Prepared in cooperation with
MIAMI-DADE WATER AND SEWER AUTHORITY, DADE COUNTY,
and the SOUTH FLORIDA WATER MANAGEMENT DISTRICT

INTRODUCTION

The first municipal water supply for Miami, Fla., was obtained in 1908 from four naturally flowing wells located near the mouth of the Miami River (Matson and Sanford, 1913, p. 291). The wells were 73 to 95 feet deep and penetrated limestone and sandstone, later described by Parker (1951, p. 820-823) as the Biscayne aquifer. After 12 years of operation, the wells stopped flowing and pumps were required. The wells finally had to be plugged back to shallower depths because saltwater had migrated into the deeper limestone. The decline of water levels and the intrusion of saltwater that accompanied the withdrawals later worsened because of the deepening of the Miami River and the dredging of the Miami Canal to improve inland drainage (Parker and others, 1955, p. 585).

New and more permanent supply facilities were completed in 1924 in the Hialeah-Miami Springs area (fig. 1), adjacent to the Miami Canal and 5 miles upstream from the original water-supply site. The new facilities consisted of 12 wells on the southwest side of the canal and 3 wells on the northeast side (fig. 2) at the site of the municipal water-treatment plant. Wells were of large diameter steel casing and were 60 to 90 feet deep in limestone and sandstone of the Biscayne aquifer. Initial withdrawal from the well field was about 10 Mgal/d, but after 15 years the withdrawal rate doubled. The well field served Miami and vicinity at withdrawal rates that continued to increase until the late 1960's when the rate reached 80 Mgal/d from 23 wells. The addition of six wells in 1968-69 at the site of the water-treatment plant and the replacement of the old low-capacity pumps with high-capacity pumps at all existing wells increased the final capacity of the well field to 150 Mgal/d. Miller (1978, p. 8-9) presented a summary of the development of the well field and the growth in withdrawal capacity.

Since its establishment, the well field at the Hialeah-Miami Springs area has been affected by saltwater intrusion. Intrusion was attributed to the following factors: (1) uncontrolled drainage of the area by canals before 1946 that permitted excessive lowering of water levels and that disturbed the historic hydrologic balance between freshwater and salty tidewater (Parker and others, 1955, p. 584-591); (2) lack of or inadequate placement of control structures in the Miami and Tamiami Canals to prevent saltwater from migrating upstream to the well field, thus, failing to maintain adequate freshwater heads to retard intrusion; and (3) the persistent increase in the withdrawals in the well field, which increased the inland hydraulic gradient and, therefore, accentuated intrusion in the immediate well-field area. Measures to alleviate the problem of intrusion were initiated by the Dade County water-control agencies in 1946 and the Central and Southern Florida Flood Control District (named South Florida Water Management District in 1971) by the installation and operation of flow regulation structures in the canals.

The purpose of this report is to trace the occurrence and movement of saltwater in the Biscayne aquifer in the Hialeah-Miami Springs area. In this area, the water resources are affected by the status of the Miami and Tamiami Canals and by the increase in withdrawals at the well field operated by the Miami-Dade Water and Sewer Authority. The report reviews and analyzes the changes in the pattern of saltwater intrusion in the Hialeah-Miami Springs area through 1985.

SALTWATER INTRUSION BEFORE 1946

As early as 1939, 15 years after water withdrawals originally occurred in the Hialeah-Miami Springs well field, some municipal supply wells adjacent to the tidal reach of the Miami Canal began showing evidence of contamination from salty canal water that had extended up the canal and beyond the well-field area. During deficient freshwater outflow, the salty canal water advanced up the canal and beyond the well-field area, percolated into the aquifer, and was drawn laterally toward the clusters of supply wells affected by the average withdrawal rate of the supply wells of 20 Mgal/d (see fig. 2, A and B). As a result, some wells had to be shut down because they yielded water with chloride concentrations greater than permitted by health regulations. A comparison of the areas affected by the increased chloride concentrations in December 1939 and in August 1945 is shown in figure 2 (Parker and others, 1955, figs. 193 and 196).

An intruding lobe of saltwater along the Miami Canal fluctuated seasonally, advancing landward and increasing in chloride concentration during dry seasons, and regressing seaward and becoming diluted during wet seasons. To retard saltwater intrusion, which became a major threat to the well field during the 1944-46 dry seasons, a temporary control structure of sheet-steel piling was driven into the bottom of the Miami Canal at NW 36th Street in 1946 (fig. 2C). The structure prevented the direct upchannel movement of saltwater, reduced the drainage of fresh ground water from the area, and raised the water table in the overall Hialeah-Miami Springs area.

The patterns of intrusion for December 27, 1939, and August 30, 1945 (fig. 2), indicate that saltwater in the uncontrolled Miami Canal was the main source of contamination in the well field, and that the pumping of supply wells was drawing the saltwater from the canal. The patterns also show a widening of the saltwater lobe along the lower reach of the Miami Canal and westward into the Miami Springs area along NW 36th Street.

SALTWATER INTRUSION DURING 1946-76

The installation of the sheet-steel piling into the bottom of the Miami Canal at NW 36th Street, although rudimentary, had an immediate effect of reducing the chloride contamination in the well-field area. Water control could still be accomplished by withdrawing sections of sheet-steel piling as needed to discharge surplus freshwater for flood protection. By replacing the sections gradually to full closure at the beginning of the dry season, the overdrainage of ground water was prevented and seaward hydraulic gradients in the aquifer were maintained in the vicinity. Lines of equal chloride concentration for December 30, 1946 (Parker and others, 1955, fig. 195) (fig. 2), indicate the marked decrease in the area affected by saltwater intrusion. At that time, none of the areas of municipal well clusters contained water that exceeded the standard for chloride concentration in drinking water (250 mg/L [milligrams per liter]). The December 1946 map also shows that a lobe of high chloride water persisted in the vicinity of NW 36th Street.

The successful method of controlling intrusion through regulation of canal discharge provided the water-supply and water-control agencies with a basis for increasing the withdrawals in the Hialeah-Miami Springs well field needed to satisfy greater water-supply demands during the 1950's and 1960's. The number of wells in Miami Springs was increased to 23, and in the middle to late 1960's, 6 more wells were added to the system on the Hialeah (northeast) side of the Miami Canal; this boosted the capacity of the well field to about 120 Mgal/d. Further improvements were made to pumping facilities, increasing the final combined capacity of the 29 wells to 150 Mgal/d.

The hydrograph (fig. 3) of well S-68, which is located in the south cluster of wells in Miami Springs (see fig. 4 for location), shows the gradual decline of the water table as withdrawals were increased. Figure 4 shows the configuration of the lobe of saltwater intrusion near the end of the dry season (May) in 1971, after 25 years of increased well-field withdrawals and the regular seasonal operations of the control structure in the Miami Canal. The withdrawal rate in 1971 was about 120 Mgal/d. As a result, saltwater intrusion was effectively retarded, except along NW 36th Street and the Miami International Airport where westward and slight northward migration of saltwater occurred from the uncontrolled tidal reach of the Tamiami Canal. As described by Parker and others (1955, p. 590), the Tamiami Canal was controlled southwest of the airport (see fig. 4), enabling tidal conditions to extend inland and saltwater to migrate into the deep rock pits south of the airport during dry seasons (Meyer, 1972, fig. 17).

The near-record dry season in 1970-71 again caused concern for saltwater contamination in the well field, but the threat this time was by northward migration of saltwater from the uncontrolled reach of the Tamiami Canal and the connected deep rock pits. A temporary sheet-steel pile control was installed in the Tamiami Canal at a site southeast of the airport (fig. 5) in September 1971 that reduced, by about 3,000 feet,the potential area subject to seasonal contamination by saltwater from the Tamiami Canal. Water levels in the well-field area during the dry seasons of 1973 and 1974, after the temporary control was operational, and the effect that the control of the canal flow had on the configuration of the lobe of saltwater, are shown in figure 5 (Miller, 1978, figs. 5 and 8). The 100-mg/L and the 1,000-mg/L lines of equal chloride concentration were shifted east because of the buildup of hydraulic gradient in the vicinity of the Tamiami Canal upstream of the control. However, the 100-mg/L line was also deflected north as a result of the severe water-level declines caused by large withdrawals at the Hialeah area supply wells, which were about 120 Mgal/d during May 1973 and about 135 Mgal/d during May 1974.

SALTWATER INTRUSION DURING 1976-84

To manage effectively the water resources of the Miami-Tamiami Canal basin and to control saltwater intrusion in the aquifer, the U.S. Army Corps of Engineers constructed and began operation of a permanent control structure in the Tamiami Canal just east of Le Jeune Road in April 1976. This site is about 3,000 feet downstream from the temporary site. Subsequent timely operations of the new structure, together with operations of the permanent structure on the Miami Canal at NW 36th Street by the South Florida Water Management District, resulted in maintaining high freshwater heads upstream of the structures. This reduced chloride concentrations within the intruding saltwater lobe.

Progressive changes in the shape of the intruding saltwater lobe and the configuration of the lines of equal chloride concentration within the lobe at the base of the aquifer for the dry seasons of 1980-83 are shown in figures 6 through 9. The lines of equal chloride concentration changed gradually in response to the installation of the temporary structure in 1971 and later by the installation and operation of the permanent structure. The factors influencing the local area and the saltwater lobe included: (1) the relatively large increase in a northward hydraulic gradient along the southern perimeter of the Miami International Airport as a result of maintaining a head of 2.5 feet in the Tamiami Canal during most of the year; (2) the continued heavy pumping in the well field, which induced a constant steep northward gradient toward the center of the well field; (3) the constant high head maintained in the controlled reach of the Miami Canal; and (4) changes in the water levels and periodic discharges produced by operations of both control structures for flood control and water management. Also, influencing the saltwater lobe is the effect of heavy pumping.

A comparison of the contours in figures 6 through 9 shows the gradual decay of the saltwater lobe during 1980-83. In general, the most marked changes in chloride concentration occurred in the forward (inland) section of the lobe of saltwater where concentrations were less than 500 mg/L. The decrease in the concentration is probably attributable to: (1) maintenance of a relatively high freshwater head in the areas upstream of the control structures in the Miami and Tamiami Canals, which retarded further intrusion or caused it to retreat seaward; (2) pumping at the well field (as much as 150 Mgal/d in 1983), which drew off some water from the forward part of the saltwater lobe; and (3) dilution by lateral and vertical dispersion. By May 1983, the lobe had decayed to the extent that virtually all of the area north of NW 36th Street contained ground water of chloride concentrations less than 500 mg/L.

SALTWATER INTRUSION IN 1985

A series of analyses for toxic substances in untreated water from supply wells in the Hialeah-Miami Springs area well field and from the surrounding area were made by the Dade County Department of Environmental Resources Management. They concluded, in early 1984, that local discharges of industrial waste products, containing volatile organic compounds and other toxic substances, had percolated into the aquifer in quantities that potentially could affect public health. In response, the Miami-Dade Water and Sewer Authority reduced withdrawals from the Hialeah-Miami Springs well field and transferred the bulk of its municipal pumping to the newly established Northwest well field, 7 miles west in The Everglades (fig. 1). In order that all wells in the Hialeah-Miami Springs area well field could be maintained in operable condition in case of emergencies, the Authority was given the option to alternately pump one different well each day at a rate of 10 Mgal/d.

As a result of the reduction in withdrawals, the water table rose (see fig. 3) as much as 10 feet in the area near the cluster of wells in Hialeah where the water-level drawdown had been greatest, and the water table sustained an altitude of 2.0 to 2.5 feet in the overall area of the well field. The saltwater lobe was further freshened and reduced in size in April 1985, about 1 year after the moderation of well-field withdrawals (fig. 10). Additional freshening can be expected, following successive high water levels during subsequent wet seasons, with the resumption of a seaward hydraulic gradient in the Hialeah-Miami Springs area, and with the probable increase in outflows through the Miami and Tamiami Canals, which would include water from the saltwater lobe.

Through the years, the Hialeah-Miami Springs well field has become a dependable and low-cost source of municipal water supply that has only recently been affected by low-grade contamination from toxic substances. The repeated partial purging of saltwater from the well-field area during the wet seasons of the 1930's, 1940's, and 1980's through water-control and management techniques also suggests the possibility of the purging of existing toxic substances. Locating and controlling the sources of the toxic discharges to prevent continued contamination, continuation of effective and intensive water-management practices, and application of innovative water-treatment methods may enable full utilization of the well field in the future.

SUMMARY

A lobe of salty ground water that had intruded the Hialeah-Miami Springs area municipal well field, adjacent to the Miami and Tamiami Canals in Dade County, Fla., was stabilized after flow-regulation structures were installed in the canals in 1946. However, in 1971, the saltwater began to readvance toward the center of the well field because of water-level declines caused by large increases in withdrawals during a near-record dry season.

To better protect the well field, a temporary flow-regulation structure, constructed in 1971, in the Tamiami Canal was moved in 1976 to a permanent site, about 3,000 feet farther seaward. This water-management procedure brought about a gradual freshening of the ground water and canal water and enabled maintenance of a high freshwater head above the structure and along the south side of the well field. The combined effect resulted in a dilution of the intruding saltwater lobe and a marked contraction of its size even though large municipal withdrawals continued at the adjacent well field. A major cutback in municipal withdrawals in early 1984 resulted in a recovery of water levels in the well-field area, causing further freshening of the saltwater lobe.

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Parker, G.G., 1951, Geologic and hydrologic factors in the perennial yield of the Biscayne aquifer: American Water Works Association Journal, v. 43, no. 10, p. 817-835.

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ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to metric (International System) units and abbreviation of units

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

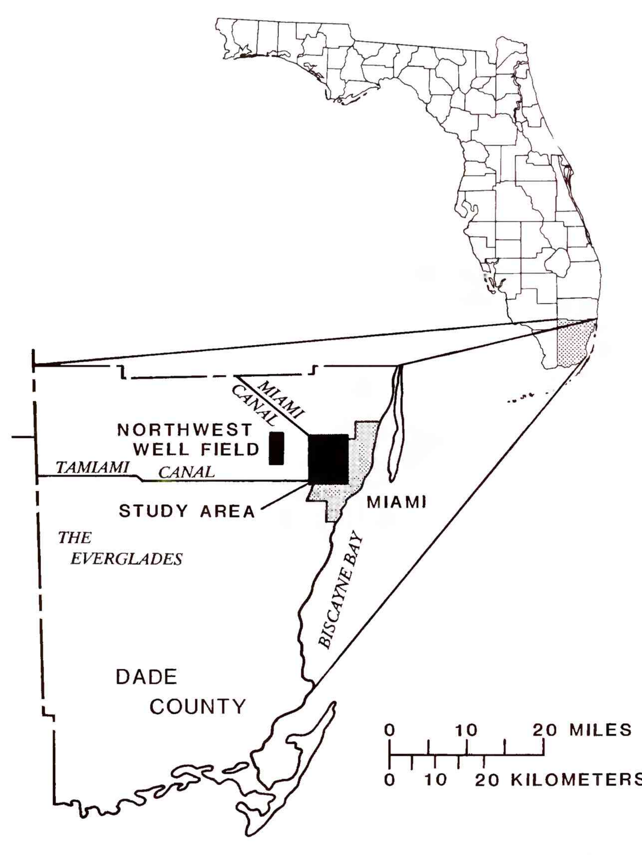

Figure 1.--Dade County showing location of the Hialeah-Miami Springs study area.

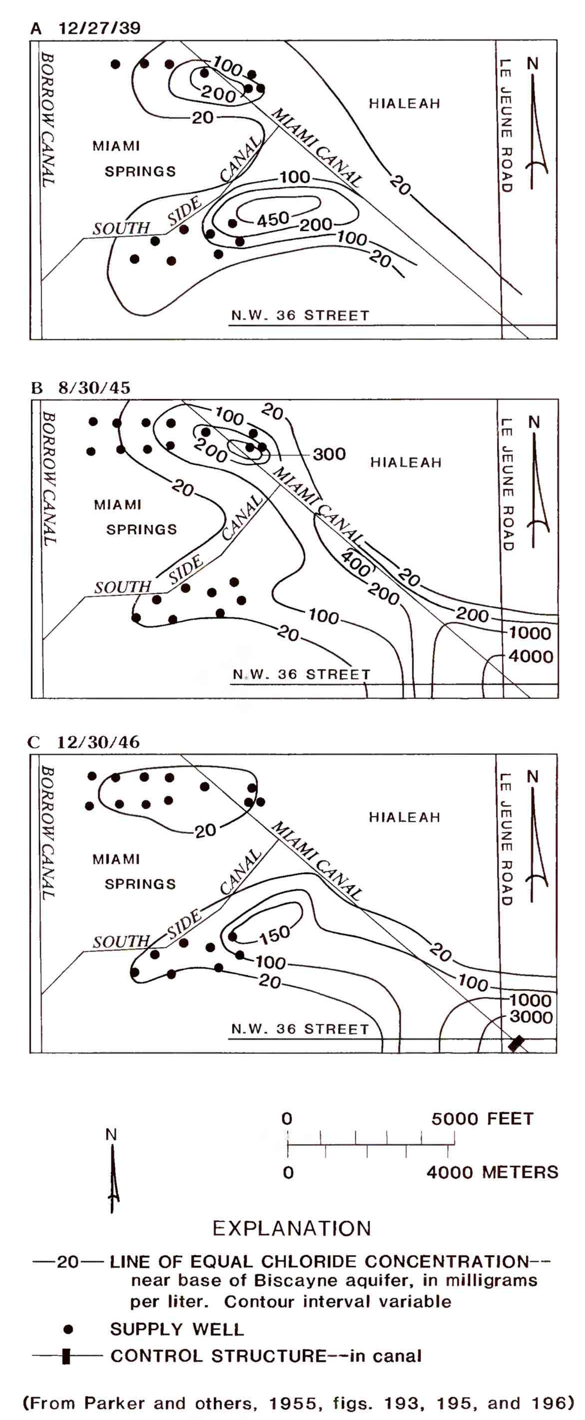

Figure 2.--Hialeah-Miami Springs area showing lines of equal chloride concentration, (A) December 27, 1939, (B) August 30, 1945, and (C) December 30, 1946, supply wells, and control structures.

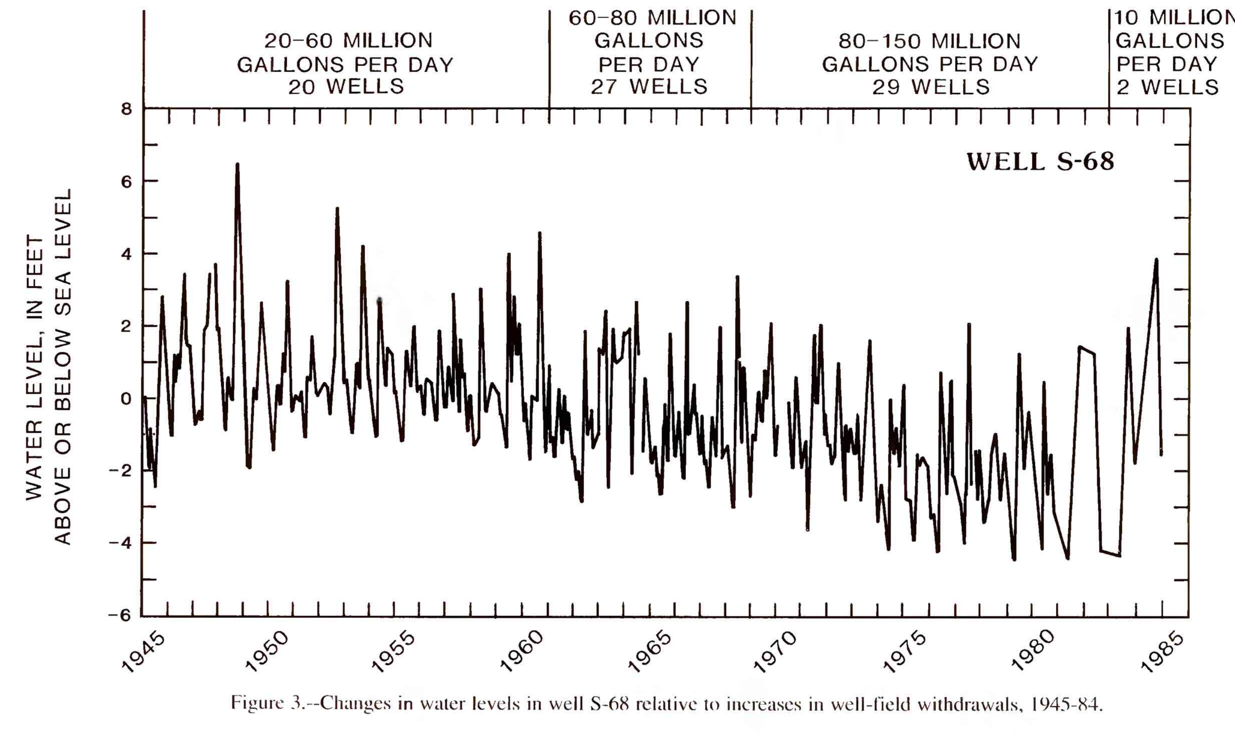

Figure 3.--Changes in water levels in well S-68 relative to increases in well-field withdrawals, 1945-84.

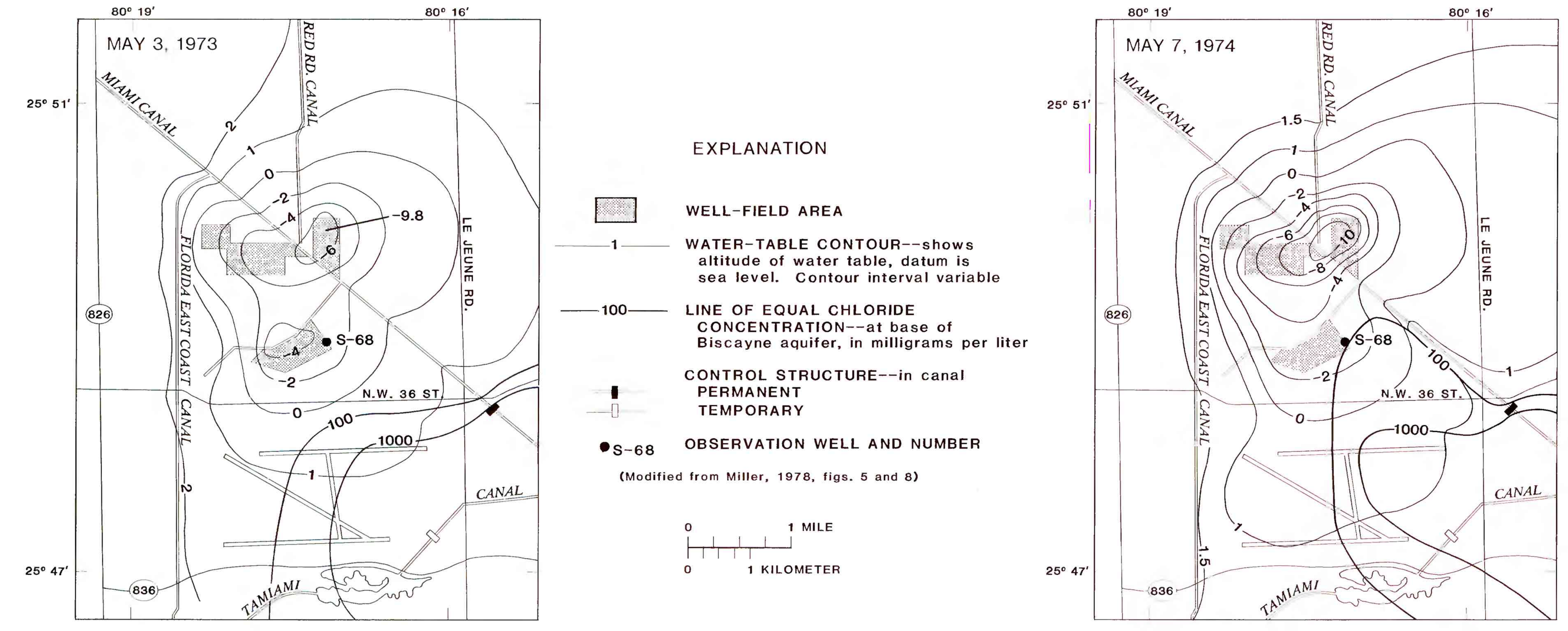

Figure 5.--Hialeah-Miami Springs area showing altitude of the water table and lines of equal chloride concentration, May 3, 1973, and May 7, 1974, well fields, and control structures.

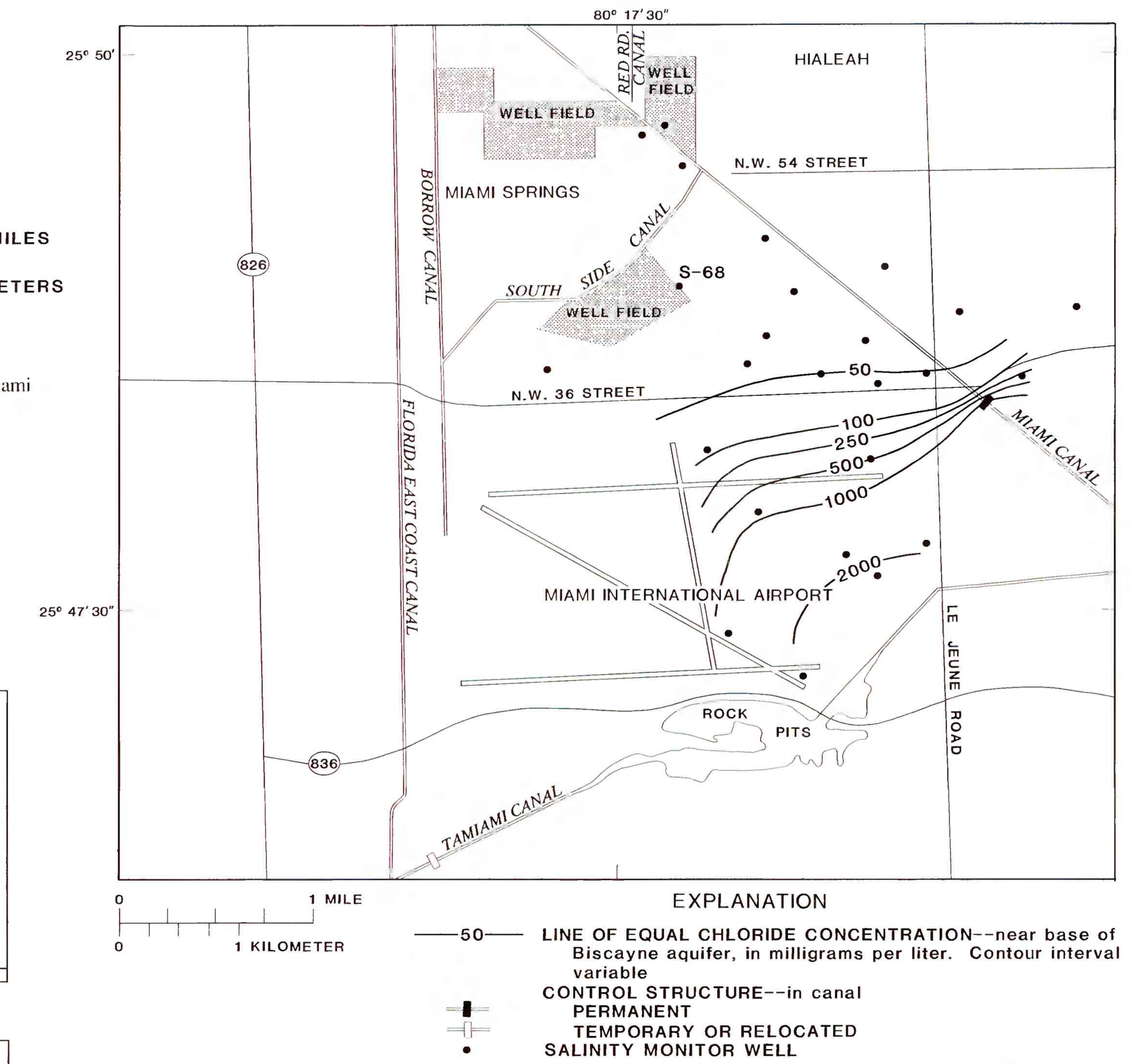

Figure 4.--Hialeah-Miami Springs area showing lines of equal chloride concentration, May 1971, well fields, and control structures.

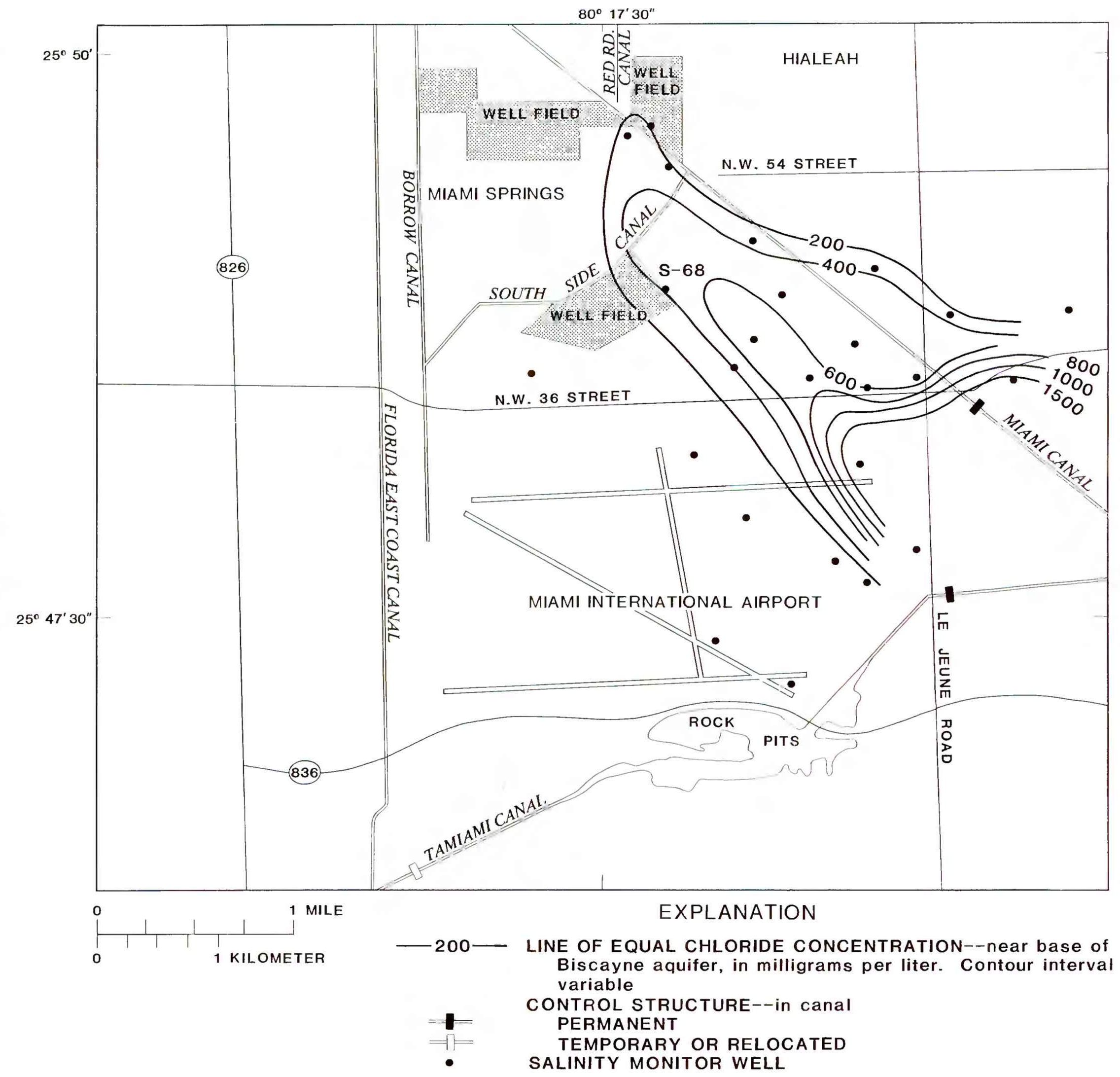

Figure 6.--Hialeah-Miami Springs area showing lines of equal chloride concentration, April 1980.

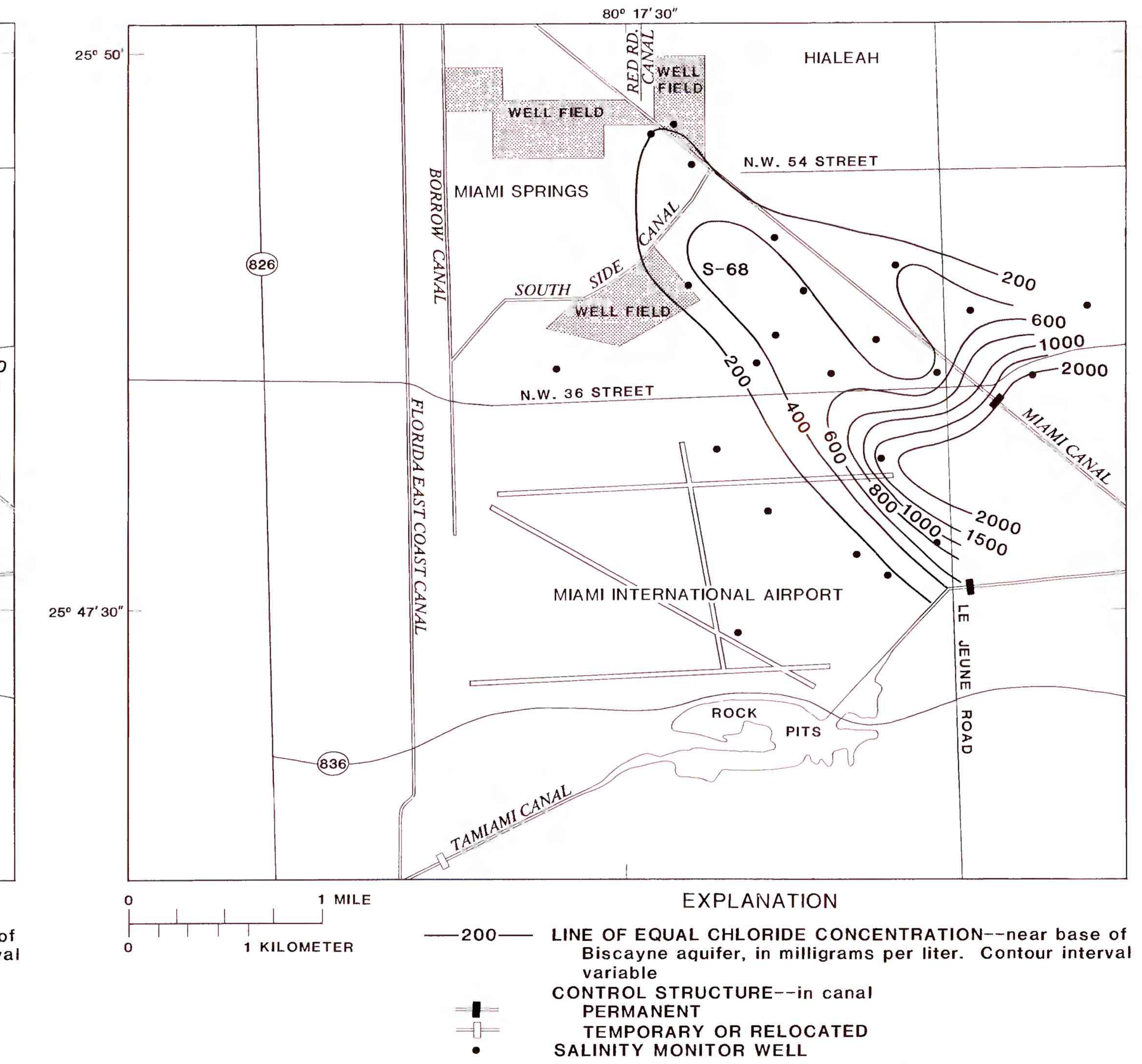

Figure 7.--Hialeah-Miami Springs area showing lines of equal chloride concentration, May 1981.

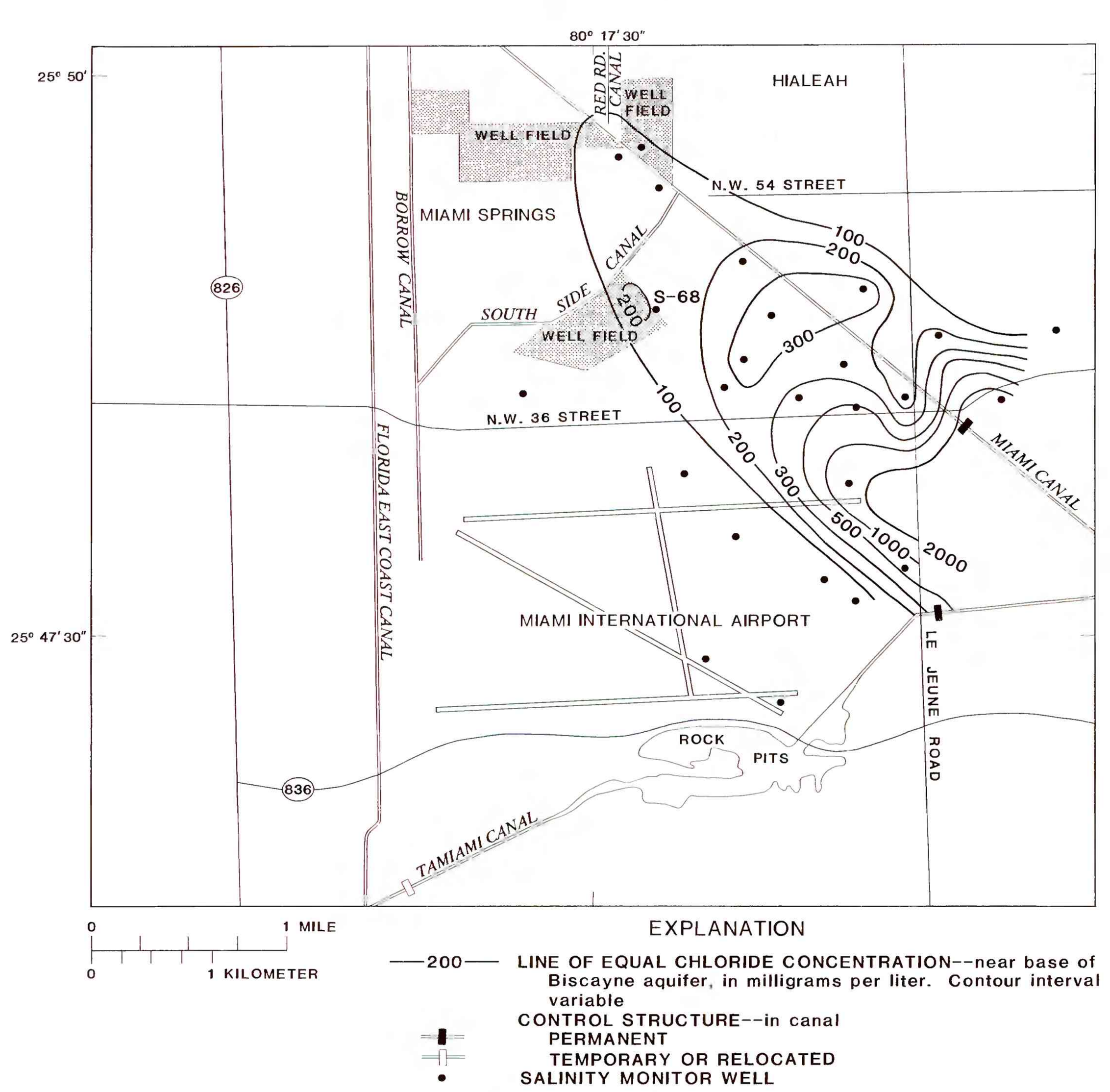

Figure 8.--Hialeah-Miami Springs area showing lines of equal chloride concentration, June 1982.

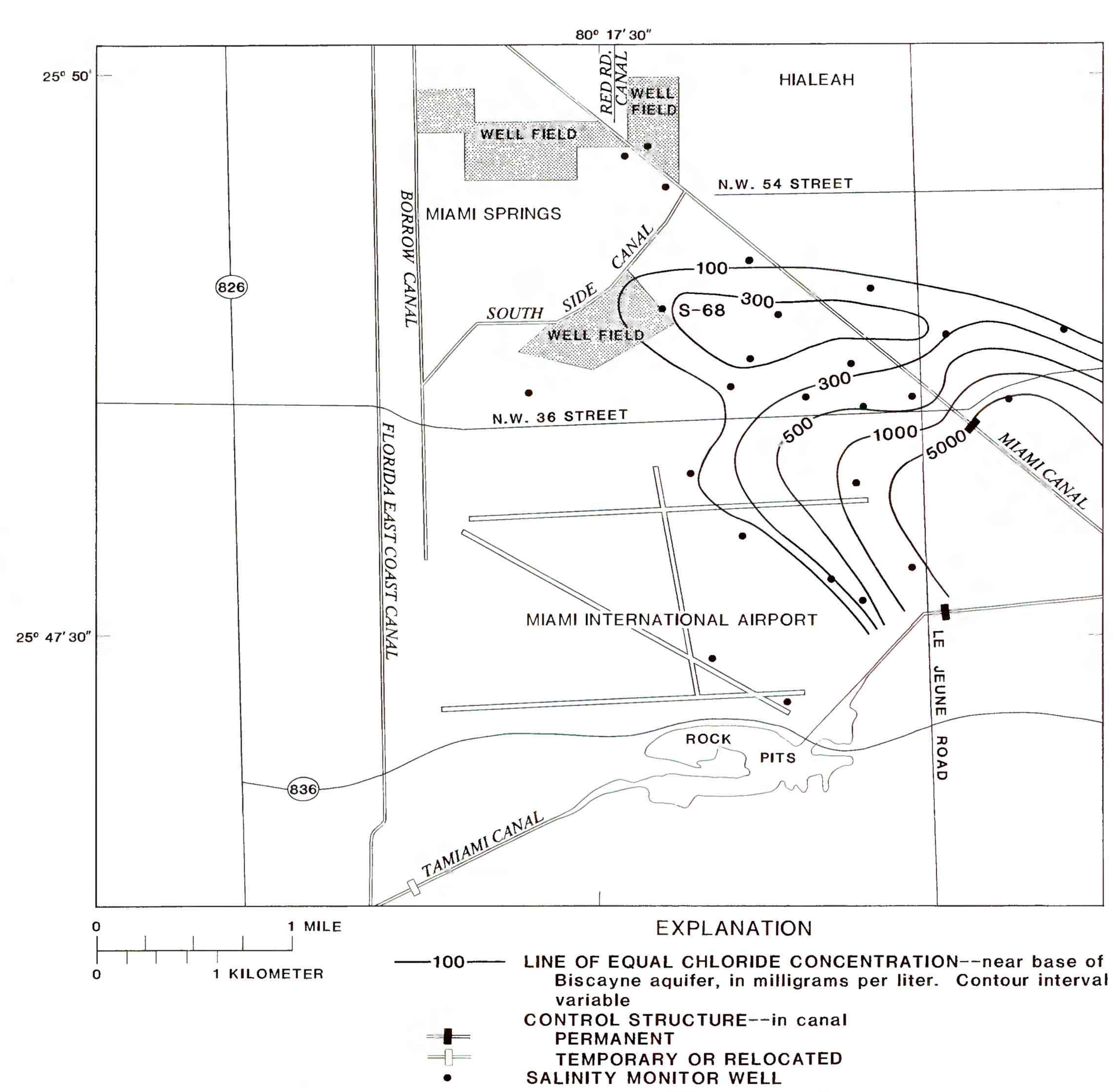

Figure 9.--Hialeah-Miami Springs area showing lines of equal chloride concentration, May 1983.

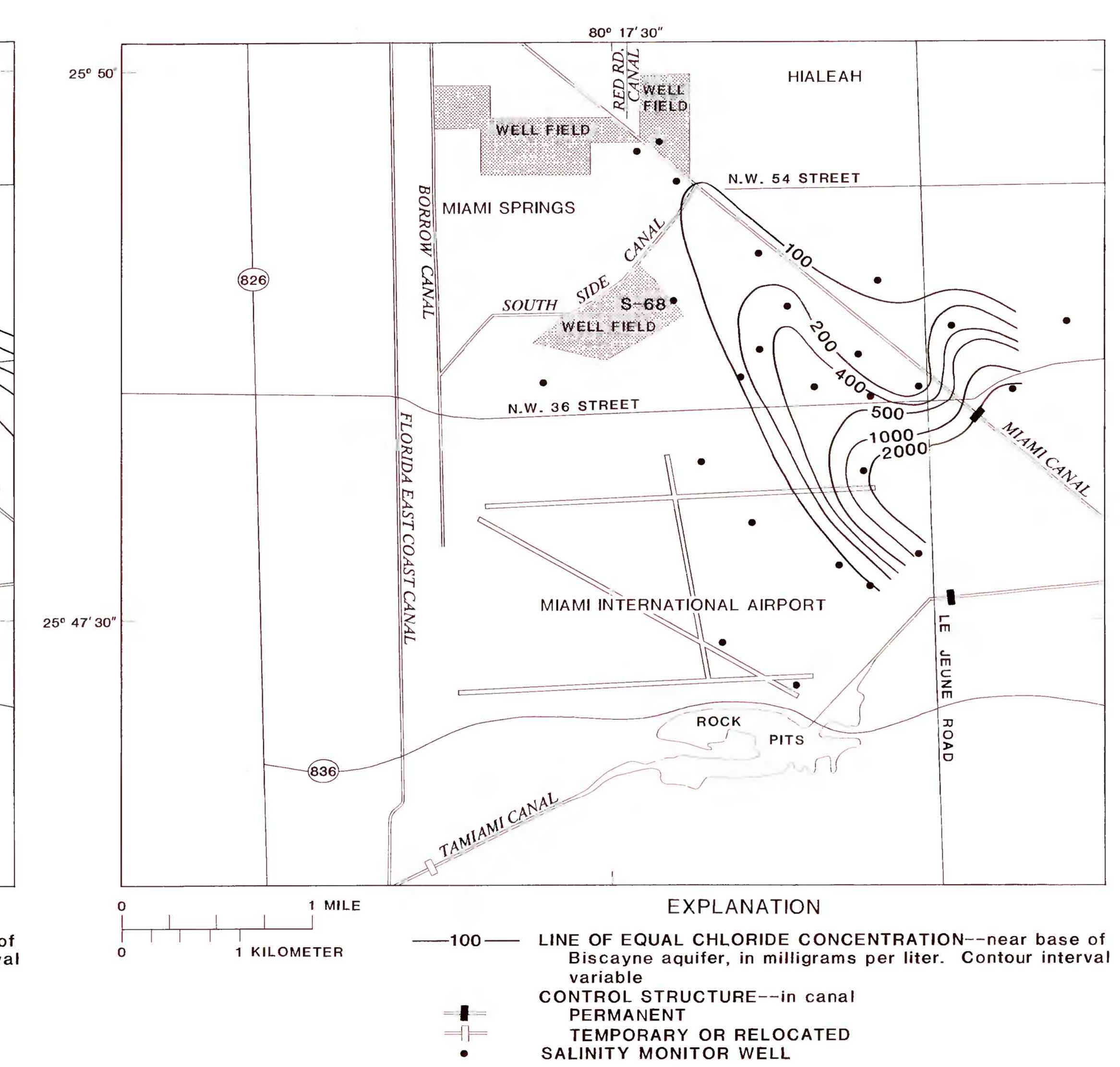

Figure 10.--Hialeah-Miami Springs area showing lines of equal chloride concentration, April 1985.

CHANGES IN SALTWATER INTRUSION IN THE BISCAYNE AQUIFER, HIALEAH-MIAMI SPRINGS AREA, DADE COUNTY, FLORIDA

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