TECHNICAL MEMORANDUM
April 1984

# PRELIMINARY EVALUATION OF THE GROUNDWATER MONITORING NETWORK IN COLLIER COUNTY, FLORIDA

Prepared for the

Big Cypress Basin Board

DRE 181

by

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SUMMARY

This report was undertaken in response to a growing concern over the usefulness of the existing regional groundwater monitoring network in Collier County as a resource management tool. The purpose of this study was: a) to classify all the existing U. S. Geological Survey monitoring wells by the aquifer which it monitors, b) identify major gaps and redundancies in the existing data base and to present preliminary recommendations for the redesign of the monitoring network, c) relate the function of the Saline Water Intrusion Monitor and Management (SWIMM) Program to the current USGS monitor network, and d) determine a format in which water level data can be used to identify problem areas rapidly by non-technical personnel.

The existing USGS monitoring network consists of seventy-four wells which provide water level and water quality data from four regional aquifers. The wells were classified by aquifer based on a knowledge of the regional hydrogeology and well construction details (Appendix I). Nearly one-half of the monitoring network is located around the City of Naples wellfield. The remaining 36 wells are located throughout the remainder of the County.

A generic technique known as kriging was used to determine the degree of uncertainty in a related spatial distribution scheme. This technique differs from other surface generating techniques such as trend analysis in that: a) the estimated value calculated by the model at each control point can equal the actual measured value,(i.e. an exact estimator) and b) the estimated values between control points are calculated in such a way as to minimize the variance. As a result, the model produces a more accurate representative surface while quantifying the uncertainty for every calculated elevation. The uncertainty values were used to identify data gaps in the existing monitoring network. The model was successfully used in locating

redundancies and data gaps in the water table aquifer, throughout much of the County, and for the lower Tamiami aquifer in the Naples area.

For some aquifers, there were too few wells to warrant modeling. In this case, the locations of additional monitoring sites were based on a conventional geographic distribution scheme. Numerical modeling of these aquifers using the data collected from the new monitoring stations are recommended for the next phase of the study, to be completed in two years.

Based on this study, a total of 62 additional wells are recommended to be added to the existing monitoring network throughout the western half of Collier County (Table 4). These are summarized as follows:

| | |
|---|---|
| Water Table Aquifer | 32 |
| Lower Tamiami Aquifer | 19 |
| Sandstone Aquifer | 5 |
| Mid-Hawthorn Aquifer | 6 |

Thirty-two of these wells have already been drilled by the South Florida Water Management District prior to this study and are available for monitoring. Seven of the original 74 USGS stations are recommended to be discontinued due to redundancies in the data collected.

A second statistical technique, known as time series analysis, was used to determine sampling frequency based on historical water level data from each station. This technique identifies trends in a series of time dependent variables and determines the amount of time which will pass before a predicted value will attain the maximum allowable error. This technique was used on continuous water level data from eleven wells. Based on the result of the analysis, four of these wells are recommended for monthly monitoring.

The SWIMM program is managed by the Resource Control Department of the South Florida Water Management District (SFWMD). Groundwater data collected from 178 monitoring wells are used to assess the local impacts of large groundwater users in coastal areas. The data are collected by the permittee and sent to the District for analysis. This program is independent of the regional network which is sampled and maintained by the USGS.

Expanded versions of the statistical methods used in this report can be developed into a user-friendly management tool. When applied to regional monitoring networks, these models would be capable of predicting water levels at any location in the County and specify the range of error for each predicted value. An unbiased regional water level map for each aquifer could also be generated. Areas where measured field values exceed a specified error criteria from the predicted value would be flagged, allowing managers to determine the probable source of the anomalies in the field and to take immediate action, if warranted.

## ACKNOWLEDGEMENTS

This report was prepared under the direction of Mr. Nagendra Khanal, Director of the Groundwater Division of the South Florida Water Management District, whose guidance and support is gratefully acknowledged. This investigation was greatly aided by the suggestions and editorial review of Aaron Higer, Deputy Sub-District Chief of the U. S. Geological Survey in Miami. Unpublished water level and water quality data for the 1982 water year was expeditiously supplied by Roy Sonenshein, also from the U. S. Geological Survey Miami office. The authors also wish to recognize the valuable data regarding the location and construction details of the existing U. S. Geological Survey groundwater monitoring network furnished by the U. S. Geological Survey office in Fort Myers under the direction of Henry LaRose.

Gratitude is extended to the members of Resource Control and Resource Planning staff of the South Florida Water Management District for their input into the editorial process. Recognition is made to Fred Vidzes and members of the Big Cypress Basin Board whose genuine concern over the groundwater resources of Collier County made the study possible.

## INTRODUCTION

The United States Geological Survey (USGS) has been collecting geologic and hydrologic data in Collier County since the early 1950's. Working out of the Ft. Myers Field Station, the USGS collects drill cuttings, geophysical data, groundwater elevations, and groundwater quality data in addition to stage data from major streams, lakes, and canals. This information is either turned over to the County as raw data in annual data releases or formalized and interpreted in technical reports. In addition, the USGS provides consultants and well drillers with long term, quality controlled data which is applied to local hydrologic studies.

The funding for these services is provided through a cost sharing cooperative between the federal government and state or local agencies. In 1976, the Big Cypress Basin Board (BCBB), which was formed to manage the water resources of Collier County, began providing major funding to the USGS. Funding for the 1983-84 fiscal year totaled $80,000 with the Basin Board and the USGS both contributing $40,000 each. This money is used for data collection, analysis, and maintenance of 13 surface water and 74 groundwater stations.

Recently, however, the Basin Board has expressed concern whether the U. S. Geological Survey is providing information from these monitoring wells in a usable form to support groundwater management decisions.

In a letter dated January 26, 1984, Fred Vidzes, the Basin Administrator, outlined three priority issues the Board feels the monitoring network should address. These include:

1. Monitoring the saltwater interface in coastal regions with specific concerns towards protecting the City of Naples wellfields and the Marco Island reservoir and Isle of Capri wellfield.

2. Determining the effect of development on the groundwater resources of the area. This incorporates local impacts caused by large scale users as well as monitoring the regional effects of surface drainage on recharge areas.
3. Determining a format in which trends and anomalies can be rapidly identified by a non-technical user so problem areas can be identified and investigated more rapidly.

This study examines the existing groundwater monitoring network and makes appropriate recommendations towards improving the data base in Collier County. Where possible, numerical techniques are utilized to determine areas of high uncertainty in the existing network and to determine optimum sampling frequency. Possible applications of these techniques toward developing a resource management model are also examined.

## PURPOSE AND SCOPE

The purpose of this evaluation is to:

1. Identify and summarize the existing USGS groundwater network (as of January 1, 1984) and to classify each well by the aquifer which it monitors.
2. Identify major gaps or redundancies in the existing data base.
3. Summarize the Saline Water Intrusion Monitoring and Management Program (SWIMM) which is managed by SFWMD and relate it to the USGS monitor network.
4. Present preliminary recommendations for the modification of the USGS network where necessary.
5. Determine a possible format in which the data can be used to identify problem areas rapidly by non-technical managerial personnel.

The complete evaluation and redesign of a regional monitoring network is a complex and time consuming task. It involves a detailed understanding of the regional flow system, the areal extent of each aquifer identified, and existing and future land use plans. This study considers only the areal extent of each aquifer and the regional flow system in defining areas which need additional data collection. As an upcoming report on the groundwater resources of Collier County may act to influence land use decisions, consideration of land use in this evaluation is limited only to areas of existing or potential municipal wellfields. The regional flow patterns were determined from the existing monitoring network and, due to the scarcity of data points outside of Naples, are considered very generalized. The proposed modifications made here represent the minimum effort needed to develop the existing network into a resource management tool.

Quantitative assessments using a regionalization technique known as kriging were made to determine the degree of uncertainty between stations. This analysis was performed on the water table aquifer for Collier County (excluding the Naples area) and on the lower Tamiami aquifer in the Naples area. Sampling frequency in these two regions was determined using statistical methods. Qualitative assessments were made of the remaining aquifers because the number of existing monitoring wells compared to the area did not warrant a numerical modeling approach. A conventional geographic distribution scheme based on the regional flow systems was used in these cases. No quantitative assessments of sampling frequency for water quality data were made in this report.

The time constraints on this report did not allow for the design of a "complete" monitoring network which would quantify and predict water levels and water quality on both the local and regional scale. Therefore, the recommendations in this "preliminary" investigation are directed toward providing a foundation upon which to develop a more comprehensive network in the future.

## HYDROGEOLOGY OF COLLIER COUNTY

Despite a large number of groundwater studies that have been undertaken in Collier County, the regional groundwater resources have yet to be defined. This has caused a great deal of confusion when dealing with the Collier County groundwater monitoring network. While the construction details of each monitoring well are known, the lack of detailed knowledge of the regional hydrostratigraphy makes it very difficult to identify which aquifer is being monitored or which monitoring wells are related. This problem is further complicated by inconsistencies in terminology. For example, the Coastal Ridge Aquifer, Tamiami Aquifer System Zone I, and the shallow artesian aquifer, all refer to a single aquifer which occurs throughout the western half of the County.

In order to clarify this problem, the SFWMD began a two year project to define and quantify the groundwater resources of the County (Knapp and Burns, 1984). In the initial phase of this project, the existing data base was assessed to determine areas requiring additional data collection. Over thirty monitoring wells were drilled to supplement the existing USGS network. These sites have not been destroyed and are available for permanent monitoring. The terminology used in this report will be presented in detail in the upcoming report.

The grouping of wells by aquifer was based on comparisons of well construction details with structure and isopach maps constructed for each aquifer. This information was supplemented with water level data and compared to potentiometric maps. In some cases the aquifer designations are considered tentative pending additional data and may be reassigned at a later date.

The lithologic units which underlie Collier County have been grouped into three major aquifer systems. These systems are the Surficial Aquifer System, the Hawthorn Aquifer System, and the Floridan Aquifer System. Each system is further divided into aquifers or producing zones, and confining zones based on the hydraulic properties of each rock unit. A generalized hydrostratigraphic column for Collier County is shown in Figure 1.

The Surficial Aquifer System is composed of two high yielding producing zones separated by a semi-confining clay layer. The uppermost producing zone is the water table aquifer which occurs throughout the County. This aquifer is unconfined and receives direct recharge from surface percolation. In coastal regions the aquifer is in direct contact with seawater and is susceptible to saline intrusion. The aquifer is composed of medium grained unconsolidated sands which overlie well lithified biogenic limestones and sandstones of the Anastasia, Fort Thompson, and upper Tamiami Formations. In areas where aragonitic shells have been dissolved by groundwater, high secondary porosities have developed making the unit capable of storing and transmitting large quantities of water. Thickness for the aquifer ranges from 10 to 75 feet.

The water table aquifer is confined below by the Tamiami confining zone. The Tamiami confining zone is a tan to grey calcareous clay facies within the Tamiami Formation. The unit is regionally extensive throughout much of southern Lee and Collier Counties. It is thin, ranging between 10 and 30 feet, and is considered to be leaky in most areas allowing vertical recharge to occur.

Below the confining zone is the lower Tamiami aquifer. This aquifer consists of white biogenic limestones which grade into greenish medium grained sandstones to the east. The aquifer is characterized by well-developed moldic porosity and is very productive in the western half of Collier County (City of Naples and Golden Gate Wellfields). To the east the amount of sand increases and well yields decrease. The unit ranges in thickness from 50 to 100 feet. Water quality is generally good with the exception of localized

**STRATIGRAPHY** / **HYDROSTRATIGRAPHY**

| SYSTEM | SERIES | FORMATION | LITHOLOGY OF HYDROSTRATIGRAPHIC UNITS | SYSTEM | UNIT |
|---|---|---|---|---|---|
| Quaternary | Holocene to Pleistocene | Undifferentiated Anastasia Fm Ft. Thompson Fm | Upper portion consists of medium to fine grained subangular quartz sand. Lower part consists of biogenic sandy limestones that are sometimes coralline and exposed at the surface. The unit ranges in thickness from 20 to 75 [illegible] | Surficial Aquifer System | Water Table Aquifer |
| Tertiary | Pliocene | Tamiami Formation | Very sandy calcareous [illegible] thickness [illegible] feet. | | Tamiami Confining Zone |
| | | | Sandy biogenic limestones with minor percentage of dolomite. Grading into a well cemented medium grained sandstone at depth. Thickness ranges from 20 to 130 feet. | | Lower Tamiami Aquifer Zone |
| | Miocene | Hawthorn Formation | Clayey and sandy phosphatic dolosilts. Coarse clastics occur at top and are sometimes interbedded throughout the section. Normally less than 90 feet thick. | Hawthorn Aquifer System | Upper Hawthorn Confining [redacted] |
| | | | Sandy limestones and calcareous sandstones interbedded with medium to coarse quartz sand. The unit is thickest in Immokalee and pinches out to the south. | | Sandstone Aquifer |
| | | | Clayey and sandy phosphatic dolosilts. Usually around 150 feet thick. Sometimes interbedded with sandy phosphatic limestones. Rubble bed at base. | | Mid-Hawthorn Confining Zone |
| | | | Sandy and phosphatic dolomitic limestones. Thickness varies from 30 to 100 feet. Gradational into lower confining zone. | | Mid-Hawthorn Aquifer |
| | | | Interbedded limestone, dolomite and dolosilt being sandy and phosphatic throughout. Normally ranges from 200 to 400 feet in thickness. | | Lower Hawthorn Confining Zone |
| | | Tampa Limestone | Biogenic, micritic and very fine grained limestone being sandy and slightly phosphatic throughout. Less than 75 feet thick. | Floridan Aquifer System | Lower Hawthorn/ Tampa Producing Zone |
| | Oligocene | Suwannee Limestone | Medium grained, moderately indurated, biogenic calcarenite with minor percentages of quartz sand. Ranges from 200 to 450 feet in thickness. | | Suwannee Aquifer |

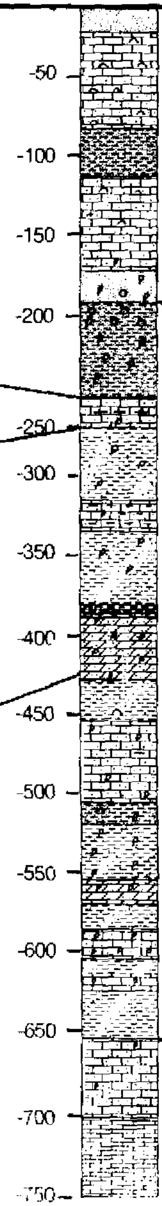



**Figure 1 Generalized Hydrostratigraphic Column For Collier County, Florida**

areas of brackish connate water. This aquifer is extensively monitored in the Naples area but is sparsely monitored throughout the remainder of the County.

The lower Tamiami aquifer is confined below by the upper Hawthorn confining zone. This confining zone consists of dark green dolosilts interbedded with coarse grained quartzite sand. The zone occurs throughout the County except in the Immokalee area where the lower Tamiami aquifer and the underlying Sandstone aquifer converge. The upper Hawthorn confining zone is thicker and more competent than the Tamiami confining zone and leakage is generally less.

Beneath the upper Hawthorn confining zone is the Sandstone aquifer. This aquifer is composed of sandy biogenic dolomites interbedded with medium to coarse quartz sand. The Sandstone aquifer is extensive throughout the eastern half of Lee County and Hendry County, however, it pinches out to the south near SR 84 in Collier County. This aquifer is used extensively for agriculture in northern Collier County where the unit is over 75 feet thick and is also tapped by the Immokalee Wellfield. Although the water in this aquifer is generally more mineralized than water in the shallower aquifers, water quality is usually within potable supply standards.

The Sandstone Aquifer is confined below by the mid-Hawthorn confining zone. This confining zone consists of olive dolosilts with up to twenty percent phosphatic sand. The confining zone is thickest south of SR 84 where it grades into the upper Hawthorn confining zone and attains thicknesses over 300 feet. The base of this unit is characterized by a high gamma emitting phosphatic rubble bed which is identified on borehole geophysical logs.

Beneath the rubble bed, at depths between 300 and 400 feet, is the top of the mid-Hawthorn aquifer. The aquifer consists of light grey medium grained sandy phosphatic limestones and dolomites. Fossil content is generally low and porosity is mostly intergranular and moldic. Artesian head pressures are sufficient to cause mid-Hawthorn wells to flow at land surface. Typically, well yields are less than 100 gallons per minute. Water quality is generally good in northern Collier County except in areas contaminated by short-cased Floridan wells or abandoned oil test wells. The mid-Hawthorn aquifer is seldom used due to the abundance of high yielding freshwater aquifers at shallower depths.

The mid-Hawthorn aquifer is confined below by a thick sequence of interbedded lime muds and dolosilts known as the lower Hawthorn confining zone. Beneath this confining zone are the high pressure, saline waters of the Floridan Aquifer System. The top of the Floridan in Collier County occurs between 500 and 700 feet below land surface. The Floridan Aquifer System is a thick (over 2500 feet) sequence of medium grained limestones and dolomites. This aquifer is extensively developed in north central Florida, but is very saline to the south and dissolved chloride concentrations frequently exceed 1000 mg/l. Despite yields of over 1000 gpm by natural flow, the aquifer is not developed in Collier County due to the high chloride levels.

## METHODOLOGY

Portions of the water table and lower Tamiami aquifer monitoring networks were statistically analyzed to identify areas of maximum and minimum uncertainty. These extremes would indicate where existing monitoring stations could be deleted or new stations should be added. The water table was chosen for preliminary modeling because it most directly impacted by development. In addition, in several areas of the County, the water table aquifer has a large potential for development, such as in the Corkscrew Swamp and south Naples areas. The lower Tamiami aquifer was modeled only in the Naples area where a disproportionately large number of monitoring wells are located around the City of Naples wellfields.

### Kriging

A major purpose of establishing a monitoring network is to adequately describe the variable monitored over the entire area of interest. Projecting point measurements over a larger area involves estimating values between observation points. Traditionally, this is accomplished by generating a visually estimated contour map from the monitored points and approximating a value between adjacent contour lines. However, the accuracy of such an estimate is always in question and the production of such maps requires an intimate knowledge of the local hydrologic regime. A regionalization technique known as kriging (Shriven and Karlinger, 1980) can provide unbiased estimates of the given variable (groundwater levels) in such a way as to define and minimize the variance at each node on the model grid. Kriging differs from other surface generating techniques such as trend analysis, in that while both make interpolative estimates of values between observation points, kriging matches the estimated value with the actual measured value for each data collection point. The result is a more dynamic surface which more closely represents the actual field observations.

There are four components to the kriging model as applied in this study. The first generates a large scale trend surface over the study area. This is a regional surface whose elevation and dip is based on the mean field values. The second component is to generate a semi-variogram, which expresses uncertainty as a function of distance, from the residuals of the observed values from the trend surface. The third component uses the semi-variogram in the kriging to estimate values at unobserved points and to quantify the estimation variance at the same time. The fourth component of the model generates maps of: (a) the "best" estimates of groundwater level, which is the result of trend values modified by kriged residuals (trend plus krige), (b) the estimated uncertainties, and (c) the percent error at each node.

The input data consisted of semi-annual water level data collected from 10/77 to 4/82. From these data, two values were calculated; the mean and the variance. The mean ($\mu$) is described as the sum of the measurement divided by the number of measurements :

$$\mu = \sum_{i=1}^{n} x_i/n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where $x_i$ represents an individual measurement value.

The variance ($\sigma^2$), is the square of the standard deviation ($\sigma$) where:

$$\sigma^2 = \sum_{i=1}^{n} (x_i - \mu)^2/n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The standard deviation describes the spread or deviation of values about the mean.

The kriging model was run twice in each study area. One run used the mean value, the second used both the mean and variance values calculated for each station. In the second case, the model treats variance as measurement error.

The output data, using only the mean for each control point, located the areas of maximum uncertainty in the geometric center of surrounding control points. This is because all the mean values had zero uncertainty making the area of highest uncertainty occur at equal distances from the surrounding control points. Running the model using variance data gave each control point an initial uncertainty based on the degree of water level fluctuation over the five year period. As a result, areas of maximum uncertainty are located closer to control points having the highest initial variance. When the variance was high for all surrounding control points, the magnitude of the uncertainty in the center increased. It is felt that the model runs using the mean combined with the variance produced the most realistic assessment of uncertainty and these results provided the basis for the recommendation.

Time Series Analysis

A statistical technique generally known as time series analysis was attempted to determine an optimal water level measurement frequency for wells monitoring the water table aquifer and the lower Tamiami aquifers. Time series models identify trends in a series of time dependent variables and determines the amount of time which will pass before a predicted value will attain the maximum allowable error.

There are many methods in which historical water level data are used to predict future water levels. The simplest one is known as a mean model in which a data set is described by one value (the mean). The mean is then used as a prediction of water levels at any time in the future (Figure 2A). The amount of error associated with a predicted value using a mean model, is constant and independent of time and can be described by the standard deviation of this series. The actual value will fall within the range of plus or minus one standard deviation 68% of the time. At some time in the future, another water level measurement can be made and the mean recalculated.

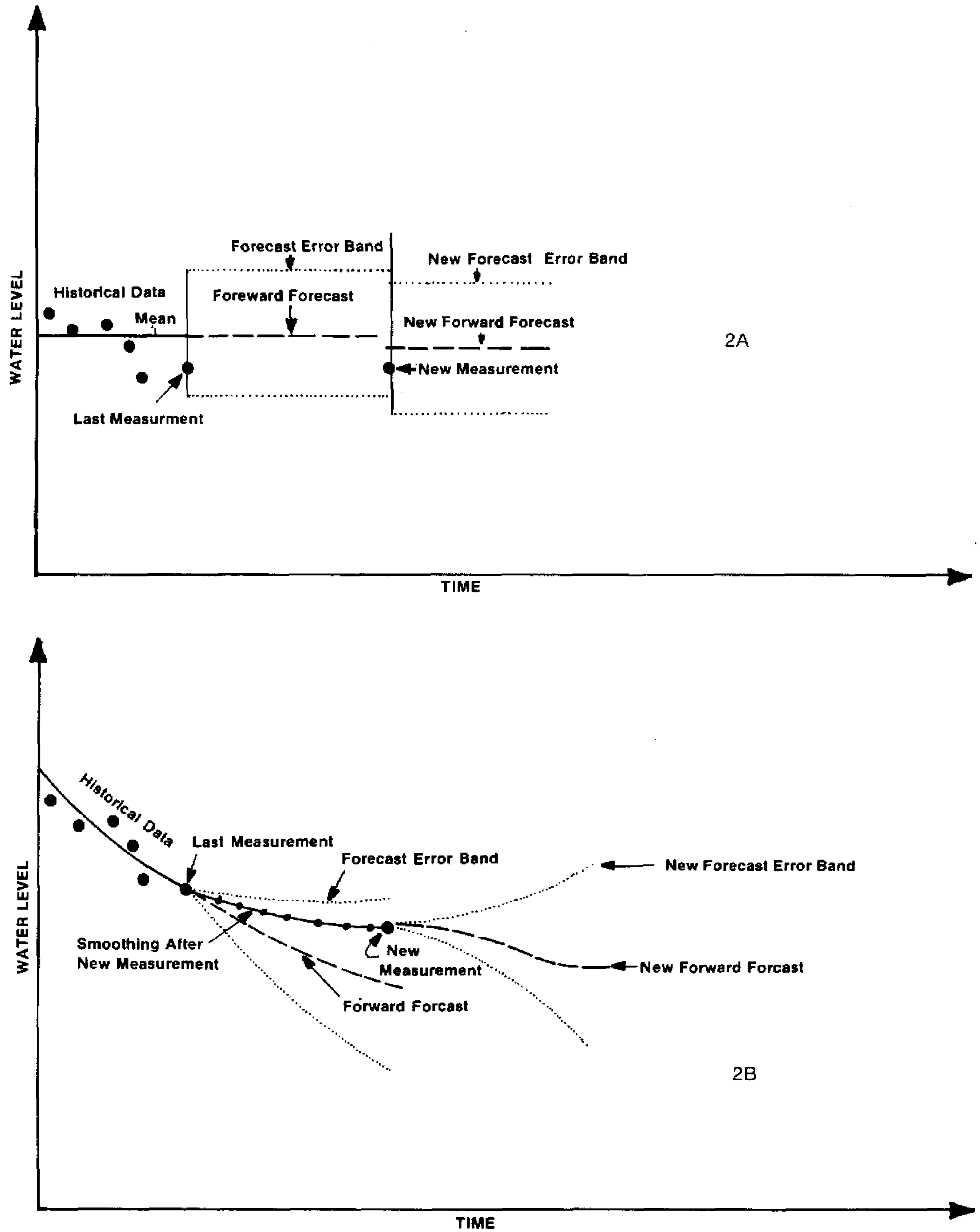



**Figure 2 Error Description For Water Level Forecast Models**

However, the error associated with the next prediction will remain constant as before.

A more dynamic method of predicting water levels is through the use of time series analysis. This model identifies trends in the data set along with describing the variations from the trends. The error associated with a forecast model is time dependent with the magnitude of error increasing with time and approaches infinity (Figure 2B). Therefore, at some time after the last data reading, $t_{max}$, the error will equal that associated with the mean model. At any time prior to $t_{max}$, the error will be less. Once new data are collected and the model adjusted, the degree of error is reduced to the accuracy of the measurement and the cycle begins again. By specifying an error criteria in terms of standard deviation, a determination of sampling frequency can be made.

In this study the Box-Jenkins Time Series Models (W.J. Dixon, et al. 1981) were used to describe temporal trends and to predict optimal sampling frequency for eleven monitoring stations. This study dealt with each monitor station as a single series. A regional model, where the relationship of the stations to each other is included, is recommended for future development. Water level data sampled every five days from April 1976 to October 1982 was used as input for the models. Rainfall data, which is a major cause of water level fluctuations, was not input into the analysis due to the time constraint on this study. When developing a predictive model for the County, these data will be used. The error criteria specified in this study was one-half of the standard deviation of each series. While improving the error criteria would further improve the accuracy of the forecast, the cost of collecting the data may not justify the marginal reduction in error. Development of an optimal forecast model can make the entire data collection and monitoring effort far more cost-effective.

This same technique was attempted for the lower Tamiami aquifer in the Naples region. Only 17 months of monthly data had been collected from these stations, prior to that many stations were sampled semi-annually. As a result of the limited data, the Box-Jenkins time series analysis could not be applied. Nine stations located along the periphery of the study area were selected and statistically compared with the only station in which continuous data was available.

A ranking system was developed based on the degree or variance from each station and from a correlation matrix which described the similarities between stations. Stations with high variance are first selected as monitoring "seed" stations. Some of these "seed" stations are then further eliminated among themselves when low correlation exists between a seed station and the remaining stations. Geographical distribution of the stations was also considered in the final recommendation of the monitoring network.

## QUANTITATIVE ANALYSIS OF THE WATER TABLE AQUIFER, COLLIER COUNTY

The area modeled is located between latitudes 26°32'00" and 25°56'00" and longitudes 81°46'00" and 81°15'00" (Figure 3). The model boundaries extended into portions of Lee County and included four Lee County monitoring wells located near the county line. The area modeled did not include the eastern half of Collier County (east of the Hendry-Collier County line) because only one data point (C-54) existed in this region. The City of Naples area also was deleted because the major interest in that area is in the lower Tamiami aquifer (see next section). A square grid of 45 seconds (approximately 4275 feet per side) was used in the evaluation.

The regional flow pattern determined by the kriging model based on data provided solely from the existing monitoring network, is shown on Figure 3. Stage data from major canals were not included in this preliminary study. The direction of flow is from north to south with a shift towards the west along the coastal region. The highest groundwater elevations, predicted over 40 feet msl, occur northeast of Immokalee in Hendry County. Land elevations in this region are approximately 35 feet msl. The lack of any control points here causes the model to extrapolate the elevations for this region. Hydraulic gradients are greatest adjacent to the Coastal Ridge near Naples. Regions of low hydraulic gradients occur to the southwest (Fakahatchee Strand) and along the Corkscrew Swamp. Both locations are considered as major recharge and storage areas for the water table aquifer.

Results generated by the semi-variogram function of the kriging model were used to identify the areas of uncertainty which are shown on Figure 3. Zone I occurs along the southeast portion of the study area roughly paralleling US 41 from Gordon Pass to SR 29. Of principal concern in this region are the water levels in the vicinity of the Marco Island Pit and the Isle of Capri wellfield (Figure 4). In addition, east of the Marco Island Pit is an area of high

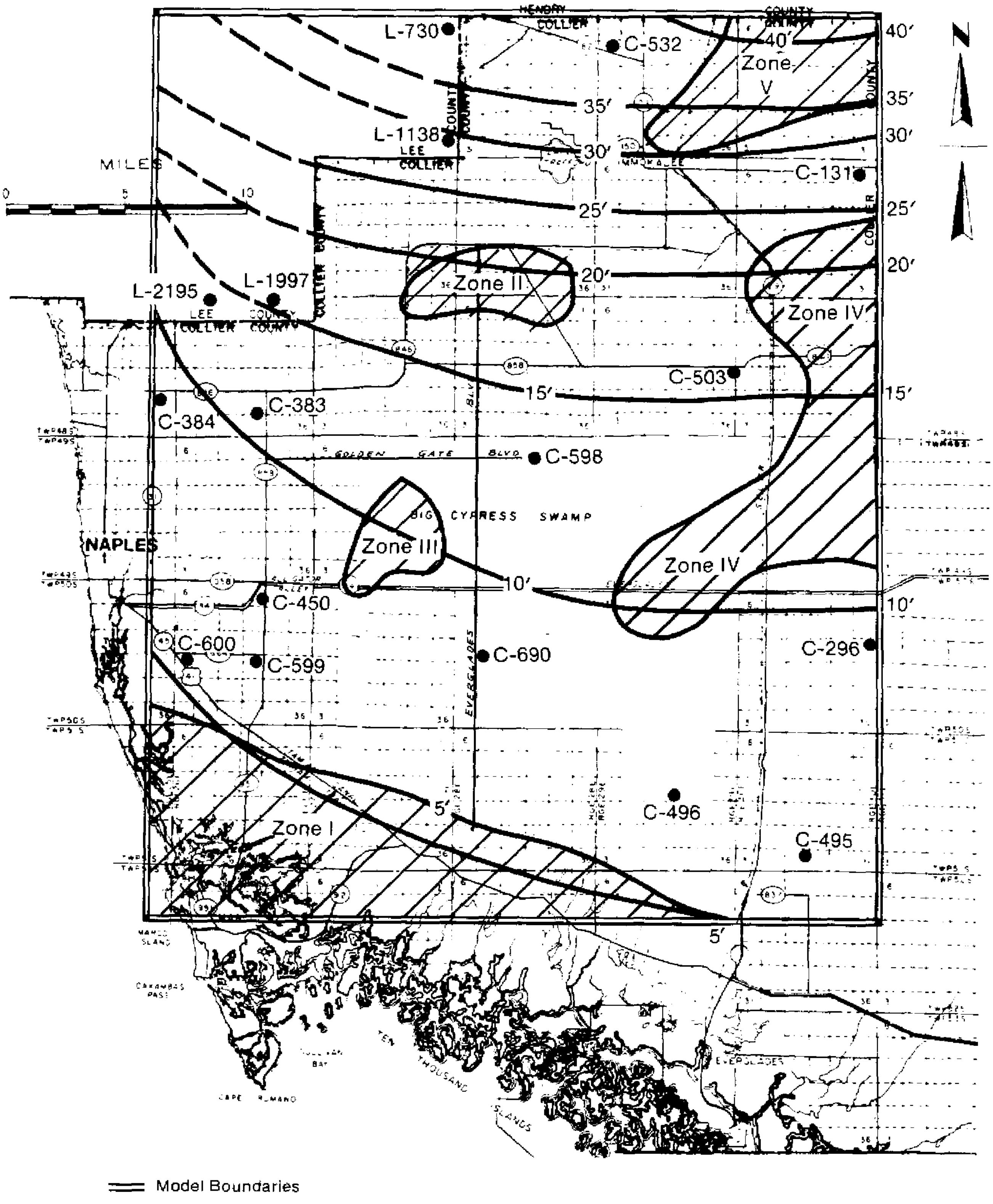





**Figure 3 Identified Regions of High Uncertainty Within the Existing Water Table Aquifer Monitoring Network**

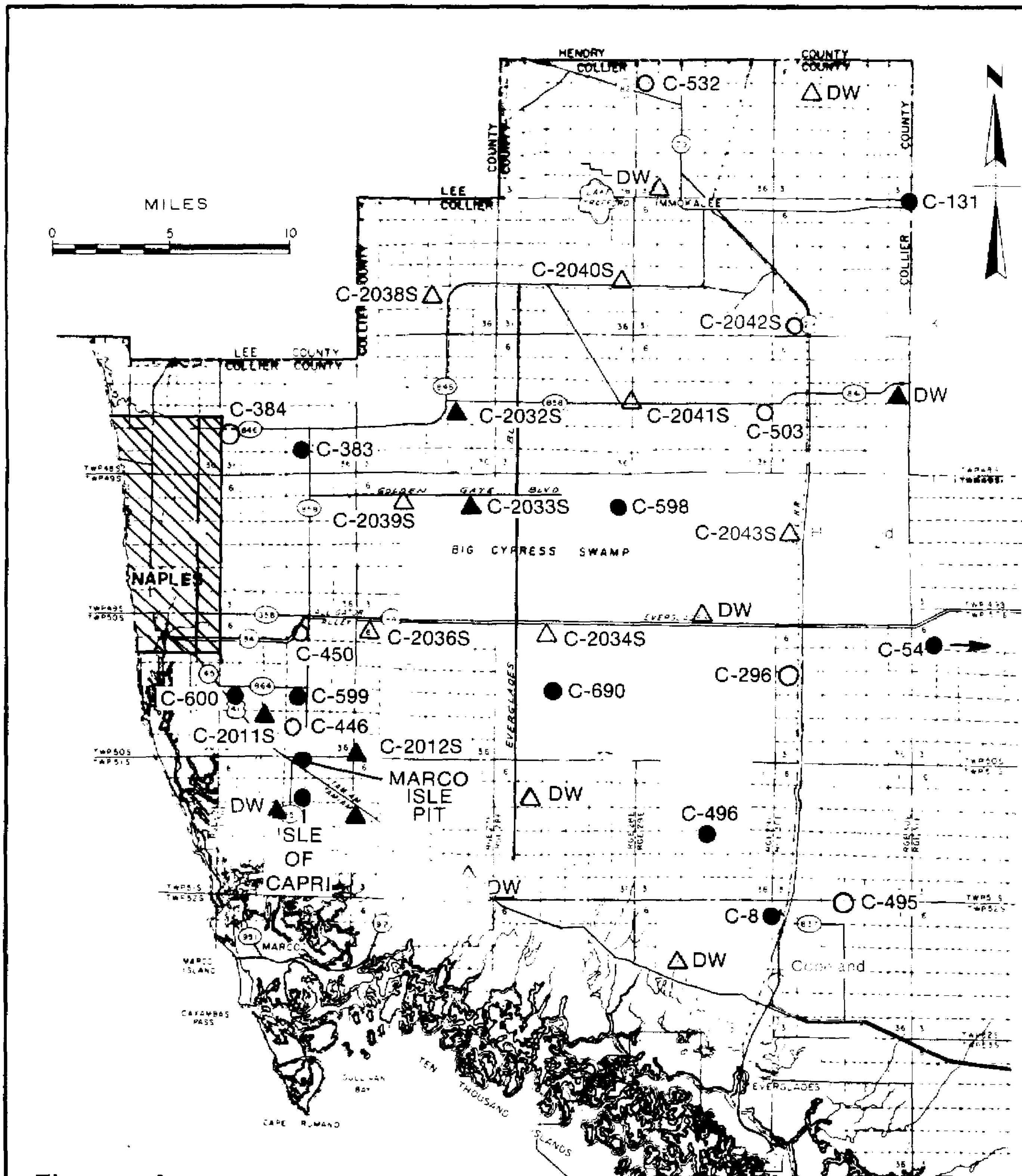



**Figure 4**

Collier County Water Table Aquifer Monitoring Network

○ Existing Site; Monthly Water Level, Semi Annual Water Quality

● Existing Site; Continuous Water Level, Semi Annual Water Quality

△ Proposed Site; Monthly Water Level, Semi Annual Water Quality

▲ Proposed Site; Continuous Water Level, Semi Annual Water Quality

DW Proposed Site; To Be Drilled

transmissivity (Jacob, 1983) which represents a possible future source of groundwater. For these reasons, it is recommended that a monitoring well be drilled in Belle Meade down gradient from the Marco Island Pit and the Isle of Capri Wellfield. As water levels may be influenced by both pumpage and tidal fluctuations, a continuous water level recorder should be installed initially. Data from three existing monitoring stations, C-2011, C-2012 and C-2013 owned by the Water Management District, should be incorporated into the regional network.

In addition, a minimum of two wells north of US 41 should be drilled to the east of Marco Island; one near Royal Palm Hammock and the second approximately five miles west of Copeland. A third well should be drilled approximately five miles south of C-690 and is recommended as a monthly monitoring site.

Zone II occurs at Big Corkscrew Island roughly up gradient from an area currently being considered for a municipal wellfield site. Presently, there are four existing wells, drilled by SFWMD, which surround Zone II. These stations are C-2032S, C-2038S, C-2040S, and C-2041S. The recommended measuring frequency for these stations is a minimum of once per month. More frequent measuring may be necessary if the water table aquifer is developed for municipal supply in the region.

Zone III occurs down gradient from the Golden Gate Wellfield in central Collier County. Four SFWMD test wells, C-2039S, C-2033S, C-2036S, and C-2034S border Zone III and are recommended for monitoring. Water level data for stations C-2036S, C-2034S, and C-2039S should be collected at a minimum of once per month; however, station C-2032S should be monitored continuously at first. This is due to the high variance calculated for nearby station C-598 which may be caused by withdrawal from the wellfield.

Zone IV occurs generally east of SR 29 between SR 84 and Immokalee. Agricultural interests dominate this region and groundwater requirements are substantial. Two existing monitoring wells, C-2042S located at Owl Hammock and C-2043S located near Hog Island, are recommended to be added to the network. In addition, a well located off SR 84 at the county line and another well located on SR 84 approximately four miles west of SR 29 should be drilled. Water levels for all but the well on SR 84 should be measured on a monthly basis. The well on SR-840 should be monitored continuously.

Zone V occurs in the northeastern corner of the County. This area is also influenced by agricultural interests; however, most of the groundwater used comes from deeper, more productive aquifers. A well constructed in this region is recommended to determine maximum elevations for the water table aquifer. The construction of this station is considered a lower priority.

The optimal sampling frequency for nine water table wells which collect continuous water level data were determined using the Box-Jenkins time series analysis. The results of this analysis are summarized in Table 1. All wells with a recommended sampling frequency of four weeks or less should be monitored continuously (C-131, C-496, C-392, and C-489). As development of the water table aquifer along the Cocohatchee Swamp would possibly influence C-383, it is recommended that this station be monitored continuously also. The remaining wells C-495, C-296, C-503, and C-384 can be monitored on a monthly basis and their recorders used on other wells.

Results from this exercise indicate that consideration of water level variance alone to determine relative sampling frequency can be misleading. This is demonstrated by station C-296. This station occurs in the middle of the Fakahatchee Swamp and is undisturbed by development. The standard deviation is greatest for this station. Although the magnitude of the seasonal fluctuations are large, the fluctuations are nearly constant and are

TABLE 1: SUMMARY OF TIME SERIES ANALYSIS FOR SELECTED WATER TABLE MONITOR WELLS

| Well No. | Recommended Sampling Frequency | Maximum Sampling Frequency | Mean (ft. msl) | Standard Deviation |
|---|---|---|---|---|
| C-131 | 2 weeks | 2 months | 23.2 | 1.6 |
| C-383 | 4 weeks | 6 months | 9.6 | 1.7 |
| C-503 | 4 weeks | 6 months | 15.9 | 1.6 |
| C-495 | 6 weeks | 6 months | 4.7 | 1.3 |
| C-496 | 3 weeks | 3 months | 6.5 | 1.7 |
| C-296 | 8 weeks | 6 months | 9.6 | 2.3 |
| C-392 | 2 weeks | 2 months | 6.5 | 0.9 |
| C-489 | 2 weeks | 2 months | 4.1 | 2.1 |
| C-384 | 6 weeks | 6 months | 7.3 | 1.4 |
| L-730 | 5 weeks | 6 months | 26.7 | 1.2 |

easy to predict. In contrast, C-392, which is located in Naples, had the lowest standard deviation value. Water levels in this station are affected both by downward leakage caused from pumping the underlying aquifer and rainfall. As a result, although of less magnitude, the water levels behave more erratically and require frequent measurement.

Generally, more frequent monitoring should be applied in areas where water levels are suspected of behaving erratically. For all new monitoring stations in which the behavior of the water levels is unknown, water levels should be measured continuously. This may not be financially feasible. Therefore, based on the data shown in Table 1, therefore, a sampling frequency of once every two weeks will most likely meet or exceed the recommended error criteria. If maintaining such a sampling frequency is still not feasible, a less frequent schedule of one measurement per month can be applied. Less than one measurement per month is not advised.

## QUANTITATIVE ANALYSIS OF THE LOWER TAMIAMI AQUIFER, NAPLES AREA

A quantitative evaluation of the lower Tamiami aquifer using the kriging model was done in the Naples area. Input data consisted of semi-annual water level data collected from 28 stations between October 1977 and April 1982. A square grid of five seconds (approximately 475 feet per side) was used. Two model runs were completed and compared. One used the mean calculated from the data recovered from each station, the second used the mean and variance values.

The location of the modeled area along with the location of the existing wells is shown on Figure 5. The contour lines shown were generated by the "trend plus krige" analysis from the monitoring well data above. This surface differs from conventional potentiometric maps of the areas because water levels from the pumped wells were not used. To reflect the aquifer responses around a wellfield, a subroutine can be added which will calculate water levels in pumped wells given the discharge rate. It is significant that the one foot contour line located in the southern end of the wellfield is not closed in the model due to a lack of data off the coast. Most contour maps of the area estimate that this contour is closed somewhere off the coast, however, data are not available to quantify the seaward extent of this depression.

Comparison of the uncertainty maps derived using mean values versus the mean and variance show major discrepancies in the northern half of the study area. The model run with the mean values alone showed very low uncertainty throughout the region, indicating large redundancies in the data base. In contrast, uncertainty was much greater over the area using the mean and variance as input data, especially north of SR 896. This is related to the range and trend in variance values calculated for each station in the monitoring network. In the southern portion of the study area, where water

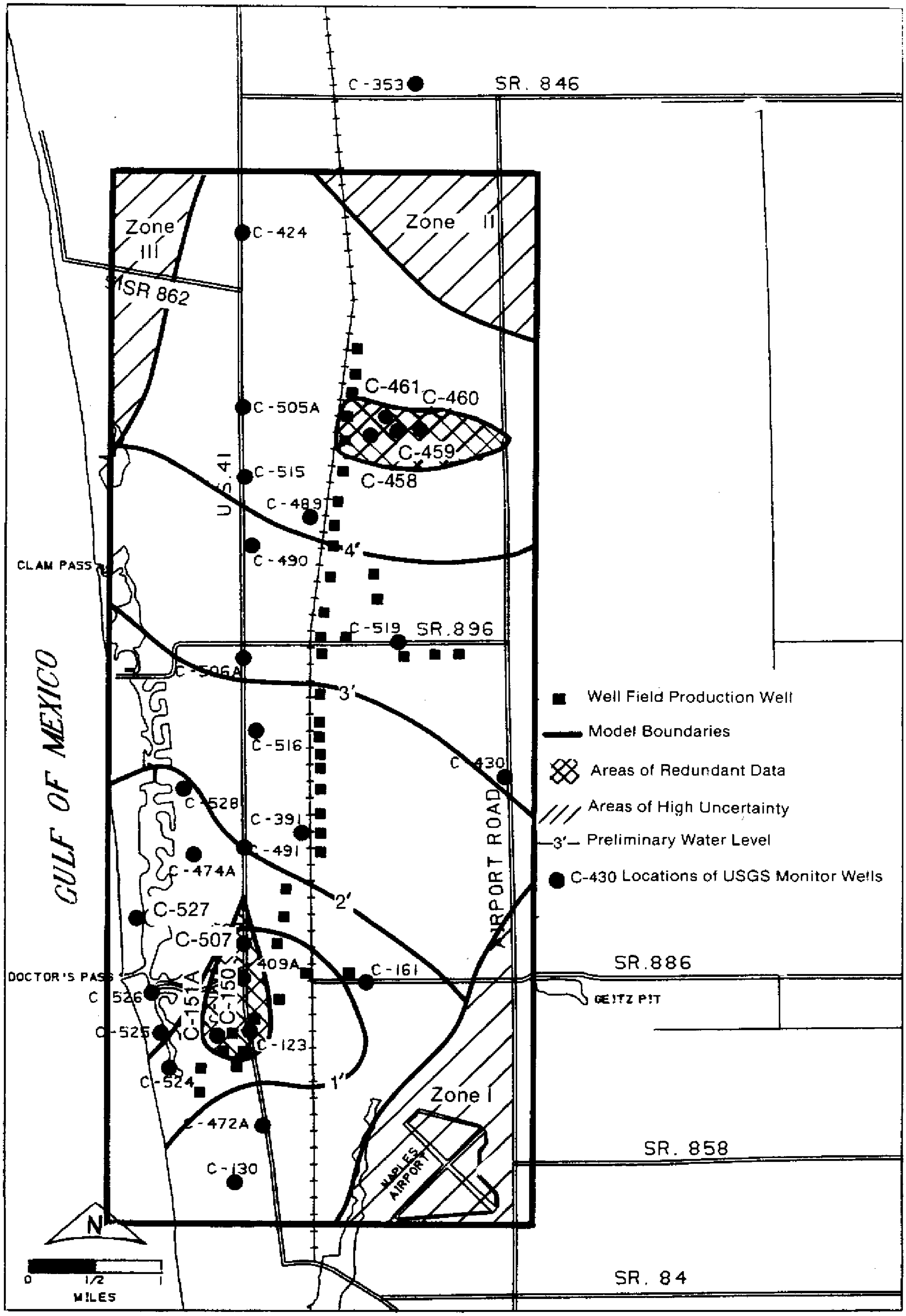



**Figure 5 Identified regions of High and Low Uncertainty Within the Existing Lower Tamiami Aquifer, City of Naples**

levels are influenced by constant pumpage, the calculated variance was low. However, towards the north, where the drawdown is less, the variance increases. Water levels in the northern portion of the study area fluctuate over four feet between wet and dry seasons. As a result, uncertainty values calculated, based on mean and variance input data, are considered more reliable and provide more accurate information for discrimination of monitoring points.

From the uncertainty map generated from both model runs, two regions of redundant data were identified. From this information and review of the actual water levels, the following stations are recommended to be discontinued: C-150, C-151A, C-507, C-459 and C-461. Although these stations would not be required as part of a regional network, they might still prove useful for monitoring drawdowns in the City of Naples under the SWIMM program. Therefore, these stations should be preserved.

Areas of high uncertainty were also identified. In Zone I, a monitoring well should be constructed near the intersection of SR 858 and Airport Road. The recommended monitoring network for the lower Tamiami aquifer in the Naples area is shown on Figure 6. In Zone II, a well should be located approximately one mile south of SR 846 on Airport Road. The data provided by these wells will help define the eastward extent of the cone of influence generated by the wellfield. A station at Zone III is considered a lower priority at this time; however, if increased pumpage should expand the cone of depression to the north, coastal monitoring wells in Zone III will be necessary.

A quantitative analysis of the water level data collected from the lower Tamiami aquifer in the vicinity of the Naples Wellfield was attempted to determine the optimal measurement frequency. Water level data is collected continuously from two stations in Naples (C-391 and C-392), and a time series analysis was run for these stations. The analysis of station C-391 which

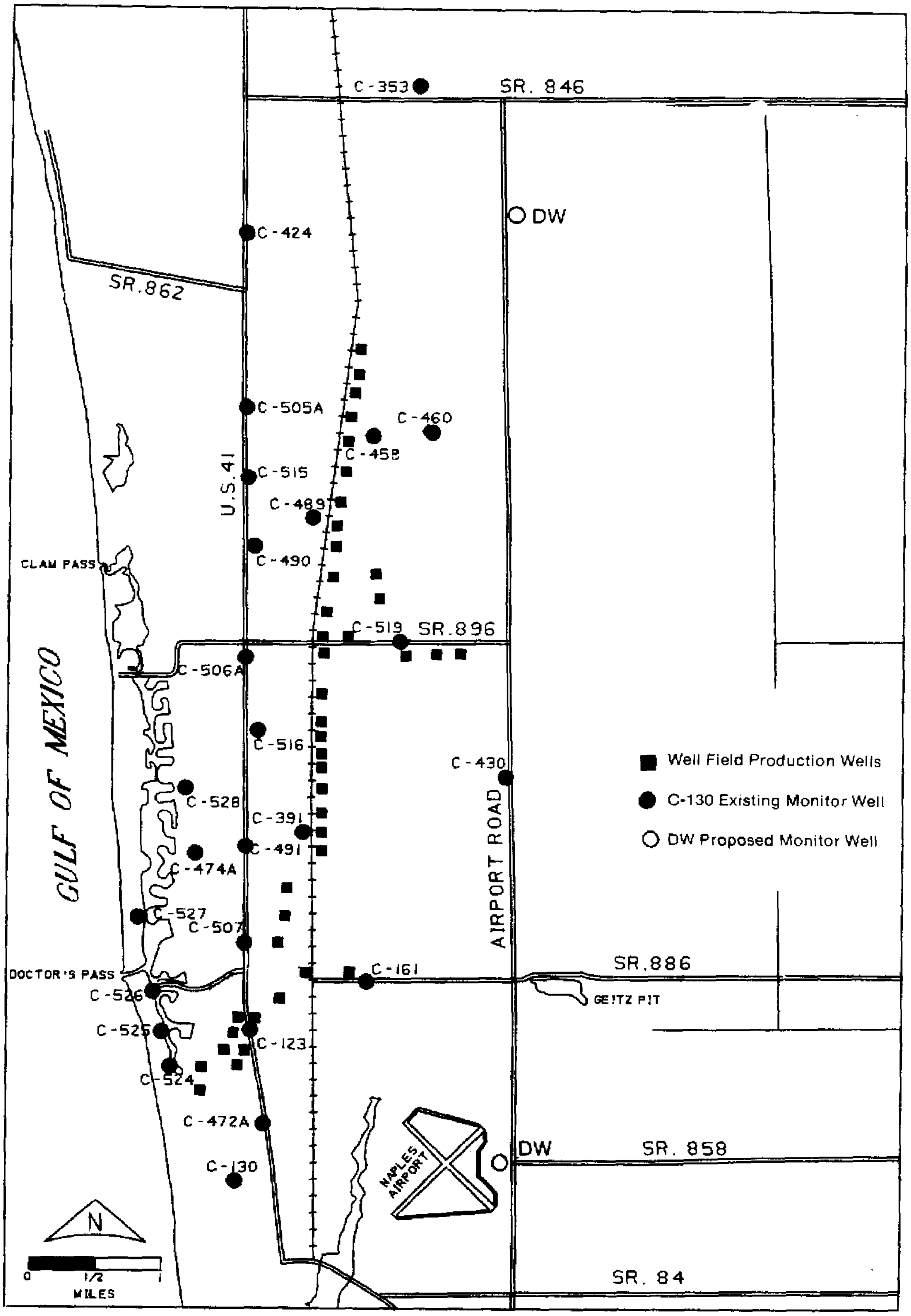



**Figure 6 Recommended Lower Tamiami Aquifer Monitoring Network, Naples Area**

monitors the lower Tamiami aquifer indicates a necessity for continuous monitoring. This is because C-391 is located in the wellfield and water level fluctuations are erratic due to varying pumping frequencies. Station C-392 is also located in the wellfield; however, it monitors the water table aquifer. Water level fluctuations at this station are less erratic, responding to both rainfall and gradual downward leakage into the pumped zone. This requires water level measurements every two weeks.

In the Naples area, water level data had been collected from the lower Tamiami aquifer on a semi-annual basis until October 1982 when measurements started being collected monthly. Attempts at time series analysis using these data are considered questionable due to an insufficient length of record. As a result, an evaluation using the standard deviation and variance values for each station was attempted. It was determined from the time series analysis of the Collier County water table wells that high standard deviation values did not necessarily mean a high sampling frequency was required. However, in an artesian system, water level do not respond dramatically to rainfall and are generally characterized by lower water level fluctuations unless influenced by pumpage. Potentiometric surface maps published by the USGS (Buchmiller, 1982) indicate all the monitoring wells in the Naples area are affected by pumpage. Therefore, until additional data is collected, stations with high deviations in the lower Tamiami aquifer in the Naples area will be considered as requiring frequent monitoring.

Since the potentiometric levels of all the monitoring well are influenced by erratic pumping schedules. Continuous records are probably justified for all stations. This is cost prohibitive, however, so a selection process was undertaken to identify several wells with large deviations that are correlatable with other wells over large areas. Out of the 28 lower Tamiami monitoring wells in the Naples area, nine were randomly selected based on

TABLE 2: STATISTICAL ANALYSIS FOR SELECTED LOWER TAMIAMI MONITOR WELLS, CITY OF NAPLES

| WELL NO. | MEAN (ft. LSD) | MEAN (ft. MSL) | STANDARD DEVIATION | COEFFICIENT OF VARIATION | | RANKING |
|---|---|---|---|---|---|---|
| | | | | MSL DATUM | LSD DATUM | |
| C130 | 5.48 | 2.40 | 0.48 | .417 | .087 | 11 |
| C353 | 7.99 | 4.44 | 3.16 | .712 | .396 | 2 |
| C409A | 12.93 | -0.12 | 0.77 | 6.417 | .059 | 8 |
| C424 | 10.19 | 2.59 | 3.23 | 1.247 | .317 | 1 |
| C430 | 5.47 | 5.02 | 1.10 | .219 | .202 | 6 |
| C460 | 7.72 | 4.67 | 2.26 | .484 | .293 | 3 |
| C506A | 16.95 | 3.66 | 1.46 | .399 | .086 | 5 |
| C526 | 3.30 | 2.41 | 0.53 | .220 | .160 | 10 |
| C528 | 1.92 | 2.47 | 0.92 | .372 | .479 | 7 |
| C392 | 13.20 | 3.22 | 0.57 | .177 | .043 | 9 |
| C391 | 13.23 | 2.10 | 1.91 | .909 | .144 | 4 |

TABLE 3: CORRELATION MATRIX RELATING SELECTED LOWER TAMIAMI MONITOR WELLS IN THE NAPLES AREA

| WELL NO. | C130 | C353 | C409A | C424 | C430 | C460 | C506A | C526 | C528 | C392 | C391 | RANKING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C130 | 1.000 | | | | | | | | | | | 7 |
| C353 | .301 | 1.000 | | | | | | | | | | 4 |
| C409A | .526 | .331 | 1.000 | | | | | | | | | 5 |
| C424 | .262 | .989 | .291 | 1.000 | | | | | | | | 6 |
| C430 | .378 | .785 | .536 | .732 | 1.000 | | | | | | | 3 |
| C460 | .341 | .813 | .387 | .785 | .917 | 1.000 | | | | | | 1 |
| C506A | .401 | .579 | .462 | .521 | .907 | .826 | 1.000 | | | | | 3 |
| C526 | .495 | .519 | .831 | .498 | .579 | .519 | .449 | 1.000 | | | | 5 |
| C528 | .689 | .595 | .561 | .533 | .787 | .809 | .751 | .654 | 1.000 | | | 4 |
| C392 | .593 | .668 | .740 | .604 | .941 | .823 | .897 | .719 | .860 | 1.000 | | 2 |
| C391 | -.500 | -.726 | -.137 | -.781 | -.408 | -.448 | -.266 | -.380 | -.375 | -.370 | 1.000 | 7 |
| Combined Ranking (Standard Deviation & Correlation Coefficient) | | | | | | | | | | | | |
| | 17 | 6 | 13 | 6 | 9 | 4 | 8 | 15 | 11 | 11 | 10 | |
| Overall Ranking | | | | | | | | | | | | |
| | 10 | 2 | 8 | 3 | 5 | 1 | 4 | 9 | 7 | 7 | 6 | |

their geographical distribution throughout the area. The monthly water level data from these wells were analyzed to determine the standard deviation and the coefficient of variability (Table 2). The coefficient of variation $C_v$ is the ratio of the standard deviation ($\sigma$), to the absolute value of the mean $\mu$:

$$C_v = \frac{\sigma}{|\mu|} \qquad \text{.........................} \quad (3)$$

This value is an expression of variability of the data with respect to the mean.

The statistics from the nine wells were then compared with the two continuously monitored stations, C-291 and C-292 (Table 2). As a result, the ranking established is based mainly on the standard deviation with the stations exhibiting the higher standard deviation values being considered for more frequent sampling.

The standard deviation for stations C-391 and C-392 were 1.91 feet and .57 feet, respectively. Since the time series analysis indicated a sampling frequency of two weeks for station C-392, stations with standard deviation of less than .57 were not considered for continuous monitoring.

In an attempt to derive the maximum benefit from the minimum number of wells, a correlation matrix was established to determine the area of influence from each well (Table 3). From this, a relative ranking system was established based on the number of neighboring wells which correlated with a given station. Eighty percent (.800) was selected as the criterion for good correlation. The negative values shown for C-391 indicate that this well is out of phase with the other wells. This is due to its proximity to a pumped well.

The rankings from both the standard deviation and the correlation coefficient were combined to yield the overall rating of each station

(Table 3). From these data, stations C-353, C-460, C-430, 506A, and 409A are recommended for continuous water level recording. The high deviation associated with well C-353 is more likely caused by pumpage from the neighboring Quail Creek and Pelican Bay wellfields located to the east. If the Basin Board is more interested in the effects of the Naples Wellfield, station C-424 can be substituted for C-353. A SFWMD groundwater station located near county road 846 and Airport Road has collected continuous water level data since 1981 and can be substituted for a recorder at C-430. However, it is anticipated that water levels will fluctuate more at C-430, and if funding is available, C-430 should be monitored continuously.

Water level measurements should be made at the remaining stations at a minimum frequency of once per month.

## QUALITATIVE EVALUATION

The scope of this study did not allow for a quantitative analysis for every regional aquifer identified in the County. Instead, a qualitative approach was taken for the remaining aquifers. In these cases, there are not enough monitoring wells available to warrant a modeling effort. The recommendations for additional monitoring sites made here are based on a geographical distribution scheme and a knowledge of the regional flow system. Data from new stations recommended in this section should be collected until such time that a complete quantitative analysis can be undertaken.

### Water Table Aquifer, Naples Area

The water table aquifer in the Naples area is a thin sequence of sands and sandy limestones. The unit is generally less than 50 feet thick and is not largely developed. However, the water table aquifer provides recharge to the underlying lower Tamiami aquifer and the City of Naples wellfields through downward leakage across semi-confining beds. For this reason, the water table aquifer is closely monitored in the Naples area. Until recently, the number of monitoring stations was adequate to excessive. However, over the last two years, several road construction projects have destroyed 25 monitoring wells in the area (Figure 7). This has mostly affected the monitoring network to the east of the production wells.

The remaining monitoring network, consisting of ten wells, is shown on Figure 8. The configuration of the water table surface in the Naples area is highly variable with hydraulic gradients exceeding 14 feet per mile near the coast. As a result, a higher density of monitoring wells are needed to accurately describe the surface. Water table maps prepared by the USGS (Buchmiller, 1982) were qualitatively examined to identify major trends and to determine areas of uncertainty within the old network. Road construction destroyed all but one monitoring well east of the wellfield. Six wells are

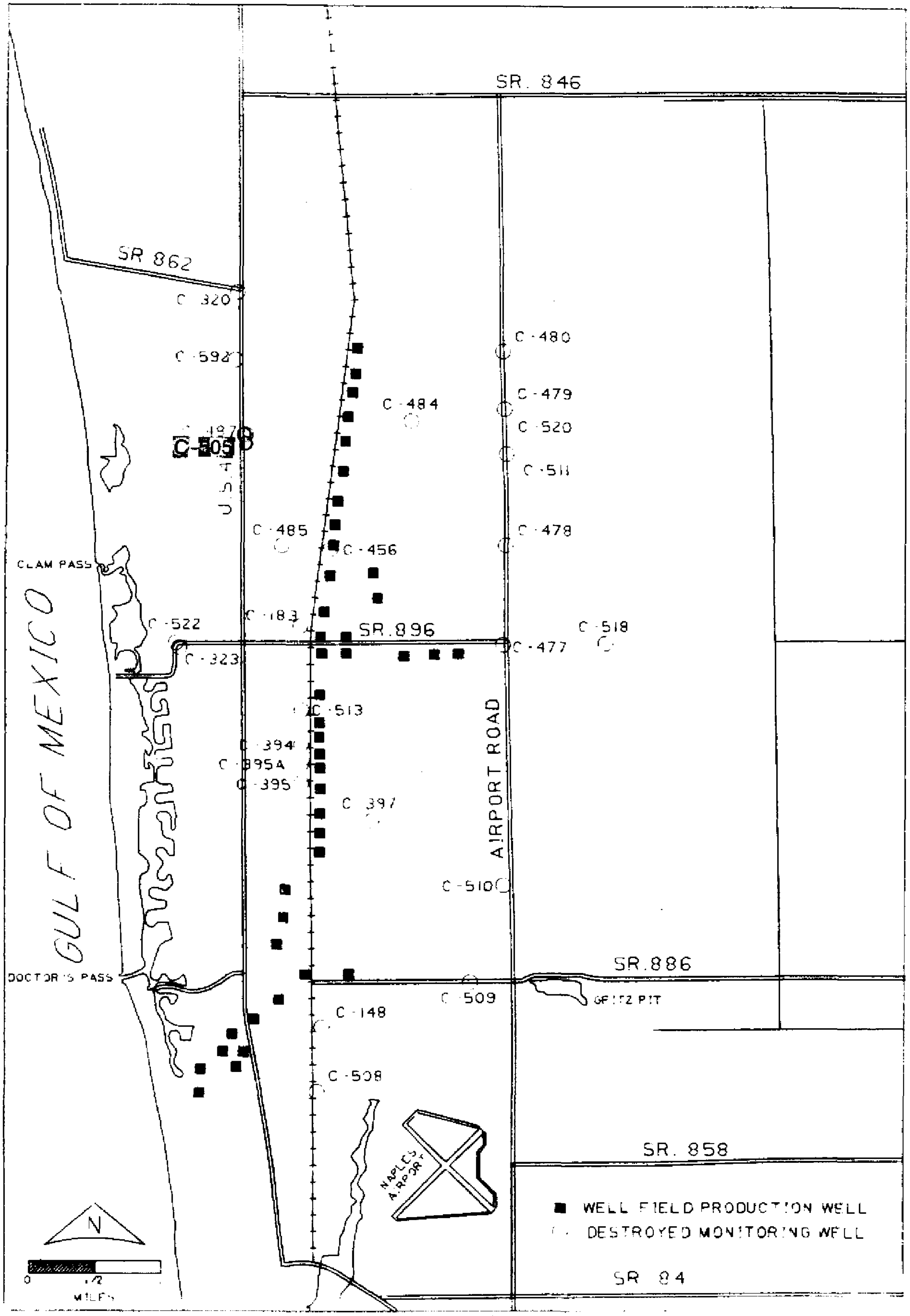
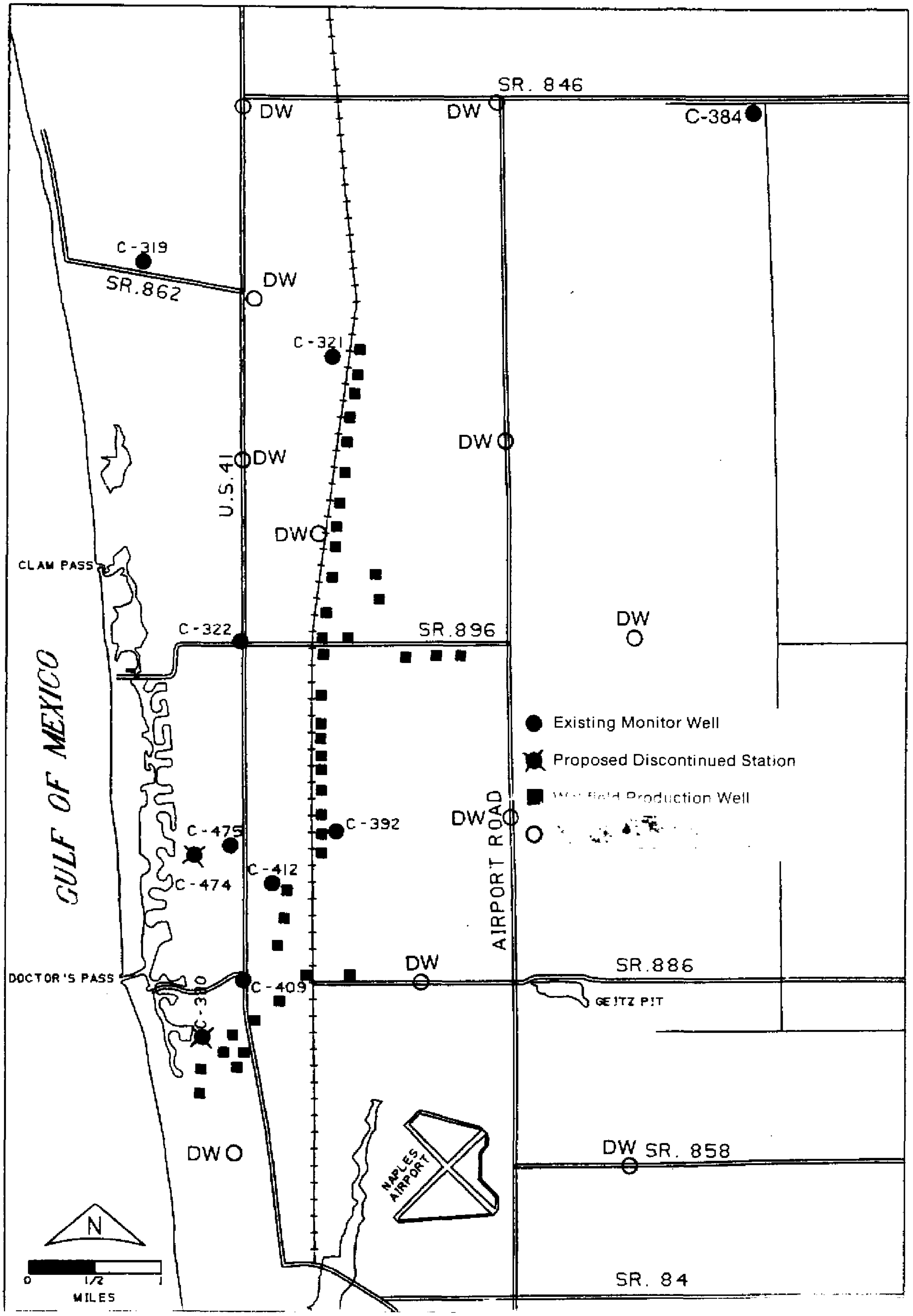



**Figure 7 Location of Destroyed USGS Monitoring Wells, Water Table Aquifer, City of Naples**




Water Table Aquif

recommended to be added to the network in this region. Four of these wells are located to replace former wells C-590, C-510, C-518, and C-520 along Airport Road. The remaining two wells, one located at the intersection of SR 846 and Airport Road and the other on SR 858 one mile east of Airport Road, are recommended to reduce the uncertainty outside the wellfield area.

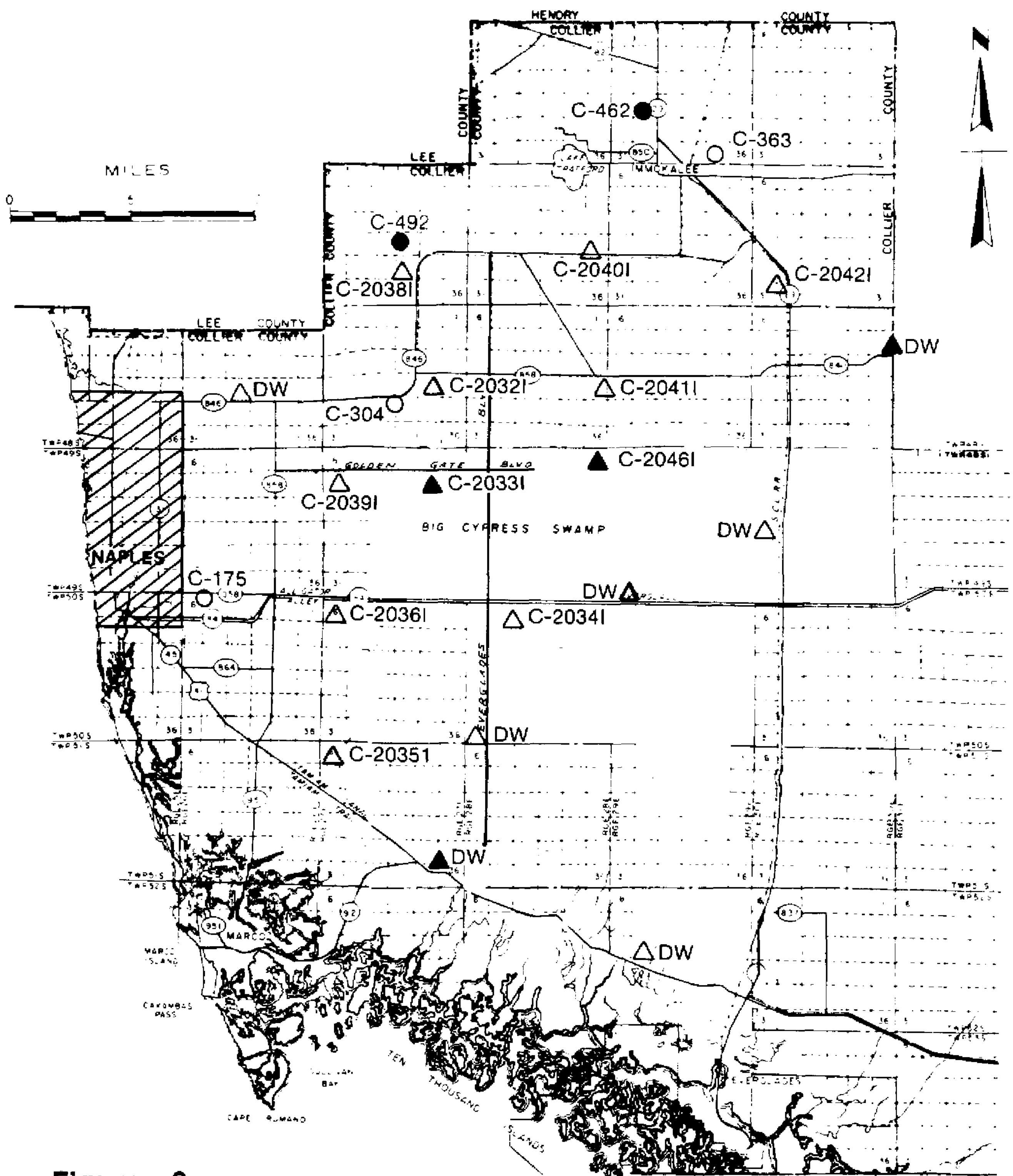
On the western side of the wellfield, five wells should be constructed to replace the twelve wells which were destroyed. Three of these stations are to replace former USGS wells C-320, C-505, and C-485. The other two are to reduce the uncertainty to the north and south.

Review of the existing data indicates that stations C-474 and C-475 (Figure 8) exhibit similar water level fluctuations. Water levels from station C-474, located between C-475 and the Gulf of Mexico, are always lower than water levels in C-475 and can be approximated by a water level model. As a result, station C-474 can be discontinued without affecting the accuracy of the monitoring network. These conditions are also true for station C-330 which is located between C-409 and the Gulf of Mexico. Station C-330 can also be discontinued.

The Lower Tamiami Aquifer, Collier County

While the lower Tamiami aquifer is extensively monitored in the Naples area, there are only five stations in the remainder of the County. Preliminary data collected by the Water Management District indicated that this aquifer is regionally extensive throughout the western half of Collier County and the southern tip of Lee County. The aquifer is productive, with transmissivities often exceeding 100,000 gpd/ft. and has good development potential.

During the exploratory drilling phase of the SFWMD's Collier County groundwater study, eleven test wells were drilled into the aquifer and are recommended for monitoring (Figure 9). Two of these wells, C-2032I and




## Figure 9

**Recommended Lower Tamiami Aquifer Monitoring Network, Collier County**

○ Existing Site; Monthly Water Level, Semi Annual Water Quality

● Existing Site; Continuous Water Level, Semi Annual Water Quality

△ Proposed Site; Monthly Water Level, Semi Annual Water Quality

▲ Proposed Site; Continuous Water Level, Semi Annual Water Quality

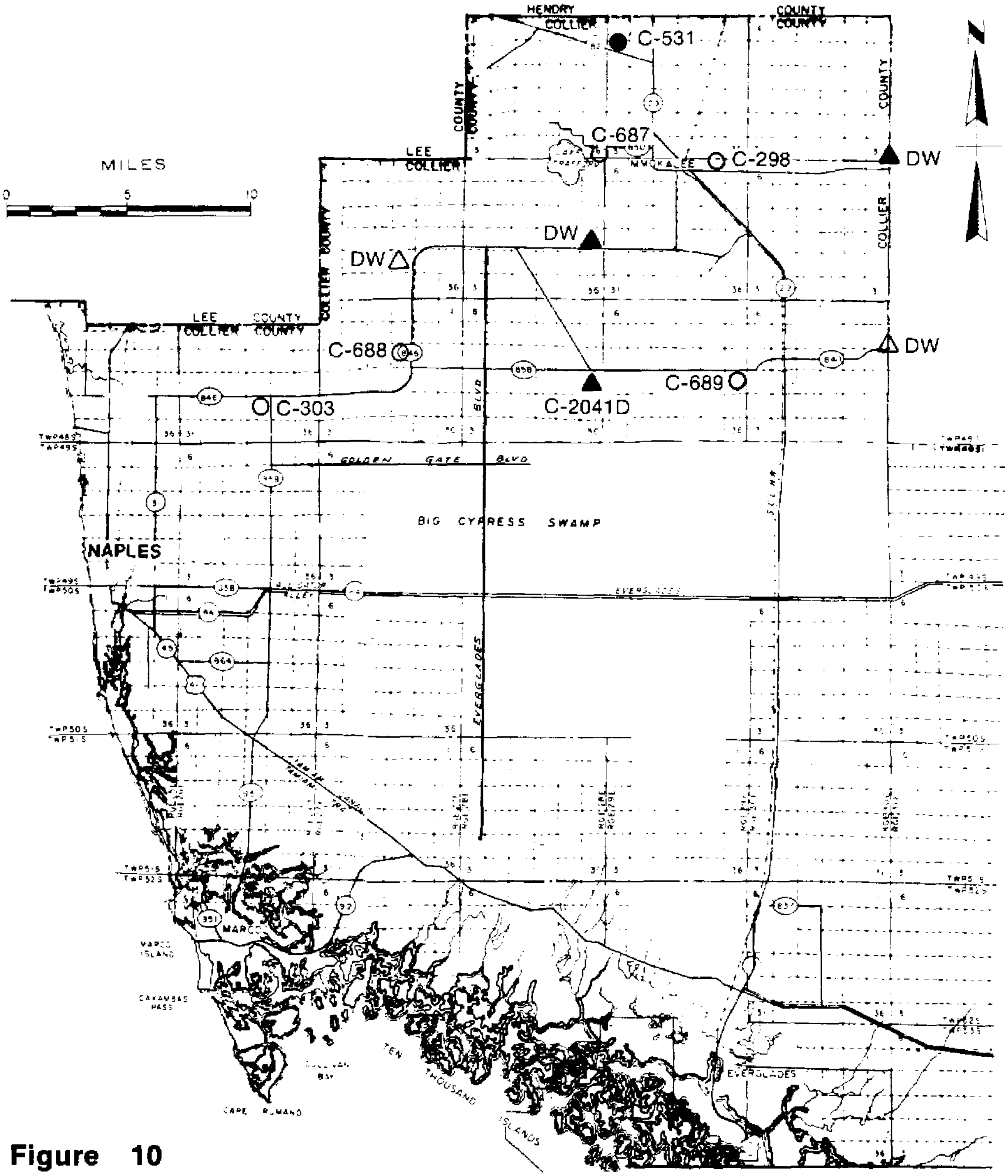
C-2038I, are located near existing USGS monitoring wells. For this reason, station C-2032I may not be necessary. However, data should be collected from C-2038I and compared to C-492 because C-492 samples only a four foot interval and it is not clear whether the station monitors the water table or the lower Tamiami aquifer. The sampling frequency for water levels in these stations should be a minimum of once per month. The exceptions are stations C-2033I which may be influenced by pumpage from Golden Gates Wellfield, and C-2046I which is influenced by large agricultural users. These stations should be monitored continuously.

Six additional wells are also recommended to be constructed. The general geographic locations of these wells were influenced by the results of the water table kriging model. Additional stations may be required along SR 29 south of SR 84, but development is light and additional monitoring in this region is a lower priority at this time. Water level data should be collected monthly for all stations except the wells to be located at the Collier-Hendry County line and the wells to be located at the end of Everglades Boulevard and US 41. These stations should be monitored continuously. Water quality sampling for the new stations is preferred on a quarterly basis but should be collected no less frequently than semi-annually.

Sandstone Aquifer

The Sandstone aquifer occurs in the northern portion of the County and is currently being monitored by six wells. The aquifer pinches out north of SR 84 but is used extensively in the north for municipal supply and agriculture.

Five stations are recommended to be added to the network (Figure 10). One well, C-2041D, was drilled by the SFWMD and is available for monitoring. The other four will have to be drilled. Two should be located along SR 846, southwest of Immokalee, and the remaining wells should be located along the Collier-Hendry County line, one off SR 846 and the other off SR 840. Water




# Figure 10

**Recommended Sandstone Aquifer Monitoring Network, Collier County**

○ Existing Site; Monthly Water Level, Semi Annual Water Quality

● Existing Site; Continuous Water Level, Semi Annual Water Quality

△ Proposed Site; Monthly Water Level, Semi Annual Water Quality

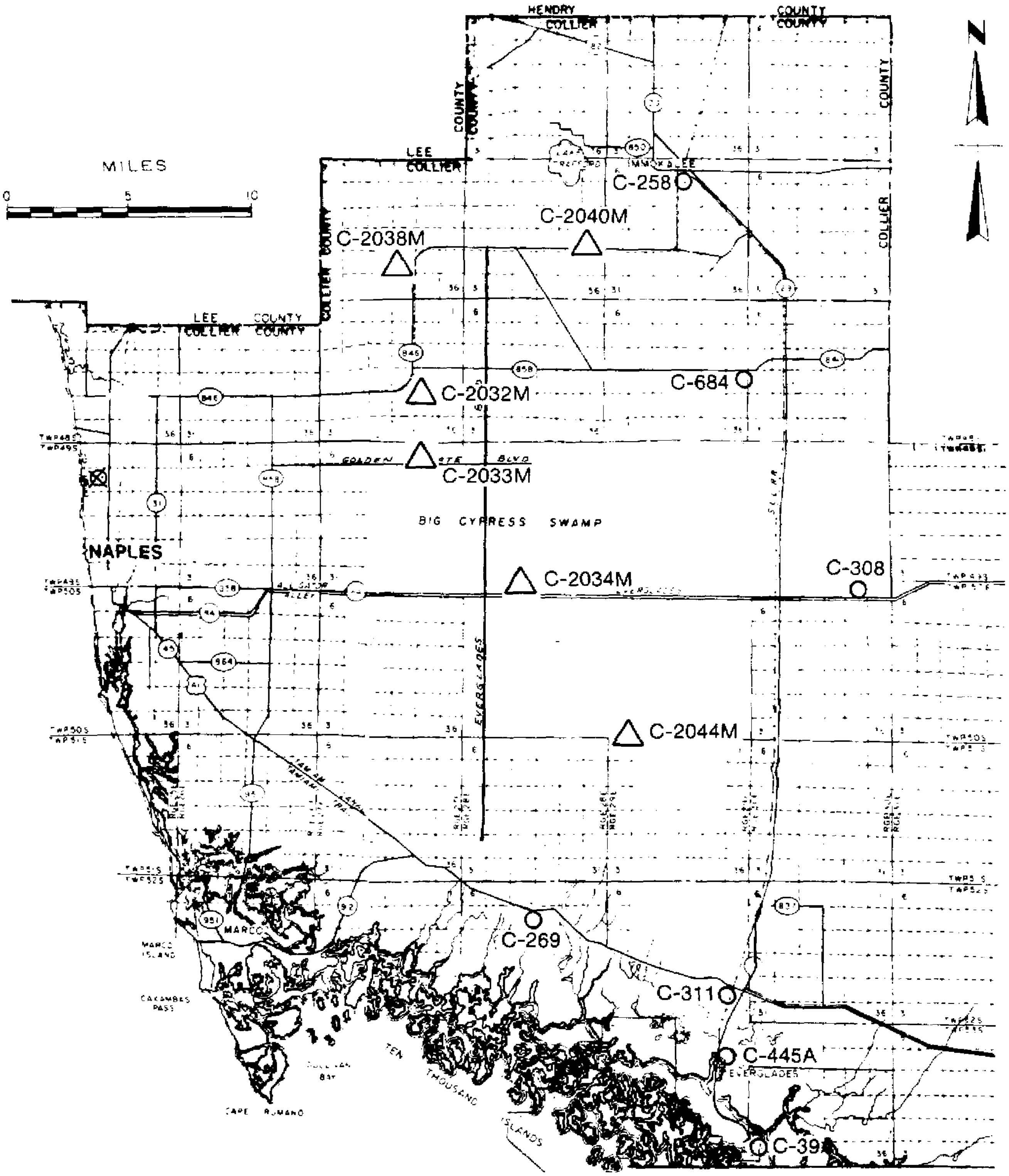
▲ Proposed Site; Continuous Water Level, Semi Annual Water Quality

DW Proposed Site; To Be Drilled

level data should be collected monthly and water quality data sampled quarterly or semi-annually. The exception is the well located at the county line off SR 846 and the existing station C-2041D which should be monitored continuously due to the development of the aquifer by agricultural interests in these regions.

The Mid-Hawthorn Aquifer

The mid-Hawthorn Aquifer is regionally extensive throughout Lee and Collier County. Wells which tap this aquifer yield freshwater at rates of 20 to 100 gpm. Due to the abundance of good quality water at shallower depths, the unit has not developed extensively in Collier County. The locations of six additional wells which can be added to the existing network are shown on Figure 11. Water level data should be collected monthly and water quality semi-annually. Due to the lack of development of this aquifer in Collier County, monitoring of this unit is considered a lower priority.




# Figure 11

**Recommended Mid-Hawthorn Aquifer Monitoring Network, Collier County**

○ Existing Site; Monthly Water Level, Semi Annual Water Quality

△ Proposed site Monthly Water Level, Semi Annual Water Quality

## THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT SWIMM PROGRAM

The Saline Water Intrusion Monitoring and Management or SWIMM Program, is a monitoring network established by the SFWMD to assess the local impact of large scale groundwater users in coastal areas. In Collier County there are nine active SWIMM programs which monitor 178 groundwater wells and several surface water stations (Appendix B). These wells are clustered around the wellfield and are owned and maintained by the individual utility. Both water quality and water level measurements may be required. Water level data is collected on a monthly basis, however, in times of drought, more frequent monitoring may be requested. The only exception to the is the City of Naples whose SWIMM wells are owned by the USGS.

All sampling of the SWIMM wells is done by the utility or by a consultant hired by the utility. Water level data is determined manually. Water quality determinations are limited to dissolved chloride concentration and specific conductance. Dissolved chloride concentrations are generally determined by silver nitrate titrations and specific conductivity is measured with a field conductivity bridge. These data along with pumpage information is sent to the Water Management District where it is analyzed by a hydrogeologist and stored in the computer. Any anomalies are identified and appropriate action taken to protect the wellfield.

In general, the USGS monitoring network, which monitors the regional flow system, acts independently of the SWIMM program. The exception occurs along the Naples wellfields where both the utility and the USGS collect data from 13 of the same wells at the same frequency (Appendix II, Page II-7). This duplication of data does little to improve the management of the resource. As the District SWIMM Program has been effectively monitoring the saltwater interface for years and is in a position to regulate the wellfield, it is not necessary for the USGS to collect monthly chloride data from these same stations. However, it is recommended that the USGS sample for water quality (major constituents) on a semi-annual basis from these 13 duplicate stations. Water level measurements by the USGS, however, should be made at the frequency determined in this report despite duplication with the utility. This is to maintain continuity in the existing data record and because of the high degree of quality control maintained by the USGS in water level monitoring.

## RECOMMENDATIONS

1. A total of sixty-two additional monitoring wells are recommended to be added to the existing USGS regional monitoring network and are summarized in Table 4. Seven existing USGS wells are recommended to be discontinued.
2. There are a number of existing test wells and discontinued monitoring wells, owned by the USGS and private consultants, which may be available to be added to the monitoring network. Inquiries should be made to determine if any of these wells occur in the areas where additional stations were recommended.
3. Water level measurements for all new water table aquifer monitoring wells should be made as frequently as financially feasible. This is because water levels fluctuate rapidly in response to rainfall. Ideally, all new stations should be monitored continuously until a sufficient amount of data is collected to determine the optimal sampling frequency for each station. If continuous monitoring is not possible, a measuring frequency of once every two weeks is recommended. If semi-monthly water level data cannot be collected, monthly measurements can be made.
4. Of nine wells which were analyzed using time series analysis, four water table aquifer wells, which are being monitored continuously, are recommended to be monitored on a monthly basis. These stations are C-296, C-384, C-495, and L-730 (a Lee County well).
5. Water levels in confined aquifers are generally less variable compared to water table aquifers. Therefore, water level measurements for confined aquifers should be made on a monthly basis. The exceptions occur near wellfields where water levels are controlled by pumpage rates. Higher frequency monitoring is required in these regions.

## TABLE 4: SUMMARY OF THE PROPOSED MONITORING NETWORK FOR COLLIER COUNTY

### Water Table Aquifer

| | |
|---|---|
| Number of existing USGS monitoring stations | 25 |
| Number of existing USGS monitoring stations recommended for discontinuation | 2 |
| Number of additional wells recommended to the network | 32 |
| Number of SFWMD wells recommended to the network | 13 |
| Number of monitor stations to be constructed | 19 |
| Number of existing USGS wells with continuous recorders | 12 |
| Number of existing continuously monitored wells recommended for less frequent water levels | 4 |
| Minimum number of well with additional continuous recorders(3 of which already have recorders) | 6 |

### Lower Tamiami Aquifer

| | |
|---|---|
| Number of existing USGS monitoring stations | 35 |
| Number of existing USGS monitoring stations recommended for discontinuation | 5 |
| Number of additional wells recommended to the network | 20 |
| Number of SFWMD wells recommended to the network | 11 |
| Number of new monitor stations to be constructed | 8 |
| Number of existing USGS wells with continuous recorders | 4 |
| Minimum number of additional continuous recorders | 7 |

### Sandstone Aquifer

| | |
|---|---|
| Number of existing USGS monitoring stations | 6 |
| Number of additional wells recommended to the network | 5 |
| Number of SFWMD wells recommended to the network | 1 |
| Number of new monitor stations to be constructed | 4 |
| Number of existing USGS wells with continuous recorders | 1 |
| Minimum number of additional continuous recorders | 2 |

### Mid-Hawthorn Aquifer

| | |
|---|---|
| Number of existing USGS monitoring stations | 8 |
| Number of additional wells recommended to the network | 6 |
| Number of SFWMD wells recommended to the network | 6 |
| Water level measurement frequency for new and existing stations | once per month |

6. Water quality sampling for new stations should be made quarterly. Sampling of the existing USGS monitoring wells should remain as specified until a quantitative analysis of the data can be completed. The exception occurs for 13 lower Tamiami aquifer monitoring wells, located in the Naples area, which are currently being sampled at the same frequency by both the City of Naples and the USGS. It is recommended that the USGS sample these 13 wells semi-annually, and that the utility continue monthly water quality sampling.
7. An additional analysis is recommended for the entire Collier County groundwater monitoring network to be completed in two years. The purpose of this study would be to further refine the regional monitoring network and to develop a computer model capable of generating aquifer system status maps and also to identify problem areas clearly and rapidly to a non-technical user. This study would be more detailed and incorporate both canal stage and rainfall data, as well as, water level and water quality data. Input data would be collected from local and regional groundwater monitoring networks.

# BIBLIOGRAPHY

Buchmiller, R. C., 1982. Semi-annual Water-Table and Potentiometric Surface for Two Water-Yielding Zones in the Surficial Aquifer, 1975-79, Naples Area, Florida: United States Geological Survey, WRI Open File Report 82-120.

Dixon, W. J. et. al., 1981. BMDP Statistical Software 1981: University of California Press, Berkeley.

Jacob, P. G., 1983. Hydrogeology of the Shallow Aquifer South of Naples, Collier County: South Florida Water Management District, Tech. Publication 83-3.

Klein, H., 1954. Groundwater Resources of the Naples Area, Collier County: Florida Geological Survey, R.I. No. 11.

Knapp, M. S. and Burns, W. S., 1984. Evaluation of the Groundwater Resource of Collier County: South Florida Water Management District, Tech. Publication (in preparation).

McCoy, H. J., 1962. Ground-Water Resources of Collier County, Florida: Florida Geological Survey, R.I. No. 63.

McCoy, H. J., 1967. Ground-Water in the Immokalee Area, Collier County, Florida: Florida Geological Survey, IC No. 51.

Sherwood, C. B. and Klein, H., 1961. Ground-Water Resources of the Naples Area, Collier County, Florida: Florida Geological Survey, R.I. No. 11.

Skriven, J. A. and Karlinger, M. R., 1980. Semi-Variogram Estimation and Universal Kriging Program (Computer Program Documentation User's Manual): United States Geological Survey, WRD-WRI-80-064.

U. S. Geological Survey, 1977-1981. Water Resource Data for Florida, Vol. 2B, South Florida Surface Water: USGS Water-Data Report FL-77-2B, FL-78-2B, FL-79-2B, FL-80-2B, and FL-81-2B.

# APPENDIX I

## SELECTED DATA FROM THE 1983-1984
## U. S. GEOLOGICAL SURVEY
## COLLIER COUNTY GROUNDWATER MONITOR NETWORK

## 1983-1984 USGS MONITOR NETWORK

## WATER TABLE AQUIFER

| Well No. | LOCATION Latitude | LOCATION Longitude | Total Depth | Casing Depth | DATA COLLECTED Water Quality | DATA COLLECTED Water Level |
|---|---|---|---|---|---|---|
| C-8 | 25°56'37" | 81°21'38" | 30 | 15 | S | - |
| C-54 | 26°10'18" | 80°53'02" | 9 | 8 | S | C |
| C-131 | 26°25'21" | 81°16'19" | 24 | 22 | S | C |
| C-296 | 26°06'40" | 81°20'43" | 45 | 8 | S | C |
| C-319 | 26°15'24" | 81°48'04" | 12 | 9 | S | S |
| C-321 | 26°14'35" | 81°47'25" | 12 | 9 | S | S |
| C-322 | 26°12'40" | 81°48'04" | 12 | 9 | S | S |
| C-330 | 26°10'01" | 81°48'12" | 12 | 9 | S | S |
| C-383 | 26°15'30" | 81°41'21" | 22 | 10 | S | C |
| C-384 | 26°16'20" | 81°45'05" | 58 | 9 | M | C |
| C-392 | 26°11'24" | 81°47'30" | 30 | 23 | M | M |
| C-409 | 26°10'24" | 81°48'01" | 16 | 14 | S | S |
| C-412 | 26°11'03" | 81°47'49" | 16 | 14 | S | S |
| C-446 | 26°04'49" | 81°41'15" | 24 | 8 | S | - |
| C-450 | 26°09'13" | 81°41'13" | 30 | 8 | S | M |
| C-474 | 26°11'14" | 81°48'23" | 13 | 11 | S | S |
| C-475 | 26°11'11" | 81°48'01" | 13 | 11 | S | S |
| C-495 | 25°57'53" | 81°18'43" | 70 | 8 | S | C |
| C-496 | 26°01'11" | 81°24'39" | 59 | 8 | S | C |
| C-503 | 26°17'40" | 81°23'54" | 50 | 8 | S | C |
| C-532 | 26°29'28" | 81°27'29" | 13 | 3 | S | M |
| C-598 | 26°14'17" | 81°30'54" | 36 | 32 | S | C |
| C-599 | 26°06'30" | 81°41'14" | 50 | 40 | S | C |
| C-600 | 26°05'49" | 81°44'19" | 52 | 48 | S | C |
| C-690 | 26°06'29" | 81°32'36" | 45 | 40 | S | C |

S = Semi-annually
C = Continuously
M = Monthly

## 1983-1984 USGS MONITOR NETWORK

## LOWER TAMIAMI AQUIFER

| Well No. | LOCATION Latitude | Longitude | Total Depth | Casing Depth | DATA COLLECTED Water Quality | Water Level |
|---|---|---|---|---|---|---|
| C-123 | 26°10'03" | 81°48'37" | 157 | 97 | M | M |
| C-130 | 26°09'02" | 81°48'04" | 72 | 69 | M | M |
| C-150 | 26°10'02" | 81°48'17" | 54 | 51 | S | S |
| C-151A | 26°10'02" | 81°48'17" | 166 | 145 | S | S |
| C-161 | 26°10'23" | 81°47'07" | 135 | 118 | M | M |
| C-175 | 26°09'12" | 81°43'47" | 123 | 104 | S | M |
| C-304 | 26°16'35" | 81°36'13" | 130 | 125 | S | M |
| C-353 | 26°16'25" | 81°46'42" | 52 | 42 | M | M |
| C-363 | 26°25'56" | 81°24'26" | 119 | 84 | M | M |
| C-391 | 26°11'24" | 81°47'33" | 80 | -- | M | C |
| C-409A | 26°10'24" | 81°48'01" | 73 | 63 | M | M |
| C-424 | 26°15'24" | 81°48'04" | 132 | 126 | M | M |
| C-430 | 26°11'46" | 81°46'07" | 65 | 63 | M | M |
| C-458 | 26°14'01" | 81°46'14" | 63 | 62 | S | S |
| C-459 | 26°14'03" | 81°47'07" | 64 | 63 | S | S |
| C-460 | 26°14'05" | 81°46'55" | 66 | 63 | M | M |
| C-461 | 26°14'11" | 81°47'08" | 65 | 63 | S | S |
| C-462 | 26°27'25" | 81°26'13" | 100 | 50 | S | C |
| C-472A | 26°09'25" | 81°47'52" | 72 | 63 | M | M |
| C-474A | 26°11'14" | 81°48'23" | 72 | 63 | M | M |
| C-489 | 26°13'30" | 81°47'33" | 83 | 63 | M | C |
| C-490 | 26°12'43" | 81°48'03" | 71 | 70 | M | M |
| C-491 | 26°11'17" | 81°48'01" | 71 | 70 | M | M |
| C-492 | 26°22'23" | 81°36'20" | 64 | 60 | S | C |
| C-505A | 26°14'14" | 81°48'03" | 74 | 63 | M | M |
| C-506A | 26°12'33" | 81°48'02" | 71 | 62 | M | M |
| C-507 | 26°10'38" | 81°48'01" | 53 | 50 | S | S |
| C-515 | 26°13'46" | 81°48'02" | 71 | 63 | S | S |
| C-516 | 26°11'56" | 81°47'58" | 63 | 46 | S | S |
| C-519 | 26°12'40" | 81°46'54" | 62 | 42 | S | S |

## 1983-1984 USGS MONITOR NETWORK

## LOWER TAMIAMI AQUIFER - CONTINUED

| Well No. | LOCATION Latitude | Longitude | Total Depth | Casing Depth | DATA COLLECTED Water Quality | Water Level |
|---|---|---|---|---|---|---|
| C-524 | 26°09'48" | 81°48'33" | 80 | 63 | M | M |
| C-525 | 26°10'02" | 81°48'37" | 83 | 63 | M | M |
| C-526 | 26°10'18" | 81°48'41" | 68 | 63 | M | M |
| C-527 | 26°10'48" | 81°48'48" | 72 | 63 | M | M |
| C-528 | 26°12'00" | 81°48'30" | 90 | 63 | M | M |

S = Semi-annually
M = Monthly
C = Continuously

## 1983-1984 USGS MONITOR NETWORK

## SANDSTONE AQUIFER

| Well No. | LOCATION Latitude | Longitude | Total Depth | Casing Depth | DATA COLLECTED Water Quality | Water Level |
|---|---|---|---|---|---|---|
| C-298 | 26°25'07" | 81°23'52" | 303 | 254 | S | M |
| C-303 | 26°16'22" | 81°41'23" | 300 | 232 | S | M |
| C-531 | 26°29'28" | 81°27'29" | 253 | 210 | S | C |
| C-687 | 26°25'54" | 81°28'38" | 310 | 290 | S | M |
| C-688 | 26°18'02" | 81°35'48" | 242 | 220 | M | M |
| C-689 | 26°17'40" | 81°23'54" | 265 | 230 | S | M |

S = Semi-annually

M = Monthly

C = Continuously

**1983-1984 USGS MONITOR NETWORK**

**MID HAWTHORN & FLORIDAN AQUIFER SYSTEM**

| Well No. | LOCATION Latitude | Longitude | Total Depth | Casing Depth | DATA COLLECTED Water Quality | Water Level |
|---|---|---|---|---|---|---|
| C-39 | 25°48'50" | 81°21'47" | 484 | 436 | S | - |
| C-258 | 26°25'04" | 81°24'54" | 738 | - | S | M |
| C-269 | 25°56'25" | 81°28'12" | 392 | 300 | S | - |
| C-308 | 26°09'19" | 81°15'59" | 485 | - | S | - |
| C-311 | 25°54'37" | 81°21'54" | 450 | 430 | S | M |
| C-445A | 25°51'27" | 81°23'09" | 467 | 346 | S | - |
| C-575 | 26°13'10" | 81°48'07" | 640 | 345 | M | S |
| C-684 | 26°17'40" | 81°23'54" | 490 | 440 | S | M |

S = Semi-annually

M = Monthly

# APPENDIX II

## SELECTED DATA FROM THE

## SOUTH FLORIDA WATER MANAGEMENT DISTRICT'S SWIMM PROGRAM

## APPENDIX II

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**Figures**

## THE EAGLE CREEK SWIMM MONITOR NETWORK*

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Water Quality | Aquifer Monitored |
|---|---|---|---|---|---|
| CO-544** | 45 | - | - | M | Lower Tamiami |
| CO-545** | 45 | - | - | M | Lower Tamiami |
| CO-218 | 45 | 40 | - | M | Lower Tamiami |
| CO-237 | 45 | 40 | - | M | Lower Tamiami |
| CO-238 | 15 | 10 | - | M | Water Table |
| CO-591 | 12 | - | M | - | Water Table |
| CO-592 | 12 | - | M | - | Water Table |
| CO-593 | 12 | - | M | - | Water Table |
| CO-594 | 9 | - | M | - | Water Table |
| CO-595 | 16 | - | M | - | Water Table |
| CO-596 | 11 | - | M | - | Water Table |
| CO-597 | 50 | - | - | M | Lower Tamiami |
| CO-598 | 50 | - | - | M | Lower Tamiami |
| CO-599 | 50 | - | - | M | Lower Tamiami |

M = Monthly sampling interval

* = Water quality is being collected from two additional groundwater stations and one surface water station not shown on the map.

** = Production well

## THE EVERGLADES CITY SWIMM MONITOR NETWORK

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Water Qual.* | Aquifer Monitored |
|---|---|---|---|---|---|
| CO-305 | 22 | 12 | M | M | Water Table |
| CO-587 | 50 | 48 | M | M | Water Table |
| CO-589 | 50 | 48 | M | M | Water Table |
| CO-590 | 48 | 47 | M | M | Water Table |

* = Chloride and specific conductivity

M = Monthly sampling interval requested, however, utility submits data on weekly basis

## THE CAPRI WATERWORKS SWIMM MONITOR NETWORK

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Dissolved Chlorides | Aquifer Monitored |
|---|---|---|---|---|---|
| PW-1 | 28 | 20 | M | M | Water Table |
| PW-5 | 35 | 20 | M | M | Water Table |
| PW-6 | 35 | 20 | M | M | Water Table |
| PW-7 | 28 | 20 | M | M | Water Table |
| PW-8 | 35 | 20 | M | M | Water Table |
| PW-9 | 35 | 20 | M | M | Water Table |
| PW-10 | 35 | 20 | M | M | Water Table |
| PW-11 | 38 | 20 | M | M | Water Table |
| PW-12 | 38 | 20 | M | M | Water Table |
| PW-13 | 38 | 20 | M | M | Water Table |
| Mon. Well | 40 | 30 | | M | Water Table |
| Plant Water (finished) | | | | M | |

M = Monthly sampling interval

PW = Production Well

## THE MARCO ISLE SWIMM MONITOR NETWORK

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Water Quality* | Aquifer Monitored |
|---|---|---|---|---|---|
| Mon Well #1 | 192 | 190 | | M | Lower Tamiami |
| Mon Well #2 | 24 | 20 | | M | Water Table |

M = Monthly sampling interval

* = Chloride data is being collected from seven surface water stations by the permittee

## THE QUAIL CREEK SWIMM MONITOR NETWORK

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Dissolved Chlorides | Aquifer Monitored |
|---|---|---|---|---|---|
| CO-94 | 105 | 80 | M | | Lower Tamiami |
| CO-95 | 15 | 10 | M | | Water Table |
| CO-96 | 105 | 80 | M | | Lower Tamiami |
| CO-97 | 15 | 10 | M | | Water Table |
| CO-98 | 100 | 85 | M | | Lower Tamiami |
| CO-100 | 100 | 85 | M | | Lower Tamiami |
| CO-104 | 70 | 65 | M | | Lower Tamiami |
| CO-105 | 15 | 12 | M | | Water Table |
| CO-108 | 100 | 87 | M | | Lower Tamiami |
| CO-110 | 75 | 65 | M | | Lower Tamiami |
| CO-111 | 15 | 10 | M | | Water Table |
| CO-112 | 100 | 80 | M | | Lower Tamiami |
| CO-224 | 35 | 20 | | M | Water Table |
| CO-225 | 35 | 25 | M | M | Water Table |
| CO-239 | 40 | 20 | M | | Water Table |
| CO-295* | 40 | 18 | | M | Water Table |
| CO-296* | 105 | 75 | | M | Lower Tamiami |
| CO-297* | 105 | 80 | | M | Lower Tamiami |

M = Monthly sampling interval

* = Locations not shown on map

## THE GLADES SWIMM MONITOR NETWORK

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Dissolved* Chlorides | Aquifer Monitored |
|---|---|---|---|---|---|
| CO-1[1] | 58 | 40 | | M | Lower Tamiami |
| CO-2[1] | 61 | 40 | | M | Lower Tamiami |
| CO-4[2] | 100-125 | - | | M | Lower Tamiami |
| CO-5[2] | 100-125 | - | | M | Lower Tamiami |
| CO-8[2] | 60 | 40 | | M | Lower Tamiami |
| CO-27 | 90 | 35 | M | M | Lower Tamiami |
| CO-28 | 90 | 35 | M | M | Lower Tamiami |
| CO-29 | 90 | 36 | M | M | Lower Tamiami |
| CO-30 | 85 | 35 | M | M | Lower Tamiami |
| CO-31 | 90 | 35 | M | M | Lower Tamiami |
| CO-32 | 90 | 35 | M | | Lower Tamiami |
| CO-34 | 12 | 7 | M | | Water Table |
| CO-35 | 55 | 38 | | M | Lower Tamiami |
| CO-36[2] | 40 | - | | M | Lower Tamiami |
| CO-37[2] | 30 | - | | M | Lower Tamiami |
| CO-38[2] | - | - | | M | Lower Tamiami |

* = Chloride data is being collected from three additional monitor wells not shown on map

1 = Municipal supply well

2 = Irrigation supply well

M = Monthly sampling interval

## THE PELICAN BAY SWIMM MONITOR NETWORK

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Dissolved* Chlorides | Aquifer Monitored |
|---|---|---|---|---|---|
| CO-13 | 100 | 43 | M | M | Lower Tamiami |
| CO-14 | 90 | 53 | M | M | Lower Tamiami |
| CO-15 | 15 | 10 | M | - | Water Table |
| CO-16 | 90 | 50 | M | M | Lower Tamiami |
| CO-17 | 21 | 14 | M | - | Water Table |
| CO-18 | 90 | 51 | M | M | Lower Tamiami |
| CO-19 | 19 | 14 | M | - | Water Table |
| CO-20 | 90 | 55 | M | M | Lower Tamiami |
| CO-21 | 225 | 170 | - | M | Sandstone |
| CO-22 | 75 | 61 | M | M | Lower Tamiami |
| CO-23 | 25 | 21 | M | - | Water Table |
| CO-24 | 15 | 15 | M | - | Water Table |
| CO-25 | 16 | 10 | M | M | Water Table |
| CO-26** | 90 | 53 | | | Lower Tamiami |

M = Monthly sampling interval

* = Chloride data is being collected from six additional monitor wells not shown on map

** = Production Well

## THE EAST GOLDEN GATE SWIMM MONITOR NETWORK*

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Dissolved Chlorides | Aquifer Monitored |
|---|---|---|---|---|---|
| P-1 | 71 | 42 | - | M | Lower Tamiami |
| P-2 | 93 | 42 | - | M | Lower Tamiami |
| P-3 | 80 | 39 | - | M | Lower Tamiami |
| P-4 | 81 | 42 | - | M | Lower Tamiami |
| P-5 | 98 | 42 | - | M | Lower Tamiami |
| P-6 | 101 | 42 | - | M | Lower Tamiami |
| P-7 | 109 | 47 | - | M | Lower Tamiami |
| P-8 | 133 | 42 | - | M | Lower Tamiami |
| P-9 | 82 | 42 | - | M | Lower Tamiami |
| P-10 | 131 | 42 | - | M | Lower Tamiami |
| P-11 | 80-100 | 40-60 | - | M | Lower Tamiami |
| P-12 | 80-100 | 40-60 | - | M | Lower Tamiami |
| P-13 | 80-100 | 40-60 | - | M | Lower Tamiami |
| P-14 | 80-100 | 40-60 | - | M | Lower Tamiami |
| P-15 | 80-100 | 40-60 | - | M | Lower Tamiami |
| P-16 | 80-100 | 40-60 | - | M | Lower Tamiami |
| P-17 | 80-100 | 40-60 | - | M | Lower Tamiami |
| P-18 | 80-100 | 40-60 | - | M | Lower Tamiami |
| G-1 | 25 | 20 | M | M | Water Table |
| G-2 | 25 | 20 | M | M | Water Table |
| G-6 | 25 | 20 | M | M | Water Table |
| G-11 | 100 | 42 | - | M | Lower Tamiami |
| G-15 | 100 | 42 | M | M | Lower Tamiami |
| G-16 | 25 | 20 | - | M | Water Table |
| G-18 | 25 | 20 | - | M | Water Table |
| W-1 | 17 | 12 | M | M** | Water Table |
| W-3 | 15 | 10 | M | M** | Water Table |
| W-4 | 14 | 9 | M | M** | Water Table |
| W-5 | 17 | 12 | M | M** | Water Table |
| W-6 | 17 | 12 | M | M** | Water Table |

M = Monthly sampling interval
* = Stage level and dissolved chloride data collected at five surface water stations
** = Specific conductance and dissolved chloride data collected

**THE CITY OF NAPLES COASTAL RIDGE SWIMM MONITOR NETWORK**

**(Monitor Wells)**

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Dissolved Chlorides | Aquifer Monitored |
|---|---|---|---|---|---|
| C-151A | 166 | 145 | M | M | Lower Tamiami |
| C-150 | 51 | 54 | M | M | Lower Tamiami |
| C-161* | 135 | 118 | M | M | Lower Tamiami |
| C-355 | 152 | 140 | M | M | Lower Tamiami |
| C-409A* | 73 | 63 | M | M | Lower Tamiami |
| C-424* | 132 | 126 | M | M | Lower Tamiami |
| C-430* | 65 | 63 | M | M | Lower Tamiami |
| C-474A* | 72 | 63 | M | M | Lower Tamiami |
| C-490* | 71 | 70 | M | M | Lower Tamiami |
| C-491* | 71 | 70 | M | M | Lower Tamiami |
| C-505A* | 74 | 63 | M | M | Lower Tamiami |
| C-524* | 80 | 63 | M | M | Lower Tamiami |
| C-525* | 83 | 63 | M | M | Lower Tamiami |
| C-526* | 68 | 63 | M | M | Lower Tamiami |
| C-527* | 72 | 63 | M | M | Lower Tamiami |
| C-528* | 80 | 63 | M | M | Lower Tamiami |
| A-1 | 80 | 60 | M | M | Lower Tamiami |
| A-2(D) | 80 | 60 | M | M | Lower Tamiami |
| A-2(S) | 25 | 20 | M | M | Water Table |

M = Monthly sampling interval

* = Station monitored at same frequency by the USGS

# THE CITY OF NAPLES COASTAL RIDGE SWIMM MONITOR NETWORK

## (Production Wells)

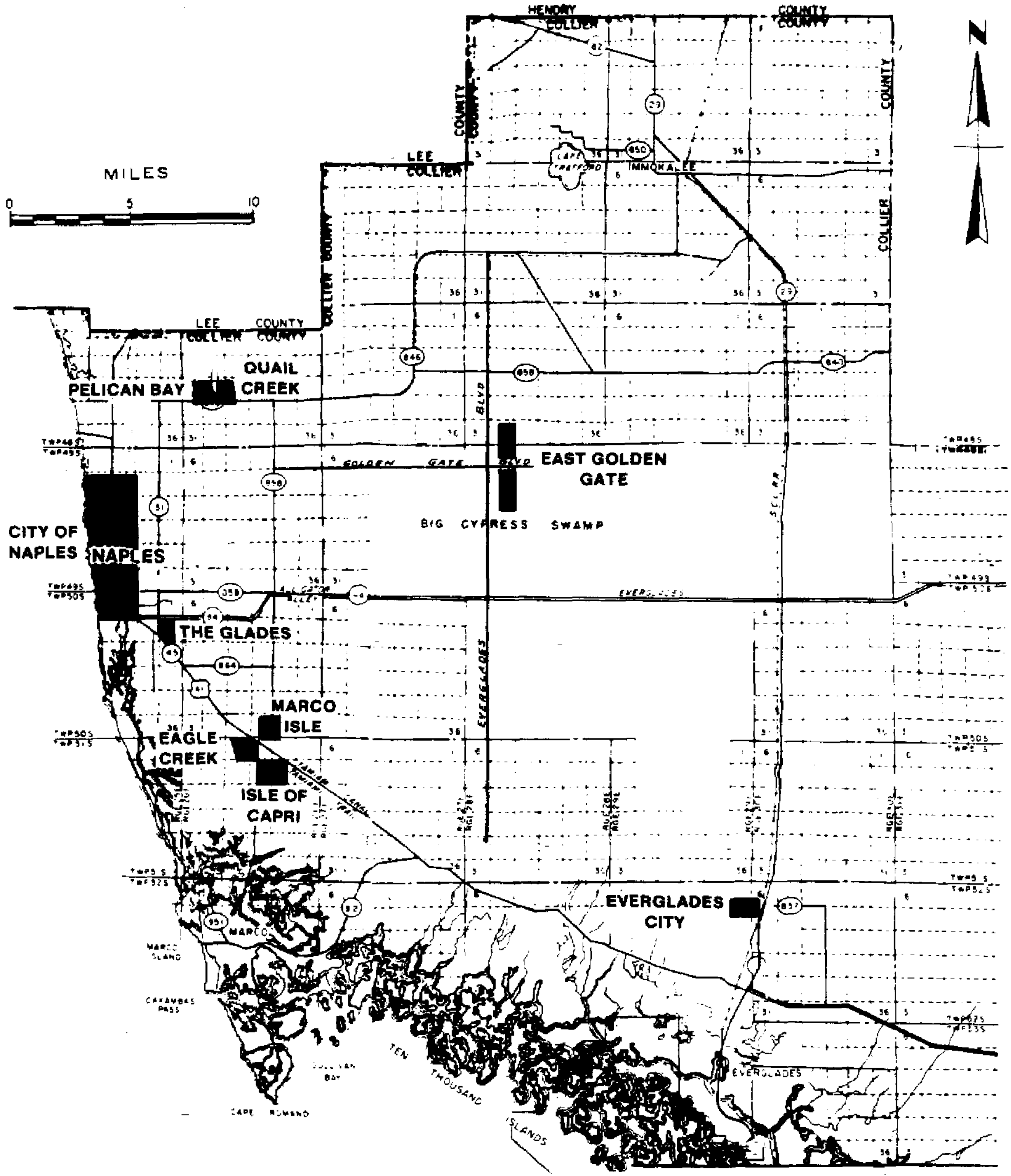
| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Dissolved Chlorides | Aquifer Monitored |
|---|---|---|---|---|---|
| 1 | 90 | 56 | - | M | Lower Tamiami |
| 2 | 87 | 57 | - | M | Lower Tamiami |
| 3 | 89 | 56 | - | M | Lower Tamiami |
| 4 | 82 | 53 | - | M | Lower Tamiami |
| 5 | 82 | 54 | - | M | Lower Tamiami |
| 6 | 82 | 51 | - | M | Lower Tamiami |
| 7 | 89 | 60 | - | M | Lower Tamiami |
| 8 | 80 | 58 | - | M | Lower Tamiami |
| 9 | 40 | 24 | - | M | Lower Tamiami |
| 10 | 87 | 54 | - | M | Lower Tamiami |
| 11 | 87 | 64 | - | M | Lower Tamiami |
| 12 | 83 | 64 | - | M | Lower Tamiami |
| 13 | 83 | 62 | - | M | Lower Tamiami |
| 14 | 83 | 64 | - | M | Lower Tamiami |
| 15 | 83 | 64 | - | M | Lower Tamiami |
| 16 | 80 | unknown | - | M | Lower Tamiami |
| 17 | 85 | 61 | - | M | Lower Tamiami |
| 18 | 85 | 61 | - | M | Lower Tamiami |
| 19 | 85 | 61 | - | M | Lower Tamiami |
| 20 | 85 | 62 | - | M | Lower Tamiami |
| 21 | 85 | 61 | - | M | Lower Tamiami |
| 22 | 85 | 61 | - | M | Lower Tamiami |
| 23 | 85 | 61 | - | M | Lower Tamiami |
| 24 | 85 | 63 | - | M | Lower Tamiami |
| 25 | 85 | 62 | - | M | Lower Tamiami |
| 26 | 85 | 62 | - | M | Lower Tamiami |
| 27 | 85 | 61 | - | M | Lower Tamiami |
| 28 | 85 | 61 | - | M | Lower Tamiami |
| 29 | unknown | unknown | - | M | Lower Tamiami |

## THE CITY OF NAPLES COASTAL RIDGE SWIMM MONITOR NETWORK - CONTINUED

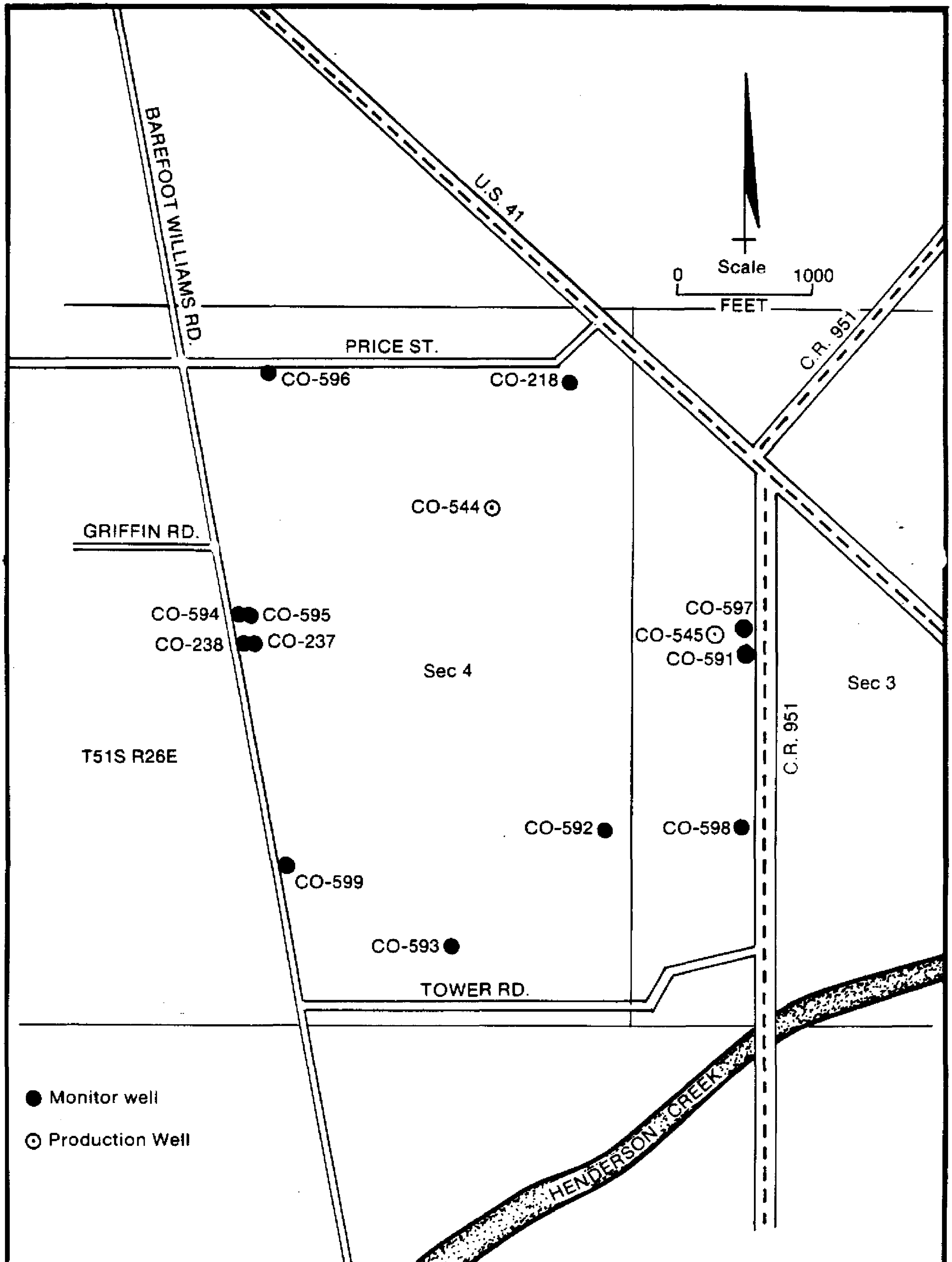
### (Production Wells)

| Well No. | Total Depth (ft) | Casing Depth (ft) | DATA COLLECTED Water Level | Dissolved Chlorides | Aquifer Monitored |
|---|---|---|---|---|---|
| 30 | unknown | unknown | - | M | Lower Tamiami |
| 31 | unknown | unknown | - | M | Lower Tamiami |
| 32 | unknown | unknown | - | M | Lower Tamiami |
| 33 | unknown | unknown | - | M | Lower Tamiami |
| 34 | unknown | unknown | - | M | Lower Tamiami |
| 1A | 96 | 85 | - | M | Lower Tamiami |
| 2A | 85 | 58 | - | M | Lower Tamiami |
| 3A | 76 | 55 | - | M | Lower Tamiami |
| 4A | 73 | 50 | - | M | Lower Tamiami |
| 5A | unknown | unknown | - | M | Lower Tamiami |
| 6A | 95 | 74 | - | M | Lower Tamiami |
| 7A | 85 | 70 | - | M | Lower Tamiami |
| 8A | 86 | 68 | - | M | Lower Tamiami |
| Standby WP#2 | 95 | 66 | - | M | Lower Tamiami |

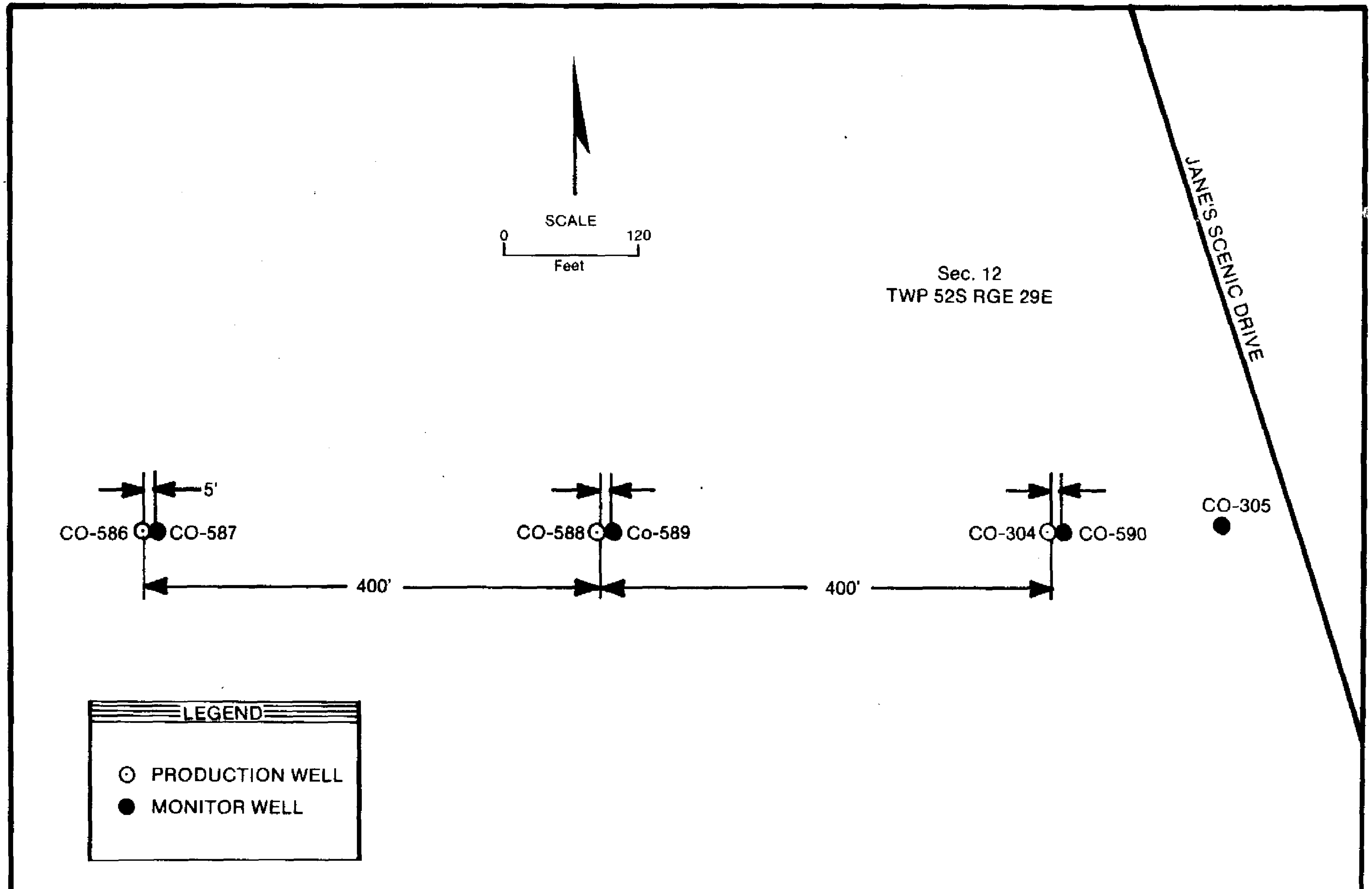
M = Monthly sampling interval




**Location of Saline Water Intrusion Monitor & Management (SWIMM) Programs**

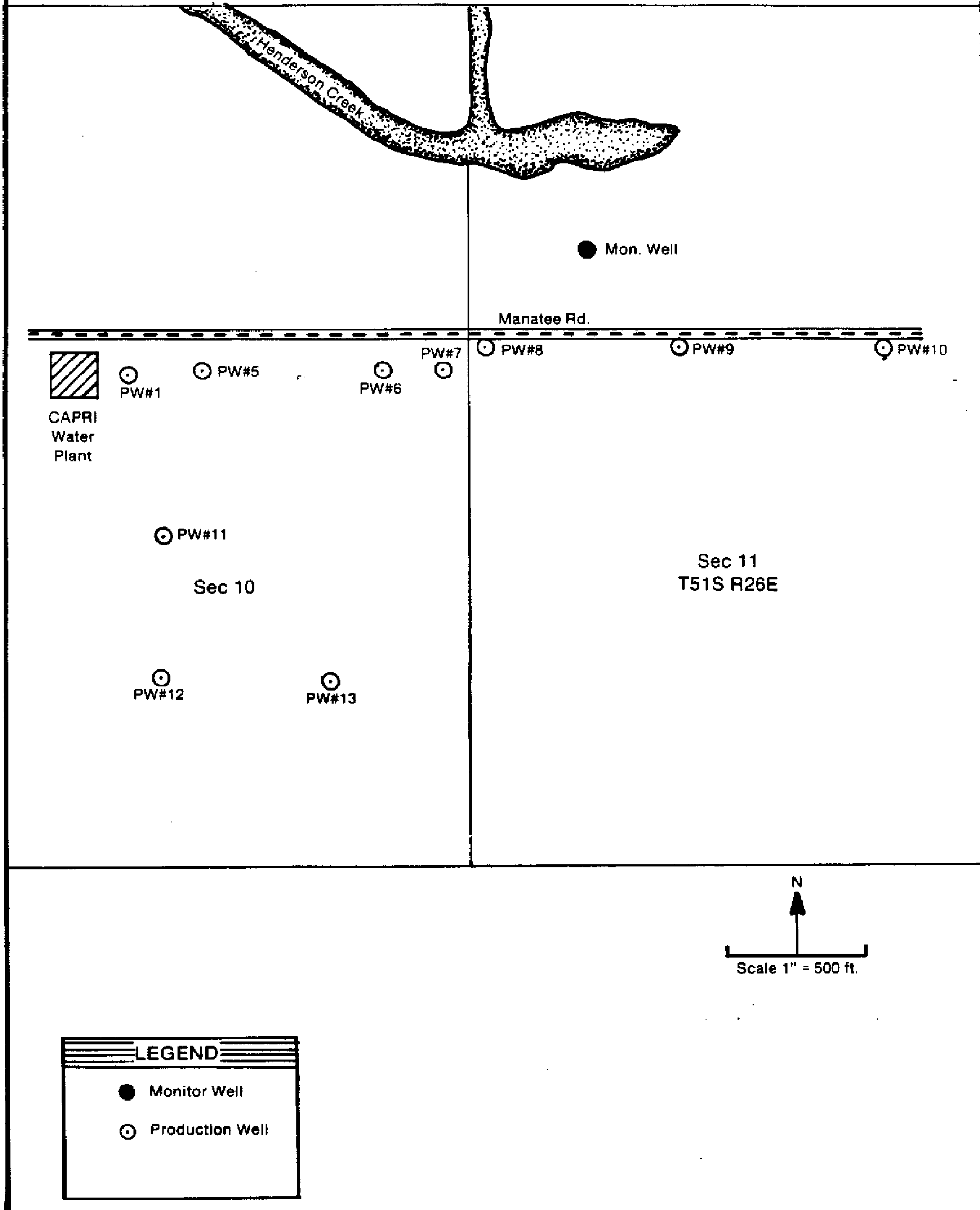


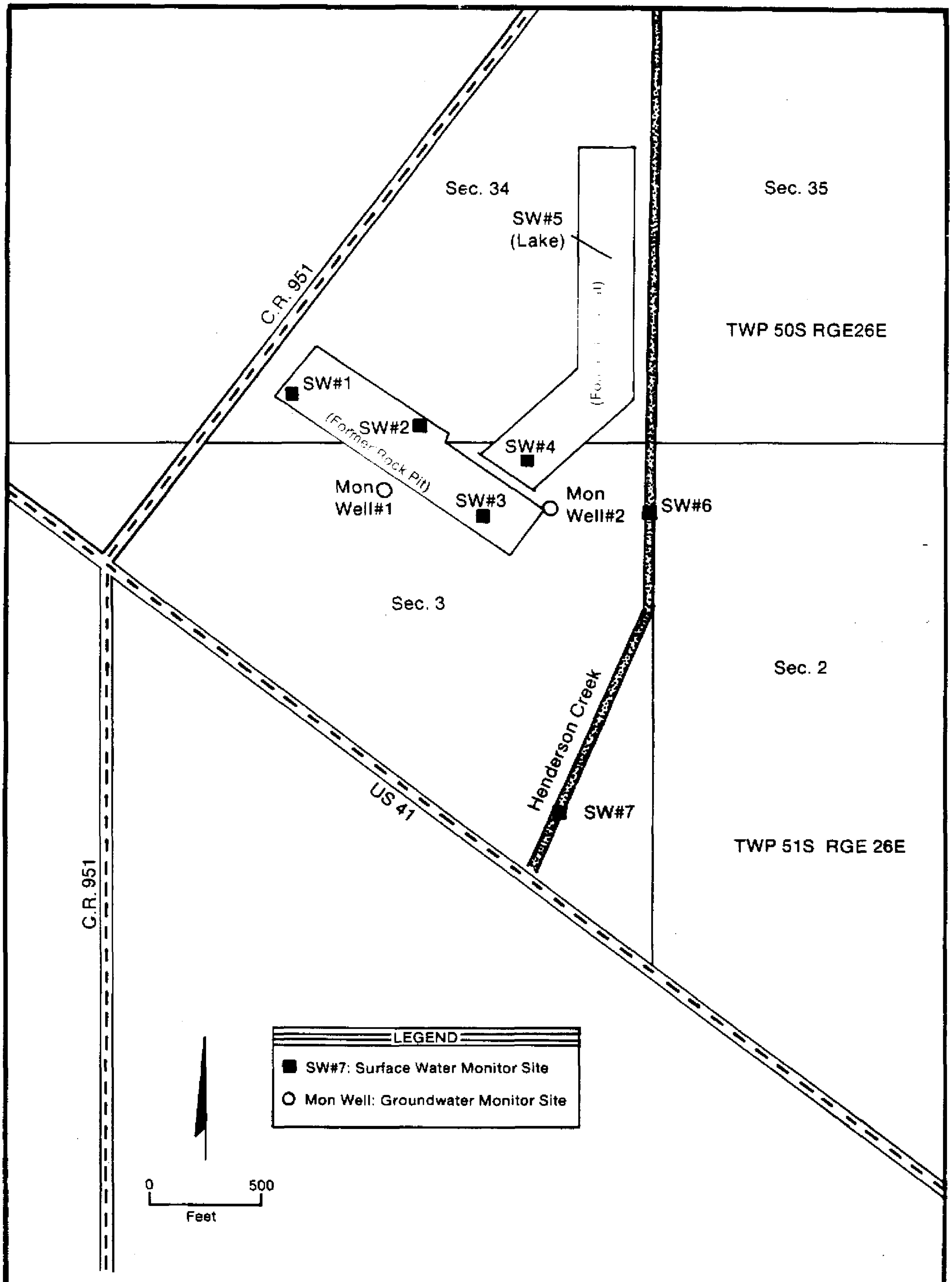

**Observation and Production Well Locations For The Eagle Creek SWIMM Program**



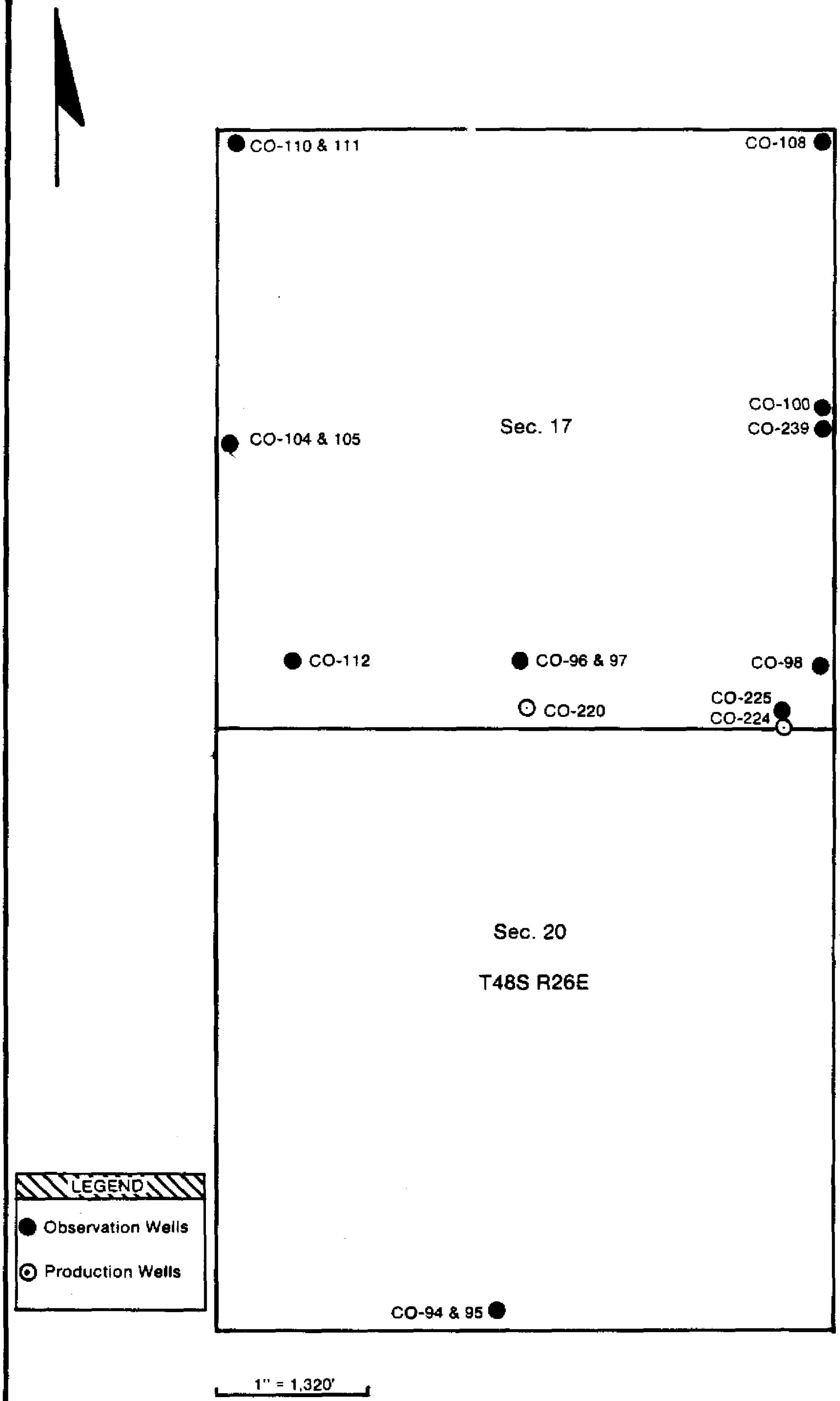

**Observation and Production Well Locations for the Everglades City SWIMM Program**

**Observation and Production Well Locations For The Isle of Capri SWIMM Program**

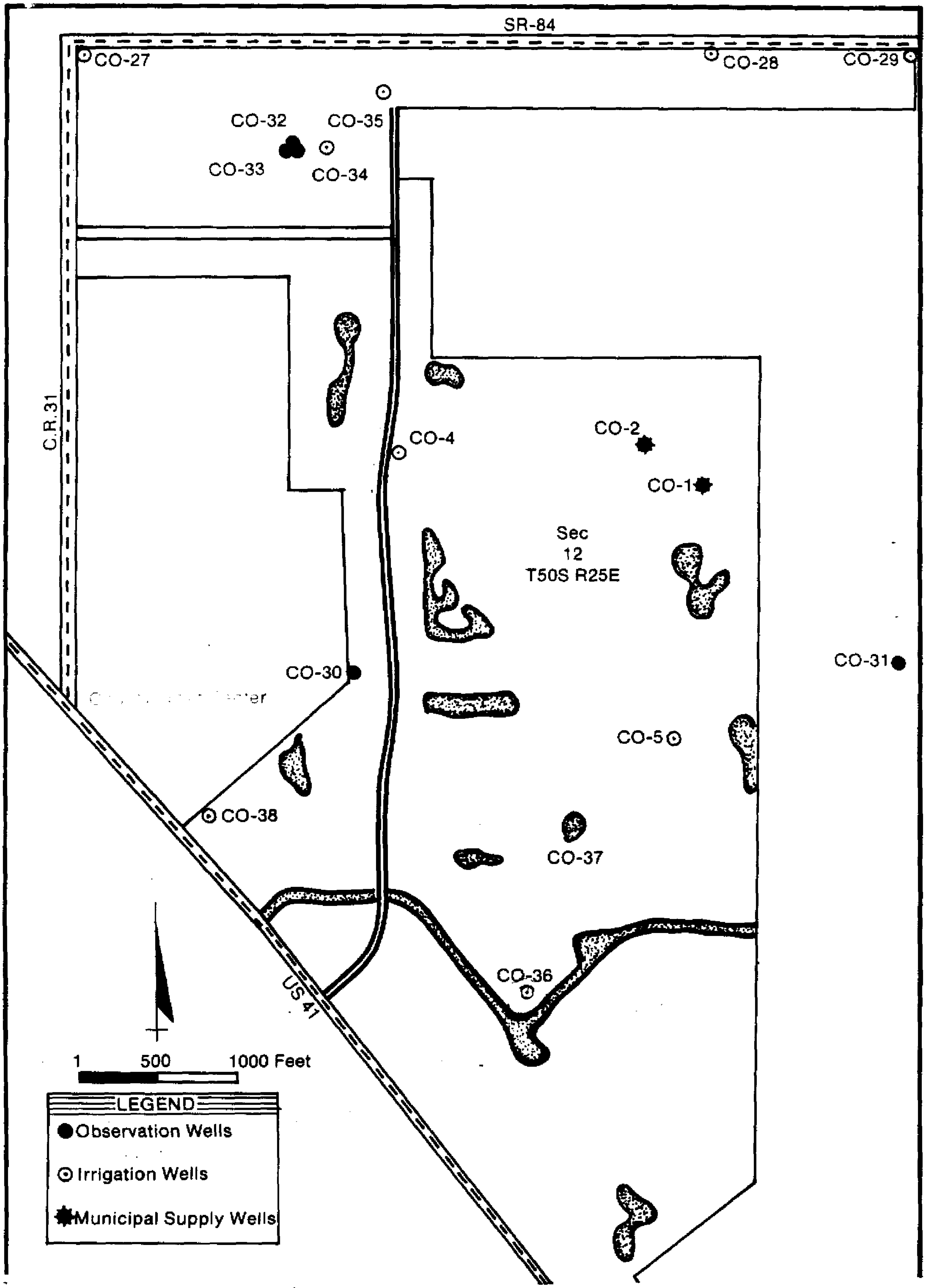





**Water Quality Sampling Points For The Marco Isle Utility SWIMM Program**

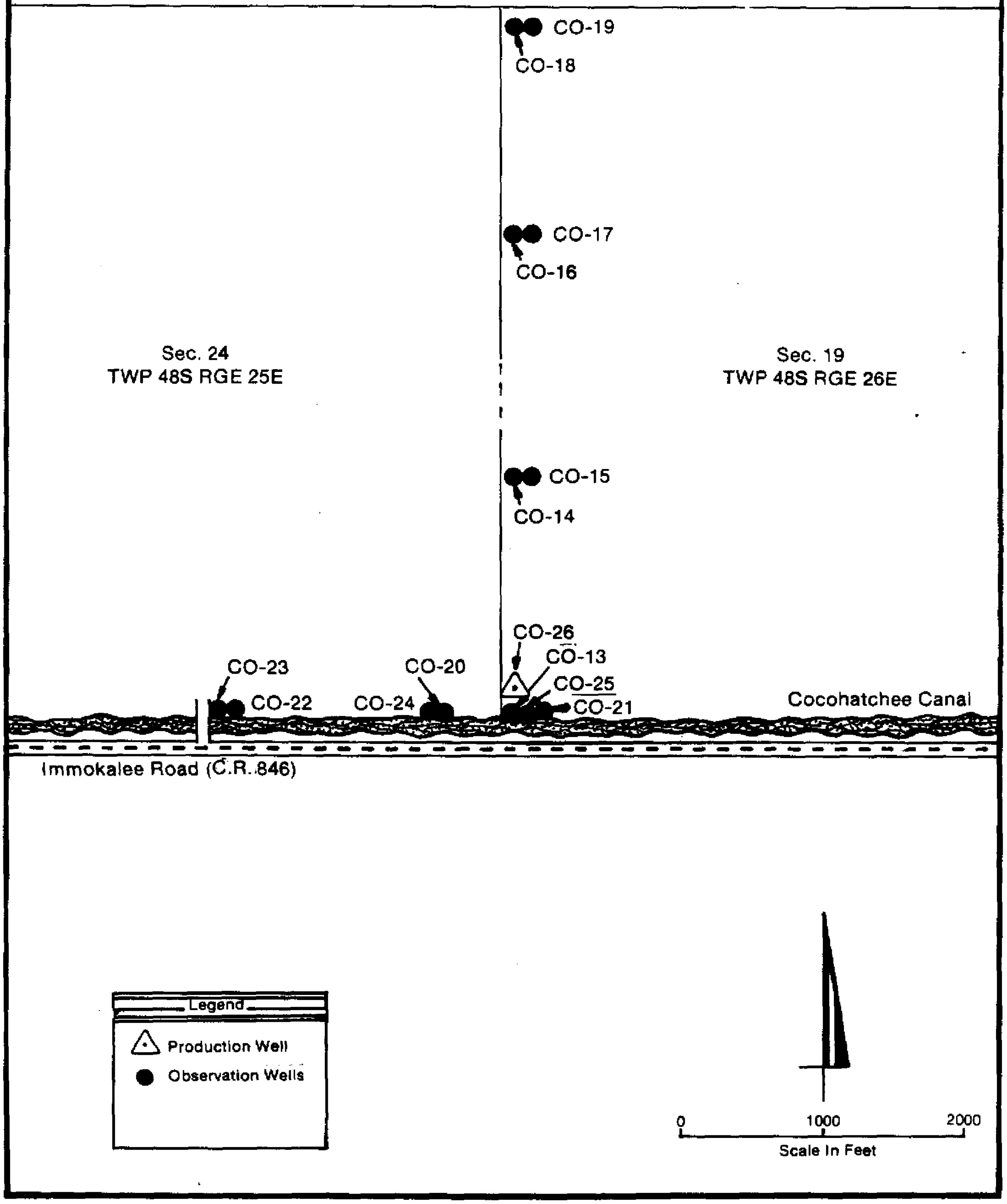


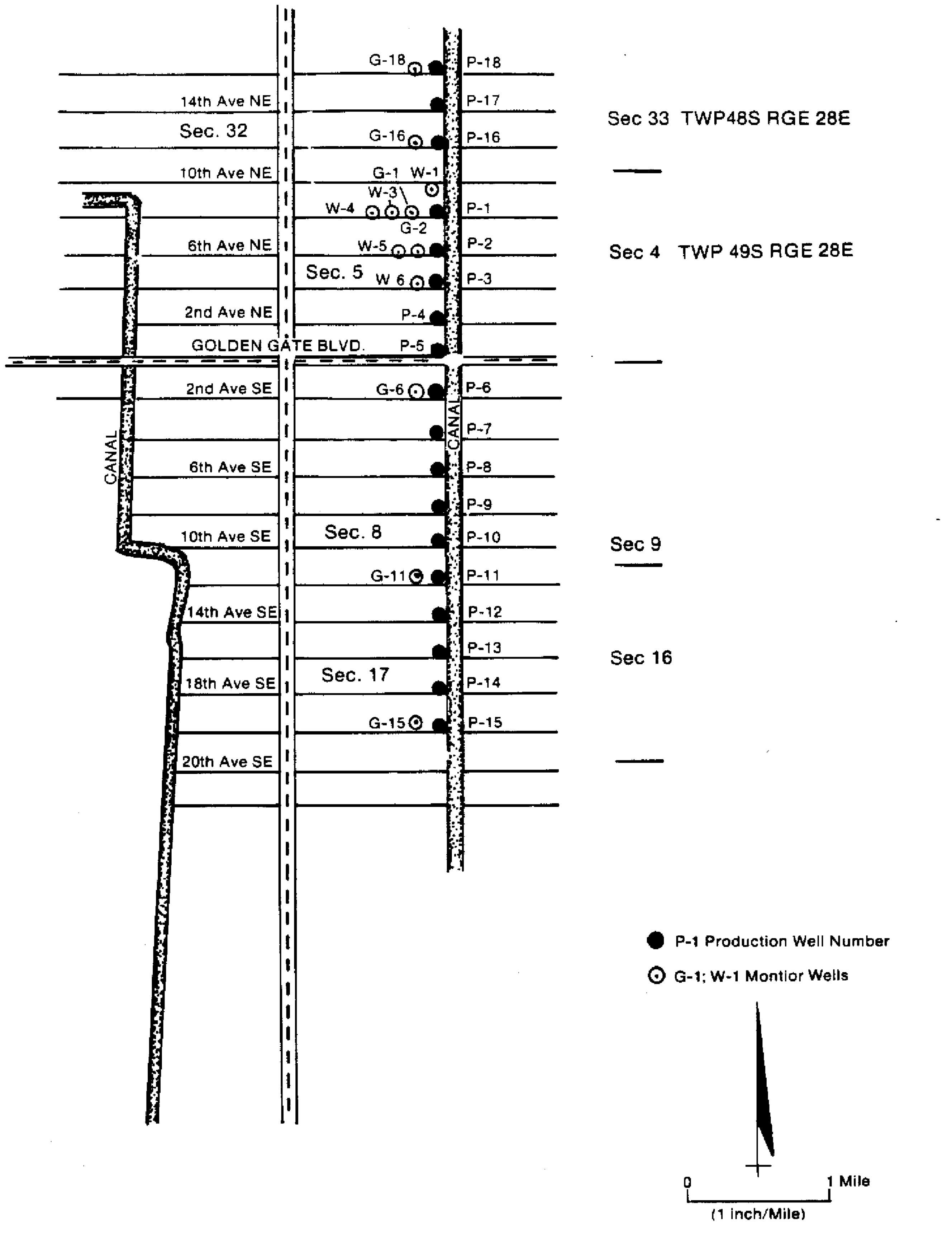

**Observation and Production Well Locations For The Quail Creek SWIMM Program**



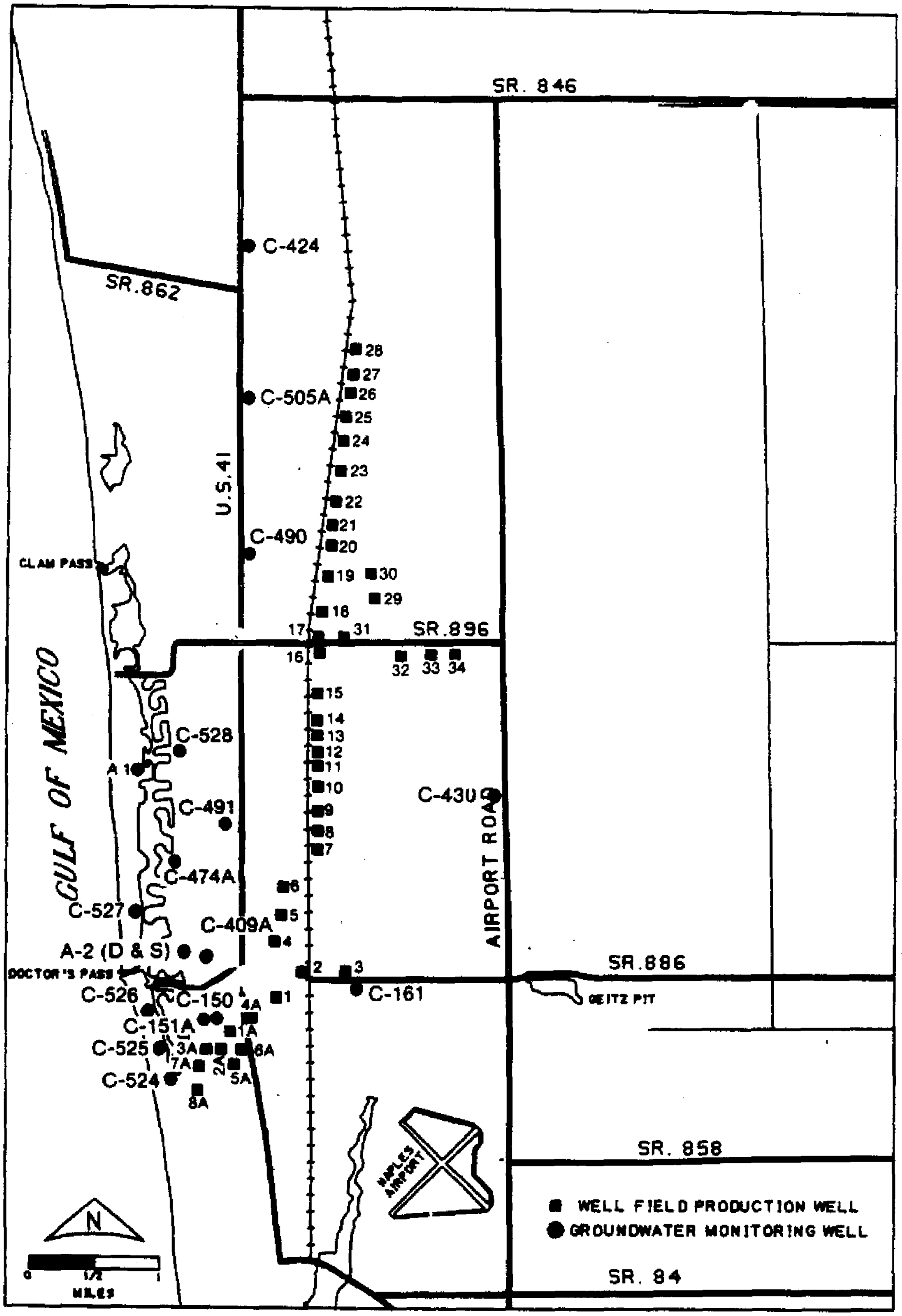

**Observation and Production Well Locations For The Glades SWIMM Program**

**Observation and Production Well Locations For The Pelican Bay SWIMM Program**






**Observation and Production Well Locations For The East Golden Gate SWIMM Program**




**Observation and Production Well Locations For The City of Naples Coastal Ridge SWIMM Program**