# A Review of Municipal Services Provided by the City of Lakeland

Roberto Ignacio Pedroso
*University of Central Florida*

# A REVIEW OF MUNICIPAL SERVICES PROVIDED BY THE CITY OF LAKELAND


BY

ROBERTO IGNACIO PEDROSO
B.S.Ch.E., Georgia Institute of Technology, 1963


RESEARCH REPORT

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Engineering
in the Graduate Studies Program of the College of Engineering
of Florida Technological University


Orlando, Florida
1977

ABSTRACT

For this report, four municipal services provided by the City of Lakeland were studied. The environmental impact of these services was discussed. Recommendations were made for solutions to problems found.

It was found that the water supply service has one deleterious impact on the environment. Hydrogen sulfide occasionally found in the water supply gives the latter objectionable odor and taste. Installation of a centralized water treatment plant with aeration facilities for hydrogen sulfide removal was recommended for resolution of the problem.

The waste water treatment plant removes 91% of the $BOD_5$ and the suspended solids in the plant influent. The plant effluent and dried sludge are used for irrigation and fertilization in local agricultural enterprises. It was concluded that this service has a beneficial impact on the environment.

It was determined that the electric power supply service has one deleterious impact on the environment. Sulfur dioxide emitted from five power generating units results in higher than allowable ground level concentrations. Several recommendations were made for resolution of the problem. Taller stacks were recommended for all five units. Burning lower sulfur content fuel oil was recommended for three of the units. Installation of an ammonia scrubbing system for sulfur dioxide removal was recommended for the other two units.

Sanitary landfill disposal of solid waste collected by the city has two potentially deleterious impacts on the environment. Available land area may be quickly exhausted. Water runoff may leach undesirable materials out of buried refuse and contaminate ground water supplies. Incineration of Lakeland's solid waste in one of the city's power generating units was recommended as the solution to the problem.

As follow-up to this report, a discussion has been held with city officials concerning the potential sulfur dioxide problem.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to the following persons, without whose help the writing of this report would not have been possible.

Allison, J. K., Assistant Director, Department of Public Works, City of Lakeland

DuCharme, W. J., Superintendent, Refuse Collection Division, Department of Public Works, City of Lakeland

Jernigan, R. F., Superintendent, North Central Sanitary Landfill, Polk County

Lesnett, W. R., Assistant Director, Department of Electric and Water Utilities, City of Lakeland

Libey, J. A., Superintendent, Power Generating Division, Department of Electric and Water Utilities, City of Lakeland

Locke, E. T., Jr., Superintendent, Sanitary Sewerage Division, Department of Public Works, City of Lakeland

McIntosh, C. D., Jr., Director, Department of Electric and Water Utilities, City of Lakeland

Opalinski, M. P., Environmental Coordinator, Power Generating Division, Department of Electric and Water Utilities, City of Lakeland

Warner, W. P., Director, Department of Public Works, City of Lakeland

Williams, T. B., Superintendent, Water Division, Department of Electric and Water Utilities, City of Lakeland

Wilson, F. L., Director, Environmental Services, Polk County

Youkey, R. V., City Manager, City of Lakeland

Much of the information in this report was received from the foregoing, without specific reference being cited herein.

CONTENTS

TABLES

ILLUSTRATIONS

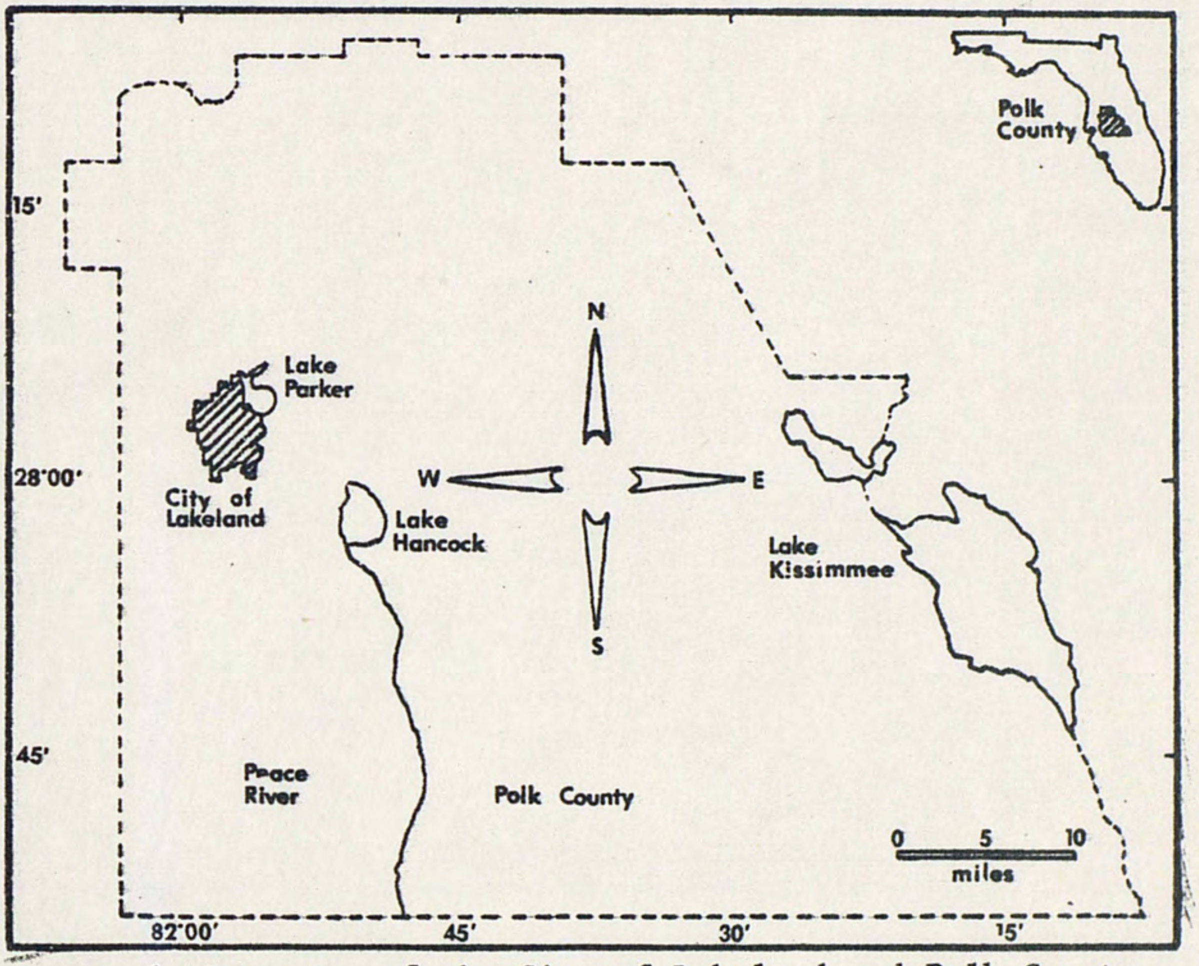
# INTRODUCTION

Lakeland started as a rail camp settlement on the shores of Lake Wire soon after the Civil War. The City of Lakeland was incorporated on January 1, 1885, when twenty-seven citizens approved the charter. In May, 1891, only six years later, the first arc lights were turned on in the center of town. The first municipal well, designed to deliver 300 gallons of water per minute, was completed a few years later in 1905.

The City of Lakeland has enjoyed a steady progressive growth and is known today as the "World's Citrus Center." Lakeland was awarded the 1970 "All America City" by the National Municipal League and Look Magazine for the improvement of black opportunity, improvement program for the downtown core area, and the preparation for the boom expected to come from Disneyworld.

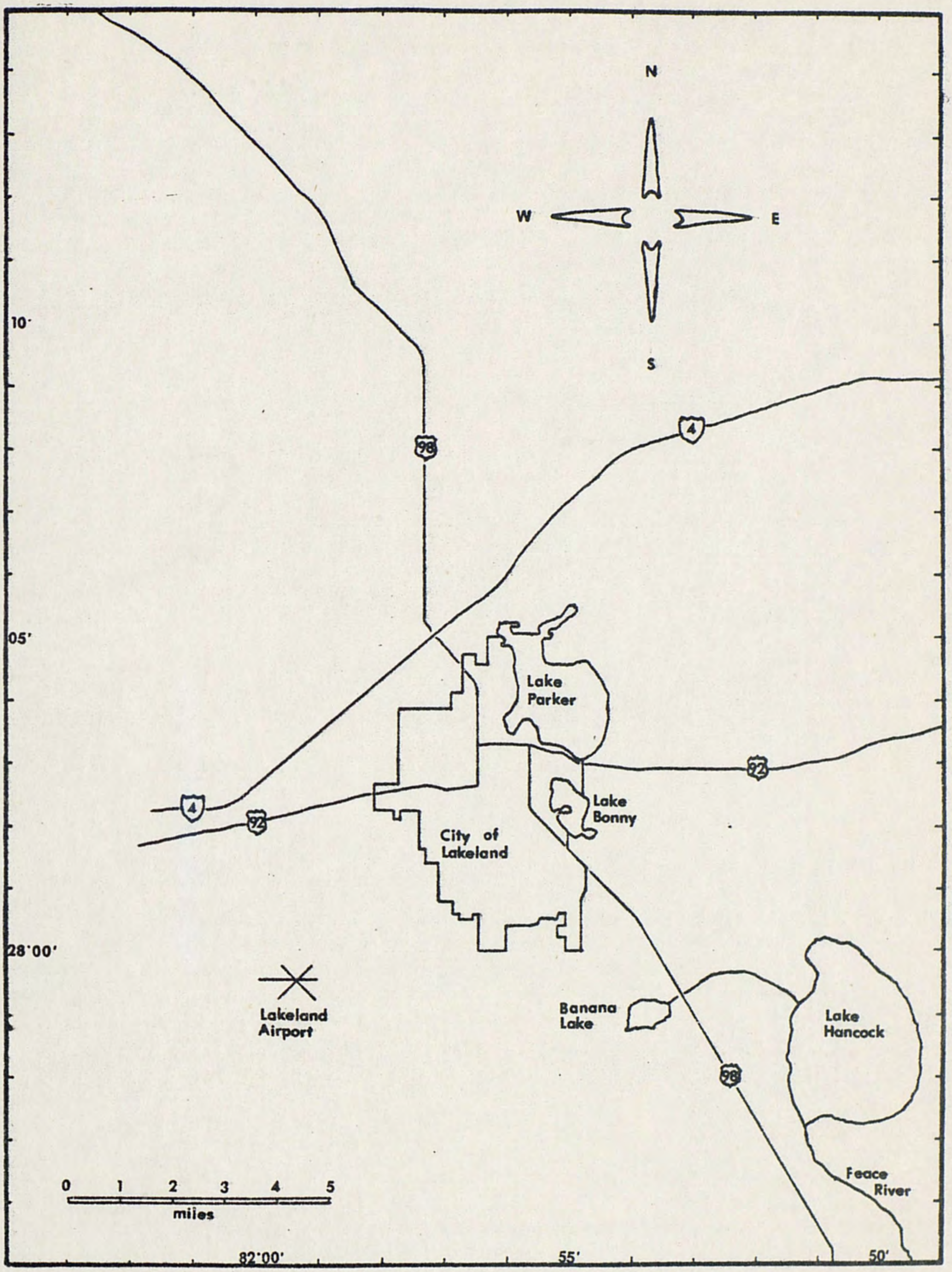
Lakeland is the geographic center of Florida. Located in the citrus highlands of Polk County, between Orlando and Tampa, it is the hub of the Sunshine State. Its modern airport, a system of interstate highways and daily passenger and freight railroads add to its convenience. Map 1 shows the location of the City of Lakeland and Polk County. Map 2 shows some of the topographic features of the city and its surroundings.

As the largest city in Polk County, more than 100,000 persons live in the 100 square miles of greater Lakeland. As the name implies,




Map 1. Location of the City of Lakeland and Polk County

SOURCE: Robertson (1973)




Map 2. City of Lakeland

SOURCE: Dolph Map Co. (1977)

Lakeland has thirteen fresh water lakes within its city limits. Lake Parker, on which the power plants are located, has an area of over 2,000 acres. Several main East-West and North-South arteries intersect in Lakeland. Federal Interstate Highway 4, connecting Tampa, Orlando, and Daytona Beach passes through Lakeland. United States Highways 92 and 98 pass through Lakeland. Lakeland is located the following distances from points of interest in Florida.

| | |
|---|---|
| Tampa, Florida | 35 miles |
| Disney World | 40 miles |
| Orlando, Florida | 50 miles |
| Kennedy Space Center | 100 miles |
| Miami, Florida | 210 miles |

In 1970, Polk County had approximately 15,000,000 citrus trees and ranked first in the state of Florida with an annual production of over 43,000,000 boxes of citrus fruit. Lakeland is headquarters for the Florida Citrus Commission and Florida Citrus Mutual, a cooperative marketing organization whose 14,500 members produce 90% of the state's huge crop. Florida Tangerine Co-op, Growers Administrative Committee, Florida Frost Warning Service and most of the other citrus agencies are located in Lakeland.

Polk County ranks first in Florida in the production of cattle with more than 108,000 head. Approximately 75% of the phosphate produced in the United States is mined within 25 miles of Lakeland.

The total enrollment of twenty-two elementary schools, five junior high schools and two senior high schools is over 16,000. There are several private and parochial schools in the area. Higher education

institutions include Florida Southern College, Polk Junior College and Polk Vocational - Technical Center. Florida Southern College, with a student body of approximately 1,700 students, has a 92,000 volume library and is a fully accredited four year college.

Interstate Highway 4, and U.S. Highways 92 and 98 connect Lakeland with important cities in Florida and neighboring states. Seaboard Coastline serves the commercial rail needs of the city. Amtrak provides passenger rail service connecting Lakeland with New York, Chicago and Miami. Greyhound and Trailways bus lines serve the inter-city trade and Cities Transit Company accommodates intra-city needs. Lakeland is 40 miles from Tampa International Airport and the Port of Tampa.

Lakeland has a mayor, commission - city manager form of government, a system which was adopted in 1922. The city commission, composed of seven commissioners including the mayor, appoints the city manager, who is the chief executive employee of Lakeland. Also appointed, with appointments confirmed annually, are the city attorney, assistant city attorney, municipal judge, assistant municipal judge, prosecuting attorney and many advisory and operating boards and committees made up of interested private citizens of Lakeland.

There are seven departments, including Finance, Police, Fire, Public Works, Parks and Recreation, General Service, Electric and Water Utilities, under the direction of the City Manager. The City of Lakeland employs approximately over 900 persons and the majority of the employees are covered by Civil Service.

Dividends from the Department of Electric and Water Utilities account for a full half of the money taken in by the city for general fund revenues. This income is considerably above the amount which would be provided by a franchise tax from a privately owned electric company.

Lakeland General Hospital has 800 beds and is one of the largest hospitals in Florida. The Lakeland public library system has 80,000 volumes and two bookmobiles. There are five public parks and twelve playgrounds in Lakeland.

The City of Lakeland provides the usual municipal services to its citizens through the various departments mentioned previously. In addition, the city owns and operates its own electric power generating system. The latter is not a typical municipal service.

It is the objective of this research report to study four of the municipal services provided by the City of Lakeland. The environmental impact of these services will be discussed. Recommendations will be issued for possible solutions to problems encountered. The municipal services that will be studied are:

1. Water collection, treatment and supply system
2. Waste water collection, treatment and disposal system
3. Electric power generation and distribution system
4. Solid waste collection and disposal system

# CHAPTER 1

## WATER COLLECTION, TREATMENT AND SUPPLY SYSTEM

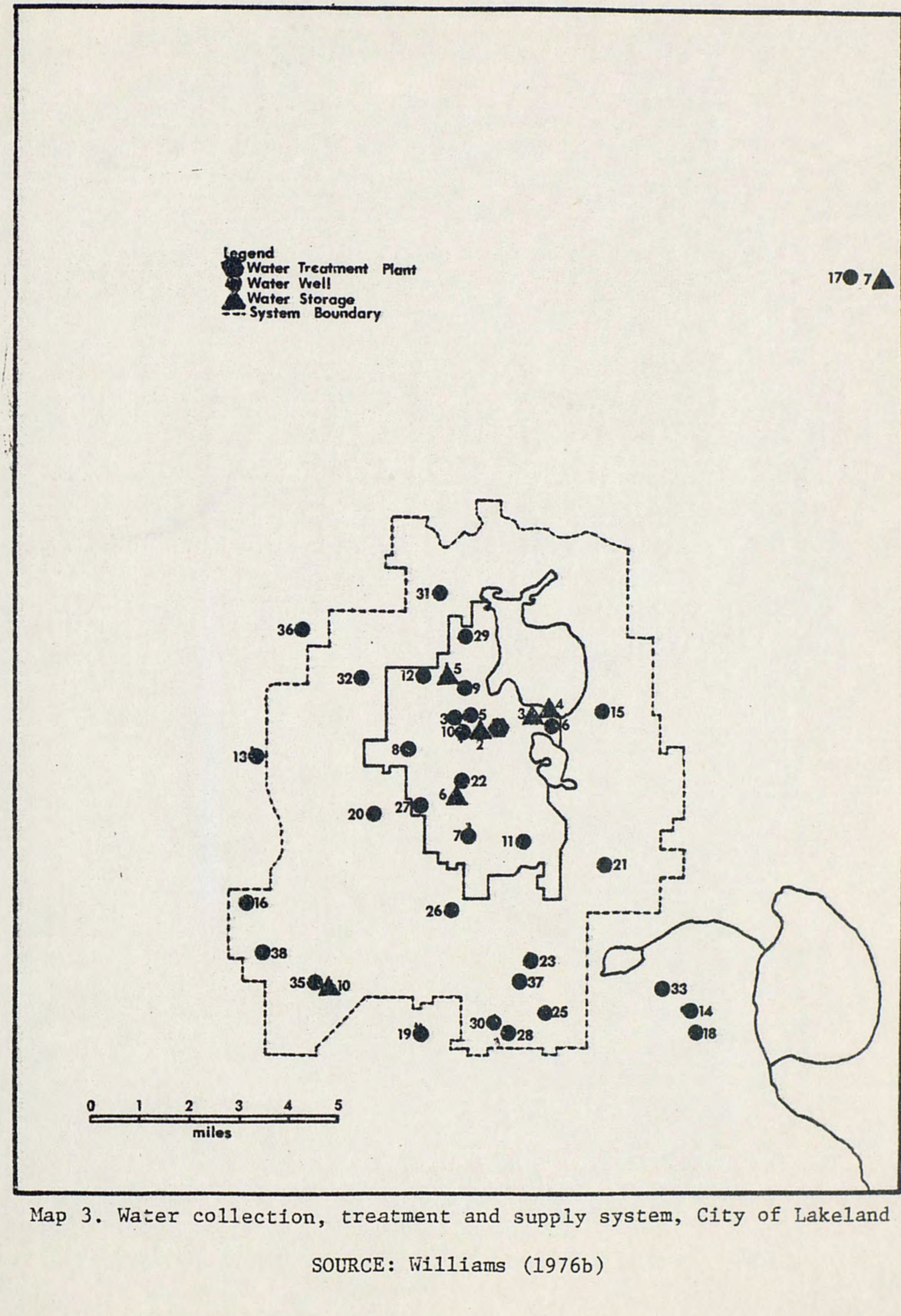
### Description of System

The City of Lakeland water collection, treatment and supply system is operated by the Water Division of the Department of Electric and Water Utilities. The boundary lines of the system are shown in Map 3.

The population served by Lakeland's water system is approximately 84,000. Total gallons pumped by the system in 1976 amounted to 6.09 billion gallons. The average per capita use was 198 gpd. This consumption is more than 30% above the national average cited by Fair, Geyer and Okun (1966). Although the above is a high per capita usage, it is not the highest experienced by the system. In 1972, 6.12 billion gallons were pumped to an estimated population of 74,000. The per capita consumption that year was 227 gpd, which is more than 50% above the national average.

The highest total annual pumpage was experienced in 1974 when 6.54 billion gallons were pumped. The highest pumpage for one day was experienced on May 20, 1973, when 32.78 million gallons were pumped. Highest one day pumpage in 1976 occurred on April 29, when 31.45 million gallons were pumped.

Figure 1 shows annual pumpage and rainfall in Lakeland for the last ten years. Figure 2 shows monthly pumpage and rainfall in Lakeland




Map 3. Water collection, treatment and supply system, City of Lakeland

SOURCE: Williams (1976b)

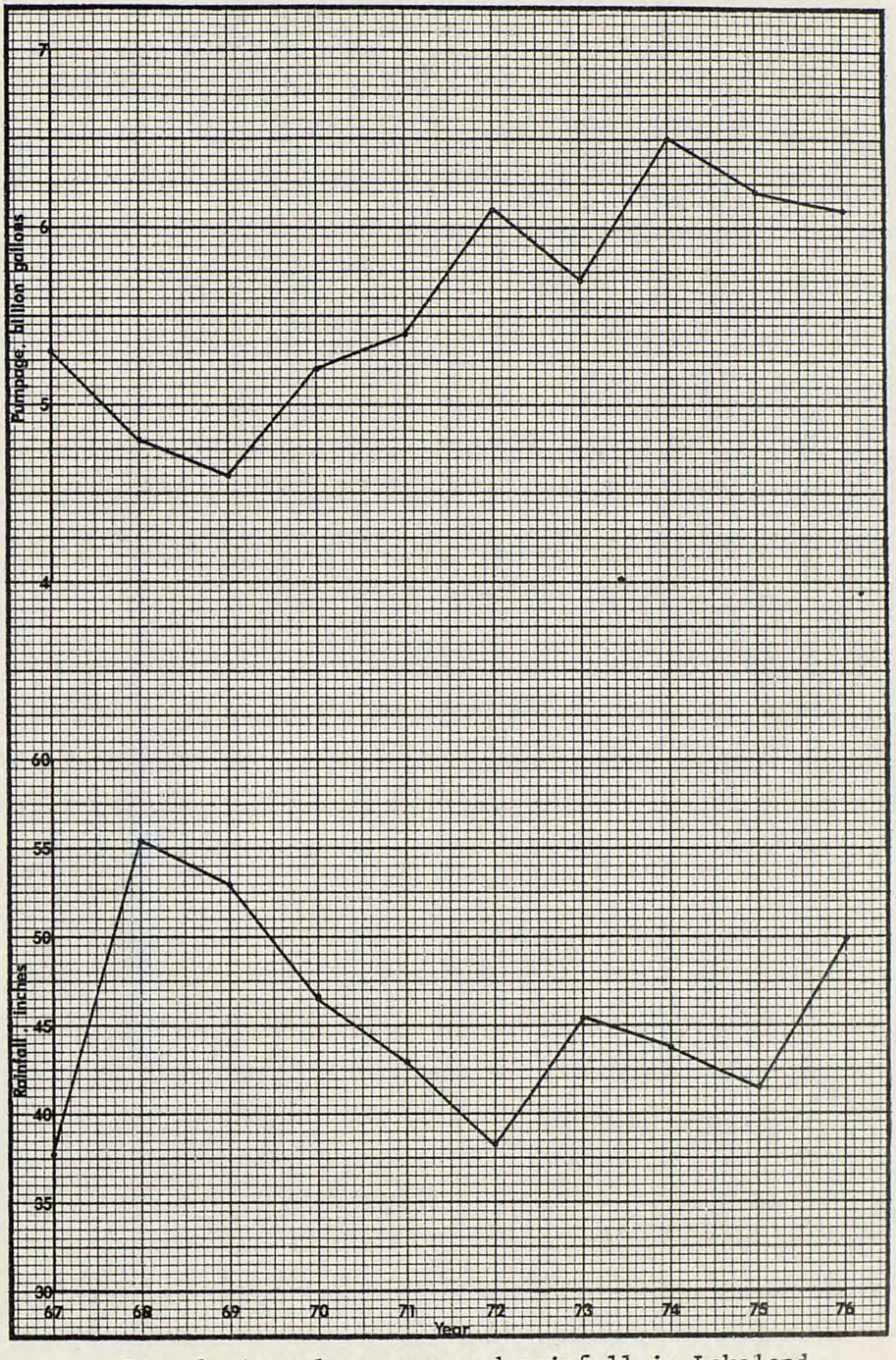



Fig. 1. Annual pumpage and rainfall in Lakeland, 1967 to 1976.

SOURCE: Williams (1977)

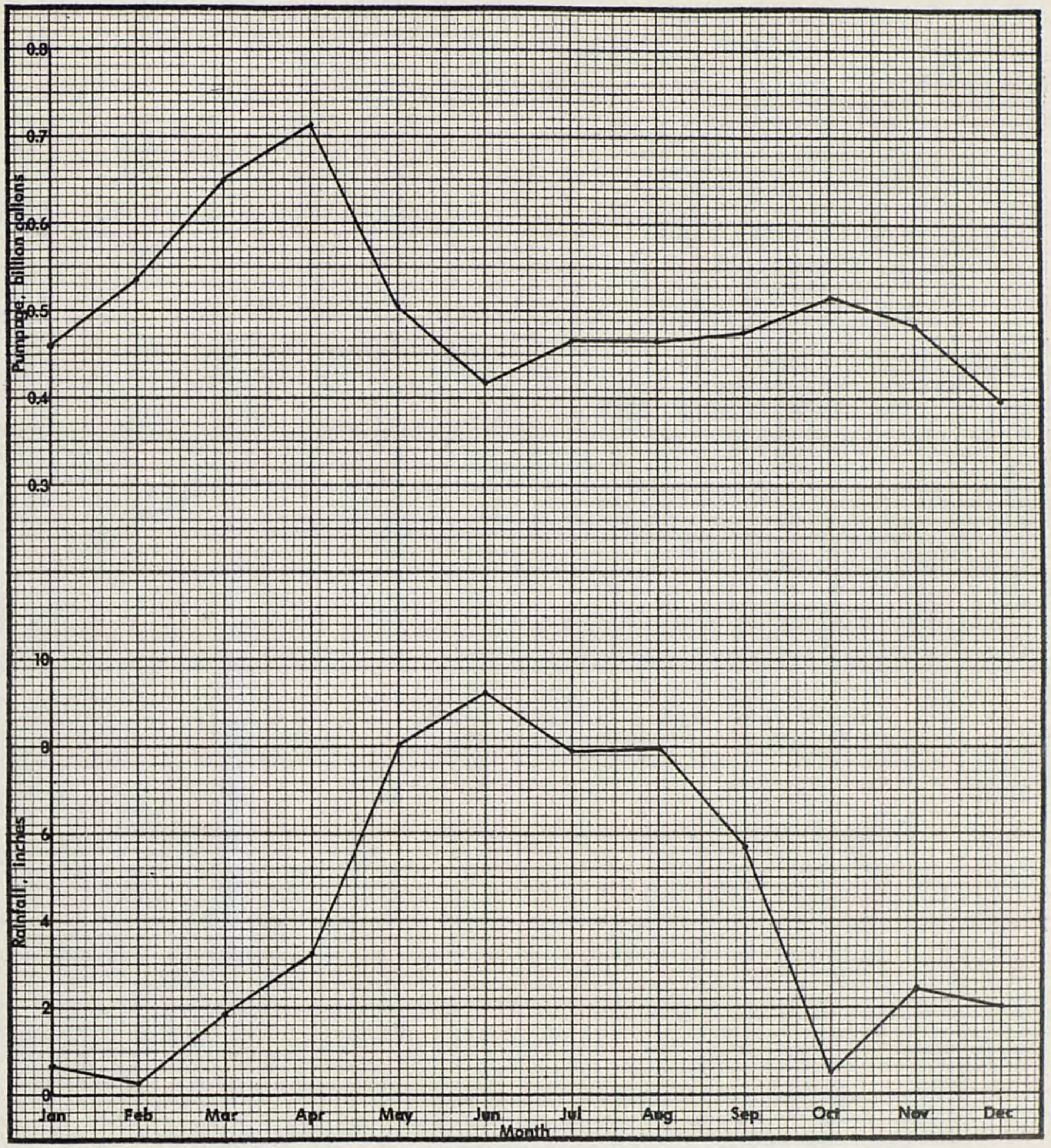



Fig. 2. Montly purpage and rainfall in Lakeland, 1976

SOURCE: Williams (1977)

in 1976. As is to be expected, there is a general trend showing increasing pumpage with decreasing rainfall.

Records kept by the Water Division indicate that the ratio of maximum daily water usage to average daily water usage has averaged 2.0. The ratio of maximum hourly water usage to average hourly water usage has averaged 3.2. These numbers are approximately 30% higher than the national averages cited by Fair, Geyer and Okun (1966).

The Lakeland area is underlain by four aquifers as described by Stewart (1966). The water table aquifer is in unconsolidated sand and clay deposits at and just below the land surface. This aquifer is used for domestic supplies and irrigation purposes requiring relatively small amounts of water.

A second, or uppermost artesian aquifer, is contained in the sand-phosphatic gravel zone of the pebble phosphate deposits. Like the water table aquifer, this aquifer is used only for domestic and small irrigation supplies.

A secondary artesian aquifer is contained in the limestones of the Hawthorn and Tampa formations. This aquifer is also a source of water for domestic and small irrigation supplies.

The major portion of Lakeland's water supply is withdrawn from the Floridan aquifer, which is contained in various limestone formations including the Suwannee, Ocala and Avon Park limestones. In the Lakeland area, the Floridan aquifer occurs at depths of from 300 to 500 feet below the land surface and is, on the average, approximately 700 feet thick.

The Floridan aquifer is one of the most productive water bearing stratums in the United States. It is estimated that more than 350 billion gallons are pumped from this aquifer in an average day. Robertson (1973) determined the transmissivity and the storage coefficient of the aquifer in the Lakeland area. An aquifer test was conducted west of Lake Parker for this purpose. From the test, a transmissivity of 750,000 gpd/ft. and a storage coefficient of 0.0009 were determined.

The Floridan aquifer is recharged by rainfall percolating through the soil. The primary area of recharge for the Floridan aquifer is the Green Swamp, located in the northern section of Polk County. The potentiometric high of the Floridan aquifer is located at the Green Swamp.

As ground water passes through the limestone formations of the Floridan aquifer, it dissolves some mineral matter, mostly calcium and magnesium. The water withdrawn from the Floridan aquifer may be classified as medium hard bicarbonate water. Since Lakeland is located near the Green Swamp recharge area, a less mineralized water is available to Lakeland than to cities located further from this area. Table 1 shows the composition of a composite sample from all of the Lakeland wells. The composition of Lake Parker water is also shown in Table 1 for comparison purposes.

The water supply provided by the City of Lakeland is of good quality and meets all chemical and bacteriological standards of the United States Public Health Service. Some of the city's wells contain hydrogen sulfide gas, which is objectionable in taste and

TABLE 1

ANALYSES OF CITY OF LAKELAND WATER
AND LAKE PARKER WATER

| Type of Analysis | City of Lakeland | Lake Parker |
|---|---|---|
| Color (units) | 5 | 45 |
| Turbidity (units) | 0.5 | 90 |
| pH | 7.70 | 9.60 |
| Specific conductance at 25°C (micromhos) | 320 | 175 |
| Concentrations in mg/liter | | |
| Total dissolved solids at 103°C | 177 | 145 |
| Total hardness (as $CaCO_3$) | 154 | 68.0 |
| Noncarbonate hardness (as $CaCO_3$) | 12.0 | 12.0 |
| Total alkalinity (as $CaCO_3$) | 142 | 56.0 |
| Carbon dioxide (as $CO_2$) | 10.0 | 0.00 |
| Dissolved oxygen (as $O_2$) | 0.00 | 9.00 |
| Silica (as $SiO_2$) | 18.0 | 0.30 |
| Calcium (as Ca) | 44.8 | 22.4 |
| Magnesium (as Mg) | 10.2 | 2.50 |
| Iron (as Fe) | 0.06 | 0.00 |
| Sodium and potassium (as Na) | 6.17 | 5.22 |
| Sulfates (as $SO_4$) | 6.00 | 8.00 |
| Chlorides (as Cl) | 13.5 | 16.5 |
| Fluorides (as F) | 0.35 | 0.70 |
| Nitrates (as $NO_3$) | 0.05 | 0.48 |
| Phosphates (as $PO_4$) | 0.00 | 0.02 |

SOURCE: Williams (1976b)

odor characteristics. This gas is converted to a nonobjectionable form by chlorination.

Lakeland's water system consists firstly of 32 deep wells, most of which penetrate the Floridan aquifer. These wells are described in Table 2. Table 3 shows the pumpage from each well in 1976. Their location is shown in Map 3. The wells have a combined capacity of 75.52 mgd. As back-up to the system, two of the wells have diesel engine driven pumps for emergency service in the event of a total power failure. These pumps are located at the Dixieland no. 22 and Oconee no. 29 wells. The pumps have a combined capacity of 9.36 mgd. The Oconee well pump is shown in Photograph 1.

Consumptive permits were granted by the Southwest Florida Water Management District for all of the Lakeland wells. A total of 23.3 mgd average daily consumption and 68.5 mgd maximum daily consumption were authorized. The permit expires on December 31, 1980. This permit is required as a result of the water use plan for this area developed by SWFWMD. The latter has imposed a limit on water withdrawal from the Floridan aquifer of no more than 1,000 gpad.

Most of the city's wells discharge directly into the distribution system via retention tanks. The water from every well is chlorinated as it leaves the pump and prior to entering the distribution system. The basic purpose of the retention tank is to provide sufficient time for proper mixing of chlorine with the water. Photograph 2 shows the retention tank at the Edgewood no. 11 well. Table 2 shows the discharge routing for each pump.

Lakeland's water storage consists of five elevated tanks and

TABLE 2

WELLS IN THE LAKELAND WATER SYSTEM

| Well No. | Well Name | Well Depth,ft. | Casing Size,in. | Casing Depth,ft. | Pump Flow,gpm | Pump Head,ft. | Motor hp | Discharge Routing | Ret.Tank Size,gal |
|---|---|---|---|---|---|---|---|---|---|
| 3 | Lake Mirror | 741 | 16 | 260 | 2,000 | 125 | 100 | Reservoir #3 | ...... |
| 5 | Lake Mirror | 828 | 24 | 280 | 4,000 | 135 | 200 | Reservoir #3 | ...... |
| 6 | Larsen Plant | 746 | 20 | 160 | 2,000 | 60 | 50 | Reservoir #4 | ...... |
| 7 | Orleans | 773 | 20 | 219 | 2,000 | 257 | 150 | Distr.system | 10,000 |
| 8 | Sycamore | 725 | 18 | 197 | 2,100 | 237 | 150 | Distr.system | 10,000 |
| 9 | North Florida | 865 | 18 | 203 | 2,100 | 237 | 150 | Distr.system | 10,000 |
| 10 | Lake Mirror | 1,216 | 24 | 323 | 2,500 | ...* | 200 | Reservoir #3 | ...... |
| 11 | Edgewood | 731 | 20 | 449 | 2,000 | 260 | 200 | Distr.system | 10,000 |
| 12 | Tenth St. | 790 | 20 | 273 | 2,800 | ...* | 300 | Distr.system | 10,000 |
| 13 | Kraft | 649 | 8 | 125 | 300 | 170 | 20 | Distr.system | 10,000 |
| 14 | Highland City #1 | ...* | 6 | ...* | 200 | ...* | 15 | Distr.system | 3,000 |
| 15 | Combee | 862 | 20 | 363 | 2,000 | 200 | 125 | Distr.system | 10,000 |
| 16 | Drane Field | 675 | 8 | 154 | 280 | 180 | 15 | Distr.system | 600 |
| 17 | Polk City | 568 | 10 | ...* | 250 | 245 | 20 | Distr.system | ...... |
| 18 | Highland City #2 | 255 | 6 | 55 | 200 | ...* | 15 | Distr.system | 600 |
| 19 | Medulla | 420 | 6 | ...* | 110 | 220 | 5 | Distr.system | 500 |
| 20 | Sand Gully | ...* | ..* | 100 | 35 | 190 | 3 | Distr.system | 350 |

TABLE 2--Continued

| Well No. | Well Name | Well Depth,ft. | Casing Size,in. | Casing Depth,ft. | Pump Flow,gpm | Pump Head,ft. | Motor hp | Discharge Routing | Ret.Tank Size,gal |
|---|---|---|---|---|---|---|---|---|---|
| 21 | Eaton Park | 1,000 | 30 | ...* | 2,000 | 260 | 200 | Distr.system | 10,000 |
| 22 | Dixieland | 891 | 20 | 264 | 3,000 | 275 | 250 | Distr.system | 10,000 |
| 23 | Montclair | 603 | 8 | 375 | 500 | 324 | 75 | Distr.system | 5,000 |
| 25 | Lakewood | 356 | 6 | 213 | 150 | 250 | 15 | Distr.system | 3,000 |
| 26 | Old Mulberry Rd. | 921 | 20 | 230 | 2,300 | 280 | 200 | Distr.system | 10,000 |
| 27 | Central Ave. | 703 | 20 | 240 | 3,000 | 285 | 250 | Distr.system | 10,000 |
| 28 | Scott Lake Est. | 790 | 10 | ...* | 450 | 300 | 40 | Distr.system | 7,000 |
| 29 | Oconee | 665 | 20 | 201 | 3,500 | 300 | 350 | Distr.system | 10,000 |
| 30 | Southside | 828 | 20 | 217 | 2,500 | 320 | 250 | Distr.system | 10,000 |
| 31 | Crescent | 827 | 20 | 224 | 2,500 | 300 | 250 | Distr.system | 10,000 |
| 32 | Owens-Illinois | 642 | 20 | 210 | 2,500 | 290 | 250 | Distr.system | 10,000 |
| 33 | Highland City #3 | ...* | 10 | ...* | 300 | 150 | 20 | Distr.system | 3,000 |
| 35 | Piper | 550 | 20 | 203 | 2,000 | 290 | 200 | Distr.system | ...... |
| 36 | Chabett Rd. | 450 | 8 | 157 | 375 | 200 | 25 | Distr.system | 5,000 |
| 37 | Highlands | 662 | 20 | 171 | 2,500 | 350 | 300 | Distr.system | 10,000 |

SOURCE: Williams (1976b)

*Not available

TABLE 3

1976 PUMPAGE FROM EACH WELL IN
THE LAKELAND WATER SYSTEM

| Well Number | Gallons Pumped, Thousands | Percent of Total |
|---|---|---|
| 3, 5, 10 | 123,989 | 2.0 |
| 6 | 24,796 | 0.4 |
| 7 | 98,868 | 1.6 |
| 8 | 402,378 | 6.6 |
| 9 | 363,351 | 6.0 |
| 11 | 221,790 | 3.6 |
| 12 | 156,517 | 2.6 |
| 13 | 8,365 | 0.2 |
| 14, 18, 33 | 41,629 | 0.7 |
| 15 | 61,982 | 1.0 |
| 16 | 13,324 | 0.2 |
| 17 | 48,694 | 0.8 |
| 19 | 4,632 | 0.1 |
| 20 | 1,686 | 0.0 |

TABLE 3--Continued

| Well Number | Gallons Pumped, Thousands | Percent of Total |
|---|---|---|
| 21 | 251,321 | 4.1 |
| 22 | 785,572 | 12.9 |
| 23 | 18,671 | 0.3 |
| 25 | 425 | 0.0 |
| 26 | 308,267 | 5.1 |
| 27 | 233,791 | 3.8 |
| 28 | 387 | 0.0 |
| 29 | 849,518 | 13.9 |
| 30 | 233,870 | 3.8 |
| 31 | 419,960 | 6.9 |
| 32 | 390,722 | 6.4 |
| 35 | 70,896 | 1.2 |
| 36 | 3,605 | 0.1 |
| 37 | 954,768 | 15.7 |

SOURCE: Williams (1976b)

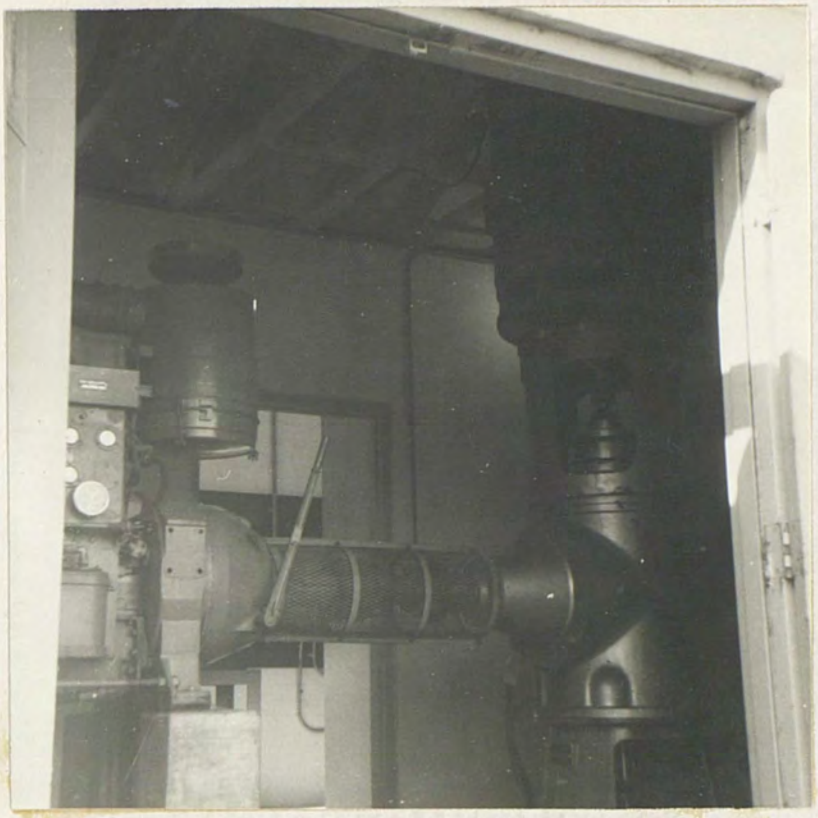


Photo. 1. Pump, motor and diesel engine at Oconee well no. 29.

Photo. 2. Retention tank at Edgewood well no. 11.

two ground reservoirs with a combined storage capacity of 1,728,000 gallons. Elevated storage tanks are necessary not only for storage but also for pressure stabilization. Table 4 describes the storage facilities. Photograph 3 shows elevated storage tank no. 5. Photograph 4 shows ground reservoir no. 2 at the Lake Mirror water treatment plant. The location of all the storage tanks is shown in Map 3. Both ground reservoirs are equipped with pumping stations. The stations are described in Table 5.

Lakeland's water system also includes a small water treatment plant at Lake Mirror. The plant consists simply of an enclosed, forced draft, multiple tray aerator. The aerator receives the discharge from Lake Mirror wells no. 5 and no. 10. The aerated water flows to ground reservoir no. 2. Two forced draft fans force 4,500 cfm of air into the bottom of the aerator, through the trays and out screened openings on the sides of the aerator enclosure. Water is fed at the top and cascades down through the trays and out the bottom. There are four trays spaced on 18" centers. The trays consist simply of wood slats. The area provided in the aerator is approximately 32 sq. ft./mgd. The water application rate is approximately 22 gpm/sq. ft. The liquid to gas ratio is approximately 1.5 gal/cu. ft. All of these parameters are well within the ranges given in the ASCE water treatment plant design manual (1969). Photograph 4 shows a view of the aerator. The performance of this aerator is no longer monitored, since it only treated approximately 2% of the total capacity of the system in 1976.

Finally, Lakeland's water system includes 552 miles of water distribution lines ranging in size from 1 inch to 24 inches diameter.

TABLE 4

STORAGE FACILITIES IN THE LAKELAND WATER SYSTEM

| Storage Number | Type of Storage | Capacity, Gallons | Elevation Above Ground, Feet |
|---|---|---|---|
| 2 | Ground reservoir | 633,000 | 0 |
| 3 | Ground reservoir | 120,000 | 0 |
| 4 | Elevated tank | 100,000 | 150 |
| 5 | Elevated tank | 350,000 | 152 |
| 6 | Elevated tank | 350,000 | 151 |
| 7 | Elevated tank | 75,000 | ...* |
| 10 | Elevated tank | 100,000 | 153 |

SOURCE: Williams (1976b)

*Not available


Photo. 3. Elevated storage tank no. 5 at Florida Ave. and Hunter St.

Photo. 4. Tray aerator and ground reservoir at Lake Mirror water treatment plant.

TABLE 5

PUMPING STATIONS IN THE
LAKELAND WATER SYSTEM

| Pump Number | Pump Capacity Flow, gpm | Head, ft. | Motor hp |
|---|---|---|---|
| Lake Mirror Pumping Station | | | |
| 1 | 4,000 | 160 | 250 |
| 2 | 2,000 | 160 | 125 |
| 3 | 2,500 | 150 | 125 |
| 4 | 3,500 | 160 | 200 |
| Lake Parker Pumping Station | | | |
| E | 2,000 | 140 | 100 |
| W | 1,600 | 200 | 125 |

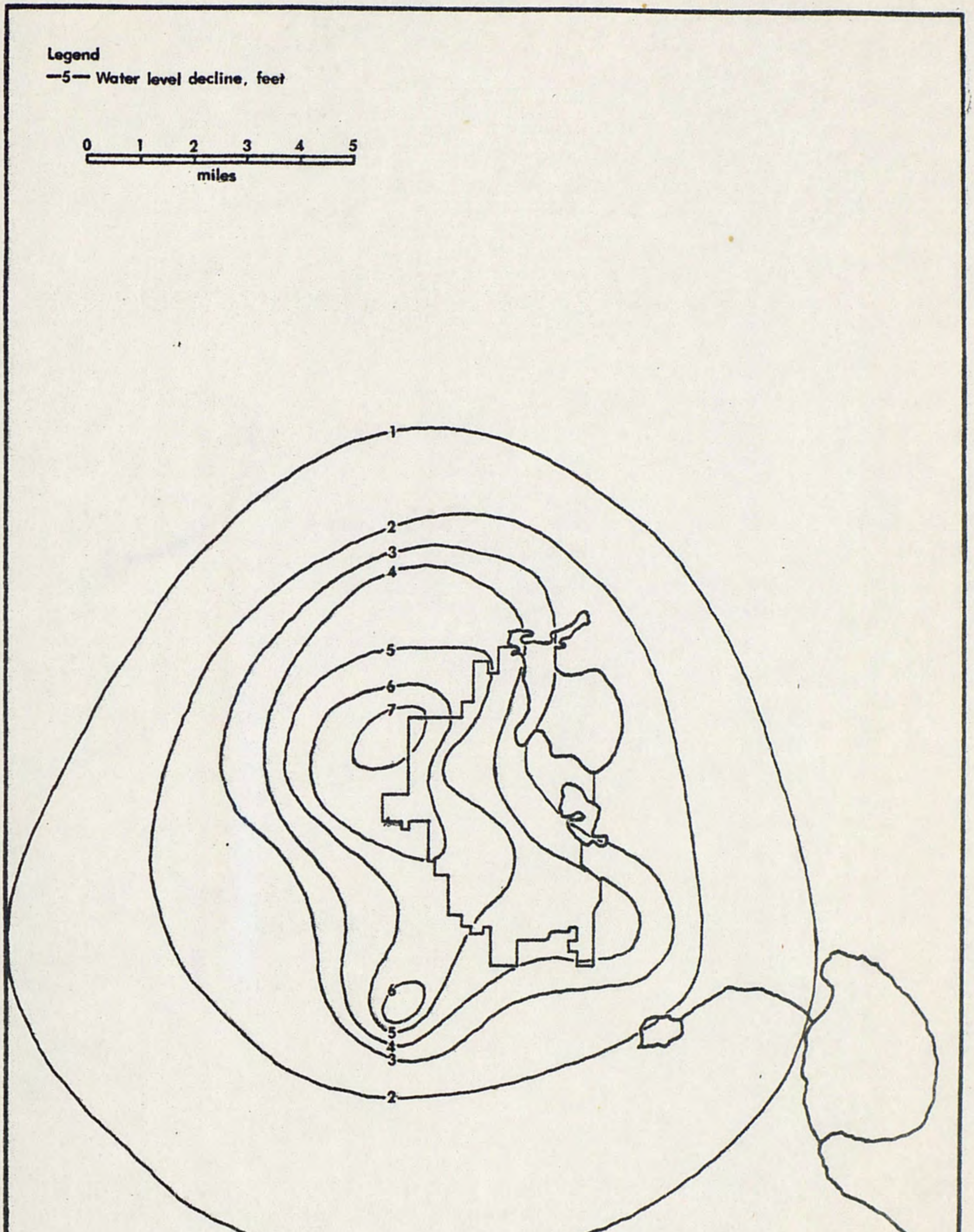
SOURCE: Williams (1977)

The types of pipe in use include cast iron, asbestos cement and PVC.

Robertson (1973) determined the generalized drawdown in the Lakeland area in 1970 due to the city water system pumpage. The leaky aquifer method was used to determine steady-state drawdowns. A transmissivity of 750,000 gpd/ft and a leakage factor of 0.001 gpd/cu. ft. were used. The yield of each well was taken as the continuous rate which, if maintained for one year, would yield the actual quantity of water withdrawn in 1970. The drawdown is shown in Map 4.

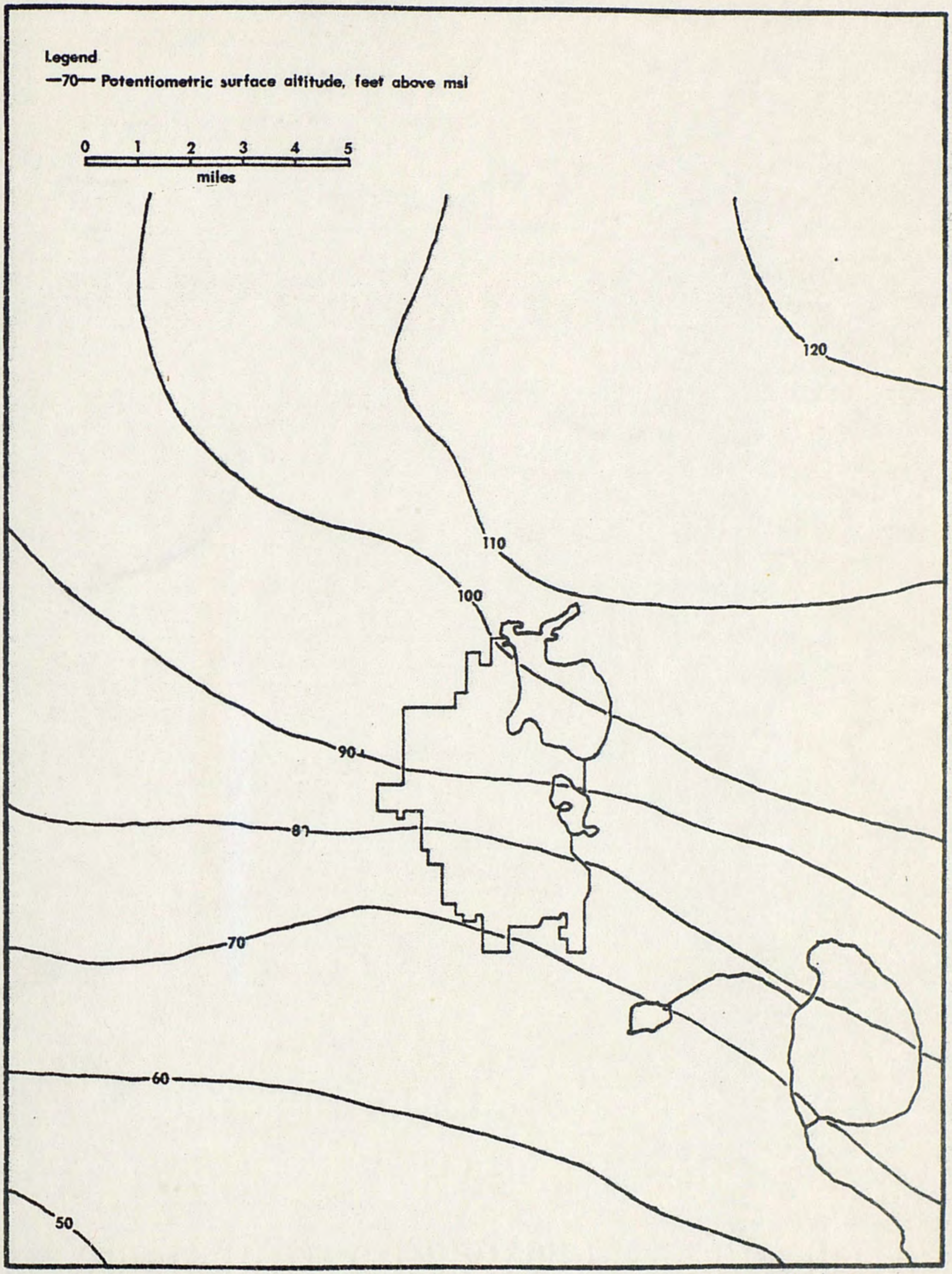
Since only Lakeland's water system was considered, the drawdown shown in Map 4 is only a part of the total drawdown of water levels in the Lakeland area. Maps 5 and 6 show contour maps of the actual potentiometric surface of the Floridan aquifer in June 1969 and May 1971. Map 7 shows the generalized decline in the potentiometric surface of the aquifer from June 1969 to May 1971. The generalized decline in the potentiometric surface of the Floridan aquifer from 1949 to 1969 is shown in Map 8 for comparison purposes.

Robertson (1973) also determined predicted generalized drawdowns in the Lakeland area in 1980 and 1990 due to projected municipal pumpage. Two different predicted drawdowns were determined. One of the drawdowns was determined under the assumption that the municipal pumpage over and above the total pumpage in 1970 would take place south of Lakeland. These predicted drawdowns are shown in Maps 9 and 10. The other drawdown was determined under the assumption that the additional municipal pumpage would take place north of Lakeland.



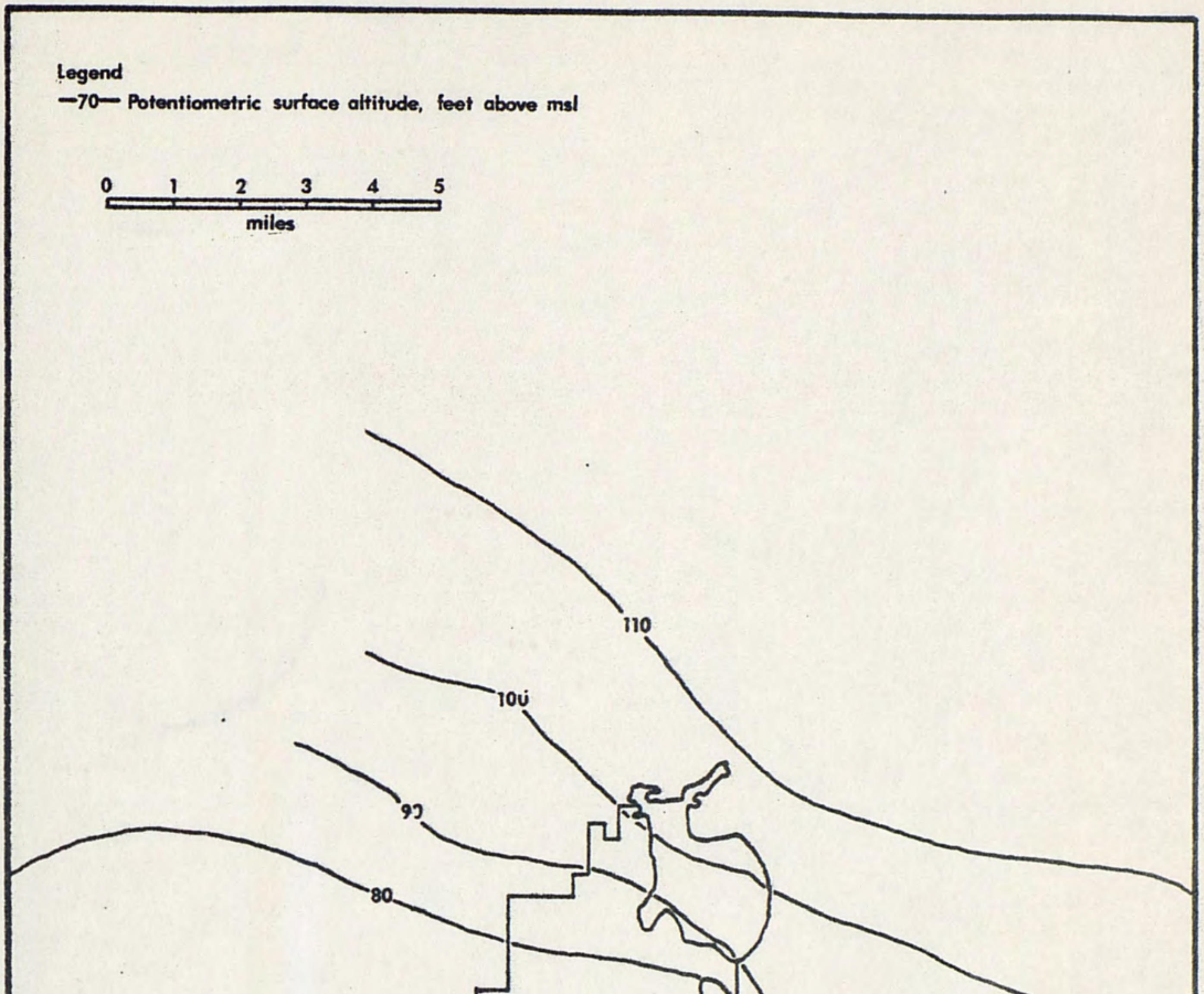

Map 4. Generalized drawdown due to municipal pumpage in Lakeland, 1970

SOURCE: Robertson (1973)



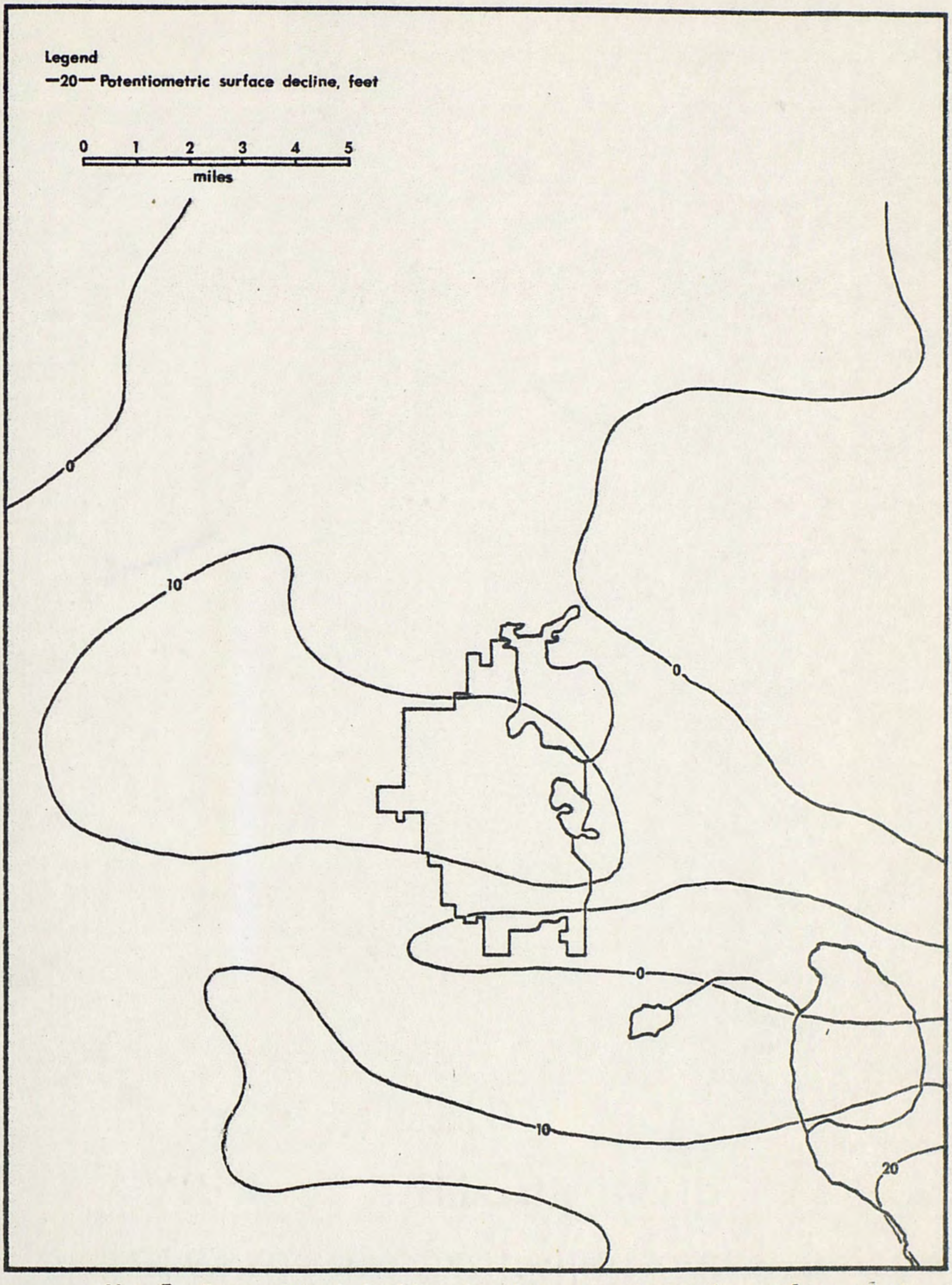

Map 5. Contour of the potentiometric surface of the Floridan aquifer, June 1969.

SOURCE: Williams (1976a)



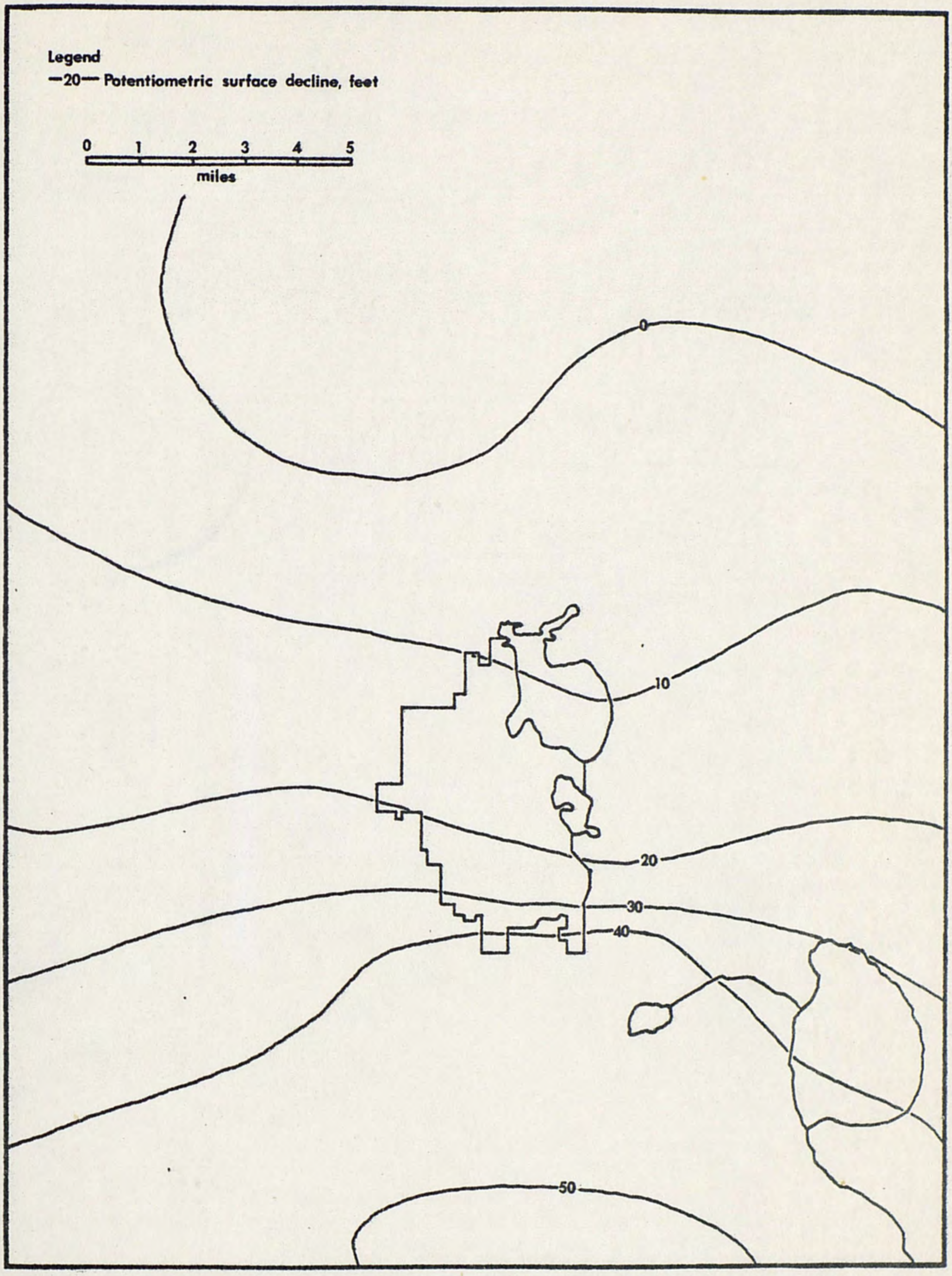

Map 6. Contour of the potentiometric surface of the Floridan aquifer, May 1971.

SOURCE: Robertson (1973)



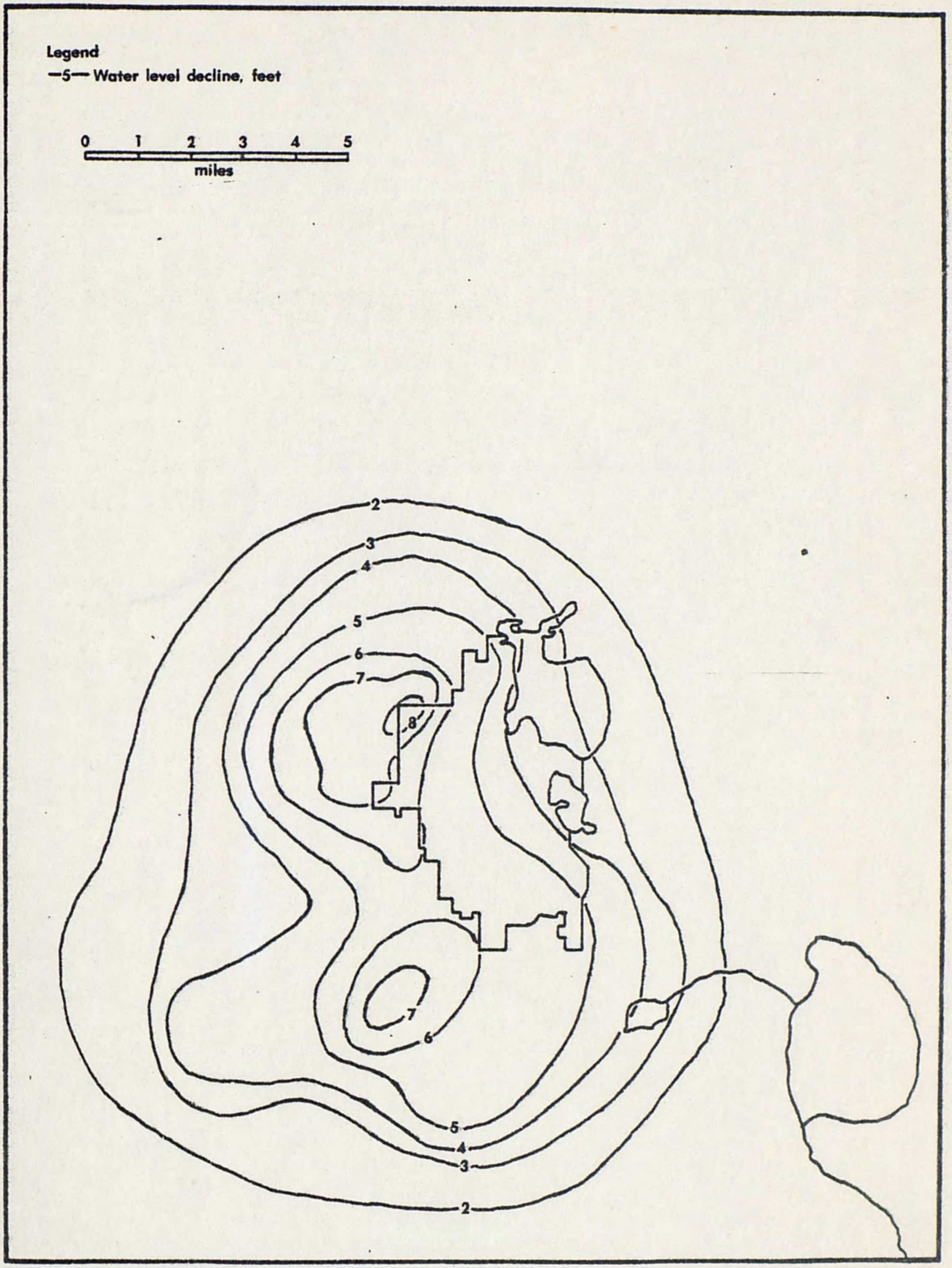

Map 7. Generalized decline in the potentiometric surface of the Floridan aquifer, June 1969 to May 1971.

SOURCE: Robertson (1973)



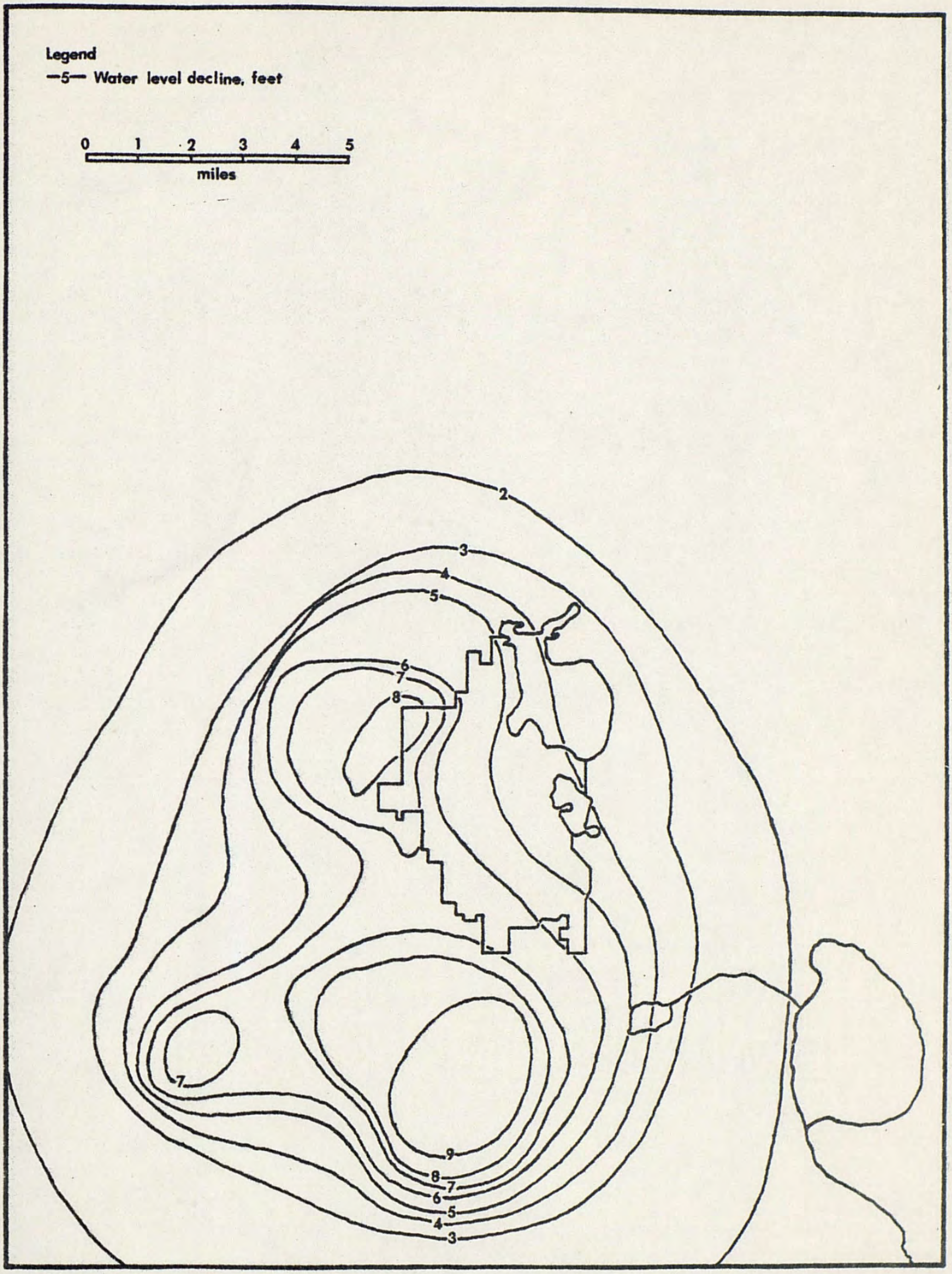

Map 8. Generalized decline in the potentiometric surface of the Floridan aquifer, September 1949 to June 1969.

SOURCE: Robertson (1973)



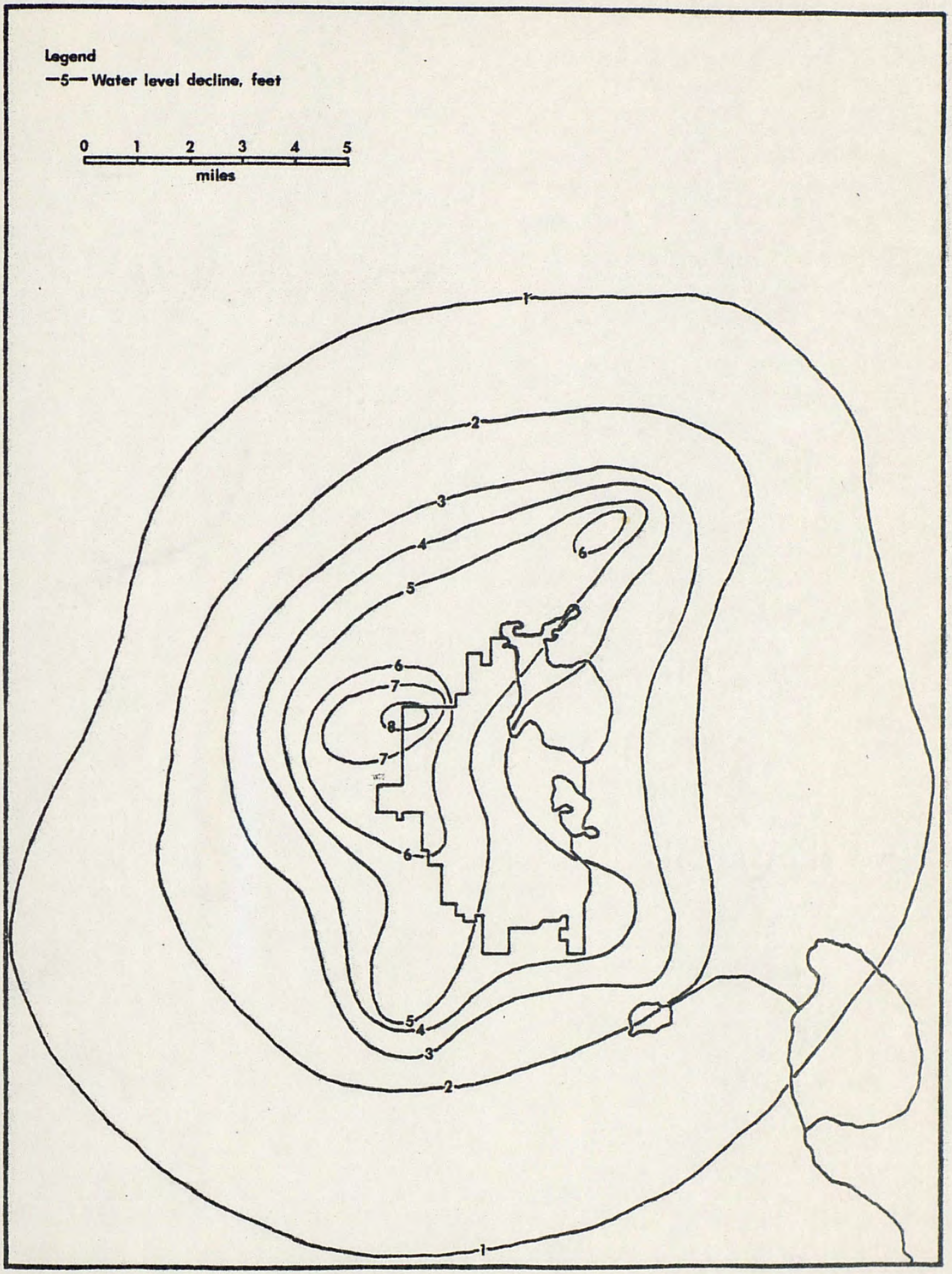

Map 9. Predicted generalized drawdown due to projected municipal pumpage south of Lakeland in 1980.

SOURCE: Robertson (1973)



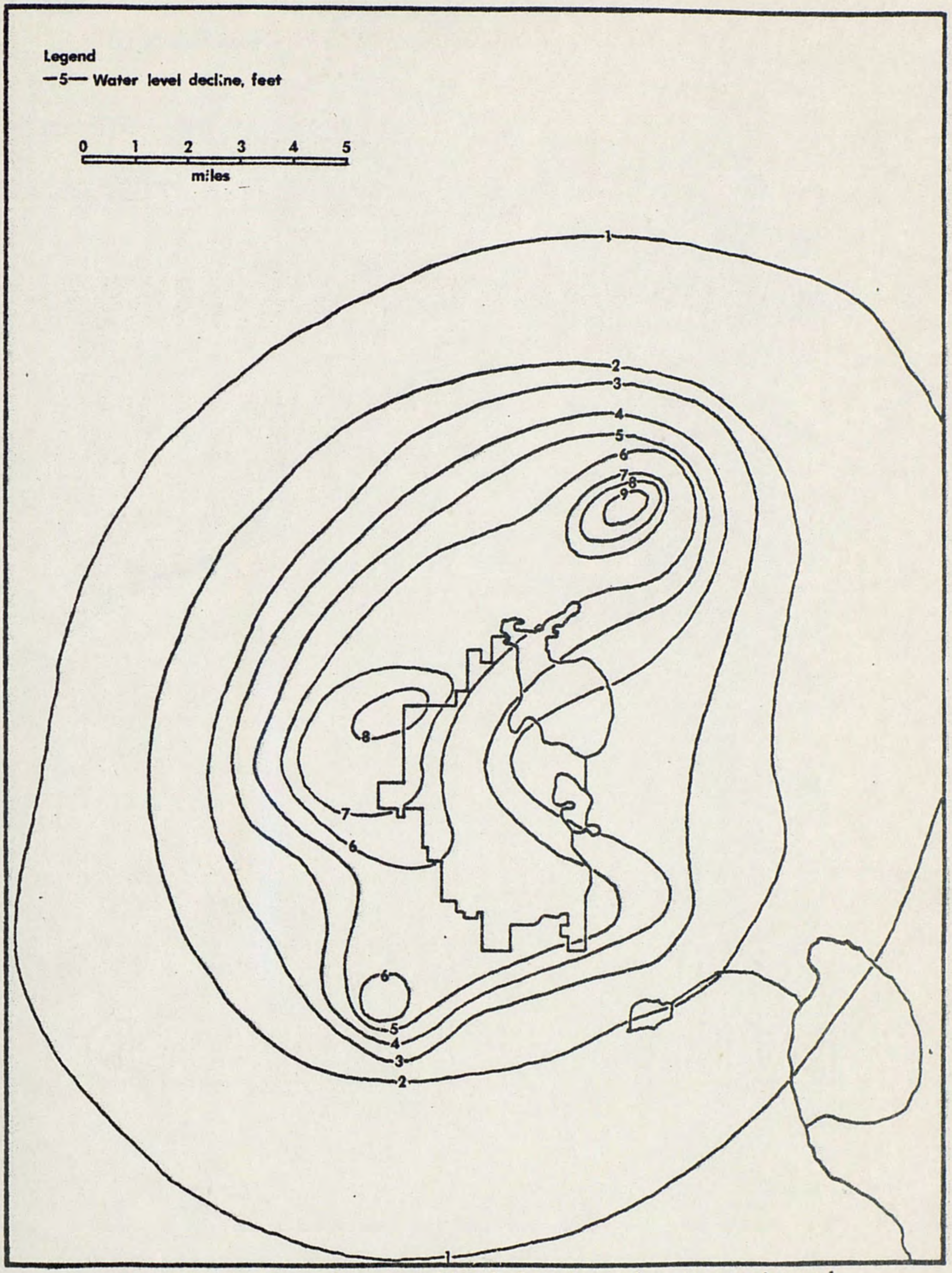

Map 10. Predicted generalized drawdown due to projected municipal pumpage south of Lakeland in 1990.

SOURCE: Robertson (1973)




Map 11. Predicted generalized drawdown due to projected municipal pumpage north of Lakeland in 1980.

SOURCE: Robertson (1973)




Map 12. Predicted generalized drawdown due to projected municipal pumpage north of Lakeland in 1990.

SOURCE: Robertson (1973)

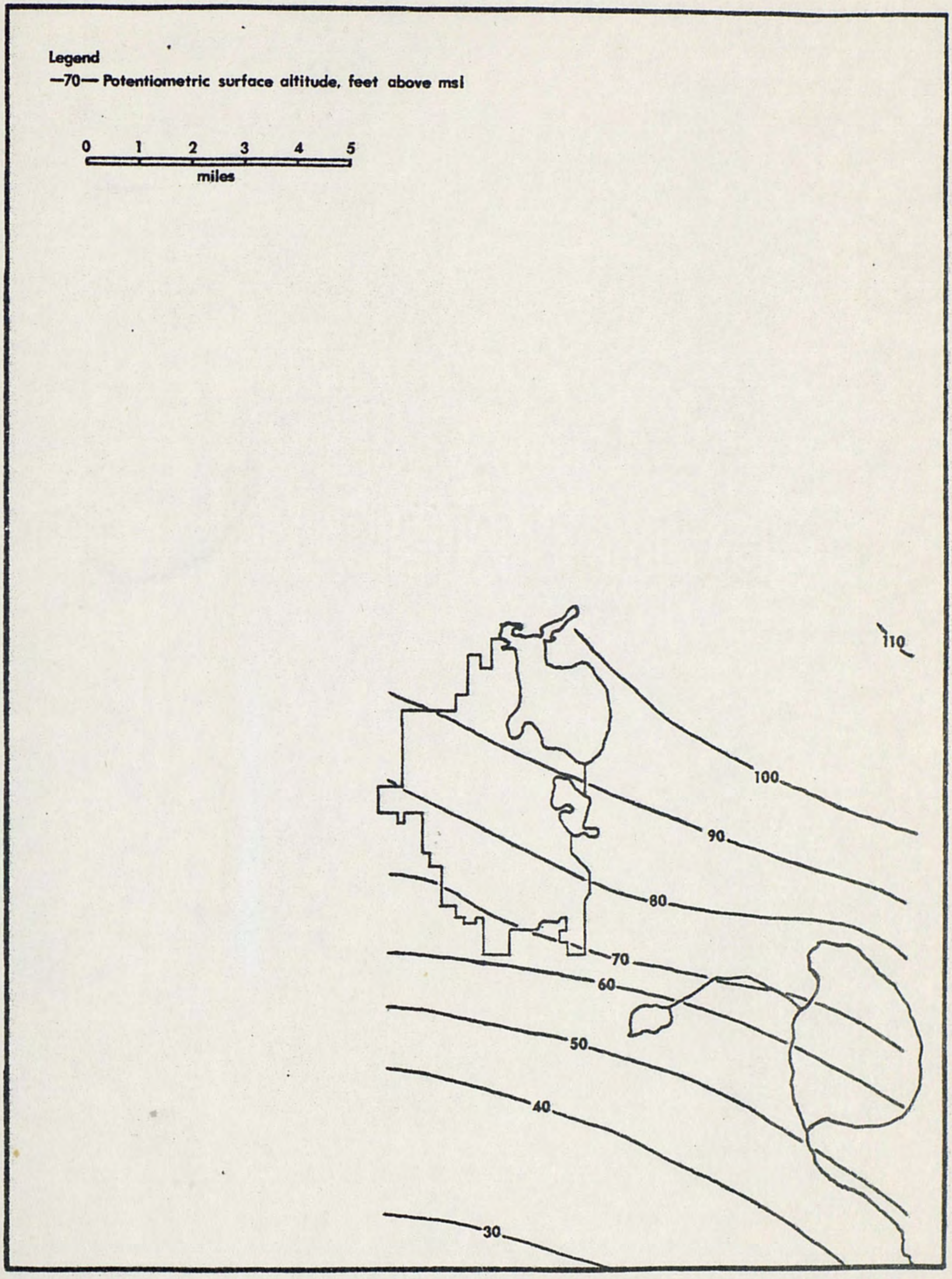
These predicted drawdowns are shown in Maps 11 and 12.

As can be seen from these maps, the projected municipal pumpage will result in an overall decline in the potentiometric surface of the Floridan aquifer of approximately 2 feet over a twenty year period.

Map 13 shows the contour map of the potentiometric surface of the Floridan aquifer in May 1975. Map 14 shows the generalized decline in the potentiometric surface of the aquifer from June, 1969 to May, 1975. These maps are provided to compare the predicted drawdowns in the Floridan aquifer due to Lakeland's municipal pumpage with the actual decline due to total water withdrawal from the aquifer.

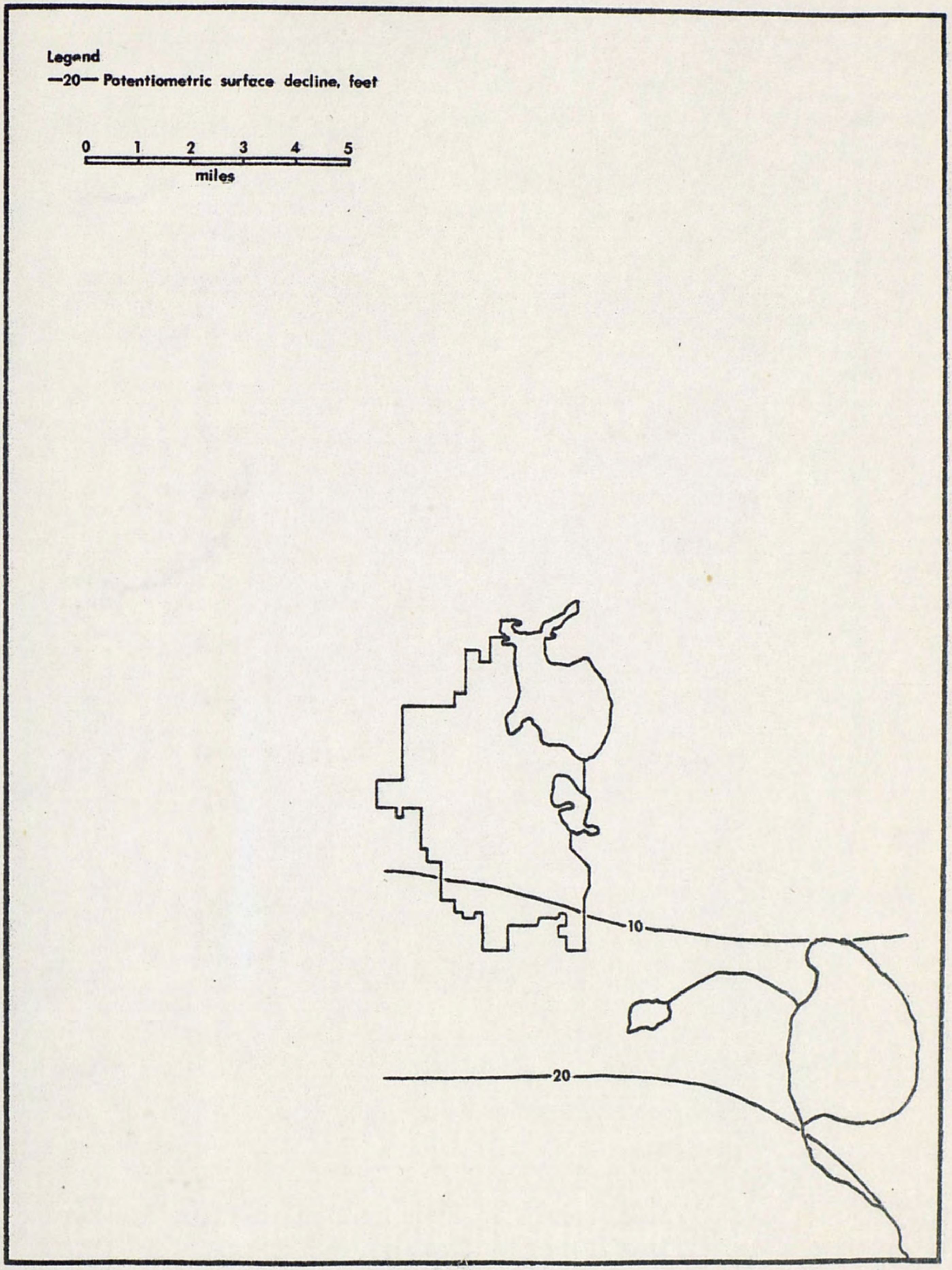
In 1970, total pumpage from the Floridan aquifer in the Lakeland area was approximately 27 billion gallons. Lakeland's municipal pumpage was 5 billion gallons. About 3 billion gallons were used for irrigation, and 1 billion gallons were used for other municipal supplies. The remainder, 18 billion gallons, was consumed by industrial users.

Most of the industrial water usage was by the phosphate industry. As new industries develop, industrial water use may increase. However, this increase may be offset as phosphate deposits in the area become depleted. In addition, the phosphate industry has increased the use of recirculated water from settling ponds in order to reduce its pumpage from the Floridan aquifer. It should be noted that most of the decline in the potentiometric surface of the Floridan aquifer is due to industrial pumpage.




Map 13. Contour of the potentiometric surface of the Floridan aquifer, May 1975.

SOURCE: Williams (1976b)




Map 14. Generalized decline in the potentiometric surface of the Floridan aquifer, June 1969 to May 1975.

SOURCE: Williams (1976b)

Environmental Impact of System

From an aesthetic point of view, the presence of hydrogen sulfide gas in the water from some of the Lakeland wells will have a deleterious impact on the environment. Hydrogen sulfide has a very unpleasant odor when present even in very small concentrations. It also imparts an objectionable taste to the water. The concentration found in the wells has never exceeded 5 mg/liter, well below the toxic threshold for this gas.

The gradual decline of water levels in the Floridan aquifer resulting from high water consumption will have a severe deleterious impact on the environment. Lowered water levels in the Floridan aquifer increase recharge rates to the aquifer in direct proportion to the head differential between the water level in the Floridan aquifer and the higher water levels in the overlying aquifers. The recharge increase supplied by the overlying aquifers, including the water table aquifer, can result in the decline of lake levels in the area.

Another severe deleterious impact on the environment that can result from declining water levels in the Floridan aquifer is the upward movement of highly mineralized water into the aquifer. Pride, Meyer and Cherry (1966) determined that highly mineralized water containing chloride concentrations above 1,000 mg/liter is present in the Lakeland area at depths about 1,500 feet below mean sea level. The depth to this highly mineralized water is related to the level of the less dense fresh water in the aquifer. Declines of the fresh water levels in the aquifer theoretically would allow the highly mineralized

water to move upward, depending on the amount of the water level decline and the vertical permeability of the aquifer and the underlying formations. Based upon the relative densities of fresh water and sea water, a decline of one foot in the fresh water levels would allow the highly mineralized water to move upward 40 feet.

## Conclusions and Recommendations

Chlorination is a solution to the problem of hydrogen sulfide gas in the well water. However, the chemical reaction between chlorine and hydrogen sulfide results in precipitation of elemental sulfur. Aeration is also a solution to the hydrogen sulfide problem. However, the aeration must be conducted under low pH conditions, e.g. 3-4, or hydrogen sulfide will ionize and will not be removed. The efficiency of hydrogen sulfide removal can be enhanced by conducting an initial aeration in an atmosphere containing a higher than normal concentration of carbon dioxide. Since hydrogen sulfide is more soluble in water than carbon dioxide, the latter would be removed first by aeration. By conducting an initial aeration in an atmosphere containing 10% carbon dioxide, the latter will stay in solution. This condition will keep the water pH low and hydrogen sulfide will be removed. Carbon dioxide can then be removed by subsequent aeration.

It is recommended that a central water treatment plant be installed for aeration of the total municipal water supply. Installation of an aerator at each well is not recommended due to lack of space and for aesthetic reasons as well. Many of the wells are located in residential areas. Installation of storage facilities and pumping stations North and South of Lakeland is also recommended.

Unless strict water conservation measures are adopted soon, salt water intrusion into the Floridan aquifer may become a sad reality. It is strongly recommended that water conservation programs being developed by the SWFWMD receive the City of Lakeland's full support.

It is also recommended that the city give some consideration to the possibility of changing the water rate structure. The writer believes that the rate charged for water should increase rather than decrease as consumption increases. This is a personal opinion.

CHAPTER 2

# WASTE WATER COLLECTION, TREATMENT AND DISPOSAL SYSTEM

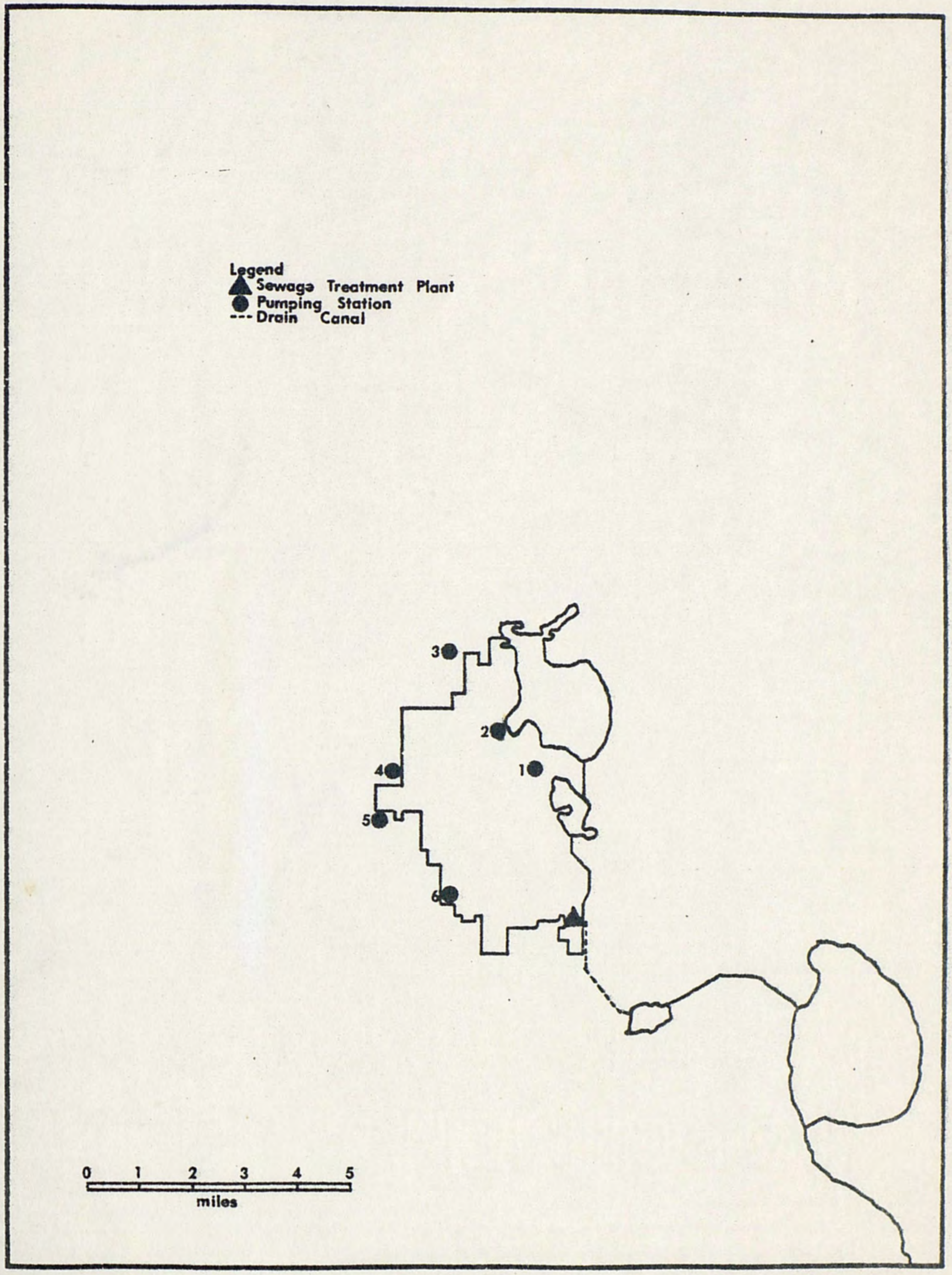
## Description of System

Waste water collection, treatment and disposal in Lakeland is carried out by the Sanitary Sewerage Division of the Department of Public Works.

The Lakeland waste water system serves an area somewhat smaller than that served by the water system. The area served by the latter is shown in Map 3. The boundary lines for the waste water system are not precisely defined. In general, the waste water system has the same boundaries as the water system, but it excludes an area south of Lakeland which is included in the water system. Most of the homes in this area utilize septic tanks for sewage disposal.

Only sanitary sewers are routed to the Lakeland waste water treatment plant. Storm sewers are routed to the many lakes in the city.

The present waste water collection system consists of approximately 225 miles of gravity sewers, ranging in size from 6 inches to 48 inches diameter, that deliver sewage either directly to the treatment plant or to any one of six pumping stations. The location of the pumping stations and the sewage treatment plant is shown in Map 15. The description of the sewage pumping stations is shown in Table 6.




Map 15. Waste water collection, treatment and disposal system, City of Lakeland.

SOURCE: Locke (1977)

TABLE 6

SEWAGE PUMPING STATIONS IN THE LAKELAND WASTE WATER SYSTEM

| Station Number | Station Name | Number of Pumps | Pump Capacity Flow, gpm | Head, ft. | Motor hp |
|---|---|---|---|---|---|
| 1 | Highway 92 | 2 | 1,600 | 62 | 50 |
| 2 | Northeast | 2 | 1,300 | 128 | 75 |
| 3 | Northside | 3 | 1,600 | 96 | 75 |
| 4 | Northwest | 2 | 4,400 | 53 | 100 |
| 5 | Westside | 3 | 900 | 36 | 15 |
| 6 | Southwest | 3 | 4,900 | 54 | 100 |

SOURCE: Locke (1977)

The number of people served by the system is estimated at 63,000. This number has not changed in the last four years. Although the population of the City of Lakeland has increased during this period, the increase has taken place in areas not connected to the sewer system. The measured daily influent flow to the sewage treatment plant for the last three years has averaged 5.96, 5.64 and 5.72 mgd. The average per capita flow is 92 gpd, which is very near the national average of 100 gpcd cited in Fair, Geyer and Okun (1966). Figure 3 shows the monthly fluctuation in sewage flow in 1976.

The present sewage treatment plant was installed in 1960. It is a trickling filter plant designed for 85% $BOD_5$ and suspended solids removal, and its design capacity is 8 mgd. In 1976, the actual flow to the plant was 5.72 mgd, and a 91% removal of both $BOD_5$ and suspended solids was achieved. $BOD_5$ and suspended solids concentrations in the plant influent averaged 180 and 160 mg/liter. The $BOD_5$ and suspended solids concentrations in the plant effluent averaged 16 and 15 mg/liter.

A flow diagram of the sewage treatment plant is shown in Figure 4. The plant consists of two parallel comminutors with a bypass bar screen, an inlet Parshall flume, a pumping station, an aerated grit removal chamber, two parallel primary clarifiers, two parallel high-rate trickling filters, a pumping station, two parallel secondary clarifiers, an outlet Parshall flume, an aerobic stabilization pond, two parallel open-top anaerobic digesters, and five sludge drying beds.

Raw sewage flows by gravity through two comminutors. The comminutors are 25 inch diameter shredders. Either or both comminutors can be bypassed through a bar screen. The latter has a face area of

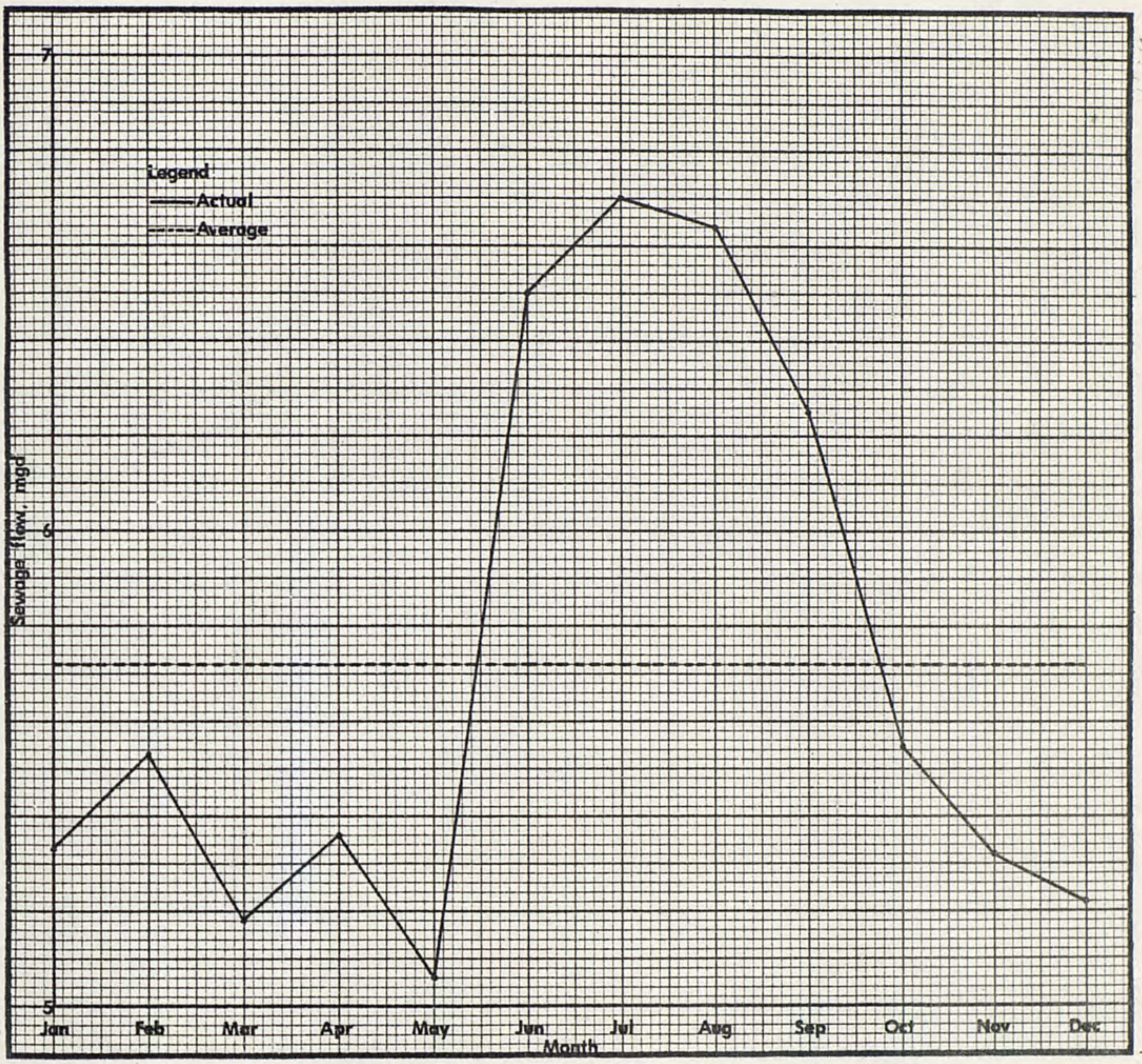



Fig. 3. Monthly sewage flow in Lakeland, 1976

SOURCE: Locke (1977)

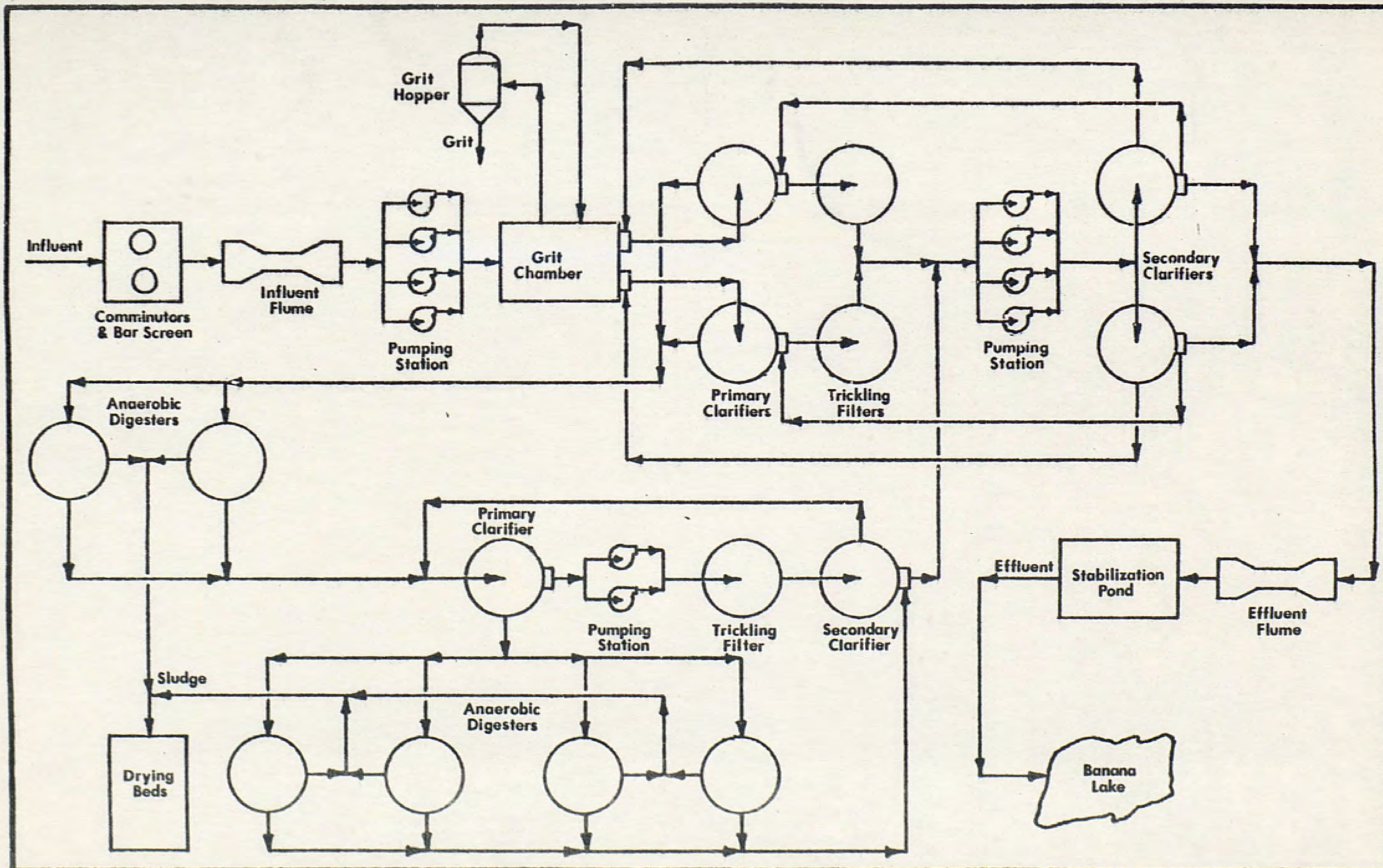



Fig. 4. City of Lakeland sewage treatment plant flow diagram

SOURCE: Locke (1977)

32 square feet, a slope of 60° from the horizontal and 1-1/2 by 3/4 inch openings. The comminutors and bar screen are shown in Photograph 5.

Raw sewage from the comminutors flows by gravity through a Parshall flume for flow measurement. From the flume, raw sewage is lifted by a pumping station to an aerated grit removal chamber. The pumping station consists of two main 4,500 gpm pumps and two auxiliary 2,500 gpm pumps.

In the grit chamber, two air diffusers induce a spiral flow pattern in the sewage entering the chamber. The velocity of roll is controlled by regulating the flow rate of diffusion air. Air is supplied by two rotary blowers. Grit collected in the hopper is pumped by two water driven jet type mud eductors to a cone bottom holding tank. Motive water overflows from the holding tank to the grit chamber. The holding tank is periodically emptied into a truck, and the grit is taken to a sanitary landfill and buried. Grit removed from the raw sewage amounts to 0.37 cu. ft./mg. An overall view of the chamber is shown in Photograph 6. A top view of the chamber showing the flow pattern induced by the air diffusers is shown in Photograph 7.

Sewage from the grit chamber flows by gravity to the primary clarifiers. The primary clarifiers are circular with center feed and peripheral outlet, and are equipped with scum removal mechanisms. Both primary clarifiers are 85 feet diameter and 9 feet deep, and are operated at an average overflow rate of 750 gsfd, which is within the

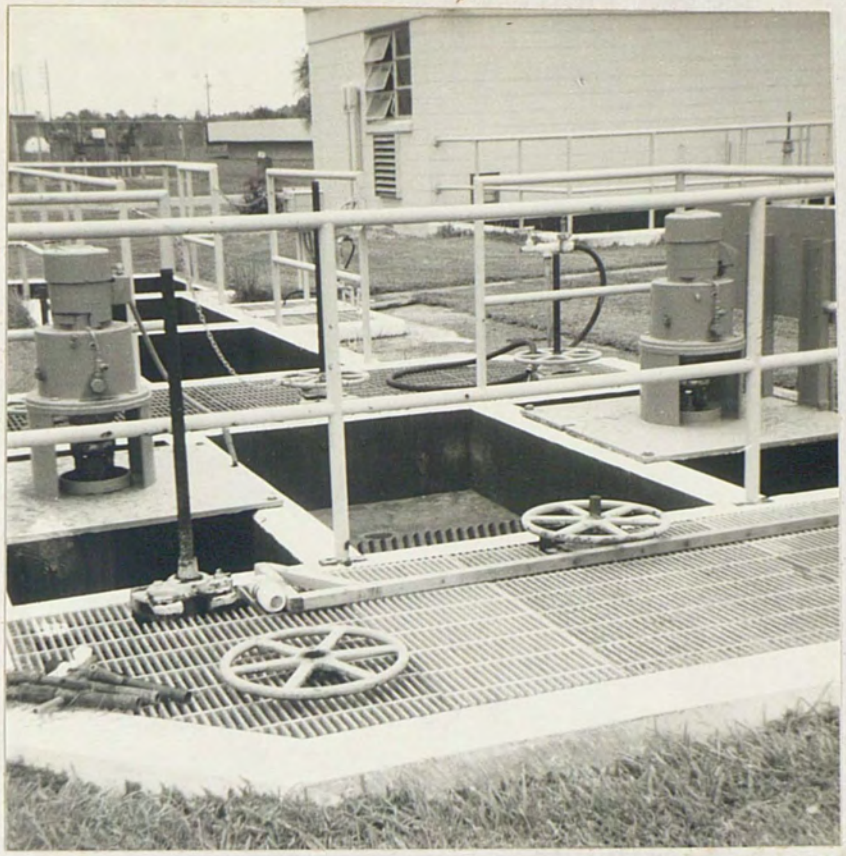


Photo. 5. Comminutors and bypass bar screen

Photo. 6. Aerated grit removal chamber

Photo. 7. Flow pattern in grit chamber

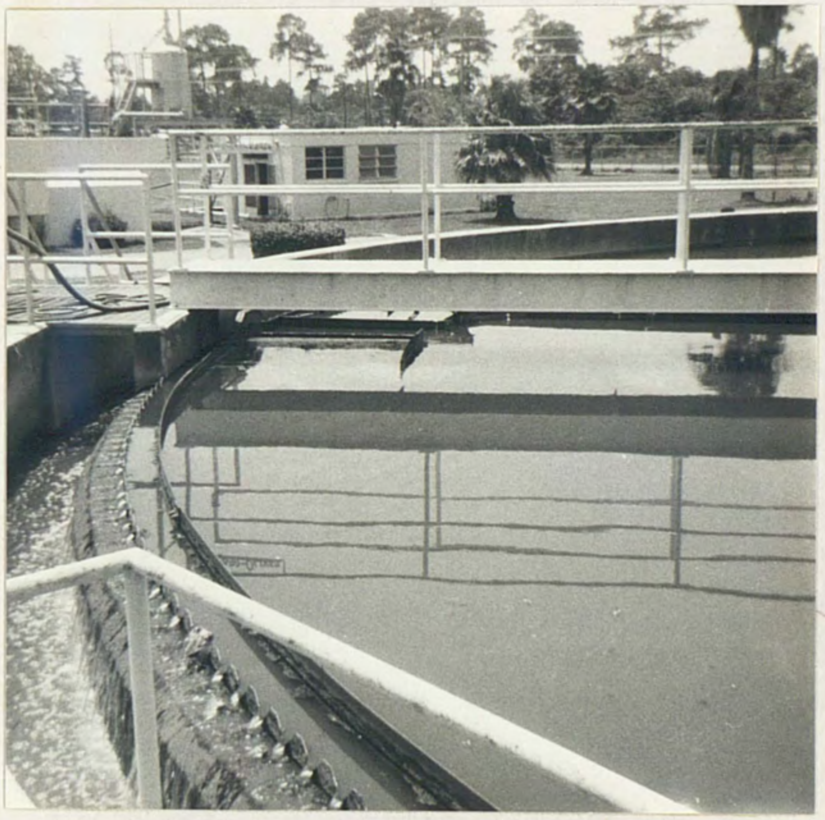


Photo. 8. Primary clarifier with scum removal mechanism.

range specified by the ASCE sewage treatment plant design manual (1959). The clarifiers remove 60% of the applied suspended solids and 51% of the applied $BOD_5$. Settled sewage overflowing from the primary clarifiers flows by gravity to the trickling filters. The underflow sludge, containing approximately 3-4% solids, is pumped to the sludge digesters. One of the clarifiers is shown in Photograph 8.

Settled sewage from the primary clarifiers is combined with recycled overflow from the secondary clarifiers and is treated in two high-rate trickling filters. Both filters are 145 feet diameter and are packed with 4-1/2 feet of South Carolina granite ranging in size from 2 to 4 inches. The hydraulic load applied to each filter is 15 mgad. The organic load applied to each filter is 1,560 pafd or 36 ptcfd. Both the hydraulic and organic loads are within the ranges recommended by the ASCE sewage treatment plant design manual (1959). The trickling filters remove 43% of the applied $BOD_5$. The NRC formula in the ASCE sewage treatment plant design manual (1959) predicts a $BOD_5$ removal efficiency of 79%. The Eckenfelder formula (1966) predicts a $BOD_5$ removal efficiency of 64% for the filters. A partial view of one of the trickling filters and one of the secondary clarifiers is shown in Photograph 9.

Treated sewage from the filters is lifted by a pumping station to the secondary clarifiers. The pumping station consists of two main 4,500 gpm pumps and two auxiliary 2,500 gpm pumps.

The secondary clarifiers are 85 feet diameter and 9 feet deep, and are operated at an overflow rate of 750 gsfd. Secondary clarifier

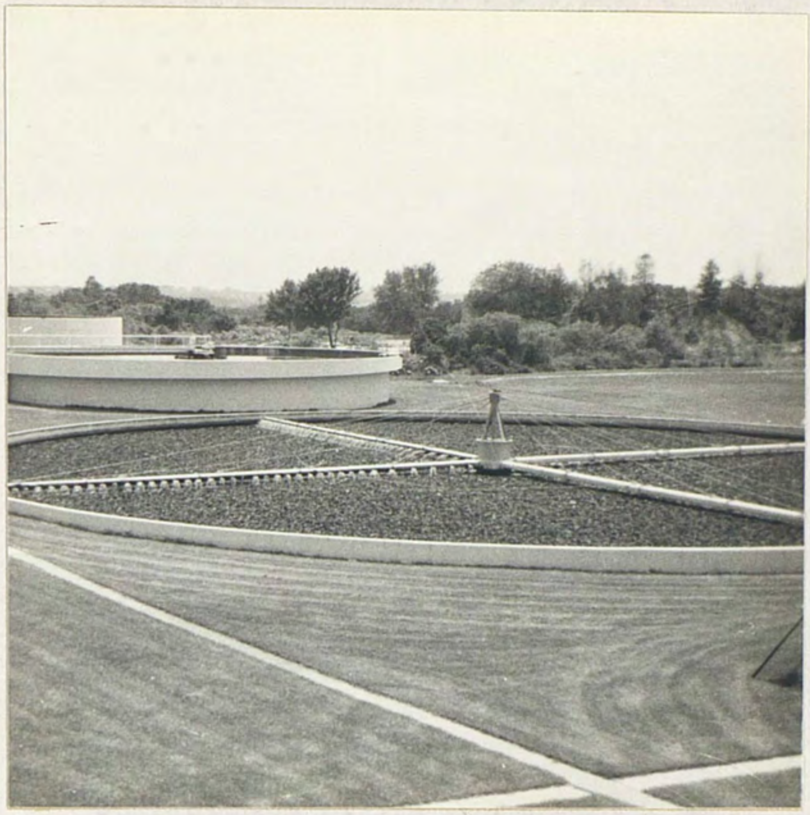


Photo. 9. Trickling filter and secondary clarifier.

Photo. 10. Aerobic stabilization pond

overflow is recycled to the trickling filter inlet at a recycle ratio of 1/2 the influent flow. Secondary clarifier underflow is recycled to the primary clarifier inlet at a recycle ratio of 1/2 the influent flow.

Combined effluent from the secondary clarifiers flows by gravity through a Parshall flume for flow measurement. The effluent is also chlorinated at this point.

From the flume, effluent flows by gravity to an aerobic stabilization pond. The pond is 3 feet deep and has an area of 25 acres. The retention time at design flow of 8 mgd is 3 days. The average organic loading is approximately 60 pad, well within the range given in the ASCE sewage treatment plant design manual (1959). A 50% reduction in $BOD_5$ is achieved in the pond. Pond effluent flows by gravity through a discharge canal to Banana Lake. Banana Lake is used for irrigation only, and drains to Hancock Lake. The latter forms the headwaters of the Peace River. A partial view of the pond is shown in Photograph 10.

Primary clarifier sludge is treated in two open-top anaerobic digesters. The digesters are 85 feet diameter and 20 feet deep. Gas produced in the digesters is not collected, since it is not necessary to heat the sludge to provide mesophilic operation in the digesters. The retention time in the digesters is 75 days. The capacity available in the digesters is 16 cfpd. The ASCE sewage treatment plant design manual (1959) predicts a 50% reduction in volatile matter for the digesters based on the above parameters. However, only a 10% reduction is achieved. A 500 gpm pump is used intermittently to recycle supernatant to the top of the digester to break up scum. A view of one of

the digesters is shown in Photograph 11.

Digested sludge from the digesters, containing 6-8% solids, flows by gravity to sludge drying beds. The area of the beds is 24,000 square feet. The beds are underlain by 24 inches of sand, 12 inches of gravel, and 12 inches of drain tile. The solids load applied to the beds is approximately 200 psfy. The sludge is applied in 10-12 inch "lifts." This loading is much greater than the range given in the ASCE sewage treatment plant design manual (1959), however, the manual stresses that said loadings are required only for northern climes. Dry sludge from the beds is given away to area farmers. A partial view of the sludge drying beds is shown in Photograph 12.

The digester supernatant is processed through an existing, older sewage treatment plant, which is located adjacent to the present plant. The old plant was installed in 1948 and is rated at 2 mgd. It has not been used for raw sewage since the new plant was installed, however, it is available for emergency purposes.

The old sewage treatment plant consists of:

1. One primary clarifier, 70 feet diameter, 8 feet deep
2. One trickling filter, 90 feet diameter, 6 feet media
3. One secondary clarifier, 70 feet diameter, 8 feet deep
4. Four anaerobic digesters, each 48 feet diameter, 16 feet deep

As in the main plant, the secondary clarifier underflow is recycled to the primary clarifier. The secondary clarifier effluent is recycled to the main plant secondary clarifier inlet. The primary clarifier sludge flows to the anaerobic digesters. Digested sludge flows to the sludge drying beds. Digester supernatant flows to the

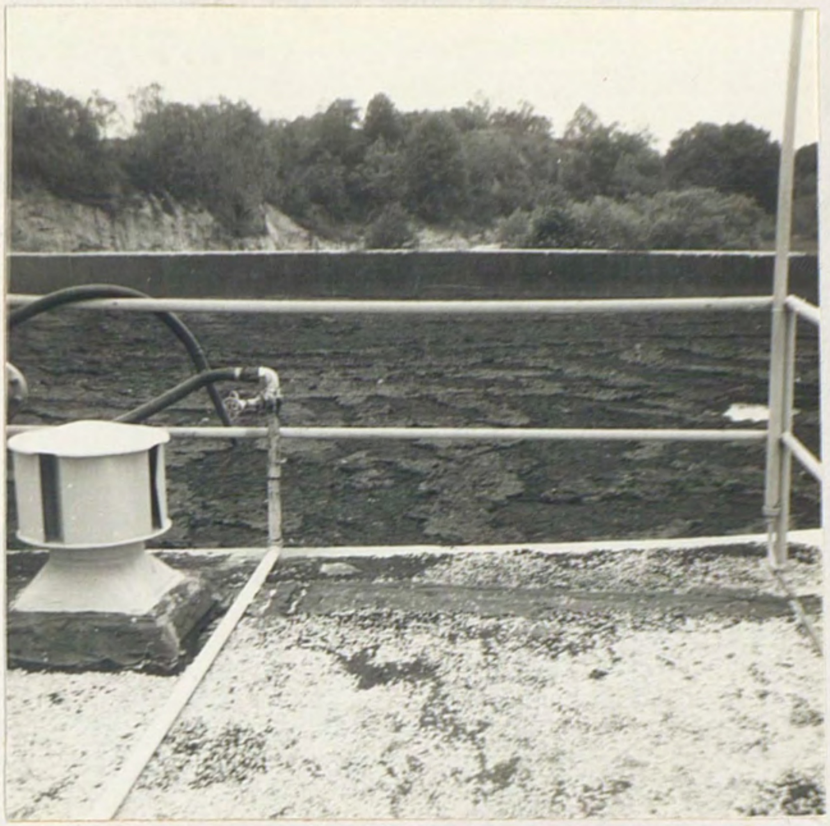


Photo. 11. Open top anaerobic sludge digester.

Photo. 12. Sludge drying beds

main plant primary clarifier inlet.

## Environmental Impact of System

The waste water collection, treatment and disposal system of the City of Lakeland has very little deleterious impact, if any, on the environment. The sewage treatment plant itself is a very clean plant, with little or no odor discernible. The trickling filters are remarkably free of insects. In personal interviews with nearby residents, few complaints were heard.

The three effluents from the sewage treatment plant are handled quite well. One of the effluents, dried sludge, actually has a beneficial impact on the environment, as it is used as a natural fertilizer by local farmers. The other solid effluent, grit, is buried in a sanitary landfill with little or no deleterious impact on the environment, as it represents an insignificant fraction of the total solid waste buried in the landfill.

The liquid effluent also has a beneficial impact on the environment, as it is used for irrigation in the citrus groves and other local crops. As previously mentioned, the stabilization pond effluent flows into a drain canal, where it is diluted by a 4-1/2 to 1 ratio, before flowing into Banana Lake. The lake water is used for irrigation purposes only. The pond effluent is of good quality, as can be seen from the following characteristics: (1) very low $BOD_5$ and suspended solids concentrations of 16 and 15 mg/liter respectively, (2) a fecal coliform count of 0-10/100 ml, (3) a pH of 7.7, and (4) a dissolved oxygen content which is always at or near saturation and which will occasionally increase above saturation as a result of the algal

activity in the pond. This dissolved oxygen level, of course, does not produce a sag in the receiving body of water.

## Conclusions and Recommendations

The waste water collection, treatment and disposal system of the City of Lakeland has no deleterious impact on the environment. In fact the system has a beneficial impact on the environment, since two of the three effluents are used advantageously in agricultural enterprises.

The sewage treatment plant can accept a total raw sewage flow of 10 mgd. At present, the actual flow is 5.7 mgd. Since the population served by the waste water system appears to have reached a saturation level, capacity should be more than adequate for the next 15 years.

# CHAPTER 3

# ELECTRIC POWER GENERATION AND DISTRIBUTION SYSTEM

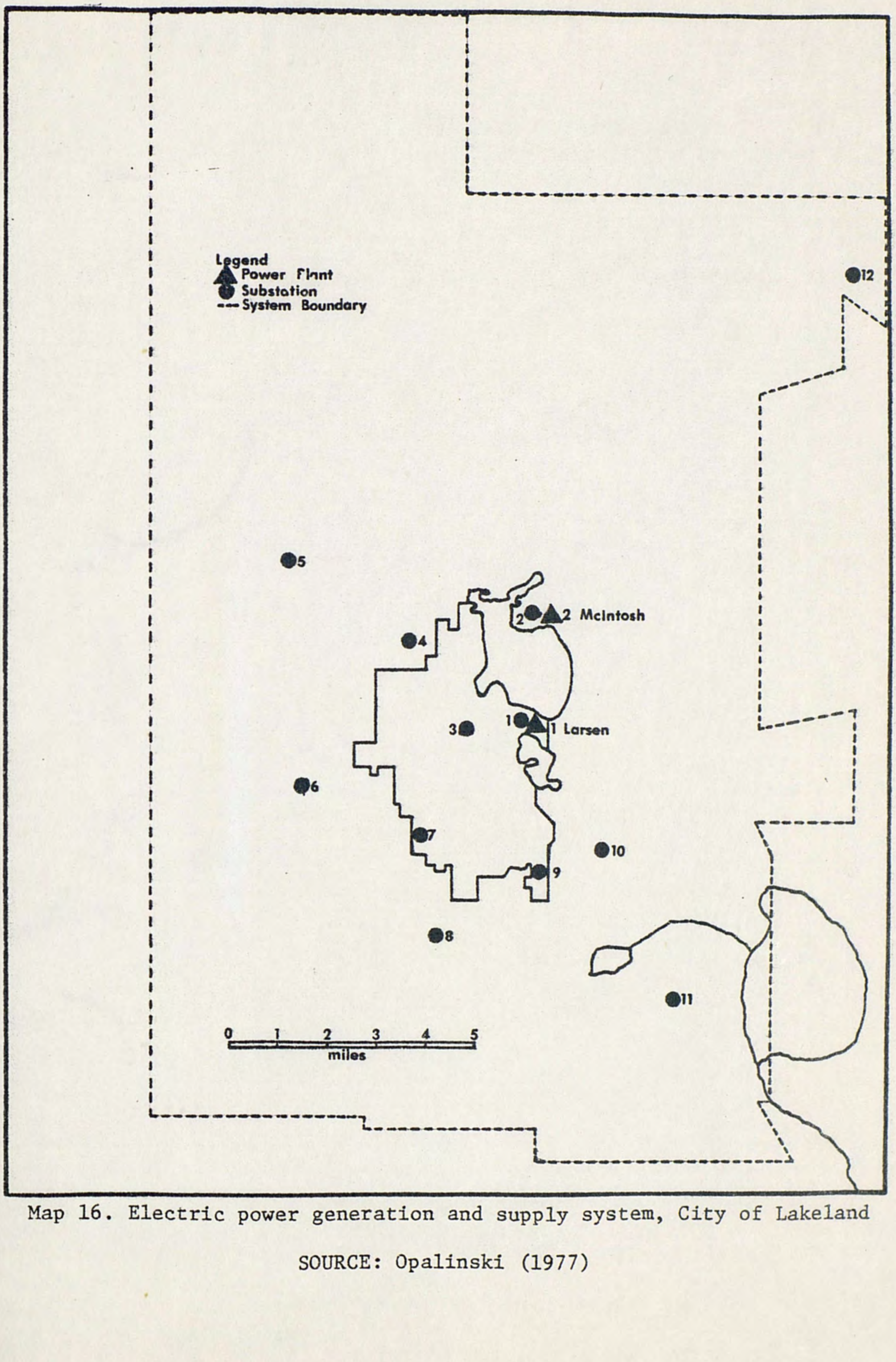
## Description of the System

The City of Lakeland provides electric power not only to the greater Lakeland area, but also to the nearby communities of Eaton Park, Highland City and Polk City. The boundary lines of the power system are shown in Map 16. An area of approximately 260 square miles is covered by the power system. The Lakeland power generation system is operated by the Power Generating Division of the Department of Electric and Water Utilities.

There are two power generating stations in Lakeland, the Charles Larsen Power Plant and the Dan McIntosh Power Plant. The location of both plants is also shown in Map 16.

The existing power generating facilities consist of six steam generating units, four gas turbine units and two diesel engine units. The power generating capacity of each unit is shown in Table 7. It should be mentioned that the capacities of the steam generating units shown in the table are summer capacities. Higher capacities can be achieved in winter as a result of colder cooling water availablility.

The Larsen plant is the older of the two. The first unit at Larsen was installed in 1950 and the last one in 1966. The first unit at McIntosh was installed in 1970 and the second one in 1975.




Map 16. Electric power generation and supply system, City of Lakeland

SOURCE: Opalinski (1977)

TABLE 7

POWER GENERATING UNITS IN THE LAKELAND POWER SYSTEM

| Unit Number | Unit Type | Capacity, Megawatts | Heating Rate Btu/kWhr |
|---|---|---|---|
| | Larsen Power Plant | | |
| 4 | Steam | 20 | 15,100 |
| 5 | Steam | 25 | 12,900 |
| 6 | Steam | 25 | 13,800 |
| 7 | Steam | 45 | 11,800 |
| . | Gas turbine #1 | 11.25 | 23,100 |
| . | Gas turbine #2 | 11.25 | 23,100 |
| . | Gas turbine #3 | 11.25 | 23,100 |
| | McIntosh Power Plant | | |
| 1 | Steam | 90 | 10,600 |
| 2 | Steam | 125 | 10,900 |
| . | Gas turbine | 20 | 15,700 |
| . | Diesel engine #1 | 2.75 | 10,300 |
| . | Diesel engine #2 | 2.75 | 10,300 |

SOURCE: Opalinski (1977)

The steam generating units are utilized to carry the base electric load or demand. The gas turbine and diesel engine units are utilized to carry peak electric load during heavy demand periods of the day. Table 8 shows the number of hours each unit operated in 1976, as well as the average load each unit carried while it was operating.

It will be noted that Unit 4 did not operate at all in 1976. This is the oldest unit in the system. It is also the most inefficient unit in the system, exclusive of the gas turbine power generating units. The unit was not required to operate as a base load unit in 1976. This would have been necessary only if two or more of the other steam generating units had been shut down for scheduled or emergency maintenance. It is planned to retire Unit 4 in 1981.

Power generated by the units is transmitted from the two main stations through 58 miles of 69,000 volt transmission lines to ten substations. From the substations, 927 miles of 12,000 volt and 4,000 volt overhead lines and 16 miles of underground lines distribute power to the system. The location of the substations is shown in Map 16. The load capacity of each substation is shown in Table 9.

Electric power demand on the Lakeland system is growing at a rapid pace. Figure 5 shows the actual total and residential power consumption for the last ten years and comparable projected figures for the next ten years. Figure 6 shows ten year actual and ten year projected figures for the number of residential customers (households) served by the system and the yearly power consumption per customer. It should be noted that the 1976 yearly power consumption per customer in

TABLE 8

1976 PERFORMANCE OF THE GENERATING UNITS IN THE LAKELAND POWER SYSTEM

| Unit Number | Hours Operated | Average Load, Megawatts |
| --- | --- | --- |
| Larsen Power Plant | | |
| 4 | 0 | 0 |
| 5 | 2,012 | 21 |
| 6 | 879 | 21 |
| 7 | 5,919 | 44 |
| Gas turbine #1 | 384 | 9 |
| Gas turbine #2 | 384 | 9 |
| Gas turbine #3 | 384 | 9 |
| McIntosh Power Plant | | |
| 1 | 6,872 | 62 |
| 2 | 8,525 | 72 |
| Gas turbine | 261 | 20 |
| Diesel engine #1 | 328 | 2.5 |
| Diesel engine #2 | 328 | 2.5 |

SOURCE: Opalinski (1977)

TABLE 9

POWER TRANSMISSION SUBSTATIONS
IN THE LAKELAND POWER SYSTEM

| Substation Number | Substation Name | Capacity, Megawatts |
|---|---|---|
| 3 | Lake Mirror | 20 |
| 4 | Northwest | 40 |
| 5 | Galloway | 40 |
| 6 | West | 40 |
| 7 | Southwest | 40 |
| 8 | Medulla | 40 |
| 9 | Glendale | 20 |
| 10 | Eaton Park | 40 |
| 11 | Highland City | 40 |
| 12 | Polk City | 20 |

SOURCE: Opalinski (1977)

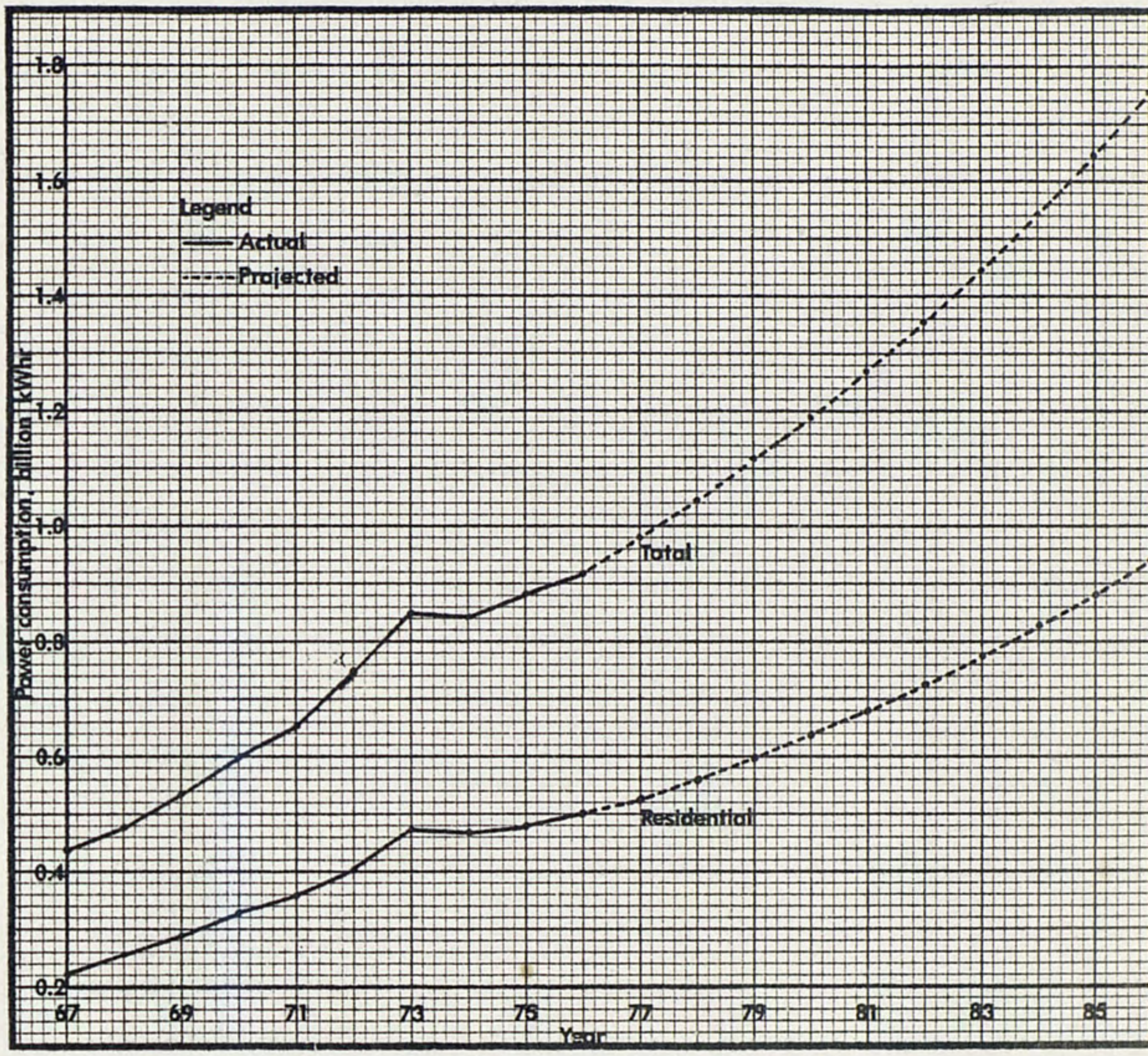



Fig. 5. Annual total and residential power consumption in Lakeland, 1967 to 1986.

SOURCE: Opalinski (1977)

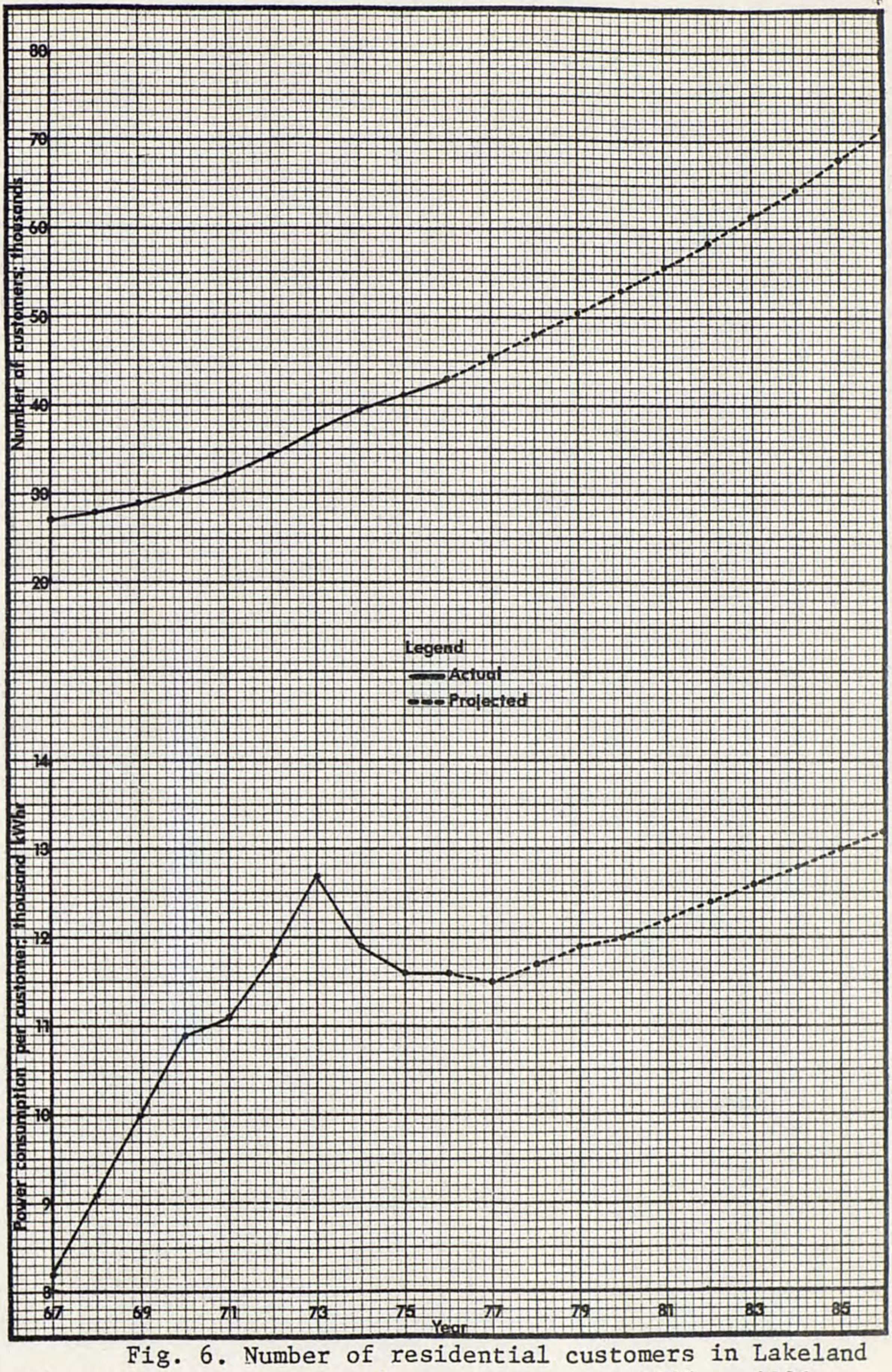



Fig. 6. Number of residential customers in Lakeland and annual power consumption per customer, 1967 to 1986.

SOURCE: Opalinski (1977)

Lakeland of 11,600 kWhr is almost 50% above the national average. Figures 7 and 8 show the average daily power load and average monthly power consumption in 1976. The average daily power load curve is very useful to the power plant operating personnel, as it enables them to determine when peak load units should be started up. The average monthly power consumption curve is also very useful, as it enables power plant operating personnel to determine when a base load unit can be shut down for annual inspection.

The present total power generating capacity of the Lakeland system is 330 megawatts base load and 60 megawatts peak load. In addition, there is an 80 megawatts capacity tie-in to the Tampa Electric Company power system for emergency back-up power. The highest peak load imposed to date on the system was 292 megawatts registered in January 1977 when a record cold wave was experienced in the City of Lakeland.

As can be seen in Figure 7, the average daily load on the Lakeland system in 1976 was 115 megawatts. The average daily peak load was 135 megawatts. These loads are expected to increase to 210 and 280 megawatts respectively by 1986. It is desirable to have an installed base load power generating capacity of 200% of the average daily peak load. For this reason, the City of Lakeland is presently planning to retire the 20 megawatts Unit 4 and add a 250 megawatts base load unit to the generating system in 1981. This would result in a total base load generating capacity of 560 megawatts, which is 200% of the projected average daily peak load in 1986.

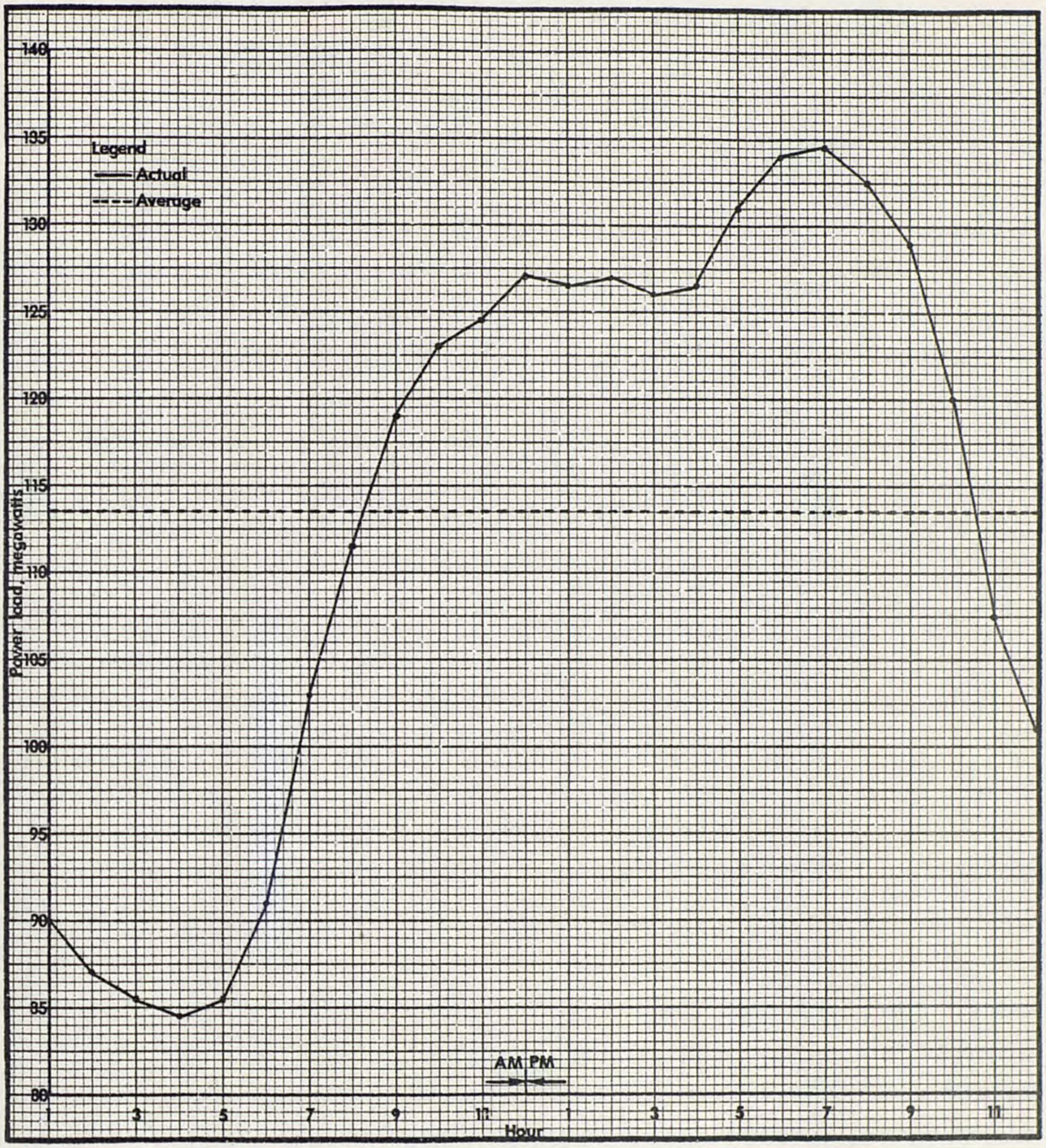



Fig. 7. Average daily power load in Lakeland, 1976

SOURCE: Opalinski (1977)

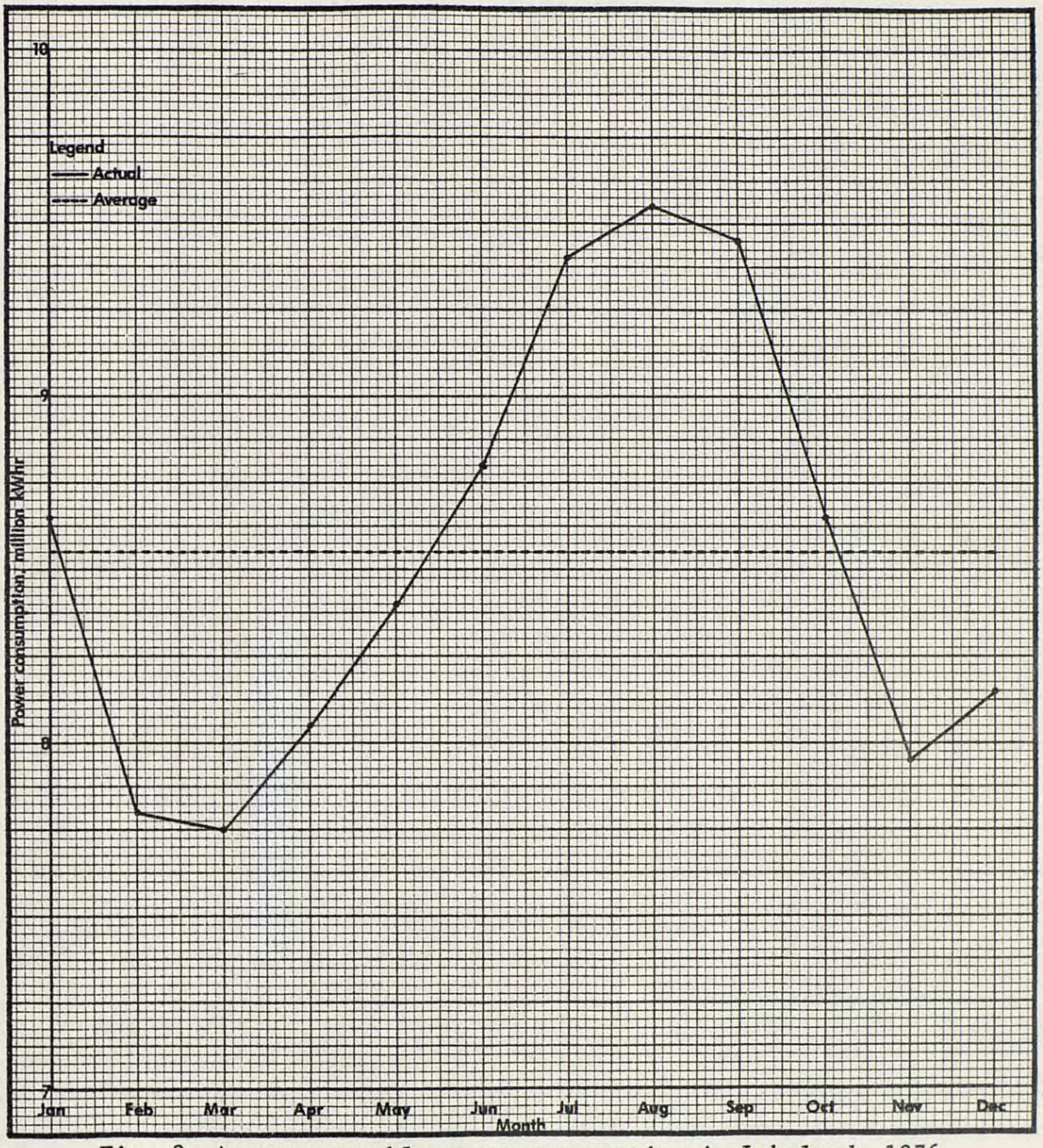



Fig. 8. Average monthly power consumption in Lakeland, 1976

SOURCE: Opalinski (1977)

At present, all units in the Lakeland power system are fuel oil fired units. Natural gas is also used as fuel whenever available due to its lower cost, but only 0.3% of the total heat input to the units in 1976 was provided by natural gas. The planned addition to the system will be a coal fired unit. The reason for changing to a coal fired unit is the recently enacted Federal regulation forbidding the construction of new fuel oil or natural gas fired power plants.

There is usually only one type of effluent from a gas turbine or diesel engine unit, and that is a gaseous effluent resulting from the combustion of fuel. Combustion of fuel will result in atmospheric emissions of gaseous sulfur and nitrogen oxides and solid particulate such as fly ash or oil soot. All of these emissions result in air pollution.

There are two types of effluents from fuel oil or natural gas fired steam generating units. One is the gaseous effluent resulting from the combustion of fuel for steam generation. The other is a liquid effluent that can result from a combination of several sources. These sources are listed below and then discussed:

1. Cooling water from the steam turbine condenser
2. Cooling water from other types of cooling systems
3. Blowdown from a "closed" circuit cooling system
4. Blowdown from the boiler water closed circuit
5. Blowdown from the regeneration of water demineralizers
6. Boiler drain water
7. Boiler wash water
8. Combustion chamber wash water

9. Air preheater wash water

Type 1 liquid effluent is a continuous stream. Steam turbine condenser cooling water is by far the largest single liquid effluent from a steam generating unit. This cooling water does not pick up chemical contaminants. However, it does return to its source at a higher temperature, and this may result in thermal pollution.

Type 2 effluents are also continuous streams. However, they are much smaller in volume than type 1, e.g., typically about 5%. Type 2 effluents can be turbine bearing cooling water, air compressor cooling water, etc. Like type 1, these cooling water streams do not pick up any appreciable contamination. A small amount of lube oil may be present. Also like type 1, they do return to their source at a higher temperature. However, the flow is usually so small that it will not result in thermal pollution.

Type 3 effluent is also a continuous stream. A closed circuit cooling system will be either a cooling tower or a cooling pond. Both systems use the same principle, that is, cooling of the circulating stream by ambient air as a result of evaporation of water into the air. A cooling tower will occupy considerably less space than a cooling pond. The volume of a cooling tower or cooling pond blowdown stream is typically about 0.5% of the volume of the circulating stream. Therefore, although it will be at the same temperature as the circulating stream -- a few degrees above ambient -- it will not cause thermal pollution like the circulating stream would. These blowdown streams also contain a fairly high concentration of dissolved solids, e.g., typically 6 times greater than surface water or ground water supplies. However, these

solids were originally present in the make-up water supplied to the cooling circuit. Therefore, they are only being returned to their original source and should not be deemed to cause water pollution. There are some contaminants present in closed cooling circuit blowdown streams. These are compounds added to the cooling circuit to prevent corrosion or scaling in the cooling water users. These contaminants are present only in trace amounts and will not cause water pollution.

Type 4 effluent is also a continuous stream. It is also the smallest in volume of all the continuous effluents from a steam generating unit. Boiler blowdown is very hot -- it is boiling water -- and contains a high concentration of undissolved solids and trace amounts of dissolved solids. Boiler blowdown streams are very small and must be cooled to a safe temperature, e.g., 120°F, before being discharged as an effluent. For these reasons, it will not cause thermal pollution. Like closed cooling circuit blowdown, the undissolved solids present in boiler blowdown were present as dissolved solids in the source of boiler make-up water. Therefore, these solids are also being returned to their original source and again should not be deemed to cause water pollution. There is a possible water pollution effect caused by boiler blowdown. It is typically very low in dissolved oxygen content, and may cause a dissolved oxygen sag in a receiving body of water. Because of the very small volume of the stream, even this sag is unlikely to occur.

Type 5 effluent is not a continuous stream. Demineralizers are regenerated periodically. The actual frequency depends on their demineralization capacity and the actual mineral content of the water being

treated. A typical frequency might be once a week. The demineralizer regeneration blowdown stream will contain a high concentration of dissolved solids. However, as in the case of closed cooling circuit and boiler water circuit blowdown streams, these solids are only being returned to their original source. Therefore, these solids should not be deemed to cause water pollution. However, to drive these solids out of the ion exchange beds in the demineralizers, solutions of sulfuric acid and sodium hydroxide are used. To effect proper regeneration of the demineralizers, these solutions must be used in quantities in excess of the theoretical requirements. The resulting blowdown streams therefore contain at times relatively high concentrations of sulfuric acid or sodium hydroxide. These streams are of a relatively high volume. Even though the duration of discharge is short, the blowdown can and will cause pollution in a receiving body of water if it is discharged without treatment.

Type 6, 7, 8 and 9 effluents are very infrequent. Typically they occur only once a year when a steam generating unit is shut down for annual inspection. Type 6, 7, 8 and 9 effluents can and will cause pollution in a receiving body of water if discharged without treatment.

Type 6 effluent, boiler drain water, is chemically very similar to boiler blowdown water. It is a high volume, short duration effluent.

Type 7 effluent, boiler wash water, is also a high volume short duration effluent. Chemically, it consists of city water that contains trace amounts of minerals present in ground water or surface water used for make up to the boiler. During boiler operation, these

minerals accumulate and form a scale inside the boiler. It will also contain a relatively high concentration of undissolved iron oxides which form due to corrosion of the boiler internal walls and accumulate as scale on the latter.

Type 8 effluent, combustion chamber wash water, is also a high volume, short duration effluent. This stream consists of city water that may contain relatively high concentrations of minerals that are originally present in trace amounts in fuel oil and adhere to the combustion chamber internal walls or to the boiler external walls after combustion of the fuel oil. It may also contain a relatively high concentration of iron salts which form due to corrosion of the boiler external walls and accumulate as scale on the latter. Finally, combustion chamber wash water may also contain a relatively high concentration of soot which forms after combustion of fuel oil and accumulates as scale on either the combustion chamber internal walls or on the boiler external walls.

Type 9 effluent, air preheater wash water, is also a high volume, short duration effluent. This stream consists of city water containing relatively high concentrations of iron salts which form due to corrosion of the air preheater walls and accumulate as scale on the latter.

Tables 10 and 11 show the liquid effluents from each steam generating unit. The only effluents discharged from the units are turbine condenser cooling water from Units 4, 5, 6 and 7 at the Larsen plant and from Unit 1 at the McIntosh plant, and cooling tower blowdown water from Unit 2 at the McIntosh plant. The

TABLE 10

COOLING WATER EFFLUENTS FROM STEAM GENERATING UNITS IN THE LAKELAND POWER SYSTEM

| Unit Number | Cooling Water Effluent Type | Flow, gpm | ΔT, °F |
|---|---|---|---|
| | Larsen Power Plant | | |
| 5 | Turbine condenser | 54,000 | 3 |
| 6 | Turbine condenser | 54,000 | 3 |
| 7 | Turbine condenser | 74,000 | 3 |
| | McIntosh Power Plant | | |
| 1 | Turbine condenser | 82,000 | 7 |
| 2 | Cooling tower blowdown | 200 | 10 |

SOURCE: Opalinski (1977)

TABLE 11

CONTAMINATED WATER EFFLUENTS FROM
STEAM GENERATING UNITS IN THE
LAKELAND POWER SYSTEM

| Type of Effluent | Unit Number 5 | 6 | 7 | 1 | 2 |
|---|---|---|---|---|---|
| Flow in Hundred Gallons/Day | | | | | |
| Boiler blowdown | 8 | 8 | 28 | 50 | 70 |
| Demineralizer blowdown | 6 | 6 | 20 | 32 | 40 |
| Flow in Thousand Gallons/Year | | | | | |
| Boiler drain water | 22 | 22 | 34 | 28 | 38 |
| Boiler wash water | 40 | 40 | 40 | 40 | 40 |
| Combustion chamber wash water | 30 | 30 | 30 | 30 | 30 |
| Air preheater wash water | 40 | 40 | 40 | 40 | 40 |

SOURCE: Opalinski (1977)

effluent streams flow to discharge channels at each plant. The channels flow into Lake Parker.

Photograph 13 shows a view of the Units 4, 5, and 6 turbine condenser cooling water outlets into the discharge channel at the Larsen plant. Photograph 14 shows a view of the Unit 7 turbine condenser cooling water outlet and the Larsen plant discharge channel outfall into Lake Parker. Photograph 15 shows a view of the Unit 1 turbine condenser cooling water outlet and the Unit 2 cooling tower blowdown outlet into the discharge channel at the McIntosh plant. Photograph 16 shows a view of the McIntosh plant discharge channel outfall into Lake Parker.

The remaining liquid effluents from the units at the Larsen plant are sent to a 120,000 gallon retention-neutralization basin. The remaining liquid effluents from the units at the McIntosh plant are sent to a 160,000 gallon retention-neutralization basin. The neutralized water from each basin is pumped to a lined spray evaporation pond located at the McIntosh plant. Two circulating pumps spray the water at a rate of 4,000 gpm through 100 spray nozzles. The evaporation rate from the pond, approximately 50 gpm, is greater than the equalized flow rate from the retention basins. The latter is approximately 28 gpm. Therefore, none of these streams cause water pollution. An overall view of the neutralization basin at the Larsen plant is shown in Photograph 17. A partial view of the evaporation pond is shown in Photograph 18.

Tables 12 and 13 show the sulfur dioxide and particulate matter emissions from the steam generating units in the Lakeland power plants.

Photo. 13. Effluent channel, Larsen power plant.

Photo. 14. Outfall, Larsen power plant

Photo. 15. Effluent channel, McIntosh power plant.

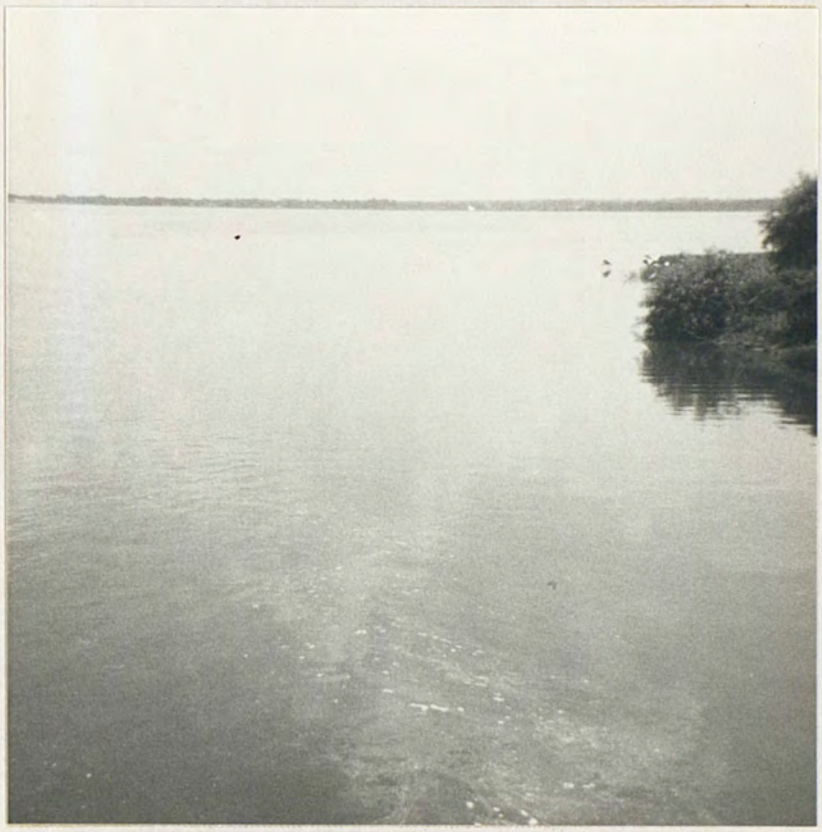


Photo. 16. Outfall, McIntosh power plant

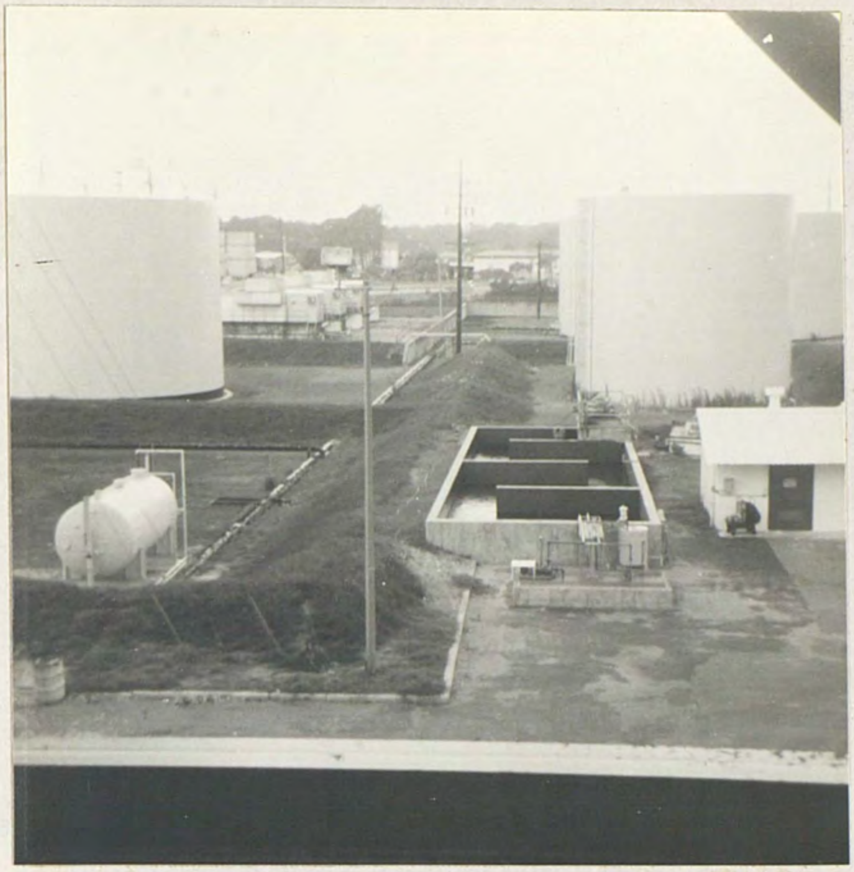


Photo. 17. Retention-neutralization basin, Larsen power plant.

Photo. 18. Spray evaporation pond, McIntosh power plant.

TABLE 12

SULFUR DIOXIDE EMISSIONS FROM STEAM GENERATING UNITS IN THE LAKELAND POWER SYSTEM

| Unit Number | Emission, lb/MM Btu Heat Input Actual | Allowable |
|---|---|---|
| Larsen Power Plant | | |
| 5 | 0.96 | 2.75 |
| 6 | 0.96 | 2.75 |
| 7 | 0.91 | 2.75 |
| McIntosh Power Plant | | |
| 1 | 2.66 | 2.75 |
| 2 | 0.74 | 0.80 |

SOURCE: Opalinski (1977)

TABLE 13

PARTICULATE EMISSIONS FROM STEAM GENERATING UNITS IN THE LAKELAND POWER SYSTEM

| Unit Number | Emission, lb/MM Btu Heat Input Actual | Allowable |
|---|---|---|
| Larsen Power Plant | | |
| 5 | 0.027 | 0.10 |
| 6 | 0.027 | 0.10 |
| 7 | 0.038 | 0.10 |
| McIntosh Power Plant | | |
| 1 | 0.039 | 0.10 |
| 2 | 0.011 | 0.10 |

SOURCE: Opalinski (1977)

The applicable State of Florida allowable emission for either pollutant is also shown in the tables. The gas turbine and diesel engine units are not subject to regulations and are not shown for this reason.

Photograph 19 shows an overall view of Units 4, 5, 6 and 7 at the Larsen plant. Two of the units were in operation at the time the picture was taken. It will be left up to the reader to determine which two of the four stacks are the ones serving the units in operation. Photograph 20 shows an overall view of Units 1 and 2 at the McIntosh plant. Both units were in operation at the time the photograph was taken. As can be seen from the photographs, solid particulate emission from operating units, although present, is not visible.

Ground level concentrations of sulfur dioxide and particulate matter for each steam generating unit were calculated by the writer using the simplified equation of the Gaussian plume model. Horizontal and vertical dispersion coefficients as a function of downwind distance from the source were obtained from Turner (1970). Average atmospheric stability was assumed. The Holland equation given in Rossano (1969) was used to calculate the plume rise in order to determine effective stack height.

Tables 14 and 15 show the calculated ground level concentrations. The State of Florida ambient air quality standard for both types of pollutants allows a ground level concentration of 60 micrograms/cubic meter.

## Environmental Impact of the System

The environmental impact of the liquid effluents from the power plants will be discussed first.

Photo. 19. Units 4, 5, 6, and 7, Larsen power plant.

Photo. 20. Units 1 and 2, McIntosh power plant.

TABLE 14

SULFUR DIOXIDE GROUND LEVEL CONCENTRATIONS
PRODUCED BY STEAM GENERATING UNITS
IN THE LAKELAND POWER SYSTEM
(Ground Level Concentrations
in Micrograms/Cubic Meter)

| Unit Number | Distance from Source, Meters 100 | 1,000 | 10,000 | 100,000 |
|---|---|---|---|---|
| Larsen Power Plant | | | | |
| 5 | 135 | 110 | 85 | 60 |
| 6 | 200 | 165 | 130 | 95 |
| 7 | 170 | 140 | 110 | 80 |
| McIntosh Power Plant | | | | |
| 1 | 780 | 640 | 500 | 360 |
| 2 | 700 | 575 | 450 | 325 |

NOTE: The concentrations shown in the table were calculated by R. I.Pedroso.

TABLE 15

PARTICULATE GROUND LEVEL CONCENTRATIONS
PRODUCED BY STEAM GENERATING UNITS
IN THE LAKELAND POWER SYSTEM
(Ground Level Concentrations
in Micrograms/Cubic Meter)

| Unit Number | Distance from Source, Meters 100 | 1,000 | 10,000 | 100,000 |
|---|---|---|---|---|
| Larsen Power Plant | | | | |
| 5 | 4 | 3 | 2 | 1 |
| 6 | 6 | 5 | 4 | 3 |
| 7 | 7 | 6 | 5 | 4 |
| McIntosh Power Plant | | | | |
| 1 | 11 | 9 | 7 | 5 |
| 2 | 10 | 8 | 6 | 4 |

NOTE: The concentrations shown in the table were calculated by R. I. Pedroso.

The Florida Department of Environment Regulation rules concerning heated water discharges existing on July 1, 1972 prohibit such discharge if it will increase the temperature of the receiving body of water so as to cause substantial damage or harm to the aquatic life or vegetation therein or interfere with beneficial uses assigned to the receiving body of water. This regulation applies to the effluents from Units 5, 6, and 7 at the Larsen plant and the effleunt from Unit 1 at the McIntosh plant.

DER rules concerning heated water discharges existing after July 1, 1972 prohibit such a discharge if its temperature is above 92°F or more than 3°F higher than the ambient temperature of the receiving body of water. This regulation applies to the effluent from Unit 2 at the McIntosh plant.

DER rules concerning contaminants need not be considered for the effluents from Units 5, 6, 7 and 1, since there is no contamination of the once-through cooling water. However the rules must be considered for the Unit 2 effluent.

As can be seen from Table 10, the cooling water effluents from Units 5, 6, and 7 are in compliance with the rules for new heated discharges, even though they need not comply. These effluents are also in compliance with the rules for existing heated water discharges. This point will be discussed later.

If the Unit 2 effluent had an independent outfall into Lake Parker, it would violate the rules concerning dissolved solids and chromium concentrations. However, prior to discharging into Lake Parker, the Unit 2 effluent is combined with the Unit 1 effluent.

The former is diluted by the latter at a 400 to 1 ratio. The resulting combined effluent then meets all the rules concerning contaminant concentrations. In any event, the dissolved solids concentration in the Unit 2 effluent should not be deemed in violation, since these solids are simply being returned to their source.

The Unit 2 effluent theoretically is in violation of the rules concerning new heated water discharges. The Unit 1 effluent need not comply with these rules, and is in compliance with the rules for existing heated water discharges. Since both effluents are combined before discharging into Lake Parker, it is debatable whether the Unit 2 effluent does or does not violate the rules.

It was stated previously that Units 5, 6, 7 and 1 comply with the rules for existing heated water discharges. Looking closely at Photographs 14 and 16, numerous aquatic fowl can be seen at or near the outfalls from either power plant. Many of these fowl feed on fish, and the fish in turn feed on aquatic vegetation. It can be deduced that aquatic life and vegetation thrive in the environment of the outfalls.

In January 1977 a severe cold wave was experienced in Lakeland. Record low temperatures for the date were set on at least two consecutive days. During the cold wave, massive fish kills took place in some lakes in the city, but not in Lake Parker. The only plausible explanation for this exception is that the warm water from the power plant outfalls kept the fish alive in Lake Parker. This combination of circumstances would appear to indicate that the heated water discharging from the power plants into Lake Parker has a

beneficial impact on the environment.

As can be seen from Tables 12 and 13, the sulfur dioxide and solid particulate emission levels from all the steam generating units are below the allowable emission levels for these pollutants. However, as can be seen from Tables 14 and 15 the calculated ground level concentrations of sulfur dioxide emitted by all the units exceed the concentrations allowed by the standards.

There is still some debate about the actual concentrations of either pollutant that will be harmful to animal life or vegetation. However, there can be no question about the harmful effect of high sulfur dioxide and/or solid particulate concentrations in ambient air. Convincing evidence was provided in London, England in 1952. The incident is described by Rossano (1969). In that city, many more people died than would normally be expected during a seven day period. An unusually heavy amount of air pollution that persisted for several days and resulted from coal burning took place during the same time period.

From an aesthetic point of view, overhead power transmission lines have a minor deleterious impact on the environment. However, only very young, planned communities have resorted to fully underground power lines.

## Conclusions and Recommendations

The heated water discharge from the power plant generating units does not appear to have a deleterious impact on the environment. In fact, it appears to have a beneficial impact on the environment. However, to ensure compliance with state regulations, it is recommended that the next addition to the generating system have

a cooling system designed for a low temperature rise, e.g., 3°F.

It is the writer's opinion that the Florida State Department of Environment Regulation should revise its rules for new heated water discharges. It would appear that the rule for existing heated water discharges is a more logical rule, since it takes into consideration the environmental impact of the discharge.

All the steam generating units are in compliance with allowable sulfur dioxide emission levels. However, allowable ground level concentrations are being exceeded by every unit. These high ground level concentrations can have a serious deleterious impact on the environment. The allowable ground level concentrations can be met by a combination of the following actions:

1. Installing a sulfur dioxide removal system
2. Increasing stack height
3. Burning lower sulfur content fuel oil

The present stack height for Units 5, 6 and 7 is 165 feet. Doubling the stack height and burning 0.7% sulfur fuel oil instead of 0.9% sulfur fuel oil will enable Units 5, 6 and 7 to meet the allowable ground level concentrations. Stack heights of 330 feet are quite common in present day power plants. Since this course of action is fairly inexpensive, it is strongly recommended.

The same course of action will not enable Units 1 and 2 to meet the allowable ground level concentration. This is especially true for Unit 2, which normally burns 0.7% sulfur fuel. The recommended course of action is to again double the stack height for both units, and to install on both units a sulfur dioxide removal system

capable of 90% removal. Unit 2 can be switched to 0.9% sulfur fuel and still meet allowable ground level concentrations. This switch will partially offset the cost of the recommended course of action.

It is further recommended that the sulfur dioxide removal system installed be of the ammonia scrubbing type. This system will produce ammonium sulfate as a product. Ammonium sulfate can be readily sold to any one of the synthetic fertilizer manufacturing companies located near Lakeland, as an additive to their product. The ammonia raw material required for the removal system is also readily obtainable in the area.

No recommendation will be issued for correcting the minor, deleterious environmental impact of overhead power lines. It would be economically unfeasible to bury all the overhead lines for the sole purpose of beautifying the City of Lakeland.

# CHAPTER 4

# SOLID WASTE COLLECTION AND DISPOSAL SYSTEM

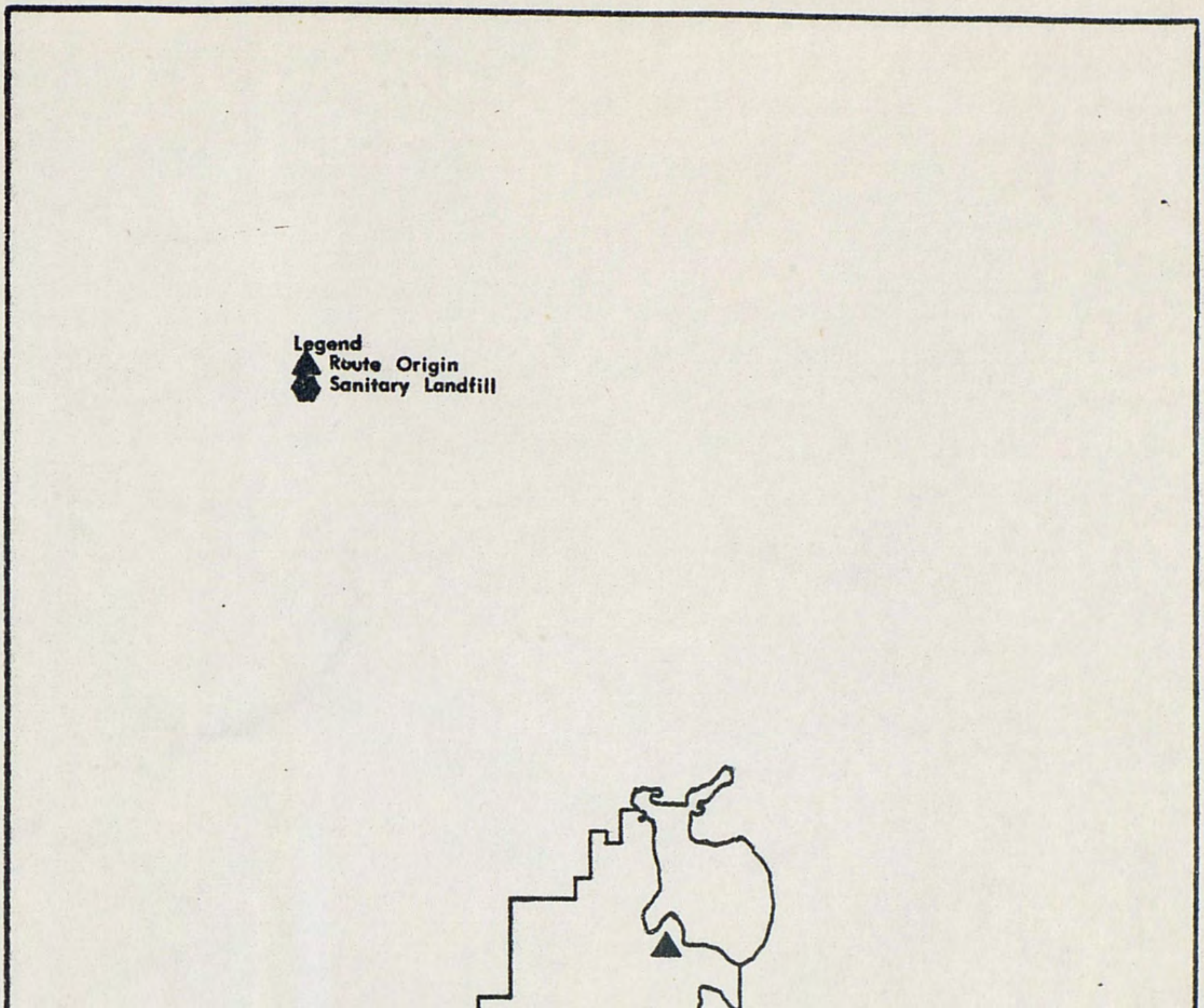
## Description of the System

The City of Lakeland provides solid waste collection service only within the city limits. Lakeland's solid waste is buried at the Polk County north central sanitary landfill. The locations of the landfill site and the site where the refuse collection routes originate in the city are shown in Map 17.

Refuse collection in Lakeland is carried out by the Refuse Collection Division of the Department of Public Works. The landfill is operated by Polk County's Environmental Services Department.

Total refuse collected by the City of Lakeland in 1976 amounted to 37,500 tons. The number of people served by the system is estimated at 50,000. The average weight collected per capita then amounts to 1,500 lb/yr. This per capita amount is very close to the national per capita average of 1,435 lb/yr determined by an APWA survey (1966). Monthly variation in the amount of refuse collected is shown in Figure 9.

Residential refuse collected accounts for approximately 55% of the total yearly tonnage. Residential refuse composition was reported by city personnel as 40% garbage and 60% rubbish. Figures are not available to determine what percentage of the rubbish is combustible versus noncombustible.




Map 17. Refuse collection and disposal system, City of Lakeland

SOURCE: DuCharme (1977)

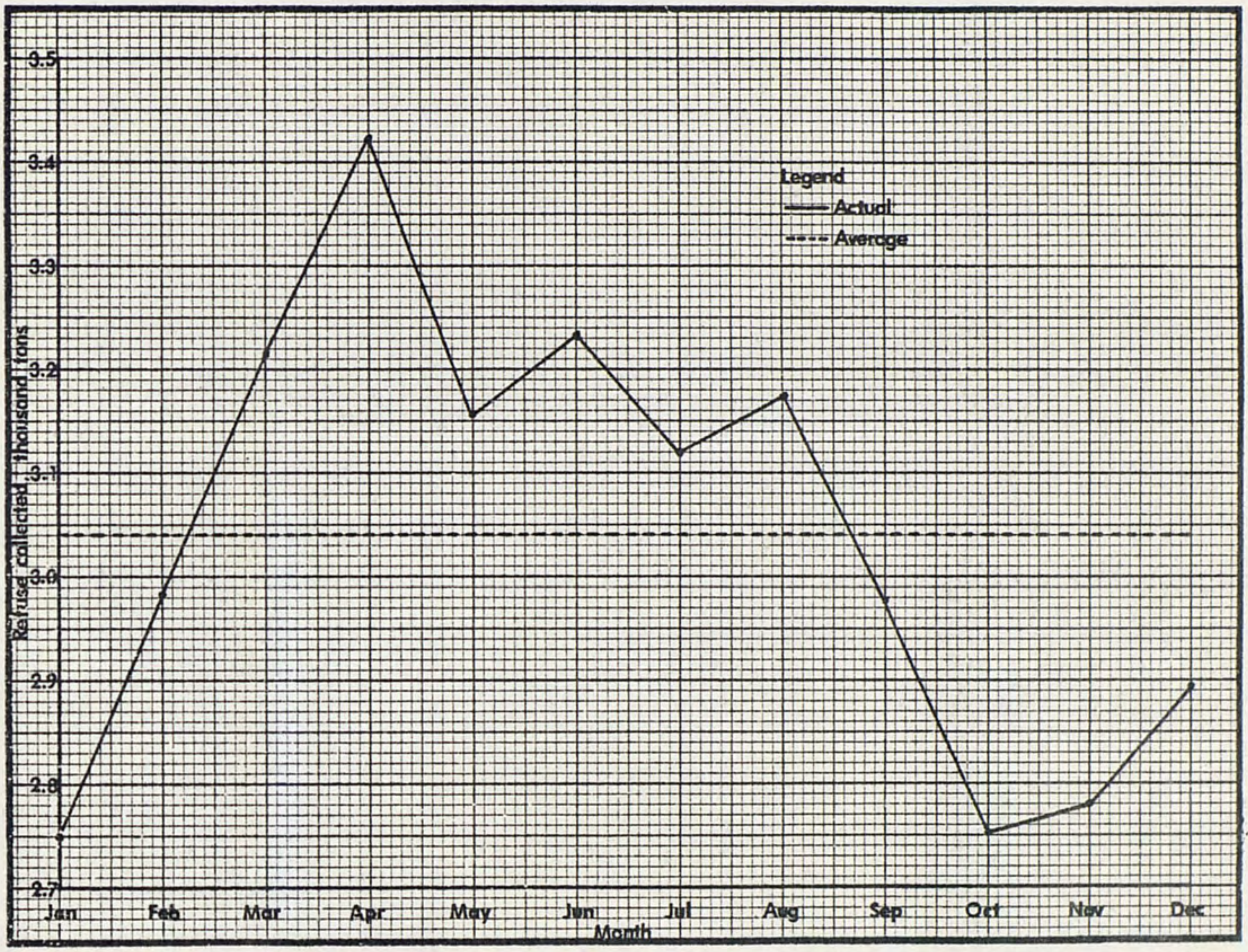



Fig. 9. Monthly refuse tonnage collected by the City of Lakeland, 1976

SOURCE: DuCharme (1977)

Residential refuse collection frequency is twice weekly. There are nine residential collection routes, with approximately 800 stops per route. The routes are determined by an equal tonnage basis. About two days are required to cover the nine routes. Collection proceeds from Monday morning through Tuesday afternoon, then again from Thursday morning through Friday afternoon. Any unusually large amount of refuse that was noticed but not collected due to space limitations on Monday or Tuesday is collected on Wednesday. This large amount of refuse is usually composed of yard clippings typically accumulated on weekends.

The residential refuse collection crews consist of three men, one driver and two loaders. The collection method consists of curb collection only. As mentioned above, the work is assigned on a definite task, daily route basis. Work incentive is provided by allowing the crews to go home when they are finished on Tuesday and Friday while still receiving a full day's pay.

Residential collection equipment consists of eleven rear loading, fully enclosed packer trucks. Nine trucks are used to cover the routes and two are on standby in the event of mechanical problems. The trucks have a capacity of 25 cubic yards. The packers are capable of compacting collected refuse to a density that averages about 675 lb/cu. yd. This density is higher than the national average of 475 lb/cu. yd. determined by an APWA survey (1966). The trucks used on the routes are washed with water only daily except on Wednesday when soap is used. Some of the trucks are shown in Photograph 21.

Commercial refuse collected accounts for approximately 45%

Photo. 21. Residential refuse collection trucks.

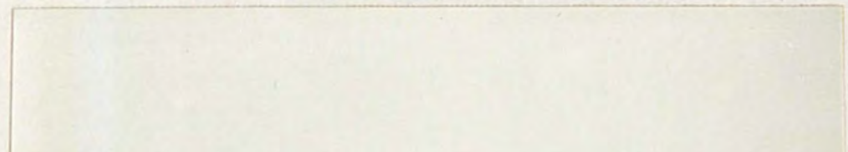


Photo. 22. Commercial refuse and large object collection trucks.

of the total yearly tonnage. Commercial refuse composition was reported as 50% garbage and 50% rubbish. As with residential rubbish, figures are not available to determine what percentage of the rubbish is combustible versus noncombustible.

Commercial refuse is stored in containers with capacities of 2, 3, 4, 6 or 8 cubic yards. The containers are either provided by the city on a lease arrangement or bought by the users using city specifications. Approximately 1,400 commercial enterprises are served by the Refuse Collection Division.

Commercial refuse collection frequency varies from once a week to five times a week, depending on the user's needs. There are five commercial collection routes, with approximately 75 containers per route. As with residential refuse collection, the commercial routes are determined by an equal tonnage basis.

The commercial refuse collection equipment consists of seven front loading, fully enclosed packer trucks. Five trucks are used to cover the routes and two are on standby in the event of mechanical problems. Four of the seven trucks have a capacity of 25 cubic yards, while the other three have a capacity of 30 cubic yards. The trucks are equipped with hydraulically operated loading arms that pick up the refuse containers and dump the refuse into the body of the truck through a top opening with a retractable cover. Some of the trucks are shown in Photograph 22.

The commercial packers are capable of compacting the collected refuse to a density that averages about 585 lb/cu. yd. This density is lower than that achieved by the residential packers. The reason

is that the compressing ram in the commercial packers is driven from the front end to the back end of the truck when a load is picked up, then is retracted to its original position. This allows the compressed refuse to "spring back," losing some of the degree of compaction. In the residential packers, the compressing ram is always in an extended position, except of course when accepting a new load.

The commercial refuse collection crews consist of only one man who drives the truck. The commercial crews are provided with the same work incentive as the residential crews.

Street sweeping service is also provided by the city. Two street sweepers and a dump truck are available for this service. When a street sweeper has collected a full load, it is unloaded to the dump truck. The truck then hauls the sweepings to any area in the city that requires dirt fill. If none are available, the sweepings are taken to the county sanitary landfill.

The city also has three flat bed trucks with mechanical loading arms that are used for pick-up of unusually large or heavy objects such as discarded appliances or furniture. Some of these trucks are also shown in Photograph 22. At least twice, usually three and occasionally four times a year, the city announces a special clean-up period during which large objects will be collected. The clean-up period is well publicized in advance by the news media.

Large objects such as trees or discarded lumber must be reduced in size so that the length or girth does not exceed 5 feet before the city will collect these objects. This is done by the regular collection crews.

Other unusual collection problems are kept well under control by the city. Bulky objects have already been mentioned. Some of the other problems are discussed next.

The city will not collect any construction or demolition debris. Removal of this debris is the responsibility of the construction or demolition contractor and must be done within a week of project completion.

When a vehicle is abandoned within the city limits, the city will have the vehicle towed to a local junk yard and attempt to locate the owner. If the owner is found, he will be advised of the disposition of his vehicle and will be assessed with a towing charge. If the owner cannot be found, the junk yard is allowed to retain possession of the vehicle.

Small dead animals are picked up by the city as soon as possible upon notification and are taken to the sanitary landfill. Large dead animals are picked up by an animal rendering enterprise, the Tampa Soap Company. There have not been any large dead animals found within the city limits for at least twenty years.

There is no coal heating of homes or buildings in Lakeland. Consequently there is no need for disposal of ashes from such a source. Ash from institutional incinerators is handled as commercial refuse.

The city will not accept animal or agricultural waste such as manure, crop residue, pesticides or insecticides. It is the responsibility of the user to dispose of this material.

The city will not accept hazardous waste such as pathogenic, radioactive, explosive or toxic materials. It is the responsibility of the user to dispose of this material. Florida Refuse Company collects and disposes of these materials.

The city will accept small, empty oil containers from gasoline service stations and other vehicle repair and maintenance enterprises. These are handled as commercial refuse. However, large drums full of used lube oil are not accepted by the city. The Tampa Oil Reclaiming Company will accept these containers.

Refuse collection outside of Lakeland's city limits is carried out by private refuse collection contractors. Furthermore, there are some commercial and institutional enterprises located inside the city limits that are also serviced by private contractors. The reason for this is that these enterprises could not economically use the largest containers that the city commercial trucks can accept. Private contractors operating within the city limits are not given a franchise. They are granted permission to operate by the city and must negotiate a contract with their customers.

As previously mentioned, solid waste collected in Lakeland is hauled to a Polk County sanitary landfill for disposal. The refuse collection trucks go directly to the landfill after collecting a full load. The economic feasibility of using a transfer station was studied a year ago. It was determined that the degree of compaction required to make a transfer station more economical was such that the weight of the transfer trucks would exceed the weight limitation on the county road where the present sanitary landfill used by Lakeland is located.

Serious consideration has been and is being given to incineration of Lakeland's refuse. Previously, it had been determined that it would not be economically feasible to provide an incinerator solely for refuse collected in the city. At present, however, Lakeland's power generating system must be expanded to meet an increasing demand. By 1981, a power generating unit must be added to the system. This new unit must be a coal fired boiler, since a recently enacted Federal regulation will not allow construction of new fuel oil or natural gas fired power generating units. Very serious consideration is being given to incineration of Lakeland's solid waste to provide a portion of the heat input to the boiler. Studies indicate that incineration of Lakeland's projected solid waste production for 1981 will provide approximately 7% of the heat input required for the average daily power consumption. Refuse collected in Lakeland has an average heat value of 4,800 to 5,000 Btu/lb. This heat value is very close to the average of 4,917 Btu/lb determined in studies conducted by Purdue University. The results of the study were published by APWA (1966).

Although the City of Lakeland does not operate its own solid waste disposal system, the disposal will be described to some extent. Polk County's north central sanitary landfill accepts all of Lakeland's solid waste as well as that from nearby cities and towns. The waste buried in the landfill amounts to approximately 76,600 tons/year from Lakeland plus 114,900 tons/year from other users, or 191,500 tons/year total. The present projected capacity of the landfill is 12 years. The projected capacity would be 20 years if Lakeland's solid waste were being incinerated. Approximately 320 acres will be filled with refuse.

Photo. 23. Compactor and transfer truck at Polk County north central sanitary landfill.

The landfill is of the cut and cover or trench type. Each cell is approximately 530 feet long and 100 feet wide. The space between cells is approximately 6 inches. Each cell is built up to a depth of about 7 feet, then covered with 3 feet of excavated earth. The same cell is built up again another 7 feet, and again covered with another 3 feet of earth. The front face of the fill is worked at a 30° slope from the horizontal. Daily fills are covered on top and the front face with 6 inches of earth. No refuse is ever left uncovered from one day to the next. A wind fence surrounds the entire site.

Equipment used in the landfill consists of four Caterpillar D-7 bulldozers, one 60,000 lb steel wheeled compactor and two draglines with 2 cubic yard capacity buckets. Usually, only one bulldozer and the compactor work on filling a cell. The other bulldozers and the draglines work on excavating new cells. Occasionally, it becomes necessary to use two bulldozers in the cell that is being filled in order to accelerate the movement of refuse collection trucks. Photograph 23 shows the compactor at work and a transfer truck unloading refuse.

The cell filling crew consists of a spotter for refuse collection trucks and one operator for each piece of equipment. The cell excavating crew consists of one operator for each piece of equipment.

The compactor is capable of compacting refuse to a density ranging from 900 to 1,400 lb/cu. yd. The steel wheels have tracks with a chevron pattern. This type wheel makes the compactor more maneuverable than one with stud or peg type wheels. The bulldozers

are only capable of compacting refuse to a density ranging from 700 to 900 lb/cu. yd. However, their flexibility in moving either refuse or earth in addition to their compacting capability makes then indispensable for the operation of the landfill. The degree of compaction achieved by this equipment is within the range described by the APWA (1970).

An important feature in the operation of the landfill is the disposal of rain water accumulation or ground water encountered in excavation. Rain water or ground water in a newly excavated cell is pumped to nearby Lake Hancock. However, any rain water falling on a filled area is pumped to a leachate cell or pond. It is then recirculated through a spraying system by circulating pumps until it evaporates. The leachate cell lies above impermeable strata.

## Environmental Impact of the System

Lakeland's solid waste collection and disposal system has only a minor deleterious impact on the environment at the present time.

From an aesthetic point of view, it would be preferable to have a set out-set back method for residential refuse collection rather than the curb method. This would avoid the unsightliness of refuse containers at the curb for several hours. Furthermore, stray dogs and sometimes even pet dogs will occasionally turn refuse containers over, spilling the contents and causing an even uglier sight. However, the set out-set back method would increase the collection cost and some of the citizens may and will be opposed to a change.

By the same token, the sanitary landfill is exemplary from an aesthetic point of view. Not only is the landfill site itself kept as clean as practical, it is completely hidden from view by surrounding foliage in spite of the fact that it is only a few hundred feet from a well-travelled county road. Furthermore, there is no evidence of wind blown refuse on the county road or on the access road to the landfill, nor is any odor discernible from the roads. In addition, present plans are to construct a county owned and operated recreational area on top of the fill when the site is exhausted. This action will have a beneficial impact on the environment.

One of the possible deleterious effects on the environment is the possibility of communities generating more solid waste than can be adequately and aesthetically handled by sanitary landfills. If all solid waste were to be buried, eventually unsightly mountains would spring up around the country side. Even though adequately covered, these mountains would detract from the beauty of the landscape. This situation must be avoided. An evidence of this possibility is that the duration capacity of the landfill being discussed will be shortened by at least 40% unless Lakeland's solid waste is incinerated.

Finally, a possible deleterious effect of sanitary landfills on the environment is that of water leaching undesirable material from the fill, percolating through the ground and eventually contaminating ground water supplies. Although this problem is handled as well as possible in the landfill under discussion, nevertheless it is a real possibility.

## Conclusions and Recommendations

In general, the Lakeland solid waste collection system is well operated. No doubt this was one of the unmentioned factors contributing to the city being awarded the "All America City" honor in 1970. One recommendation for improvement is that the curb collection method for residential refuse be changed to a set out-set back collection method. This recommended change could be proposed to the citizens by way of a referendum when local elections take place.

A logical conclusion is that sanitary landfills, no matter how well operated they may be, are not the only solution to the solid waste disposal problem. Furthermore, serious deleterious impact on the environment can result from abuse of this method. Therefore, it is strongly recommended that all due consideration be given to incineration of Lakeland's solid waste at the new power generating unit to be built in the near future. If emissions from the boiler are properly controlled, solid waste incineration will result in a beneficial impact on the environment by reducing consumption of dwindling fossil fuel supplies.

## SUMMARY

Lakeland is a city with a greater metropolitan area population of 100,000. The city is located in Polk County, near the geographic center of the state of Florida. Polk County is the headquarters of the citrus fruit and synthetic fertilizer industries in the U.S. Lakeland has a mayor, city commission-city manager form of government. The city manager directs the operation of seven departments.

This research report studies four municipal services provided by the city of Lakeland. The services studied are water supply, waste water treatment, electric power supply, and solid waste collection. The environmental impact of these services is discussed. Recommendations are issued for possible solutions to problems encountered.

Water supplied by the city of Lakeland is withdrawn from the Floridan aquifer. The water is of good quality, with medium hardness. The only treatment given to the water prior to distribution is chlorination. The supply system consists of 32 deep wells, 552 miles of distribution lines, 5 elevated storage tanks and 2 ground level reservoirs. The water consumption in Lakeland is approximately 200 gpcd.

The water supply system has two deleterious impacts on the environment. One of the impacts is the presence of hydrogen sulfide gas in the water. The former imparts to the latter objectionable

odor and taste. The other impact is the decline of the potentiometric surface of the Floridan aquifer. This can cause a decline of lake levels in the area and salt water intrusion into the aquifer.

To resolve the hydrogen sulfide problem, installation of a central water treatment plant with aeration facilities is recommended. To resolve the declining water level problem adoption of strict water conservation measures is recommended. Plans developed by the Southwest Florida Water Management District (SWFWMD) constitute one possibility. Another is to change the water rate structure, and charge more money for greater water consumption.

Waste water collected in the city of Lakeland is approximately 100 gpcd. There are 225 miles of sewer lines and six pumping stations delivering sewage to the waste water treatment plant. The latter consists of two comminutors, a grit chamber, two primary clarifiers, two trickling filters, two secondary clarifiers, two anaerobic sludge digesters, five sludge drying beds and an aerobic stabilization pond. Two intermediate pumping stations transfer sewage through the plant, and Parshall flumes measure the influent and effluent flows. The plant removes 91% of the $BOD_5$ and the suspended solids in the influent. The plant effluent flows to Banana Lake.

Waste water treatment provided by the city of Lakeland does not have a deleterious impact on the environment. Dried sludge is used by farmers as one of the ingredients in fertilizers. Effluent is used for irrigation of agricultural crops after mixing into the receiving water of Banana Lake. Grit is buried in a sanitary landfill.

It could be said that the waste water treatment service has a beneficial impact on the environment.

The waste water treatment plant appears to have ample capacity at least for several years. Also, the plant is well operated, with high $BOD_5$ and suspended solids removal efficiencies. For these reasons the only recommendation made is to continue to monitor plant performance to detect any decline in the latter.

Electric power supplied by the city of Lakeland is produced in two generating stations. The stations have a power generating capacity of 330 megawatts base load and 60 megawatts peaking load. Power generated by the stations is transmitted to ten substations through 58 miles of transmission lines. The substations have a capacity of 340 megawatts. Power is transmitted from the substations to the users through 943 miles of transmission lines. The yearly power consumption per residential customer (household) in the city of Lakeland in 1976 was 11,600 kWhr. All the power generating units in the system are fuel oil fired. Natural gas is used as fuel whenever it is available.

The electric power supply system has one deleterious impact on the environment. Sulfur dioxide is emitted from all the power generating units during combustion of fuel oil. The resulting ground level concentration of sulfur dioxide exceeds the allowable limit at distances as great as 60 miles from the source. Cooling water discharged from one of the generating units is in violation of the Florida State Department of Environment Regulation rules concerning heated water discharges. However, it is debatable that this too hot

water, which discharges into a lake, has a deleterious impact on the environment. There is some evidence that this heated water may have prevented a massive fish kill in the receiving lake during a record cold wave experienced in Lakeland in January 1977. It appears that the heated water discharge may possibly have a beneficial impact on the environment.

To partially resolve the sulfur dioxide ground level concentration problem, installation of taller stacks on all the power generating units is recommended. It is also recommended that three of the five units be fired with lower sulfur content fuel oil. It is further recommended that a sulfur dioxide removal system capable of 90% removal be installed on the two remaining units. The removal system should be of the ammonia scrubbing type, which produces an ammonium sulfate byproduct readily marketable in the Lakeland area.

Solid waste collected by the city of Lakeland in 1976 amounted to 37,500 tons. Average weight collected per capita is approximately 1,500 lb/yr. Residential refuse accounts for 55% of the total, and is collected in rear loading, fully enclosed packer trucks by crews using the curb collection method. Commercial refuse accounts for 45% of the total, and is collected by front loading, fully enclosed packer trucks with mechanical loading arms. Very little industrial refuse is collected by the city of Lakeland. Construction and hazardous solid wastes are not collected by the city.

Solids waste collected by the city of Lakeland is buried in a nearby sanitary landfill operated by Polk County. The landfill is of the cut and cover or trench type. The ultimate capacity of the landfill

is 2.3 million tons which will cover 320 acres. A steel wheeled compactor and bulldozers are used in the operation of the landfill.

From an aesthetic point of view, the curb refuse collection method has a minor deleterious impact on the environment. To resolve this problem, implementation of a set out-set back collection method is recommended.

Sanitary landfills, even when properly operated, have a potentially deleterious impact on the environment. Firstly, it is possible to generate more solid waste than can be adequately handled in available landfill areas. Secondly, water runoff can leach undesirable materials from refuse and contaminate ground water supplies. To partially resolve this problem, solid waste can be incinerated in a power generating unit. This approach is being considered by the city of Lakeland, and its implementation is strongly recommended.

In the writer's opinion, the quality of the municipal services studied in this report are indicative of an extremely well managed city. Most of the problems found have been addressed by the department supervisors.

No problems were found in the waste water treatment service. It is to be commended for an outstanding oepration.

Complaints about hydrogen sulfide in the water supply are resolved in a very short time period. The writer has personal experience in this respect. It should be noted that the city presently is receiving bids from engineering firms that will study the water supply system. The objectives of the study are resolution of water quality problems and economic feasibility of system centralization. This service also deserves commendation for its outstanding operation.

The decline in the potentiometric surface of the Floridan aquifer is due mostly to industrial rather than municipal usage of water. In any event, the Water Division adheres strictly to water conservation measures imposed by SWFWMD.

The refuse collection service is also to be commended for an outstanding operation. Ample evidence can be observed when traveling through Lakeland. Although refuse disposal is not provided by the city, it is of course an intimately related service. A potential problem exists concerning refuse disposal. Again, city officials have addressed the problem and a satisfactory solution is expected.

The electric power supply service is also outstanding. Power failures seldom occur in Lakeland. When a failure does occur, it is resolved in a very short time period. Here again, the writer has personal experience in this respect. The service is also to be commended for the outstanding treatment given to contaminated water streams from the power generating units. This treatment results in zero discharge to the environment.

The only real problem found in the power supply service is that of high sulfur dioxide ground level concentrations. These are caused by gaseous emissions from the power generating units. It is the writer's opinion that this problem has not been adequately addressed by city officials. However, it is possible that the calculated concentrations could be in error.

As follow up to this report, a discussion has been held with city officials regarding the potential sulfur dioxide problem.

## BIBLIOGRAPHY


APWA. 1966. Refuse collection practice, p.29. Chicago: Public Administration Service

Ibid., p. 35.

Ibid., p. 38.

APWA. 1970. Municipal refuse disposal, p. 100. Chicago: Public Administration Service

ASCE. 1959. Manual of engineering practice no. 36: Sewage treatment plant design, p.93. New York: ASCE press.

Ibid., p. 155.

Ibid., p. 167.

Ibid., p. 189.

Ibid., p. 212.

Ibid., p. 266.

ASCE. 1969. Manual of engineering practice no. 19: Water treatment plant design, 2nd. ed., p. 53. New York: AWWA press.

Dolph Map Co. 1977. Dolph's map of greater Lakeland and Winter Haven, including general highway map of Polk County, Florida. Fort Lauderdale, Fla.: Dolph Map Co. printing service.

DuCharme, W. J. 1977. Superintendent, Refuse Collection Division, Department of Public Works, City of Lakeland. Personal communication.

Eckenfelder, W. W., Jr. 1966. Industrial water pollution control, p. 191. New York: McGraw-Hill.

Fair, G. M., Geyer, J. C., and Okun, D. A. 1966. Water and wastewater engineering. Vol. 1: Water supply and wastewater removal, p. 5-13. New York: John Wiley and Sons.

Ibid., p. 5-16.

Ibid., p. 5-22.

Locke, E. T., Jr. 1977. Superintendent, Sanitary Sewerage Division, Department of Public Works, City of Lakeland. Personal communication.

Opalinski, M. P. 1977. Environmental Coordinator, Power Generating Division, Department of Electric and Water Utilities, City of Lakeland. Personal communication.

Pride, R. W., Meyer, F. W., and Cherry, R. N. 1966. Florida Geol. Survey Rept. Inv. 42: Hydrology of the Green Swamp area in central Florida. Tallahasee, Fla.: U.S. Geol. Survey printing service.

Robertson, A. F. 1973. Florida Geol. Survey Rept. Inv. 64: Hydrologic conditions in the Lakeland Ridge area of Polk County, Florida, p. 14. Tallahasee, Fla.: U.S. Geol. Survey printing service.

Ibid., p. 44.

Ibid., p. 45.

Ibid., p. 20.

Ibid., p. 21.

Ibid., p. 44, 46.

Ibid., p. 47.

Ibid.

Ibid., p. 48.

Ibid.

Rossano, A. T., Jr., ed. 1969. Air pollution control guidebook for management, p. 29. Danbury, Conn.: Environmental Science Service Division.

Ibid., p. 112.

Stewart, H. G., Jr. 1966. Florida Geol. Survey Rept. Inv. 44: Ground water resources of Polk County, Florida. Tallahasee, Fla.: U.S. Geol. Survey printing service.

Turner, D. B., 1970. Workbook of atmospheric dispersion estimates. PHS publ. no. 999-AP-26.

[Williams, T. B.] 1976a. Lakeland's water supply and system of the Department of Electric and Water Utilities, p. 19. Lakeland, Fla.: City of Lakeland printing service. (Mimeographed.)

[Williams, T. B.] 1976b. City of Lakeland, Department of Electric and Water Utilities, Water Division: statistical report, p. 7. Lakeland, Fla.: City of Lakeland printing service. (Mimeographed.)

Ibid., p. 21.

Ibid., p. 16.

Ibid., p. 37.

Ibid., p. 17-20.

Ibid., p. 15.

Ibid., p. 22.

Williams, T. B. 1977. Superintendent, Water Division, Department of Electric and Water Utilities, City of Lakeland. Personal communication.