HYDROGEOLOGIC INVESTIGATION OF THE HAWTHORN AND SUWANNEE AQUIFER SYSTEMS AT WELLFIELD CLUSTER SITE B SANIBEL ISLAND, FLORIDA

Prepared for

THE ISLAND WATER ASSOCIATION, INC.

P.O. Box 56
Sanibel, Florida 33957

December, 1985

MISSIMER AND ASSOCIATES, INC.

Consulting Hydrologists, Geologists, and Environmental Scientists

Cape Coral, Florida

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December 31, 1985

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Island Water Association, Inc.
P. O. Box 56
Sanibel, Florida 33957

Subject: Final report "Hydrogeologic Investigation of the Hawthorn and Suwannee Aquifer Systems at Wellfield Cluster Site B, Sanibel Island, Florida"

Dear Mr. Derowitsch:

Missimer and Associates, Inc. is pleased to submit the subject report. This document is the result of the investigation of the expansion area of the Suwannee Aquifer wellfield. The quantity of water available in the Suwannee Aquifer System-Zone I is less than anticipated. However, there are several other aquifers available for use and the overall yield from the site may be substantially greater than anticipated. Water quality in all usable aquifers at site B is quite good and this should reduce future water treatment costs.

The investigators for Missimer and Associates, Inc. were:

Project Manager: Larry K. Holland, Senior Hydrogeologist
Thomas M. Missimer, Senior Hydrogeologist
James Andersen, Hydrogeologist
David B. Hire, Hydrologic Technician

This project was conducted under the general supervision of Mr. Dick Derowitsch, and the members of the Island Water Association, Inc. Board of Directors listed below:

William D. Angst, President
C. H. Brooks, Vice President
William Lees, Jr.
James Hermes
Everett D. Kilmer

We would be pleased to answer any questions regarding our findings during this investigation at any time.

Sincerely,
MISSIMER AND ASSOCIATES, INC.

Thomas M. Missimer
President

TMM:sm

Enclosure

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I. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

A hydrogeologic investigation of the Hawthorn and Suwannee Aquifer System was conducted at wellfield cluster site B, located about 2 miles west of the existing reverse osmosis plant along Sanibel-Captiva Road. The investigation involved the drilling of a deep test well for the purpose of obtaining geologic and water quality information, the construction of a test-production well and an observation well, the performance of an aquifer performance test, and the collection of water samples for chemical analyses. The data collected during this program were combined with and compared to information previously collected to conclude the following:

1) The geology of the lower part of the Hawthorn Formation is much different at site B compared to site A. This difference in geology is a thickened section of clay which separates Hawthorn Aquifer System-Zone IV from the underlying Suwannee Aquifer System-Zone I. At site A these zones act as a single aquifer, but at site B they are separate, unique aquifers.

2) Because of the change in geology, individual production wells at site B will not produce as much water as the production wells at site A.

However, at site A (existing wellfield) there is only one usable aquifer, but at site B there are up to four usable aquifers.

3) Water quality in all tested zones at site B is much better compared to site A. A comparison of water qualities in the various zones shows the following:

Zone	Dissolved Chlorides (mg/1) Site A (existing)	Site B (new)
Hawthorn-II	10,700-12,200	600-700
Hawthorn-III	1,420- 1,750	260-320
Hawthorn-IV	1,400- 1,640	560-580
Suwannee-I	1,500	1,000-1,160
Suwannee-II	5,100- 5,700	1,240-1,540

4) The aquifer coefficients for the combination of Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I are:

Transmissivity = 46,000 gpd

Storage Coefficient = 3.4×10^{-5}

Leakance (lower) = 2×10^{-3} gpd/ft^3 (approx.)

Leakance (upper) = 1.2×10^{-4} gpd/ft^3 (approx.)

5) Based on the available water quality and hydraulic data collected at site B, the Island Water Association, Inc. should have a continuing supply of better quality feedwater for both the reverse osmosis and electrodialysis treatment plants. The higher quality water found at site B should significantly

reduce future water treatment costs.

6) In order to develop an efficient wellfield at site B, it will be necessary to collect some additional hydrogeologic data on some of the isolated aquifers. After these data are obtained, it is likely that a larger number (greater than 3) of production wells will be necessary to obtain the overall desired yield from the site.

7) Until all of the necessary hydrogeologic data are collected, the combination of production wells S-5 and S-4 will provide enough water to feed the new R.O. train. This situation should be considered temporary and the new site B wellfield should allow the use of S-4 to be limited to standby or rotational for site A.

2. Recommendations

1) An inflatible packer should be placed in well S-5 to separate Hawthorn Aquifer System-Zone IV from Suwannee Aquifer System-Zone I and an aquifer performance test should be conducted on the isolated Hawthorn-Zone IV. The existing observation well, open to both Hawthorn-Zone IV and Suwannee-Zone I, should be modified into a dual piezometer with each zone tapped by an isolated casing.

This observation well should then be used during the aquifer test on Hawthorn-Zone IV.

2) The pumping rate on well S-5 should be limited to the range of 400 to 450 gpm until the complete wellfield is designed. It is likely that well S-5 should be modified to tap only one zone, not both zones.

3) Individual observation wells should be constructed into Hawthorn Aquifer System-Zone II and Hawthorn Aquifer System-Zone III. These wells would be used to assess water quality and as observation wells for future aquifer tests and monitoring.

4) The final wellfield design should be based on all of the new Hydrogeologic test data to be collected and then the wellfield design should be coordinated with future expansion of the reverse osmosis treatment plant.

5) Production well S-5 should eventually be modified to yield from either Hawthorn-Zone IV or Suwannee-Zone I, but not both aquifers. The decision on which aquifer to be used should be based on the recommended aquifer test.

6) It is quite important that the Island Water Association, Inc. initiate a monitoring program on Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I as soon as possible. Two

new observation wells should be constructed between the existing wellfield and known sources of higher salinity water.

II. INTRODUCTION

1. Authorization

Missimer and Associates, Inc. was authorized on April 19 and May 22, 1985, by the Island Water Association, Inc. of Sanibel, Florida to begin a hydrogeologic investigation of the lower part of the Hawthorn Aquifer System and the upper part of the Suwannee Aquifer System at site B. Site B is located about 8,000 feet west of the existing reverse osmosis treatment plant and wellfield (Figure 2-1). This investigation specially included: 1) field data collection from a 900-foot deep on-site test well, 2) analysis of subsurface conditions to determine the observation well construction details, 3) supervision of well construction for 1 observation well and 1 production well, 4) geophysical logging as required, 5) step-drawdown tests and an aquifer test, and 6) a final report with recommendations on development of water at site B.

2. Purpose and Scope

The purpose of the investigation is to explore the hydrogeology of wellfield cluster site B in order to develop additional water from Suwannee Aquifer System-Zone I. The scope of services includes all of the tasks outlined in the authorization.

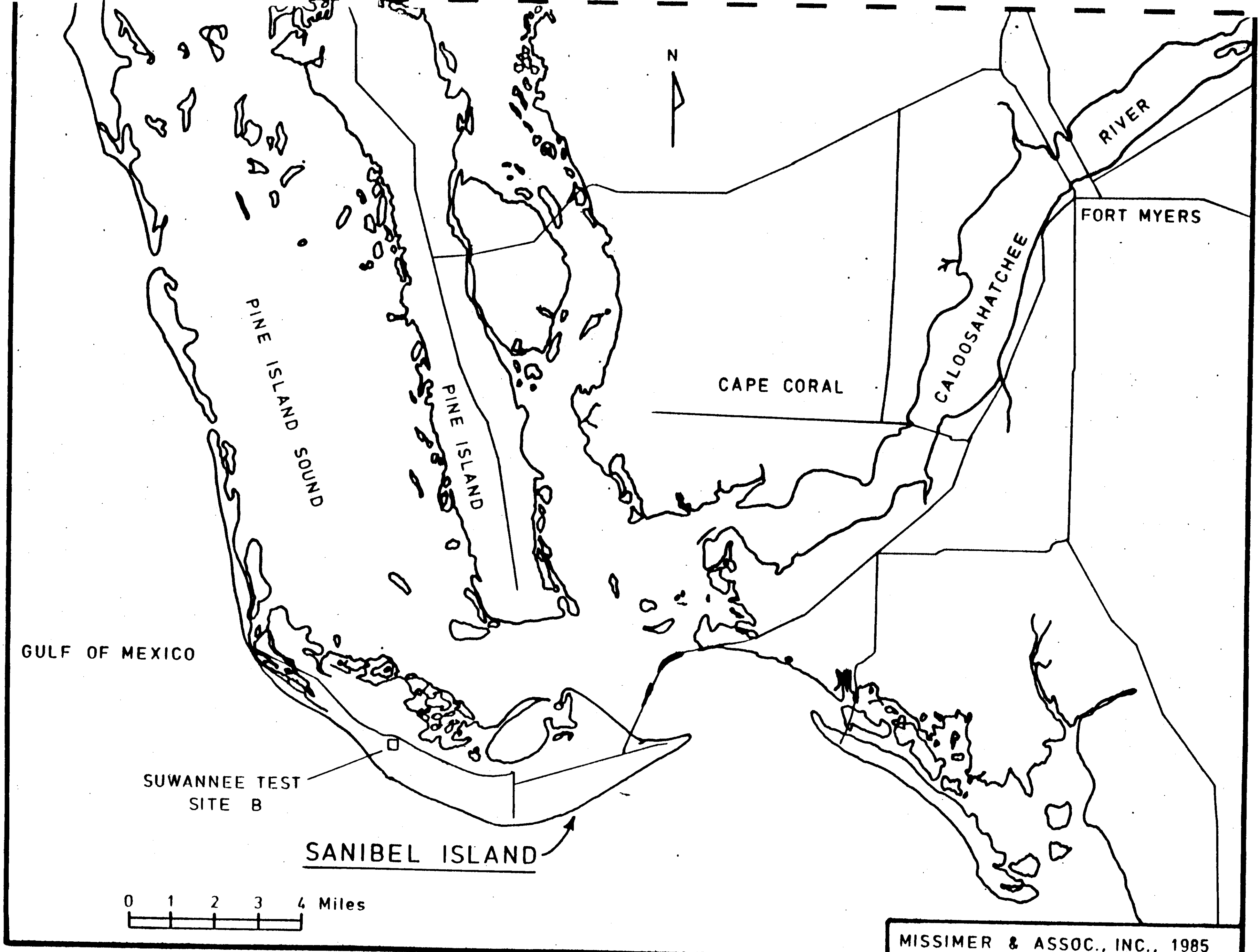


FIGURE 2-1. MAP SHOWING THE LOCATION OF SANIBEL ISLAND.

3. Acknowledgments

We sincerely thank the following persons: Mr. Bob Hollander, General Manager, and Mr. Dick Derowitsch of the Island Water Association, Inc. and Dr. Pat Gleason of the South Florida Water Management District.

III. DESCRIPTION OF THE SITE B HYDROGEOLOGIC INVESTIGATION

1. Introduction

This investigation is one in a series of hydrogeologic studies made for the Island Water Association, Inc. in order to maintain a continuous supply of water to the residents of Sanibel and Captiva Islands (see Geraghty & Miller, Inc., 1978; Missimer and Associates, Inc., 1978b, 1979a, 1979b, 1980, 1982). Detailed hydrogeologic investigations, including aquifer tests, have been conducted on Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I as individual units and in combination (Missimer and Associates, Inc., 1979a, 1980). All previous studies on these aquifers have been limited to the area adjacent to the reverse osmosis water treatment plant. This area is known as wellfield cluster site A. In 1981, it was recommended to the IWA that when additional water was necessary to feed the plant, the new production wells should be located at two additional cluster sites designated as B and C (Missimer and Associates, Inc., 1981). This investigation will serve to determine the hydrogeologic conditions at site B (see Figure 3-1 for location of the site).

2. Test Drilling and Well Construction

A test-drilling program was initiated along the northern

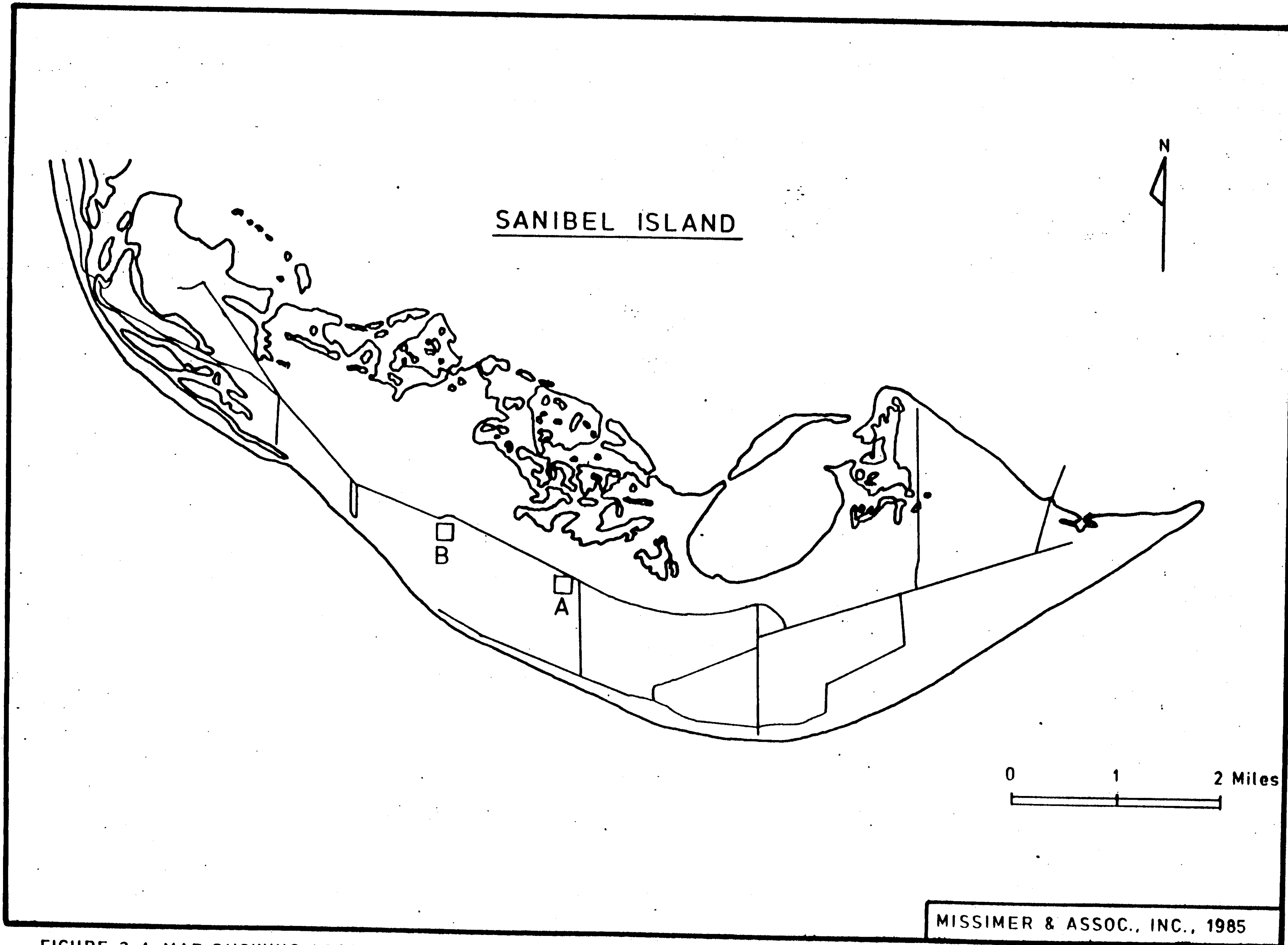


FIGURE 3-1. MAP SHOWING LOCATION OF SUWANNEE AQUIFER WELLFIELD SITES A AND B.

site boundary adjacent to Sanibel-Captiva Road. The geologic, geophysical, and water quality data were collected from a well to be converted into an observation well rather than a production well. Although this differed from the past procedure, it allowed the collection of good quality hydrogeologic data without the risk of losing a production well or the cost of cementing back a large diameter hole.

The initial test well constructed into the Suwannee Aquifer System was designed to collect both geologic and water quality information. A 22-inch diameter hole was drilled by the hydraulic rotary-mud method to a depth of about 101 feet below surface. A string of 16-inch diameter (I.D.) steel surface casing was installed to a depth of 99 feet below surface. This casing was pressure-grouted with Type A neat cement. Drill cuttings were collected from the upper 100 feet and a set of electric logs was obtained. An 8-inch diameter pilot hole was drilled by the hydraulic rotary-mud method to a depth of about 400 feet. Again, drill cuttings were collected by the on-site geologist and electric logs were run on the hole. Upon analyzing the initial data, the borehole was reamed to a 15-inch nominal diameter to 400 feet. A string of 8-inch diameter (I.D.), Schedule 40, PVC casing was installed to a depth of about 400 feet below surface. This casing was pressure-grouted using Type A neat cement. An 8-inch exploratory hole was drilled by the reverse-air rotary method to a depth of 905 feet. Drill cuttings were collected during the entire process, water samples were collected a minimum of each 10 feet, and geophysical logs were run on the test hole. Each water sample was analyzed for dissolved chlorides and conductivity. Upon completion of the data collection, the well was backfilled with Type A neat cement to a depth of 770 feet below surface. After the cement set, the open-hole was backfilled with clean sand to about 665 feet below surface. A 665-foot string of Schedule 40, PVC casing was installed in the open-hole. Centralizers were placed at 40-foot increments. The annulus was pressure grouted with Type A neat cement. After the cement set, the sand was cleaned from the open-hole by drilling it out with freshwater. The well was then developed with compressed air for a few hours. A diagram showing the construction details of Well L-M-2464 is given in Figure 3-2.

The hydrogeologic data collected during the drilling of the observation well were used to determine the specifications of the final production well. The construction sequence on production Well L-M-2465 began with the drilling of a 22-inch diameter hole by the hydraulic rotary-mud method to a depth of about 100 feet below surface. A string of 16-inch diameter steel casing was installed to a depth of 100 feet and the annulus was pressure-grouted with Type A neat cement. A 16-inch borehole was then drilled by the hydraulic rotary-mud method to a depth of about 664 feet below surface. The drilling mud was carefully cleared of cuttings by use of a mechanical screening device and the borehole was prepared for casing

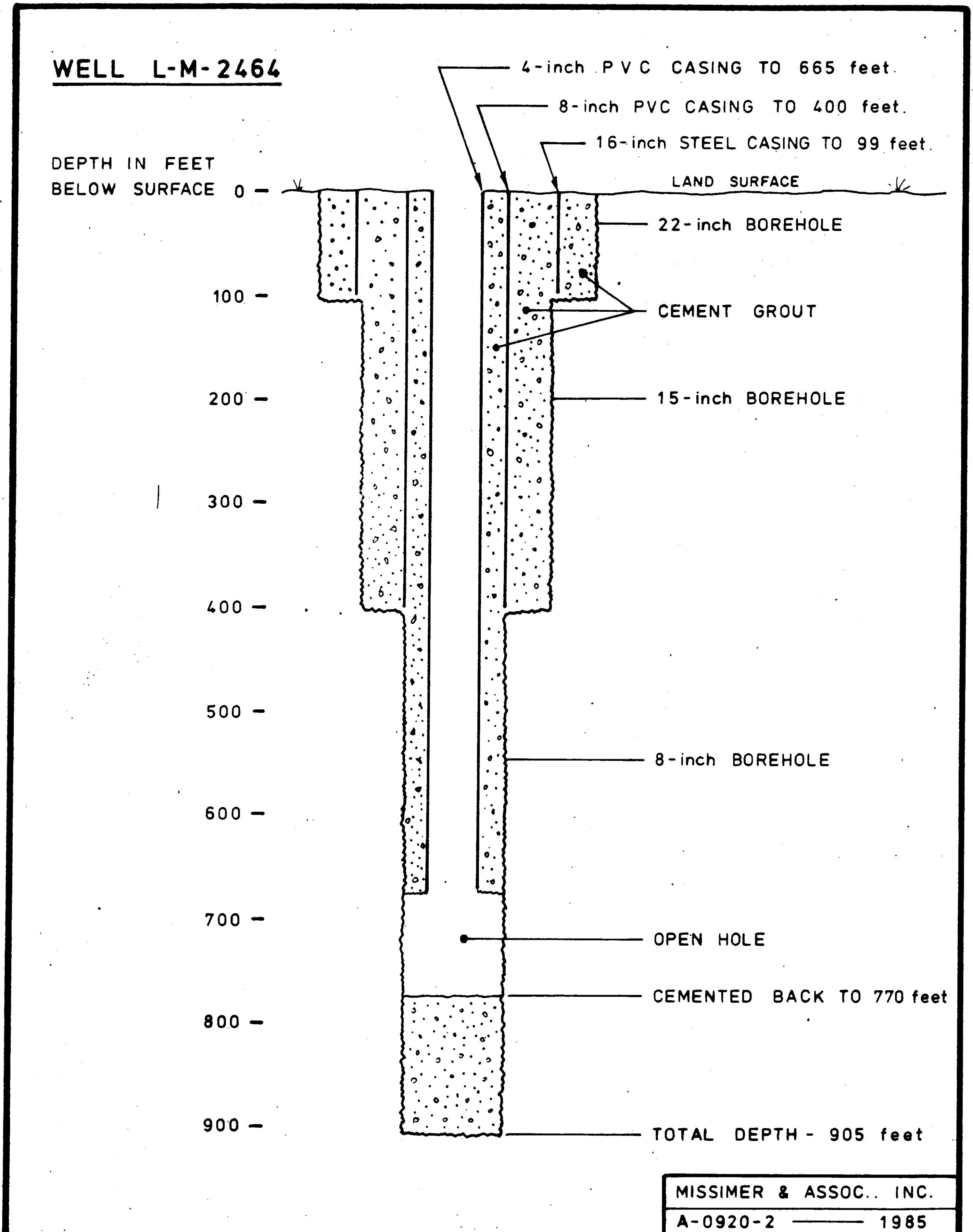


FIGURE 3-2. DIAGRAM SHOWING THE CONSTRUCTION OF TEST WELL L-M-2464.

installation and grouting. A string of 664 feet of 1/4-inch wall thickness fiberglass casing was installed in the hole. Centralizers were placed at a minimum spacing of 40 feet. The annulus was then pressure grouted using Type B neat cement. Additional cement was later added by tremie pipe to compensate for some shrinkage and cement exfiltration during pressure grouting. This additional cement filled the annulus to land surface. After a 48-hour period, a nominal 8-inch diameter hole was drilled by the reverse-air rotary method to a depth of 770 feet below surface. A diagram showing the construction details of production Well L-M-2465 is given in Figure 3-3.

3. Aquifer Test

An aquifer test was performed on a combination of Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I. Based on past analyses of aquifer test data at site A, these two zones react as a single aquifer. Production Well L-M-2465 was pumped continuously at a rate of 402 gpm for 2,530 minutes at which time the turbine pump driveshaft broke. The production well was equipped with an extended shaft turbine pump powered by a diesel engine. Pump discharge was monitored using a standard orifice with an elevated clear manometer tube. The discharge free-fell from the end of the orifice plate into a mosquito control ditch. A diagram

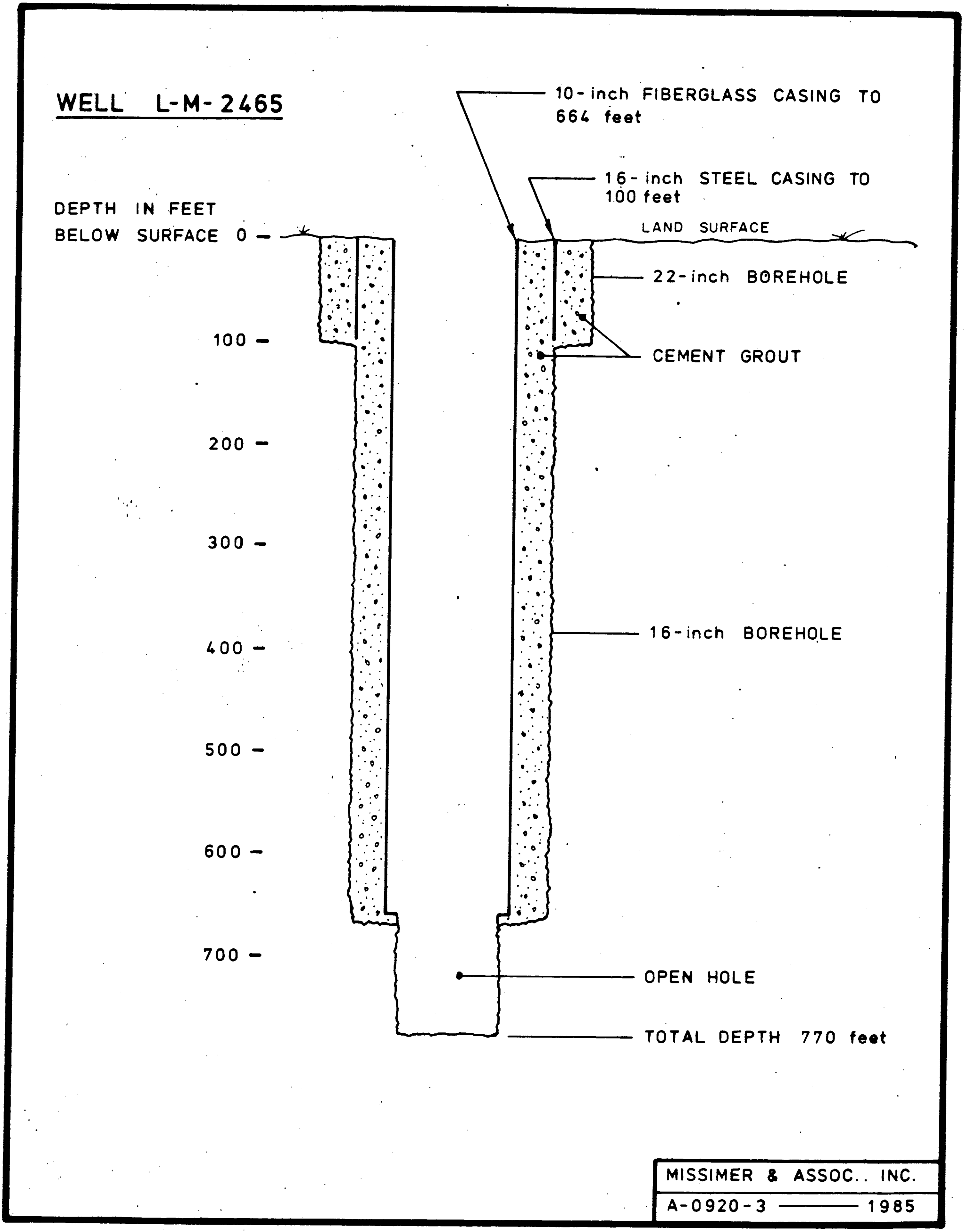


FIGURE 3-3. DIAGRAM SHOWING THE CONSTRUCTION OF PRODUCTION WELL LM-2465.

showing the aquifer test set-up is given in Figure 3-4.

The aquifer test pumping rate was established by conducting a standard step-drawdown test a few days before initiation of the primary test. Each step had a duration of 30 minutes. The pump discharge rates were: 293 gpm, 402 gpm, 503 gpm, and 602 gpm. Analysis of drawdowns at these pumping rates indicated that the best rate to run a long-term aquifer test was 402 gpm.

Drawdown in production Well L-M-2465 was measured using a combination of a pressure gage, for the initial few minutes of the test, and an electric tape for the remainder of the test. Since the drawdowns in the production well stabilized rapidly during the test, measurements were discontinued after the first 3 hours.

Drawdowns of the potentiometric surface of Suwannee Aquifer System-Zone I at a distance of 194 feet from the production well were measured in observation well L-M-2464. This well was equipped with a Stevens Type-F water level recorder, which was manually checked at each measurement time throughout the test. Because the static head pressure within the observation well occurred at more than 20 feet above land surface, it was necessary to extend the well casing with a 4-inch diameter PVC riser pipe to 25 feet above surface. The riser pipe and recorder shelter were supported by scaffolding which was anchored by staked lines.

Because of the rather sudden failure of the pump, it was not possible to obtain recovery data from either well.

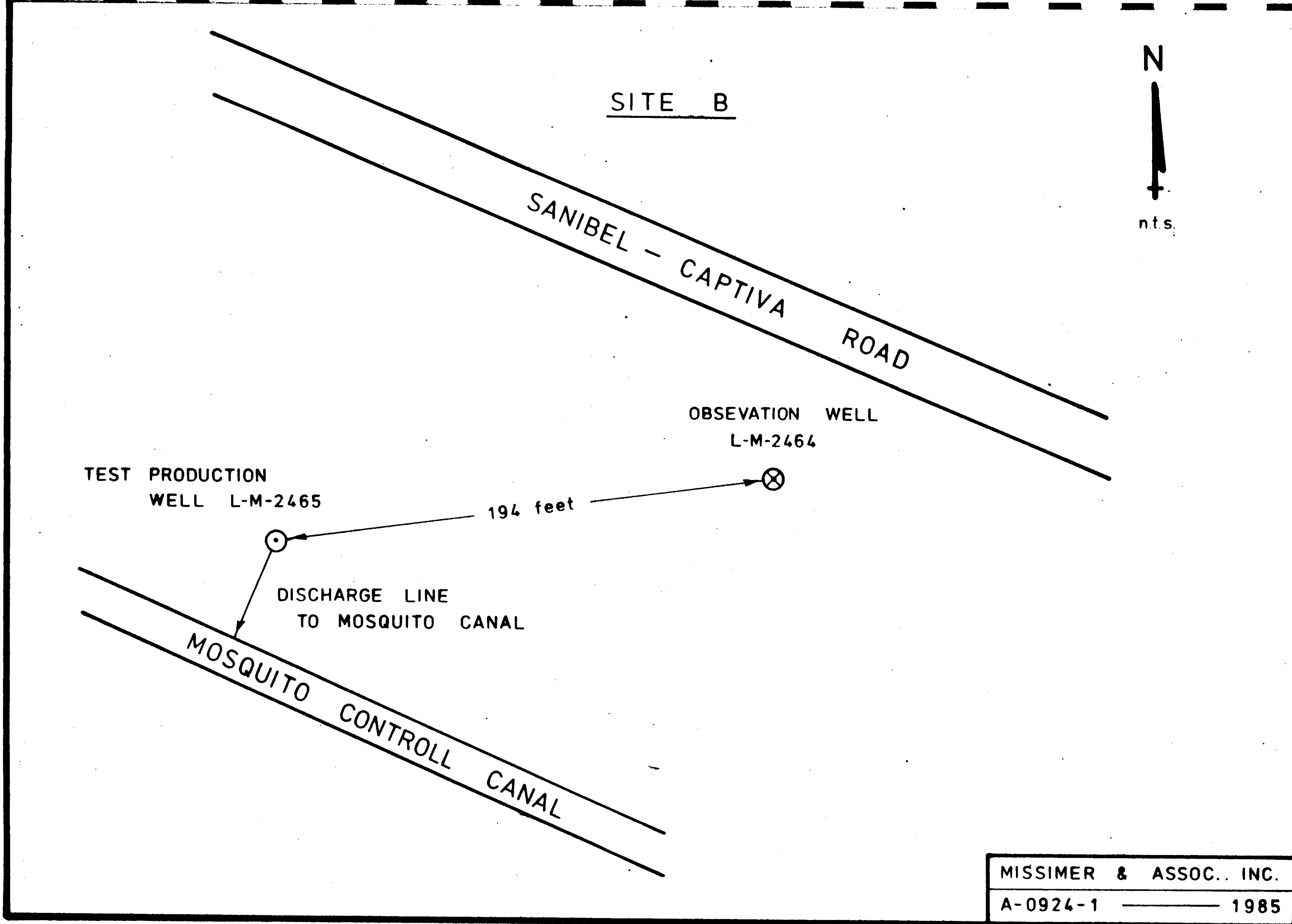


FIGURE 3-4. SCHEMATIC DIAGRAM SHOWING THE AQUIFER TEST SET-UP.

IV. HYDROLOGY AND GEOLOGY OF THE SITE B WELLFIELD

1. Geology

Sedimentary rock strata ranging in age from Holocene to Late Jurassic underlie Sanibel Island to a depth of over 18,000 feet. The upper 905 feet of the sedimentary section was explored in the first test well at Site B. A complete geologic log of test well L-M-2464 is given in Figure 4-1 and a descriptive log is given in Table A-2. The information collected from the upper 400 feet of geologic sections is not as detailed as the deeper data, because the reverse air-rotary drilling technique could not be utilized in this interval.

Holocene

Sediments deposited in the last 10,000 years occur to a depth of 33 feet below surface. This Holocene-age sediment contains three minor stratigraphic units, which are: tan to light gray, quartz sand and shell, 2) fine, gray, quartz sand, and 3) carbonate mud, clay, quartz sand, and shell. This sediment sequence has been described in detail by Missimer (1973).

Tamiami Formation

The definitions of both the Tamiami Formation and the underlying Hawthorn Formation have recently been changed to

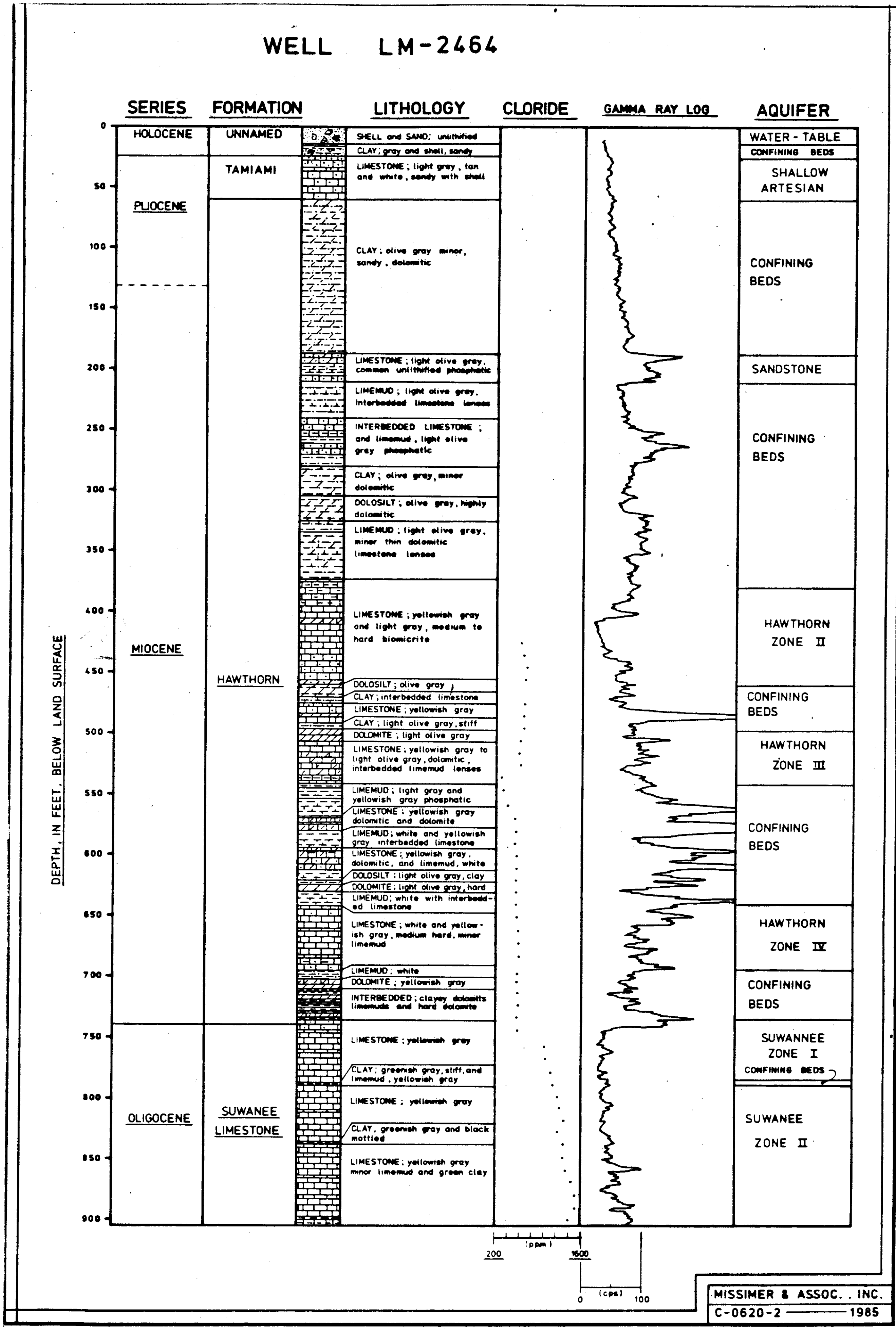


FIGURE 4-1. GEOLOGIC LOG, GAMMA RAY LOG, WATER QUALITY, AND AQUIFER LOCATIONS IN WELL LM-2464.

reflect past work and new work on world-wide eustatic sea level changes (Missimer and Banks, 1982; Missimer, 1984). The Tamiami Formation now includes only the upper limestone facies termed the Pinecrest Limestone, the Ochopee Limestone, and the Buckingham Limestone. In well L-M-2464, the unit is only 27 feet thick. It contains a variety of lithologies ranging from gray, tan, and white limestone to sandstone to unlithified quartz sand.

Hawthorn Formation

The Hawthorn Formation in south Florida begins with the first vertical appearances of a regional green dolosilt unit or a thick accumulation of clastics. It is a regional stratigraphic unit, which underlies most of Florida and parts of Georgia and South Carolina. The formation ranges from Miocene to Early Pliocene in age.

A regional disconformity separates the Tamiami Formation from the Hawthorn Formation, which is almost 700 feet thick at this location. The Hawthorn Formation was deposited in a series of cycles caused by changes in the position of sea level (Missimer and Banks, 1982). Each cycle usually contains a basal carbonate, mostly limestone, and a mix of carbonate lithologies and clastics toward the top of each cycle. The mixed sediment sequence contains a large number of comparatively thin beds. The base of the formation occurs between 736 and 744 feet below surface and the top of the formation occurs at 60 feet below surface.

Certain conclusions have been drawn concerning the geologic history of the Hawthorn Formation. These conclusions have a significant bearing on the groundwater system. The conclusions are: 1) the three principal limestone units within the formation represent extensive time periods with relatively constant depositional environments, 2) the large number of thin lithic units represents a period of time when there was a large number of short duration changes in the depositional environment caused by both eustatic sea level changes and structural instability, 3) the clastic sediment percentage increases upward within each cycle and within the formation as a whole, 4) a major regional disconformity divides the formation, 5) the sediments above the disconformity are predominantly clastic, which appear to be deltaic, 6) the permeability of the limestones is directly related to the time of continuous depositions and the percentage of clastics, and 7) the basal limestone in each cycle forms the aquifer and the thinly bedded sediments form the confining beds.

All of the "clays" in the Hawthorn Formation are relatively well-compacted and dense. The "clays" are predominantly lime and dolomitic muds with a variable percentage of quartz sand and silt, phosphate, and true clay minerals. Recent studies of Hawthorn Formation "clays" in Cape Coral have shown that some of the thin units consist of nearly 80% montmorillonite and others contain variable percentages of attapulgite and sepiolite with traces of feldspar. The darker colored units tend to contain a higher percentage of clay minerals. The compacted lime muds and dolosilts have a somewhat higher vertical permeability compared to the clays.

Numerous geologists have separated the phosphatic sediments of south Florida into two formations, the Hawthorn Formation and the Tampa Limestone. A recently published paper by King and Wright (1979) shows that the Tampa Limestone does not extend south of the Sarasota County area. Therefore, the Tampa Limestone does not occur beneath Sanibel Island.

All limestone lithologies given in the sediment descriptions are named according to the classifications of Folk (1968) and Dunham (1962). Most of the limestones in the Hawthorn Formation are micrites or biomicrites with variable percentages of nodular phosphorite and quartz sand.

The basal unit of the Hawthorn Formation is an interbedded limestone and lime mud. At the contact between the Hawthorn Formation and the underlying Suwannee Limestone, there is an abrupt decline in gamma ray activity. This appears to make the contact a disconformity.

Suwannee Limestone

About 161 feet of the Suwannee Limestone was penetrated in well L-M-2464. The upper half of the Suwannee Limestone penetrated is predominantly a lithified microfossiliferous, yellowish gray, calcarenite. It is soft and has a medium permeability. A stiff yellowish gray lime mud occurs between 787 and 789 feet below surface and a dark greenish gray clay occurs from 836 to 837 feet below surface. The lower half of the unit contains a number of different limestone lithologies, some of which are wackstones that contain a higher permeability compared to the calcarenites. The two thin clay units do appear to have an extremely low vertical permeability.

The carbonate sediments found in the Suwannee Limestones are typical of those observed in other areas of Florida with a few exceptions (MacNeil, 1944). The clay strata within the formation are not typical, however, in other areas of Florida, confining beds in the formation are lithified chert deposits. Sediments like those found in the upper part of the Suwannee Limestone are presently being deposited in areas such as the Bahama Banks and Joulters Cay. The lower Suwannee Limestone appear to have been deposited in an environment, such as Florida Bay.

2. Aquifer and Confining Bed Descriptions

Eight water-bearing units or aquifers were penetrated in test well L-M-2464 (Figure 4-1). The water-table, shallow artesian, and Sandstone Aquifers are of little significance to the water system maintained by the IWA and are, therefore, not discussed. Detailed discussions of these aquifers can be found in Boggess (1973), Missimer (1976), and Missimer and Associates, Inc. (1978b, 1979). In many parts of Sanibel

Island, an immediate aquifer, known as Hawthorn Aquifer System-Zone I, occurs and produces water. This aquifer does not appear to exist at site B.

Confining Beds Between the Sandstone Aquifer and Hawthorn Aquifer System-Zone II

A thick sequence of lime mud, dolosilts, marls, and sandy clays separate Hawthorn Aquifer System-Zone II from the overlying aquifer. The sequence is about 313 feet thick and it provides a very high degree of confinement. The vertical hydraulic gradient is directed upward at this location. Even if Hawthorn-Zone II was being pumped, it is unlikely that any significant leakage would occur through this confining bed.

Hawthorn Aquifer System-Zone II

Hawthorn-Zone II occurs within the third depositional cycle, basal limestone of the Hawthorn Formation. It is about 86 feet thick and consists of bedded light gray to yellowish gray limestone. The upper 30 feet of the unit contains lime mud infilling pore spaces within the limestone. The lower section of the aquifer contains some sandy limestone. Based on the lithologic data, this aquifer could yield a considerable volume of water.

Confining Beds Between Hawthorn-Zones II and III

About 37 feet of mixed beds of lime mud, dolosilt, and clayey limestone separates Hawthorn-Zone II from Hawthorn-Zone III. The upper 11 feet of the confining bed is a very stiff dolosilt and the lower 5 feet of the confining bed is a stiff lime mud or clay. This 16 feet of material provides most of the vertical separation, because the intermediate bed contains a variety of lime muds, marls, and limestone, some of which would provide little confinement. The overall sequence in the confining bed does provide a high level of separation between the aquifers. However, leakage will occur across this unit and water may be released from storage within the unit as Zone II or Zone III would be pumped.

Hawthorn Aquifer System-Zone III

Hawthorn-Zone II occurs in the second cycle, basal limestone of the Hawthorn Formation. It is basically a limestone unit, but it contains several lenses of lime mud. The aquifer is 46 feet thick and appears to be quite well confined. Based on the lithology of the unit at this location, it should have a limited overal permeability.

Confining Beds Between Hawthorn-Zones III and IV

The confining beds separating Hawthorn-Zone III and IV are extremely inhomogeneous. Although the total tickness of the unit is about 101 feet, no individual lithology is thicker than about 14 feet. There are 15 separate lithologies, each containing its own distinctive hydraulic characteristics. Of the 101 feet of confining strata, 46 feet are lime muds and dolosilts of low permeability and an additional 15 feet are interbedded lime muds and limestone. This overall sequence appears to provide a high degree of confinement between Hawthorn Aquifer System-Zones III and IV.

Hawthorn Aquifer System-Zone IV

Previous test drilling and subsequent aquifer performance testing at site A (Missimer and Associates, Inc., 1980), showed that Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I acted as a single system and the minor confining beds between them were insignificant. However, at this location the geologic sequence is different and the lithologies appear to indicate that these zones are separate aquifers. In well L-M-2464, Zone IV is 53 feet thick and it contains some interbedded lime mud. Although most of this unit is a biomicrudite of high permeability, the thickness of the most permeable limestone is less at this location.

Confining Beds Between Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I

In other areas of Sanibel Island, the confining beds between these zones are thin and consist of lime mud or clayey calcarnite. However, in well L-M-2464 the confining beds are thick and consist of a number of different lithologies. The confining beds are 41 feet thick and there are 13 beds each being a different lithology. Of the 41 feet, a total of 24 feet are very low permeability lime muds, clays, and dolosilts. At this location, there appears to be a high degree of confinement between Hawthorn-Zone IV and Suwannee-Zone I.

Suwannee Aquifer System-Zone II

Suwannee Aquifer System-Zone II was penetrated from 789 to 905 feet below surface. Because of the thinness of the potential confining beds, it is not possible to precisely delineate how many water-bearing zones occur in this section. The limestone constituting the aquifer ranges from a calcarenite to a wackestone. The overall permeability appears to be only medium based on past experience with this aquifer.

3. Aquifer Characteristics

An accurate determination of the hydraulic properties of an aquifer is required in order to assess its response to long-term pumping. In order to calculate these properties, it is necessary to obtain the following information: 1) detailed geologic data, 2) aquifer performance test data, and 3) aquifer pressure data. The test program designed to evaluate Suwannee Aquifer-Zone I at site B was based on the data previously collected at site A.

There are four types of aquifers defined by Kruseman and DeRidder (1970) in terms of their degree of confinement. The four types are: 1) unconfined, 2) semi-unconfined, 3) semi-confined, and 4) confined aquifers (Figure 4-2). All of the primary, deep aquifers penetrated during this investigation are semi-confined.

Semi-confined aquifers occur where continuous beds of low permeability bound the aquifer both above and below it and confine it from the atmosphere and other aquifers. Although the aquifer is fully confined, water can still move vertically through the confining beds. When a semi-confined aquifer is pumped, water is withdrawn not only from the aquifer, but also from and through the adjacent confining beds. Since pumping reduces the pressure in the aquifer, groundwater in the confining beds moves vertically into the aquifer. In long term pumping of a semi-confined aquifer, an equilibrium between the discharge rate of the pump and the recharge rate through the confining beds will occur. In order to properly assess the effects of pumping a semi-confined aquifer, it is necessary to determine three hydraulic coefficients from aquifer test data. These coefficients are:

Transmissivity (T) - - The ability of an aquifer to transmit water, reported in gallons/day/foot (gpd/ft)

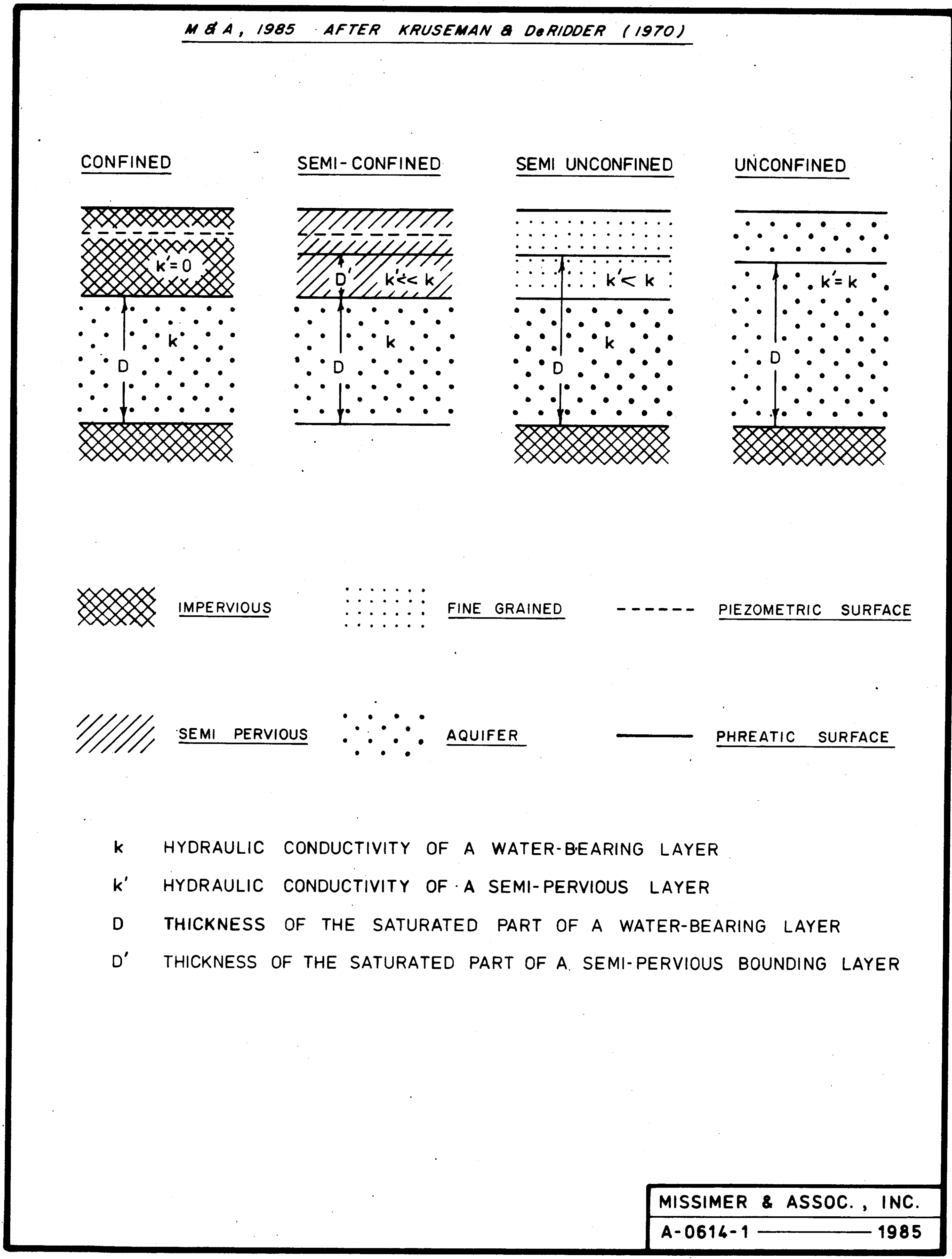


FIGURE 4-2. AQUIFER TYPES BASED ON DEGREE OF CONFINEMENT

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, reported as a dimensionless number.

Leakance (k'/b') - The effective permeability of a confining bed divided by the thickness of the confining bed, reported in gallons/day/cubic foot (gpd/ft^3)

Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I

Before any primary aquifer test could be conducted, a preliminary step-drawdown test was run on production well L-M-2465. The open-hole section in well L-M-2465 was first terminated at a depth of about 706 feet below surface. A pump was placed on the well and a step-drawdown test was attempted. Since the pump suction was quickly broken at a low discharge rate, it was decided to deepen the well to 765 feet in order to open more of the upper Suwannee Limestone. A step-drawdown test was conducted on the deepened production well at the following pumping rates: 293 gpm, 402 gpm, 502 gpm, and 602 gpm. The step-drawdown data are given in Table A-3. An analysis of well efficiency shows that at a discharge of 300 gpm, the efficiency is 82.5% and at a discharge of 600 gpm the efficiency is 58.8% (Figure 4-3). Based on these data, an aquifer test discharge rate of 402 gpm was chosen.

During the aquifer performance test, water was pumped

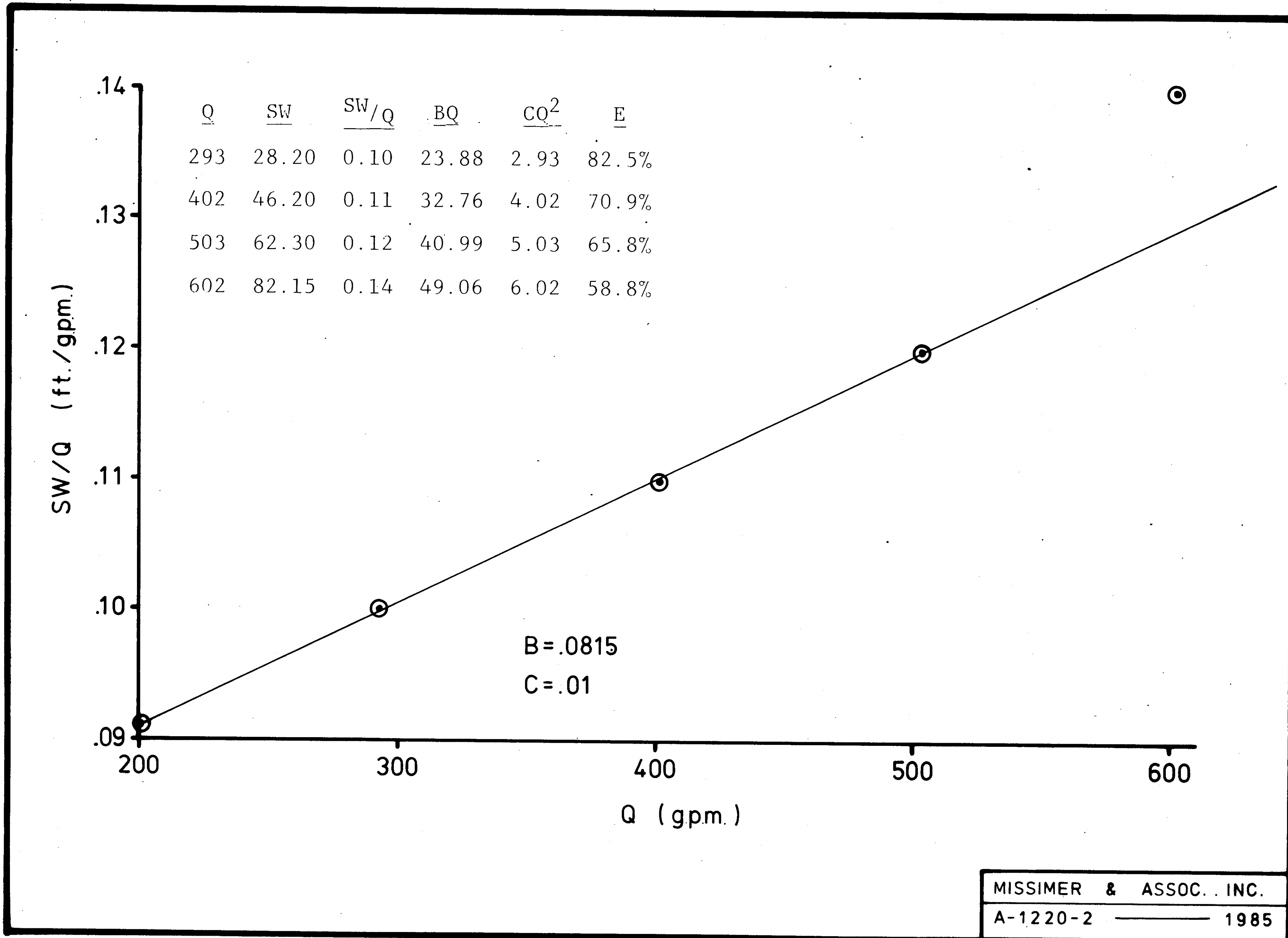


FIGURE 4-3. A PLOT OF DISCHARGE (gpm.) VERSUS DRAWDOWN (ft.) DIVIDED BY DISCHARGE (gpm.) AND A WELL EFFICIENCY ANALYSIS.

from well L-M-2465 and water level declines were measured both in the production well and in observation well L-M-2464. Background water level data were collected before and after the test. The production well was pumped beginning on 8-28-85 for a period of 2,530 minutes, at which time the pump failed. Drawdown in the production well stabilized at a maximum of 49 feet which yields a specific capacity of 8.2 gpm/ft of drawdown. Drawdown data for the production well are given in Table A-4.

Drawdown data were recorded continuously in observation well L-M-2464, which was located 194 feet from the production well. After 2,530 minutes of continuous pumping, a drawdown of 8.69 feet was recorded in the well. At the termination of the test, pressure in the aquifer was fluctuating abnormally probably because of extraneous pumping, tidal effects, and lack of equilibrium between the zones being pumped. Raw time and drawdown data for well L-M-2464 are given in Table A-5.

A preliminary analysis of the drawdown data was made assuming that the aquifer was fully confined. The Jacob straight line method was used for the analysis (Cooper and Jacob, 1946; Jacob, 1950). Semi-log plots of drawdown versus time for well L-M-2464 with a Jacob analysis is given in Figure 4-4. The analysis yielded a transmissivity of 50,500 gpd and a storage coefficient of 5×10^{-3}.

A primary analysis of the drawdown data from well

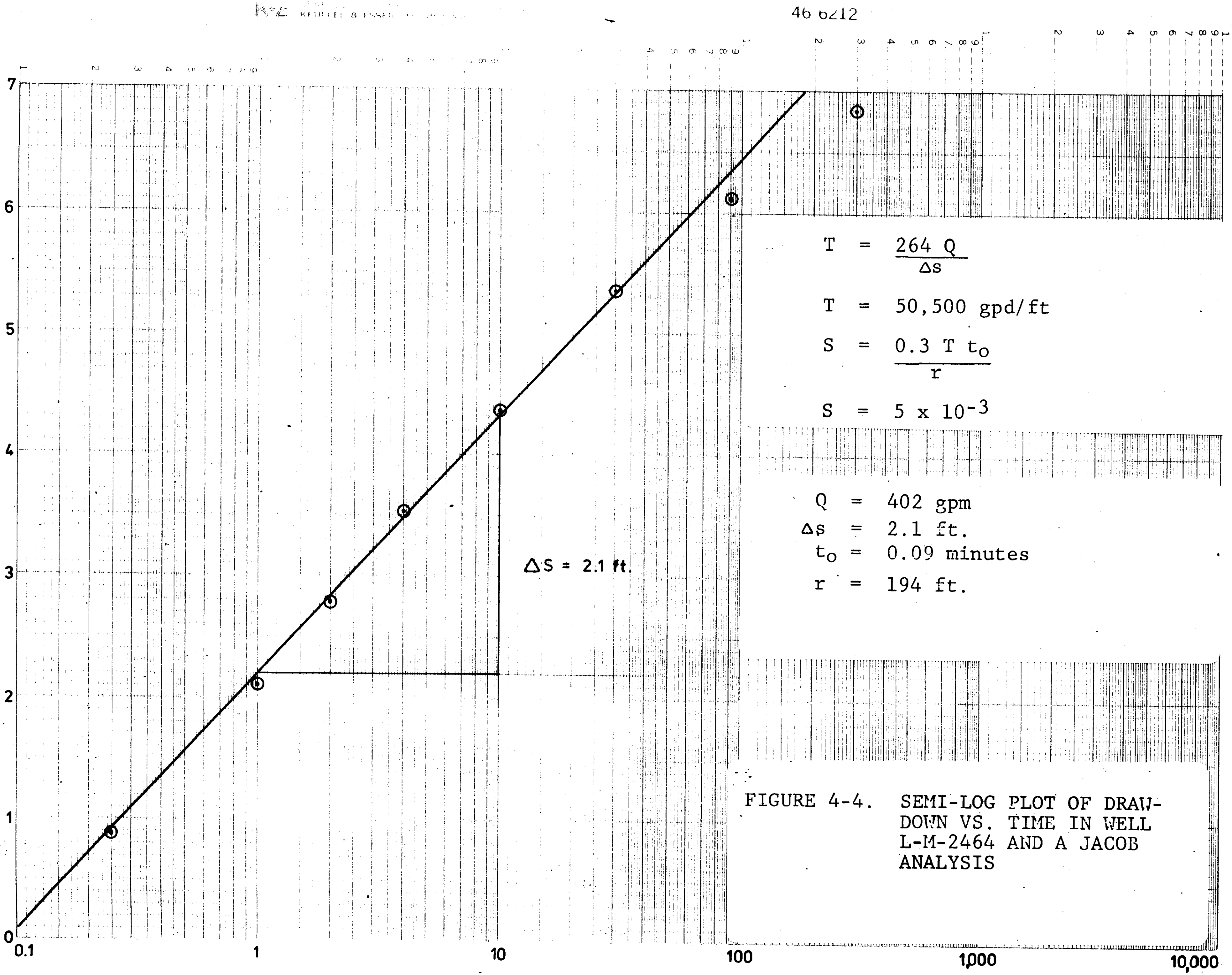


FIGURE 4-4. SEMI-LOG PLOT OF DRAW-DOWN VS. TIME IN WELL L-M-2464 AND A JACOB ANALYSIS

L-M-2464 was made using the method of Hantush and Jacob (1955) as modified by Walton (1960) for semi-confined aquifers. The data from well L-M-2464 were plotted on a log plot of time versus drawdown and the resultant curve was matched to the appropriate Walton function type-curve (Figure 4-5). The match point was substituted into the following equations as given by Lohman (1979):

$$T = \frac{Q\ L(u,v)}{4\pi s}$$

$$S = \frac{4T\ t/r^2}{1/u}$$

$$k'/b' = \frac{4\ T\ v^2}{r^2}$$

where,

- T = transmissivity, in ft^2/day
- Q = discharge, in ft^3/day
- $L(u,v)$ = Hantush Curve function
- s = drawdown, in feet
- S = storage coefficient, dimensionless
- u = Hantush Curve function
- t = time, in days
- r = distance from pumped well, in feet
- k' = vertical permeability of confining beds, in ft/day
- b' = thickness of confining strata, in feet
- k'/b' = leakance, in 1/days
- v = Hantush Curve function

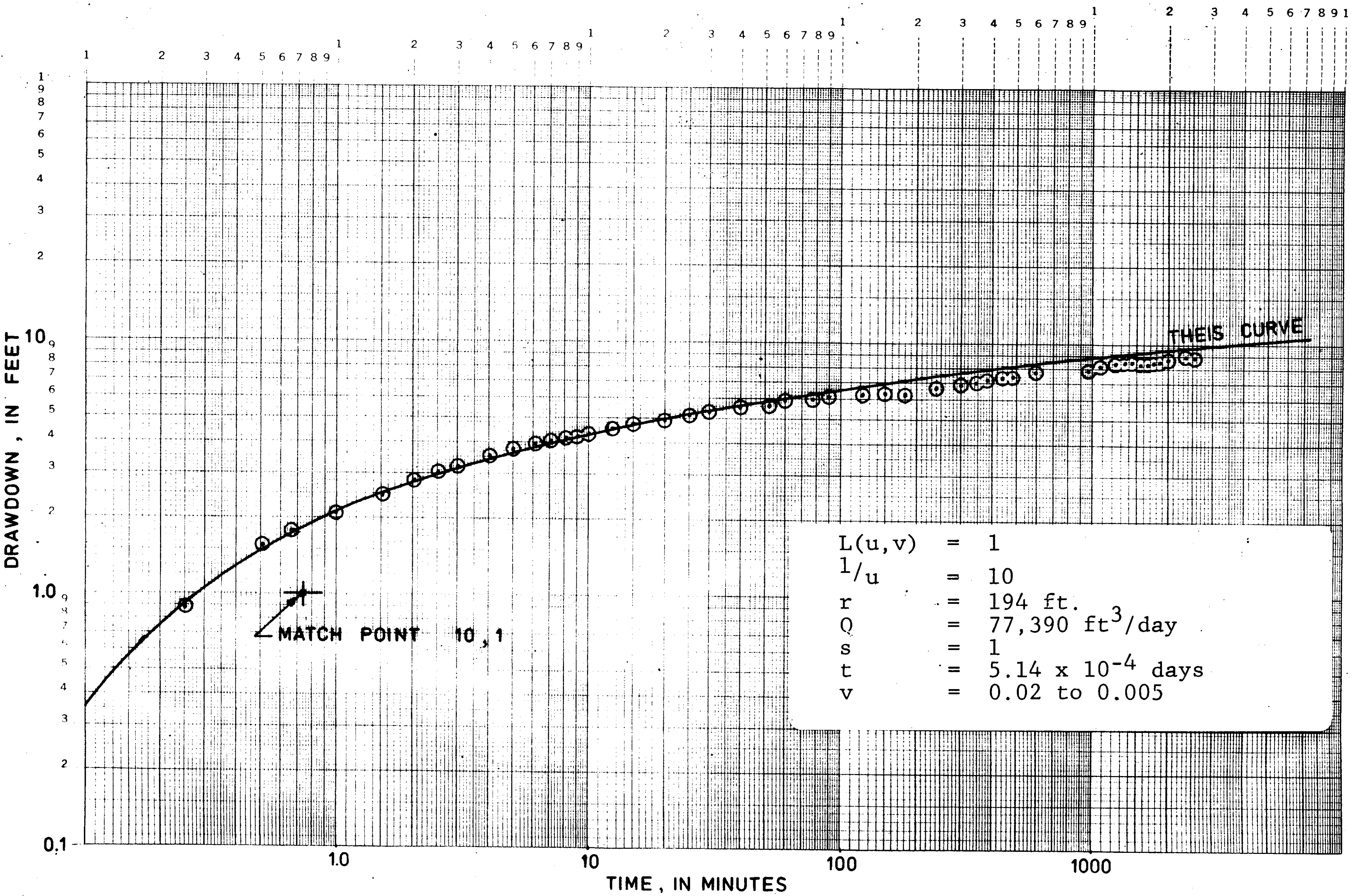


FIGURE 4-5. LOG PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-2464 AND COMPARISON TO THE APPROPRIATE HANTUSH-JACOB TYPE CURVES.

unit conversions:

$$(7.48 \text{ g/ft}^3)(\text{ft}^2/\text{day}) = 1 \text{ gpd/ft}$$
$$(7.48 \text{ g/ft}^3)(1/\text{days}) = 1 \text{ gpd/ft}^3$$

The most accurate analysis method for this test data is assumed to be the Hantush-Jacob, semi-confined aquifer method (Table 4-1). As shown in Figure 4-5, the match of the drawdown data to the Theis curve shows it is quite good for the early part of the test. This allowed a very accurate transmissivity and storage coefficient to be calculated. However, the departure of the drawdown data along a leakage curve was partly masked by tidal pressure effects, by outside pumpage, and by the effects of pumping the combined two aquifers. The value for the Hantush curve function "v" varies between 0.02 and 0.005 depending on whether the initial curve departure is used or the average trend of the curve is used. A clue to the solution of this problem is given by the site B geology in comparison to the site A geology with the corresponding aquifer test data. At site B Hawthorn Aquifer System-Zone III appears to be tightly confined and therefore, the corresponding leakance is probably 1.2×10^{-4} gpd/ft^3. The higher value probably corresponds to the leakance of the confining beds beneath Suwannee-Zone I, which is 2×10^{-3} gpd/ft^3.

TABLE 4-1. AQUIFER COEFFICIENTS FOR THE COMBINED HAWTHORN AQUIFER SYSTEM-ZONE IV AND SUWANNEE AQUIFER SYSTEM-ZONE I TEST

Well L-M-2464

Analysis Method	T gpd/ft	S	k'/b' (gpd/ft^3)
1. Jacob (confined)	50,500	5×10^{-3}	
2. Hantush-Jacob (semi-confined)	46,000	3.4×10^{-5}	2×10^{-3} to 1.2×10^{-4}

4. Water Levels and Recharge

Water levels (pressure) in and recharge to many of the aquifers underlying Sanibel Island were described in detail by Boggess (1974a, 1974b) and Missimer (1976). Potentiometric pressure data on Hawthorn-Zones I and II are not readily available on Sanibel Island. More detailed data exist on Hawthorn-Zone III, Hawthorn-Zone IV, and Suwannee-Zone I as reported in Missimer and Associates, Inc. (1978b, 1979, and 1980).

Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I

The potentiometric surface of Hawthorn-Zone IV responds to changes in the pressure of overlying aquifers as well as barometric pressure changes, and ocean tidal head changes. The static head in Hawthorn-Zone IV was measured on August 16, 1985, to be 25.5 feet above land surface. When this value is corrected to a temperature of 20°C and a salinity of 0 mg/l, the potentiometric head was 26.0 feet above land surface. The static head measured in Suwannee-Zone I was 28.13 feet above land surface when corrected for salinity and temperature. These pressure measurements were made when Zone IV was isolated in production well L-M-2465 and when the well was open to both zones. It is probable that the head differential between the two zones is greater than the 2 feet measured, because Suwannee-Zone I was not fully isolated.

Hawthorn-Zone IV and Suwannee-Zone I are recharged by lateral flow through the aquifer from the mainland and by vertical leakage of water through the confining beds. Under natural conditions, lateral recharge is dominant and the aquifer is flushed with water moving offshore from the east. Water quality to the west of the wellfield is controlled strictly by what is present in the aquifer along the flow lines. When an aquifer is being pumped, induced vertical leakage becomes the dominant means of recharge. Water quality in the production zone is then controlled by the quality of water within and outside of the adjacent confining beds.

Regional recharge to these aquifers is the quantity of water which moves horizontally from the mainland to Sanibel and Captiva Island. It is calculated by utilizing a modified form of the Darcey Equation given below:

$$Q = TIL$$

where,

- Q = recharge, in gallons per day
- T = transmissivity, in gallons per day per foot
- I = hydraulic gradient, in feet per mile
- L = width of the area, in miles

Recharge to the combined Hawthorn-Zone IV and Suwannee-Zone I system was assessed by using the average transmissivity measured at the two sites of 63,000 gpd/ft (80,000 gpd +

46,000 gpd, all divided by 2), a regional hydraulic gradient of about 2 feet/mile (approximated from Boggess, 1974b), and a cross-sectional length of 9 miles (distance from Captiva to Sanibel in the cone of influence). The horizontal recharge value is about 1,134,000 gallons/day. Because of uncertainty in the hydraulic gradient, with a range from 1.5 to 2.5 feet/mile, the recharge value lies between 850,000 and 1,417,500 gpd.

Although all data indicate that Hawthorn-Zone IV and Suwannee-Zone I are separate, independent aquifers at site B, the recharge rate is calculated using the combined aquifers because the transmissivity value measured during the test was from both aquifers.

5. Water Quality

The quality of water in the various aquifers underlying Sanibel has been studied by several investigators (Boggess, 1974a, 1974b; Geraghty & Miller, Inc., 1978; Missimer, 1976; Missimer and Associates, Inc., 1978a, 1978b, 1979a, 1979b, 1980, 1981, and 1982). Water quality between a depth of 400 feet and 900 feet below surface will be discussed in this report.

Water quality data were collected during drilling and from the completed wells during pumping. A graph showing the vertical variation in dissolved chloride concentration is given in Figure 4-1. Chloride and conductivity data from both wells L-M-2464 and L-M-2465 are given in Appendix Tables A-6, A-7, and A-8. Complete chemical analyses of the water in the completed production well, L-M-2465, are given in Tables A-9 and A-10.

Hawthorn Aquifer System-Zone II

Some water samples were collected for analysis from Hawthorn-Zone II during the construction of well L-M-2464. The dissolved chloride concentration appeared to range between 600 and 700 mg/l with a corresponding conductivity range of 2,160 to 3,290 umhos. Although no packer stem tests were conducted on this test well to absolutely isolate the various zones, it does appear that water quality in Zone II is quite good. This water quality is markedly different compared to the other areas of Sanibel Island. Hawthorn-Zone II usually contains highly saline water with a dissolved chloride concentration in excess of 10,000 mg/l. The quality of water in this zone is very important to the evaluation of long-term water quality changes induced by pumping some of the deeper zones.

Hawthorn Aquifer System-Zone III

The quality of water found in Hawthorn-Zone III at site B is remarkably good. It appears that the dissolved chloride concentration ranges between 260 and 320 mg/l. It is quite possible that potable water exists in this zone, because of the mixing of water which could have occurred in the sampling process. These water quality data correspond closely to the information collected at the Fire Station Test Site (Missimer and Associates, Inc., 1978a). The conductivity of water from this zone appears to be between 2,510 and 2,540 umhos. This conductivity is somehwat higher than would be expected for water containing the comparatively low dissolved chloride concentrations. It is quite possible that abnormally high sulfate concentrations occur in this water.

Hawthorn Aquifer System-Zone IV

Water quality in Hawthorn-Zone IV is again quite good compared to the water quality found in the same zone at locations on Sanibel Island to the east of site B. The dissolved chloride concentration at site B ranges between 560 and 580 mg/l with a corresponding conductivity of 2,800 umhos. It was also observed that the concentration of dissolved chlorides increase across the confining beds between Zones III and IV. When the open-hole includes both Hawthorn-Zone IV and Suwanneee-Zone I, the chloride concentration is higher at 1,080 mg/l (Tables A-9 and A-10).

Suwannee Aquifer System-Zone I

The quality of water in Suwannee-Zone I appears to be stratified with a dissolved chloride concentration ranging from 1,000 to 1,160 mg/l. There is a sharp quality change across the confining beds separating Hawthorn-Zone IV and Suwannee-Zone I. The conductivity of the water ranges between 3,850 and 4,410 umhos. This variation in water quality across this confining bed is similar to the variation in well L-M-943, but is totally different compared to the variation at site A.

Suwannee Aquifer System-Zone II

The dissolved chloride concentration in Suwannee-Zone II increases steadily with depth from 1,240 to 1,540 mg/l. There are several thin confining beds that could have some influence on the water quality variation, but without detailed packer-stem tests, it is not possible to assess these variations. No evidence was found for a large increase in salinity across any confining bed penetrated. Since it is quite important to the analysis of long-term water quality changes, a test hole should be used to penetrate to the maximum depth of treatable water.

V. COMPARISON OF AQUIFER HYDROGEOLOGY AT SITES A AND B

A considerable change in the subsurface conditions between site A and site B is quite evident (Figure 5-1). There are a larger number of minor lithic units at site B compared to site A. Most of the additional units are various types of lime muds or clays. The most notable differences in geology are: the thinning of the most significant Hawthorn limestone (Zone II), the addition of lime mud into the primary Hawthorn limestones, the thickening of the clay confining beds between the Hawthorn and Suwannee Aquifer Systems, and the thinning of the basal confining bed between Suwannee Aquifer System-Zone I and II. A comparison of aquifer locations and thicknesses is given in Table 5-1.

Most of the water yielded from the site A production wells, S-1 to S-4, originates in the lowermost limestone of the Hawthorn Formation. This unit is well-connected to the uppermost limestone in the Suwannee Limestone at site A, but little or no water comes from the lower limestone unit. The transmissivity of the full aquifer thickness, both limestone units, and the transmissivity of Hawthorn-Zone IV are both 80,000 gpd/ft. At site B, Hawthorn-Zone IV and Suwannee-Zone I are separate, distinct aquifers. The full thickness of both aquifers was tested and it yielded a transmissivity value of 46,000 gpd/ft. Based on the existing data, it is not possible to assess which zone yielded the majority of the water.

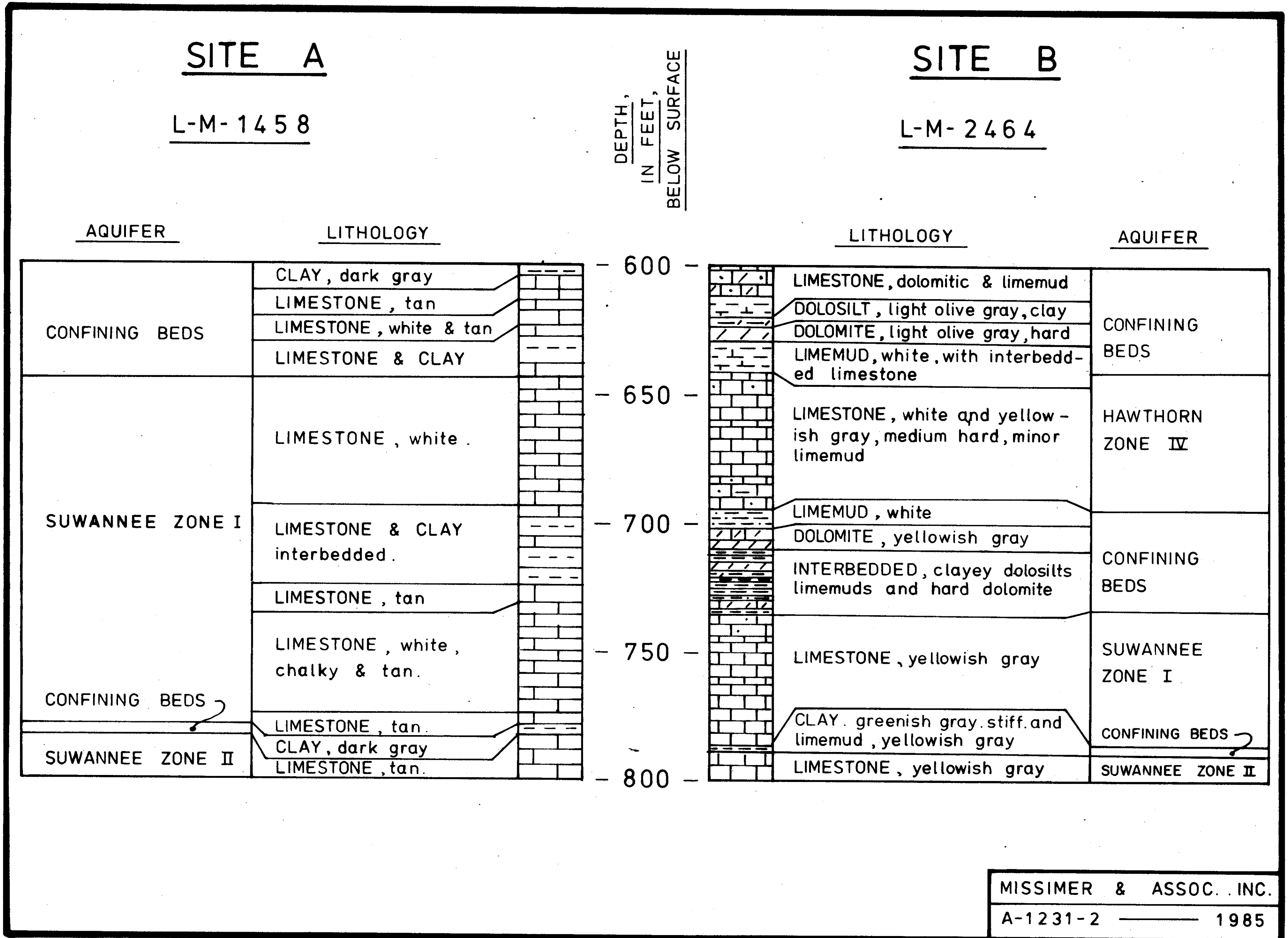


FIGURE 5-1. COMPARISONS OF GEOLOGY AND AQUIFER LOCATIONS IN WELLS L-M-1458 AND L-M-2464.

TABLE 5-1. COMPARISON OF AQUIFER LOCATIONS, THICKNESSES, AND TRANSMISSIVITIES

Aquifer	Depth Interval (ft. below surface) Site A	Site B	Thickness (feet) Site A	Site B
Hawthorn-Zone II	350 - 460	373 - 459	110	86
Hawthorn-Zone III	525 - 570	496 - 541	45	45
Hawthorn-Zone IV	645 - 695	642 - 695	50	53
Suwannee-Zone I	725 - 780	736 - 787	55	51
Hawthorn-Zone IV-Suwannee-Zone I (combination)	645 - 780	---	135	

Aquifer	Transmissivity Site A	Site B
Hawthorn-Zone IV	80,000	
Suwannee-Zone I		
Hawthorn-Zone IV-Suwannee-Zone I (combination)	80,000	46,000

This question must be answered before the wellfield design can be finalized. As shown in Table 5-1, the transmissivity of the combined aquifers at site B is 42% less than at site A. Therefore, the yield of individual production wells in the combined aquifers will be reduced.

The most significant difference between wellfield sites A and B involves water quality (Table 5-2). At site A, Hawthorn-Zone II contained very poor quality water with near seawater characteristics and Suwannee-Zone II also contained poor quality water. The result of the production zone being sandwiched between aquifers containing higher salinity water was that long-term pumping will cause slow degradation of water quality in the production aquifer. At site B, the quality of water in all aquifers tested appears to be acceptable as feedwater to the reverse osmosis plant. The obvious consequence is that the long-term, pumping induced, water quality changes will be less significant and water treatment costs will be lessened.

TABLE 5-2. COMPARISON OF WATER QUALITY IN THE AQUIFERS AT SITES A AND B

Aquifer	Dissolved Chlorides, in mg/l Site A	Site B
Hawthorn-Zone II	10,700 - 12,200	600 - 700
Hawthorn-Zone III	1,420 - 1,750	260 - 320
Hawthorn-Zone IV	1,400 - 1,640	560 - 580
Suwannee-Zone I	1,500	1,000 - 1,160
Suwannee-Zone II	5,100 - 5,700	1,240 - 1,540

VI. AQUIFER YIELD AND WATER MANAGEMENT

1. Introduction

Four water-bearing zones, which yield acceptable quality water, have been located beneath site B. These zones are: 1) Hawthorn Aquifer System-Zone II, 2) Hawthorn Aquifer System-Zone III, 3) Hawthorn Aquifer System-Zone IV, and 4) Suwannee Aquifer System-Zone I. Suwannee Aquifer System-Zone II also contains relatively good water quality, but no basal confining beds could be located, which separate the aquifer from higher salinity water. This fact suggests that this aquifer should not be used unless further work is performed on it to verify the deeper water quality pattern.

Normally, in this section of reports directed to the IWA, we discuss the yield characteristics of the aquifer system, the impacts of pumping, the long-term estimated water quality changes, and the ways to best manage the groundwater system. However, the information obtained at site B is not quite complete in order to recommend a final wellfield design. There are a number of options that need to be assessed and some direction is required from the IWA Board of Directors. Therefore, a series of options is discussed and a general discussion of the impacts and water quality changes is given.

2. Wellfield Design Options

The original concept for the design of cluster site B was to have three production wells tapping the upper limestone unit of Suwannee Aquifer System-Zone I (Hawthorn-Zone IV). This concept was based on the hydrogeologic data collected at site A, which is located only 2 miles away. Each production well was to have a yield of approximately 550 gpm. This design was based on four general assumptions: 1) Hawthorn Aquifer System-Zone IV and Suwannee Aquifer System-Zone I are one aquifer, 2) Suwannee Aquifer System-Zone I (including Hawthorn Aquifer System-Zone IV) is the only aquifer available for use, 3) the transmissivity of Suwannee Aquifer System-Zone I is near 80,000 gpd/ft, and 4) most of the water yielded from Suwannee Aquifer System-Zone I originates from the upper limestone unit. As previously discussed in this report, it was found that: 1) Hawthorn-Zone IV and Suwannee-Zone I are different aquifers beneath site B, 2) there are four usable aquifers beneath site B, 3) the transmissivity of the combination of Hawthorn-Zone IV and Suwannee-Zone I is 46,000 gpd/ft, and 4) the relative yield characteristics of the individual zones is unknown.

Taking all of the hydrogeologic facts into consideration, it is obvious that it is necessary to modify the original design concept based on the new data in order to construct the most efficient wellfield possible. Before any final recommendations can be given, some key information must be collected.

First, a determination must be made concerning the relative hydraulic characteristics of Hawthorn-Zone IV and Suwannee-Zone I. This determination must be made by conducting an aquifer test on Hawthorn Aquifer System-Zone IV. In order to conduct an aquifer test, an inflatible packer must be placed in production well L-M-2465 (S-5) at a depth of about 735 feet below surface. A pump would then be placed on the well and an aquifer test would be conducted. Observation well L-M-2464 must be modified into two piezometers, one tapping Hawthorn-Zone IV and one tapping Suwannee-Zone I. This test would yield all of the necessary hydraulic data to finish the design involving these two aquifers.

Before Hawthorn Aquifer-Zones II or III could be tapped for use, it is necessary to obtain water quality samples for complete chemical analyses. One observation well should be constructed into each zone in order to provide the higher degree of isolation (2 wells). If the chemical analyses shows the water to be fully usable at the reverse osmosis plant, then at least one production well could be constructed into each aquifer. Hawthorn-Zone III has been extensively tested at other locations and it should not be necessary to conduct an additional aquifer performance test. However, it would be necessary to perform an aquifer test on Hawthorn-Zone II to assess its yield characteristics before additional production wells are drilled.

In order to obtain the desired 1,650 gpm of feedwater from site B, it will be necessary to construct a larger number of production wells (assuming that Hawthorn-Zone II does not have an extremely large yield). Based on the available information, the combination of Hawthorn-Zone IV and Suwannee-Zone I in a well will not safely yield more than about 400 gpm on a long-term basis. If it is found that a large portion of the total yield is found either in Hawthorn-Zone IV or in Suwannee-Zone I, then the highest yielding zone should be fully developed with three or four production wells. Production well S-5 should then be modified to yield from only one zone. If it is found that Hawthorn-Zone IV and Suwannee-Zone I yield equal volumes of water, then separate production wells should be drilled into each zone and yields would be limited to about 200 gpm per production well. Again, well S-5 should be modified to produce from a single zone.

There are numerous possible combinations of production wells that could be used to develop feedwater at site B. Some estimates on the number of production wells and yields in the various aquifers underlying site B are given in Table 6-1. The site should be large enough to accommodate all of the production wells listed, a total of 13 wells. Because the wells would tap different aquifers, up to four wells could be constructed on a single well pad. The original three well pads, as shown in the site plan presented to the

TABLE 6-1. POSSIBLE WELLFIELD COMBINATIONS FOR SITE B

Aquifer	Estimated Number Production Wells	Estimated Yield (gpm) Per Well	Total
Hawthorn-Zone II	3	400+	1,200
Hawthorn-Zone III	2	250	500
Hawthorn-Zone IV	4	200	800
Suwannee-Zone I	4	200	800
		Total	3,300

City of Sanibel, would be sufficient if the number of production wells tapping Hawthorn-Zone IV or Suwannee-Zone I would be limited to three wells each. If four wells would be constructed into either of these aquifers, then four well pads should be constructed. A possible wellfield configuration is given in Figure 6-1. It should be noted that site B has the potential to yield up to 3,300 gpm if all available aquifers would be utilized. Again, before the final aquifer yields and wellfield configuration can be assessed, the collection of additional information is necessary. Also, some decisions must be made concerning which aquifers yield the desired water qualities.

On a temporary basis, production well S-5 may be used as a multi-zonal well until it is modified. However, the well should be pumped continuously and should not be left with the valve closed for extended periods of time. The pressure in Suwannee-Zone I is greater than that in Hawthorn-Zone IV. Therefore, the higher salinity water in the deeper zone will enter the upper zone while the well is not pumped.

3. Monitoring

As pumping is increased in the aquifers underlying Sanibel, it is extremely important that the monitoring of aquifer pressures and water quality be initiated in areas adjacent to the production wells. Presently, water quality

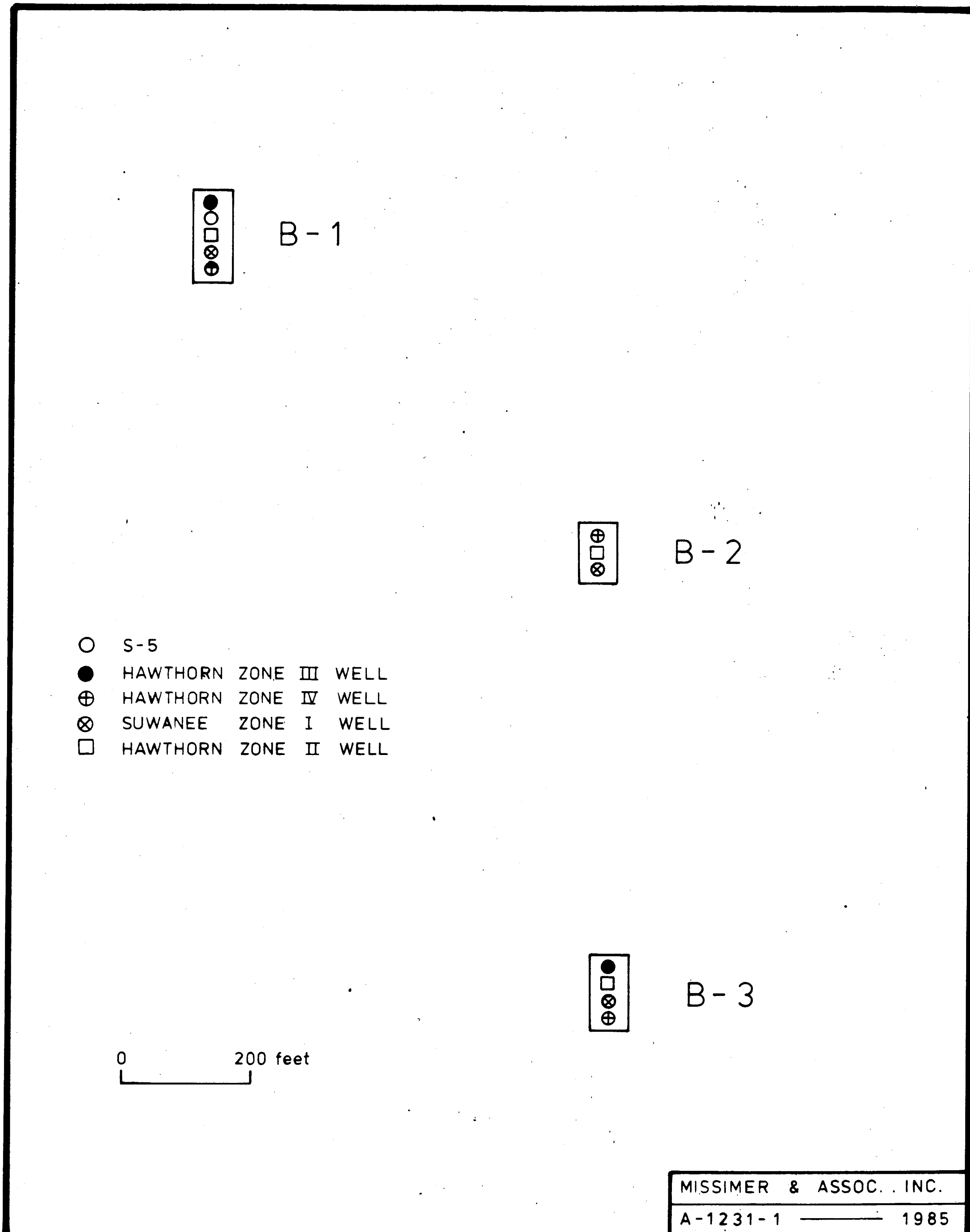


FIGURE 6-1. LOCATIONS OF WELL PADS AND A POSSIBLE WELLFIELD CONFIGURATION AT SITE B.

is slowly changing in production well S-2, which is the closest well to higher salinity water. This may indicate some horizontal movement of higher salinity water. In order to assess lateral saline water intrusion problems, observation wells should be constructed at key locations. One of the old, unused Hawthorn wells should be modified into a Suwannee Aquifer observation well. This well should be located between the R.O. plant and the E.D. plant. Another Suwannee Aquifer System-Zone I observation well should be constructed to the south of cluster site A. These observation wells should be constructed with an open-hole section through the full thickness of the aquifer. Monthly water quality and pressure measurements should be made on each observation well, including the observation wells at the R.O. plant, site B, and the fire station.

VII. REFERENCES

Boggess, D. H., 1974a, The shallow fresh-water system of Sanibel Island, Lee County, Florida, with emphasis on the sources and effects of saline waters: Florida Department of Natural Resources, Bureau of Geology, Rept. of Investigation No. 69, 52 p.

Boggess, D. H., 1974b, Saline ground-water resources of Lee County, Florida: U. S. Geological Survey, open-file report No. 74-247, 62 p.

Cooper, H. H., and Jacob, C. E., 1946, Generalized graphical method for evaluating formation constants and summarizing wellfield history: Trans. Amer. Geophys. Union, V. 33.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional textures in Classification of Carbonate Rocks (ed. W.E. Ham): Am. Assoc. of Petro. Geologists, Tulsa, Oklahoma.

Folk, R. L., 1968, Petrology of Sedimentary Rocks: University of Texas, Austin, Texas.

Geraghty & Miller, Inc., 1978, Effects of ground-water withdrawals from the lower Hawthorn aquifer on Sanibel Island, Florida; Report to Island Water Association.

Hantush, M. S., and Jacob, C. E., 1955, Nonsteady radial flow in an infinite leaky aquifer: Am. Geophys. Union Trans., V. 36, No. 1, pp. 95-100.

Jacob, C. E., 1950, Flow of groundwater in Engineering Hydraulics (H. Rouse, ed.), John Wiley and Sons, New York.

Kruseman, G. P., and DeRidder, M. A., 1970, Analysis and evaluation of pumping test data, International Institution for Land Reclamation and Improvement, Bull. II, Wageningen, The Netherlands.

MacNeil, F. S., 1944, Oligocene stratigraphy of southeastern United States: Am. Assoc. Petroleum Geologists Bull., V. 28, pp. 1313-1354.

Missimer, T. M., 1976, Sanibel Island: Hydrology in The Sanibel Report: Formulation of a comprehensive land use land plan based on natural systems (ed. John Clark): The Conservation Foundation, Washington, D.C.

Missimer, T. M., 1978, The Tamiami Formation - Hawthorn Formation contact in southwest Florida: Florida Scientists V. 41, No. 1, 31-39 pp.

Missimer, T. M., 1984, The geology of south Florida: A summary in Environments of South Florida: Present and Past, II, P. J. Gleason, Editor, Miami Geological Society, Memoir 2, p. 385-404.

Missimer, T. M., and Banks, R. S., 1982, Miocene cyclic sedimentation in western Lee County, Florida, in T. M. Scott and S. B. Upchurch, eds., Miocene of Southeastern United States: Florida Bur. of Geology Special Publication 25, p. 285-299.

Missimer, T. M., and Gardner, R. A., 1975, High resolution seismic reflection profiling, a useful tool in mapping shallow aquifers underlying part of Lee County, Florida, U. S. Geological Survey, Water Resources Investigation, 76-45, 30 pp.

Missimer and Associates, Inc., 1978a, Hydrology and geology of a proposed new wellfield site in south Lee County, Florida: Rept. to Lee County Commissioners.

Missimer and Associates, Inc., 1978b, Hydrologic Investigation of the Hawthorn Aquifer System in the northwest area, Sanibel, Florida: Rept. to the Island Water Association, Inc., 101 pp.

Missimer and Associates, Inc., 1979a, Hydrologic Investigation of the Hawthorn and Suwannee Aquifer Systems in the central area, Sanibel, Florida: Rept. to the Island Water Association, Inc., 98 pp.

Missimer and Associates, Inc., 1979b, Hydrologic investigation of the Hawthorn and Suwannee Aquifer System at the Three-Star Store Site, Sanibel, Florida: Letter report to the Island Water Association, Inc.

Missimer and Associates, Inc., 1980, Hydrologic investigation of the Hawthorn and Suwannee Aquifer Systems at the new Island Water Association wellfield, wellsite No. 2: Consultants Rept. to the Island Water Association, Inc., 97 p.

Missimer and Associates, Inc., 1981, Evaluation of the Suwannee Aquifer System for future development of raw water for Sanibel, Florida: Consultants Rept. to the Island Water Association, Inc., 69 p.

Missimer and Associates, Inc., 1982, Hydrologic investigation of the Ocala Aquifer: Consultants letter report to the Island Water Association, Inc.

Walton, W. E., 1970, Groundwater Resources Evaluation: Mc-Graw Hill Publishers, New York.

VIII. APPENDICES

1. Geologists Logs

TABLE A-1. GEOLOGIST'S LOG OF WELL L-M-2465

Depth(feet)	Lithology
0-15	Shell and sand, unlithified, quartz fine-sand size common, high permeability.
15-25	Clay, olive gray, lime mud, unlithified, 10-20% quartz silt, interbedded oyster and barnacle fragments more abundant with depth, low permeability.
25-30	Sandstone, medium gray, hard, 50-75% fine quartz sand and silt, shell fragments and fossil molds common, medium permeability.
30-34	Limestone, yellowish gray and light gray, micrite, soft to medium, common quartz silt and fine sand, abundant shell fragments, partial solutioning common, good moldic porosity, medium to high permeability (increased drilling fluid loss from 30 feet).
34-35	Lime mud, white, shelly marl, unlithified, low permeability.
35-37	Limestone, yellowish gray to brown, similar to 30-34 feet interval, medium to hard, medium to high permeability.
37-50	Limestone, as above, but yellowish gray and medium gray, finer moldic porosity, softer with depth, medium permeability.
50-52	As above, and interbedded light gray clayey lime mud, medium to low permeability.
52-68	Sand, unlithified, fine to medium sand sized quartz and minor phosphate, occasional interbedded shelly limestone lenses, becoming clayey with depth, medium to low permeability.
68-110	Clay, olive gray, unlithified, abundant quartz and phosphate sand upper 5 feet, denser more clayey with depth, low permeability.
110-155	Clay, olive gray, clayey, dense, sandy, dolomitic, low permeability.
155-188	Clay, olive gray, as above, looser with depth, low permeability.

TABLE A-1. GEOLOGIST'S LOG OF WELL L-M-2465 - Continued:

Depth(feet)	Lithology
188-208	Limestone, light olive gray, soft, and interbedded lime mud, unlithified, same, dolomitic, 40-50% quartz sand, abundant white shell fragments, phosphate pebble lense from 188 feet, low to medium permeability.
208-213	Limestone, ligh gray, hard to medium, 40-50% quartz sand, minor phosphate sand and pebbles, minor friable, same, medium to low permeability.
213-235	Lime mud, light olive gray, unlithified to poorly lithified and abundant unlithified quartz sand, occasional hard interbedded sandy limestone lenses, as above, and minor phosphate sand and pebbles, common shell, overall low permeability.
235-248	Limestone, light olive gray, medium to hard and interbedded lime mud as above, abundant quartz sand, common phosphate sand and pebbles, fossil fragments, unlithified and sandier from 245 feet, low to medium permeability.
248-275	Sandstone, sandy limestone, light olive gray, soft to medium and interbedded lime mud, same and white, 50-75% fine quartz sand, common phosphate pebbles and sand, occasional shell fragments.
275-309	Clay, olive gray, stiff, unlithified, clayey, common quartz sand and silt, probable interbedded lenses of unlithified quartz and phosphate sand from 282 feet.
309-318	Dolosilt, olive gray, as above but highly dolomitic, dense, very low permeability.
318-324	Lime mud, light olive gray, dolomitic, silty, phosphate sand and pebble lense from 318 feet, low permeability.
324-347	Lime mud, as above, and interbedded, soft, light gray, sandy limestone lenses, dolomitic, minor phosphate sand, low permeability.
347-367	Lime mud, white and minor interbedded, soft, limestone, same, minor quartz and phosphate sand, fossiliferous, low permeability.
367-374	Lime mud, as above, white and light olive gray, unlithified, low permeability.

TABLE A-1. GEOLOGIST'S LOG OF WELL L-M-2465 - Continued:

Depth(feet)	Lithology
374-398	Limestone, white to yellowish gray, micrite, medium soft and medium hard, commonly unlithified, minor quartz and phosphate sand, shell and shell molds common, fair moldic porosity, medium permeability.
398-437	Limestone, white to yellowish gray, as above, soft to medium, minor hard, arenitic to fine moldic texture, fair to good moldic porosity, highly fossiliferous, also hard dolomitic limestone lense, pale olive, microcrystalline, from 407 feet, medium permeability.
437-458	Limestone, yellowish gray, biomicrite, hard and medium, 5-10% quartz sand and phosphate sand, abundant fossil molds and casts, good moldic porosity, medium permeability.
458-459	Limestone, light olive gray, hard, secondary dolomitization common, microcrystalline, minor fossil molds, low to medium permeability.
459-463	Dolosilt, greenish gray, unlithified, dense, clayey, highly dolomitic, low permeability.
463-475	Dolosilt, light olive gray becoming olive gray with depth, similar to above, highly dolomitic, low permeability.
475-484	Interbedded clay, as above, and yellowish gray limestone, poorly lithified to unlithified, fossils abundant, predominant echinoid spines and corals, quartz sand common, medium to low permeability.
484-486	Dolomite, olive brown, hard, microcrystalline, occasional small vugs, fine moldic porosity, medium to low permeability.
486-494	Limestone, light yellowish gray, medium to hard, microcrystalline sparite, occasional white micrite filled molds, porosity similar to above, medium to low permeability.
494-500	Clay, light olive gray, stiff, clayey, possible dolomitic, minor better lithified, same, and white lime mud with depth, trace silty, low permeability.

TABLE A-1. GEOLOGIST'S LOG OF WELL L-M-2465 - Continued:

Depth(feet)	Lithology
500-510	Limestone, yellowish gray, medium hard, microcrystalline sparite, minor unlithified white lime mud, fine moldic porosity with minor sparry calcite and chert infilling, medium permeability.
510-534	Limestone, similar to above, but light olive gray, highly dolomitic, occasional interbedded white lime mud, better developed secondary moldic porosity, medium to high permeability.
534-553	Interbedded, dolomitic limestone, hard, yellowish gray and unlithified dolomitic lime mud, same, also interbedded white to light gray lime mud, minor lithified, occasional fossils, minor phosphate sand, low to medium permeability - overall.
553-582	Lime mud, yellowish gray to light olive gray, unlithified and interbedded, hard, similar limestone, highly dolomitic, phosphate fine sand and pebbles common, possoble thin, hard, dolomite lense, light olive gray from 573 feet, low permeability.
582-592	Lime mud, white to light olive gray, unlithified, and interbedded hard yellowish gray limestone, dolomitic, sparite, fossil molds common, low to medium permeability.
592-608	Lime mud, light olive gray, unlithified, similar to above, interbedded yellowish gray dolomitic limestone from 606 feet, low permeability.
608-613	Limestone, yellowish gray to light olive gray, hard, biosparite, highly dolomitic, microcrystalline, fair to good moldic porosity, medium permeability.
613-623	Lime mud, white, unlithified, hard dolomitic limestone lense, as above, from 619 feet, low to medium permeability.
623-626	Dolosilt, light olive gray, stiff, clayey, highly dolomitic, low permeability.
626-632	Dolomite, light olive gray, hard to medium, microcrystalline, occasional white shell fragments, low to medium permeability.

TABLE A-1. GEOLOGIST'S LOG OF WELL L-M-2465 - Continued:

Depth(feet)	Lithology
632-635	Lime mud, white, unlithified, minor dolomitic and interbedded thin lenses of yellowish gray hard dolomitic limestone, overall low permeability.
635-644	Limestone, white, biomicrudite, medium to hard, fossiliferous, trace quartz and phosphate sand, good moldic porosity, medium to high permeability.
644-665	Limestone, as above, but white and yellowish gray, better secondary porosity than above, partial spar infilling of molds common, trace unlithified white lime mud, medium to high permeability.
665-673	Limestone, yellowish gray, biomicrudite, medium to hard, similar to above, medium to high permeability.
673-698	Limestone, light yellowish gray and light gray, hard and medium, trace unlithified white lime mud, possibly from 684 feet, fossil molds and casts common, minor spar, trace quartz fine sand, medium permeability.
698-706	Lime mud, white, unlithified and interbedded thin lenses of hard limestone, similar to above, trace quartz silt, low permeability.
706-708	Dolomite or dolomitic limestone, yellowish gray, medium to hard, microcrystalline, highly dolomitic (basal light olive gray dolomitic clay from 708 feet), low to medium permeability.
708-710	Clay, light olive gray, very dense, unlithified, clayey, silty, low permeability.
710-714	Lime mud, white, dense, minor dolomitic, minor fine quartz sand, low permeability.
714-717	Dolomite or dolomitic limestone, yellowish gray, hard to medium, minor unlithified same, microcrystalline, medium to low permeability.
717-719	Dolosilt, dark greenish gray, unlithified, dolomitic, clayey, silty, low permeability.
719-720	Clay, (dolosilt?), olive gray unlithified, dense clayey, silty, low permeability.

TABLE A-1. GEOLOGIST'S LOG OF WELL L-M-2465 - Continued:

Depth(feet)	Lithology
720-722	Lime mud, white, unlithified, trace dolomitic, clayey, trace fine quartz sand, low permeability.
722-726	Limestone, light olive gray, medium soft, dolomitic and interbedded unlithified clay, same, with depth, common quartz sand and silt, low to medium permeability.
726-734	Limestone, yellowish gray, medium, microcrystalline, highly dolomitic, silty, light olive gray clay and white lime mud, interbedded from 731 feet, similar composition, minor phosphate sand, low to medium permeability.
734-738	Limestone, yellowish gray, medium hard, biomicrite, common microfossils, minor calcite spar, common fine moldic porosity, medium permeability.
738-742	Limestone, yellowish gray, wackestone, soft, loosely cemented, calcarenite, possible thin white lime mud lense from 740 feet, fair intergranular porosity, medium to low permeability.
742-761	Limestone, yellowish gray and light gray, microfossiliferous calcarenite, medium to hard, large secondary calcite spar and micrite fossil molds common, excellent moldic and intergranular porosity, medium to high permeability (increased formational water flow after encountering this unit during drilling).
761-770	Limestone, yellowish gray, as above but softer, minor friable, less moldic than above, medium permeability.

TABLE A-2. GEOLOGIST'S LOG OF WELL L-M-2464 (OBSERVATION WELL)

Depth (feet)	Lithology
0-14	Shell and sand, unlithified, quartz fine sand size common, high permeability.
14-16	Clay, olive gray, lime mud, unlithified, 10-20% quartz silt, low permeability.
16-24	Shell and clay, lime mud, light gray, 20-30% fine quartz sand and silt, medium to low permeability.
24-33	Sandstone, medium gray, hard, 50-75% fine quartz sand and silt, shell fragments and fossil molds common, medium permeability.
33-37	Limestone, yellowish gray and light gray, micrite, soft to medium, common quartz silt and fine sand, abundant shell fragments, partial solutioning common, good moldic porosity, medium to high permeability (much increased drilling fluid loss from 35 feet).
37-40	Limestone, as above, but tan to brown, hard, common secondary carbonate spar infilling of vugs, medium to high permeability.
40-50	Limestone, as above, soft to medium, increased vugular infilling, medium permeability.
50-60	Limestone, white, micrite, soft to medium, 10-20% unlithified, same, abundant fossils, sandy, common vugular infilling with carbonate mud and spar, fair moldic porosity, medium permeability.
60-110	Clay, olive gray, unlithified, abundant quartz sand, minor phosphate sand; denser, more clayey with depth, low permeability.
110-147	Clay, olive gray, clayey, dense, sandy, dolomitic, low permeability.
147-179	Clay, olive gray, as above, 10-20% fine sandy, low permeability.
179-187	Clay, olive gray, as above but less dense, low permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth(feet)	Lithology
187-195	Limestone, light olive gray, soft, friable, dolomitic, 40-50% quartz sand, abundant phosphate pebbles, common white shell fragments, low to medium permeability.
195-205	Lime mud, light olive gray, as above but unlithified, minor interbedded limestone, same, medium hard, low permeability.
205-210	Limestone, light gray, hard to medium, 40-50% quartz sand, minor phosphate sand and pebbles, minor unlithified same, medium to low permeability.
210-240	Lime mud, light olive gray, very sandy, unlithified to poorly lithified; occasional hard interbedded limestone lenses, as above, and minor phosphate sand and pebbles, common shell, overall low permeability.
240-255	Limestone, light gray to light olive gray, as above but soft to medium hard, softer and unlithified, same, from 250 feet, low to medium permeability.
255-261	Lime mud, white, unlithified, clayey, shell fragments and phosphate pebbles common, low permeability.
261-270	Sandstone, sandy limestone, light olive gray, soft to medium, friable, 50-75% fine quartz sand, common phosphate pebbles and sand, occasional shell fragments, low to medium permeability.
270-280	Lime mud, light olive gray, clayey, silty, less sandy than above, abundant phosphate pebbles, low permeability.
280-304	Clay, olive gray, stiff, unlithified, clayey, minor quartz silt, minor dolomitic, low permeability.
304-325	Dolosilt, olive gray, as above, but highly dolomitic, dense, very low permeability.
325-334	Lime mud, light olive gray, dolomitic, silty, trace phosphate sand, thin sandy limestone lense, same, from 326 feet, low permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth(feet)	Lithology
334-373	Lime mud, light olive gray, as above, and occasional interbedded soft, light gray, sandy limestone lenses, dolomitic, 5% phosphate sand, low permeability.
373-396	Limestone, white to yellowish gray, micrite, medium hard, commonly unlithified, minor quartz and phosphate sand, shell and shell molds common, fair moldic porosity, medium permeability.
396-405	Limestone, white to yellowish gray, as above, hard to medium, good moldic porosity, minor secondary infilling of pore spaces with carbonate mud, medium permeability.
405-410	Limestone, pale olive, hard microcrystalline, dolomitic, spar infilled casts common, fair moldic porosity, medium permeability.
410-426	Limestone, light yellowish gray, wackestone, soft to medium, arenitic texture, abundant microfossils, abundant pink barnacle fragments from 420 feet, intergranular to fine moldic porosity, medium permeability.
426-435	Limestone, yellowish gray, as above, micritic, medium to hard, good (fine) moldic porosity, trace phosphate sand, medium permeability.
435-440	Limestone, light gray, biomicrite, hard, trace phosphate and quartz sand, good moldic porosity, medium to high permeability.
440-450	Limestone, yellowish gray, micrite, soft, common friable, 5-10% fine quartz and phosphate sand, minor molds, poor secondary porosity, medium permeability.
450-456	Limestone, yellowish gray, as above but medium hard, abundant fossil molds and casts, good moldic porosity, medium to high permeability.
456-459	Limestone, light olive gray, hard, secondary dolomitization common, microcrystalline, dolomite and micrite matrix, minor quartz and phosphate sand, minor shell and fossil molds, medium permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth(feet)	Lithology
459-463	Dolosilt, greenish gray, unlithified, dense, clayey, highly dolomitic, low permeability.
463-465	Dolosilt, light olive gray, as above but less dense, minor quartz silt, basal greenish gray dolosilt as above, low permeability.
465-470	Dolosilt, olive gray, dense, clayey, highly dolomitic, becoming silty and lighter in color with depth, low permeability.
470-475	Interbedded clay, as above, and limestone, yellowish gray, poorly lithified to unlithified, fossils abundant, predominantly echinoid spines and corals, quartz sand common, medium to low permeability.
475-480	Limestone, as above, medium permeability.
480-483	Limestone, yellowish gray and light gray, biomicrudite, medium, fossils abundant, trace sandy, good moldic porosity, medium permeability.
483-486	Dolomite, olive brown, hard, microcrystalline, occasional small vugs, fine moldic porosity, medium to low permeability.
486-491	Limestone, light yellowish gray, medium to hard, microcrystalline sparite, porosity similar to above, medium to low permeability.
491-496	Clay, light olive gray, stiff, clayey, possible dolomitic, trace silty, low permeability.
496-506	Dolomite, yellowish gray and light olive gray, medium, microcrystalline, minor small fossil fragments, good fine moldic porosity, medium permeability.
506-515	Limestone, yellowish gray, medium hard, microcrystalline sparite, dolomitic, trace phosphate sand, fine moldic porosity, minor spar and chert infilling, medium permeability.
515-534	Limestone, light olive gray, as above, highly dolomitic; unlithified, thin, white lime mud lense from 523 feet; better developed secondary moldic porosity, medium to high permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth (feet)	Lithology
534-538	Limestone, white, soft, and lime mud, white to yellowish gray, fossiliferous, abundant echinoid spines, minor phosphate sand, low to medium permeability.
538-541	Limestone, yellowish gray, medium hard, sparite, dolomitic, trace fine quartz and phosphate sand, occasional small vugs, medium to low permeability.
541-545	Lime mud, light gray, unlithified, trace phosphate and quartz sand, minor white shell fragments, low permeability.
545-553	Lime mud, similar to above but yellowish gray, low permeability.
553-568	Lime mud, as above, and limestone, same, hard, highly interbedded, thin olive gray, dolomitic clay lense from 558 feet, abundant sand and pebble size phosphate nodules, overall low permeability.
568-569	Dolomite, light olive gray, hard, microcrystalline, splintery fracture, low to medium permeability.
569-574	Limestone, pale olive, medium to soft, then unlithified from 571 feet, microcrystalline, highly dolomitic, trace phosphate and quartz sand, thin dolomite lense (as above) from 573 feet, medium to low permeability.
574-580	Limestone, yellowish gray and light olive gray, mottled appearance, hard, sparite, highly dolomitic, abundant phosphate pebbles and fossil molds, good secondary porosity, medium to high permeability.
580-585	Lime mud, white becoming light olive gray with depth, minor poorly lithified, white micrite limestone from 580 feet, low permeability.
585-590	Lime mud, light yellowish gray, unlithified, trace phosphate sand, hard, thin limestone lense, same from 589 feet, low permeability.
590-594	Lime mud, white, unlithified and interbedded, hard, yellowish gray limestone, dolomitic, sparite, fossil molds common, low to medium permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth(feet)	Lithology
594-602	Limestone, light olive gray, sparite, hard, highly dolomitic, gold moldic porosity, unlithified from 597 feet, same composition, phosphate pebbles common, overall medium permeability.
602-612	Limestone, yellowish gray to light olive gray, hard, highly dolomitic, biosparite, minor phosphate and quartz sand, fossil molds and casts abundant, excellent moldic porosity, medium to high permeability.
612-621	Lime mud, white, unlithified, minor dolomitic; hard dolomitic limestone lense (as above) from 618 feet, low permeability.
621-624	Dolosilt, light olive gray, stiff, clayey, highly dolomitic, low permeability.
624-630	Dolomite, light olive gray, hard to medium, microcrystalline, occasional white shell fragments, low to medium permeability.
630-642	Lime mud, white, unlithified, minor dolomitic and interbedded thin lenses of yellowish gray, hard dolomitic limestone, overall low permeability.
642-644	Limestone, white, biomicrudite, medium to hard, fossiliferous, trace quartz and phosphate sand, good moldic porosity, medium to high permeability.
644-650	Limestone, as above but light gray, better secondary porosity than above, partial spar infilling of fossil molds common, high to medium permeability.
650-660	Limestone, white, hard, biomicrudite, similar to above, good moldic porosity, medium to high permeability.
660-677	Limestone as above but yellowish gray, medium hard, medium to high permeability.
677-695	Limestone, white, biomicrudite, medium, minor unlithified, same, fossil molds and casts common, minor spar, trace quartz fine sand, medium permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth(feet)	Lithology
695-702	Lime mud, white, unlithified, trace quartz silt, low permeability.
702-706	Limestone, light yellowish gray, sparitic, minor micritic, soft to medium, minor microcrystalline dolomite, medium to low permeability.
706-710	Dolomite or dolomitic limestone, yellowish gray, hard, microcrystalline, highly dolomitic, medium to low permeability.
710-712	Clay, light olive gray, very dense, unlithified, clayey, silty, low permeability.
712-715	Lime mud, white, dense, clayey, minor fine quartz sand, low permeability.
715-718	Dolomite or dolomitic limestone, yellowish gray, hard to medium, microcrystalline, medium to low permeability.
718-721	Dolosilt, dark greenish gray, unlithified, dolomitic, clayey, silty, low permeability.
721-722	Clay (dolosilt?), olive gray, unlithified, dense, clayey, silty, low permeability.
722-725	Lime mud, white, unlithified, trace dolomitic, clayey, trace fine quartz sand, low permeability.
725-728	Clay, light olive gray, unlithified, stiff, 20-30% quartz fine sand and silt, trace dolomitic, low permeability.
728-730	Lime mud, white, unlithified, minor quartz silt, becoming poorly lithified with depth, low permeability.
730-733	Limestone, yellowish gray, medium, microcrystalline, highly dolomitic, silty, light olive gray, clay interbedded from 732 feet, similar composition, trace phosphate sand, low to medium permeability.
733-736	Lime mud, white to light yellowish gray, unlithified, clayey, minor lithified, interbedded, as above, overall low permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth(feet)	Lithology
736-744	Limestone, yellowish gray, wackestone, soft, common friable, trace fossil molds, thin white lime mud lense from 739 feet, minor quartz and calcareous sand, fair moldic to intergranular porosity, medium to low permeability.
744-760	Limestone, yellowish gray, microfossiliferous, calcarenite, medium to hard, large secondary calcite spar and micrite fossil molds common, excellent moldic and intergranular porosity, medium to high permeability (increased formational water flow after encountering this unit during drilling).
760-767	Limestone, yellowish gray, similar to above, but softer and friable, less moldic, medium permeability.
767-768	Limestone, yellowish gray, hard, similar to 744 through 760 feet, medium to high permeability.
768-773	Limestone, light yellowish gray, micorfossiliferous wackestone, organism tests commonly fragmented in a micrite matrix, possibly reworked, minor larger fossil molds, medium permeability.
773-778	Limestone, yellowish gray, packed microfossiliferous calcarenite, commonly filling large gastropod and bivalve casts, spar matrix, good moldic and intergranular porosity, medium to high permeability.
778-787	Limestone, as above but poorly consolidated to loose, less large fossil molds, medium permeability.
787-789	Clay, yellowish gray lime mud and greenish gray, clayey, stiff, unlithified, low permeability.
789-794	Limestone, yellowish gray, medium to hard, biosparite, microfossils and larger fossil molds common, casts occasionally micritic, good moldic porosity, medium to high permeability.
794-798	Limestone, yellowish gray, calcarenite, soft to medium, fragmented microfossils abundant, spar and micrite cement, possible poorly washed or reworked, medium to low permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth(feet)	Lithology
798-800	Limestone, as above with occasional light gray micritic fossil molds, better induration, medium permeability.
800-807	Limestone, light yellowish gray, similar to 794 to 798 feet interval but very fine granular texture also common, better moldic porosity, medium permeability.
807-809	Limestone, yellowish gray, biosparite, hard, individual sparry casts, but very poorly consolidated together, abundant bivalve and gastropod casts, less than 2-3 mm, intergranular porosity, medium permeability.
809-820	Limestone, light yellowish gray, soft, friable, harder with depth, microfossil fragments in micrite and spar matrix, fine granular texture, medium to low permeability.
820-830	Limestone, as above, but medium to hard, minor unlithified, same composition, fair moldic porosity, medium permeability.
830-836	Limestone, as above, more abundant microfossils, occasional organism borings, medium permeability.
836-837	Clay, dark greenish gray and black mottled appearance, clayey, stiff sticky texture, low permeability.
837-845	Limestone, lighter and darker yellowish gray, interbedded, soft and hard, biomicritic and biosparitic, respectively, microfossils common, granular texture, fair moldic to intergranular porosity, medium to low permeability.
845-848	Limestone, light yellowish gray, soft, wackestone, minor unlithified, occasional 2-20 mm fossil molds, minor microfossils, fair moldic porosity, medium to low permeability.
848-853	Limestone, as above, but darker yellowish gray, common unlithified same, medium to low permeability.

TABLE A-2.
GEOLOGIST'S LOG OF WELL L-M-2464 - Continued:

Depth(feet)	Lithology
853-858	Limestone, light gray and yellowish gray, calcarenite, medium and soft, occasional friable, microfossils abundant, sparry calcite cement, intergranular and minor moldic porosity, medium permeability.
858-863	Limestone, as above, minor soft from 858 feet becoming medium hard and fair to good moldic porosity, medium permeability.
863-868	Limestone, light yellowish gray, medium to hard, sparry microfossil and larger fossil casts, in a micrite matrix, occasional large micritic molds, fair to good moldic porosity, medium permeability.
868-879	Limestone, as above, but molds and casts finer and more abundant, medium permeability.
879-890	Limestone, light yellowish gray to white, micrite, medium hard, minor unlithified white lime mud interbedded, occasional calcarenite limestone also interbedded, slightly darker in color, fair moldic porosity, overall medium to low permeability.
890-897	Limestone, as above, micrite, soft, friable, occasional moldic, trace of organism borings, medium to low permeability.
897-900	Lime mud, white, unlithified, clayey, low permeability.
900-905	Interbedded, yellowish gray, calcarenite limestone, micritic matrix, and yellowish brown, grayish green mottled clay, dense, clayey, overall low to medium permeability.

2. Geophysical Logs

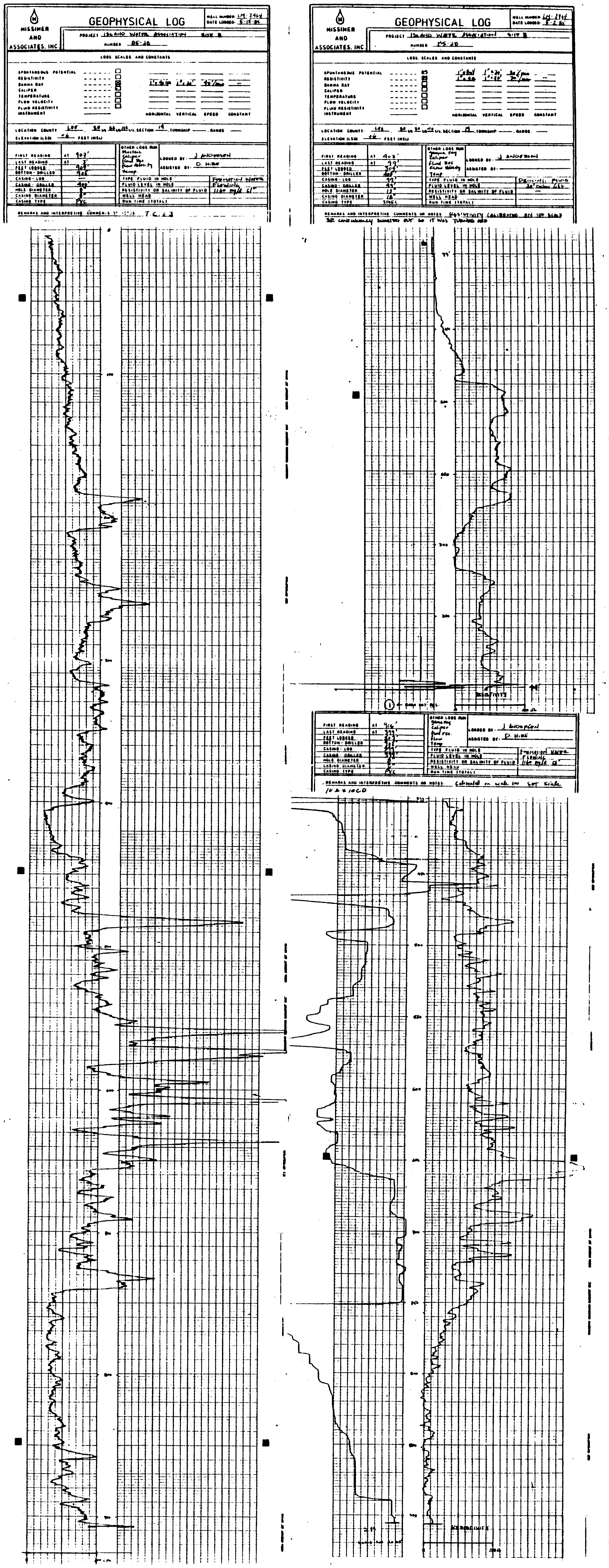


FIGURE A-1. GAMMA RAY AND ELECTRIC LOG FOR WELL L-M-2464

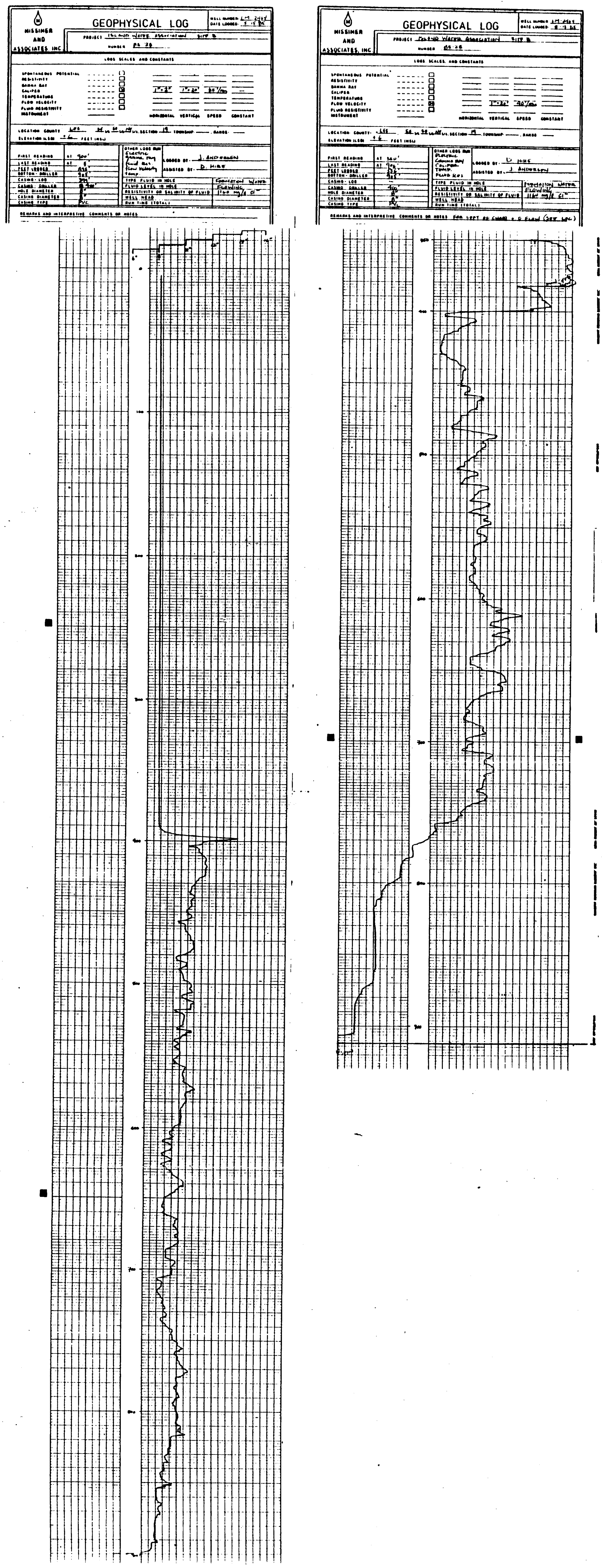


FIGURE A-2. CALIPER AND FLOW VELOCITY LOGS FOR WELL L-M-2464

GEOPHYSICAL LOG

MISSIMER AND ASSOCIATES, INC.

WELL NUMBER: LM-2464
DATE LOGGED: 5-15-85

PROJECT: ISLAND WATER ASSOCIATION SITE B
NUMBER: 85-28

LOGS, SCALES, AND CONSTANTS

Log		Horizontal	Vertical	Speed	Constant
SPONTANEOUS POTENTIAL	☐				
RESISTIVITY	☐				
GAMMA RAY	☐				
CALIPER	☐				
TEMPERATURE	☒		1" = 20'	50'/min	—
FLOW VELOCITY	☐				
FLUID RESISTIVITY	☐				
INSTRUMENT					

LOCATION: COUNTY: LEE, SE 1/4 SE 1/4 NE 1/4, SECTION 19, TOWNSHIP: —, RANGE: —
ELEVATION (LSD) +6 FEET (MSL)

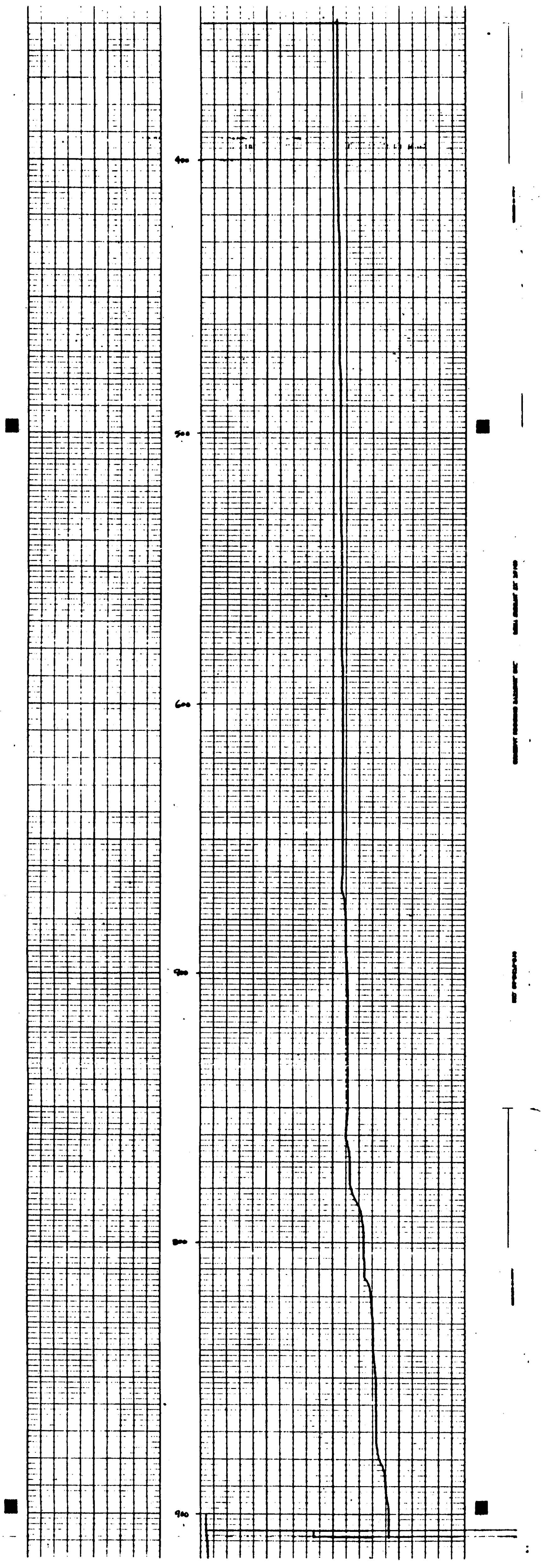
FIRST READING	AT 350'
LAST READING	AT 907'
FEET LOGGED	557'
BOTTOM - DRILLER	905'
CASING - LOG	—
CASING - DRILLER	400'
HOLE DIAMETER	8"
CASING DIAMETER	8"
CASING TYPE	PVC

OTHER LOGS RUN: Electric, Gamma Ray, Caliper, Flow Velocity, Fluid Res.

LOGGED BY: D. HIRE
ASSISTED BY: J. ANDERSON

TYPE FLUID IN HOLE	Formation Water
FLUID LEVEL IN HOLE	Flowing
RESISTIVITY OR SALINITY OF FLUID	1160 mg/l Cl⁻
WELL HEAD	
RUN TIME (TOTAL)	

REMARKS AND INTERPRETIVE COMMENTS OR NOTES: SPAN SET AT 990



GEOPHYSICAL LOG

MISSIMER AND ASSOCIATES, INC.

WELL NUMBER: LM-2464
DATE LOGGED: 5-15-85

PROJECT: ISLAND WATER ASSOCIATION SITE B
NUMBER: 85-28

LOGS, SCALES, AND CONSTANTS

Log		Horizontal	Vertical	Speed	Constant
SPONTANEOUS POTENTIAL	☐				
RESISTIVITY	☐				
GAMMA RAY	☐				
CALIPER	☐				
TEMPERATURE	☐				
FLOW VELOCITY	☐				
FLUID RESISTIVITY	☒		1" = 20'	40'/min	
INSTRUMENT					

LOCATION: COUNTY: LEE, SE 1/4 SE 1/4 NE 1/4, SECTION 19, TOWNSHIP: —, RANGE: —
ELEVATION (LSD) +6 FEET (MSL)

FIRST READING	AT 350'
LAST READING	AT 910'
FEET LOGGED	560'
BOTTOM - DRILLER	905'
CASING - LOG	—
CASING - DRILLER	400'
HOLE DIAMETER	8"
CASING DIAMETER	8"
CASING TYPE	PVC

OTHER LOGS RUN:

LOGGED BY: J. ANDERSON
ASSISTED BY: D. HIRE

TYPE FLUID IN HOLE	Formation Water
FLUID LEVEL IN HOLE	Flowing
RESISTIVITY OR SALINITY OF FLUID	1160 mg/l Cl⁻
WELL HEAD	
RUN TIME (TOTAL)	

REMARKS AND INTERPRETIVE COMMENTS OR NOTES:

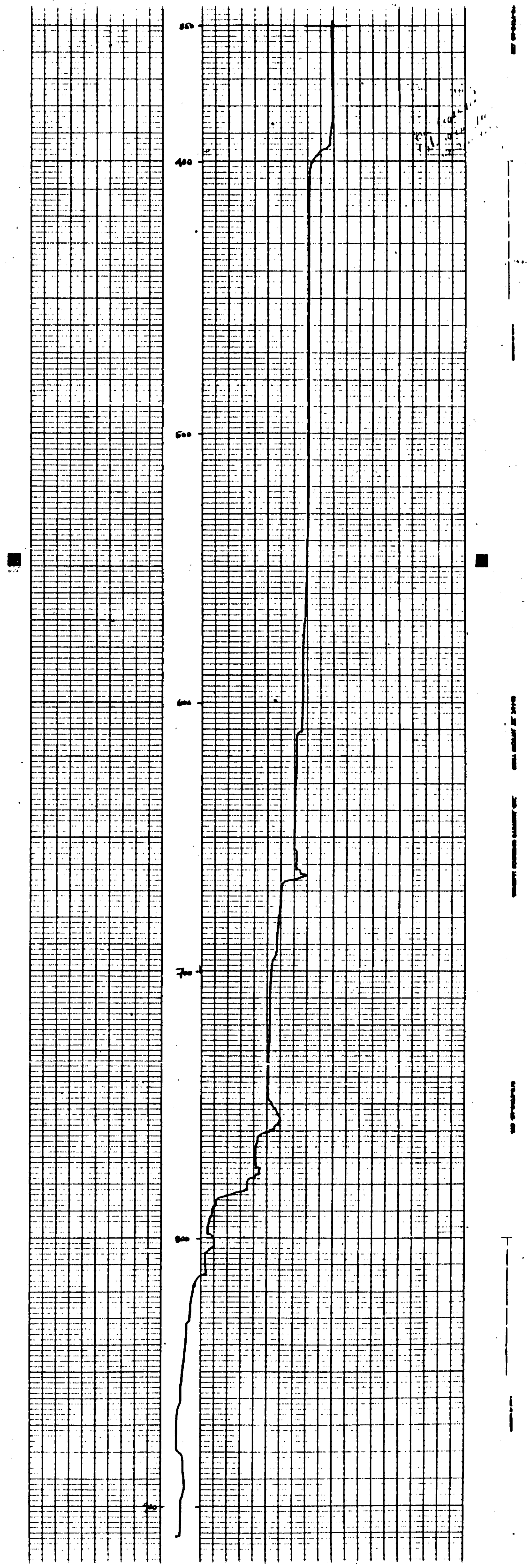


FIGURE A-3. TEMPERATURE AND FLUID RESISTIVITY LOGS FOR WELL L-M-2464

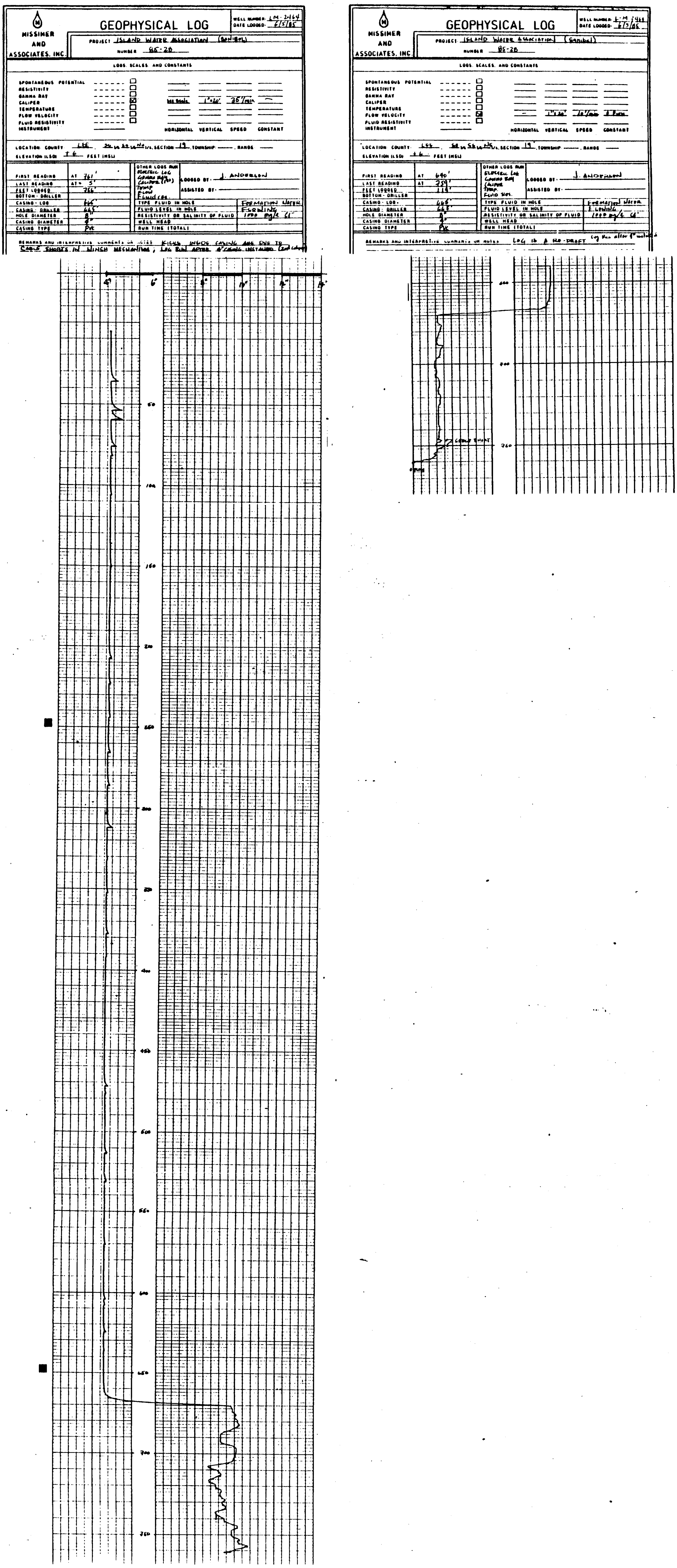


FIGURE A-4. CALIPER AND FLOW VELOCITY LOGS FOR WELL L-M-2464 FINAL CONSTRUCTION LOG

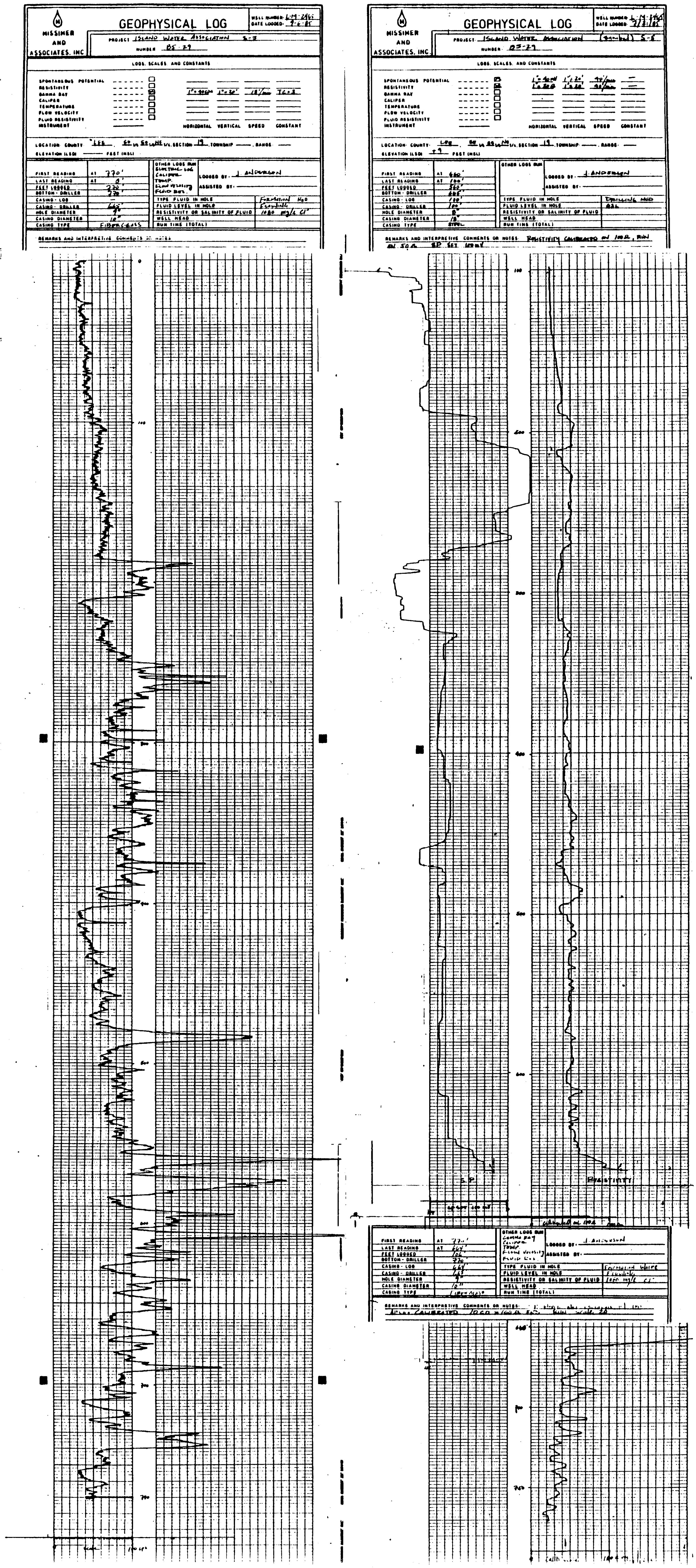


FIGURE A-5. GAMMA RAY AND ELECTRIC LOG FOR WELL L-M-2465

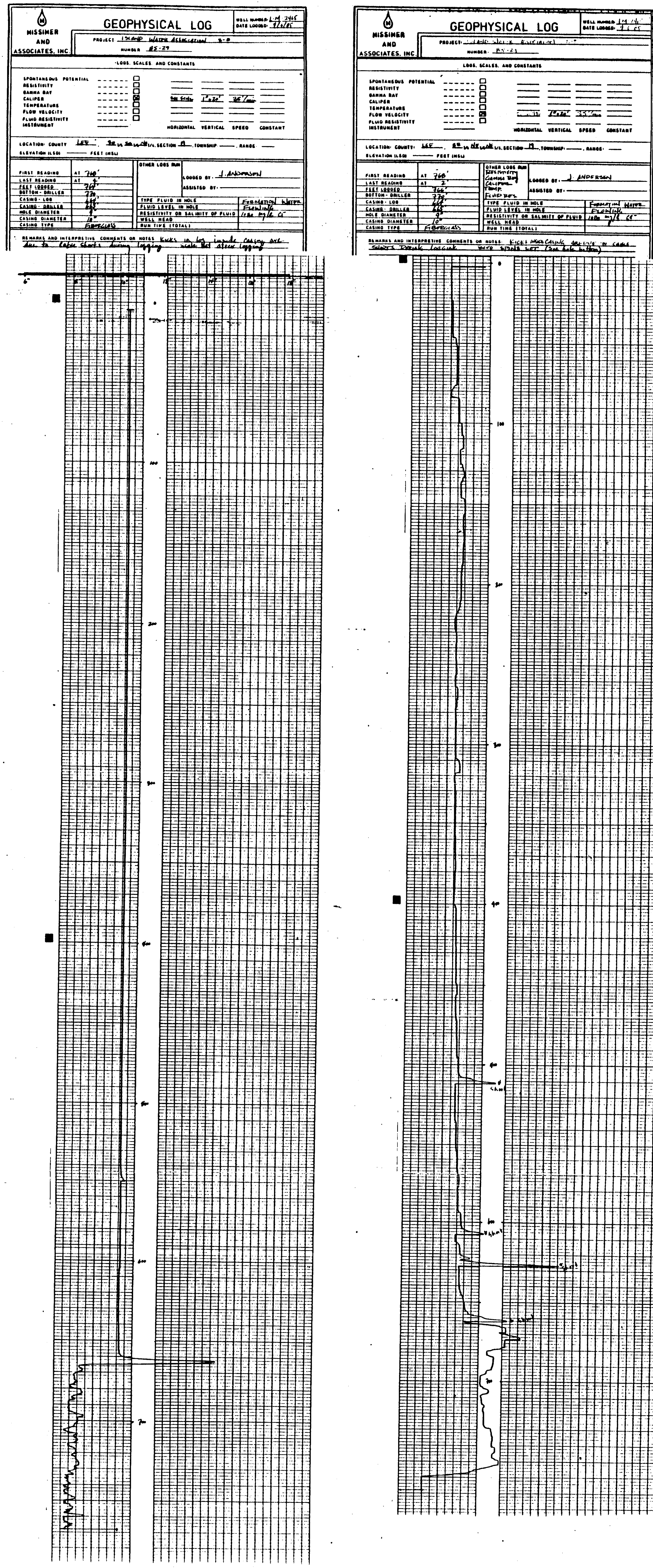


FIGURE A-6. CALIPER AND FLOW VELOCITY LOGS FOR WELL L-M-2465

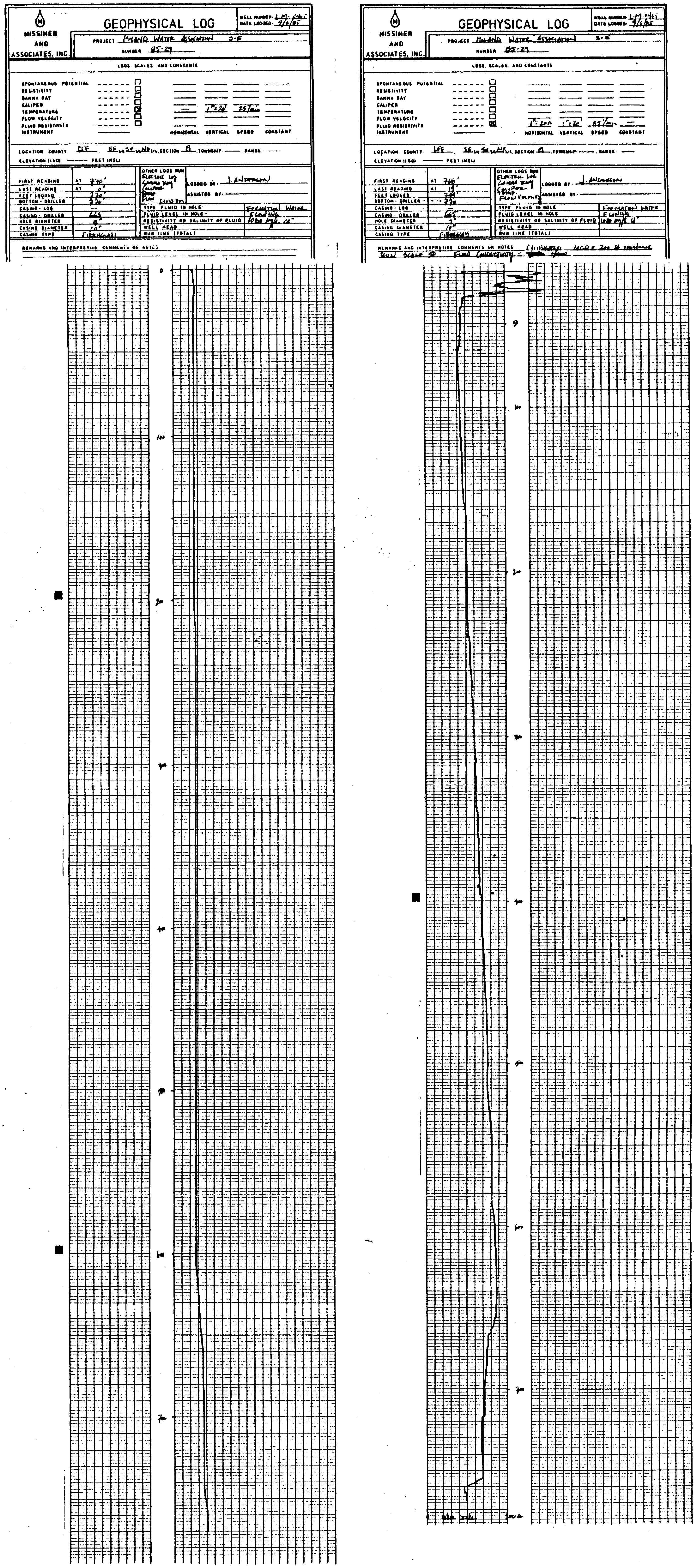


FIGURE A-7. TEMPERATURE AND FLUID RESISTIVITY LOGS FOR WELL L-M-2465

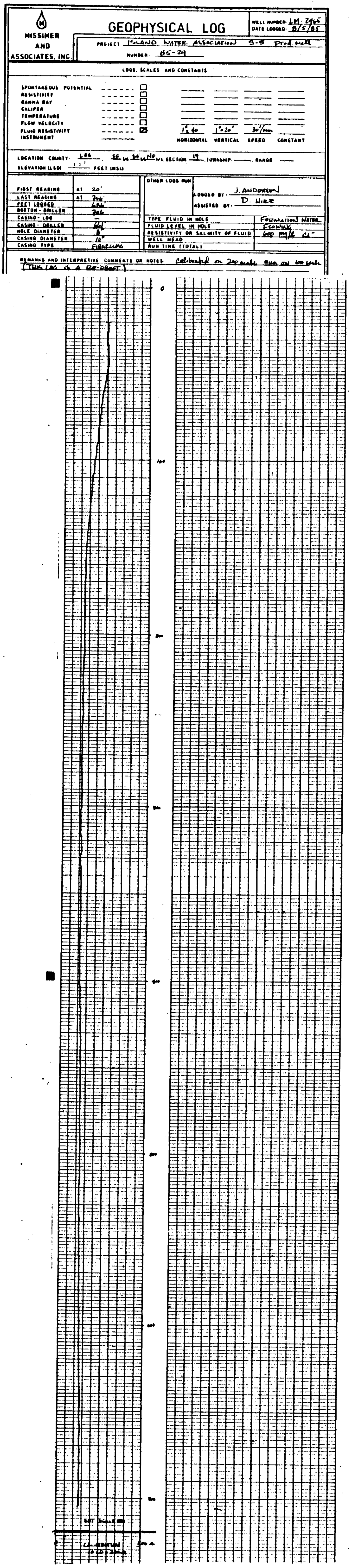


FIGURE A-8. FLUID RESISTIVITY LOG FOR WELL L-M-2465

3. Aquifer Test Data

TABLE A-3. STEP DRAWDOWN TEST DATA FOR PRODUCTION WELL L-M-2465 (S-5)

Static Water Level = 20.2 feet above land surface

Discharge Rate (gpm)	Time (minutes)	Drawdown (feet)	Specific Capacity (gpm/ft)	Efficiency (%)
293	5	28.90		
	10	28.95	10.1	82.5
	15	28.70		
	25	28.45		
	30	28.20		
402	5	44.10		
	10	44.60		
	15	45.30		
	20	45.90		
	25	46.20		
	30	46.20	8.7	70.9
503	7	62.00		
	12	62.00		
	20	62.10		
	26	62.30		
	30	62.30	8.1	65.8
602	5	78.35		
	10	81.20		
	20	81.50		
	30	82.15		
	45	82.35		
	60	83.50	7.2	58.8
	80	82.10		
	100	81.90		

TABLE A-4. TIME AND DRAWDOWN DATA FOR PRODUCTION WELL L-M-2465 (S-5) DURING THE AQUIFER TEST

Time(minutes)	Drawdown(feet)
0	0
2.5	44.0
3.5	44.65
5	45.4
8	45.7
10	45.8
15	47.15
20	46.75
26	48.3
30	48.35
50	48.25
60	49.5
78	48.5
90	48.65
120	48.65
150	48.55
180	45.6

TABLE A-5. TIME AND DRAWDOWN FOR OBSERVATION WELL L-M-2464 (r = 194 feet)

Time (minutes)	Drawdown (feet)
0	0
.083	.08
.25	.88
.50	1.55
.75	1.77
1	2.10
1.5	2.49
2	2.78
2.5	3.02
3	3.23
4	3.51
5	3.76
6	3.93
7	4.07
8	4.18
9	4.25
10	4.35
12.5	4.60
15	4.75
20	4.93
25	5.17
30	5.33
40	5.55
52	5.71
60	5.88
78	6.00
90	6.12
122	6.28
150	6.37
180	6.27
240	6.68
300	6.83
324	6.95
380	7.19
440	7.32
480	7.43
600	7.72
960	7.75
1080	8.09
1260	8.21
1380	8.33
1440	8.30
1560	8.21
1680	8.33
1800	8.39
1860	8.48
2020	8.65
2378	8.80
2530	8.69

4. Water Quality

TABLE A-6. DISSOLVED CHLORIDE AND CONDUCTIVITY DATA COLLECTED DURING DRILLING OF OBSERVATION WELL L-M-2464

	Bottom Samples		Wellhead Samples	
Depth (feet)	Dissolved Chlorides (mg/l)	Conductivity (umhos)	Dissolved Chlorides (mg/l)	Conductivity (umhos)
425	600	2300	--	--
435	660	3290	680	2150
445	700	2800	--	--
455	680	2390	--	--
465	--	--	700	2560
475	680	2160	--	--
485	660	2320	--	--
496	660	2320	680	2510
506	600	2580	--	--
526	600	2980	680	2980
536	300	2500	--	--
546	320	2540	340	--
558	400	--	260	2510
569	510	2810	--	--
580	530	2850	--	--
590	520	2860	280	2450
605	540	2790	--	--
610	540	2840	--	--
620	540	2790	500	2850
630	540	2700	--	--
640	540	2800	--	--
650	560	2800	500	2800
662	580	2850	--	--
672	580	2850	--	--
683	580	2400	640	2980
697	560	2810	--	--
703	560	2800	--	--
713	580	2850	600	2900
723	580	2840	--	--
733	560	2840	--	--
744	580	2890	660	3050
			590 next day	2790 field
757	1000	3850	--	--
767	1040	4050	620	2690
778	1120	--	960	3600
788	1160	4410	840	3890
798	1240	5000	900	3800
807	1280	5100	940	3890
817	1340	4990	940	3800
827	1240	5000	940	4100
837	1330	5000	1030	4100

TABLE A-6. DISSOLVED CHLORIDE AND CONDUCTIVITY DATA COLLECTED DURING DRILLING OF OBSERVATION WELL L-M-2464 Continued:

	Bottom Samples		Wellhead Samples	
Depth (feet)	Dissolved Chlorides (mg/l)	Conductivity (umhos)	Dissolved Chlorides (mg/l)	Conductivity (umhos)
848	1340	4900	940	3810
858	1380	5000	960	4100
868	1460	6000	1000	3790
879	1520	5400	1030	4060
890	1530	5300	--	--
900	1420	5100	990	4000
905	1500	5500	1110	4350
Flow from rod after disconnect @900	1540	5200		

TABLE A-7. DISSOLVED CHLORIDE AND CONDUCTIVITY DATA COLLECTED DURING CONSTRUCTION OF PRODUCTION WELL L-M-2465 (S-5)

	Bottom Samples		Wellhead Samples	
Depth (feet)	Dissolved Chlorides (mg/l)	Conductivity (umhos)	Dissolved Chlorides (mg/l)	Conductivity (umhos)
665-706	IWA treated water added to allow drilling			
706	--	--	580[a] 600[b]	--
706	600	2640	--	--
716	--	--	600	2720
725	560	2720	--	--
735	600	2710	620	2690
745	580	2630	620	2780
755	1080	4020	960	3650
765	--	--	1020	3840
developed flow		--	1030	3890

[a]Sample collected after 1.5 hours of development.

[b]Sample collected after 2 hours of development.

TABLE A-8. DISSOLVED CHLORIDE AND CONDUCTIVITY DATA FROM LOGGER GRAB SAMPLES IN L-M-2465 (S-5)

Depth (feet)	Dissolved Chlorides (mg/l)	Conductivity (umhos)
Wellhead flow	1030	3960
670	1040	4030
760	1080	4130

TABLE A-9. CHEMICAL ANALYSIS OF WATER FROM PRODUCTION WELL L-M-2465 COLLECTED SEPT. 11, 1985, AFTER 6 HOURS OF FLOW AT 140 gpm.

DRINKING WATER ANALYSIS

Client: Missimer & Assoc. Date Received: 9/12/85

Address: Rt. 8, Box 625-D, Cape Coral, FL 33909

Sample Identification: Project # IWA-5-5 (85-29) Lab # S353 & S354

PARAMETER	RESULTS	PARAMETER	RESULTS
Arsenic(As)	mg/l	– Chloride	1,080 mg/l
Barium(Ba)	mg/l	– Total Dissolved Solids(105°C)	2,347 mg/l
Cadmium(Cd)	mg/l	Suspended Solids(105°C)	mg/l
– Calcium(Ca)	93 mg/l	– Fluoride	1.9 mg/l
Chromium(Cr)	mg/l	– Color	7 PCU
– Copper(Cu)	<.01 mg/l	TKN(N)	mg/l
– Iron(Fe)	<.01 mg/l	NH_3(N)	mg/l
Lead(Pb)	mg/l	NO_3(N)	mg/l
– Magnesium(Mg)	107 mg/l	T-PO_4(P)	mg/l
– Manganese(Mn)	<.01 mg/l	O-PO_4(P)	mg/l
Mercury(Hg)	mg/l		
Potassium(K)	mg/l	– Total Alkalinity($CaCO_3$)	139 mg/l
Selenium(Se)	mg/l	– Phenolphthalein Alkalinity	0 mg/l
Silver(Ag)	mg/l	– Total Hardness($CaCO_3$)	1670 mg/l
– Sodium(Na)	566. mg/l	– Calcium Hardness($CaCO_3$)	520 mg/l
Zinc(Zn)	mg/l	– Magnesium Hardness($CaCO_3$)	150 mg/l
		Non-Carbonate Hardness($CaCO_3$)	mg/l
– Odor	7200 TON*	OH($CaCO_3$)	mg/l
– Turbidity	0.93 NTU	– CO_3($CaCO_3$)	0 mg/l
Conductivity	µmhos/cm	– HCO_3($CaCO_3$)	139 mg/l
– Sulfate(SO_4)	370 mg/l	– OH(OH)	0 mg/l
Hydrogen sulfide(H_2S)	mg/l	CO_3(CO_3)	mg/l
– Silica (SiO_2)	32.8 mg/l	– HCO_3(HCO_3)	113 mg/l
Surfactants(Foaming Agents)	mg/l		
– pH	7.1	– Carbonate Alkalinity ($CaCO_3$)	0 mg/l
– pH_s	7.03		
– Langelier Index(Corrosivity)	+.07		
– Stability Index	6.96		

*solids too high for nomographic determination of CO_2

LEE COUNTY ENVIRONMENTAL LABORATORY
2099-2 Beacon Manor Drive
Fort Myers, Florida 33907
(813) 939-7908

Lab Certification #44031

B. Loewe
LAB ANALYST

[signature]
LAB SUPERVISOR

* 7200 on lg bottle
no odor or 1 T.O.N. on smaller bottle

TABLE A-10. CHEMICAL ANALYSIS OF WATER FROM PRODUCTION WELL L-M-2465 COLLECTED BY THE ISLAND WATER ASSOCIATION, INC.

DRINKING WATER ANALYSIS

Client: Island Water Assoc. Date Received: 9/12/85

Address:

Sample Identification: Well 5-5 Lab # 5855, 5856, 5857

PARAMETER	RESULTS	
Arsenic(As)		mg/l
Barium(Ba)		mg/l
Cadmium(Cd)		mg/l
Calcium(Ca)	95	mg/l
Chromium(Cr)		mg/l
Copper(Cu)	<.01	mg/l
Iron(Fe)	<.01	mg/l
Lead(Pb)		mg/l
Magnesium(Mg)	104	mg/l
Manganese(Mn)	<.01	mg/l
Mercury(Hg)		mg/l
Potassium(K)	26.5	mg/l
Selenium(Se)		mg/l
Silver(Ag)		mg/l
Sodium(Na)	551	mg/l
Zinc(Zn)		mg/l
Odor	100	TON
Turbidity	0.82	NTU
Conductivity		µmhos/cm
Sulfate(SO_4)	420	mg/l
Hydrogen sulfide(H_2S)		mg/l
Silica (SiO_2)	19.2	mg/l
Surfactants(Foaming Agents)		mg/l
pH	7.6	
pH_s	7.06	
Langelier Index(Corrosivity)	+.54	
Stability Index	6.52	

PARAMETER	RESULTS	
– Chloride	1,070	mg/l
– Total Dissolved Solids(105°C)	2,580	mg/l
Suspended Solids(105°C)		mg/l
– Fluoride	2.0	mg/l
– Color	3	PCU
TKN(N)		mg/l
NH_3(N)		mg/l
NO_3(N)		mg/l
T-PO_4(P)		mg/l
O-PO_4(P)		mg/l
– Total Alkalinity($CaCO_3$)	137	mg/l
– Phenolphthalein Alkalinity	0	mg/l
– Total Hardness($CaCO_3$)	660	mg/l
– Calcium Hardness($CaCO_3$)	520	mg/l
– Magnesium Hardness($CaCO_3$)	140	mg/l
Non-Carbonate Hardness($CaCO_3$)		mg/l
OH($CaCO_3$)		mg/l
– CO_3($CaCO_3$)	0	mg/l
HCO_3($CaCO_3$)		mg/l
– OH(OH)	0	mg/l
CO_3(CO_3)		mg/l
– HCO_3(HCO_3)	111	mg/l

– Carbonate Alkalinity ($CaCO_3$) 0 mg/l

– Bicarbonate Alkalinity ($CaCO_3$) 137 mg/l

* Solids too high for nomographic determination of CO_2

LEE COUNTY ENVIRONMENTAL LABORATORY
2099-2 Beacon Manor Drive
Fort Myers, Florida 33907
(813) 939-7908

Lab Certification #44031

B. Loewe
LAB ANALYST

[signature]
LAB SUPERVISOR