HYDROLOGIC INVESTIGATION OF TAMIAMI AQUIFER SYSTEM — ZONE II AT THE BURNT STORE MARINA DEVELOPMENT LEE COUNTY FLORIDA

PREPARED FOR

PUNTA GORDA ISLES, INC.
1625 WEST MARION AVENUE
PUNTA GORDA, FLORIDA 33950

JUNE, 1979

BY

MISSIMER AND ASSOCIATES, INC.
CONSULTING HYDROLOGISTS, GEOLOGISTS,
AND ENVIRONMENTAL SCIENTISTS
CAPE CORAL, FLORIDA

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1. Conclusions

The ground-water system at the Burnt Store Marina Development was investigated in order to evaluate the potential for development of an adequate irrigation water supply and to assess the impacts of pumping from the aquifer system.

Information compiled and analyses performed as part of this investigation lead to the following conclusions:

1) Water of suitable quality for irrigation use was located in Tamiami Aquifer System - Zone II;
2) Water in Zone II is limited in quantity, the hydraulic coefficients are:

   Transmissivity = 4800 gpd/ft

   Storage Coefficient = 5.7×10^{-5}

   Leakance = 1.1×10^{-4} gpd/ft^3

   This means that recharge to the aquifer is slow, the cone of depression from pumping is large with drawdowns at equilibrium relatively large a long distance from the center of pumpage;
3) .29 MGD of fresh water can be safely pumped from Zone II for many years;
4) There will be no impact on other water users of the surface environment from the pumping of Zone II;
5) Since recharge of Zone II comes primarily from the overlying water-table aquifer, more water quality data should be collected from the water-table aquifer to better predict the useful life expectancy of the system. This data should be obtained prior to lake construction in order to determine the best lake depths.
6) There are some existing old wells near the property which may now be causing a saline-water intrusion

problem or could in the future;

7) Quality of water in the Hawthorn Aquifer System - Zone I well on the site has 76 mg/l of dissolved chlorides, making it a good candidate for a conjunctive or alternate source of irrigation water.

2. Recommendations

1) A maximum of 0.29 MGD can be withdrawn from Tamiami Aquifer System - Zone II at the site;
2) All old, deep wells in the areas adjacent to the site should be plugged;
3) A detailed monitoring program, as given in Chapter VII, must be initiated and operated to properly manage the system (i.e. detect saline-water intrusion);
4) The Hawthorn Aquifer System - Zone I should be investigated as a supplemental or alternate irrigation water supply;
5) Prior to lake construction, water-table aquifer wells should be constructed at each site in order to determine the local quality for determination of optimum lake depths;
6) The possibility of utilizing secondary treated sewage effluent generated from the development for a supplemental source of irrigation water should be investigated;
7) An example of Burnt Store Marina projected irrigation water demand and scheduled uses of the possible water sources to satisfy those demands is given in the following table:

LONG-TERM WATER MANAGEMENT PLAN

Year	Water Need(MGD)	Sources	Daily Withdrawal(MGD)
1984	0.29 = 105.84 MGY	Lakes	0.1
		Tamiami-Zone II	0.19
1989	0.60	Lakes	0.13
		Tamiami-Zone II Sandstone	0.20 ←
		Hawthorn-Zone I (mid)	0.15
		Sewage Effluent	0.12
1994	0.75	Lakes	0.21
		Tamiami-Zone II	0.20 ←
		Hawthorn-Zone I	0.15
		Sewage Effluent	0.19
1999	0.75	Lakes	0.22
		Tamiami-Zone II	0.13 ←
		Hawthorn-Zone I	0.15
		Sewage Effluent	0.25

II. INTRODUCTION

1. Authorization

Missimer and Associates, Inc. was authorized in August, 1978, by Punta Gorda Isles, Inc. to investigate the adequacy of the Tamiami Aquifer System - Zone II at the Burnt Store Marina Development site for the purpose of providing an irrigation water source for the proposed development. The investigation was to include: 1) compilation of all existing hydrogeologic information; 2) a test drilling and observation well construction program; 3) a detailed aquifer test of 72 hours duration; 4) analysis of test data and water quality data; 5) recommendations on the availability of water; and 6) a final report with assessments of the impact of projected pumpage on the ground-water system.

2. Area of Investigation

The Burnt Store Marina Development totals 628 acres and is located in Section 1 of Township 43S, Range 22E, and Section 6 of Township 43S, Range 23E in Lee County (Figures 2-1 and 2-2). At full development, Burnt Store Marina will contain approximately 2500 dwelling units in low-rise condominiums and garden villa-type apartment units with recreational facilities. A large part of the property will be composed of lakes, landscaped areas, and golf courses with the latter two areas requiring a large volume of water for irrigation.

A hydrologic investigation was conducted within the property boundaries and adjacent areas to Burnt Store Marina.

3. Purpose

The primary purpose of the investigation was to determine

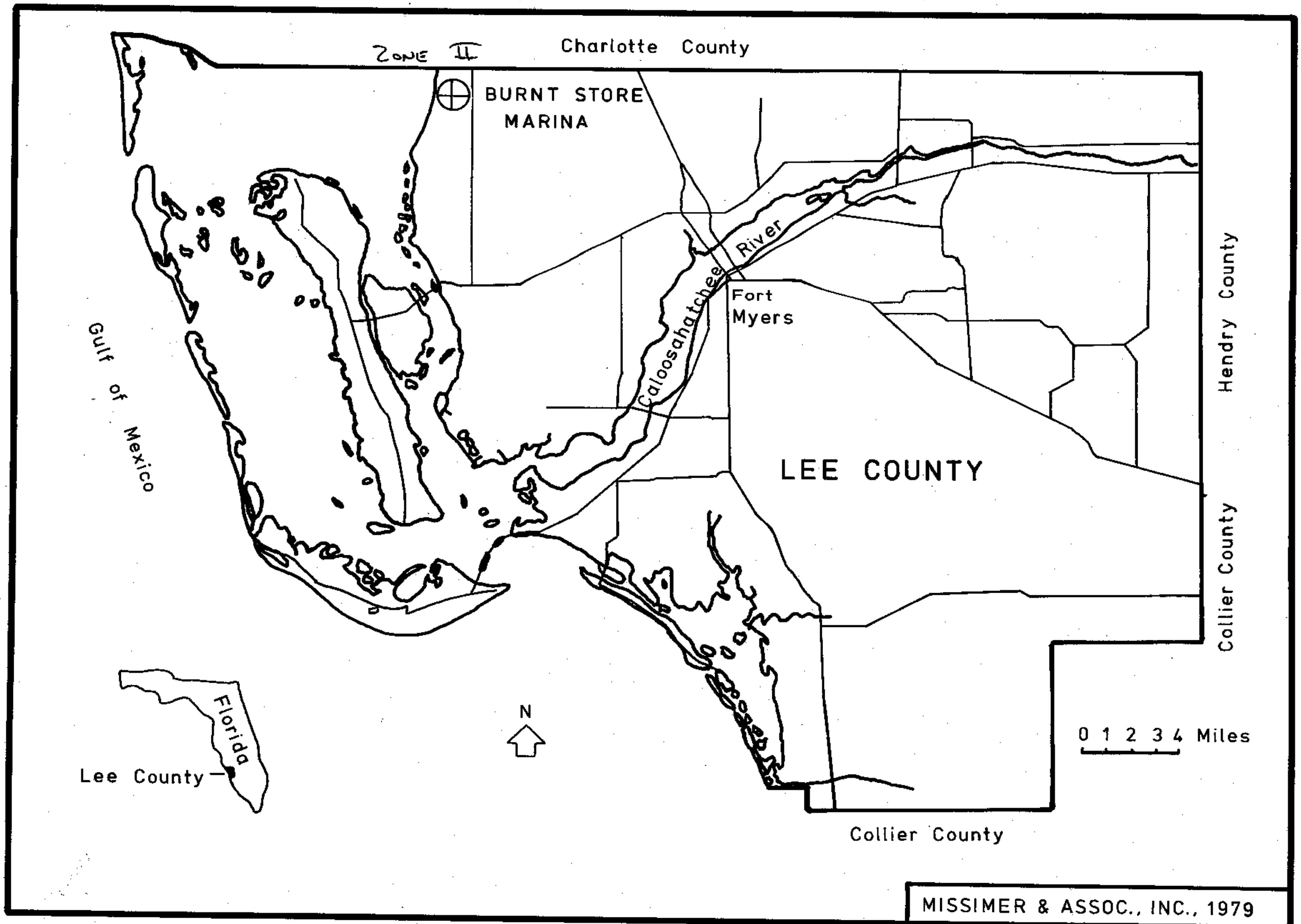


FIGURE 2-1. MAP OF LEE COUNTY SHOWING THE LOCATION OF THE BURNT STORE MARINA.

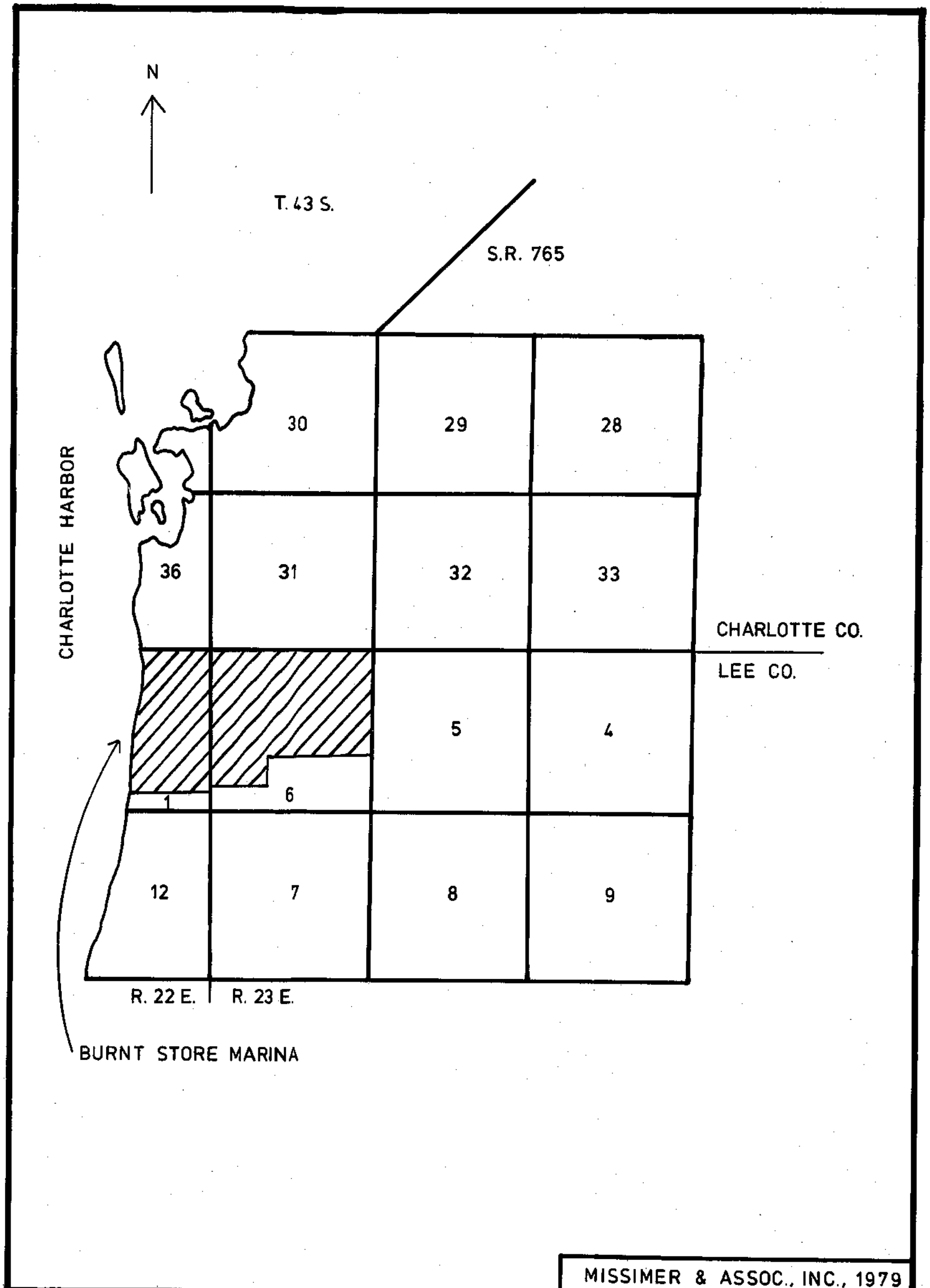


FIGURE 2-2. MAP SHOWING THE BURNT STORE MARINA PROPERTY BOUNDARIES.

the availability and adequacy of the groundwater resources on-site for meeting the future needs of the development. The information compiled herein is needed for utilizing and managing the local resource and is required to answer permitting questions of the South Florida Water Management District.

4. Acknowledgments

We wish to thank Mr. Durward Boggess and Mr. Henry LaRose of the U.S. Geological Survey, Fort Myers office, for providing basic hydrogeologic information; Mr. Horace Sutcliffe of the U.S.G.S., Sarasota, for providing basic information in Charlotte County; Mr. Bill Bocskocsky and Mr. Walt Wetterhall of the Southwest Florida Water Management District, for basic information in Charlotte County; Dr. Patrick Gleason of South Florida Water Management District for reviewing the plan of investigation; Mr. Ed Johnson of Florida Irrigation for information on the irrigation system design; Mr. Dick Bessire of Punta Gorda Isles, Inc. for coordinating our activities; and Mr. Ted Yeatts and Mr. Dave Johnson of Punta Gorda Isles, Inc. for their helpful information on the development.

III. GEOLOGY AND HYDROLOGY OF NORTHWESTERN LEE COUNTY

1. Introduction

The geology beneath northwestern Lee County consists of a mixture of carbonate rocks which contain bedded and disseminated clastic sediments (clays and sands). Between 5 and 8 distinctive water-bearing zones occur within the geologic section. This chapter provides a general overview of the regional geology and hydrology of northwestern Lee County in order to put the site-specific data in the proper framework.

2. Geology

A general description of subsurface stratigraphic units underlying northwest Lee County is given from land surface down to a depth of about 800 feet in Figure 3-1. This information has been obtained from hydrologic investigations performed by Missimer and Associates and from various governmental agencies. The terminology used for description of the various geologic formations and members comes from Missimer and Associates, Inc. (1978).

Pamlico Formation

The Pamlico Formation or Pamlico Sand is the uppermost geologic formation penetrated. It is Pleistocene in age and was deposited during the last interglacial period. It is a medium to fine-grain, quartz sand, which contains some shell and laminated, crystalline limestone. It varies in thickness from 5 feet to nearly 40 feet and is rarely uniform in thickness over large areas (more than one square mile). The upper two to four feet of the Pamlico Sand is the soil zone, which contains varying percentages of clays and organic detritus.

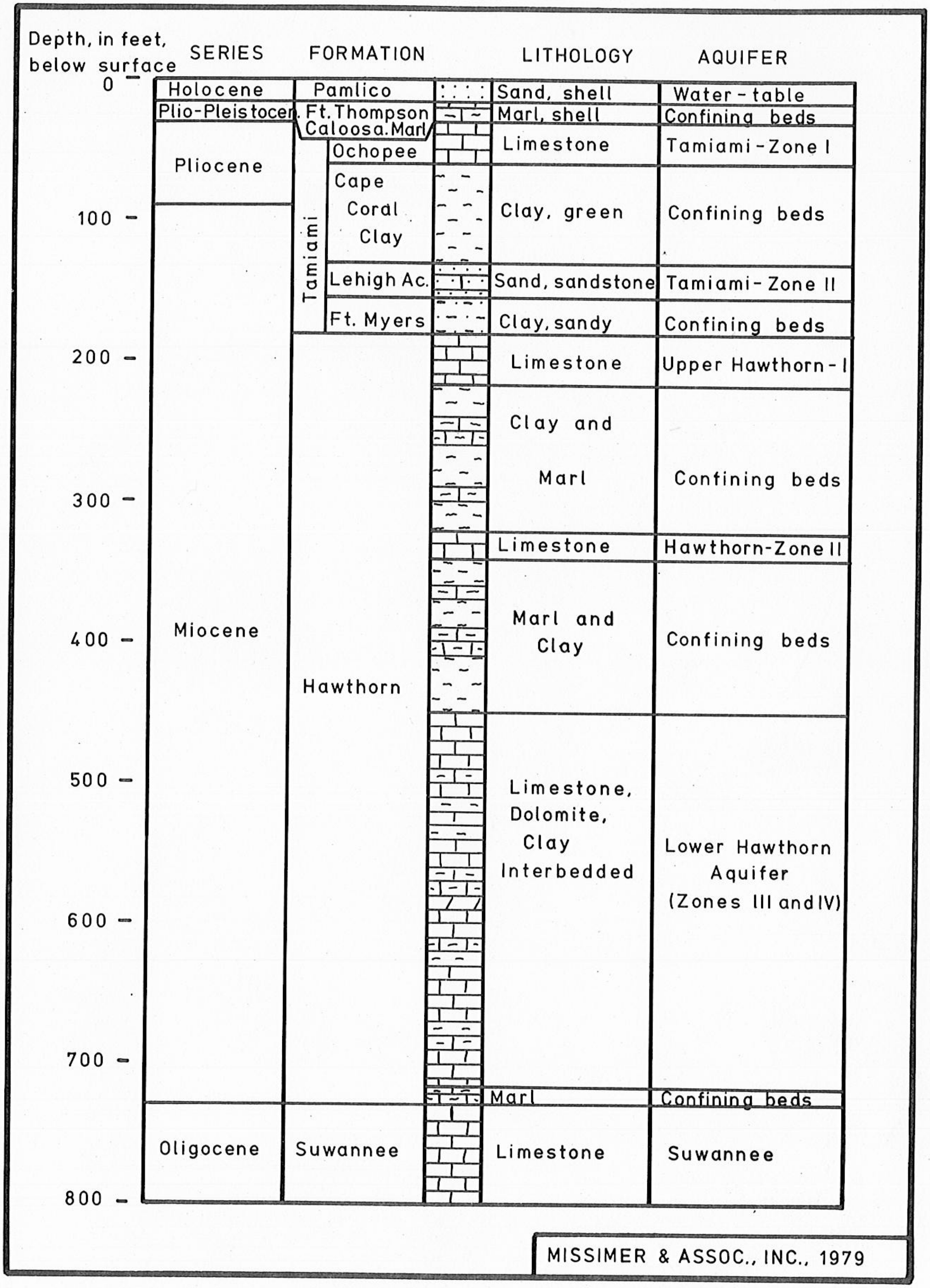


FIGURE 3-1. DIAGRAM SHOWING THE GENERAL SERIES, FORMATIONS, LITHOLOGIES, AND AQUIFER LOCATIONS IN WESTERN LEE COUNTY.

The Pamlico Sand occurs as far west as Pine Island, but does not occur on the outer barrier islands. The barrier islands and offshore sands were deposited in more recent times.

Fort Thompson Formation - Caloosahatchee Marl

These two formations are difficult to separate in the subsurface of western Lee County. Therefore, they are grouped as a single undifferentiated unit. The Fort Thompson Formation is Pleistocene in age and the Caloosahatchee Marl ranges from Pleistocene to late Pliocene in age. These units have a collective thickness ranging from 0 to 25 feet.

Many different lithologies occur within these formations. The most common lithologies are: shell; sand and shell; marl; and light gray clay.

Acline Formation

In the late 1940's, a group of paleontologists from the U.S. National Museum and the U.S. Geological Survey made an extensive collection of mollusks from a pit located in southwest Charlotte County. These fossil remains were significantly different from the fauna of the overlying Caloosahatchee Marl and the underlying Tamiami Formation and therefore, a new formation was defined informally as the Acline Formation. This formation contains shell, lime mud, and quartz sand in various proportions (personal communication, Mr. F. Stearns MacNeil, U.S. Geological Survey, ret.). There are some very permeable shell beds within the Acline Formation. The areal occurrence of this unit is probably limited to the coastal fringe of southern Charlotte and northern Lee County adjacent to Pine Island Sound (see Figure 2-1). It is quite possible that the Acline Formation is time equivalent to the upper part of the Cape Coral clay member of the Tamiami Formation.

Tamiami Formation

The Tamiami Formation is a lithologically complex formation underlying all of western Lee County. It ranges from late Miocene to middle Pliocene in age. There are 6 mapable members in the formation, which occur in western Lee County (see Figure 3-1). The collective thickness of the formation ranges from 100 to 250 feet in the area.

The Ochopee limestone is the uppermost member of the Tamiami Formation. This unit occurs in segmented areas of western Lee County and is not continuous over wide areas. Where present, it ranges from 5 to about 50 feet thick. It is a light gray to tan limestone and in some areas is a calcareous sandstone.

The Buckingham limestone member lies directly beneath the Ochopee limestone in many areas. This member is absent in some of the northern areas and where present, it is only 5 to 10 feet thick. It is a gray marl, clayey limestone, or carbonate mud with large thin shells and rock fragments.

The Cape Coral clay member underlies the Buckingham limestone member. This member underlies all of western Lee County. It ranges from 50 to 100 feet thick. The Cape Coral clay is a green carbonate mud with varying percentages of quartz sand and silt, and shell fragments. It contains angular beds which dip west to east (see Missimer and Gardner, 1975). These beds fine upward and some contain quartz sand and shell at the base. They are probably of deltaic origin.

The Lehigh Acres sandstone member lies beneath the Cape Coral clay. In northwestern Lee County, this unit is minor but is quite continuous. It ranges from 5 to 20 feet thick. The most common lithology is unconsolidated, fine, quartz sand, and in some areas it is a gray limestone or sandstone.

The Green Meadows clay member underlies the Lehigh Acres sandstone. It is a rather indistinct unit in northwestern Lee County. The unit is mostly a gray to green carbonate clay with varying percentages of quartz sand. It ranges from 5 to 15 feet in thickness.

The Fort Myers clay is the basal member of the Tamiami Formation in all of Lee County. It is a dark gray clay with a large percentage of phosphorite, quartz sand and silt. In some localities, it is more than 90% very fine quartz sand. It ranges from 15 to 25 feet thick. This unit has been defined in detail by Missimer (1978).

Hawthorn Formation

The Hawthorn Formation underlies all of southwest Florida. It is a middle Miocene-age mixed sequence of phosphatic carbonate rocks and terrestrial clays and sands. In northwestern Lee County, the upper formational contact is usually well-defined except in certain coastal areas (e.g. Sanibel Island). The formation varies in thickness from about 350 to 500 feet. The definition of the Hawthorn Formation used in this report includes all phosphatic sediments lying below the Tamiami Formation and above the Suwannee Limestone. The Tampa limestone is considered to be part of the Hawthorn Formation or it is not present in Lee County.

Numerous members of the Hawthorn Formation could be defined in northwestern Lee County, but the availability of data is insufficient to perform the task at this time. However, it is worth mentioning certain units that are known to be laterally extensive.

In northwestern Lee County, the uppermost part of the Hawthorn is a sequence of phosphatic limestones commonly called "salt and pepper" by local well drillers. This limestone is often interbedded with various types of clay. The sequence ranges from 10 to 50 feet thick.

A carbonate clay unit lies below the upper limestone. It is gray to green in color and ranges from 50 to 100 feet in thickness. It is phosphatic and contains a considerable percentage of quartz sand. This unit sometimes is marly or is a clayey limestone. It is regionally extensive.

A minor unit of phosphatic limestone lies below the clay. It is phosphatic and sometimes water-bearing. It is not known at present whether this unit is regionally extensive, but it does occur in Cape Coral and Sanibel Island.

Another sequence of carbonate clays and marls lies below the limestone. It ranges from 30 to 50 feet thick in some areas. It is gray to green in color and it contains quartz sand and silt. It is regionally extensive.

Below the underlying clay unit, a sequence of limestones and dolomites predominates the section. Only thin clays or marls (less than 10 feet thick) occur within the Hawthorn Formation below the second clay. Lithologies in the rock sequence include the following: hard microcrystalline, gray limestones; soft, white, phosphatic limestones; tan, microcrystalline dolomites; and numerous other mixed lithologies. A large percentage of the lower part of the Hawthorn Formation consists of water-bearing strata.

Suwannee Limestone

The Suwannee Limestone is another major geologic unit. which underlies all of Lee County. It is Oligocene in age and lies conformably beneath the Hawthorn Formation. Little is known about the regional changes in the lithology of the Suwannee Limestone. It is known to contain limestones, marls, and quartz sand in Lee County. The upper part of the formation is water-bearing and it is probable that most of the unit is also water-bearing. The Suwannee Limestone is between 300 and 400 feet thick in northwestern Lee County.

3. Aquifer Descriptions

The stratigraphic position of each water-bearing zone is shown in Figure 3-1. A general description of the aquifer properties, including geology, water levels, water quality, and hydraulic properties is given in this section for northwestern Lee County.

Water-table aquifer

The water-table aquifer is unconfined or directly open to atmospheric pressure. It is recharged directly by rainfall.

The Pamlico Sand forms a major part of the water-table aquifer in northwestern Lee County. In some areas, the upper part of the Fort Thompson Formation - Caloosahatchee Marl sequence, and part of the Acline Formation is water-bearing and is hydraulically connected to the overlying Pamlico Sand. Therefore, the water-table aquifer occurs within both of these stratigraphic units. The aquifer ranges from 5 to 40 feet in thickness in northwestern Lee County.

Water levels in the aquifer fluctuate in response to climate changes. When rainfall is abundant, water levels are high and vice-versa. In areas not affected by drainage ditches or canals, the water table rises to near land surface in the wet season and lowers 3 to 5 feet in the dry season.

Enhanced drainage in many areas of northwestern Lee County has lowered the water table on a more or less permenent basis.

Water quality in the water-table aquifer is good under natural conditions. It normally meets most drinking water standards except where it is affected by saline-water intrusion near the coastline. The concentration of dissolved iron and the color of the water do not meet drinking water standards. Dissolved iron concentrations range up to 8 mg/l and the water is often highly colored with organic acids such as tannin and lignin.

No actual aquifer tests have been performed on the water-table aquifer in northwestern Lee County. Therefore, only estimates can be made on the hydraulic properties. Because of the extreme variation in thickness and sediment type, the aquifer transmissivity is estimated to range from about 200 to about 30,000 gpd/ft and specific yields range from 0.01 to 0.3.

The water-table aquifer is not heavily used for potable supply or irrigation in northwestern Lee County. However, some wells are used to supply irrigation water for individual home lawns and a few municipal supply wells produce water in the Waterway Estates Wellfield.

Tamiami Aquifer System - Zone I

Tamiami Aquifer System - Zone I lies in the Ochopee limestone member of the Tamiami Formation. The Ochopee limestone member is discontinuous over northwestern Lee County as previously mentioned. The aquifer occurs beneath most of the coastal area, such as Sanibel Island, and parts of Cape Coral. Zone I is totally confined in all areas where it occurs.

Water level data on the aquifer are sparse, but where data are available, the potentiometric surface of the aquifer occurs at or slightly below the position of the water table. This relationship is caused by the leaky nature of the aquifer.

Water quality in Zone I is very poor in western Lee County. It ranges from very saline to hyper-saline. Extremely high dissolved chloride concentrations occur in Zone I wells located in south Cape Coral.

There are no existing data available on the aquifer hydraulic properties. The transmissivity is estimated to range from 2,000 to 20,000 gpd/ft. It is not possible to estimate the storage coefficient or leakance.

There is no known use of water from Tamiami Aquifer System - Zone I in northwestern Lee County.

Tamiami Aquifer System - Zone II

Tamiami Aquifer System - Zone II, commonly known as the Sandstone Aquifer, lies in the Lehigh Acres sandstone member of the Tamiami Formation. This aquifer is fully confined by low-permeability clays in overlying units and confined to a variable degree from underlying aquifers. Zone II is not well-developed as an aquifer in western Lee County. It is essentially a thin sand facies with some sandstone. The aquifer ranges in thickness from about 5 to 20 feet. There are some isolated areas where the sands are not present and only clays occur. Zone II is absent in those areas.

Water level data are not available from Tamiami Aquifer System - Zone II in western Lee County. It is probable that the Zone II potentiometric surface lies at a position several feet below the water table.

Water quality data have been collected from a few Zone II wells in the Waterway Estates area of western Lee County. Dissolved chloride concentrations were all below 200 mg/l.

Only small quantities of water are used from Tamiami - Zone II. A few wells tap the zone in Waterway Estates and just east of Burntstore Road. Only single-family domestic supplies and lawn irrigation wells tap the aquifer. The 2-inch diameter wells yield 10 to 20 gpm, but would have greater capacities if they were properly screened.

Upper Hawthorn Aquifer (Hawthorn Aquifer System - Zone I)

The term "Upper Hawthorn Aquifer" was first formally used by Sproul, Boggess, and Woodard (1972). The Upper Hawthorn Aquifer was defined as a water-bearing zone in the uppermost part of the Hawthorn Formation. In this report, the Upper Hawthorn Aquifer is termed Hawthorn Aquifer System - Zone I. This nomenclature change is necessary because of confusion on the position of the four to six water-bearing zones which occur within the Hawthorn Formation.

Hawthorn Aquifer System - Zone I is confined from the overlying Tamiami Aquifer System and from underlying water-bearing zones by low-permeability clays and marls. There are areas of western Lee County, where there is a low degree of confinement between Hawthorn - Zone I and Tamiami - Zone II, such that a considerable volume of water is free to move between them especially during a pumping condition. Hawthorn - Zone I is quite well-confined from underlying water-bearing zones in all areas.

Zone I varies in thickness from about 5 feet up to 50 feet. The limestone sequence is often interbedded with clay and shell.

Water levels in the aquifer have shown a significant historical decline in many areas of western Lee County. The potentiometric surface decline is a result of very heavy pumping of water from the aquifer for both domestic and municipal supplies. The magnitude of the decline is up to 80 feet. Flow of water through the aquifer no longer follows any ordered regional pattern, but the flow is now directed toward local centers of pumpage. In northwestern Lee County, the regional flow direction is probably from northeast to southwest.

Water quality in the aquifer is potable over large areas of northwestern Lee County. In areas away from the coast, the natural dissolved chloride concentrations range from about 60 to 200 mg/l. Higher chloride concentrations occur in the aquifer beneath areas adjacent to the coast and in areas affected by saline-water intrusion from wells. The use of steel cased wells in coastal areas has allowed entry of saline water into the aquifer through corrosion holes in the casing. Old, deep wells with an insufficient length of casing allow saline-water, under high pressure, to intrude Hawthorn Aquifer System - Zone I. These wells are the primary cause of water quality degradation in the aquifer (see Boggess, Missimer, and O'Donnell, 1977).

Only a few aquifer tests have been performed on Hawthorn - Zone I. Transmissivity values generally range from 4,000 to 15,000 gpd/ft, but lower values are common (Missimer and Associates, Inc., 1978b). The storage coefficient is estimated to range from 1×10^{-4} to 1×10^{-5} and the leakance is estimated to range from 5.0×10^{-4} to 5.0×10^{-6} gpd/ft^3. These values are only approximate.

Hawthorn Aquifer System - Zone I is the most heavily used aquifer in western Lee County. There are three major wellfields which tap the aquifer. These wellfields collectively produce over 5 MGD. Between 15,000 and 20,000 domestic supply and lawn irrigation wells presently tap the aquifer. This pumpage from these wells is estimated to range between 1 and 3 MGD.

Lower Hawthorn Aquifer (Hawthorn Aquifer System - Zones II, III, and IV)

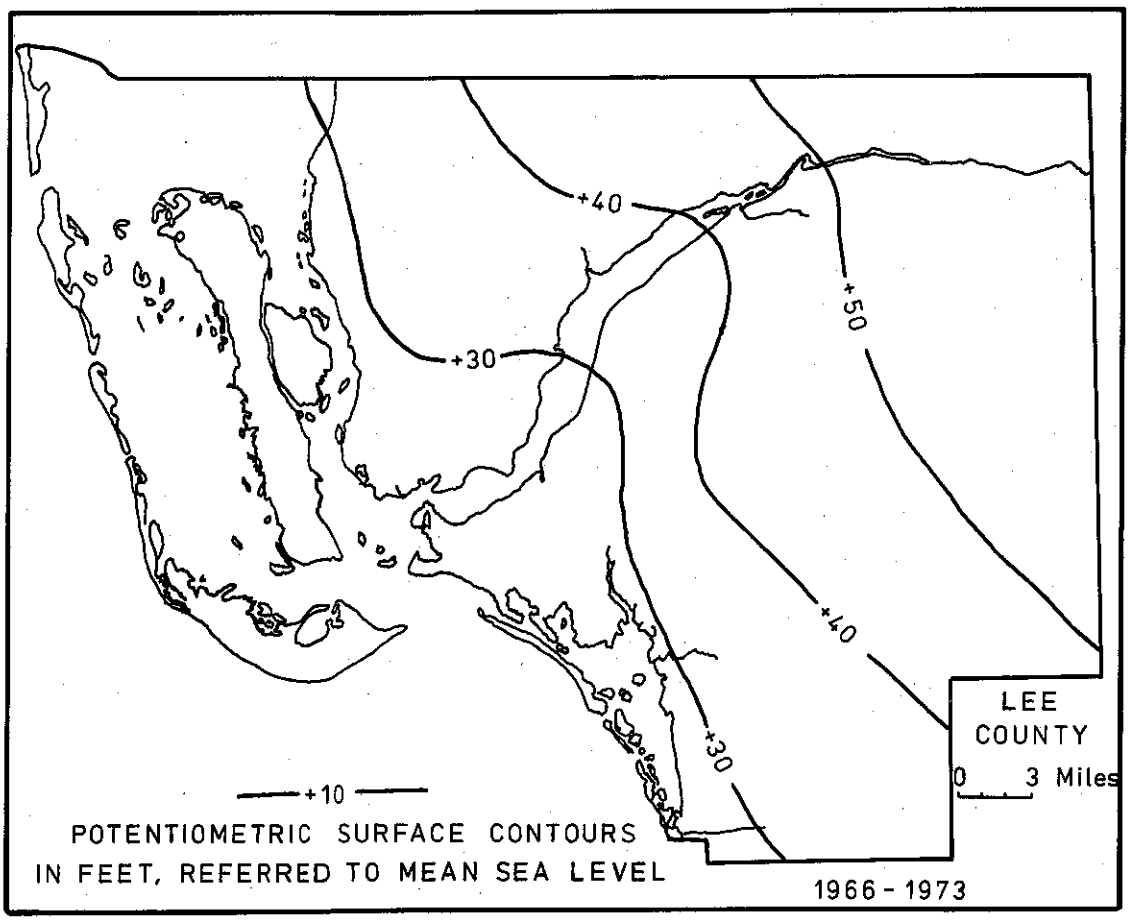
There are several fully confined water-bearing zones in the lower part of the Hawthorn Formation. In order to simplify the system, it is assumed that only four zones are present. Each zone has its own set of properties with different potentiometric surfaces, water qualities, and hydraulic characteristics. These zones have not been mapped on a regional basis over Lee County. Therefore, only general characteristics for the collective group of water-bearing zones can be described.

Hawthorn Aquifer System - Zones II to IV have a collective thickness of more than 200 feet. This system of aquifers is leaky, and a certain volume of water moves between the zones depending on the vertical permeability of the confining clays and the head differential.

The potentiometric surfaces of Zones II to IV are all well above mean sea level. In western Lee County, the potentiometric surfaces of Zones II and IV range from 20 to 40 feet above mean sea level (see Figure 3-2). The surfaces of Zones III and IV are probably very close to being equal, but the Zone II surface is probably several feet lower than Zones III and IV.

Natural water in Zones II to IV contains dissolved chloride concentrations ranging from 400 to 2,000 mg/l in most of northwestern Lee County. Poorer quality water lies in these zones in the coastal areas, such as Sanibel Island and Pine Island. Information available on Zone II in Cape Coral indicates that the dissolved chloride concentration is between 350 and 600 mg/l. Upward leakage of high temperature saline water from great depths has caused dissolved chloride concentrations in the McGregor Isles area, southwest of Fort Myers, to range up to 19,000 mg/l.

Only a few aquifer tests have been performed on Hawthorn Aquifer System - Zones II to IV. Zone II has not been tested in any area. Most of the tests have been made on wells open to both Zones III and IV. Transmissivity values have ranged



FROM BOGGESS (1974)

MISSIMER & ASSOC., INC., 1979

FIGURE 3-2. MAP SHOWING THE POTENTIOMETRIC SURFACE OF THE LOWER HAWTHORN AND SUWANNEE AQUIFERS, 1966-73.

from about 40,000 to 120,000 gpd/ft. Isolated tests on Zone III beneath Sanibel Island, which has a questionable correlation to mainland zones, showed transmissivity values from about 6,000 to 15,000 gpd/ft. Storage coefficients are estimated to range from 1 x 10^{-3} to 1 x 10^{-5}, and leakance is estimated to range from 1 x 10^{-3} to 1 x 10^{-6} gpd/ft^3.

A significant volume of water is presently used from Hawthorn Aquifer System - Zones II to IV. Several wellfields tap these zones for raw water to supply desalination treatment plants. More than 3,000 wells tap the zones for irrigation or other uses in Lee County. Several million gallons of water per day is either used from the aquifers, or is wasted through improperly constructed wells.

Suwannee Aquifer System

The "Suwannee Aquifer" was first defined as the water-bearing strata lying above and below the contact between the Suwannee Limestone and the Hawthorn phosphatic limestones (Sproul, Boggess, and Woodard, 1972). The specific characteristics of the aquifer or aquifer system are not presently known. Since the Suwannee Limestone is a continuous geologic formation over a large area of south Florida, it is assumed that the Suwannee Aquifer System is also a regional aquifer. The degree of confinement between the lowest Hawthorn zone and the uppermost Suwannee zone is not known and in certain areas these zones may be directly connected.

Where the Suwannee Aquifer System and the Hawthorn Aquifer System are separated by confining clays, the potentiometric surface of the Suwannee stands higher than the Hawthorn. The head difference could range up to 10 feet and could be greater if the Hawthorn system is being pumped.

Water quality in the Suwannee Aquifer System shows considerable variation. Dissolved chloride concentrations range from 800 to more than 1,400 mg/l. The aquifer appears to have a density stratification with poorer quality water occurring at the base of the system.

The hydraulic characteristics of the Suwannee Aquifer System are unknown. It is probably as productive or more productive than Hawthorn Aquifer System - Zones III and IV combined.

Some water is presently used from the Suwannee Aquifer System for principally irrigation purposes. There are approximately 300 to 500 wells that tap the upper part of the aquifer in Lee County. It is not possible to quantify the usage rate from the aquifer with the available data.

IV. INVESTIGATION OF THE BURNT STORE MARINA DEVELOPMENT SITE

1. Introduction

The existing information on the hydrology and geology of northwestern Lee County and southwestern Charlotte County, as summarized in Chapter III was used to determine the additional data needs for this investigation, such as: 1) geologic data; 2) aquifer coefficients (pumping test); 3) water level data; and 4) water quality data.

2. Test Drilling and Observation Well Construction

A test drilling and observation well construction program was completed at the Burnt Store Marina site. Four exploratory observation wells tapping the Tamiami Aquifer System - Zone II were initially constructed on and adjacent to the site. Two observation wells and one test-production well were then constructed into Zone II on-site. Two additional observation wells, one Hawthorn Aquifer System - Zone I well and one water-table aquifer well were also constructed at the test site. Geologic and water quality data were collected from each observation well. The test-production well was drilled into Zone II for the primary purpose of stressing (pumping) the aquifer and observing drawdowns in specifically spaced observation wells. Discharge water from the test-production well was sampled several times during the test to check for possible water quality changes. Construction details on each well are given in Table 4-1, and locations of wells are shown in Figure 4-1 (test wells off site specific are shown in Figure 4-3).

3. Aquifer Test

An aquifer test was made on Tamiami Aquifer System - Zone II. Test-production well L-M-1271 was pumped continuously

TABLE 4-1. CONSTRUCTION DETAILS ON WELLS

Well Number	Depth(ft.)	Casing Depth(ft.)	Diameter(in.)	Aquifer Tapped	Use
CH-5	120	90	4	Tamiami-Zone II	Test Well
CH-6	120	93	4	Tamiami-Zone II	Test Well
CH-7	120	100	4	Tamiami-Zone II	Test Well
L-M-1278	90	80	4	Tamiami-Zone II	Test Well
L-M-1270	240	205	4	Upper Hawthorn	Observation
L-M-1268	120	screen 85-90	4	Tamiami-Zone II	Observation
L-M-1269	100	screen 85-90	4	Tamiami-Zone II	Observation
L-M-1271	110	screen 80-100	8	Tamiami-Zone II	Test-Production
L-M-1272	20	screen 15-20	2	Water-table	Observation

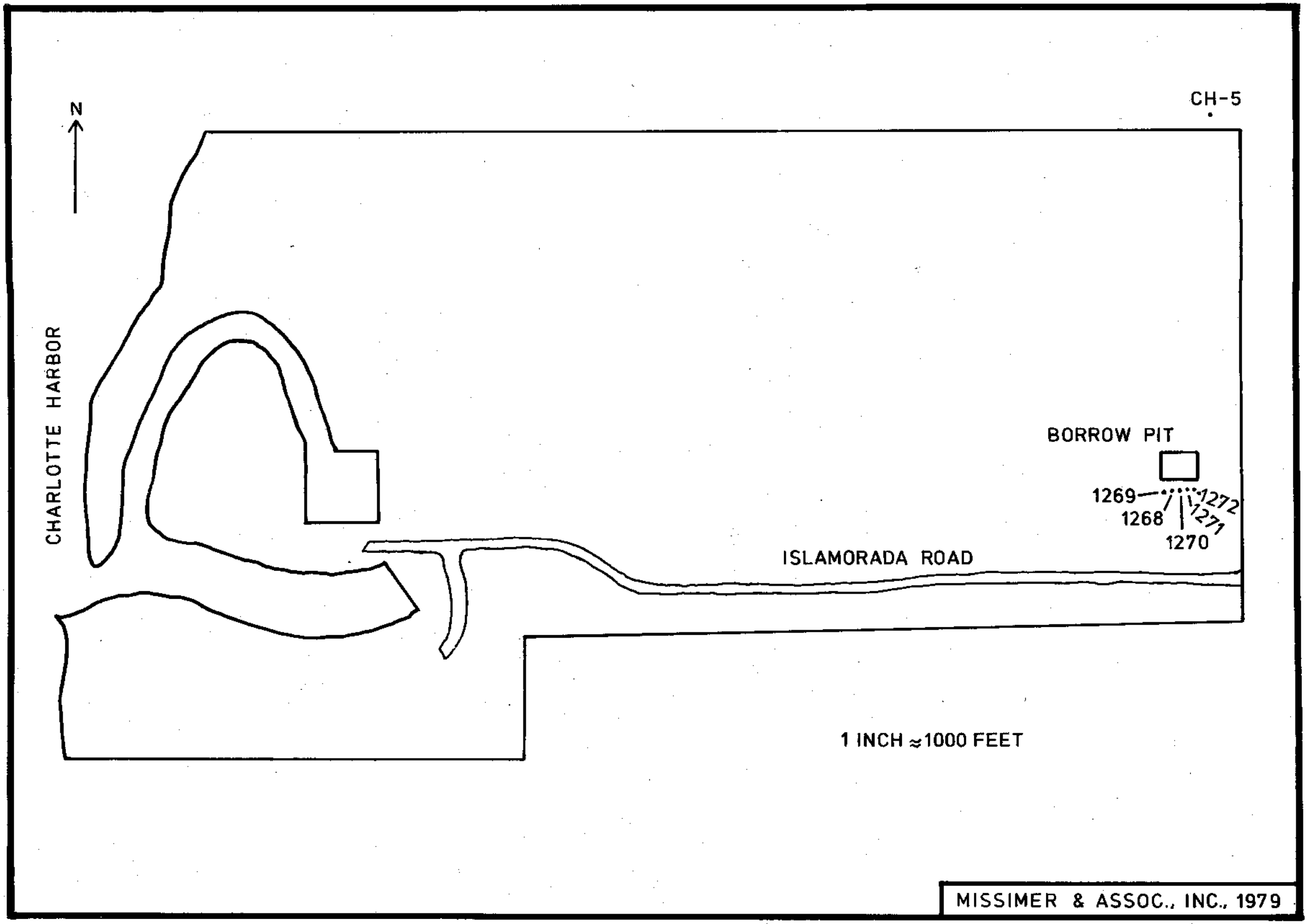


FIGURE 4-1. DIAGRAM SHOWING BURNT STORE MARINA DEVELOPMENT.

at a rate of 100 GPM for 72 hours. Well L-M-1271 was equipped with an extended shaft, turbine pump powered by a diesel motor. The pump bowls were set at 75 feet below land surface. Pump discharge was calibrated and monitored using an orifice plate and a manometer tube. Drawdowns of the potentiometric surface of Zone II were measured in the test-production well and in two observation wells. Water levels in the pumped well were measured with an air pressure water level gage. The two Zone II observation wells, L-M-1268 and L-M-1269, and the Hawthorn - Zone I observation well were each equipped with a Stevens Type-F water level recorder. The water-table aquifer observation well (L-M-1272) was tape measured at various intervals during the test. A schematic diagram of the aquifer test set-up for Zone II is given in Figure 4-2.

Recovery of the Zone II potentiometric surface was monitored upon termination of pumping in the test-production well and in the two observation wells equipped with recorders. The recovery data were used to check and verify the drawdown data.

Barometric pressure fluctuations, were recorded at the site during the test using a Weather Measure Model B211-Microbarograph.

4. Well Inventory and Water Use Assessment

Two abandoned wells, which were plugged, were the only wells located at the Burnt Store site other than the ones installed during the test program. The few wells located in the adjacent sections are listed with all known details in Table 4-2 and the locations are shown in Figure 4-3..

A total of 15 wells, some of which were plugged and others wild flowing, were located in the surrounding area.

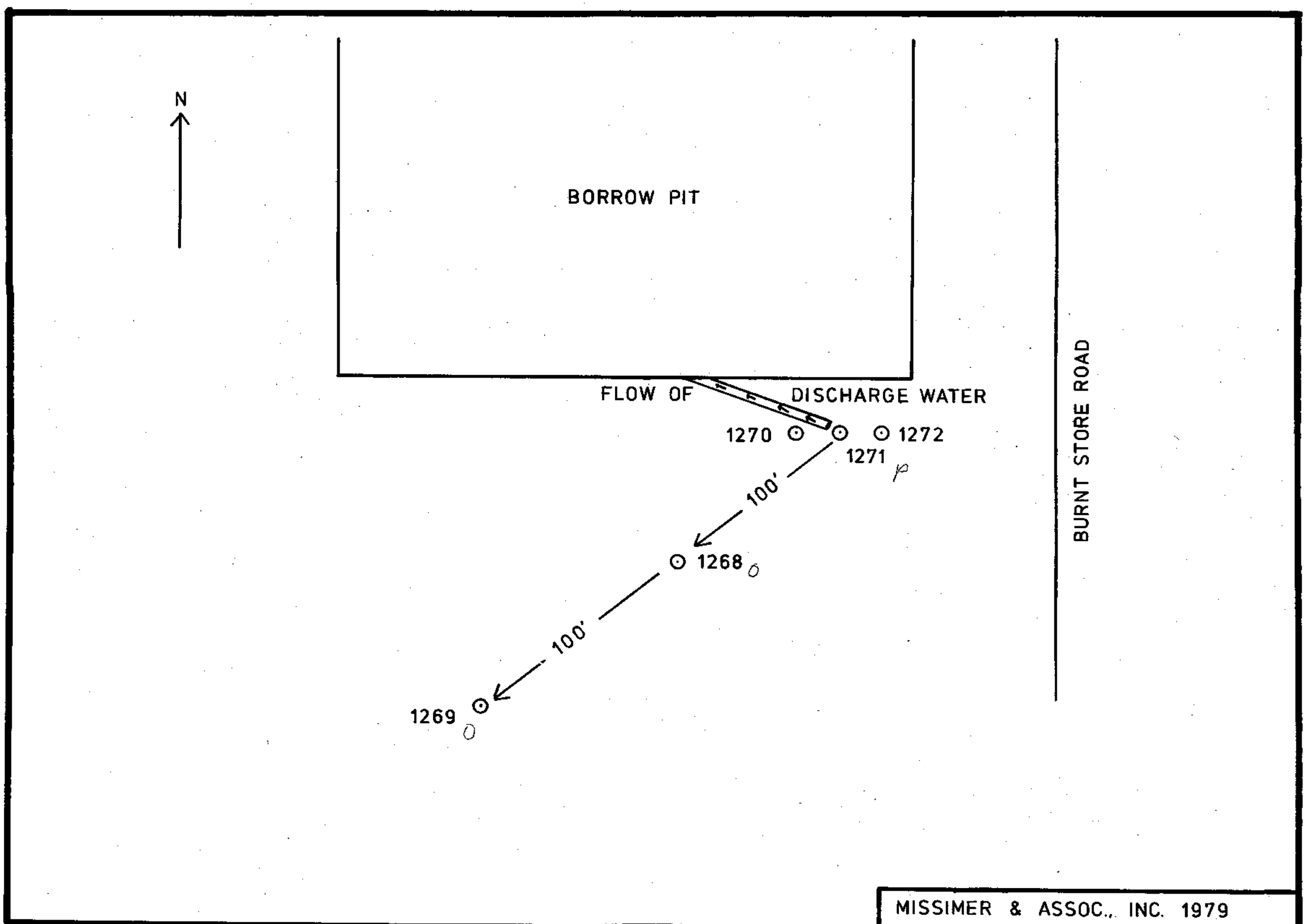


FIGURE 4-2. SCHEMATIC DIAGRAM OF AQUIFER TEST SET-UP.

TABLE 4-2. CONSTRUCTION DETAILS AND WATER QUALITY OF INVENTORIED WELLS

Well No.	Depth(ft).	Casing Depth(ft.)	Diameter(in.)	Use	Cl^- (mg/l)
L-M-1276	200+	156	2	Obs. (USGS)	450
L-M-1277	600	300	4	Obs. (USGS)	560
L-M-1279	217	188	3	Rept. Plugged	Rept. Salty
L-M-1280	247	168	4	"	"
L-M-1281	200+	-	4	Irr. (not in use)	750
L-M-1282	-	-	6	Irr. (not in use)	-
L-M-1283	-	-	6	Irr. (not in use)	-
L-M-1284	-	-	6	Irr. (not in use)	1140(?)
L-M-1285	-	-	6	Irr. (not in use)	-
CH-14	600	-	6	Irr. (plugged)	820 (1968)
CH-15	920	230	6	Irr. (plugged)	760 (1957)
CH-16	450	230	6	Public Supply	
CH-17	1420	-	6	Oil Test (Destroyed)	
CH-18	-	-	6	Indus.	700 (1968)
CH-19	730	-	6	Irr. (plugged)	-
CH-20	254	246	6	Stock	860
CH-21	850	186	6	Stock	960
CH-22	-	-	6	Stock	920
CH-23	1200	-	6	Oil Test (Destroyed)	
CH-24	578	184	6	Stock	925
CH-25	-	-	-	-	-
CH-26	560	-	6	Unused (Destroyed)	-
CH-27	1097	188	6	-	775

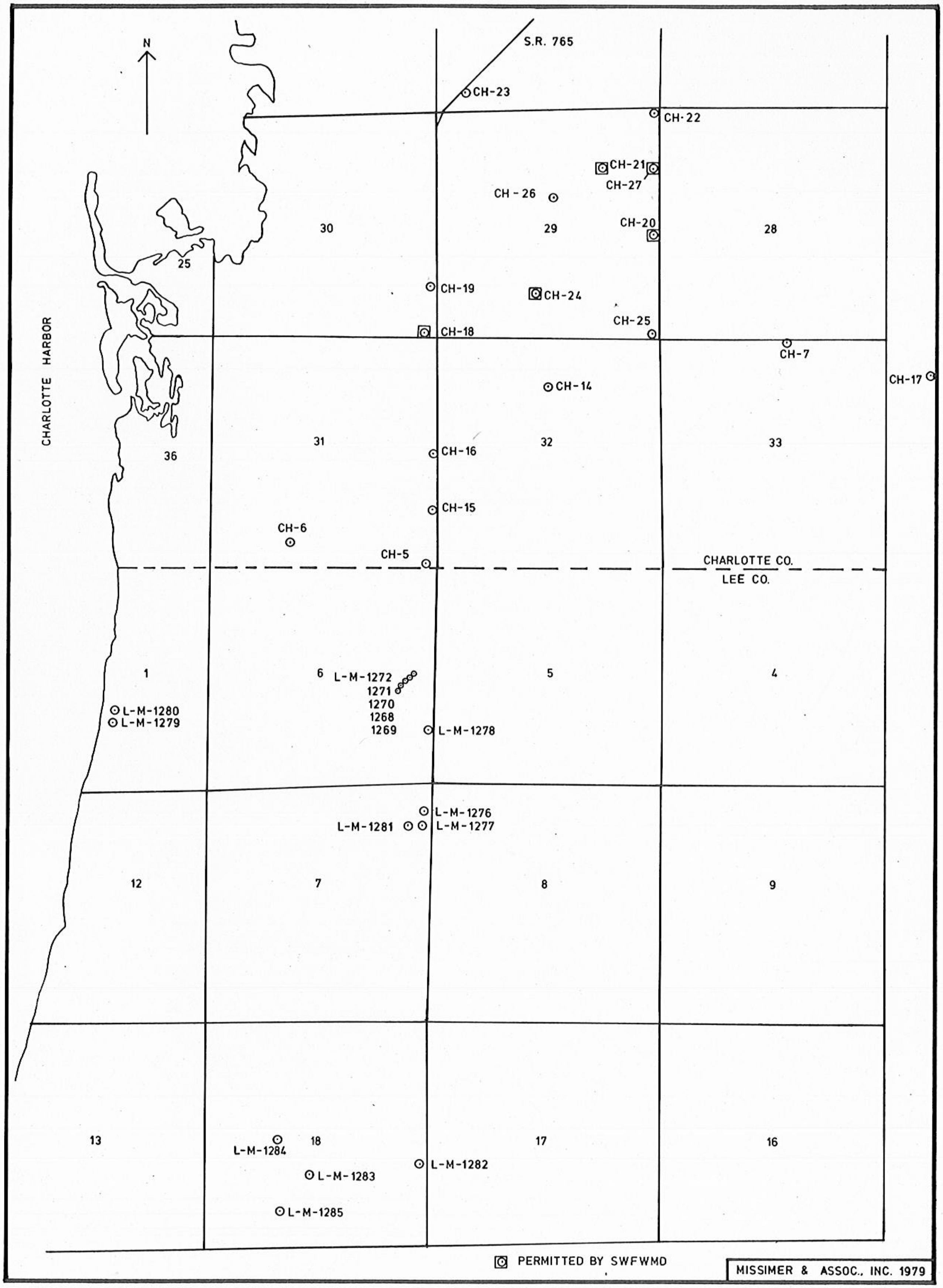


FIGURE 4-3. MAP SHOWING THE LOCATIONS OF INVENTORIED WELLS.

Most of the remaining wells are presently used for agricultural purposes.

Water quality for the investigation site and surrounding areas as well as aquifer coefficients (Marina site) are given in Chapter V.

5. Environmental Description

The Burnt Store Marina site and the surrounding area is almost exclusively palmetto-pine flatwoods except for mangrove marsh areas near the coast. The natural system has been altered somewhat to facilitate the development, which will eventually include multi-family residential units and low-rise condominiums with a 27-hole golf course.

V. HYDROLOGY AND GEOLOGY OF THE BURNT STORE MARINA SITE

1. Geology

The geologic sequence beneath the Burnt Store Marina development is similar to that described in Chapter 3. The terminology used in this chapter is consistent with that shown in Figure 3-1 with a few exceptions. The geologist's logs are developed from on-site sample collection, microscopic analysis, and analysis of geophysical logs. These are given in the appendix (Tables A-1 to A-9). Descriptions of the limestone and sandstone units utilize the classification systems of Folk (1968) and Dunham (1962).

Most of the test wells were drilled with the intent to penetrate a thin water-bearing zone within the Tamiami Formation. A single well was drilled into the Hawthorn Formation. As many as 8 stratigraphic units were penetrated. The units are: the Pamlico Sand; the undifferentiated Fort Thompson Formation - Caloosahatchee Marl; the Acline Formation; the Cape Coral clay; the Lehigh Acres sandstone; and the Fort Myers clay members of the Tamiami, and the Hawthorn Formation. Geologic sections adjacent to the development are given for both a north-south line and an east-west line (see Figures 5-1 and 5-2).

Pamlico Sand

The Pamlico Sand forms a mantle over the entire Burnt Store Marina development. It varies from 3 to 10 feet in thickness. There is no specific pattern to variation of thickness of the Pamlico in this area. The Pamlico Sand is coarse to fine, brown to white, quartz sand with some shell and clay. These sands are generally very permeable.

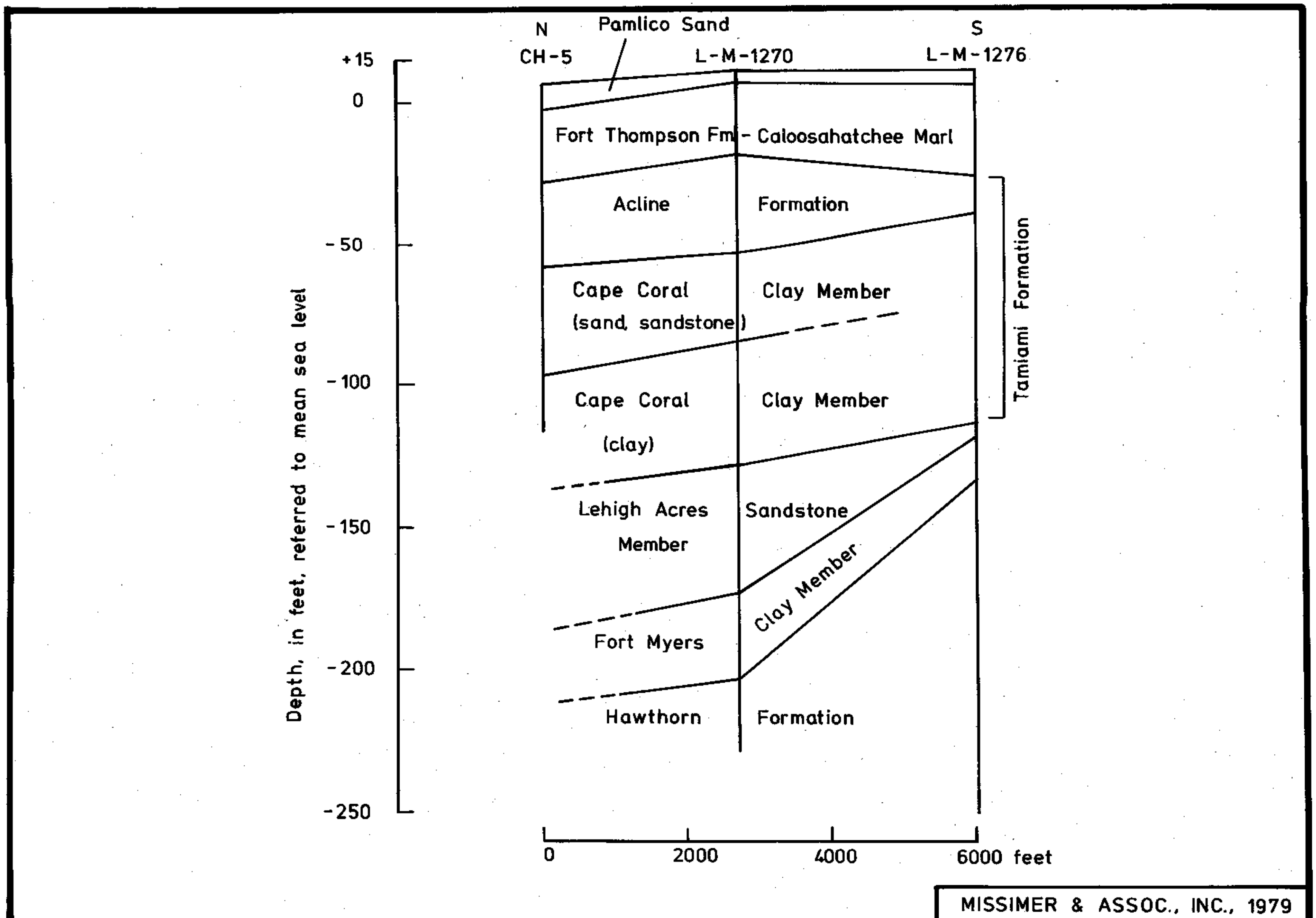


FIGURE 5-1. GEOLOGIC SECTION NORTH TO SOUTH NEAR BURNT STORE MARINA.

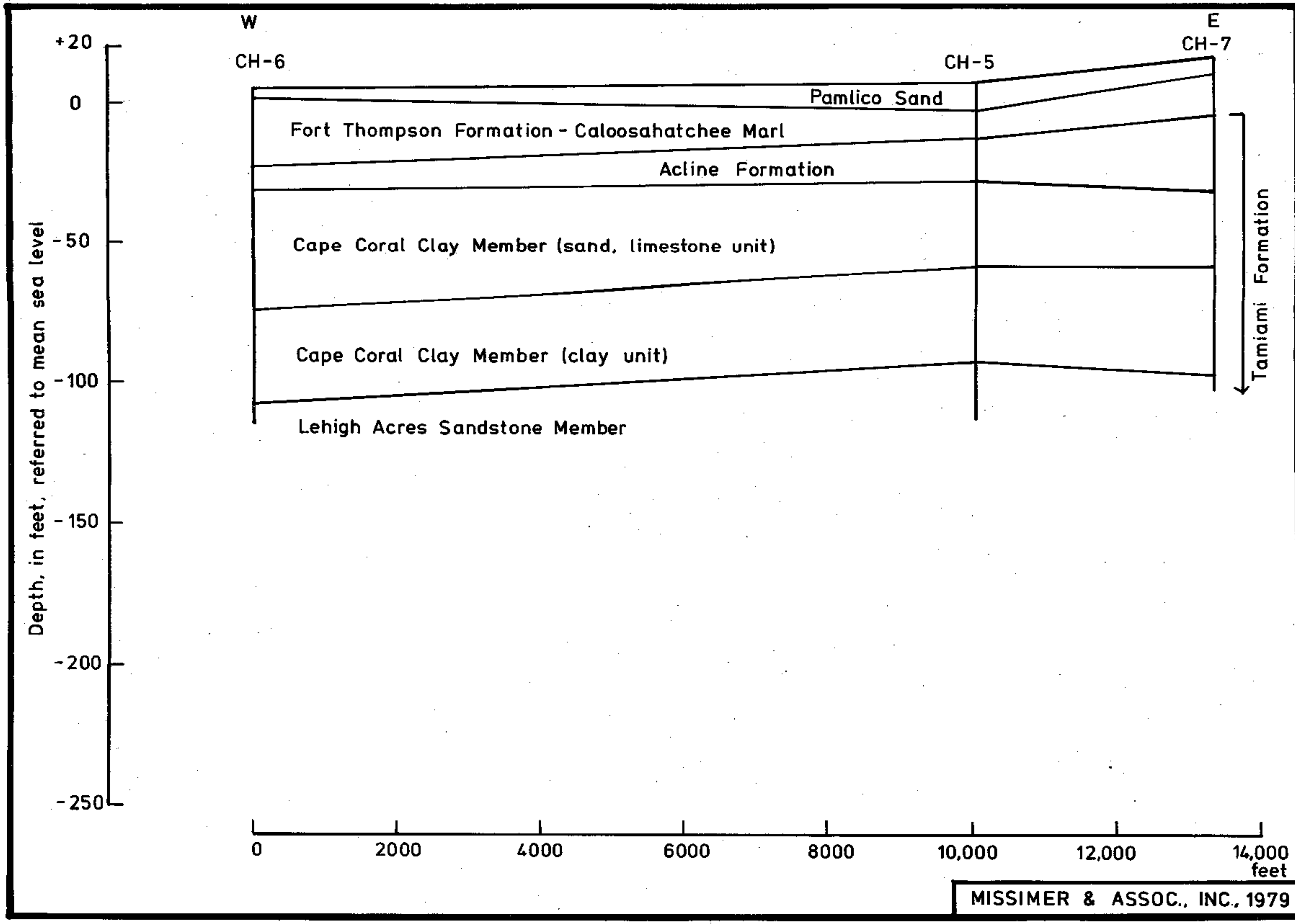


FIGURE 5-2. GEOLOGIC SECTION WEST TO EAST NEAR BURNT STORE MARINA.

Fort Thompson Formation - Caloosahatchee Marl

An inhomogeneous sequence of unconsolidated shell and marl beds lies unconformably beneath the Pamlico Sand. It is not possible to accurately differentiate these two formations in drill cuttings. Although these sediments are time equivalent to type-section sediments along the Caloosahatchee River, the lithologies as described are quite dissimilar to the type-section (see DuBar, 1958). This unit ranges from 10 to 35 feet thick. The upper part of the unit contains beds of small, thin-walled shells and bedded shell hash consisting of larger mollusk fragments. The lower part of the unit consists of limestone and marl, which is a mixture of lime mud, shell, quartz sand, and rock fragments. The various lithologies in the marl unit are both bedded as distinctive layers and mixed. The upper part of the Fort Thompson - Caloosahatchee sequence is water bearing and the lower part is not.

Acline Formation

A very distinctive geologic unit, the Acline Formation, lies unconformably beneath the Fort Thompson - Caloosahatchee sequence. The Acline Formation may be a fauna-zone rather than a true formation. It consists of green, lime mud beds, marls, and shell beds. The Acline Formation contains many species of fauna, which lie in the middle Pliocene to late Miocene age-range. It ranges from 10 to 40 feet in thickness. Most of the formation is not water bearing but some of the shell beds probably will yield some water.

Tamiami Formation

The uppermost member of the Tamiami Formation encountered at the project site is the Cape Coral clay. There is no occurrance of the Ochopee limestone or the Buckingham limestone at the site. It is possible that the Acline Formation is time-equivalent to part of the Buckingham limestone.

The Cape Coral clay is a complex unit consisting of lime mud, quartz sand, and sandstone. It varies between 75 and 85 feet in thickness. At the site, the Cape Coral clay can be subdivided into two different units: an upper unit consisting of clastic sediments and sandstone, and lime mud; and a lower unit consisting of lime mud and quartz sand. Bedding in this unit is often not parallel to present-day land surface, but is angular (see Figure 5-3). Sediments constituting the beds are graded and generally fine upward. Accumulations of coarse clastics commonly occur within the angular beds. The inclined nature of bedding is the probable result of deltaic sedimentation. Sediment was transported into the area by a series of small streams, which created a number of small to medium-sized deltas. Thick clastic accumulations, consisting predominantly of quartz sands, shell, and phosphatized limestone pebbles, formed in areas immediately upstream of the mouth of the stream in old channel fills. These detrital lenses form permeable zones within predominantly fine-grained sediment sequences such as occur in the Cape Coral clay. The sand portions of the Cape Coral clay are therefore considered to be detrital lenses of various types and origins. These sand bodies are linear and laterally discontinuous such as observed at the Burnt Store Marina Development.

The Lehigh Acres sandstone member of the Tamiami Formation lies beneath the Cape Coral clay. It consists of quartz sand, limestone, sandstone, and lime mud deposisted in a shallow marine environment. It is up to 40 feet thick. This member contains permeable strata beneath the site, but it appears to be a somewhat interbedded sequence.

The Fort Myers clay member lies at the base of the Tamiami Formation. It is typically a dark gray combination of lime

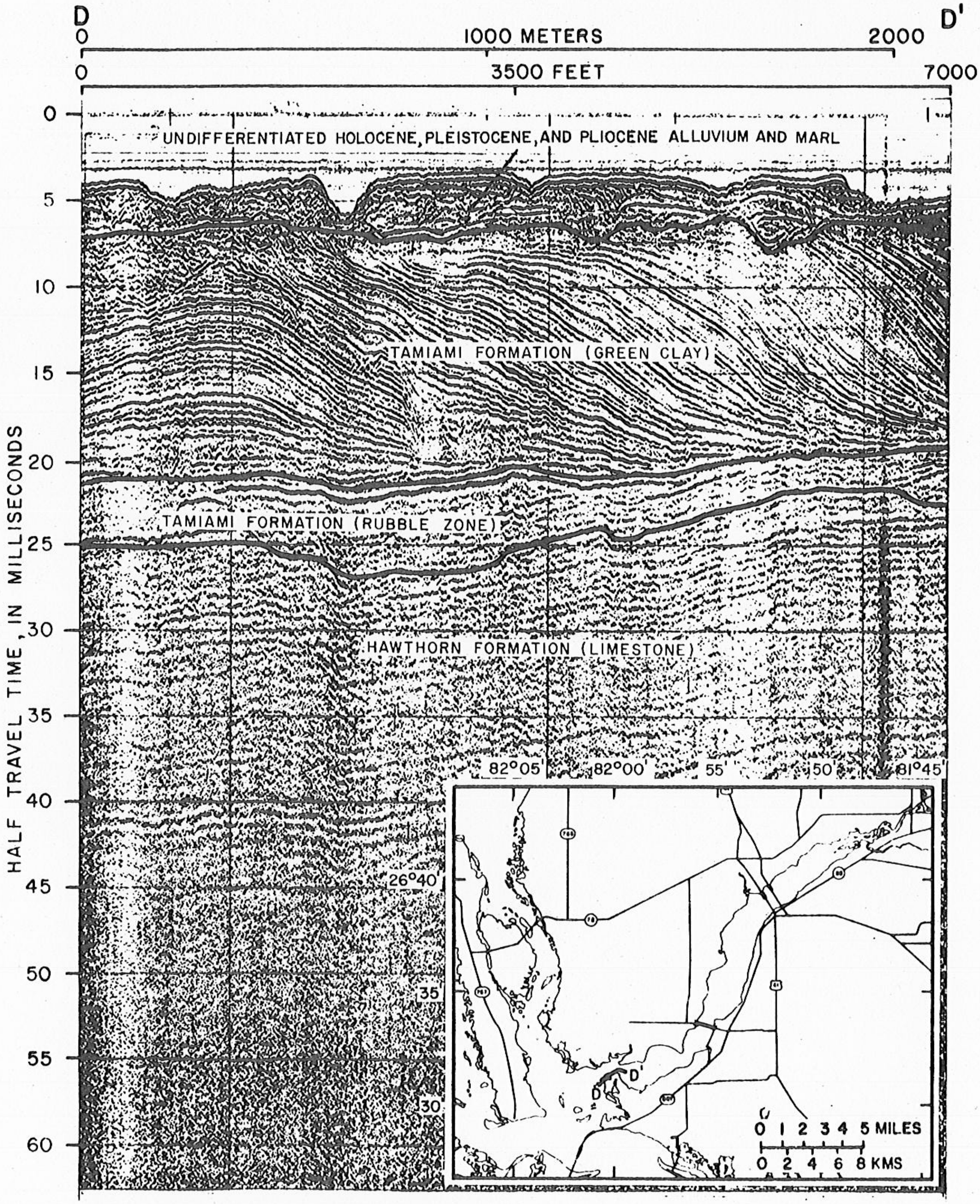


FIGURE 5-3. Seismic reflection profile showing angular bedding in the Cape Coral clay (from Missimer and Gardner, 1976, Figure 12, p. 24)

mud, quartz sand, and phosphorite nodules. However, beneath most of the site it is a medium to fine-grain quartz sand with similarly sized phosphorite nodules. It probably has about medium permeability.

Hawthorn Formation

The Hawthorn Formation lies unconformably beneath the Tamiami Formation at Burnt Store Marina. Only the uppermost 25 feet of the unit was penetrated in one of the test wells (L-M-1270). The upper 5 feet of the Hawthorn is a sandy, light gray, lime mud, which is phosphatic. The lower 20 feet penetrated is the typical Hawthorn limestone, which is a light gray to white color and contains shell fragments, quartz sand, and phosphorite. The limestone beds have a medium permeability.

2. Aquifer and Confining Bed Descriptions

Water-table aquifer

The water-table aquifer is unconfined and lies in the Pamlico Sand and part of the Fort Thompson Formation - Caloosahatchee Marl sequence (see Figure 5-4). The water-table aquifer ranges from 10 to 32 feet in thickness over the Burnt Store Marina Development. It consists of a quartz sand, shell, and limestone, sequence, which is collectively quite permeable. A limestone unit encountered in the lower part of the aquifer in well L-M-1269 appears to have a very high permeability and could yield a large volume of water.

Upper confining beds

A sequence of marls, clayey sands, and sandy clays separates the water-table aquifer from the underlying Tamiami Aquifer System. This sequence is between 45 and 60 feet thick over the site. The composition of individual beds

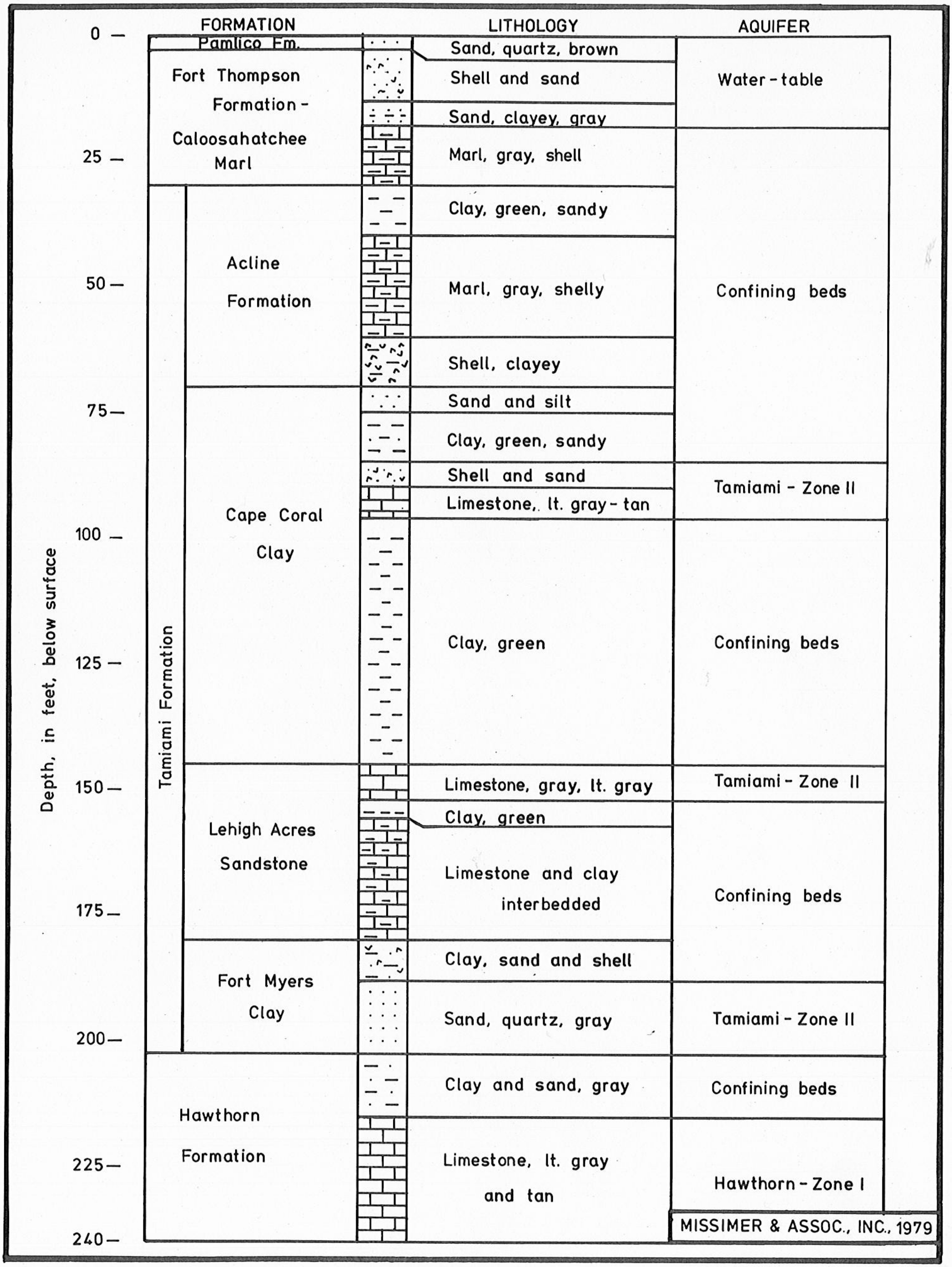


FIGURE 5-4. LOG OF WELL L-M 1270 SHOWING GEOLOGY AND AQUIFER LOCATIONS.

suggests only partial confinement, but the cumulative effect of about 50 feet of various types of confining materials probably does provide a high degree of hydraulic separation.

Tamiami Aquifer System - Zone II

Tamiami Aquifer System - Zone II normally lies solely within the Lehigh Acres sandstone member (or in part of the Fort Myers clay member) of the Tamiami Formation. At the Burnt Store Marina site, however, there are three separate water-bearing zones, which are collectively termed Zone II. Water-bearing strata occur within the Cape Coral clay member, the Lehigh Acres sandstone member, and the Fort Myers clay member of the Tamiami Formation (see Figure 5-4). These strata are not hydraulically connected in a direct sense. The aquifer in the Cape Coral clay may be partially connected to the aquifer in the Lehigh Acres sandstone through water movement along the angular beds as shown in Figure 5-3. The aquifer near the base of the Fort Myers clay is closely tied to the Hawthorn Aquifer System - Zone I. Pumping of any one of the subzones will cause water to leak vertically into it from both above and below.

Confining beds between Tamiami Aquifer System - Zone II and Hawthorn Aquifer System - Zone I

Tamiami - Zone II is separated from Hawthorn - Zone I by a sandy clay unit about 12 feet thick, which is within the Fort Myers clay member of the Tamiami Formation. The degree of separation is not great, but a considerable volume of water can move across the confining beds when the head differential is larger. The presence of a large percentage of lime mud in the confining beds does create a good barrier for preservation of water quality under static conditions.

Hawthorn Aquifer System - Zone I

Hawthorn Aquifer System - Zone I lies within the upper part of the Hawthorn Formation. Zone I usually lies at the top of the formation, but at Burnt Store Marina, it begins about 12 feet into the Hawthorn Formation. This aquifer consists of phosphatic, white to light gray limestone, which has a medium permeability. The aquifer is at least 25 feet thick.

3. Aquifer Characteristics

There are several water-bearing units underlying the Burnt Store Marina Development as shown in Figure 5-1 and 5-2. However, the only aquifer on which hydraulic characteristics were determined was Zone II of the Tamiami Aquifer System.

The Tamiami Aquifer System beneath the Burnt Store Marina Development is hydraulically very complex. An accurate determination of the hydraulic properties of the proposed production zone is required in order to predict aquifer response to long-term pumping and the perennial yield of the system. Determination of the hydraulic properties of the aquifer requires the following types of information: 1) detailed geologic data; 2) aquifer test data; and 3) water level data. The geologic information and detailed aquifer delineation has been previously presented in this chapter.

There are four basic aquifer types which occur in nature. These types, following the Dutch terminology (Kruseman and DeRidder, 1970), are: 1) unconfined; 2) semi-unconfined; 3) semi-confined (leaky); and 4) confined. Zone II of the Tamiami Aquifer System at Burnt Store Marina Development is semi-confined (leaky). This type of aquifer occurs where continuous beds having low permeability fully confine the aquifer from the atmosphere and from the underlying aquifers.

Although the aquifer is fully confined, water still moves vertically through the confining beds. When the aquifer is stressed, water is yielded from a horizontal direction until the potentiometric head is lowered to a point where vertical inflow of water occurs through the confining beds (downward and/or upward).

There are three (3) hydraulic coefficients determined in most aquifer tests:

1) Transmissivity (T) - The ability of an aquifer to transmit water, reported in gallons/day/foot or m^2 day;

2) Storage Coefficient (S) - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. Dimensionless.

3) Leakage Coefficient (k'/b') - The effective vertical permeability of a confining bed divided by the thickness of a confining bed in gpd/ft^3.

Tamiami Aquifer System - Zone II

A detailed aquifer test was performed on Zone II of the Tamiami Aquifer System. Zone II is defined in considerable detail in Section 2 of this chapter.

Water was pumped from a test-production well and two other smaller diameter observation wells were used to continuously monitor drawdown in the aquifer. Both observation wells were equipped with Stevens Type-F recorders. A significant quantity of background water level data was collected both before and after the test. A complete description of the aquifer test set-up and procedure is given in Chapter IV.

Test-production well L-M-1271 was pumped continuously at a constant discharge rate of 100 GPM for 72 hours from April 17 to April 20. The drawdown data from the test-production well were not used for calculation of aquifer coefficients. However, the raw time and drawdown data from well L-M-1271 are given in Table A-10.

Drawdown data were recorded continuously in observation wells L-M-1268 and L-M-1269, which are located 100 feet and 200 feet respectively from the test-production well. After 4320 minutes of continuous pumping, a drawdown of 14.57 feet was recorded in well L-M-1268 and 14.38 feet of drawdown was recorded in well L-M-1269 (see Tables A-11 and A-12). An anomaly occurred in the drawdown data of well L-M-1268 and these data were not weighted heavily in the final analysis. At the termination of the test, a steady state condition had not been reached.

A preliminary analysis of drawdown data collected on the Tamiami Aquifer System - Zone II was made assuming that the aquifer was fully confined. The Jacob straight line method was used (Cooper and Jacob, 1946; Jacob, 1950). The Jacob method yields only approximate values for the transmissivity and storage coefficient, but it does give useful numbers to check the validity of other methods. A semi-log plot of drawdown versus time for well L-M-1269 with a sample Jacob analysis is given in Figure 5-5. The analysis yielded the set of coefficients given in Table 5-1. These values are only slightly higher than aquifer coefficients determined by use of the leaky aquifer equations.

The primary analysis of the drawdown data from well L-M-1269 was made using the method of Hantush and Jacob (1955) for semi-confined aquifers. The drawdown data were plotted on a log plot versus time and the resultant curve was matched to the appropriate Hantush-Jacob function type-curve (see Figure 5-6). The match point was substituted into the following equations:

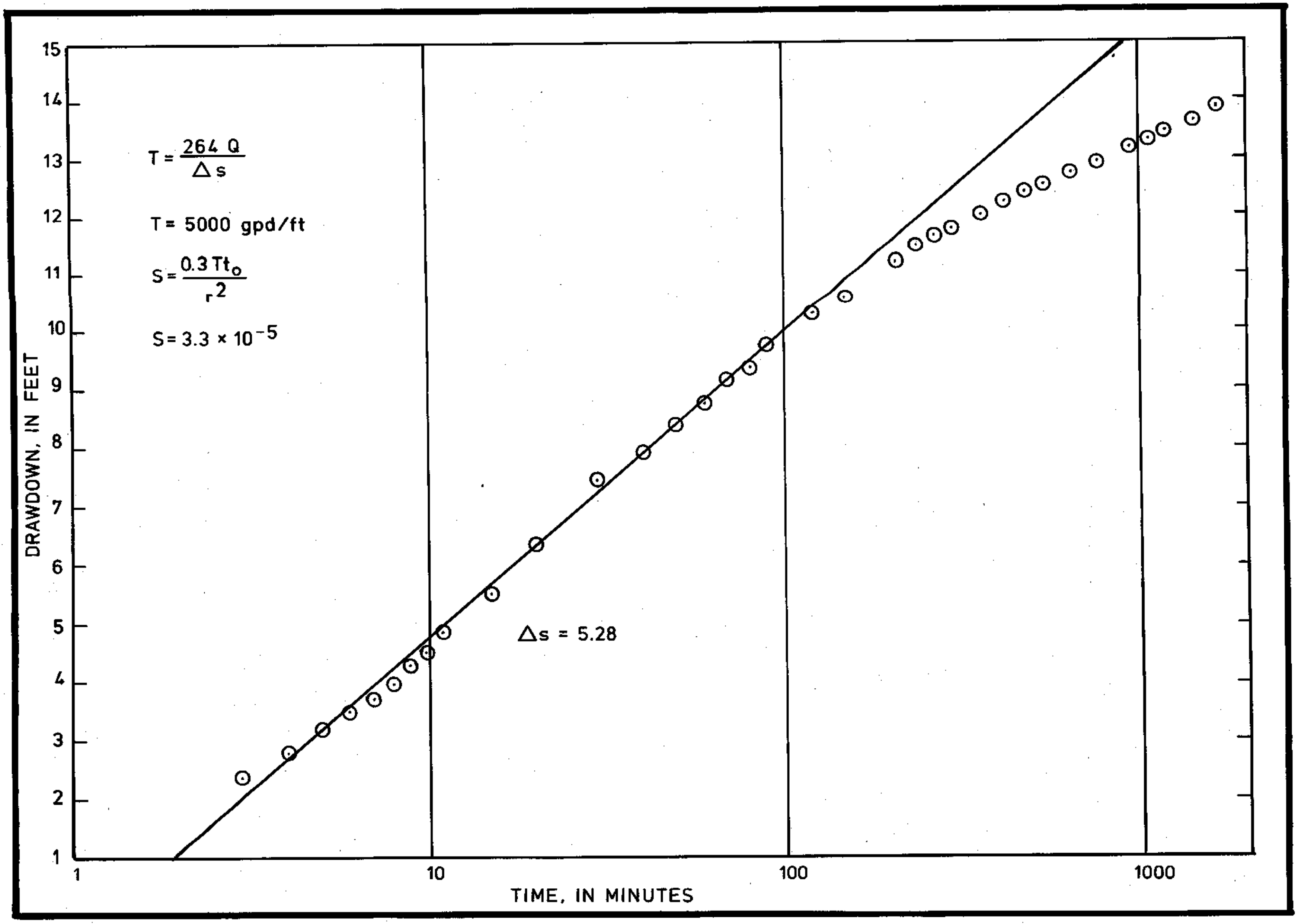


FIGURE 5-5. DIAGRAM SHOWING A SEMI-LOG PLOT OF DRAWDOWN IN WELL L-M-1269 WITH TIME AND A SAMPLE JACOB ANALYSIS.

TABLE 5-1. AQUIFER COEFFICIENTS CALCULATED FOR TAMIAMI AQUIFER SYSTEM - ZONE II USING DIFFERENT ANALYSIS METHODS

Well No.	Analysis Method	T (gpd/ft)	S	k'/b' (gpd/ft^3)
L-M-1268	Hantush-Jacob (Semi-confined)	7,300	1.5×10^{-5}	6×10^{-6}
L-M-1268	Jacob (Confined)	6,300	3.3×10^{-5}	
L-M-1269	Hantush-Jacob (Semi-confined)	4,800	3.7×10^{-5}	1.1×10^{-4}
L-M-1269	Jacob (Confined)	5,000	3.3×10^{-5}	

T = transmissivity

S = storage coefficient

k'/b' = leakage coefficient

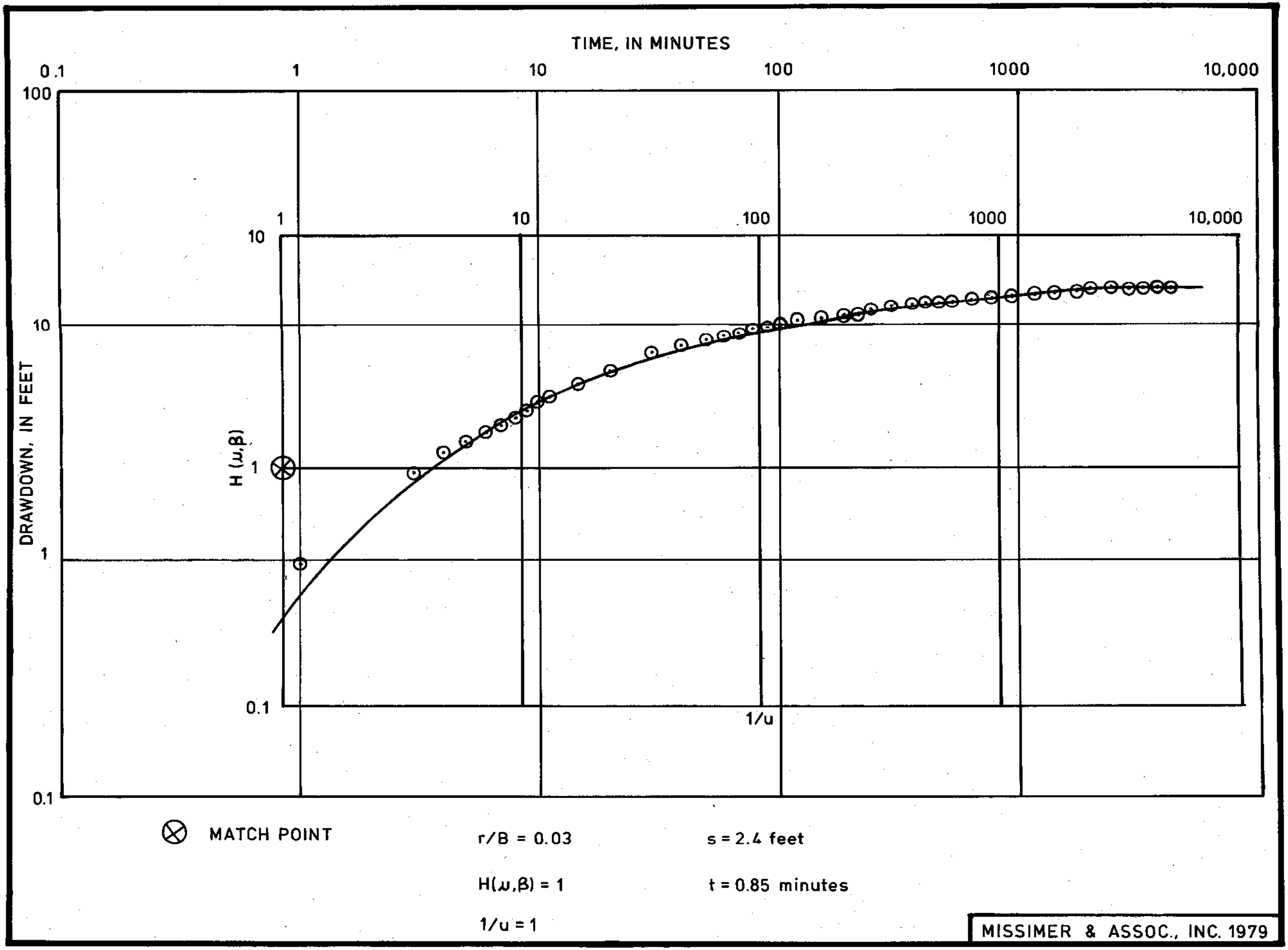


FIGURE 5-6. DIAGRAM SHOWING A LOG PLOT OF DRAWDOWN IN WELL L-M 1269 WITH TIME AND THE HANTUSH - JACOB FUNCTION TYPE-CURVE MATCH.

$$T = \frac{114.6\ Q\ H(\mu,\beta)}{s} \qquad (1)$$

$$S = \frac{T\ u\ t}{1.87\ r^2} \qquad (2)$$

$$k'/b' = \frac{T\ (r/B)^2}{r^2} \qquad (3)$$

where,

T = transmissivity (gpd/ft)

Q = discharge (gpm)

s = drawdown (ft)

S = storage coefficient

$H(\mu,\beta)$ = Hantush-Jacob curve function

t = time

r = distance from pumped well to observation well (ft)

k' = permeability of confining layer (gpd/ft^2)

b' = thickness of confining layer (ft)

r/B = Hantush-Jacob curve function

The calculations are shown in Figure 5-6. Aquifer coefficients to be used for predictive purposes were calculated as:

Transmissivity = 4800 gpd/ft
Storage Coefficient = 3.7×10^{-5}
Leakance = 1.1×10^{-4} gpd/ft^3

4. Water Levels and Recharge

Water-table aquifer

Water levels in an unconfined or water-table aquifer fluctuate in direct response to recharge and discharge, which are controlled by climatic conditions, drainage, and vegetation (evapo-transpiration). The position of the water-table at the site varies seasonally from about 0 to 4 feet below land surface.

Tamiami Aquifer System - Zone II

The potentiometric surface of Tamiami Aquifer System - Zone II usually lies at or slightly below the position of the water table. Recharge of Zone II at the site originates from downward leakage from the water-table aquifer, and also from upward leakage from the Hawthorn Aquifer System - Zone I, which has a head significantly higher than that of Tamiami - Zone II. Horizontal recharge also occurs within Tamiami - Zone II from areas to the east.

Under pumping conditions, the recharge from each of these sources will increase substantially due to the increase in the hydraulic gradient between these zones, and the interception of a much larger percentage of lateral flow within the aquifer by the cone of depression. At a 0.29 MGD pumping rate, it is expected that approximately 10 percent of the aquifer recharge will be by lateral transmission and the remainder will come from leakage from above and below the production zone.

5. Water Quality

Water-table aquifer

The quality of water in the water-table aquifer in Lee County generally meets most potable standards under normal conditions except where affected by saline-water intrusion near the coastline. Water in one well on the site, L-M-1272, had a dissolved chloride concentration of 880 mg/l. However, it is unlikely that L-M-1272 is affected by saline-water intrusion from Charlotte Harbor because of elevation of about 11 feet MSL, the westerly sloping gradient, and the distance from the coast. The well is probably affected by discharge from a deep artesian well.

Tamiami Aquifer System - Zone II

The quality of water in Tamiami Aquifer System - Zone II is quite good in the Burnt Store Marina area. Dissolved chloride concentrations range from 90-180 mg/l as water in all of the test wells drilled around the site showed concentrations of less than 200 mg/l (see Table 4-1 and Figure 4-3). Complete chemical analyses were made on water samples collected from the test-production well at the beginning and at the end of the aquifer test. At various intervals during the test, a sample was collected in the field and the dissolved chloride concentration and conductivity were measured (see Table A-15). The two complete analyses are presented in Tables A-13 and A-14, which show the water chemistry did not change significantly during the 72-hour test period.

Hawthorn Aquifer System - Zone I

The quality of water in Hawthorn - Zone I was tested in one well. A dissolved chloride concentration of 76 mg/l was measured in well L-M-1270. This water quality is quite good and is acceptable under potable water standards (Am. Public Health Assoc., 1975).

VI. IMPACT ASSESSMENTS

1. Impact on the Aquifer System

The impact of pumping Tamiami Aquifer System - Zone II was assessed by assuming continuous pumping at an equilibrium condition. A gross pumping rate of 0.29 MGD from two wells spaced 2200 feet apart was used in the analysis. Daily withdrawals at the site are not expected to exceed this rate.

The cone of depression in the potentiometric surface of Zone II for the 0.29 MGD withdrawal rate is shown in Figure 6-1. At a distance of approximately 500 feet from the center of pumpage, drawdowns will be above 20 feet. The 5-foot drawdown contour will occur about 1 mile from the center of pumpage. The maximum drawdown at the nearest property boundary is approximately 20 feet and reduces to less than 10 feet at a distance of 2000 feet away from the boundary.

2. Saline Water Intrusion

There are four possible sources of saline water located within the Zone II cone of depression. They are: 1) Charlotte Harbor tidal water; 2) saline water in the water-table aquifer; 3) deep artesian saline water in the Hawthorn Aquifer System; and 4) improperly constructed deep wells and test holes.

The most concentrated source of saline water at the site is Charlotte Harbor. This tidal water has a dissolved chloride concentration ranging from 10,000 to 19,000 mg/l depending on the seasonal discharge rate of the Peace River. Less than 10 percent of the Zone II cone of depression extends beneath Charlotte Harbor. Some water leaking through the confining beds to recharge the aquifer will originate in Charlotte Harbor, but this volume is estimated to be less than 6 percent of the total recharge. Over an extended period of time the quality of water beneath the western part of the development

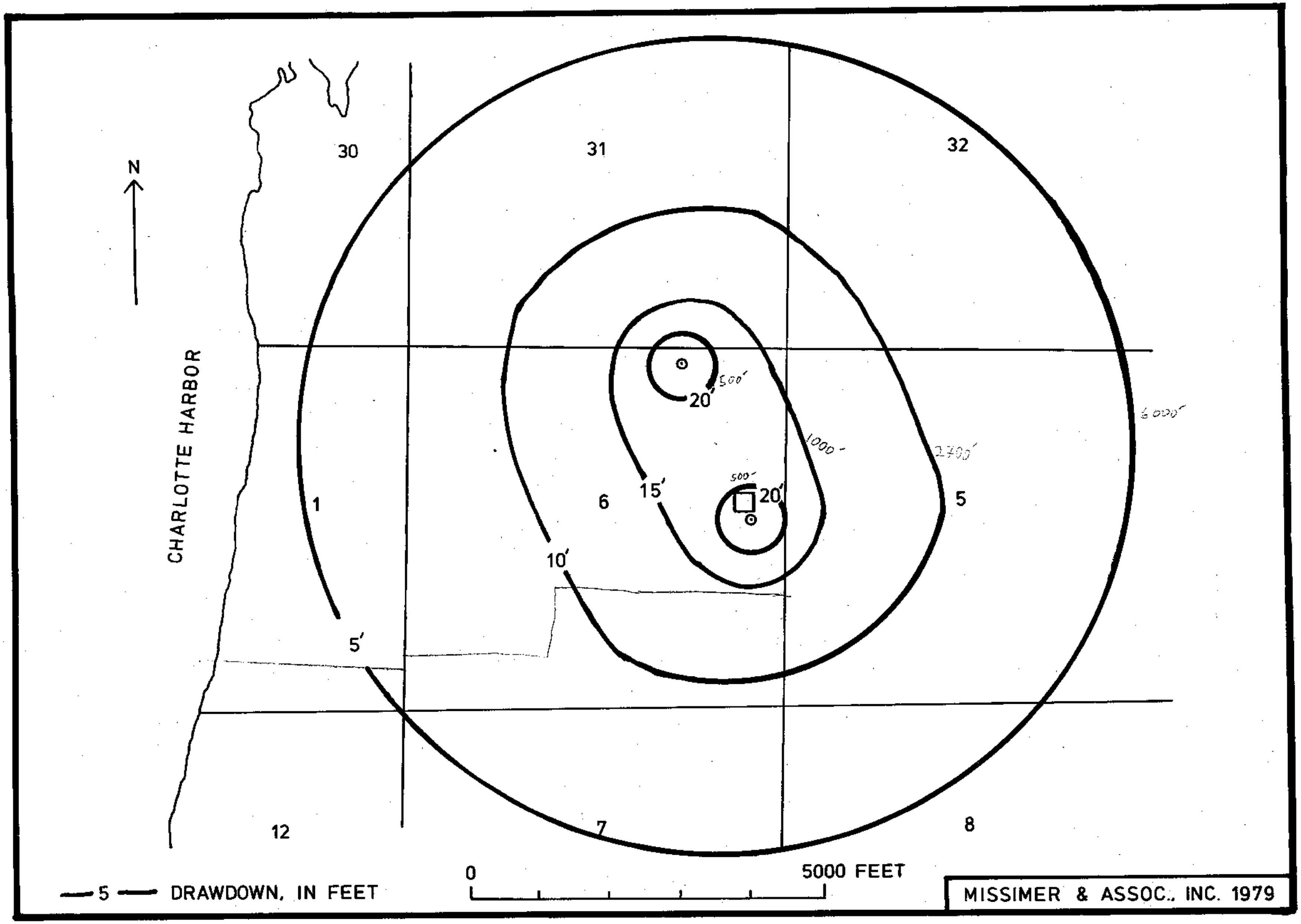


FIGURE 6-1. EQUILIBRIUM CONE OF DEPRESSION FOR A TOTAL WITHDRAWAL RATE OF 0.29 MGD FROM 2 WELLS IN TAMIAMI AQUIFER SYSTEM-ZONE II.

= 201.4 gpm

= 100.7 gpm/well

will become progressively more saline.

Some saline water does occur in the water-table aquifer, which overlies Tamiami Aquifer System - Zone II. Since the water-table aquifer provides a large part of the water, which recharges Zone II under both static and pumping conditions, poor quality water in the water-table aquifer will cause a degradation of Zone II water quality over a period of years. It is known that saline water occurs in the water-table aquifer in all areas adjacent to the coast to a distance of 100 to 500 feet east (approximate). Some saline water with an 880 mg/l chloride concentration also exists in the aquifer beneath the lake near the test site. It is assumed that over a large part of the site and in the surrounding areas that the water-table aquifer does contain fresh water with a dissolved chloride concentration of less than 50 mg/l. The unknown quality of water in the aquifer beneath most of the site tends to severely limit the accuracy of a prediction. However, it is probable that in more than half the site and in more than 75 percent of the adjacent area to the site, the water-table aquifer contains freshwater. Based on the limited data, the quality of water in Zone II will decline and eventually take on the average quality characteristics of the water-table aquifer. However, when considering the volume of water stored in the aquifer within the region of the well sites and the annual withdrawal and recharge rates, the amount of time required to cause the water quality to decline to the 800 mg/l chloride level should be in excess of 10 years. This prediction assumes a .29 MGD pumping rate and is founded on a limited amount of available data.

Saline water also occurs in the deep artesian aquifers lying beneath the site. Fortunately, Zone II at the Burnt Store Marina site is protected from these deep artesian waters by thick beds of low permeability clays. Also, Hawthorn

Aquifer System - Zone I, which is the next significant aquifer below Zone II, contains fresh water with a dissolved chloride concentration of 76 mg/l.

The last and least predictable source of saline water which could affect the site is poorly constructed, old, deep wells. Between 20 and 40 years ago, numerous agricultural wells and oil test holes were drilled near the site. Most of these holes were either improperly constructed (short-cased) or not properly plugged after abandonment. These wells yield saline water under a high artesian head and when well casings corrode and decay, the saline water can intrude the shallow freshwater aquifers. All such wells adjacent to the site should be located and plugged. One such old well located about 1 mile east of the development could be presently influencing the quality of water in the water-table aquifer along Burnt Store Road. No old, deep wells appear to be a significant factor on the site, but any sudden degradation of water quality could indicate an unknown presence. It is not believed that saline water from any of the old wells will greatly influence the Zone II production wells within the next 3 to 5 years.

3. Impact on the Surface Environment

The proposed withdrawals from the Tamiami Aquifer - Zone II will have very little effect on the position of the water table due to recycling the withdrawals as irrigation water. Therefore, no surface environment changes can be expected as a result of the proposed withdrawals. Drawdowns in the water-table aquifer will be less than 0.1 foot.

4. Impact on Other Water Users

The withdrawal of 0.29 MGD of water from Tamiami Aquifer -

Zone II will not affect any other water users. There are no other known wells in the Tamiami Aquifer - Zone II located within the cone of depression.

VII. WATER MANAGEMENT

1. Long-Term Irrigation Water Supply Plan

The exploratory program described in this report has shown the existence of two aquifers, which both yield acceptable quality water for irrigation purposes. Tamiami Aquifer System - Zone II contains water with a dissolved chloride concentration of 140 mg/l and a total dissolved solids concentration of about 600 mg/l. Although the quality of water in Zone II is good, it will not yield a large quantity. We believe that after 10 years, the water may be marginally useful as it begins to take on the characteristics of the water-table aquifer. As more information is collected, this predicted aquifer useful life expectancy may be extended. It is also possible that a larger quantity of water can safely be withdrawn from the aquifer, but only long-term monitoring of water levels and quality will answer this question.

Since Tamiami Aquifer System - Zone II does have a finite useful life expectancy, a contingency plan for development of other water resources is necessary. There are three other on-site sources of irrigation water, which can be developed as necessary. The lake system contains a significant amount of storage and some water can be pumped from the lakes as part of the requirement. As the volume of water pumped from the deeper ground-water sources is increased, the lakes will recapture more water and therefore, an increased rate of withdrawal can be utilized. Hawthorn Aquifer System - Zone I has been shown to contain freshwater of a quality suitable for irrigation. This aquifer can be further studied to see if a significant volume of water can be developed from it. As the development grows, a larger quantity of treated sewage effluent will be available for irrigation. The use of treated sewage effluent will allow a reduction in use of the ground-water sources.

The key to the continued use of water from the aquifer system is the monitoring program, which is described in more detail in this chapter. If the water from either Tamiami - Zone II or Hawthorn - Zone I becomes unuseable, then the other source would be more fully developed. If all ground-water sources would become unuseable, then an off-site supply could be developed in the same aquifers on PGI lands to the north or east. Again, there are many options available to supply the irrigation water needs and the monitoring program will yield the necessary information to best choose which sources should be used at any given time in the future.

We have developed a long-term water management plan based on the available information (see Table 7-1). This plan shows the pumpage from each of the four sources that would be required to supply irrigation needs in 1984, 1989, 1994, and 1999. The pumpage rates shown in Table 7-1 are the optium rates which would be used to maintain water quality in each source. At full build-out of the development, only about 0.28 MGD will be pumped from the two ground-water sources. A peak ground-water pumping rate of 0.34 MGD will be necessary between about 14 and 17 years into the development period. Modifications to this plan would be made in the future as necessary.

In order to fully implement the water management plan as presented, certain specific information must be collected. Before the lakes are constructed, numerous temporary observation wells should be installed in the water-table aquifer to test water quality at various depths and locations (see approximate locations in Figure 7-1). This information will

TABLE 7-1. LONG-TERM WATER MANAGEMENT

Year	Water Need (MGD)	Sources	Daily Withdrawal (MGD)
1984	0.29	Lakes	0.1
		Tamiami-Zone II	0.19
1989	0.60	Lakes	0.13
		Tamiami-Zone II	0.20
		Hawthorn-Zone I	0.15
		Sewage Effluent	0.12
1994	0.75	Lakes	0.21
		Tamiami-Zone II	0.20
		Hawthorn-Zone I	0.15
		Sewage Effluent	0.19
1999	0.75	Lakes	0.22
		Tamiami-Zone II	0.13
		Hawthorn-Zone I	0.15
		Sewage Effluent	0.25

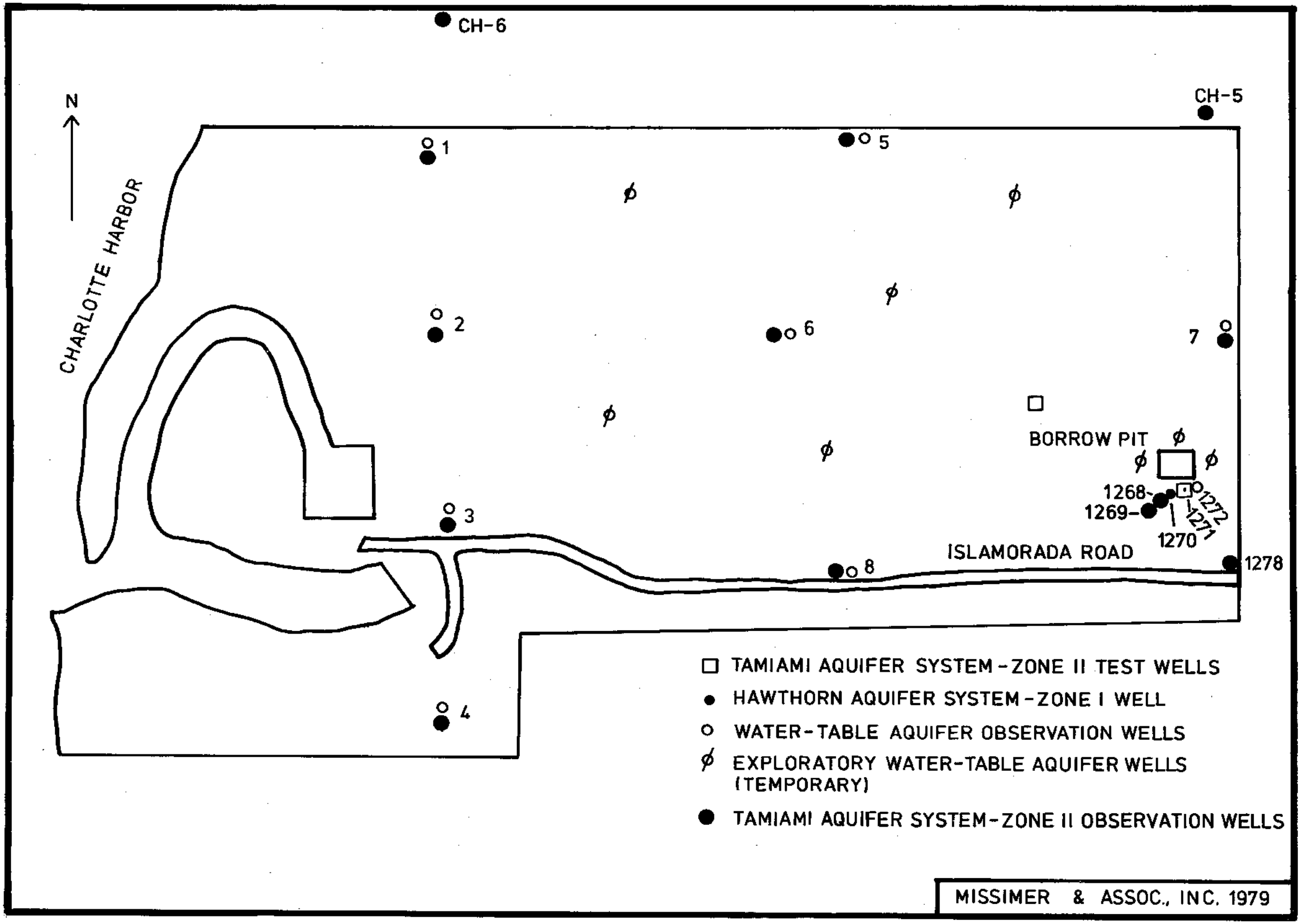


FIGURE 7-1. DIAGRAM SHOWING RECOMMENDED OBSERVATION WELLS AT BURNT STORE MARINA DEVELOPMENT.

allow proper design of the lake depths to maintain the best quality water in the system. Also, before Hawthorn Aquifer System - Zone I can be developed as a supply source, a standard testing program must be completed. This program should include observation well construction, construction of a test-production well, and an aquifer test. All of the information obtained will be necessary to modify the consumptive water use permit from the South Florida Water Management District.

2. Monitoring

A detailed monitoring program must be operated in order to properly manage the water resources at Burnt Store Marina. A series of permanent observation wells should be installed in the water-table aquifer and Tamiami Aquifer System - Zone II. The proposed locations of these wells are given in Figure 7-1 and the frequency of water level measurement suggested for each well is given in Table 7-2 and the type and frequency of water quality measurements is given in Table 7-3. This monitoring program will provide the necessary data required for management of Zone II. Each of the observation wells should be leveled to mean sea level datum by a surveyor before measurements begin.

After all of the lakes are constructed, a staff gage should be installed in each lake and should be read monthly. This will show how much supplemental water must be added from Zone II to maintain the lake stages. Water quality samples should be collected from certain lakes on a monthly basis to assess any increase in concentration of dissolved solids. Should any adverse water quality changes occur, then the lakes could be flushed with groundwater.

When Hawthorn Aquifer System - Zone I is developed as a

TABLE 7-2. WATER LEVEL MONITORING

Well Number	Measurement Frequency	Use	Aquifer
1a	Monthly	Observation	Tamiami-Zone II
1b	"	"	Water-table
2a	"	"	Tamiami-Zone II
2b	"	"	Water-table
3a	"	"	Tamiami-Zone II
3b	"	"	Water-table
4a	"	"	Tamiami-Zone II
4b	"	"	Water-table
5a	"	"	Tamiami-Zone II
5b	"	"	Water-table
6a	Continuous Recorder	"	Tamiami-Zone II
6b	Monthly	"	Water-table
7a	"	"	Tamiami-Zone II
7b	"	"	Water-table
8a	"	"	Tamiami-Zone II
8b	"	"	Water-table
CH-5	"	"	Tamiami-Zone II
CH-6	"	"	Tamiami-Zone II
1278	"	"	"
1268	"	"	"
1269	"	"	"
1270	"	"	Hawthorn-Zone II
1272	"	"	Water-table

TABLE 7-3. WATER QUALITY MONITORING

Well Number	Dissolved Chlorides and Conductivity	Complete Chemical Analysis
1a	M	-
1b	B	-
2a	M	-
2b	B	-
3a	M	-
3b	B	-
4a	M	-
4b	B	-
5a	M	-
5b	B	-
6a	M	-
6b	B	-
7a	M	-
7b	B	-
8a	M	-
8b	B	-
CH-5	M	-
CH-6	M	-
1278	B	-
1268	B	-
1269	M	-
1270	B	-
1272	B	-
1271	W	A
New Production	W	A

W = weekly

M = monthly

B = biannual

A = annual

supply source in 3 to 5 years, a series of additional observation wells should be installed in this aquifer for management purposes.

The monitoring program described in this chapter is the key to proper management of the system. It would reveal a problem well in advance of causing a failure of the irrigation system. For example, if water quality begins to change in the Zone II observation wells near the coast, the rate of change would tell us how long the aquifer can be safely pumped at a particular rate before any production well would be affected. This monitoring program should give several years warning of an impending water problem. Therefore, we can achieve a large amount of management flexibility by fully implementing the monitoring system.

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XI. APPENDIX

TABLE A-1. GEOLOGIST'S LOG - WELL CH-5

Depth(ft).	Description
0-10	Sand, quartz, and shell, coarse to fine quarz sand, brown, organic stained, shell, Caloosahatchee Marl assemblege, Parastrate sp. Olivella sp., high permeability
10-15	Shell and sand, gray to brown, clayey, mostly fine quartz sand, with some organic-rich clays, shell fragments weathered, medium permeability
15-20	Marl, light gray, shell, rock fragments, and quartz sand in matrix of lime mud, phosphatic, low permeability
20-25	Shell and sand, gray, shell and quartz sand with a minor gray clay matrix, phosphatic, medium to low permeability
25-30	Marl, light gray, medium to fine quartz sand (20-25%), shell (30-35%), lime mud (20-25%), rock fragments, and a trace of phosphorite, low permeability
30-35	Marl, light gray to gray, same generally as above, low permeability (Acline Formation)
35-40	Sand and silt, gray-green, quartz sand, and silt with shell fragments in lime mud matrix, more than 70% sand and silt, low permeability
40-45	Sand and silt, gray and green, same as above, slight increase in percentage of lime mud and clay matrix, low permeability
45-50	Sand and silt, gray-green, medium to very fine grain, silty, lime mud and clay matrix less than 10%, micro-phosphorite nodules, low permeability
50-55	Limestone, shell, and clay, gray to green, intervedded sequence, thin beds, hard limestone at 50 feet, micrite, mudstone, overall-medium to low permeability
55-60	Limestone, gray-tan, medium hard, biomicrite, wackestone, well developed secondary porasity, high permeability
60-65	Sand and silt, gray-green, lime mud and clay matrix, 10-15% sand-medium to very fine grain, 10-15% shell fragments, low permeability

TABLE A-1. CON'T.

Depth(ft.)	Description
65-70	Clay, green, lime mud and clay matrix with quartz sand and silt, and shell, matrix 25-30%, low permeability
70-75	Clay and limestone, interbedded light gray-green lime mud and high mudstone, micrite, some quartz sand, low permeability
75-84	Clay, green, trace of quartz sand, more than 90% lime mud and clay, very low permeability
84-95	Clay, dark green, quartz silt and sand, with traces of shell, trace of phosphorite, 50 to 60% matrix, low to very low permeability
95-100	Clay, green, some quartz sand and shell, microphosphorite nodules, 80-90% matrix, very low permeability
100-110	Sandstone and green clay, layered, phosphatic
110-120	Green clay, sandstone, gray, limestone, gray, phosphatic layered-hard spot right at 120'

TABLE A-2. GEOLOGIST'S LOG - WELL CH-6

Depth(ft.)	Description
0-3	Fill material, mixed sand, clay and marl
3-9	Sand and shell, gray to brown quartz sand, coarse to fine grain; shell fragments heavily weathered, Caloosahatchee Formation assemblege, high permeability
9-13	Shell and sand, gray, 2-5% lime mud matrix, phosphatic, medium to low permeability
13-20	Marl, gray, shell fragments (75-80%), quartz sand (10-15%), lime mud (5-7%), phosphorite nodules, medium to low permeability
20-28	Marl, gray, shell fragments (50-60%), quartz sand (20-25%), lime mud (10-15%), phosphorite nodules (trace), low permeability
28-32	Marl, gray, same generally as above, low permeability
32-36	Marl, gray, shell fragments (20-25%), quartz sand and silt (15-20%), rock fragments (10-15%), matrix mud (40-50%), low permeability
36-40	Clay, gray, with some thin beds of limestone at base, quartz sand and silt 30-35%, matrix mud +50%, low permeability
40-45	Clay, gray, with thin beds of hard limestone (less than 0.5-foot thick), lime mud mixed with shell fragments, limestone is a mudstone, slightly sandy, with micro-phosphorite nodules, low permeability
45-50	Clay, gray-green, with some thin laminae of limestone, more than 50% impurities-rock fragments, shell fragments, and quartz sand and silt, low permeability
50-55	Sand and clay, green, medium-size quartz sand in a matrix of green lime mud with shell and rock fragments, about 50% quartz sand, low permeability
55-60	Sand, gray-green, coarse to medium quartz sand, well-rounded, rock fragments, 5-10% matrix lime-mud and clay, low permeability
60-65	Sand and shell, gray-green, coarse to fine quartz sand, shell fragments: 40-50%, 5010% matrix, low permeability

TABLE A-2. CON'T.

Depth (ft.)	Descriptions
65-70	Sand, green, coarse to medium quartz sand, with 10-15% matrix and quartz silt, low permeability, micro-phosphorite nodules
70-75	Sand, green, same generally as above, low permeability
75-80	Sand, green, medium quartz sand, 20% matrix lime mud and quartz silt, some shell and phosphorite, low permeability
80-85	Clay, green, with quartz sand, about 50-60% matrix lime mud, some quartz silt and phosphorite, low permeability
85-90	Clay, green, mixed with quartz sand, 40-50% matrix lime muds, shell and quartz silt, low permeability
90-93	Clay, green, with quartz sand, same as above with 50-60% matrix, low permeability
93-100	Clay, green, with quartz sand and silt, 65-70% matrix, low permeability
100-108	Clay, green, 70-80% matrix, some medium-size quartz sand, well-rounded, low permeability
108-112	Clay, green, trace of quartz sand, abundant calcareous micro-fossils, some phosphatized shell, more than 80% matrix, low permeability
112-120	Sandstone, light gray-tan, medium to fine quartz sand, cemented by carbonate, abundant shell fragments, trace of phosphorite, medium permeability

TABLE A-3. GEOLOGIST'S LOG - WELL CH-7

Depth(ft.)	Description
0-9	Shell and sand, 30-35% quartz sand, medium to fine grain, high permeability
9-12	Sand, brown, quartz sand and shell with 2-5% clay, organic stained, shell fragments weathered, medium permeability
12-17	Limestone, gray, hard, fine quartz sand in carbonate matrix, 10-15% quartz, medium to high permeability
17-20	Marl, light gray, shell, rock fragments, and quartz sand in lime mud matrix, abundant microphosphorite nodules, low permeability
20-30	Marl, gray, mixture of lime mud, shell (30-35%), rock fragments, and quartz sand, trace of phosphorite, low permeability
30-40	Marl, gray, very sandy, quartz sand 30-35%, rock fragments and shell abundant, 15-25% lime mud, low permeability
40-48	Clay, gray, very shelly (50-60%), 20-30% lime mud matrix, some quartz sand, low permeability
48-56	Sand and silt, fine quartz sand, subangular, equant grains, shelly, trace of phosphorite, 5-10% matrix lime mud and clay, low permeability
56-60	Marl, gray, interbedded sequence, some thin beds of sandy limestone, medium to low permeability
60-63	Sandstone, gray-tan, very fine quartz sand in carbonate matrix, medium permeability
63-70	Clay, green-gray, 70-75% matrix with quartz sand and silt, and shell, low permeability
70-75	Limestone, gray-tan, intra-formational conglomrate, slightly sandy, phosphatic, vugged, high permeability
75-80	Clay, green, trace of quartz sand, 80-90% matrix, trace of phosphorite, low permeability
80-85	Clay, green, same generally as above, low permeability

TABLE A-3. CON'T.

Depth(ft.)	Description
85-90	Clay, green, same as above, low permeability
90-95	Clay, green, and gray sandstone, very sandy, 30-40% quartz sand and silt, medium to low permeability
95-100	Clay, green, lime mud and clay matrix, 80+%, with quartz sand, low permeability
100-104	Clay, dark green, pure matrix and quartz silt, calcareous micro-fossils, very low permeability
104-110	Clay, green, lime mud and clay 70-80%, quartz sand and silt, 10-15%, low to very low permeability
110-114	Clay, olive green, same as above, very low permeability
114-120	Sandstone, gray, quartz sand in carbonate matrix, 15-20% sand, phosphatic, medium permeability

TABLE A-4. GEOLOGIST'S LOG - WELL L-M-1278

Depth(ft.)	Description (Driller's Log)
0-10	Sand and shell
10-15	Clay, gray
15-20	Limestone, gray
20-30	Clay, gray, with shell
30-40	Clay, light gray, with shell
40-50	Clay, green
50-60	Clay, green, with shell
60-70	Clay, green, sandy
70-80	Clay, green, and shell, lime mud (60%+) with quartz sand and silt and shell (15-20%), low permeability
80-88	Limestone, gray-tan, medium hard to soft, inter-bedded with unconsolidated shell, limestone is an unsorted biosparite, grainstone, high permeability
88-90	Clay, light gray-green, mixture of lime mud, shell fragments, quartz sand and silt, and a trace of phosphorite, low permeability

TABLE A-5. GEOLOGIST'S LOG - WELL L-M-1270

Depth(ft.)	Description
0-3	Sand, quartz, brown and white, medium to fine-grain, medium to high permeability
3-8	Shell and sand, gray, quartz sand and shell with gray lime mud, low to medium permeability
8-13	Shell and sand, gray, same as above, low to medium permeability
13-16	Sand, gray-green, clayey, quartz sand and lime mud both interbedded and disseminate, low permeability
16-20	Limestone and marl, light tan to gray, soft to hard, biomicrite, wackestone, large phosphorite nodules, medium to low permeability
20-25	Marl, gray, shell in lime mud matrix with quartz sand, phosphatic, biomicrite, wacke-stone, low permeability
25-30	Marl, gray, same as above, with green lime mud at base, low permeability
30-35	Clay, green, and fine, quartz sand, some shell fragments, lime mud matrix 15-20%, low permeability
35-40	Clay, green, same generally as above, matrix above 30%, low permeability
40-45	Marl, shell, quartz sand and lime mud, mixed and interbedded, gray, medium to low permea-bility
45-50	Marl, gray, same as above, medium to low permeability
50-55	Marl, light gray and white, shell, fine to coarse, quartz sand, and lime mud, quite fossiliferous, low permeability
55-60	Marl, white, same composition as above, 20-30% matrix, low permeability
60-65	Shell, light gray, some lime mud, packestone with little cement, medium to low permeability

TABLE A-5. CON'T.

Depth (ft.)	Description
65-70	Shell, light gray, same as above, medium to low permeability
70-75	Sand and silt, quartz, gray, with 5 to 10% lime mud, some shell fragments, low to medium permeability
75-80	Clay, green, with quartz sand and silt, phosphatic, some shell fragments, low permeability
80-85	Clay, sand, shell, green, mixture of lime mud, quartz sand, and shell, low permeability
85-90	Shell, sandstone, and sand, light tan-gray, interbedded sequence, medium permeability
90-96	Limestone, light tan-gray, some phosphorite, biomicrite, wackestone, medium permeability
96-100	Clay, green, some minor quartz sand and phosphorite, 60-70% lime clay, low to very low permeability
100-105	Clay, green, same as above, low to very low permeability
105-110	Clay, green, same as above, with thin beds of sandstone, low to very low permeability
110-115	Clay, green, same as above, with some thinly-bedded sandstone, low to very low permeability (note: some water may be yielded from the thin sandstone beds)
115-120	Clay, green, same as above, with thin brown micro-crystalline limestone beds, low permeability
120-125	Clay, green, same as above, low permeability
125-130	Clay, green, same as above, with fewer impurities, very low permeability
130-135	Clay, green, same as above, low permeability
135-140	Clay, green, mixture of lime mud, quartz silt and some sand, micro-phosphorite nodules, low permeability

TABLE A-5. CON'T.

Depth(ft.)	Description
140-145	Clay, dark green, lime mud with quartz sand and silt, phosphorite gravel, low permeability
145-152	Limestone, gray and light gray, medium hard to hard, sandy, phosphatic, medium permeability
152-156	Clay, green, with quartz sand and silt, shell, phosphatic, low permeability
156-160	Limestone, gray-green, mudstone, very fine grain, phosphatic
160-165	Limestone, and clay, white phosphatic limestone interbedded with shell and lime mud with quartz sand, medium to low permeability
165-170	Limestone and clay, with shell, same generally as above, low to medium permeability
170-175	Limestone and clay, same as above, very sandy, medium to low permeability
175-180	Limestone and clay, same as above, low permeability
180-185	Clay, sand, and shell, dark green, very complex interbedded sequence, some limestone, phosphorite gravel, vertebrate fossil, low to medium permeability
185-188	Clay, sand, and shell, same as above, low to medium permeability
188-203	Sand, quartz, dark gray, phosphatic, 2 to 3% fine-grain lime mud, medium permeability
203-205	Clay, gray, very sandy, some shell, phosphatic, low permeability
205-210	Clay and sand, gray, lime mud matrix 20-25%, very phosphatic, low permeability
210-215	Sand and clay, gray, same as above, very phosphatic, low permeability
215-220	Limestone, light gray, very phosphatic, some shell, biomicrite, wackestone, medium permeability
220-225	Limestone, light gray and gray, same as above, with intercolated gray lime mud, medium permeability

Hawthorn

TABLE A-5. CON'T.

Depth(ft.)	Description
225-230	Limestone, gray and tan, phosphatic, sandy, biomicrite, wackestone, medium permeability
230-235	Limestone, light gray to gray, same as above, medium permeability
235-240	Limestone, light gray to light tan, same as above, medium permeability

TABLE A-6. GEOLOGIST'S LOG - WELL L-M-1269

Depth(ft.)	Description
0-5	Sand, white and brown, quartz, medium to fine grain, organic detritus, medium to high permeability
5-8	Sand, brown, quartz, medium to fine grain, quartz grains stained with iron percipitate, partially weathered shell fragments, medium to high permeability
8-10	Shell, some quartz sand, mostly thin-wall, small mollusk fragments, shell hash, high permeability
10-13	Shell, some gray quartz sand with a significant percentage of fines, shell consistancy same as above, medium permeability
13-16	Shell, with light gray quartz sand, clayey, shell is thick-wall assemblege than above, medium permeability
16-18	Shell and sand, light gray-brown, shell assemblege, same as above, medium permeability
18-20	Limestone, white to gray, sandy, biomicrite with calcite spars, wackestons, very high permeability
20-25	Limestone, and shell, interbedded, sandy, biomicrite, wackestone, no cement on shell beds, high permeability
25-30	Limestone, white to buff, sandy, wackestone, soft, phosphorite nodules present, medium to high permeability
30-32	Limestone, light tan-gray, sandy, soft, biomicrite, wackestone, some sandstone, medium permeability
32-40	Marl, gray, mostly shell fragments and quartz sand with a lime mud matrix (10-15%), large number of phosphorite nodules and phosphatized shell fragments, low permeability
40-45	Marl, limestone, and shell, light gray, with some quartz sand and phosphorite, medium to low permeability

TABLE A-6. CON'T.

Depth (ft.)	Description
45-50	Sand and shell, light tan to light gray, some lime mud, medium to low permeability
50-55	Marl, gray, mixture of shell fragments, limestone fragments, quartz sand, and lime mud, some phosphorite nodules, matrix 10-15%, low permeability
55-60	Marl, gray, same as above, matrix 10-20%, low permeability
60-65	Sand and clay, gray, fine quartz sand and silt with a lime mud matrix, phosphatic, some shell fragments, low permeability
65-68	Marl, gray, sand and shell in matrix of lime mud, phosphatic, low permeability
68-74	Sand and clay, gray-green, some shell fragments, matrix 10-20%, low permeability
74-80	Clay and sand, same components as above, 15-20% matrix, low permeability
80-82	Clay, gray, lime mud and quartz sand, 50-60% lime mud matrix, very low permeability
82-85	Sandstone, tan, quartz sand cemented by micrite, wackestone, clay bed at 87 feet, medium to low permeability
85-90	Sandstone and clay, interbedded, tan and gray, overall medium permeability
90-95	Sandstone, tan, wackestone, phosphatic, medium permeability
95-100	Sandstone, tan, and clay, green, clay appears to be at base of sampled interval, sandstone has medium permeability

TABLE A-7. GEOLOGIST'S LOG - WELL L-M-1268

Depth(ft.)	Description
0-3	Sand, quartz, brown and white, medium to fine-grain, medium to high permeability
3-8	Sand, brown, quartz, medium to fine grain, quartz shell fragments, medium to high permeability
8-13	Shell, some gray quartz sand, shell hash, medium to high permeability
13-16	Shell, with light gray quartz sand, clayey, medium permeability
16-20	Shell and sand, light gray-brown, limestone, white to gray, very high permeability
20-25	Limestone and shell interbedded, sandy, biomicrite, wackestone, high permeability
25-30	Limestone and shell, same as above, high permeability
30-35	Marl, gray, mostly shell fragments and quartz sand with a lime mud matrix (10-15%), low permeability
35-40	Clay, green, shell fragments, sandy, low permeability
40-45	Marl, limestone, and shell, light gray with quartz sand and phosphorite, medium to low permeability
45-50	Sand and shell, light tan to light gray, some lime mud, medium to low permeability
50-55	Marl, gray, same as above, mixture of shell fragments, limestone fragments, low permeability
55-60	Marl, gray, some green clay, low permeability
60-65	Sand and clay, gray-green, some shell fragments, low permeability
65-68	Clay, gray-green, sand and shell, phosphatic, low permeability
68-77	Sand and clay, gray-green, some shell fragments, phosphatic, low permeability
77-80	Sand and clay, same as above, low permeability

TABLE A-7. CON'T.

Depth(ft.)	Description
80-90	Sandstone, gray to tan, shell fragments and green clay in minor proportions, medium permeability
90-95	Sandstone, tan, wackestone, phosphatic, medium permeability
95-100	Sandstone, tan, and clay, green, medium to low permeability
100-105	Clay, green, some limestone, low to medium permeability
105-110	Clay, green, same as above, low permeability
110-115	Limestone, shell fragments, clay, gray-green, medium permeability
115-120	Clay, green, shell fragments, medium to low permeability

TABLE A-8. GEOLOGIST'S LOG - WELL L-M-1271

Depth(ft.)	Description
0-5	Sand, quartz, brown and white, medium to fine-grain, medium to high permeability
5-10	Shell and sand, gray, quartz sand and shell with gray lime mud, low to medium permeability
10-18	Sand, gray-green, clayey, quartz sand and lime mud both interbedded and disseminate, low permeability
18-20	Limestone and marl, light tan to gray, soft to hard, biomicrite, wackestone, large phosphorite nodules, medium to low permeability
20-25	Marl, gray, shell in lime mud matrix with quartz sand, phosphatic, biomicrite, wackestone, low permeability
25-30	Marl, gray, same as above, with green lime mud at base, low permeability
30-35	Clay, green, and fine, quartz sand, some shell fragments, lime mud matrix 15-20%, low permeability
35-40	Clay, green, same generally as above, matrix above 30%, low permeability
40-45	Marl, shell, quartz sand and lime mud, mixed and interbedded, gray, medium to low permeability
45-50	Marl, gray, same as above, medium to low permeability
50-55	Marl, light gray and white, shell, fine to coarse, quartz sand, and lime mud, quite fossiliferous, low permeability
55-60	Marl, white, same composition as above, 20-30% matrix, low permeability
60-65	Shell, light gray, some lime mud, packestone with little cement, medium to low permeability
65-70	Shell, light gray, same as above, medium to low permeability

TABLE A-8. CON'T.

Depth(ft.)	Description
70-75	Sand and silt, quartz, gray, with 5-10% lime mud, some shell fragments, low to medium permeability
75-80	Clay, green, with quartz sand and silt, phosphatic, some shell fragments, low permeability
80-85	Clay, sand, shell, green, mixture of lime mud, quartz sand and shell, low permeability
85-90	Shell, sandstone, and sand, light tan-gray, interbedded sequence, medium permeability
90-96	Sandstone, limestone, light tan-gray, some phosphorite, biomicrite, wackestone, medium permeability
96-100	Sandstone, clay, green, some minor quartz sand and phosphorite, 60-70% lime clay, low to very low permeability
100-110	Sandstone, clay, green, same as above, low to very low permeability

producing zone

TABLE A-9. GEOLOGIST'S LOG - WELL L-M-1272

Depth(ft.)	Description
0-5	Sand, white to brown, quartz, medium to fine grain, high permeability
5-10	Sand and shell, brown sand, high permeability
10-15	Shell and sand, brown, shell weathered, medium to high permeability
15-20	Shell and sand, light gray, soft slightly clayey, medium permeability

TABLE A-10. TIME AND DRAWDOWN DATA FOR TEST-PRODUCTION WELL L-M-1271

110' deep
Screen 80-100

Elapsed Time (Minutes)	Drawdown (Feet)
.5	35
1	35
2	35
3	35
4	36
5	36
6	36
7	36
8	40
9	42
10	42
15	44
20	46
30	47
40	47
50	47
60	50
70	50
80	50
90	50
100	51
120	51
150	52
180	52
210	52
240	52
270	52
300	52
360	53
420	52.5
540	53
660	52.5
780	52
960	53
1080	53.5
1200	54
1680	55
2070	56
2460	56
2940	56
3180	56
3420	56
3660	57
4020	56.5
4320	56

TABLE A-11. TIME AND DRAWDOWN DATA FOR OBSERVATION WELL L-M-1268

120'
screen 85-90

Elapsed Time (Minutes)	Drawdown (Feet)
.5	1.43
1	2.61
2	3.98
3	4.75
4	5.28
5	5.65
6	5.98
7	6.28
8	6.67
9	7.13
10	7.52
15	8.64
20	9.66
30	10.65
40	11.20
50	11.36
60	10.99
70	10.34
85	9.83
90	9.73
101	9.66
120	9.68
150	9.87
180	10.08
210	10.33
270	11.01
300	11.48
420	11.77
540	12.16
660	12.47
780	12.68
960	13.02
1080	13.18
1200	13.34
1680	13.89
2070	14.18
2460	14.34
2940	14.38
3420	14.58
4020	14.65
4320	14.57

TABLE A-12. TIME AND DRAWDOWN DATA FOR OBSERVATION WELL L-M-1269

100' screen 85'-90'

Elapsed Time (Minutes)	Drawdown (Feet)
.5	.60
1	.98
3	2.39
4	2.82
5	3.16
6	3.44
7	3.64
8	3.96
9	4.28
10	4.56
15	5.54
20	6.34
30	7.41
40	7.92
50	8.40
60	8/78
70	9.14
80	9.46
90	9.67
100	9.93
120	10.23
150	10.58
180	10.90
210	11.15
240	11.46
270	11.63
300	11.80
360	12.04
420	12.25
480	12.41
540	12.56
660	12.78
780	12.92
960	13.20
1080	13.30
1200	13.43
1320	13.57
1440	13.64
1800	13.96
1960	14.03
2070	14.08
2220	14.14
2460	14.22

(Con't.)

TABLE A-12. Continued

Elapsed Time (Minutes)	Drawdown (Feet)
2940	14.23
3180	14.34
3420	14.40
3660	14.46
4025	14.45
4320	14.38

TABLE A-13. CHEMICAL ANALYSIS OF WATER FROM WELL L-M-1271 AT THE BEGINNING OF THE AQUIFER TEST.

Orlando Laboratories, Inc.

P. O. Box 8008 • Orlando, Florida 32856 • 305/843-1661

Report to: Missimer & Associates, Inc.

Date: 23 April 79

Report Number: 17089-1

Appearance: Clear

Sampled by: Client

Identification: PGI-1

METHODS

This water was analyzed according to "Standard Methods for the Examination of Water and Wastewater," Latest Edition, APHA, AWWA and WPCF.

RESULTS

Determination	Data Significance	mg/l
Total Dissolved Solids	x.	640
Phenolphthalein Alkalinity, as $CaCO_3$	x.	0
Total Alkalinity, as $CaCO_3$	x.	255
Carbonate Alkalinity, as $CaCO_3$	x.	0
Bicarbonate Alkalinity, as $CaCO_3$	x.	255
Carbonates, as CO_3	x.	0
Bicarbonates, as HCO_3	x.	311
Hydroxides, as OH	x.	0
Carbon Dioxide, as CO_2	x.	13
Chloride, as Cl	x.	130
Sulfate, as SO_4	x.	35
Fluoride, as F	.x	0.32
pH (Laboratory)	.x	7.6
pHs	.x	6.9
Stability Index	.x	6.3
Saturation Index	.x	0.7
Color, PCU	x.	0
Odor Threshold	x.	0
Turbidity, NTU	x.	0.73

Determination	Data Significance	mg/l
Total Hardness, as $CaCO_3$	x.	343
Calcium Hardness, as $CaCO_3$	x.	300
Magnesium Hardness, as $CaCO_3$	x.	43
Calcium, as Ca	x.	120
Magnesium, as Mg	.x	10
Sodium, as Na	x.	55
Iron, as Fe	.x	0.01
Manganese, as Mn	.x	<0.05
Copper, as Cu	.x	<0.1
Silica, as SiO_2		48
Dissolved Potassium, K		3.2
Dissolved Iron, Fe		0.01

Signed: Donna Furbird
Chemist

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TABLE A-14. CHEMICAL ANALYSIS OF WATER FROM WELL L-M-1272 AT THE END OF THE AQUIFER TEST.

Orlando Laboratories, Inc.

P. O. Box 8008 • Orlando, Florida 32856 • 305/843-1661

Report to: Missimer & Associates, Inc.

Date: 23 April 79

Report Number: 17089-2

Appearance: Clear

Sampled by: Client

Identification: PGI-2

METHODS

This water was analyzed according to "Standard Methods for the Examination of Water and Wastewater," Latest Edition, APHA, AWWA and WPCF.

RESULTS

Determination	Data Significance	mg/l	Determination	Data Significance	mg/l
Total Dissolved Solids	x.	640	Total Hardness, as $CaCO_3$	x.	345
Phenolphthalein Alkalinity, as $CaCO_3$	x.	0	Calcium Hardness, as $CaCO_3$	x.	299
Total Alkalinity, as $CaCO_3$	x.	261	Magnesium Hardness, as $CaCO_3$	x.	46
Carbonate Alkalinity, as $CaCO_3$	x.	0	Calcium, as Ca	x.	120
Bicarbonate Alkalinity, as $CaCO_3$	x.	261	Magnesium, as Mg	.x	11
Carbonates, as CO_3	x.	0	Sodium, as Na	x.	55
Bicarbonates, as HCO_3	x.	318	Iron, as Fe	.x	0.01
Hydroxides, as OH	x.	0	Manganese, as Mn	.x	<0.05
Carbon Dioxide, as CO_2	x.	11	Copper, as Cu	.x	<0.1
Chloride, as Cl	x.	130	Silica, as SiO_2		46
Sulfate, as SO_4	x.	35	Dissolved Potassium, K		3.2
Fluoride, as F	.x	0.33	Dissolved Iron, Fe		0.01
pH (Laboratory)	.x	7.7			
pHs	.x	6.9			
Stability Index	.x	6.2			
Saturation Index	.x	0.8			
Color, PCU	x.	0			
Odor Threshold	x.	0			
Turbidity, NTU	x.	0.38			

Signed: Donna Furbro
Chemist

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TABLE A-15. FIELD CHEMICAL ANALYSES DURING AQUIFER TEST
4/17 through 4/20

Elapsed Time	Conductivity	Cl^- mg/l
75	825	136
145	825	136
240	825	136
420	825	136
660	825	136
960	825	136
1140	825	136
1350	825	136
1635	825	136
2220	825	136
2700	825	136
3180	825	136
4035	825	136
4320	825	136

TABLE A-16. CHEMICAL ANALYSES WATER IN TEST WELLS

Burnt Store Utilities Analysis

Well Number	After 1 hour
L-M-1278	pH 7.7 NaCl 328 Alkalinity 190 T. Hardness Ca Hardness 204 Mg Hardness 36
CH-5	pH 8.0 T. Hardness 300 Ca Hardness 188 Mg Hardness 112 Alkalinity 288 NaCl 398
CH-6	pH 8.0 T. Hardness 212 Ca Hardness 96 Mg Hardness 116 Alkalinity 220 NaCl 210
CH-7	pH 7.6 T. Hardness 220 Ca Hardness 124 Mg Hardness 96 Alkalinity 260 NaCl 164

Missimer & Associates Analysis

L-M-1278	Cl^-	160
	Conductivity	930
CH-5	Cl^-	180
	Conductivity	930
CH-6	Cl^-	100
	Conductivity	650
CH-7	Cl^-	90
	Conductivity	700