be in conjunction with testing the preferred sites to the south.

Although specific sites for all future wells could be predicted for the year 2005, hydrogeologic testing should first be performed to verify areas for selected well field expansion. Figure 11 depicts the areas of proposed well field expansion. The areas are tentatively chosen based on hydrogeology and accessibility. Tentative transmission main corridors are shown. Computer modeling results, indicates that areas to the south of the treatment plant have less drawdown than areas to the north and east. This is due to the relationship between well locations, aquifer characteristics, and surface water locations. Specific locations of wells in these areas should not be determined until hydrogeologic testing is conducted to justify expansion of the well field into that area. Testing should include a borehole to determine geology to the base of the aquifer, and a pump test to determine aquifer characteristics. These tests should be performed in each of the proposed areas in order to better predict water production and rank areas for expansion priority.



LOCATION OF PROPOSED NEW WELLS

FIGURE 9

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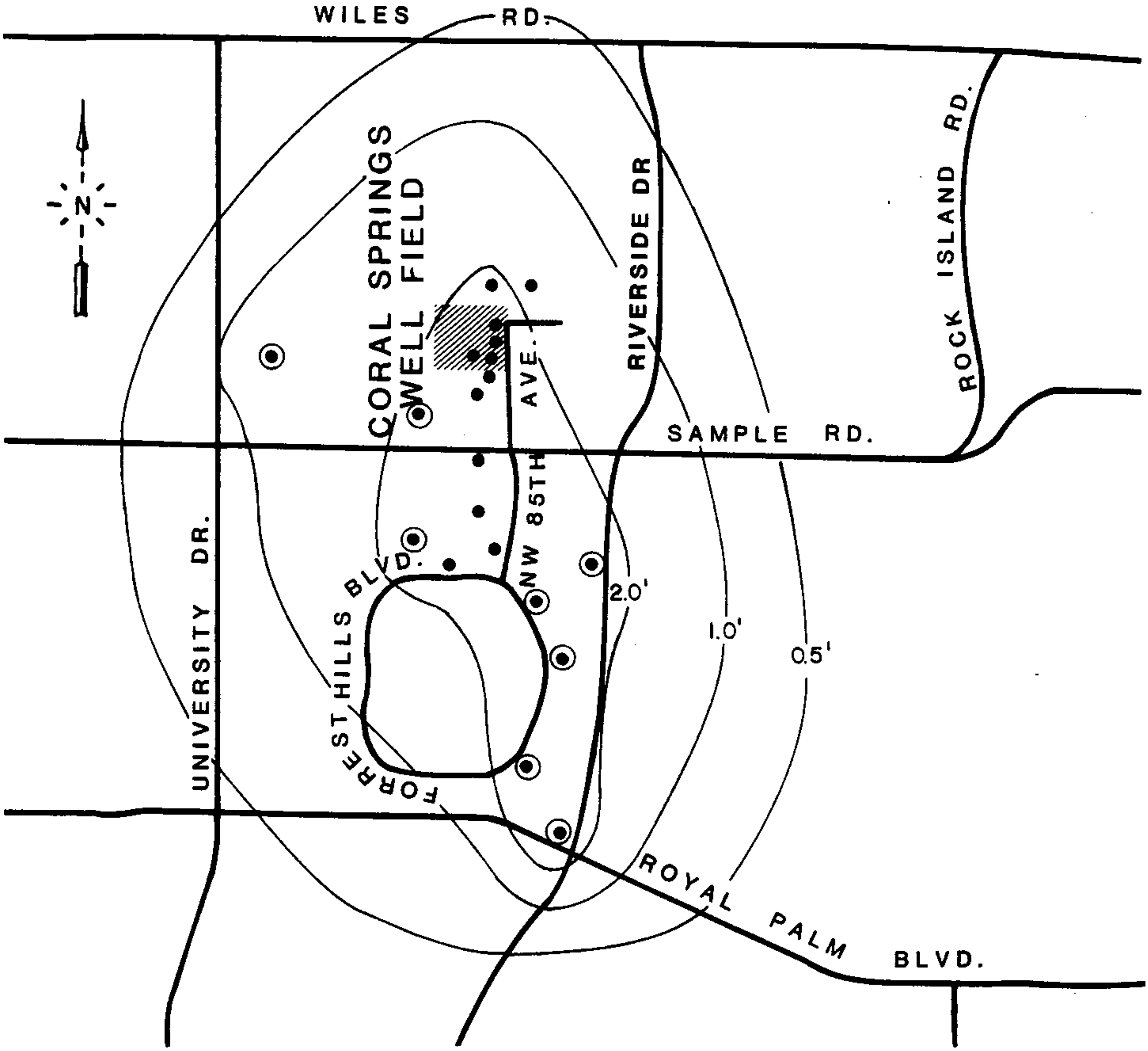


LEGEND:

WATER TREATMENT PLANT LOCATION

EXISTING WELLS

PROPOSED WELLS

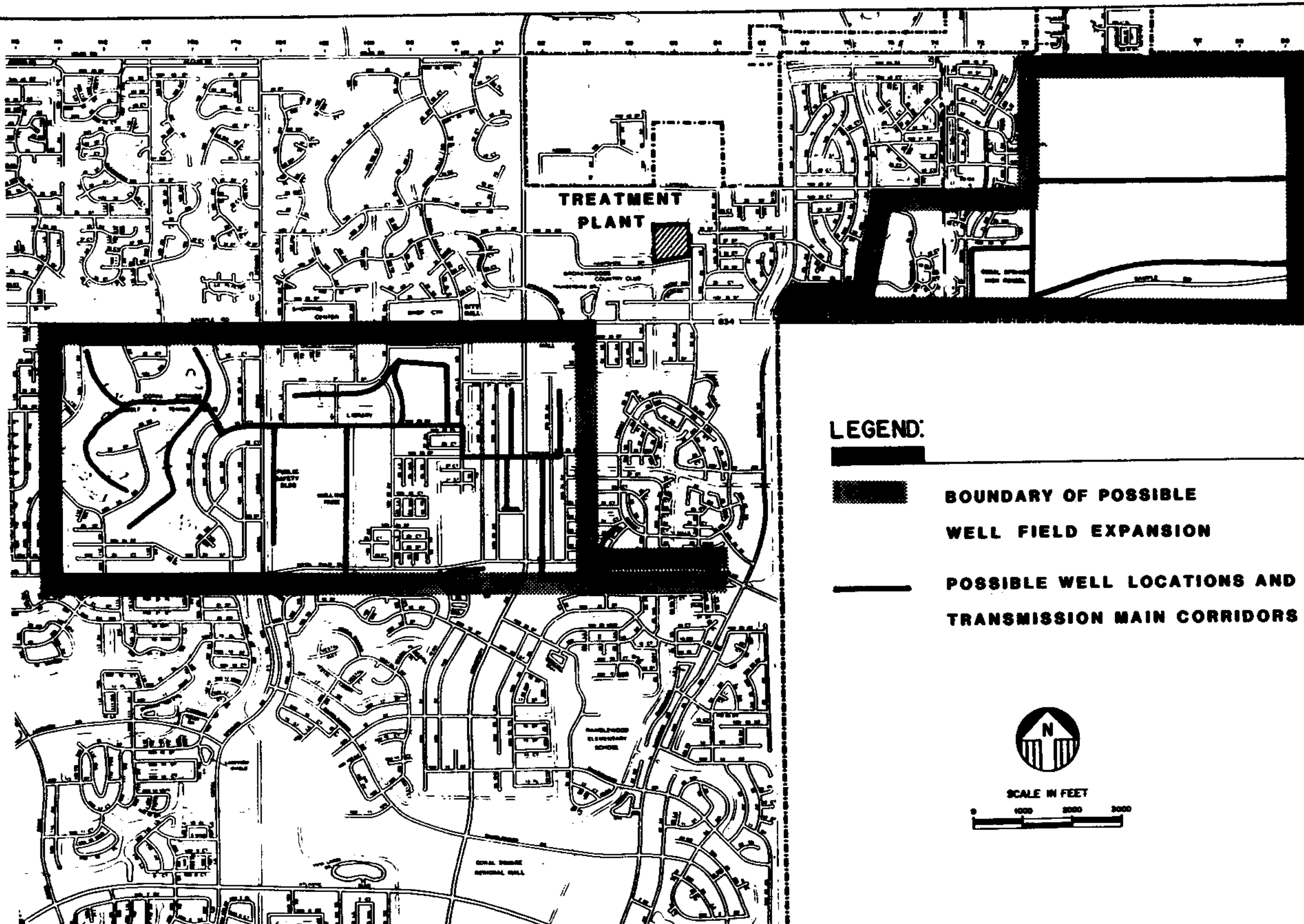
CONE OF INFLUENCE WITH ALL WELLS PUMPING

1.0 DRAWDOWN CONTOUR IN FEET

CONES OF INFLUENCE WITH WELL FIELD PUMPING

FIGURE 10

CDM



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TENTATIVE AREAS OF WELL FIELD EXPANSION

FIGURE 11

Although the preferred areas are within the City's service area, the possibility to explore other areas depends on coordination with other service areas. Consideration should be given to expansion areas at Ramblewood Elementary School and around Coral Square Regional Mall. In all cases, accessibility has been a consideration when looking for future well sites. Areas requiring relocation of a residence or business were not considered.

Well Field Protection

Broward County's Well Field Protection Ordinance #84-60, adopted for well field protection, has added a new requirement to well field selection. This Ordinance requires that the characteristics of the Biscayne aquifer system, along with land use, be considered before well field development can take place. Any substance spilled onto the land surface has a potential for entering the aquifer system by the process of infiltration. For this reason, all potential and new sources of pollution must be analyzed and considered. An additional requirement is that the surrounding zones of protection be delineated for the new well field. The Broward County Ordinance defines three zones of protection as follows:

Zone 1. The land area situated between the well(s) and the ten (10) day travel time contour.

Zone 2. The land area situated between the ten (10) day and the thirty (30) day travel time contours.

Zone 3. The land area situated between the thirty (30) day and the two hundred ten (210) day travel time contours, or the thirty (30) day and the one foot drawdown contours, whichever is greater.

The recommended placement of future well fields should be within lands zoned for residential or park use because of the potential cost to relocate existing businesses, the threat of residual contamination and potential litigation over lost revenues. Restricted areas include most business, light industry and all heavy industry areas. With this ordinance, the cone of influence must also be recognized as an environmental impact in that it may lower water levels in lakes and canals in the area. After the assessment of the above mentioned parameters, the best area for a protected well field can be determined. Proposed well locations, pipe line easements and the location of the protection zones for future expansion can all be evaluated by using computer modeling techniques.

The existing and proposed well fields were reviewed using the same technique used in developing the Ordinance. Figure 12 shows the travel time zones when the existing and proposed well field is pumping at full capacity. Comparing the existing land use and the predicted travel time zones, no violation of the Well Field Protection Ordinance will occur.

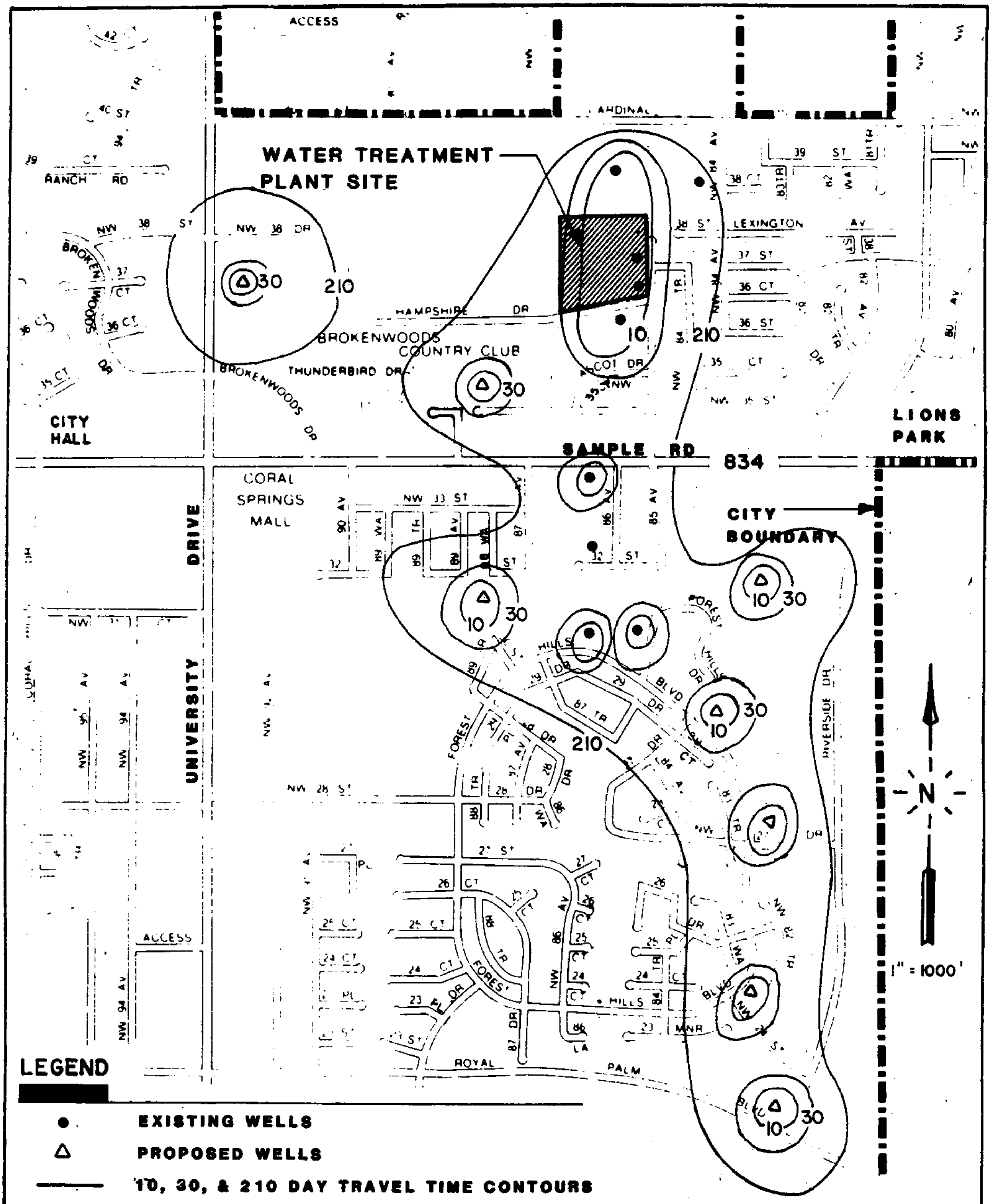
General Well Design

There are basically two types of water well designs: open hole, and screen with a gravel pack. The most economical design for well construction is the open hole construction.

The open hole construction allows the well to produce water in the most efficient manner since the design eliminates any restriction of flow. Open hole construction also eliminates the capital cost of the well screen and the maintenance cost of well screen rehabilitation. However, open hole construction is only possible in stable consolidated formations. Our investigation in Coral Springs indicates this type of well design will probably be impossible, but will be further evaluated after field testing.

The second well design is to screen and gravel pack a well. Normally this type of construction is necessary in areas where the formation is unconsolidated. The advantage of this design is that, if properly developed, the well will be sand free. Initial cost is usually higher than open hole and long-term maintenance and well rehabilitation costs must be considered.

Formation stabilization is a modification of the screen and gravel pack design and can be used in formations that are semi-consolidated. The design uses a well screen with a large slot size and usually a gravel pack



TRAVEL TIME ZONES FOR THE EXISTING & PROPOSED WELL FIELDS PUMPING

FIGURE 12

to prevent the borehole from collapsing. This does not eliminate the capital cost of the well screen and gravel pack. However, the design eliminates or reduces the cost of well maintenance and rehabilitation, and the operating requirements will be similar to that of the open hole construction. This type of design is proposed for Coral Springs if the geological conditions are acceptable.

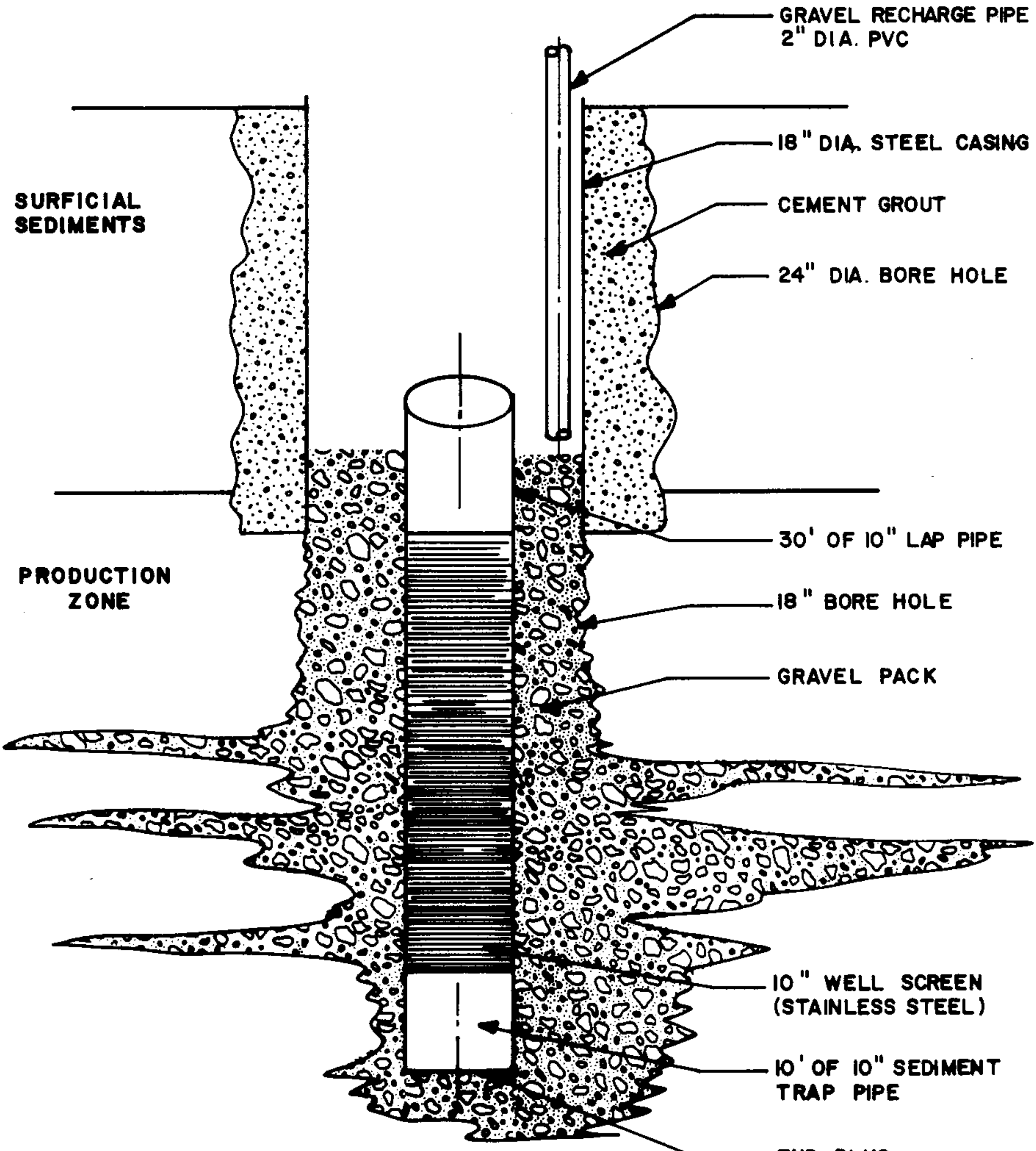
Proposed Well Design

The design of a well for the most part is controlled by the hydrogeology. Production from the Biscayne aquifer in the Coral Springs area is from a semi-consolidated to consolidated formation with sand filled solution cavities. These properties of the production zone will probably require the installation of a well screen and gravel pack. The well screen and gravel pack serve two functions; as a formation stabilizer and as a filter to prevent large quantities of sand from entering the well. The first function prevents collapse of the formation during removal of rock and sand while the well is being developed. The second function is to act as a sand filter. Most of the voids in the rock are filled with a very fine quartz sand, and as the sand is removed during development, the gravel replaces the sand in the void. As pumping continues over time, further well development occurs and the voids are continually filled with the gravel pack. Therefore, periodic replenishment of the gravel pack is required as routine maintenance. Figure 13 shows a proposed well design for future wells.

The amount of time necessary for well development is dependent on the number of voids, the amount of fine sand contained within the voids, the extent that the voids are interconnected within the formation, and the design of the screen and gravel pack. The design of a screen and gravel pack well should also take into consideration:

- replenishment of the gravel pack,
- screen entrance velocity,
- catastrophic formation collapse, and
- elimination of sand by development.

ANTICIPATED TYPICAL WELL DESIGN FOR THE CITY OF CORAL SPRINGS



NOT TO SCALE

FIGURE 13

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Modifications should be made as required by site specific information gathered during test hole drilling. Because detailed analysis of the information is required, hydrogeologic inspection by a qualified hydrogeologist should be provided during all phases of construction to ensure proper design and construction of the production well.

Project Costs and Details

The Master Plan Update prepared in 1984 outlined the cost and phasing of the well field expansion. Design details are not practical until site specific testing occurs and actual production rates estimated. Well design and pump details will then be finalized. Generalized designs and cut sheets, however, are shown in Appendix F.

The predicted costs for immediate expansion is $1,626,800. This includes well construction, transmission mains, and standby power. The standby power will be located at Forest Hills Park where site accessibility already exists. The transmission mains will range from eight to sixteen inches and connect with an existing sixteen inch main which runs south along 85th Avenue. The well locations, as shown in Figure 9, will be located to a exact field position based on easement agreements and gravity sewer lines.

Water Use Permit Modification

As previously discussed, the City was issued a permit for water use from the SFWMD on March 10, 1977. The permit expires March 10, 1987 and should be renewed before that date. Future water supplies must be anticipated and in doing so, a modified Water Use Permit will be prepared as a supplement to this report. Since information developed in the 1984 Master Plan Update will be used in the application, the application will be completed for submittal upon the signature of the City's representative. The application package will be submitted separate from this report.

The permit request will be made for five years based on the SFWMD's policy. In their Permit Information Manual Volume III-A, Section 5.1, it is stated that permits in Broward County will be issued for only five year periods.

This policy became effective after the original permit was issued and therefore ten year allocations are no longer issued.

The permit modification will request an increase in allocated water from 2.4 billion gallons per year (BGY) to 4.41 BGY. The increased allocation will reflect an increase in peak daily use to 12.07 MGD. The increase is based on a projected per capita use of 116 gallons per day and an estimated served population in 1990 of 55,300. Associated with this requested permit modification will be eight additional production wells which would bring the City's total number of wells to 20.

7. CONCLUSIONS

The City of Coral Springs has experienced continual problems with their water supply wells. Production rates have declined from each well and sand production from some wells is a continual problem. The existing wells cannot have the gravel pack replenished, and therefore further well rehabilitation is not practical. With continual increases in water use and restricted raw water production, expansion of the City's well field is necessary to meet future water needs. Eight production wells are necessary immediately with 12 additional production wells needed by the year 2000. The 1984 Master Plan Update outlines the phases and costs of the expansion program in detail, however, the estimated cost for immediate expansion is approximately $1,626,800. This includes standby power located at Forest Hills Park and the necessary transmission mains.

The recommended area for well field expansion in the near future is south of the treatment plant, and should be immediately pursued. Long-term expansion is possible in many areas but further evaluation and site specific testing should occur before any sites are finally accepted.

The new well design should include the capability to replenish the gravel pack, assuming screen and gravel pack wells are necessary. Although the proposed expansion schedule assumes a conservative production rate of 500 gpm, the actual pumping rate will depend on site specific characteristics and well design. Higher production rates than assumable should be obtainable, and therefore, once the sites are selected and tested, the number of future wells will be more accurately predicted. The case presented here is pessimistic and any change in the number of future wells should be at a decrease. For example, if production rates can be obtained from the new wells of 660 gpm, then two of the eight proposd wells can be eliminated. Based on the hydrogeologic investigation and computer modeling described herein, a minimum of 1000-foot well spacings are recommended for any well field expansion.

Expansion to meet future water needs requires modification of a SFWMD Water Use Permit. The permit modification will be made for five years based on the SFWMD's requirements. The request will include eight new wells and an annual allocation of 4.41 BG.

Expansion of the new well field should begin immediately since the City used 111% of its average capacity in 1984. The well field presently has minimal standby capacity and the total failure of any well would severely hamper the City's ability to meet demand. The need to pursue immediate expansion is also supported by the hypothesis that the existing wells have a limited life expectancy since the well construction restricts further rehabilitation efforts.

The data provided by the City for this study was in some cases complete and detailed, yet in other cases, appeared incomplete. A revision of data management would improve the City's review of future well field performance. The data should be kept such that separate files on each well reflect every activity for the well including all rehabilitation and maintenance efforts, an average monthly pumping rate, down time, and future test results. Each well should be tested every six months for specific capacity determined under maximum and average pumping rates. If a specific capacity decreases by 20% over two readings, a sand content test should be performed. A sand test should be performed on all wells at least every two years. Finally, any rehabilitation effort should be reviewed by a hydrogeologic consultant. The proper management of the well field data will significantly improve the evaluation of the well field's performance in the future.

APPENDIX A

List Of References

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12. Water Resources of Broward County, Florida, Report of Investigation #65, United States Geological Survey, C.B. Sherwood, H.J. McCoy, and C.F. Galliher; 1973.

APPENDIX B
Well Construction Specifications

WELL CONSTRUCTION SPECIFICATIONS

Well No.	Year Drilled	Casing Size	Drilling Method[1]	Total Depth In Ft.	Casing Depth In Ft.	Screen[2] Slot Size	Gravel Pack Size	Production Rate - In GPM
1	1967	10	CT	134	81	N.R	N.R.	600
2	1967	10	CT	130	77	N.R.	N.R.	600
3	1973	12	CT	165	53	30-12	N.R.	550
4	1973	12	CT	175	58	10-25	N.R.	720
5	1974	16	CT	155	67	20	6/20	760
6	1974	16	CT	175	54	20	6/20	760
7	1974	16	CT	175	58	20	6/20	735
8	1974	16	CT	156	48	20	6/20	315
9	1979*	16	MR	150	77	40	6/20	600
10	1979*	16	MR	155	77	40	6/20	600
11	1979*	16	MR	150	68	30	6/20	395
12	1979*	16	MR	150	75	30	6/20	717

[1]CT = Cable Tool
MR = Mud Rotary

[2]hundreds of an inch

N.R. = no record

*Pumps installed in 1981

APPENDIX C

Scientific Methods

1. Method of Evaluating a Step Drawdown Test for a Water Table Well
2. Method of Evaluating a Sand Test
3. Calculations & Field Data

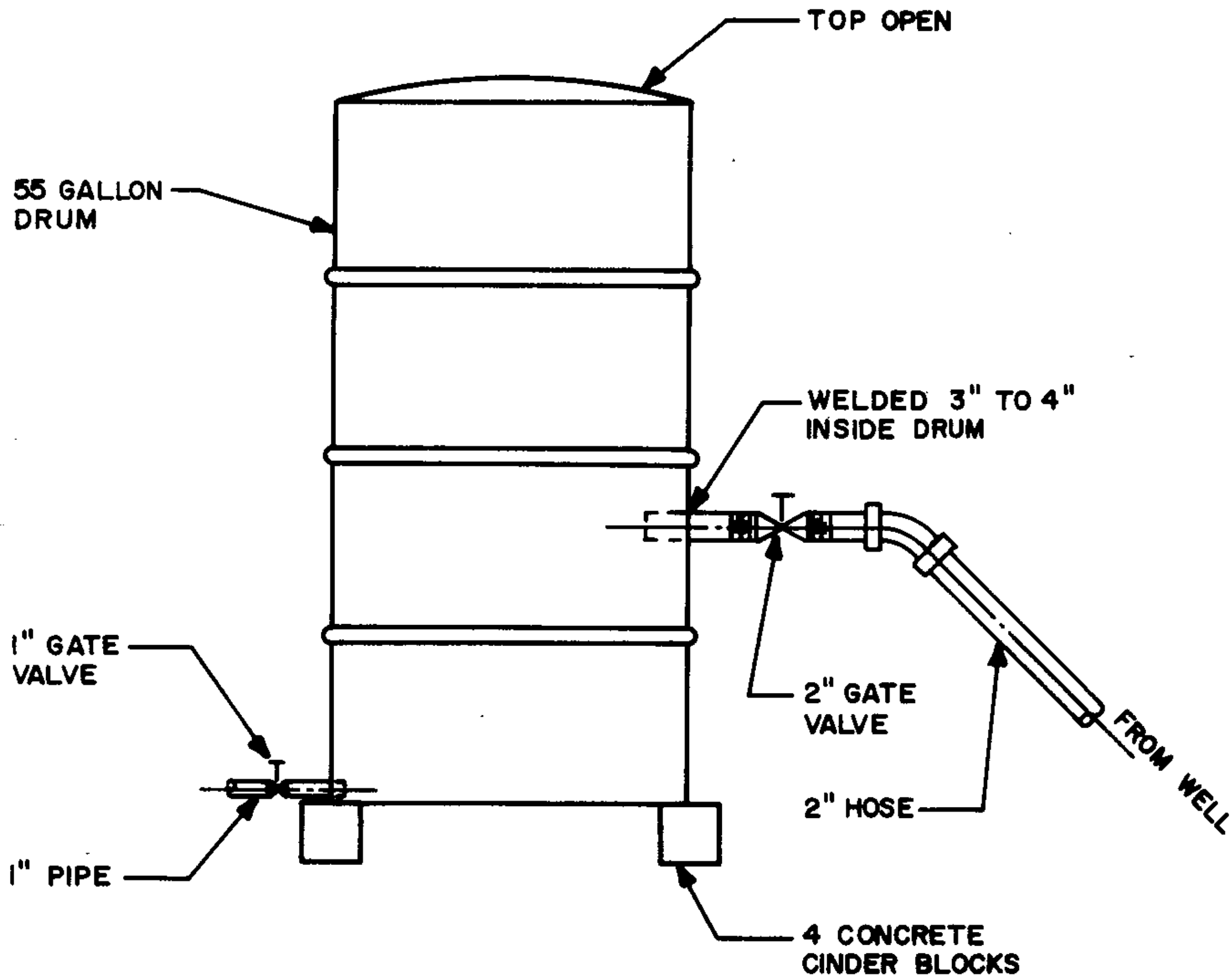
METHOD OF EVALUATING A SAND TEST

A sand test is performed on a well to determine the amount of sand produced during pumping. The device used to determine the amount of sand produced by a well is similar to a Laval Sand Separator Model No. IL-300-3-K. The device used in Coral Springs (Figure C) was made by City employees based on CDM's instructions. A specific volume of water is diverted through the sand separator during each step of a step drawdown test. Upon completion of each step, the sand is removed from the sand separator, dried and analyzed for weight at the City's laboratory. The amount of sand produced in milligrams per liter (mg/l) was determined by the following equation:

$$S = \frac{Swt \times 1{,}000}{Q \times t \times 3.785}$$

where

S	=	sand content, mg/l
Swt	=	weight of sand, grams
Q	=	rate of water through sand separator, gpm
t	=	time, minutes
3.785	=	equation constant, liters per gallon.



SAND CONTENT TESTER

N.T.S.

FIGURE C

CDM

METHOD OF EVALUATING A STEP DRAWDOWN TEST FOR WELL LOSS

The data collected during a step drawdown test is used in the evaluation of the performance, efficiency, and specific capacity of a well. The step drawdown test involves pumping a well to equilibrium at each of three increasing pumping rates. The water levels are allowed to recover to static levels before each increase in pumping rate. The changes in water level are measured usually with an electric water level probe (M-scope), during both the drawdown and recovery periods. Discharge is controlled, using a gate valve and measured with an orifice plate and manometer assembly.

The drawdown (well loss) in a production well due to the turbulent flow of water through the well screen, and inside the casing to the pump intake, may be computed with the following equation (Jacob, 1946):

$$S_{wl} = CQ^2 \qquad 1$$

where

S_{wl} = well loss, ft
C = well loss constant, sec^2/ft^5
Q = production well discharge, cfs.

The value of C may be computed from step drawdown test data using the following equation (Jacob, 1946):

$$C = \frac{\Delta s_i/\Delta Q_i - \Delta s_{i-1}/\Delta Q_{i-1}}{\Delta Q_{i-1} + \Delta Q_i} \qquad 2$$

where

i = any given pumping step
s_i = incremental drawdown associated with step i, ft
Q_i = incremental pumping that produces incremental drawdown (s_i) associated with step i, cfs

The value of C, calculated for each step, is substituted into Equation 2 to yield a range in well loss for a specific well. The s term in Equation 2 represents increments of drawdown produced by each increase Q in the rate of pumping.

WELL LOSS COEFFICIENT: WELL 3

Q_1 = 187 gpm	S_1	4.04	C_1	1.71
Q_2 = 280 gpm	S_2	6.27	C_2	-0.18
Q_3 = 530 gpm	S_3	12.19	$C_{1+2,\ 3}$	0.49
			$C_{1,\ 2+3}$	0.82

According to the results of the step drawdown test analysis on Well 3, the well appears to be unstable. The negative C_2 indicates development is occurring during the test. It also indicates well instability.

SPECIFIC CAPACITY

187 gpm = 46.3 gpm/ft @ 30 minutes

280 gpm = 44.7 gpm/ft @ 30 minutes

530 gpm = 43.5 gpm/ft @ 30 minutes

Date 7-26-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 3 Elevation of Measuring Point ________
Reference Point [illegible] Elevation of Ground Level ________
Pre-test Water Level (Ref. Measuring Point) 15.20

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
	[illegible]	15	+.20	15.20	0		
0	0435	15	+.20	15.20	0	185 gpm	
.5		20	-2.44	17.56	2.36		
1.0		20	-2.06	17.94	2.74		
1.5		20	-1.92	18.08	2.88		
2.0		20	-1.62	[illegible]	3.18		
2.5		20	-1.48	18.52	3.32		
3.0		20	-1.46	18.54	3.34		
3.5		20	-1.42	18.58	3.38		
4.0		20	-1.37	18.63	3.43		
4.5		20	-1.3[illegible]	18.67	3.47		
5.0		20	-1.29	18.7[illegible]	3.51		
6.0		20	-1.22	18.78	3.58		
7.0		20	-1.18	18.82	3.62		
8.0		20	-1.16	18.84	3.64		
9.0		20	-1.12	18.88	3.68		
10.0		20	-1.08	18.92	3.72		
12.0		[illegible]	-1.08	18.92	3.72		
14.0		[illegible]	-1.06	18.94	3.74		
16.0		[illegible]	-1.04	[illegible]96	3.76		
18.0		[illegible]	-1.00	19.00	3.80		
20.0		20	-.98	19.02	3.82		
25.0		20	-.84	19.16	3.96		
30		20	-.76	19.24	4.04		

Sheet 2 of 6
Date 7-26-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 3 | Elevation of Measuring Point ____
Reference Point TOP OF PUMP [illegible] | Elevation of Ground Level ____
Pre-test Water Level (Ref. Measuring Point) 15.20

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0	10:05	20	-.76	19.24	4.04		
.5		15	+.48	15.48	.40		
1.0		15	.42	15.42	.34		
1.5		15	.38	15.38	.30		
2.0		15	.35	15.35	.27		
2.5		15	.34	15.34	.26		
3.0		15	.32	15.32	.24		
3.5		15	.30	15.[illegible]	.22		
4.0		15	.27	[illegible]	.19		
4.5		15	.25	15.26	.17		
5.0		15	.32 ?	15.32	.24		
6.0		15	.20	15.20	12		
7.0		15	.17	15.17	.09		
8.0		15	.17	15.17	.09		
9.0		15	.15	15.15	.07		
10.0		15	.14	15.14	.06		
12.0		15	.12	15.12	.04		
14.0		15	.12	15.12	.04		
16.0		15	.10	15.10	.02		
18.0		15	.10	15.10	.02		
20.0		15	.10	15.10	.02		
25.0		15	.08	15.08	0		
30.0		15	.08	15.08	0		

Date 7-26-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-02-RT

Well No. 3

Elevation of Measuring Point ______

Reference Point TOP OF PUMP opening

Elevation of Ground Level ______

Pre-test Water Level (Ref. Measuring Point) 15.08

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		15	+.08	15.08	0	DRAWDOWN	
.5		20	-.79	19.21	4.13	270	
1.0		20	-.10	19.90	4.82		
1.5		20	+.29	20.29	5.21		
2.0		20	+.42	20.42	5.34		
2.5		20	+.52	20.52	5.44		
3.0		20	+.62	20.62	5.54		
3.5		20	+.71	20.71	5.63		
4.0		20	+.76	20.76	5.68		
4.5		20	+.88	20.88	5.80		
5.0		20	.90	[illegible]	5.82		
6.0		20	.96	20.96	5.88		
7.0		20	1.00	21.00	5.92		
8.0		20	1.05	21.05	5.97		
9.0		20	1.08	21.08	6.00		
10.0		20	1.12	21.12	6.04		
12.0		20	1.17	21.17	6.09		
14.0		20	1.20	21.20	6.12		
16.0		20	1.25	21.25	6.17		
18.0		20	1.27	21.27	6.19		
[illegible]		20	1.31	21.31	6.23		
25.0		20	1.35	21.35	6.27		
30.0		20	1.35	21.35	6.27		

Date 7-26-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 60119.03-RT

Well No. 3

Reference Point [illegible]

Elevation of Measuring Point ______

Elevation of Ground Level ______

Pre-test Water Level (Ref. Measuring Point) 15.04

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
.0		20	+ 1.25	21.35	6.27	RECOVERY	
.5		15	+ .81	15.81	.77	240 gpm	
1.0		15	+ .56	15.56	.52		
1.5		15	+ .48	15.48	.44		
2.0		15	+ .48	15.48	.44		
2.5		15	+ .44	15.44	.40		
[illegible]		15	+ .43	15.43	.39		
[illegible]		15	- .34	[illegible]	.30		
4 [illegible]		15	+ .32	15.32	.28		
[illegible]		15	+ .29	[illegible]	.25		
		15	+ .25	15.25	.21		
		[illegible]	.22	15.22	.18		
		15	.19	[illegible]	.15		
		[illegible]	.16	[illegible]	.12		
		[illegible]	.15	[illegible]	.11		
		15	.15	[illegible]	.11		
[illegible]		[illegible]	.10	[illegible]	.06		
[illegible]		[illegible]	[illegible]	15.08	.04		
		[illegible]	.08	[illegible]	[illegible]		
		[illegible]	.08	[illegible]	[illegible]		
		[illegible]	[illegible]	15.06	.02		
			.06	[illegible]	[illegible]		
		[illegible]	.04	[illegible]	[illegible]		

Date 5-26-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 3

Elevation of Measuring Point ______

Reference Point Top of pump opening

Elevation of Ground Level ______

Pre-test Water Level (Ref. Measuring Point) 15.04

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		15	+.04	15.04		530 gpm	
.5		25	-1.06	23.94	8.90	DRAWDOWN	
1.0		25	-0-	25	9.96		
1.5		25	+.60	25.60	10.56		
2.0		25	+.62	25.62	10.58		
2.5		25	+1.08	26.08	11.04		
3.0		25	+1.17	26.17	11.13		
3.5		25	+1.33	26.33	11.29		
4.0		[illegible]	+1.37	26.37	11.33		
4.5		25	1.48	26.48	11.44		
5.0		25	1.52	26.52	11.48		
[illegible]		25	1.60	26.60	11.56		
[illegible]		25	-1.73	26.73	11.69		
[illegible]		[illegible]	1.75	26.75	11.71		
9.0		25	1.83	26.80	[illegible]		
10.0		25	1.85	[illegible]	[illegible]		
12.0		[illegible]	1.93	[illegible]	[illegible]		
14.0		25	1.96	26.96	[illegible]		
16.0		25	2.00	27.00	11.96		
[illegible]		25	2.04	27.04	12.00		
[illegible]		25	2.08	27.08	[illegible]		
[illegible]		25	2.17	27.17	[illegible]		
[illegible]		25	2.23	[illegible]	12.19		
35.0		25	2.25	[illegible]	12.21		
40.0		25	2.29	[illegible]	[illegible]		

Sheet 6 of [illegible]
Date 7-26-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 3
Elevation of Measuring Point ______
Reference Point [illegible]
Elevation of Ground Level ______
Pre-test Water Level (Ref. Measuring Point) 15.04

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		25	2.29	27.29	12.25	530 gpm	
.5		15	+1.99	16.99	1.95	RECOVERY	
1.0		15	+1.25	[illegible]	1.21		
1.5		[illegible]	[illegible]	16.00	.96		
[illegible]		15	+.81	15.81	.77		
[illegible]		15	+.69	15.69	.65		
[illegible]		15	[illegible]	15.35	.63.		
4.0		[illegible]	+.5[illegible]	[illegible]	.53		
4.5		[illegible]	.50	[illegible]	.46		
5.0		[illegible]	+.46	15.46	.42		
[illegible]		15	+.42	15.42	.38		
[illegible]		15	+.33	[illegible]	.29		
[illegible]		15	+.30	[illegible]	.26		
[illegible]		[illegible]	+.25	15.25	.21		
[illegible]		15	+.19	[illegible]	.15		
[illegible]		15	+.16	15.16	.12		
14		[illegible]	.12	[illegible]	.08		
[illegible]		[illegible]	.11	15.11	.07		
[illegible]		[illegible]	.08	[illegible]	.04		
[illegible]		[illegible]	.08	[illegible]	.04		
[illegible]		[illegible]	.06	[illegible]	.02		
[illegible]		[illegible]	.06	[illegible]	.02		

WELL LOSS COEFFICIENT: WELL 8

Q_1 =	95 gpm	S_1	2.07	C_{1+2}	27.2
Q_2 =	200 gpm	S_2	7.20	C_{2+3}	6.96
Q_3 =	280 gpm	S_3	11.62	$C_{1+2,3}$	13.85
				$C_{i,\ 2+3}$	21.46

According to the results of the step drawdown test, the large decrease in values from S_1 to S_2 indicates that the well is still developing and is unstable.

SPECIFIC CAPACITY

95 gpm = 45.9 gpm/ft @ 30 minutes

200 gpm = 27.8 gpm/ft @ 30 minutes

280 gpm = 24.1 gpm/ft @ 30 minutes

Date 7-27-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 8

Elevation of Measuring Point ________

Reference Point TOP OF WELL ENCLOSURE

Elevation of Ground Level ________

Pre-test Water Level (Ref. Measuring Point) 12.92

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
	08:35	15	-2.08	12.92	0		
	09:10	15	-2.08	12.92	0		
	09:30	15	-2.08	12.92			
						DRAWDOWN	
0	09:[illegible]5	15	-2.08	12.92	0	95gpm	
.5		15	-.20	14.80	1.88		
1.0		15	-.17	14.83	1.91		
1.5		15	-.12	14.88	1.96		
2.0		15	-.04	14.96	2.04		
2.5		15	-.08	14.92	[illegible]		
3.0		15	-.06	14.94	2.02		
[illegible]		15	-.04	14.96	2.04		
4.0		15	-.03	14.97	2.05		
4.5		15	-.03	14.97	[illegible]		
[illegible]		15	.03	14.97	2.05		
6.0		15	-.02	14.98	2.06		
7.0		15	.02	14.98	2.06		
8.0		15	.02	14.98	2.06		
9.0		15	.02	14.98	[illegible]		
[illegible]		15	[illegible]	14.98	2.06		
11.0		15	.02	14.98	2.06		
12.0		15	.02	14.98	2.06		
14.0		15	.01	14.99	2.07		
16.0		15	.01	14.99	2.07		
18.0		15	-.01	14.99	2.07		
20.		15	-.01	14.99	2.07		

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 8 Elevation of Measuring Point ________

Reference Point TOP OF WELL [illegible] Elevation of Ground Level ________

Pre-test Water Level (Ref. Measuring Point) 12.92

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
25		15	-.01	14.99	2.07		
30		15	-.01	14.99	2.07		
						RECOVERY	
0		15	-.01	14.99	2.07	95gpm	
.5		15	-1.59	13.41	.49		
1.0		15	-1.79	13.21	.29		
1.5		15	-[illegible]	13.13	.21		
2.0		15	BRK [illegible]				
[illegible]		15	-1.95	13.05	.13		
3.0		15	-1.96	13.04	.12		
[illegible]		15	-1.98	13.02	.10		
[illegible]		15	-2.00	13.00	[illegible]		
[illegible]		15	-2.04	12.96	[illegible]		
5.0		15	-2.04	12.96	.04		
6.0		15	-2.06	12.94	.02		
7.0		15	-2.06	12.94	.02		
8.		15	-2.06	12.94	.02		
[illegible]		15	-2.07	12.93	.01		
[illegible]		15	-2.08	12.92	0		
12.		15	-2.08	12.92	0		
14.0		15	-2.08	12.92	0		
[illegible]		15	-2.08	12.92	0		
[illegible]		15	-2.08	12.92	0		
[illegible]		15	-2.08	12.92	0		
[illegible]		15	-2.08	12.92	0		
[illegible]		15	-2.08	12.92	0		

Date 7-27-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6[illegible]-03-[illegible]

Well No. 8

Elevation of Measuring Point ________

Reference Point [illegible] ENCLOSURE [illegible]

Elevation of Ground Level ________

Pre-test Water Level (Ref. Measuring Point) 12.92

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0	10:[illegible]					DRAWDOWN	
.5		20				200 gpm	
1.0		20	-1.96	18.04	5.12		
1.5		20	-1.03	18.97	6.05		
2.0		20	-.71	19.29	6.37		
2.5		20	-.56	19.44	6.52		
3.0		[illegible]	-.42	19.58	6.66		
3.5		20	-.17	19.8[illegible]	6.91		
4.0		20	-.25	19.7[illegible]	6.83		
4.5		20	-.27	19.73	6.81		
5.0		20	-.28	19.72	6.80		
6.0		20	-.19	19.81	6.89		
7.0		20	-.16	19.84	6.92		
8.0		20	-.12	[illegible]	6.96		
9.0		20	-.12	19.88	6.96		
10.0		20	+.08	20.08	7.16		
12.0		20	0	20.[illegible]	[illegible]		
14.0		20	-.01	19.99	7.07		
16.0		20	0	20.0	7.08		
18.0		20	+.06	20.06	7.14		
20.0		20	+.13	20.13	7.21		
25.0		20	[illegible]	20.[illegible]	7.08		
30.0		20	+.12	20.12	7.20		

Date 7-27-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 8

Elevation of Measuring Point ________

Reference Point TOP OF WELL ENCLOSURE

Elevation of Ground Level ________

Pre-test Water Level (Ref. Measuring Point) 12.92

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
.0	11:05	20	+.12	20.12	7.20		
.5		15	+.10	15.10	2.18		
1.0		15	-.92	14.08	1.16		
1.5		15	-1.21	13.79	.87		
2.0		15	-1.48	13.52	.60		
2.5		15	-1.67	13.33	.41		
3.0		15	-1.73	13.27	.35		
3.5		15	-1.81	13.19	.27		
4.0		15	-1.87	13.13	.21		
4.5		15	-1.92	13.08	.16		
5.0		15	-1.98	13.02	.10		
6.0		15	-1.94	13.06	.14		
7.0		15	-2.00	13.00	.08		
8.0		15	-2.01	12.99	.07		
[illegible]		15	-2.04	12.96	.04		
[illegible]		15	-2.04	12.96	.04		
12.0		15	-2.06	12.94	.02		
14.0		15	-2.08	12.92	0		
16.0		15	-2.08	12.92	0		
[illegible]		15	-2.08	12.92			
20		15	-2.08	12.92	0		
25		15	-2.08	12.92	0		
30.0		15	-2.08	12.92	0		

Date 7-27-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6317-03-PT

Well No. #8
Reference Point TOP OF WELL ENCLOSURE
Elevation of Measuring Point
Elevation of Ground Level
Pre-test Water Level (Ref. Measuring Point) 12.92

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		15	-2.08	12.92	0		
.5		20	+1.79	21.79	8.87	280 gpm	
1.0		25	-2.17	22.83	9.91	↓	
1.5		25	-1.79	23.21	10.29		
2.0		25	-1.50	23.50	10.58		
2.5		25	-1.29	23.71	10.79		
3.0		25	-1.21	23.79	10.87		
3.5		25	-1.12	23.88	10.96		
4.0		25	-1.11	23.89	10.97		
4.5		25	-0.94	24.06	11.14		
5.0		25	-.89	24.11	11.19		
6.0		25	-.78	24.22	11.30		
7.0		25	-.71	24.29	11.37		
8.0		25	-.67	24.33	11.41		
9.0		25	-.69	24.31	11.39		
10.0		25	-.65	24.35	11.43		
12.0		25	-.56	24.44	11.52		
14.0		25	-.54	24.46	11.54		
16.0		25	-.52	24.48	11.56		
18.0		25	-.51	24.49	11.57		
20.0		25	-.50	24.50	11.58		
25.0		25	-.49	24.51	11.59		
30.0		25	-.46	24.54	11.62		

Date 7-27-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 8

Reference Point TOP OF WELL ENCLOSURE

Elevation of Measuring Point ________

Elevation of Ground Level ________

Pre-test Water Level (Ref. Measuring Point) 12.92

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		25	.46	24.54	11.62		
.5		15	+ 1.75	16.75			
1.0		15	- .25	14.75			
1.5		15	- .81	14.19			
2.0		15	- 1.07	13.93			
2.5		15	- 1.25	13.75			
3.0		15	- 1.39	13.61			
3.5		15	- 1.46	13.54			
4.0		15	- 1.56	13.44			
4.5		15	- 1.62	13.38			
5.0		15	- 1.71	13.29			
6.0		15	- 1.76	13.24			
7.0		15	- 1.83	13.17			
8.0		15	- 1.87	13.13			
9.0		15	- 1.90	13.10			
10.0		15	- 1.94	13.06			
12.0		15	- 1.99	13.01			
14.0		15	- 2.02	12.98			
16.0		15	- 2.04	12.96			
18.0		15	- 2.07	12.93			
20.0		15	- 2.07	12.93			
25.0		15	- 2.07	12.93			
30.0		15	- 2.07	12.93			

WELL LOSS COEFFICIENT: WELL 10

Q_1 = 250 gpm	S_1	5.16	C_{1+2}	3.54
Q_2 = 500 gpm	S_2	12.52	$C_{2, 3}$	2.71
Q_3 = 720 gpm	S_3	20.39	$C_{1+2, 3}$	3.00
			$C_{1, 2+3}$	3.29

According to the results of the step drawdown test on Well 10, the well shows development is taking place because of the decrease in values from C_1 to C_2. The well loss values indicate that the well was not sufficiently developed during the previous rehabilitation reports. The amount of sand pumped at the higher rates also confirm this conclusion.

SPECIFIC CAPACITY

250 gpm = 48.4 gpm/ft @ 30 minutes

500 gpm = 39.9 gpm/ft @ 30 minutes

720 gpm = 35.31 gpm/ft @ 30 minutes

Sheet 1 of 6
Date 7-25-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 10

Elevation of Measuring Point ____

Reference Point TOP

Elevation of Ground Level ____

Pre-test Water Level (Ref. Measuring Point) 4.25

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
	09:30	10	-2.31				
	09:35	10	-2.58				
	09:40	10	-2.65				
	09:45	10	-2.66				
						250	
						DRAWDOWN	
0		10	-2.75	7.25			
0.5		10	+.75	10.75	3.5		
1.5		10	+1.25	11.25	[illegible]		
2.0		10	+1.50	11.50	4.25		
2.5		10	+1.62	11.62	4.37		
3.0		10	+1.81	11.81	4.56		
3.5		10	1.94	11.94	4.69		
4.0		10	+1.96	11.96	4.71		
4.5		10	+2.00	12.00	4.75		
5.0		10	+2.02	12.02	4.77		
6.0		10	+2.08	12.08	4.83		
7.0		10	+2.08	12.08	4.83		
8.0		10	+2.16	12.16	4.91		
9.0		10	+2.18	12.18	4.93		
10.0		10	+2.20	12.20	4.95		
12.0		10	+2.25	12.25	5.00		
14.0		10	2.27	12.27	5.02		
16.0		10	2.31	12.31	[illegible]		
18.0		10	2.31	12.31	[illegible]		
20.0		10	2.29	12.29	5.04		

Date 7-25-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 10 Elevation of Measuring Point ________

Reference Point Top Elevation of Ground Level ________

Pre-test Water Level (Ref. Measuring Point) 7.25

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
25		10	+ 2.33	12.33	5.08		
30.0		10	+ 2.41	12.41	5.16	250	Recovery
.5		10	- 1.23	8.77	1.52		
1.5		10	- 1.60	8.40	1.15		
2.0		10	- 1.79	8.21	0.96		
2.5		10	-2.06	7.94	0.69		
3.0		10	2.06	7.94	0.69		
3.5		10	2.23	[illegible]	.52		
4.0		10	-2.29	[illegible]	.46		
4.5		10	-2.33	7.67	.42		
5.0		10	2.39	7.61	.36		
6.0		10	-2.44	7.56	.31		
[illegible]		10	-2.50	[illegible]	.25		
[illegible]		10	-2.54	[illegible]	.19		
9.0		10	-2.58	7.42	.17		
10.0		10	-2.60	7.40	.15		
12.0		10	-2.67	7.33	.08		
14.0		10	-2.69	7.31	.06		
16.0		10	-2.71	7.29	.04		
18.0		10	-2.73	7.27	.02		
20.0		10	-2.73	7.27	.02		
25.0		10	-2.73	7.27	.02		
30.0		10	2.77	7.23	-.02		

Date 7-25-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 10 Elevation of Measuring Point ______

Reference Point TOP Elevation of Ground Level ______

Pre-test Water Level (Ref. Measuring Point) 7.25

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		10	-2.77	7.23	0	500	
.5							
1.0		NO	READINGS	[illegible]			
1.5			[illegible]	[illegible]			
2.0							
2.5							
3.0		20	-1.54	18.46	11.23		
3.5		20	-1.75	18.25	11.02		
4.0		20	-1.73	18.22	[illegible]		
4.5		20	-1.72	18.2[illegible]	11.00		
5.0		20	-1.12	18.[illegible]	11.65		
6.0		20	-0.96	19.04	11.81		
7.0		20	- BAD READING	—	/		
8.0		20	-.79	19.21	11.93		
9.0		20	-.73	19.22	[illegible]		
10.0		20	-.56 ?	19.40	12.[illegible]		
12.0		20	-.58	19.42	12.19		
14.0		20	-.44	19.56	1.03		
16.0		20	-.33	19.67	12.[illegible]		
18.0		20	-.31	19.69	12.[illegible]		
20.0		20	-.26	19.74	12.[illegible]		
25.0		20	-.29	19.[illegible]	12.48		
30.0		20	-.25	19.75	12.52		
35		20	-.42 ?	19.58	12.35		

Sheet 4 of 6
Date 7-25-84

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 10
Elevation of Measuring Point ________
Reference Point TOP OF [illegible]
Elevation of Ground Level ________
Pre-test Water Level (Ref. Measuring Point) 7.25

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		20	-.42	19.58	12.35	500 gpm	
.5							RECOVERY
1.0		10	+.31	10.31	3.08		
1.5		10	-.31	9.69	2.46		
2.0		10	-.64	9.36	2.13		
2.5		10	-.98	9.02	1.79		
3.0		10	-1.19	8.81	1.58		
3.5		10	-1.35	8.65	1.42		
[illegible]		10	-1.52	8.48	1.25		
[illegible]		10	-1.63	8.37	1.14		
5.0		10	-1.75	8.25	1.02		
6.0		10	-1.92	8.08	.85		
7.0		10	-2.02	7.98	.75		
8.0		10	-2.12	7.88	.65		
[illegible]		10	-2.20	7.80	.57		
10.0		10	-2.29	7.71	.48		
12.0		10	-2.39	7.61	.38		
14.0		10	-2.50	7.50	.27		
16.0		10	-2.53	7.47	.24		
18.0		10	-2.56	7.44	.21		
[illegible]		10	-2.60	7.40	.17		
25		10	-2.69	7.31	.08		
20		10	-2.71	7.29	.06		
35		10	-2.73	7.27	.04		

Date 7-25-84

STEP-DRAWDOWN TEST RECORD

Project Name: Coral Springs

Project Number: 6079-03-RT

Well No. 10 Elevation of Measuring Point ________

Reference Point Top of [illegible] Elevation of Ground Level ________

Pre-test Water Level (Ref. Measuring Point) 7.25

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		10	-2.73	7.27		720	Drawdown
.5		20	+.20	20.20	12.93		
1.0		[illegible]	+[illegible]	21.77	14.50		
1.5		[illegible]	2.87	22.87	15.60		
[illegible]		20	+3.42	23.42	16.15		
[illegible]		[illegible]	-1.19	23.81	16.54		
[illegible]		[illegible]	-.95	24.05	16.87		
[illegible]			-.64	24.36	17.09		
4.0			-.50	24.50	17.23		
[illegible]			-.19	24.81	17.54		
50			-2.02	25.02	17.75		
6.0			+.16	25.16	17.69		
7.0			+.18	[illegible]	17.91		
8.0			+.36	25.36	18.09		
9.0			+.52	25.52	18.25		
[illegible]			+.69	25.69	18.42		
[illegible]			.75	25.75	18.48		
14.0			.84	25.84	18.57		
16.0			.92	25.92	18.65		
18.0			-1.00	26.00	18.73		
20.0			1.05	26.05	18.78		
[illegible]			1.75	26.75	19.48		
[illegible]			+2.66	[illegible]	20.39		
[illegible]			+3.00	28.00	20.73		
[illegible]			+3.00	28.00	20.73		

Date 7/25-85

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. 10

Elevation of Measuring Point ______

Reference Point TOP

Elevation of Ground Level ______

Pre-test Water Level (Ref. Measuring Point) 7.25

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
0		25	+3.00	28.00	20.73	720	RECOVERY
.5		10	+2.52	12.52	5.25		
1.0		10	+1.25	11.25	3.98		
1.5		10	+.45	10.45	3.18		
2.0		10	0	10	2.73		
2.5		10	-.33	9.67	2.40		
3.0		10	-.60	9.40	2.13		
3.5		10	.85	9.15	1.88		
4.0		10	1.00	9.00	1.73		
4.5		10	1.14	8.86	1.59		
5.0		10	—	—			
6.0		10	1.48	8.52	1.25		
7.0		10	1.69	8.31	1.04		
8.0		10	1.81	8.19	.92		
9.0		10	1.94	8.06	.79		
10.0		10	2.04	7.96	.69		
12.0		10	2.08	7.92	.65		
14.0		10	2.21	7.79	.52		
16.0		10	2.20	7.80	.53		
18.0		10	2.37	7.63	.36		
20.0		10	2.43	7.57	.30		
25.0		10	2.55	7.45	.18		
30.0		10	2.61	7.39	.12		
35.0		10	2.67	7.33	.06		
40.0		10	2.71	7.29	.02		

APPENDIX D

Field Data for the Simplified Pump Test on Well 8

MINI PUMP TEST
~~STEP-DRAWDOWN~~ TEST RECORD
"Pump Test"

Project Name: CORAL SPRINGS

Project Number: 6079-03-RT

Well No. #7

Elevation of Measuring Point ______

Reference Point TOP OF WELL ENCLOSURE

Elevation of Ground Level ______

Pre-test Water Level (Ref. Measuring Point) 2.80

PUMPING WELL #8

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
.5		15	.42	14.58			DRAWDOWN
.?	13:52	15	.40	14.60			
	13:55	15	.33	14.67			
	13:58	15	-.42	14.58			
0	14:01	15	-.42	14.58			
.5	14:00.5	15	-.33	14.67	.09		
1.0	14:02	15	-.33	14.67	.09		
1.5	14:01.5	15	-.37	14.63	.05		
2.0	14:02	15	-.39	14.61	.03		
2.5	14:02.5	15	-.37	14.63	.05		
3.0	14:03	15	-.35	14.65	.07		
3.5	14:03.5	15	-.35	14.65	.07		
4.0	14:04	15	-.35	14.65	.07		
4.5	14:04.5	15	-.32	14.68	.10		
5.0	14:05	15	-.31	14.69	.11		
6.0	14:06	15	-.27	14.73	.15		
7.0	14:07	15	-.26	14.74	.16		
8.0	14:08	15	-.23	14.77	.19		
9.0	14:09	15	-.21	14.79	.21		
10.0	14:10	15	-.20	14.80	.22		
12.0	14:12	15	-.17	14.83	.25		
14	14:14	15	.10	14.90	.32		
16	14:16	15	.12	14.88	.30		
18	14:18	15	.08	14.92	.34		
20	14.20	15	.06	14.94	.36		
25	14.25	15	.06	14.94	.36		

Date

STEP-DRAWDOWN TEST RECORD

Project Name: CORAL SPRINS

Project Number: 6079-03-RT

Well No. #7 Elevation of Measuring Point

Reference Point Elevation of Ground Level

Pre-test Water Level (Ref. Measuring Point)

PUMPING WELL #8

Elapsed Time (Min:Sec)	Time (Hr:Min)	Held (Ft.)	Water Tape Dist. (Ft.)	Level Below M.P. (Ft.)	Drawdown (Ft.)	Pumping Rate (GPM)	Remarks
30	14:30	15	-.04	19.96	.38		DRAWDOWN
35	14:35	15	.06	1494	.36		RECOVERY
40-0	14:40	15	-.06	14.94	36		
.5	14:40.5	15	-.06	14.94	.36	0	
1.0	14:41	15	-.06	14.94	.36	0	
1.5	14:41.5	15	-.06	14.94	.36	0	
2.0	14:42	15	-.08	14.92	.34	.02	
2.5	14:42.5	15	-.13	14.87	.29	.07	
3.0	14:43	15	-.13	14.87	.29	.07	
3.5	14:43.5	15	-.14	14.86	.28	.08	
4.0	14:44	15	-.17	14.83	.25	.11	
4.5	14:44.5	—	—	—	ATTACKED BY GOLF BALL		
5.0	14.45	15	.18	14.82	.24	.12	
6.0	14:46	15	-.20	14.80	.22	.14	
7.0	14:47	15	-.23	14.77	.19	.17	
8.0	14:48	15	-.20	14.80	.22	.14	
9.0	14:49			—	ATTACKED BY GOLF BALL		
10.0	14:50	15	.29	14.71	.13	.23	
12.0	14:52	15	.33	14.67	.09	.27	
14.0	14:54	15	.33	14.67	.09	.27	
16.0	14:56	15	.33	14.67	.09	.27	
18.0	14:58	15	.35	14.65	.07	.29	
20.0	15:00	15	.33	14.67	.09	.27	

CDM

Date ________

AQUIFER TEST RECORD

PROJECT CORAL SPRINGS

Well No. #7   Elevation of Measuring Point ________

Reference Point ________   Elevation of Ground Level ________

Pre-test Water Level (Ref. Measuring Point) ________

Distance from Pumping well in feet ________   Pumping Rate (gpm) 280

Time	t in min.	s in feet	Tape Reading at – Meas. Point	Tape Reading at – Water Level	Depth to water below m.p.	Elev. of water level	Remarks
15		15-5					
1352		15-4 3/4					
13:55		15-4					
13:58		15-5					
1400	0	15-5					
14.	.5	15-4					
	1.0	15-4					
	1.5	15 - [illegible]					
	2.0	15-4 3/4					
	2.5	15-4 1/2					
	3.0	- 4 [illegible]					
	3.5	15-4 1/2					
	4.0	15-4 1/4					
	4.5	15-3 [illegible]					
	5.0	15-3 3/4					
	6.0	15-3 1/4					
	7.0	15 3 1/8					
	8.0	15-2 3/4					
	[illegible]	15-2 5/8					
	[illegible]	15 2 1/2					
	2	15-2"					
	4	15-1 1/2"					
	12	15-1 1/2					
	18	15-1					
	20	15 3/4					
	25	15-3/4					
	30	15-1/2					
	35	15-3/4					
	40	15-3/4					
	.5	15-3/4					
	1.0	15-3/4					
	1.5	15-3/4					
	2.0	15-1					
	2.5	15-1 3/8					
	3.0	15-1 5/8					
	3.5	15 1 3/4					
	4.0	15-2					

CDM

Date ______

AQUIFER TEST RECORD

PROJECT Coral Springs

Well No. ______ Elevation of Measuring Point ______

Reference Point ______ Elevation of Ground Level ______

Pre-test Water Level (Ref. Measuring Point) ______

Distance from Pumping well in feet ______ Pumping Rate (gpm) ______

Time	t in min.	s in feet	Tape Reading at - Meas. Point	Tape Reading at - Water Level	Depth to water below m.p.	Elev. of water level	Remarks
4/12	5	15-2 1/8					
	6	15-2 1/2					
	7	15 2 3/4					
	8	15 2 1/2					
	9						
	10	15-3 1/2					
	12	15-4					
	14	15-4					
	16	15-4					
	18	15-4 3/8					
	20	15-4					

APPENDIX E

Chronological History of Each Well

WELL NO. 1

Date	Well Construction - Work Description

The well was constructed using the cable tool method with 81 feet of 10 inch diameter casing. The well was drilled to a depth of 134 feet below land surface. An 8 inch diameter stainless steel well screen was installed from 85 to 105 feet.

1967	The well was contracted under Widell and Associates. The drilling was performed by Morton Pump and Supply, Inc.
July 1967	The well was tested at 670 gallons per minute (gpm) with 13 feet of drawdown, or a specific capacity of 51.5 gallons per minute per foot (gpm/ft) of drawdown.
April 1973	The static water level dropped in the well from 6 feet below casing to 14 feet below the casing after Wells 3 and 4 were constructed, and associated with a loss in pumping rate of 75 gpm.
August 1974	The well produced 550 gpm until January 1, 1974 after which the well had 30 feet of drawdown and was losing suction. The pumping rates were adjusted to 230 gpm. The problem occurred after Wells 5, 6, 7 and 8 were placed on line.
April 1975	The well was discontinued from service due to excessive drawdown.
March 1978	A television camera survey was performed on the well which showed no signs of encrustation or corrosion on the well screen.
1979	The well was modified with a new Peerless pump rated at 450 gpm at 60 feet total dynamic head (TDH) and 1760 rpm. The pump column pipe was increased to 50 feet below grade. When all wells are in service, the maximum pump rate drops to 390 gpm.
September 1984	The well was tested by the City personnel at 330 gpm. A specific capacity of 13.33 gpm/ft of drawdown was determined.

WELL NO. 2

Date	Well Construction - Work Description

The well was constructed using the cable tool method with 77 feet of 10 inch diameter casing. The well was drilled to a depth of 130 feet below land surface. An 8 inch of diameter stainless steel well screen was installed. The screened interval is unknown.

1967	The well was constructed by Morton Pump & Supply, Inc. under contract by Widell and Associates.
August 1967	The well was tested at 650 gpm with 16 feet of drawdown and a specific capacity of 40 gpm/foot of drawdown.
April 1973	The static water level is reportedly dropped.
August 1974	The well produced 550 gpm until January 1, 1974 after which the well had 30 feet of drawdown and had lost suction. The pumping rate was adjusted to 230 gpm. The problem occurred after Wells 5, 6, 7 and 8 were placed on line.
April 1975	The well is reported out of survice and is in need of "recharging" (as used in the RS&H report).
1979	The well was modified by installing a new Peerless pump rated at 450 gpm at 60 feet (TDH) and 1760 rpm. The pump column pipe was increased to 50 feet below grade.
September 1983	An increase in drawdown was experienced and output decreased to 180 gpm and less. The well was acidized, surged, and placed back in service by Layne-Atlantic.
September 1984	The well was tested by City personnel at 370 gpm.

WELL NO. 3

Date	Well Construction - Work Description

The well was drilled using the cable tool method with 53 feet of 12 inch diameter casing. The well was drilled 165 feet deep and has an 8 inch stainless steel screen placed between 100 and 165 feet.

May 1972	The well was tested at 550 gpm with 10.5 feet of drawdown, or a specific capacity of 52 gpm/ft of drawdown. The well was installed by Vickers Well Drilling.
January 1973	The well was accepted by the City and the well was placed in service. The well was designed for 825 gpm with 8 feet of drawdown.
May 1979	The well was reported to have a pumping rate of 350 gpm.
October 1980	The pump from Well 8 was installed in Well 3.
April 1983	A new pump was installed.
August 1984	CDM performed step drawdown test and sand test. The well has a specific capacity of 32.16 gpm/ft and a sand content of 31 mg/l.
September 1984	The City personnel tested the well at 410 gpm. A specific capacity was determined to be 32 gpm/ft of drawdown.

WELL NO. 4

Date	Well Construction - Work Description
	The well was constructed using the cable tool method with 67 feet of 16 inch casing. The well was drilled to a total depth of 155 feet. An 8 inch screen was installed but the records are not clear on the interval.
April 1972	A test was conducted on the well at 720 gpm with 12 feet of drawdown for a specific capacity of 60 gpm feet of drawdown. The well was installed by Vickers Well Drilling.
January 1973	The well was accepted and placed in service.
June 1974	UOP* Johnson advised the City on rehabilitation procedures for the well.
August 1974	It is determined that both Wells 3 and 4 each pump 50 gpm less than with one well pumping.
September 1978	It is reported that the combined flow rate is 16.5% less than when all wells are pumping separately.
May 1979	The reported capacity of the well is 415 gpm with all the Wells 1 through 8 pumping.
April 1983	A new pump is installed on the well. The pumping rate was 360 gpm.
September 1984	The well is tested by City personnel at 360 gpm. The specific capacity was 35 gpm/ft of drawdown.

*UOP - United Oil Products

WELL NO. 5

Date	Well Construction - Work Description

The well was constructed using the cable tool method with 58 feet of 12 inch casing. The well was drilled to a total depth of 175 feet. An 8 inch stainless steel screen was installed from 58 to 175 feet in segments, using blanks between screen segments.

October 1974	The well is tested operating individually. The well pumped 660 gpm with a drawdown of 3.96 feet, for a specific capacity of 167 gpm/ft of drawdown. With Wells 6, 7 and 8, the yield is 575 gpm with a drawdown of 4.59 feet; equal to a specific capacity of 125 gpm/ft of drawdown.
December 1973	A test is performed at a pumping rate of 760 gpm with 9.67 feet of drawdown for a specific capacity of 79 gpm/ft of drawdown. The well pumped a small amount of sand.
January 1974	The well is tested at in 760 gpm with 6.5 feet of drawdown for a specific capacity of 118 gpm/ft of drawdown.
May 1979	The well is pumping 350 gpm with no drawdown reported.
September 1984	The well was tested by the City personnel at 390 gpm.

WELL NO. 6

Date	Well Construction - Work Description

The well was constructed using the cable tool method with 54 feet of 16 inch casing. The well was drilled to a total depth of 175 feet. An 8 inch stainless steel screen was installed.

October 1972	A test pilot hole was drilled, and a complete lithologic log developed by Wingerter Laboratories.
January 1974	An aquifer performance test was performed. The well pumped 785 gpm with a drawdown of 6.67 feet for a specific capacity of 118 gpm/ft of drawdown. A small amount of sand was pumped.
June 1974	The well is placed in service.
September 1974	The well is pumped at 575 gpm.
October 1974	The well is tested individually at 650 gpm with 5.5 feet of drawdown for a specific capacity of 118 gpm/ft of drawdown. With Wells 5, 7, and 8 on, the well pumped 580 gpm with 37 feet of drawdown. The specific capacity was 108 gpm/ft of drawdown.
May 1979	The well is reported to have a pumping capacity of 430 gpm.
January 1984	The well was tested at 760 gpm and had a specific capacity of 111 gpm/ft of drawdown.
September 1984	The City personnel tested the well at 380 gpm.

WELL NO. 7

Date	Well Construction - Work Description

The well was drilled by the cable tool method with 58 feet of 16 inch casing. The well was drilled to a total depth of 175 feet and includes an 8 inch stainless steel screen. The screened interval is from 58 feet to 175 feet but includes areas of blank casing at various depths.

September 1972	Soil borings were drilled by Wingerter Laboratories.
September 1973	The well was acidized with 1,000 gallons of acid placed in the well. After the test, the well produced 350 gpm with 8 feet of drawdown.
October 1973	The well was horizontally jetted and development was completed. The well was retested and produced 350 gpm with 8 feet of drawdown.
October 1973	The well was tested at 735 gpm with 12.84 feet of drawdown, for a specific capacity of 57 gpm/ft of drawdown.
June 1974	The well is placed in service.
September 1974	The well pumps 575 gpm with Well 6 operating at 540 gpm.
October 1974	The well is tested at 650 gpm with a drawdown of 9.58 feet for a specific capacity of 68 gpm/ft of drawdown. The well is retested with Wells 5, 6 and 8 operating at 600 gpm. The well has 8.21 feet of drawdown for a specific capacity of 73 gpm/ft of drawdown.
May 1979	The well is rated at 490 gpm.
April 1983	A new pump is installed in the well and the tested capacity is 500 gpm.
September 1984	The well is tested by the City personnel at 510 gpm with a specific capacity of 29.13 gpm/ft of draw-down.

WELL NO. 8

Date	Well Construction - Work Description

The well was drilled using the cable tool method with 48 feet of 16 inch casing. The total well depth is 156 feet. An 8 inch stainless steel well screen is installed from 65 to 156 feet, including casing blanks. During construction, the original well casing and screen collapsed during development. The well was moved 15 feet to the east and Well 8 was redrilled and designated 8B (hereafter Well 8).

May 1974	A test on Well 8 resulted in 550 gpm with a drawdown of 17 feet, for a specific capacity of 32 gpm/ft of drawdown. The well was acidized prior to this test. The productivity of the well, changed by approximately 2 gallons per foot of drawdown.
June 1974	A letter was sent to the City by the engineers stating that drawdown is excessive, and the well should not be accepted.
October 1974	The well was tested at 620 gpm with 16.37 feet of drawdown. A specific capacity 38 gpm/ft of drawdown was determined when the well operating individually. A test with Wells 5, 6 and 7 operating, and pumping 560 gpm, resulted in 15.00 feet drawdown, for a specific capacity of 37 gpm/ft of drawdown.
April 1975	Correspondence refers to excessive drawdown in Wells 7 and 8. Problems with Well 8 is reportly due to unfavorable soil conditions.
May 1979	Well 8 is reported to have a pumping capacity of 370 gpm.
October 1980	Well 8 was shut down due to excessive drawdown.
May 1983	A television survey was performed on the well. The survey indicates possible scale build up on the well screen.
July 1983	The well is acidized and developed by surging it with air.
September 1983	The well is put in service with a new well pump designed for 340 gpm at 56 feet of head.

(Well 8 Continued)

July 1984	A step-drawdown test is performed by CDM. The well was pumped at 288 gpm (maximum pump capacity) for a specific capacity of 24.1 gpm/ft of drawdown. Sand content was 3.57 mg/l during pumping.
September 1984	The well is tested at 275 gpm by City personnel. The specific capacity is 23 gpm/ft of drawdown.

WELL NO. 9

Date	Well Construction - Work Description

The well was constructed with 77 feet of 16 inch steel casing. The annulus of the 22 inch diameter borehole was grouted with 58 bags of cement grout. A 15 inch diameter borehole was then drilled to the bottom depth of 160 feet. An 80 foot long, 8 inch I.D., 40 slot wire wrapped well screen was placed into the hole with a 5 feet length of 8 inch I.D. casing attached to the bottom. Gravel was placed into the annulus surrounding the well screen.

Date	Well Construction - Work Description
August 1979	The well was tested at a rate of 300 gpm with 11 feet of drawdown. The specific capacity of the well was 27.3 gpm/ft of drawdown.
February 1981	The pump was installed and the well placed in service.
September 1982	The well was tested at a rate of 800 gpm with 16 feet of drawdown. The specific capacity of the well was 50.0 gpm/ft of drawdown.
February 1983	The well was tested at a rate of 325 gpm with 31 feet of drawdown. The specific capacity of the well was 10.5 gpm/ft of drawdown.
March 1983	The well was tested at a rate of 320 gpm with 32 feet of drawdown. The specific capacity of the well was 10.0 gpm/ft of drawdown. The pumping rate decreased and the well was taken out of service due to decreased flow, high drawdown, and cavitation.
May 1983	When workers of Layne-Atlantic Company were attempting to remove the pump from the well they found that the pump was cemented into the well. The crew removed the cement and the pump from the well and worked to remove sand and calcium deposits in the well to a depth of 149 feet. A downhole television survey was taken in the well which showed the well screen to be in poor condition.
August 1983	A test was conducted after rehabilitation work was completed by Layne-Atlantic Company. A test on the first day at 317 gpm caused 13 feet of drawdown for a specific capacity of 24.4 gpm/ft of drawdown. The final test conducted at a rate of 513 gpm caused a drawdown of 14.17 feet for a specific capacity of 36.2 gpm/ft of drawdown. One pump stage was removed due to back pressure and control output. An effort to install a 2" gravel pack replenishment line was unsuccessful.

(Well 9 Continued)

September 1984	The well was tested by City personnel at 510 gpm. The specific capacity is 49 gpm/ft of drawdown.

WELL NO. 10

Date	Well Construction - Work Description

The well was constructed with 77 feet of 16 inch steel casing. The 22 inch diameter annulus was grouted from the bottom to the top of the hole with 60 bags of neat cement. A 15 inch diameter borehole was drilled to a finished depth of 160 feet. An 8 inch well screen was placed from 85 to 155 feet. Five feet of 8 inch casing was attached to the end of the well screen. Fifteen feet of steel casing was attached to the top of the screen from a depth of 70 to 85 feet. Gravel was placed within the annulus around the screen and casing from a depth of 70 to 160 feet.

June 1979	A test well was constructed to a total depth of 124 feet with 84 feet of steel casing and 40 feet of 4 inch I.D. well screen. The annulus of the borehole was grouted around the casing with 6 bags of grout. At the completion of the subsequent test, the well was pumped at 100 gpm with a drawdown of 11.17 feet. The specific capacity of the well was 8.95 gpm/ft of drawdown.
November 1979	The well was tested at a rate of 600 gpm with a drawdown of 20.58 feet. The specific capacity was 29.2 gpm/ft of drawdown.
August 1981	The pump was installed and the well was placed in service.
September 1982	The well was tested at a rate of 460 gpm with a drawdown of 30 feet. The specific capacity of the well was 15.3 gpm/ft of drawdown.
March 1983	The well was tested at a rate of 470 gallons per minute which caused a drawdown of 32 feet. The specific capacity of the well was 14.7 gpm/ft of drawdown. The well was acidized and surged with air by the Layne-Atlantic Company. Sand was produced prior to and after well rehabilitation. Therefore, the pumping rate was reduced in hopes of stabilizing the well.
September 1983	The well was tested and had a specific capacity of 37 gpm/ft of drawdown. One pump stage was removed.
August 1984	CDM performed a step drawdown test and sand test on the well. The well had a specific capacity of 35.31 gpm/ft of drawdown at 720 gpm and produced 527 mg/l of sand during pumping.
September 1984	The well was tested at 400 gpm by City personnel with a specific capacity of 47 gpm/ft of drawdown.

WELL NO. 11

Date	Well Construction - Work Description

Well 11 was completed to a total depth of 160 feet with 68 feet of 16 inch O.D. steel casing. The annulus of the 22 inch diameter borehole was grouted from bottom to the surface with 68 bags of Type I neat cement grout. A 15 inch diameter borehole was drilled to a total depth of 160 feet. A 60 foot, 8 inch 0.030 inch slot stainless steel well screen, with 5 feet of 8 inch steel casing at the bottom and 30 feet of 8 inch steel casing at the top, was emplaced from 60 to 155 feet. The annulus around the screen and 8 inch casing was filled with gravel.

June 1979	Test well 3A was constructed to a total depth of 200 feet with 2 inch I.D. PVC casing.
June 1979	Test well 3D was constructed to a total depth of 170 feet bls with 170 feet of 4 inch I.D. steel casing and a 40 foot well screen that was set at 124 feet.
June 1979	Tests were performed on lithologic samples from test well 3A at every five foot interval starting at 20 feet down to 190 feet.
July 1979	A test was conducted on test well 3B at a pumping rate of 100 gpm which caused 11.58 feet of drawdown. The specific capacity of the well was 8.6 gpm/ft of drawdown. A test was also conducted on test well 3C at a rate of 100 gpm which caused 13.42 feet of drawdown. The specific capacity of the well was 7.5 gpm/ft of drawdown.
August 1981	The pump was installed and the well was placed in service.
September 1982	At a pumping rate of 450 gpm Well 11 produced 14 feet of drawdown for a specific capacity of 32.1 gpm/ft of drawdown.
November 1982	The well was taken out of service due to low production, high drawdown, and cavitation.
February 1983	A test was performed on Well 11 at a rate of 100 gpm that produced 32 feet of drawdown. The associated specific capacity for this test was 3.1 gpm/ft of drawdown. After about five minutes at this pumping rate, the discharge dropped to 50 gpm.

(Well 11 Continued)

May 1983	Layne-Atlantic Company was contracted to run a television survey. After removing the pump, a bailor was lowered to 45 feet where it was obstructed by an encrustation. The bailor was repeatedly lowered onto the encrustation until the layer was successfully penetrated. A camera was lowered into the hole that confirmed encrustation.
1983	Layne-Atlantic Company acidized and developed the well. An effort to install a 2" gravel pack replenishment line was unsuccessful.
September 1984	The well is tested by City personnel at 375 gpm. The specific capacity is 26 gpm/ft of drawdown.

WELL NO. 12

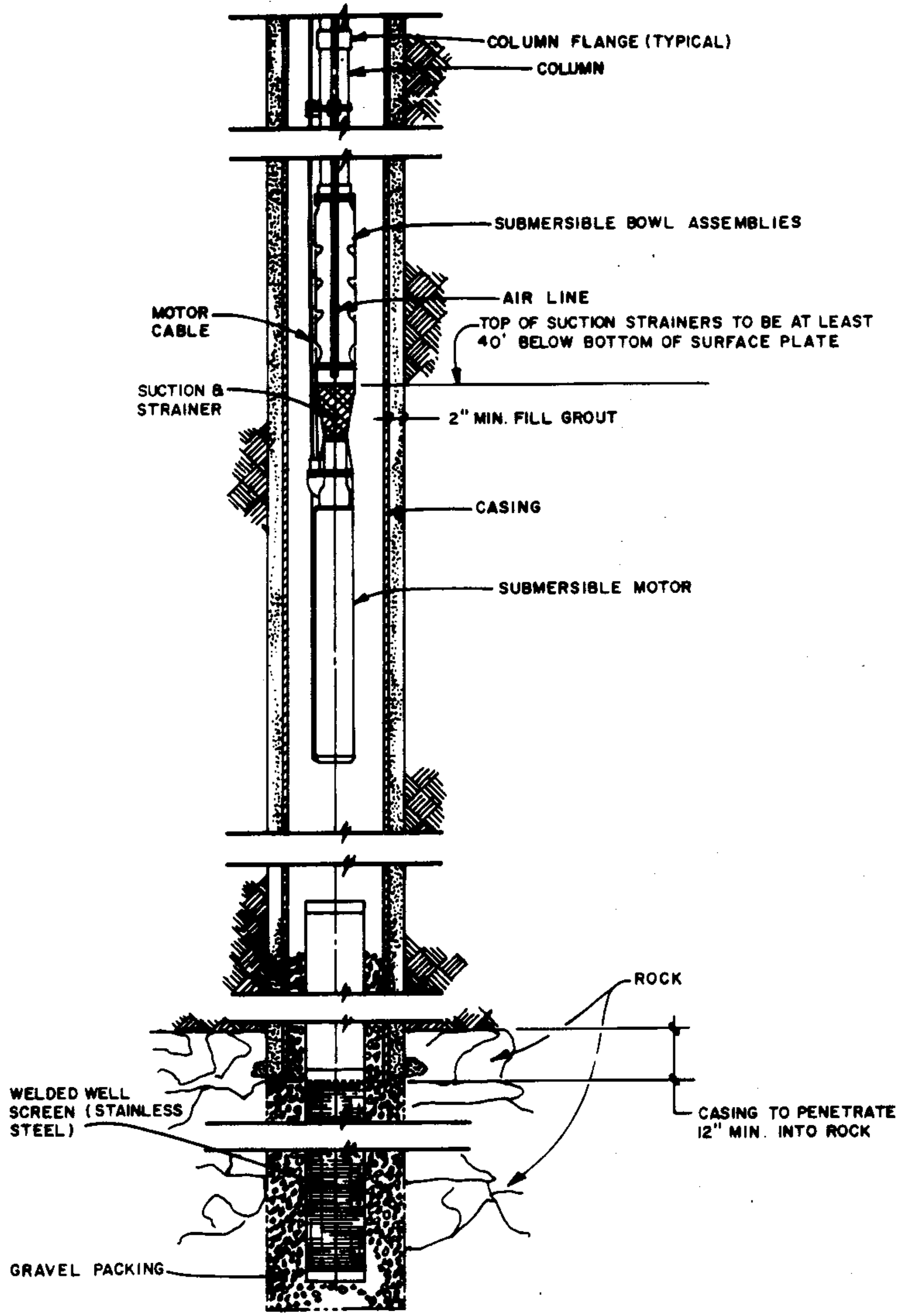
Date	Well Construction - Work Description

Well 12 as completed to a total depth of 150 feet with 75 feet of 16 inch steel casing. The annulus of the 22 inch diameter borehole was grouted from bottom to land surface with 68 bags of Type I neat cement grout. A 15 inch diameter borehole was drilled through the cement bottom to a total depth of 150 feet. A 40 foot well screen with 5 feet of 8 inch steel casing at the bottom and 30 feet of 8 inch steel casing at the top was placed in the well. The annulus around the screen and 8 inch casing was filled with gravel.

August 1980	A test was conducted to create and compare efficiency and head-capacity curves.
February 1981	The pump was installed and the well placed in service.
September 1982	At a pumping rate of 540 gpm, Well 12 produced 16 feet of drawdown and the well had specific capacity of 34 gpm/ft of drawdown.
June 1984	One pump stage was removed to reduce back pressure and control output.
September 1984	The well is tested by City personnel at 500 gpm. The specific capacity is 27 gpm/ft of drawdown.

APPENDIX F

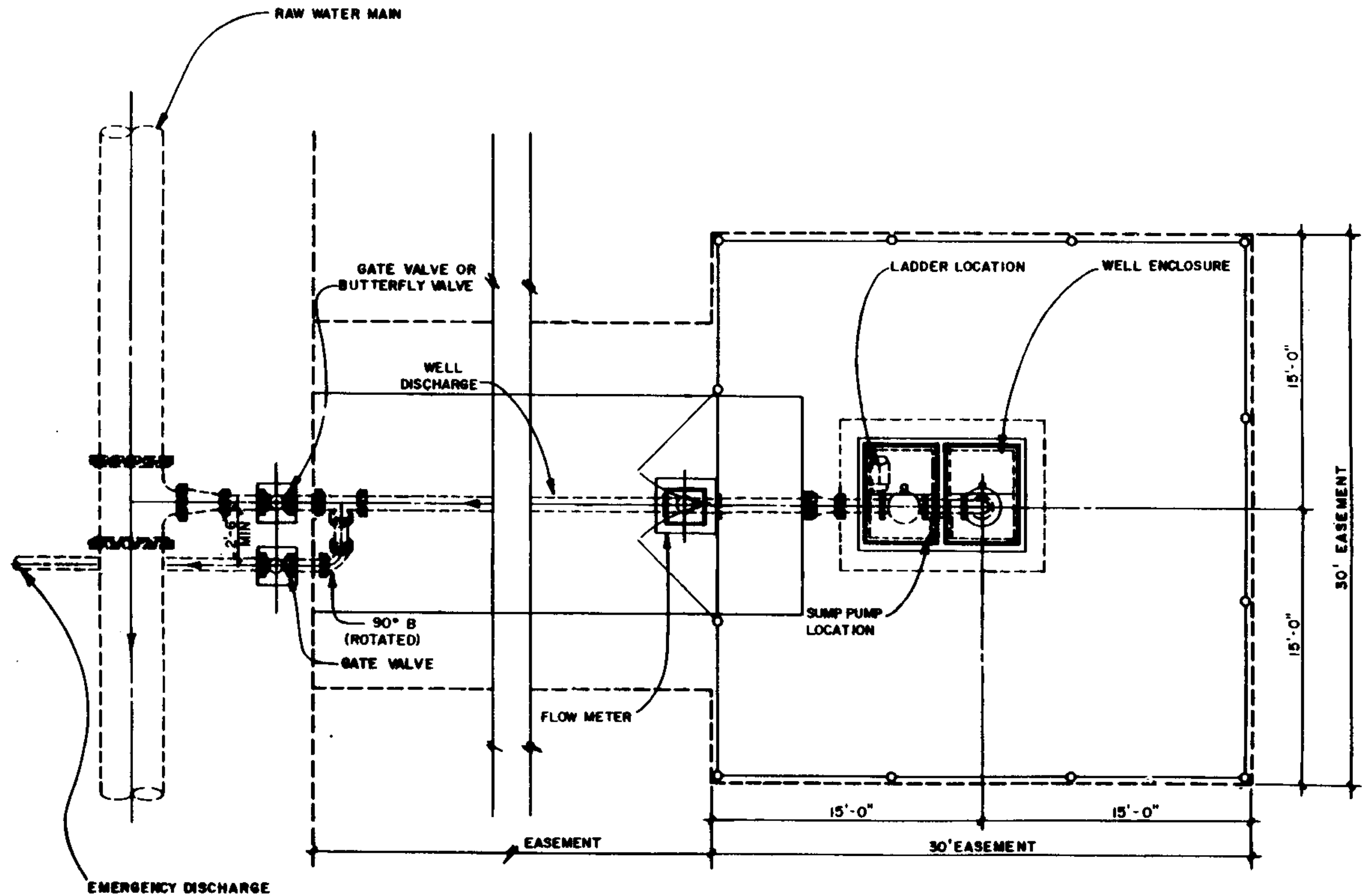
General Design Details
And Equipment Cut Sheets



WELL, TYPICAL

NTS

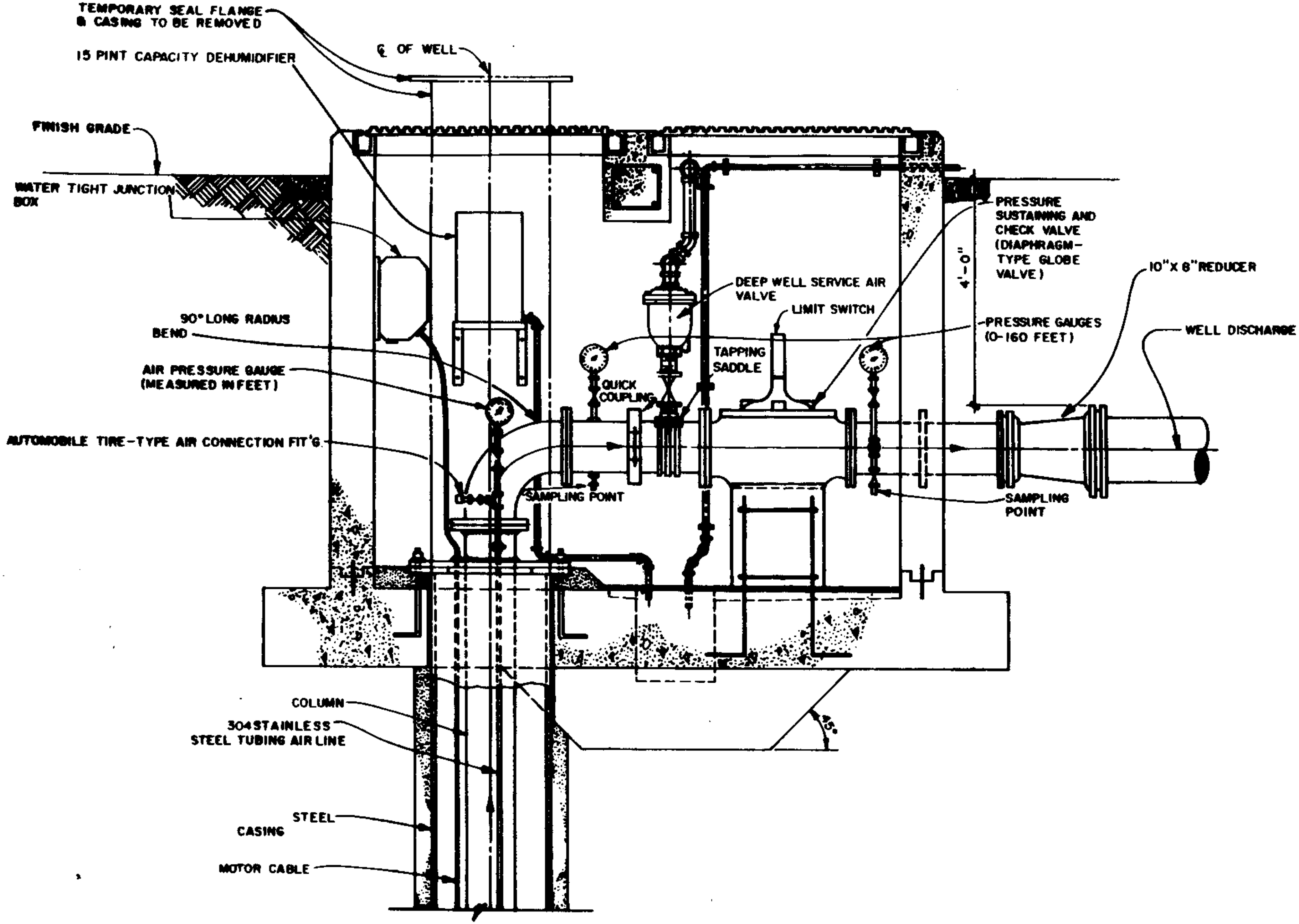
CDM



PLOT PLAN, TYPICAL

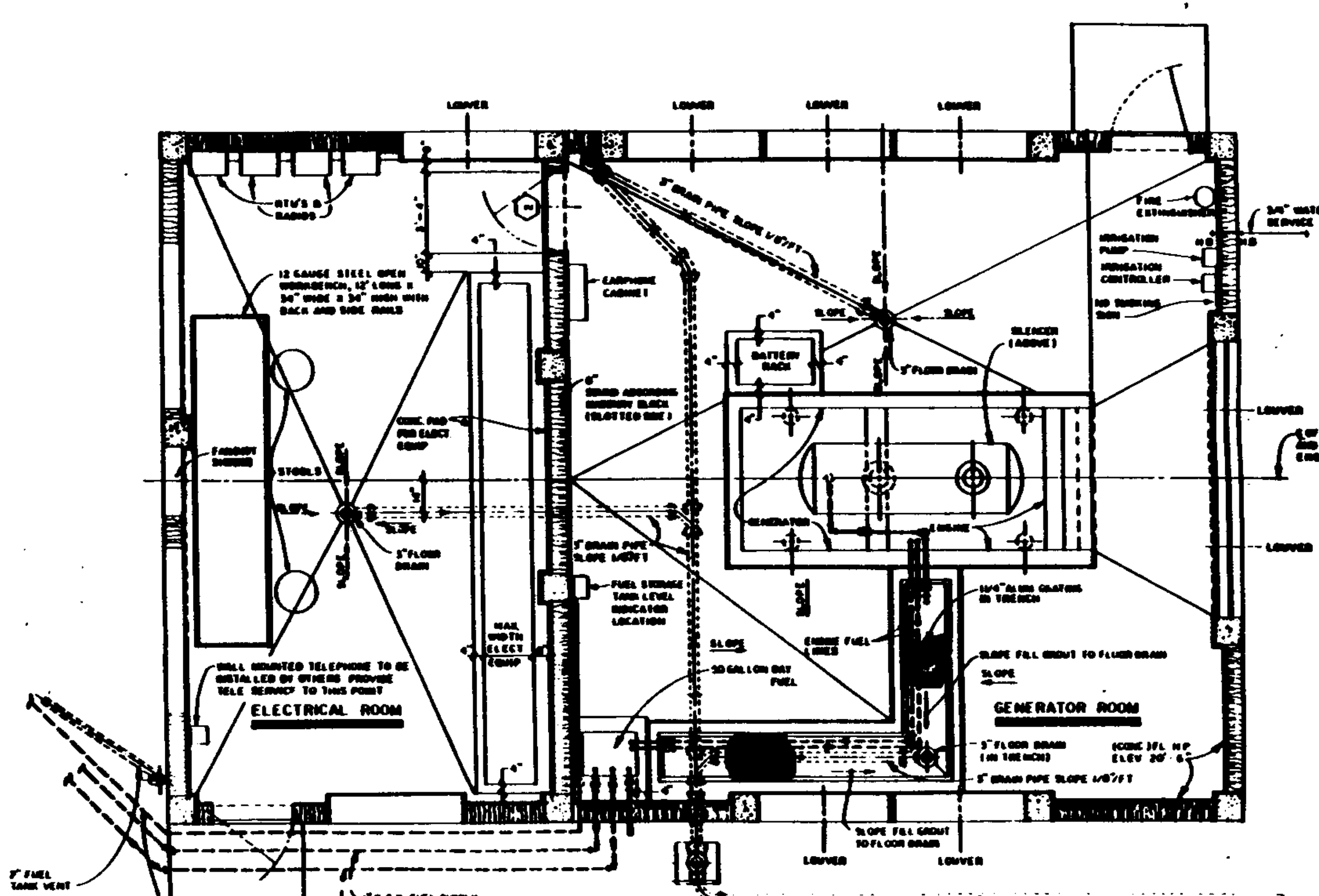
NTS

CDM



WELL VAULT, TYPICAL

CDM



FLOOR PLAN

GENERATOR BUILDING

NOT TO SCALE

CDM