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GEOLOGICAL SURVEY

GROUND-WATER QUALITY IN SELECTED AREAS SERVICED BY SEPTIC TANKS, DADE COUNTY, FLORIDA

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

GROUND-WATER QUALITY IN SELECTED AREAS SERVICED BY SEPTIC TANKS, DADE COUNTY, FLORIDA

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ABSTRACT

During 1971-74, the U.S. Geological Survey investigated the chemical, physical, bacteriological, and virological characteristics of the ground water in five selected areas serviced by septic tanks in Dade County, Florida. Periodic water samples were collected from multiple-depth groups of monitor wells ranging in depth from 10 to 60 ft at each of the five areas. Analyses of ground water from base-line water-quality wells in inland areas remote from urban development indicated that the ground water is naturally high in organic nitrogen, ammonia, organic carbon and chemical oxygen demand. Some enrichment of ground water with sodium provided a possible key to differentiating septic-tank effluent from other urban ground-water contaminant sources. High ammonia nitrogen, phosphorus, and the repetitive detection of fecal coliform bacteria were characteristic of two 10-foot monitor wells that consistently indicated the presence of septic-tank effluent in ground water. Dispersion, dilution, and various chemical processes have presumably prevented accumulation of septic-tank effluent at depths greater than 20 ft, as indicated by the 65 types of water analyses used in the investigation. Fecal coliform bacteria were present on one or two occasions in many monitor wells but the highest concentration, 1,600 colonies/100 ml, was related to storm-water infiltration rather than septic-tank

discharge.

Areal variations in the composition and the hydraulic conductivity of the sand and limestone aquifer had the most noticeable influence on the overall ground-water quality. The ground water in the more permeable limestone in south Dade County near Homestead contained low concentrations of septic-tank related constituents, but higher concentrations of dissolved sulfate and nitrate. The ground water in north Dade County, where the aquifer is less permeable, contained the highest dissolved iron, manganese, COD, and organic carbon.

INTRODUCTION

Septic tanks have been used for the disposal of domestic waste water in Dade County, in southeast Florida, for more than 70 years. By 1970 nearly 175,000 septic tanks were discharging about 40 Mgal/day of domestic waste water into the Biscayne aquifer, the prime source of fresh water in the county. Over the years of growth of Miami and its suburbs, sanitary sewer systems of different capacities were built and expanded in order to gradually reduce the loads discharged into the aquifer from septic tanks. Because of the rapid rate and the sprawling nature of the growth, the number of septic tanks installed for new housing exceeded the number of septic tanks retired from service through connections to sewer systems. Even during 1970-73, when some restrictions were placed on new septic-tank installations by zoning ordinances, the number of new septic tanks installed surpassed the number that were removed from service by sewering. Moreover, thousands of residences still depend upon individual water supply systems in areas still served by septic tanks. These residences are served by individual shallow wells for household use or lawn irrigation.

Reported incidents of polluted well water were minimal before the mid 1960's, despite the thousands of wells and septic tanks that were then operational within the couty. Recently, reported incidents have been increasing, and local officials and county, state, and federal pollution-control personnel have expressed concern over the potential for major water-quality problems if septic-tank installations were allowed to proliferate in the yet sparsely developed or undeveloped parts of the county.

Purpose and Scope

The purpose of the investigation is to evaluate the effects of septic-tank effluent on ground-water quality. Although some early data are available on ground-water quality in Dade County they are for parts of the county primarily near municipal wells. No detailed information is available concerning water quality at different depths in the aquifer. The work in this project was specifically designed to determine how water quality was affected at different depths and in places where septic-tank density varied, and where geologic and hydrologic conditions differ. The information obtained would be used by zoning and pollution-control officials in establishing interim criteria for septic-tank densities in the remaining developable areas of the county.

The scope of the investigation was restricted to a definition of the ground-water quality in long established single-family residential areas (15 years or more) where septic-tank density does not exceed four septic tanks per acre. It does not include a definition of quality in areas on which apartments or other multi-unit buildings have been constructed. To serve as a basis for comparison with the septic-tank areas, ground-water samples were collected from base-line water-quality sampling sites in uninhabited parts of the county, three times from May to October, 1973. Included in the study also was a determination of the local soil properties and the hydrologic and geologic characteristics of the Biscayne aquifer in the areas investigated.

This report, the second of this investigation, presents the results of 2 years of data collection by the U.S. Geological Survey. The investigation was begun in 1971 in cooperation with the Dade County Manager's office. Also participating were the U.S. Environmental Protection Agency, the Dade County Pollution Control Department, and the University of Miami. An interim report was released to the open file in September 1974 (Pitt, 1974).

Acknowledgments

Data and technical assistance for this investigation were supplied by the following people: Dr. Leonard Greenfield and Mrs. Frances Parsons of the University of Miami; Mr. David Hopkins and Dr. Russell Todd of the U.S. Environmental Protection Agency; and Messrs. Nystrom, Rodriguez, and Barker of Dade County Pollution Control. Messrs. Alonso, Beach, Bernstein, Franconi, and Onysko allowed the use of their properties to conduct the tests.

Appreciation is also expressed to Mr. Richard Brusuelas of the Greater Miami Chamber of Commerce and to Mr. Dennis Carter of the Dade County Manager's office for their efforts in promoting the investigation.

HYDROLOGIC SYSTEM

Biscayne Aquifer

The Biscayne aquifer is the only source of fresh ground water in Dade County, yielding about 250 Mgal/day to municipal water systems within the county in 1974. In the south part of the county where the permeability (hydraulic conductivity) is highest the Biscayne is composed primarily of solution riddled limestone and sandstone. In central and north Dade County the content of sand in the aquifer increases, thereby reducing the overall permeability. The aquifer is wedge-shaped, being thin at the west county boundary and increasing in thickness eastward to more than 150 ft at the coast in north Dade County. Contours on the bottom of the highly permeable limestone of the aquifer are shown in figure 1 (Schroeder and others, 1958, fig. 2)

Nearly everywhere in Dade County oolitic limestone forms the upper part of the Biscayne aquifer. Its maximum thickness is about 40 ft but the average thickness along the coastal ridge is 20 to 30 ft. It thins westward in the Everglades. The limestone is riddled with solution cavities, primarily in a vertical direction, and therefore rainfall infiltrates rapidly to the water table (Parker, 1951). In north and parts of central Dade County medium sized quartz sand forms a veneer over oolitic limestone. The sand also absorbs rainfall readily. All septic tanks and drainfields are cut into the oolitic limestone or the sand.

The lower part of the Biscayne aquifer is composed of cavernous limestone of overall high permeability west of the coastal ridge, and limestone, sandstone and sand of lower permeability along the coastal areas. Municipal and irrigation wells of high yield (as much as 7,000 gal/min) penetrate the permeable limestone in the lower part of the aquifer. Most wells for lawn sprinking and for residential use remote from public supply service areas withdraw water from the shallow parts of the aquifer.

The interconnection of the pore spaces in rocks affects the ability of ground water to move through the rocks. This characteristic of the rocks is referred to as hydraulic conductivity, commonly called

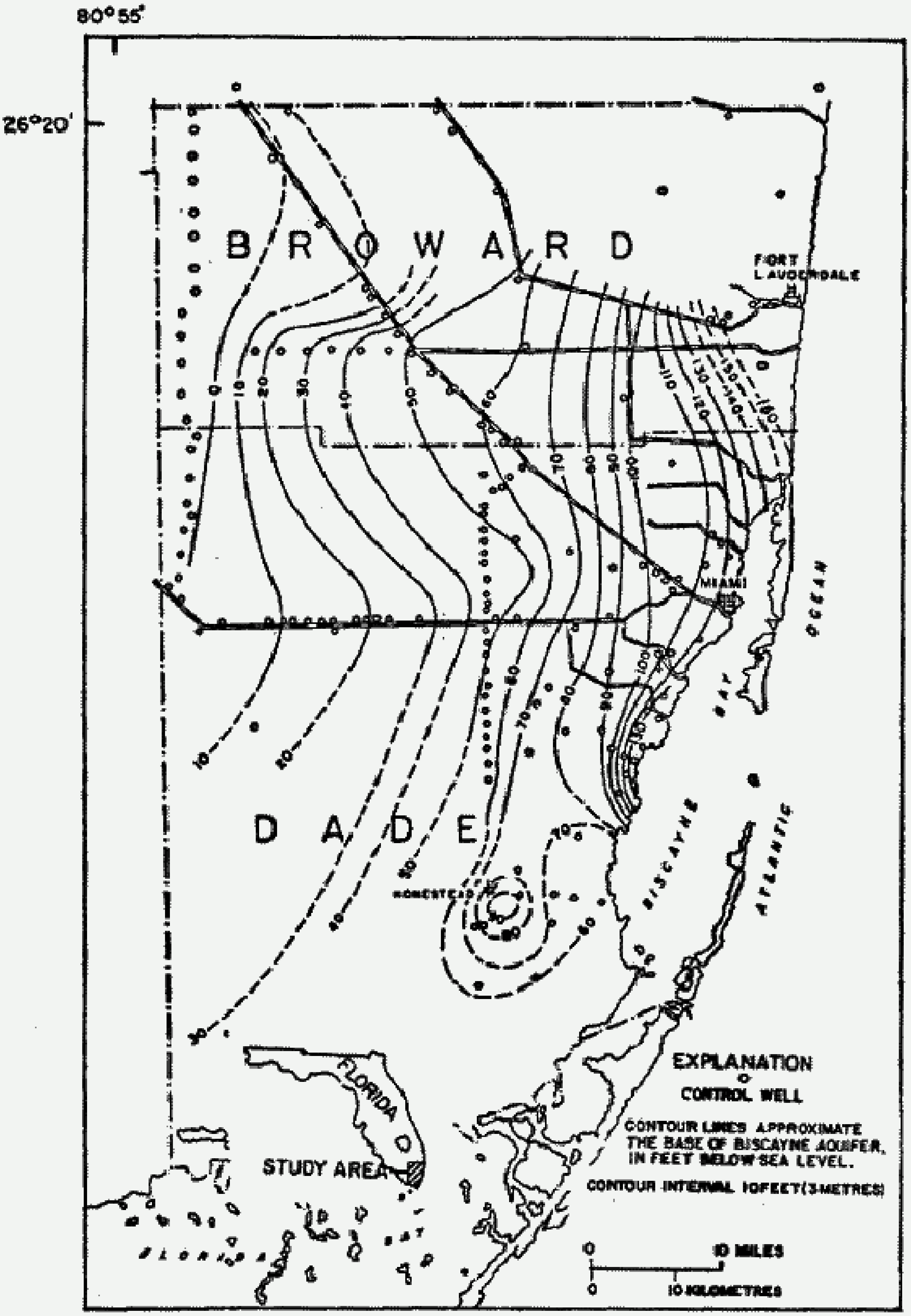


FIGURE 1.--Contours on the base of the Biscayne aquifer (Schroeder and others, 1958)

permeability. The hydraulic conductivity multiplied by the saturated thickness of the aquifer at selected locations equals the transmissivity of the aquifer at those locations. Thus, the properties of conductivity and transmissivity are important in Dade County water-quality studies because they are indicative of the ability of the aquifer to conduct contaminants, such as those related to septic tank effluent, to downgradient areas. In sandy areas of relatively low hydraulic conductivity, septic tank effluent tends to accumulate and disperse slowly, whereas in areas of high hydraulic conductivity it tends to dissipate rapidly and move long distances.

Effective porosity refers to the amount of interconnected pore space available for fluid movement. It is expressed as a percentage of the total volume occupied by the interconnecting openings. Parker (1951) suggested that this value probably ranges from 0.10 to 0.35 for the Biscayne aquifer. The high value would be associated with the cavernous sections of the aquifer.

Aquifer tests of the Biscayne aquifer made by Parker (1955), indicate that the average hydraulic conductivity ranges from 6.7×10^3 ft/day to 9.4×10^3 ft/day. The transmissivity ranges from about 3.7×10^5 ft^2/day in north Dade County to nearly 2.0×10^6 ft^2/day near Homestead (Meyer 1974). Values for the Biscayne aquifer are among the highest recorded in the United States (Parker, 1951).

Recharge to the Biscayne aquifer occurs throughout Dade County, particularly during the rainy season. Water levels therefore are usually highest during September and October, and lowest during April and May. Parker (1955) and Meyer (1971) estimated that of the 60 in. of annual rainfall in Dade County, 20 in. is evaporated. Of the 40 in. that infiltrates 20 in. is lost from the ground-water system by evapotranspiration, 18 in. is lost through canal discharge and coastal underseepage, and the remainder is used primarily for domestic and agricultural purposes. These data indicate that nearly 50 percent of the rainfall that infiltrates to the water table was discharged to the ocean by canals and by coastal seepage, and tend to confirm the high hydraulic conductivity of the limestone into which the canals are cut, and the good hydraulic connection between the canals and the aquifer. Because of the good connection, the primary canal drainage system in the county is a major influence on the occurrence and movement of ground water.

Ground-water Flow Pattern

In order to minimize flooding during heavy rainfall, control structures in canals are opened to permit drainage of excess water to the ocean. This causes ground water to move to the canals thereby lowering water levels in intercanal areas. The effect of drainage (lowering of ground-water levels) decreases with distance from the canals. The rate of ground-water movement also is greatest adjacent to the canals, decreasing with distance from the canals.

Early in the dry season the control structures are closed, and, unless unseasonal heavy rains occur thereafter, they remain closed until the next rainy season. Closure of the control structures causes the flow rate and flow distribution in the aquifer-canal system to change. After the structures are closed, the inland controlled reaches of the primary canals continue to pick up ground water from the interior parts of their basins and from Water Conservation Area 3 (fig. 2) and transfer it downstream toward the control structures where water levels are maintained at the scheduled levels of the structures. However, the levels sustained along the lower controlled reaches are usually higher than the adjacent ground-water levels so that water seeps from the canals into adjacent parts of the aquifer. This reversal in ground-water movement remains throughout the dry season in all canal basins except those in south Dade County.

In recent dry seasons water levels in the interior of south Dade County have declined below sea level, temporarily resulting in an inland hydraulic gradient. Normally the hydraulic gradient is seaward. These periodic reversals in gradient affect the area south of the latitude of Homestead. The ensuing rainfall then reestablishes a seaward gradient.

Since ground water moves downgradient along lines perpendicular to water-level contours, the direction of flow within the aquifer system in Dade County in general can be determined from the contour maps of high and low water levels shown in figures 2 and 3 (Hull and others, 1973). The contours show that the water levels are highest in Conservation Area 3 where flow originates, and lowest along the coast and in the south. General flow is east in north Dade County, and southeast and south in south Dade County.

The inland bending of the contours north of the Tamiami Canal

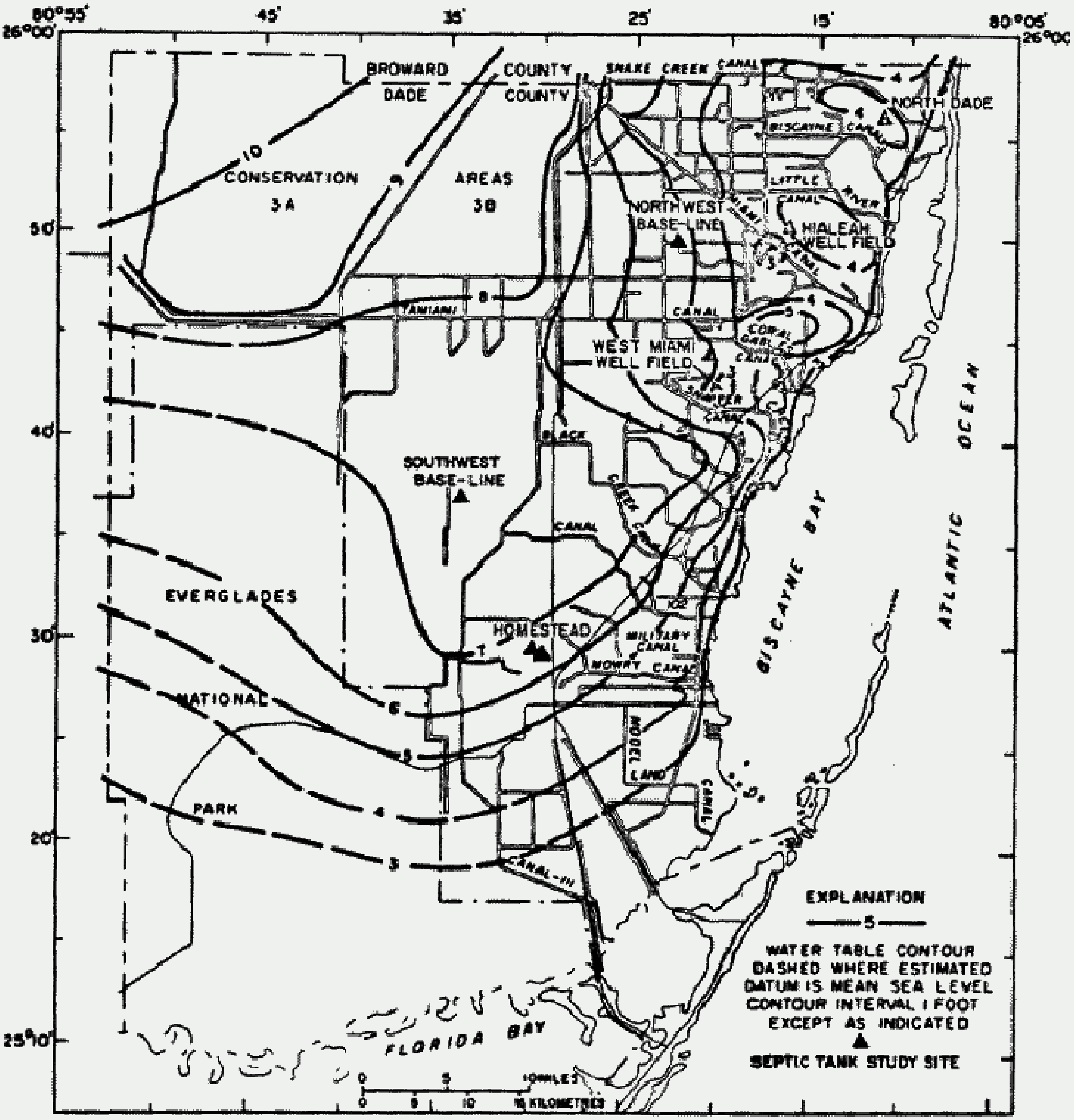


FIGURE 2.--Contours for the average yearly highest water levels, 1960-72 (Hull and others, 1973).

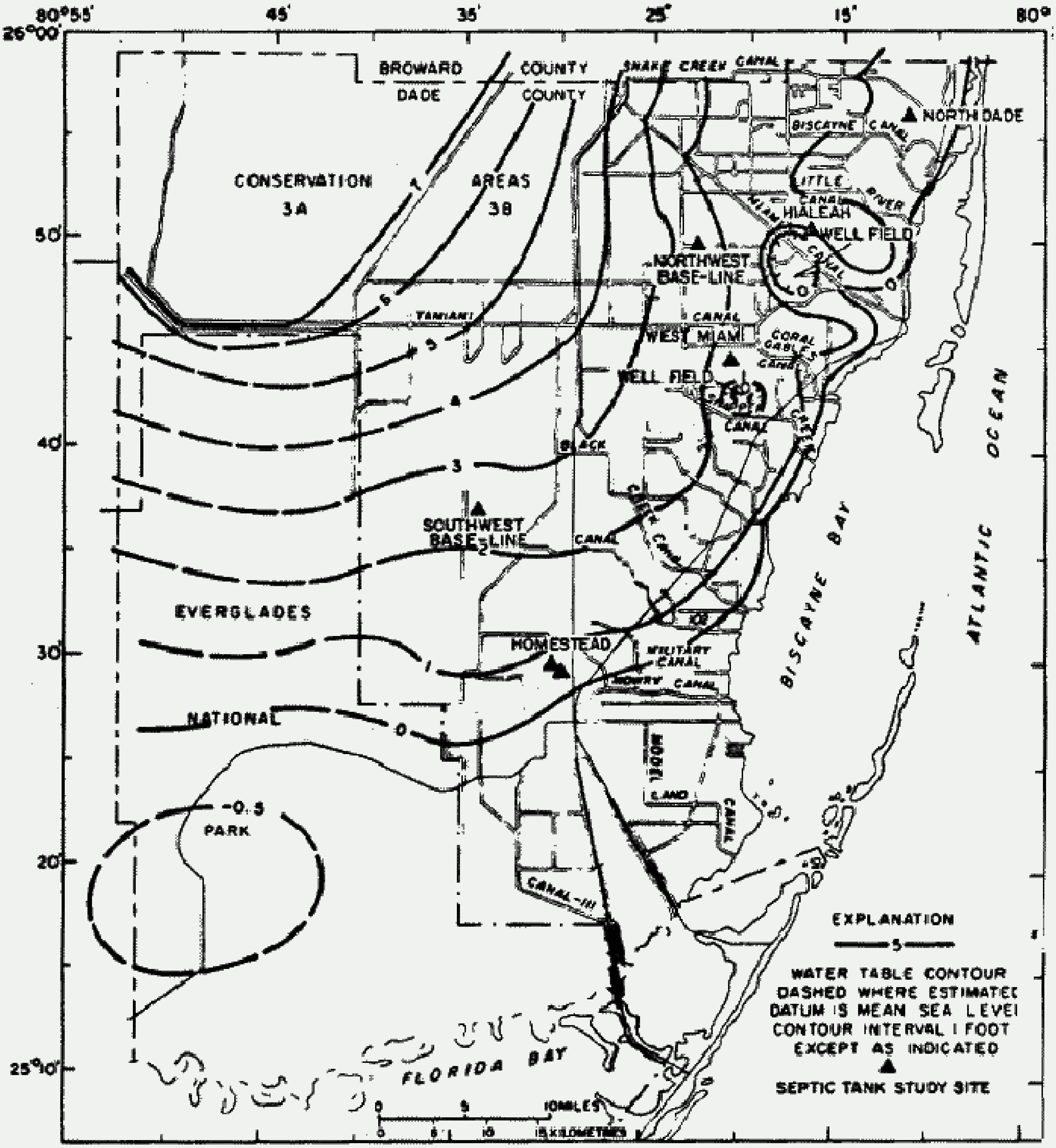


FIGURE 3.--Contours for the average yearly lowest water levels, 1960-
(Hull and others, 1973).

(fig. 2) is the result of drainage by the dense network of primary and secondary canals. In the north the temporary ground-water mounds (fig. 2) along the coastal intercanal areas during the wet season tend to confirm slower drainage to canals. There, the upper part of the aquifer is composed primarily of sand whose hydraulic conductivity is lower than that of the solution riddled limestones of the south part of the county.

An additional influence on the movement of ground water in Dade County is the continuous large withdrawals from the municipal well fields adjacent to Miami Canal (fig. 2), and the Snapper Creek Canal. All ground-water flow within the areas influenced by those withdrawals is toward the withdrawal centers. Canal water in the vicinity of the well fields feeds the well fields by seepage into the aquifer.

Movement of Contaminants in the Aquifer

Constituents in effluents reaching the saturated zone of the Biscayne aquifer, whether they be from septic tanks, soakage pits or other sources, eventually discharge to Biscayne Bay unless they are diverted en route by pumping wells or are adsorbed by the rock matrix of the aquifer. Their course and time of travel through the aquifer depend upon the location of the source of the effluent with respect to the ground-water flow system, the climatic conditions, the nature of the effluent, and the type of aquifer material through which it moves. The travel time to the bay may range from a few days to years. As indicated previously, the movement will be rapid if effluent is introduced during the wet season near a canal or the bay, and slow if the source is distant from canals in an inland area--particularly during the dry season. Within the saturated zone movement of effluent will have lateral and vertical components, as dictated by the hydraulic gradient within the aquifer, and the effluent density if it differs from that of the native ground water. If it is introduced in an area of aquifer recharge where the water level is high it will have an initial downward component. Then it will move laterally downgradient to areas of discharge, such as the bay or canals where it will then move upward (fig. 4). The main resultant plume of diffused effluent will migrate selectively through zones of high hydraulic conductivity and will be retarded by zones of low conductivity. Therefore detailed geologic and hydrologic information in addition to data on amount and types of effluent infiltration are needed to make accurate assessments of the effect of effluents on ground-water quality.

In the case of septic tanks, an unknown factor is the quantity of effluent that actually infiltrates to the water table along the urban coastal ridge where the water table is 8 to 12 ft below the septic-tank drainfields during much of the year. Part of the liquid would be evaporated or utilized by lawn grass, shrubs, and trees. The, remainder would filter through unsaturated sediments which may remove some of the constituents in the effluent. It is possible that along much of the urban ridge area, effluent from ordinary single-family residential septic tanks may not reach the water table except when it is carried downward by heavy rainfall. In areas of lower elevation west of the coastal ridge, the water table is at higher elevation, and the unsaturated zone is thinner; therefore, effluents will likely

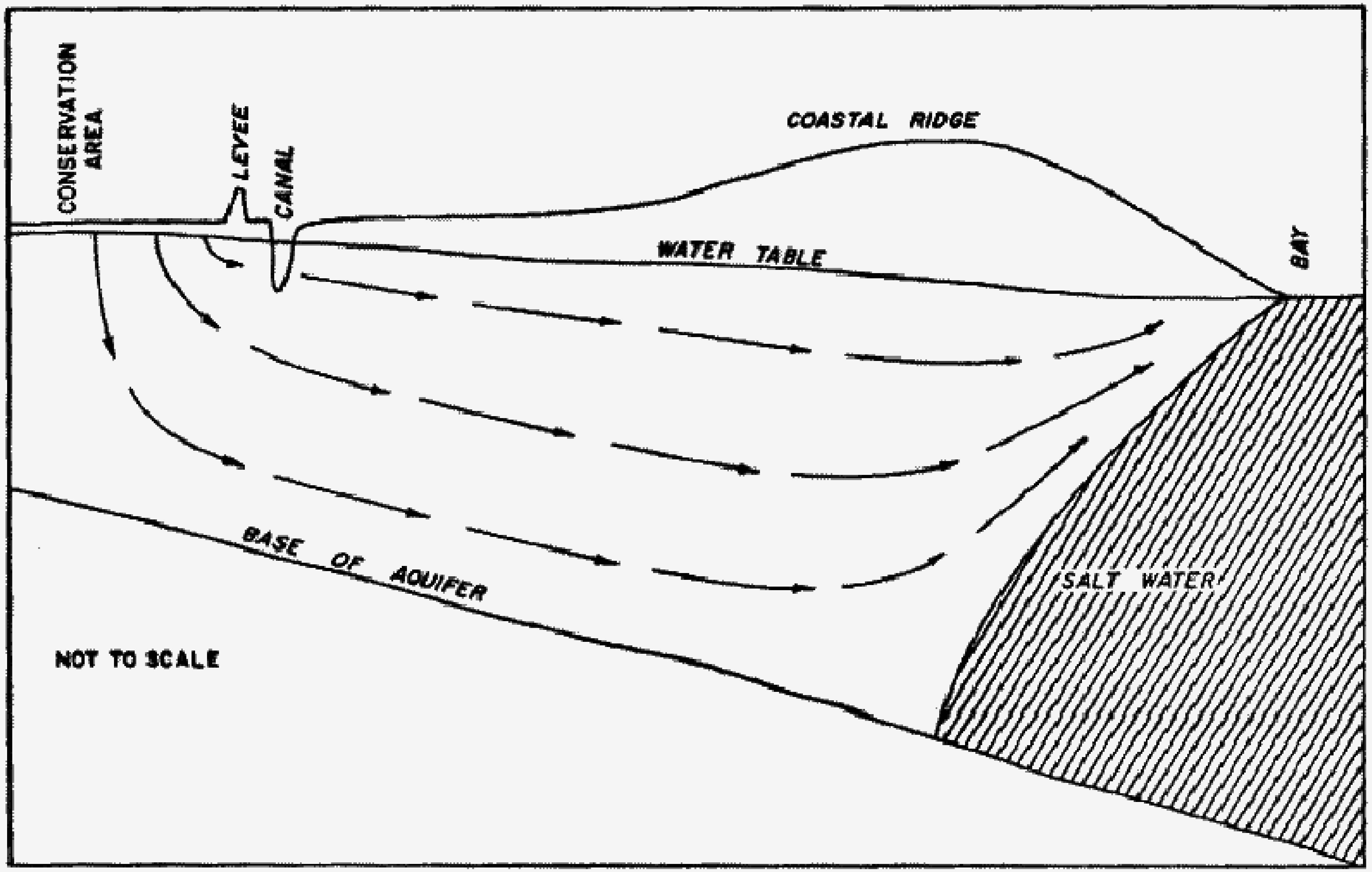


FIGURE 4.--Generalized ground-water flow paths during the dry season.

reach the water table during the dry season as well as the wet season. A large number of analyses of water and rock material would be required in order to determine the nature of the chemical, physical and ionic interactions between the effluents and the rock matrix within the saturated and unsaturated zones, and the effect that seasonal rainfall has on flushing of the matrix and dilution of the effluent. This investigation involved only the ground-water quality within the saturated zone at the five selected septic-tank areas.

In addition to septic-tank effluent, a probable major source of contamination to the aquifer-canal system is storm runoff from roads, parking lots and shopping centers, and from residential and agricultural areas. Downtown business districts and most densely developed areas near Biscayne Bay are serviced by sewer systems which discharge storm water to the bay or to tidal reaches of drainage canals. In the near-coastal areas not served by storm sewers, storm water infiltrates the aquifer to carry surface contaminants to the zone of saturation; however the residence time of the contaminants in the aquifer is relatively short because of the proximity to uncontrolled sections of drainage canals and the bay.

In the less densely developed urban and suburban parts of the county storm water runoff is downward to the zone of saturation. The storm sewer systems that have been built are for the many shopping centers scattered throughout the suburbs. These storm sewers generally discharge directly to the nearest canals. In the shopping centers distant from canals, the runoff is piped to a sump to remove solids and debris, and then to a soakage pit or gallery where it infiltrates the aquifer. Downward infiltration of rainfall in the residential areas probably carries with it soluble residues from thousands of lawns fertilized at regular intervals. Similarly, runoff percolates vertically downward in the agricultural areas of south Dade County, but there applications of fertilizer are heavier and more frequent than in residential areas. Thus the potential for nutrient enrichment of ground water in the agricultural south part of the county is greater than it is in other parts.

Since ground-water movement in the interior urban-suburban and agricultural areas is affected by operations of control structures in the major canals, the residence time of contaminants in the ground water would be long compared to that in coastal areas. As indicated, ground water in the interior moves toward the drainage canals during the rainy season when controls are open. When controls are closed, ground water continues to move toward the upper controlled canal reaches, but at a greatly reduced rate. Along the lower controlled reaches the flow is from the canals into the aquifer. Therefore contaminants in canal water along lower controlled reaches have the potential of entering the aquifer during the dry seasons.

Further alteration of canal water is from the discharge of sewage effluent into controlled reaches of canals from scattered treatment plants. Most of the effluent is given secondary treatment, some tertiary. During prolonged dry seasons when no flushing takes place, some canals become nutrient enriched to become a source of aquifer contamination along their lower reaches.

OBSERVATION-SITE DESCRIPTIONS

Location and Construction

Five sites served by septic tanks were selected for detailed geologic and ground-water quality study. They represent different hydrogeologic environs within the urbanized area (fig. 2). Two sites are in sandy areas of relatively low hydraulic conductivity in north Dade County and Hialeah, and three are in limestone areas of high hydraulic conductivity in West Miami and Homestead. The two sites in Homestead are hydrogeologically similar but they are different in septic-tank densities. Two additional base-line water-quality sites were selected in undeveloped inland areas, one west of Hialeah and another northwest of Homestead. The five selected urban test sites are plotted on the map in figure 5, which shows the approximate areas in Dade County served by sanitary sewer systems. The west edge of the sewered areas approximates the inland extent of major housing subdivisions; the intervening areas are served by septic tanks. Areas west of the subdivisions in the south half of the county are primarily devoted to citrus groves and truck farms.

Sets of wells of different depths were constructed during October-December 1971 at the five septic-tank sites, and during May 1973 at the two undeveloped base-line sites. Most of the wells were constructed of 2-in. diameter steel pipe and were completed with 1 or 2 ft of open hole at the bottom. Wells ending in sand were finished with a 2.5 ft screened well point. The wells were drilled to depths ranging from 10 to 60 ft below land surface. The 60-ft wells in areas of hard lime-

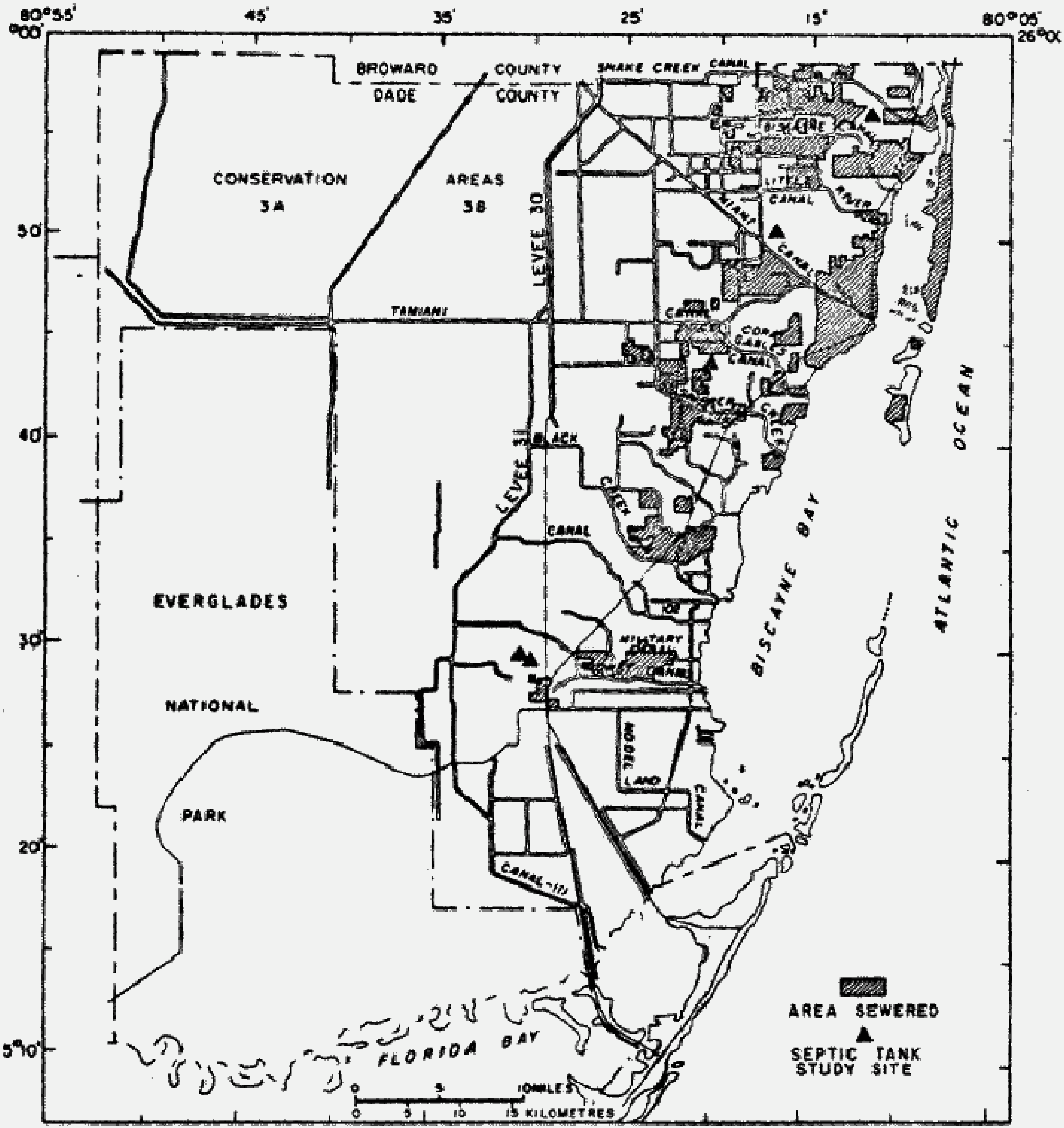
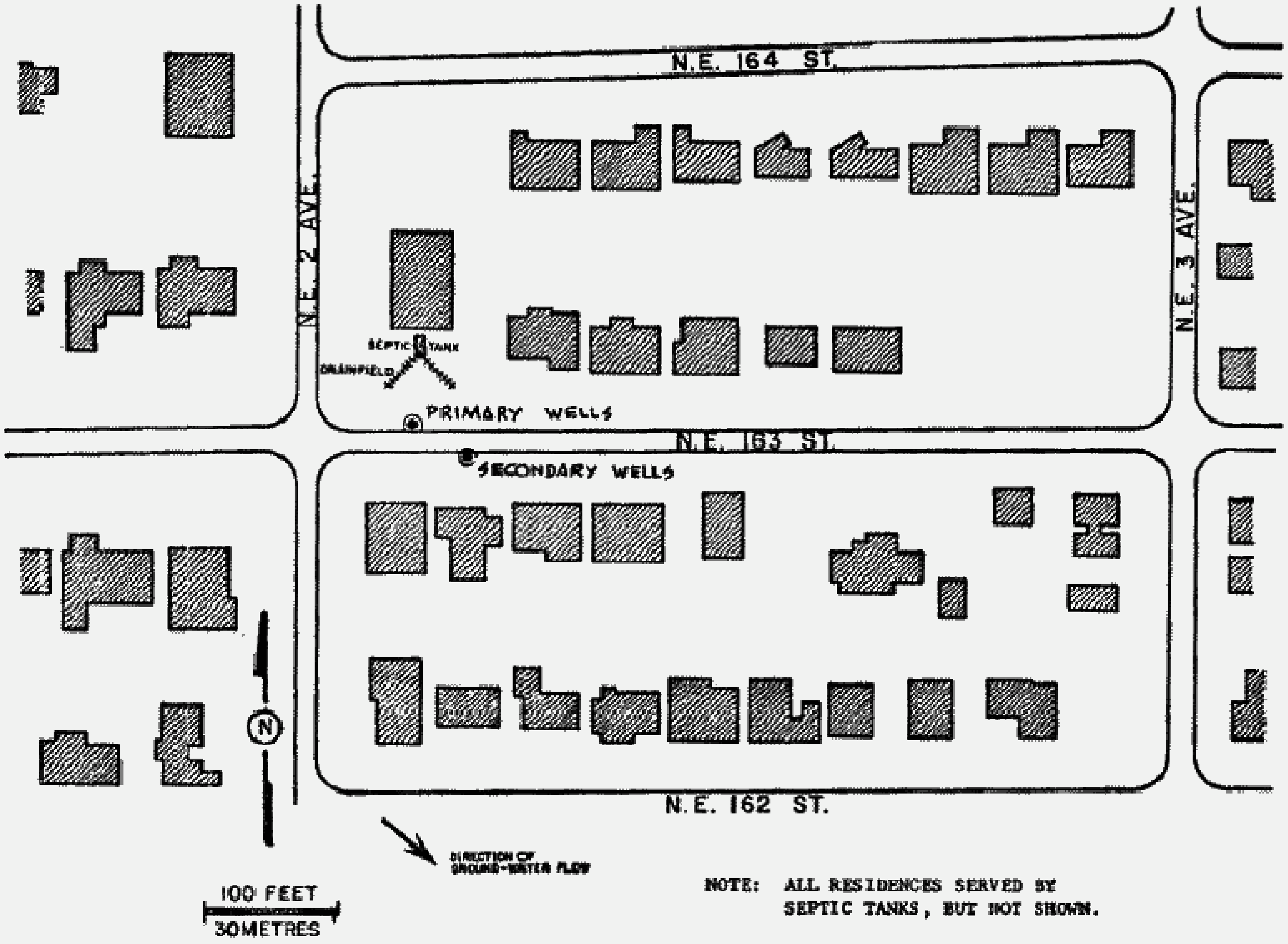


FIGURE 5.--Approximate areas serviced by sanitary sewer systems in 1970 (after Meyer, 1970)

stone were drilled by rotary machine in order to obtain rock-core samples. A steel casing was then inserted to prevent vertical mixing of water in the well bore. All the other wells were constructed by driving the casing or well point to the predetermined depth.

Details of the septic-tank study sites are shown in figure 6-10. They show the density of residences, the locations of the primary and secondary sets of monitor wells, and an indication of the normal direction of ground-water flow at the site. The primary sets are near the ends of the septic tank drainfields and the secondary sets are downgradient from them. Although they are not shown on the site location maps, each surrounding residence also has its own septic tank and drainfield. All areas are served by treated public water supplies for drinking and household uses. Scattered residences in each area utilize individual shallow wells which are pumped frequently for lawn and shrubbery irrigation. Therefore the movement and quality of ground water at the observation wells are influenced not only by the discharge from the immediately adjacent septic tank and drainfield, but also by the discharge from the surrounding drainfields and by the pumping of irrigation wells. Where the density of septic tanks and irrigation wells is high the potential for recirculating septic-tank effluent increases.

The north Dade site (fig. 6) is south of Snake Creek Canal and the direction of ground-water flow there is influenced by the Snake Creek Canal. When the control structure in the canal is opened periodically for flood control, ground-water flow at the septic-tank site is toward the canal. At all other times, the canal level is higher than the ad-



NOTE: ALL RESIDENCES SERVED BY SEPTIC TANKS, BUT NOT SHOWN.

FIGURE 6.--North Dade site showing the locations of primary and secondary monitor wells

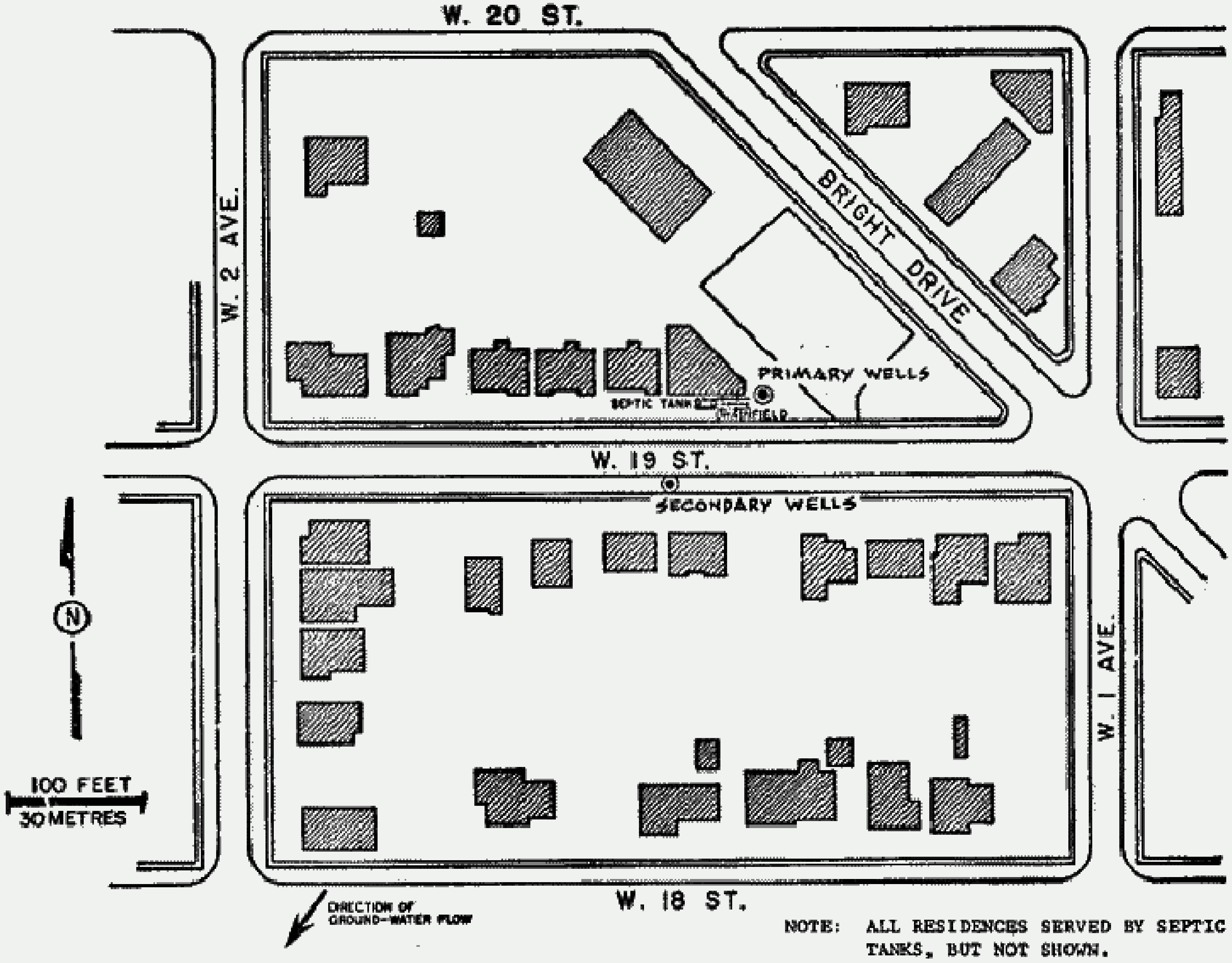


FIGURE 7.-Hialeah site showing the locations of primary and secondary monitor wells.

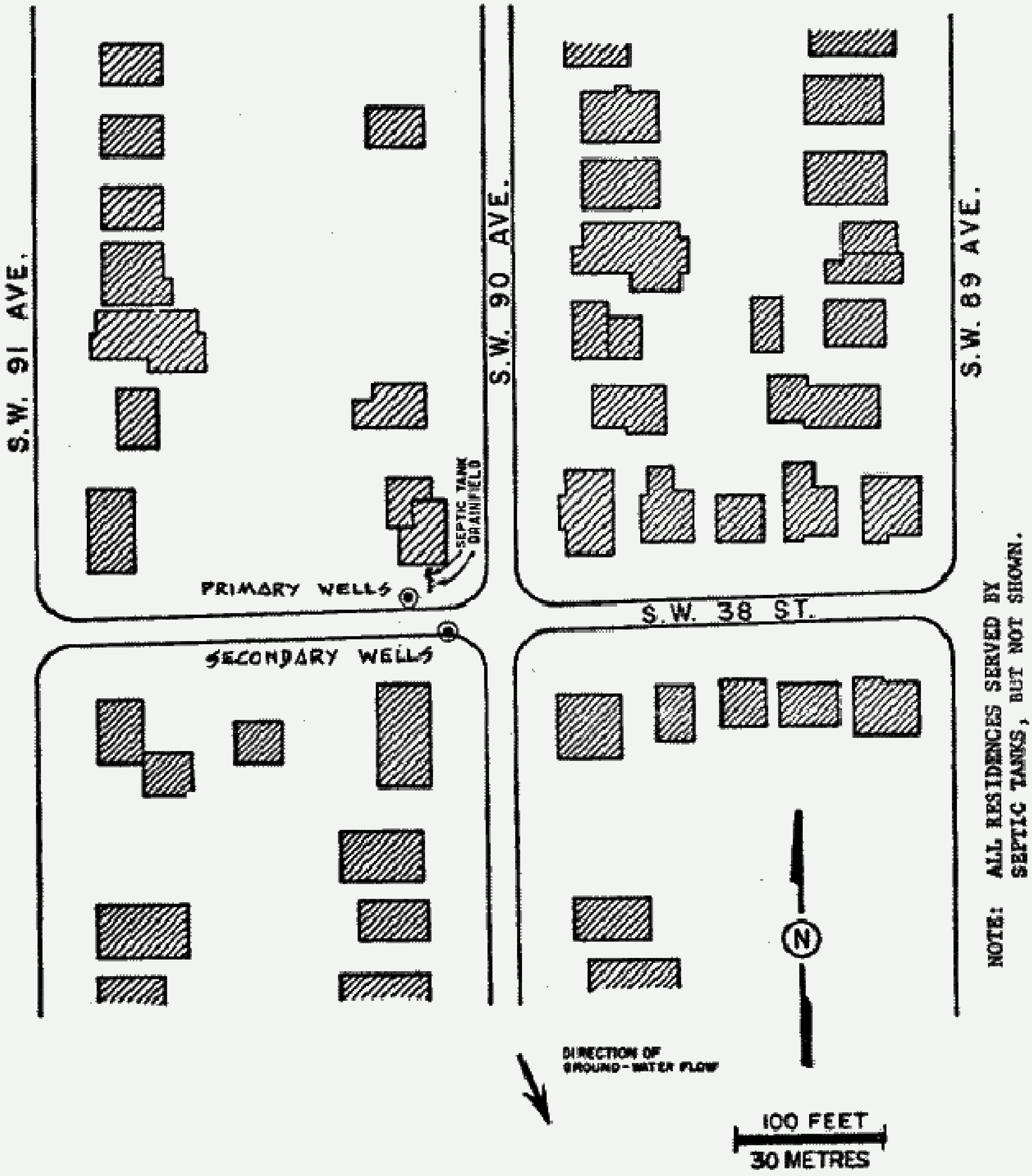


FIGURE 8.--West Miami site showing the locations of primary and secondary monitor wells.

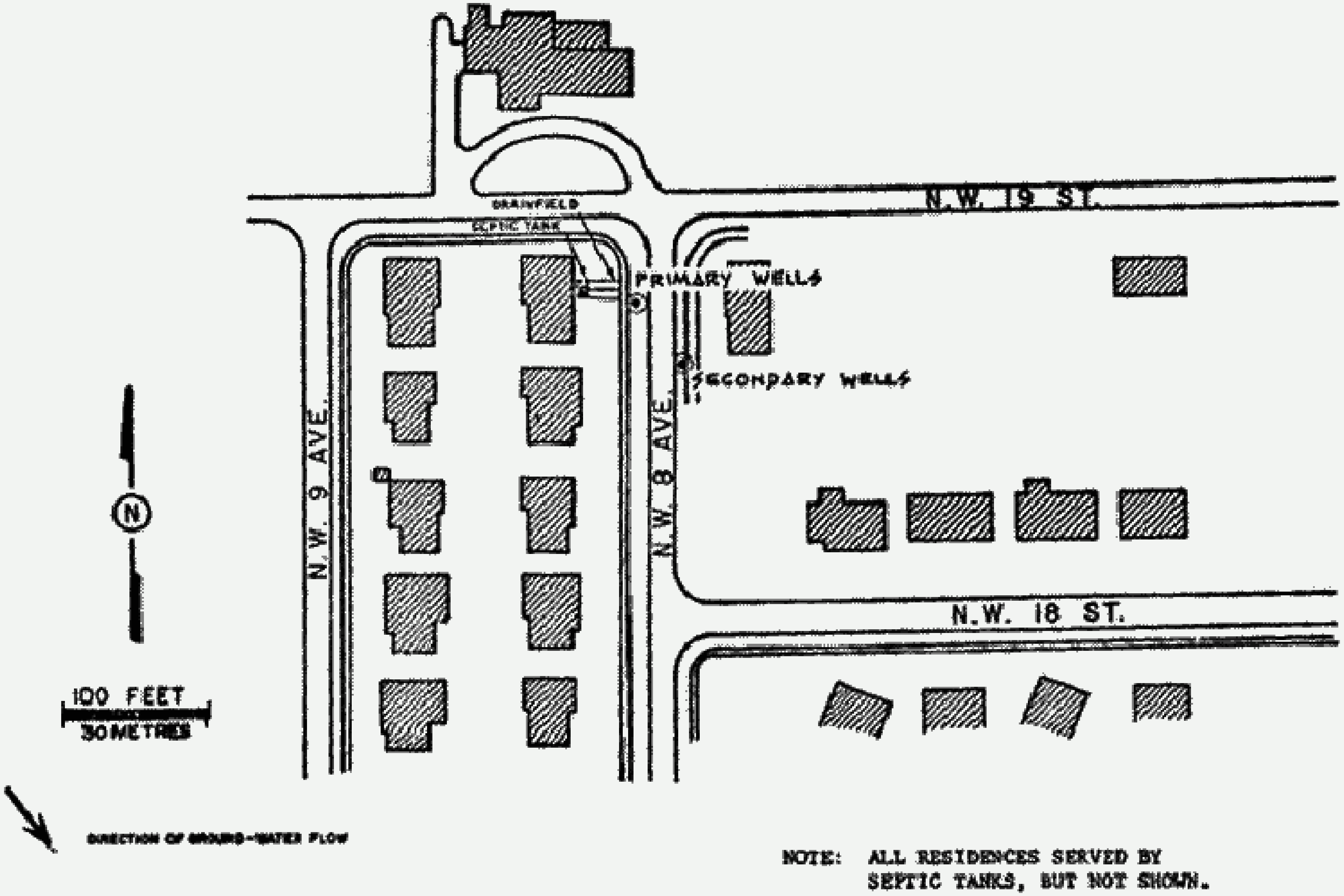
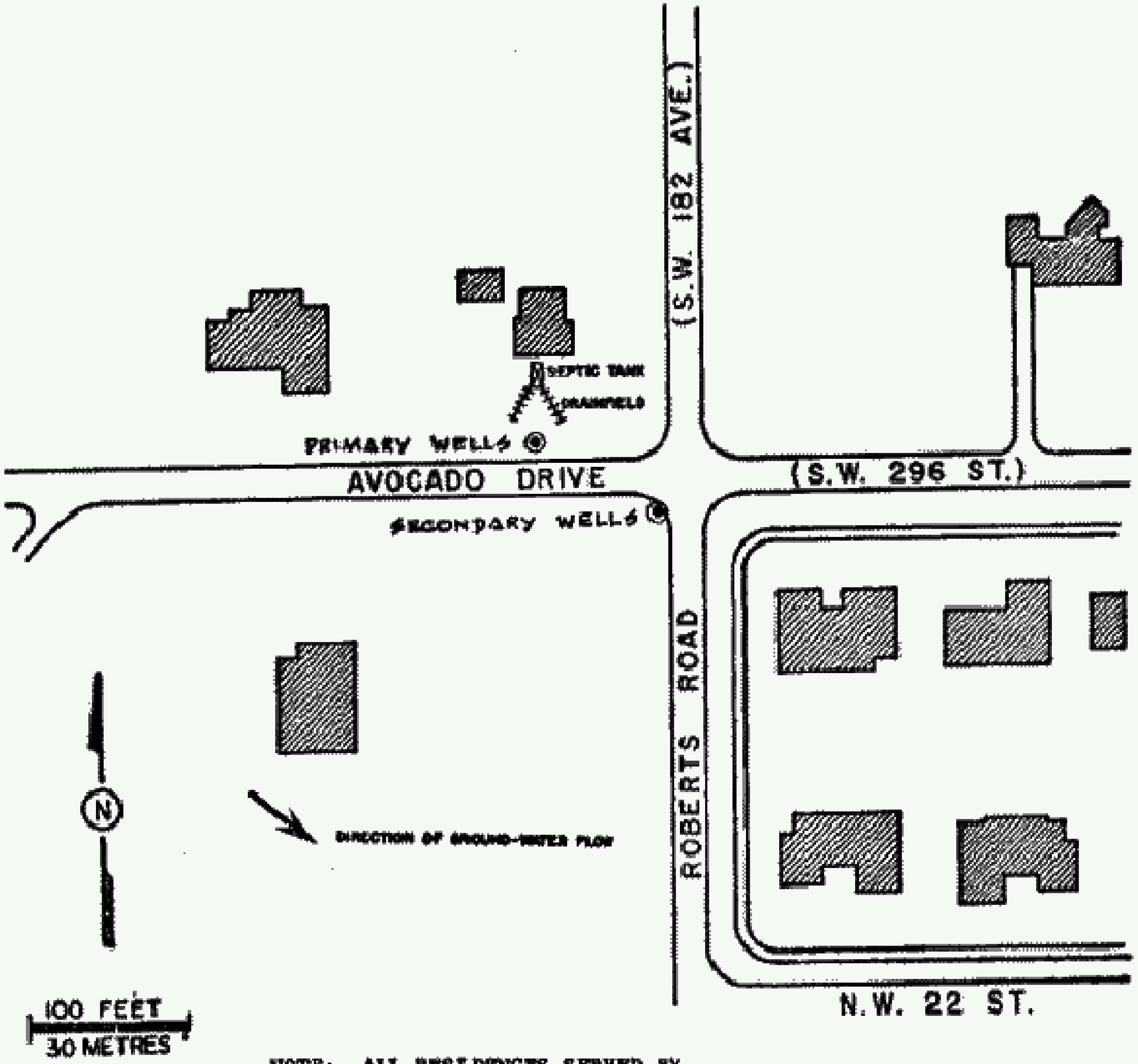


FIGURE 9.--Homestead high-density site showing the locations of primary and secondary monitor wells.



NOTE: ALL RESIDENCES SERVED BY SEPTIC TANKS, BUT NOT SHOWN.

FIGURE 10.--Homestead low-density site showing the locations of primary and secondary monitor wells.

jacent ground-water level and flow is from the canal into the aquifer. During most of the year the direction of movement at the observation site is southeast.

The direction of ground-water flow at the Hialeah site and the West Miami site is influenced by continuous heavy withdrawals at the municipal well fields. At the Hialeah site ground-water flow is southwest, and at the West Miami site, southeast. At the Homestead sites the general ground-water flow is to the southeast.

Soils and Lithology

The natural soil cover at all monitor sites has been mechanically altered by the construction of homes and roads and by landscaping. At some sites the soil probably has been completely stripped to the oolitic limestone bedrock. The soil types in the vicinity of the five septic-tank sites are listed in table 1.

The soil in the north Dade County area generally ranges in depth from 12 to 48 in. and in the Hialeah area from 6 to 10 in. At the West Miami and Homestead sites and at the 2 base-line sites the soil ranges in depth from 2 to 6 in. Soil pH is usually higher in the south part of the county than it is in the north part. In the north Dade and Hialeah sites the internal drainage (infiltration of water) of the soil is relatively slower than it is in the other sites (table 1). The West Miami and Homestead sites have very rapid internal drainage characteristics. The rate that waste water from a septic-tank drainfield can be adsorbed is higher where where the internal drainage is fast than where it is slow.

TABLE 1.--*Natural soil characteristics* (U.S. Department of Agriculture, 1958)

Site	Soil Series	Organic Content	Internal Drainage	pH	Soil Depth Inches
North Dade	Dade Fine Sand	Low to Moderate	Rapid to very rapid	7	12-48
Hialeah	Dade Fine Sand	Moderate	Rapid when low water table	7	6-10
West Miami	Rockdale Fine Sand	Low	Very rapid	7	2- 6
Homestead Low Density	Rockdale Fine Sandy Loam	Low	Very rapid	7	2- 6
Homestead High Density	Rockdale Fine Sandy Loam	Low	Very rapid	7	2- 6
Northwest Base-line	Rockdale Fine Sand	Low	Very rapid	7	2- 6
Southwest Base-line	Rockdale Fine Sandy Loam	Low	Very rapid	7	2- 6

The organic content of the soil is greatest at the Hialeah site, least toward the south part of the county. Organic material in sandy sediments is important because it has the property of aiding in the removal of certain contaminants that are in solution or suspension in water as the water percolates through it. However, as organic material decomposes it imparts soluble organic compounds to the water infiltrating the sediments and loses some of its capacity to remove contaminants.

Detailed information on the lithology and the water-bearing characteristics at each site was obtained by collecting rock material at 5 ft intervals from the 60-ft wells. The logs of these wells in figures 11-15 show that the upper 60 ft of aquifer in the north part of the county is primarily sand but in the south and central parts it is primarily limestone.

The general differences in transmissivity from north to south are reflected by the predominance of sand in the north, where transmissivity is relatively low, and the predominance of cavernous limestone in the south where transmissivity is high.

The information noted in the logs on the percent of recovery of cored material is highly important because the amount of rock recovered is a key to the hydraulic conductivity of the rock. Recovery of 80 percent or more suggests that the limestone is fairly dense, containing few cavities, and is considered a confining zone. A decrease in the percent of recovery suggests high hydraulic conductivity of the limestone because of increasing size of solution cavities. A few of the more permeable sections were noted between 35 nd 40 ft at Homestead (30

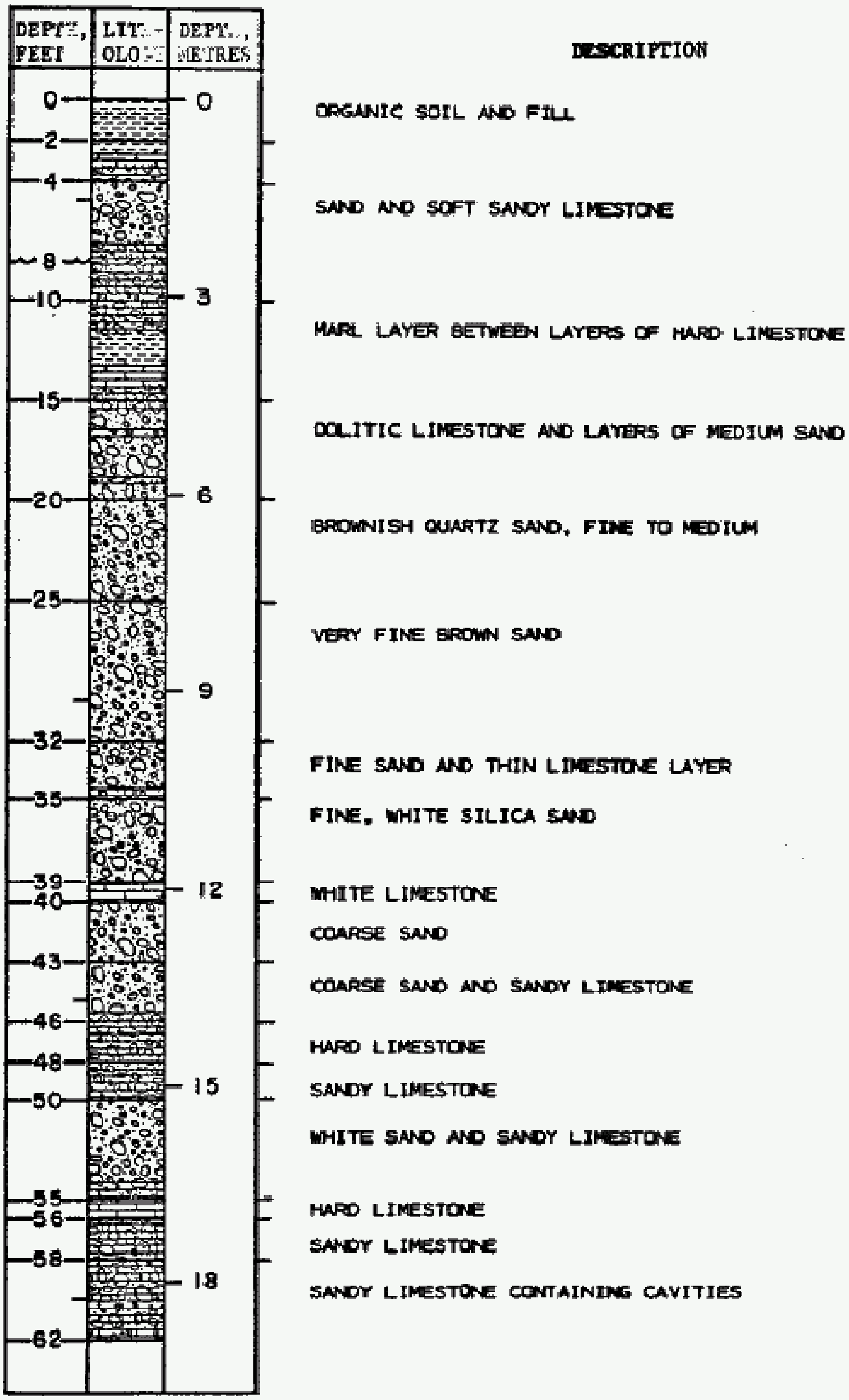


FIGURE 11.--Lithologic section, north Dade site.

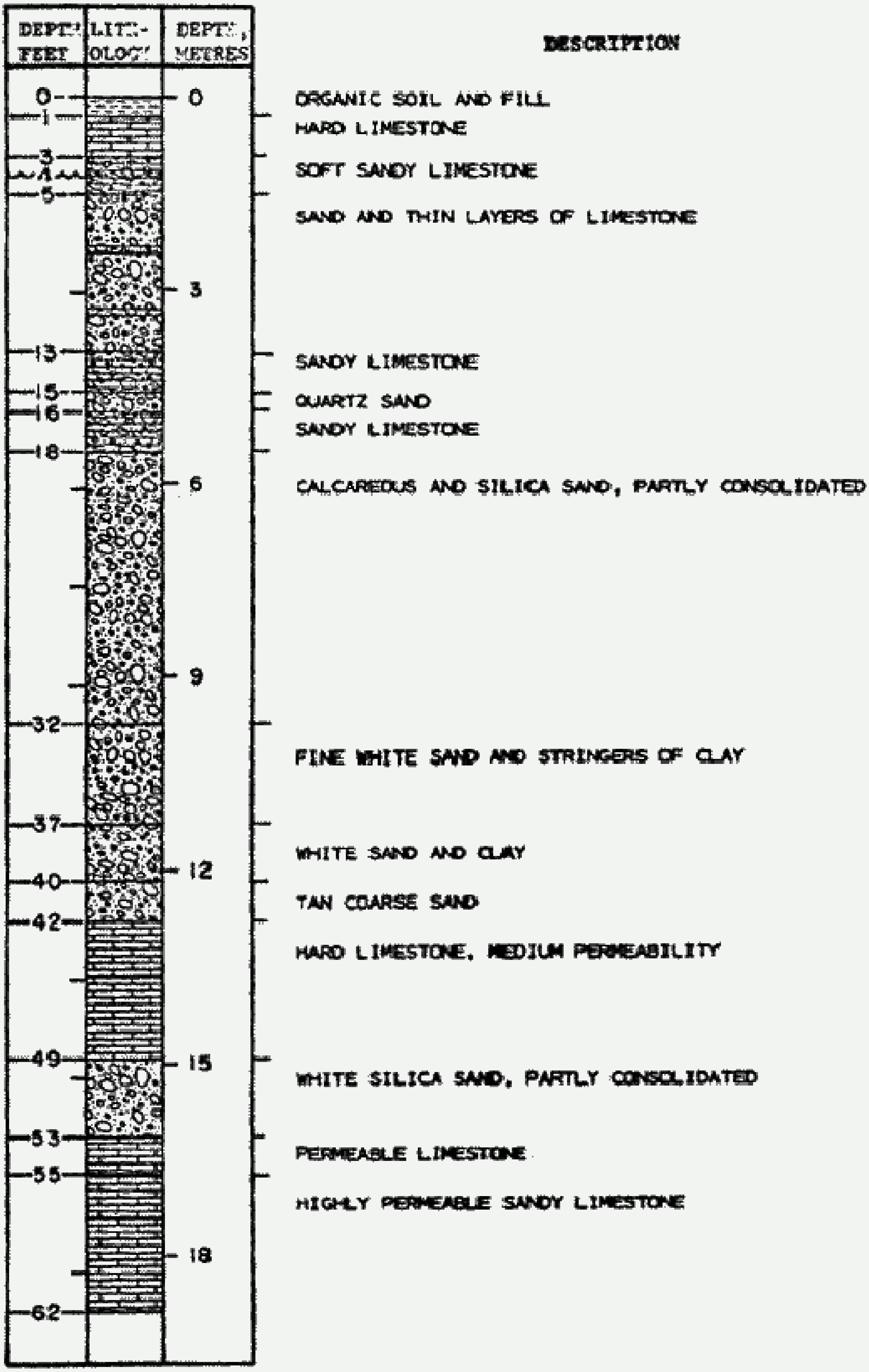


FIGURE 12.--Lithologic section, Hialeah site.

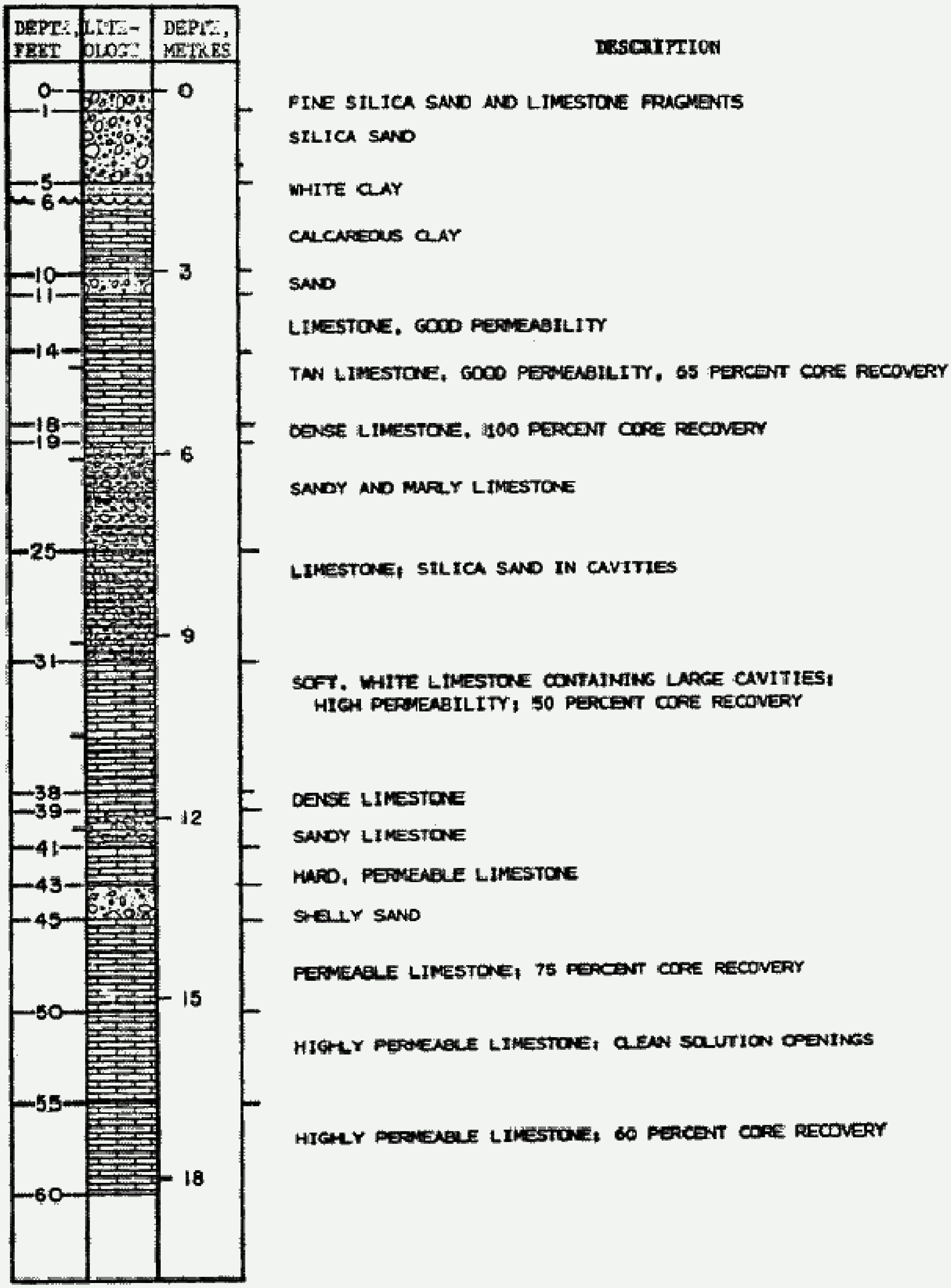


FIGURE 13.--Lithologic section, West Miami site.

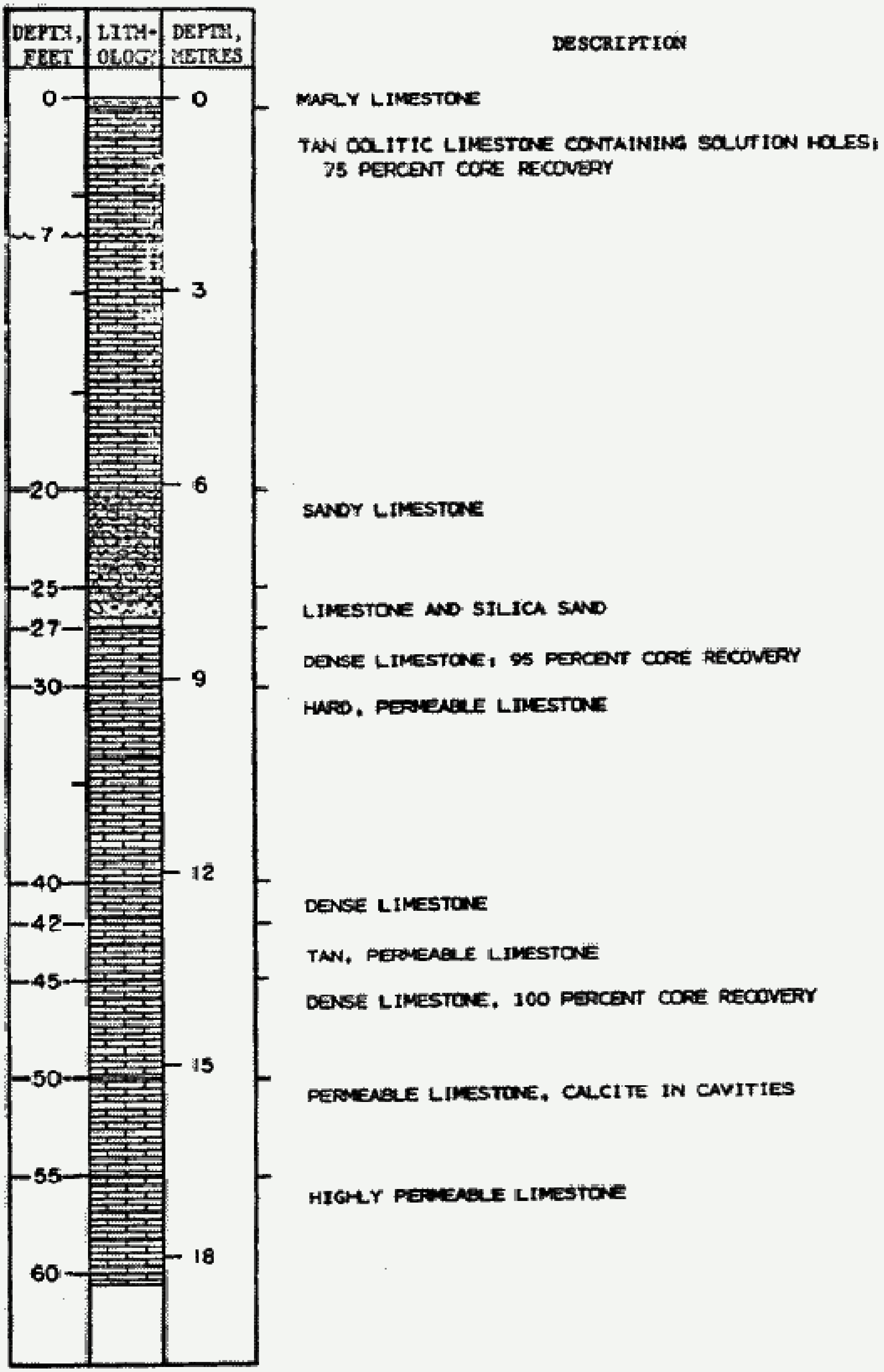


FIGURE 14.-Lithologic section, Homestead low-density site.

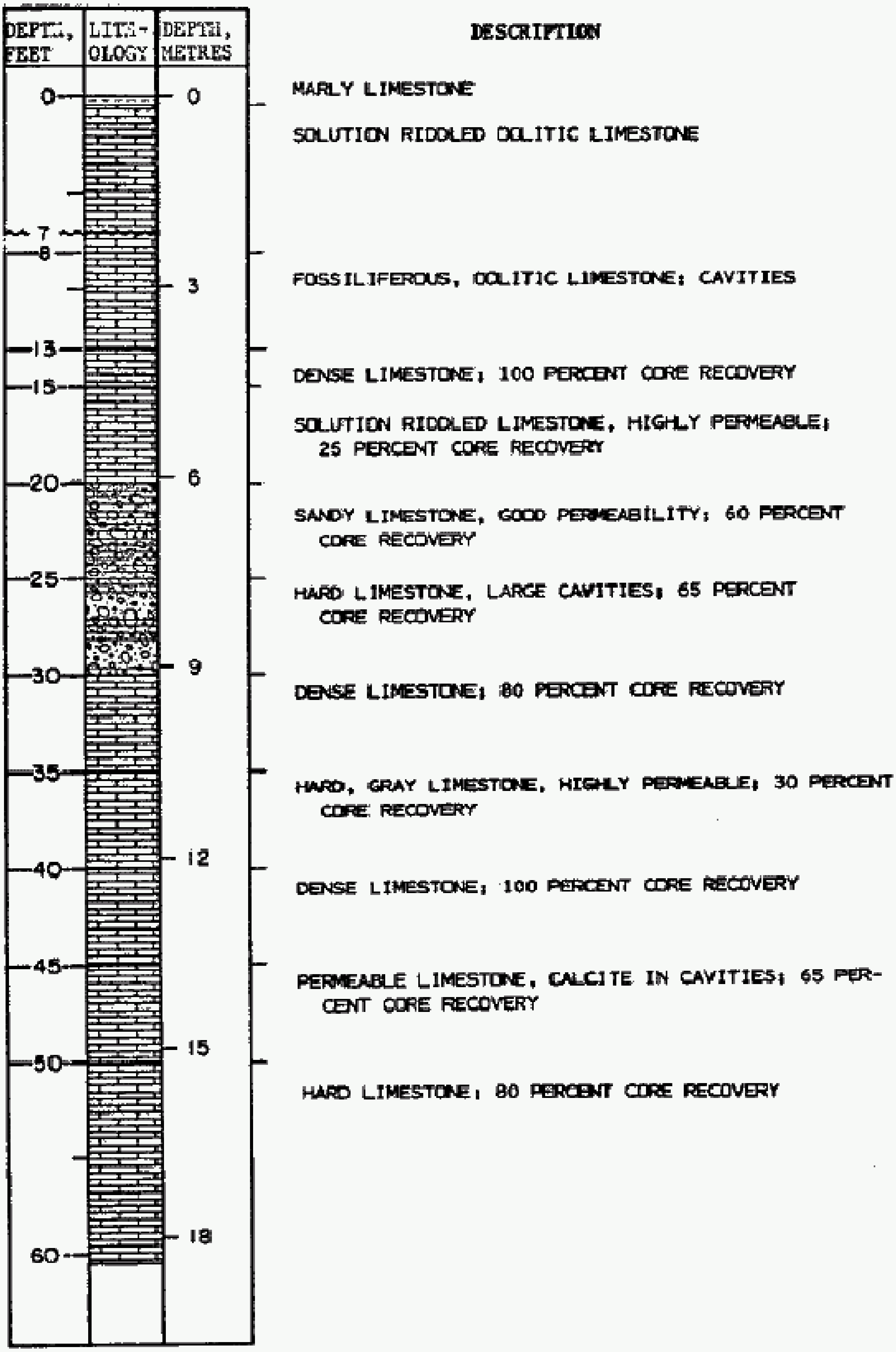


FIGURE 15.--Lithologic section, Homestead high-density site.

percent recovery), and between 31 and 38 ft at West Miami (50 percent recovery).

The limestone section to 60 ft in the south half of the county is marked by frequent layers of hard, dense limestone ranging in thickness from 1 in. to more than 5 in. Although these are relatively impermeable and tend to locally retard downward circulation of ground water, individual layers appear to be discontinuous and collectively, therefore, they do not prevent the movement of water. Selective samples of cores of the dense limestone were analyzed in the laboratory for values of hydraulic conductivity. Table 2 shows that the hydraulic conductivity ranges from 1.8×10^{-7} ft/d at a depth of 37 ft in the Homestead site, to 7.2×10^{-1} ft/d at a depth of 42 ft in the West Miami site.

Tracers were used to determine if the secondary sets of wells at the five sites were properly located to obtain water samples that were representative of the septic-tank effluent, as the effluent moved downgradient. Sodium nitrate and a fluorescent dye were injected 2.5 ft below land surface at the head of the high density drainfields, and directly into the septic-tank distribution box at the low density Homestead site. Each tracer was introduced as a 20 gal slug during 3 to 4 h.

Data from observations of the tracer movement from sampling in secondary monitor wells indicate that the ground water moved at rates ranging from 2 ft/d at the north Dade site to 11 ft/d at the Homestead site. Ground-water velocities determined from tracer tests are given in table 3. The velocity for the Hialeah site (table 3) may appear to

TABLE 2.--*Laboratory analyses of limestone cores.*

Location	Depth (ft)	Specific gravity of solids (gm/cc)	Total porosity (percent)	Hydraulic conductivity (ft/d)	Hydraulic conductivity (m/d)
West Miami	19.2-19.5	2.73	19.8	9.18×10^{-5}	2.8×10^{-5}
Homestead	27.6-27.9	2.73	15.0	1.54×10^{-6}	4.7×10^{-5}
Homestead	36.9-37.2	2.73	20.6	1.8×10^{-7}	5.5×10^{-6}
West Miami	41.8-42.1	2.70	24.8	7.2×10^{-1}	2.2×10^{-1}
West Miami	51.0-51.3	2.70	20.1	5.9×10^{-3}	1.8×10^{-3}
Homestead	56.6-57.1	2.69	5.8	4.3×10^{-5}	1.3×10^{-5}

TABLE 3.--*Ground-water velocities at five septic-tank test sites.*

North Dade	Hialeah	West Miami	Homestead Low-Density	Homestead High-Density
Velocities by tracer test (ft/d)				
2.4	3.3	2.9	11.4	*

* Inconclusive data.

be high for an inland area composed mostly of sand. The observed rate probably is influenced by the proximity of the site to the large municipal water-supply withdrawal area.

The much higher velocity at the Homestead low-density site, even though perhaps not representative, confirms that septic-tank effluent will disperse more rapidly in the south part of the county than in the north part.

Ground-Water Sampling

Nearly 19,000 chemical, physical, and bacteriological analyses were made during this study. Most of the analyses were made by the Geological Survey, using methods outlined by Rainwater and Thatcher (1960), Brown and others (1970), or in accordance with procedures of American Public Health Association (1971). Many of the BOD (biochemical oxygen demand) determinations were done by personnel of the Dade County Pollution Control Department, and some of the COD (chemical oxygen demand) and the bacteriological analyses were done by the U.S. Environmental Protection Agency. The University of Miami analyzed for viruses.

With the exception of the base-line well sites, which were sampled 3 times during May 1973-October 1974, all the wells were sampled quarterly for 2 y in order to span two climatologic and hydrologic seasons. During the first year samples were collected by pumping the wells through sterile flexible transparent tubing using a centrifugal pump. During the second year, a vacuum pump was used to facilitate the sampling. Ultraviolet radiation was used to sterilize the pump and tubing prior to pumping using procedures discussed by Pitt (1974). Each well was pumped at a low rate until one and a half times the volume of water stored in the casing was removed before a sample was collected. This method minimized vertical and horizontal movement of water to the well by collecting only small volumes of water from the section of aquifer immediately adjacent to the bottoms of the wells.

The period of ground-water sampling and the number of samples collected from each monitor well are shown in table 4. The general spatial relationship of the primary and secondary sampling wells and their numerical designations are shown in figure 16.

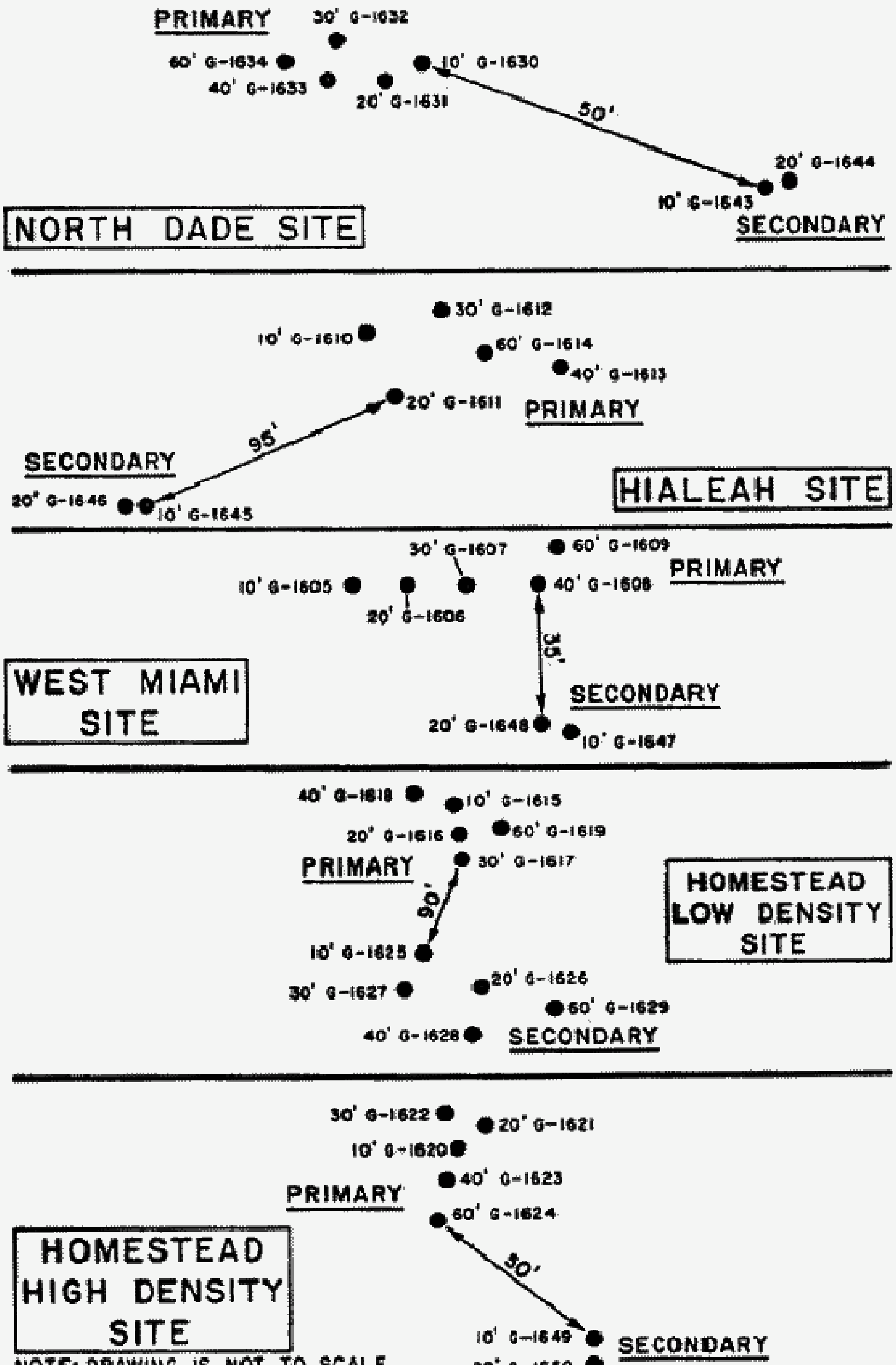
QUALITY OF GROUND WATER

The chemical quality of the ground water in Dade County varies only slightly; most differences are related to the nature of the aquifer and local land-use patterns. The observed concentrations of the various parameters are influenced by numerous factors, including rainfall and dry fallout composition, reactions with soils and the aquifer materials, application of fertilizers and pesticides, biological processes at and below the surface, various waste loadings, chemical reactions between constituents, temperature, and pressure.

Eighty-three physical, chemical, and biological indicators of ground-water quality were used during the study. The numerous analytical results are separated into five sections; natural ground-water constituents, septic-tank related parameters, trace metals, pesticides, and viral characteristics. While several parameters are included in one or more sections, the analytical results suggest that certain constituents in the ground water are naturally occurring (table 5) and some are identifiable as being associated with septic-tank effluent

TABLE 4.--*Period of sampling monitor wells*

Site	Depth (Feet)	Well Number	Date of First Sampling	Date of Last Sampling	Number of Sample
North Dade Primary	10	G-1630	72-02-18	73-10-15	9
	20	G-1631	72-02-18	73-10-15	9
	30	G-1632	72-02-18	73-10-15	9
	40	G-1633	72-02-18	73-10-15	9
	60	G-1634	72-02-18	73-10-15	9
North Dade Secondary	10	G-1643	72-05-23	73-10-15	7
	20	G-1644	72-05-23	73-10-15	7
Hialeah Primary	10	G-1610	71-10-28	73-10-16	9
	20	G-1611	71-10-28	73-10-16	9
	30	G-1612	71-10-28	73-10-16	9
	40	G-1613	71-10-28	73-10-16	9
	60	G-1614	71-10-28	73-10-16	9
Hialeah Secondary	10	G-1645	72-05-24	73-10-16	7
	20	G-1646	72-05-24	73-10-16	7
Northwest Base-line	20	G-3025	73-05-23	74-10-15	7
	60	G-3026	73-05-23	74-10-15	7
West Miami Primary	10	G-1605	71-08-27	73-10-16	9
	20	G-1605	71-10-27	73-10-16	9
	30	G-1607	71-10-27	73-10-16	9
	40	G-1608	71-10-27	73-10-16	9
	60	G-1609	71-10-27	73-10-16	9
West Miami Secondary	10	G-1647	72-05-23	73-10-16	7
	20	G-1648	72-05-23	73-10-16	7
Homestead Low Density Primary	10	G-1615	71-10-28	73-10-17	9
	20	G-1616	71-10-28	73-10-17	9
	30	G-1617	71-10-28	73-10-17	9
	40	G-1618	71-10-28	73-10-17	9
	60	G-1619	71-10-28	73-10-17	9
Homestead Low Density Secondary	10	G-1625	72-02-17	73-10-17	8
	20	G-1626	72-02-17	73-10-17	8
	30	G-1627	72-02-17	73-10-17	8
	40	G-1628	72-02-17	73-10-17	8
	60	G-1629	72-02-17	73-10-17	8
Homestead High Density Primary	10	G-1620	72-02-16	73-10-18	8
	20	G-1621	72-02-16	73-10-18	8
	30	G-1622	72-02-16	73-10-18	8
	40	G-1623	72-02-16	73-10-18	8
	60	G-1624	72-02-16	73-10-18	8
Homestead High Density Secondary	10	G-1649	72-05-24	73-10-18	7
	20	G-1650	72-05-24	73-10-18	7
Southwest Base-line	20	G-3023	73-05-23	73-10-18	3
	50	G-3024	73-05-23	73-10-18	3



NOTE: DRAWING IS NOT TO SCALE.

FIGURE 16.--Well depth and numbering system for the five septic-tank sites.

TABLE 5.--*Natural ground-water constituents*

Parameter	Analytical Techniques	Lab	Number of Samples	Average	Units	Standard Deviation	Range
Well Depth	Tape	M	42		Feet		10. - 60.
Temperature	Thermometer	M	239	25.5	Degrees C	1.32	23.5 - 31.
Turbidity	Turbidimeter	O	313	18.2	JTU	25.1	0. 190.
pH	pH Electrode	M	329	7.7*	pH Units		6.8 - 8.5
Specific Conductance	Wheatstone Bridge	M	329	541.	mmho	67.4	182. - 694.
Dissolved Solids Residue	Evaporation 180°C	O	329	321	mg/l	34.1	136. - 446.
Dis. Solids Calculated	Major Ion Sum		328	302	mg/l	35.4	98. - 370.
Inorganic Carbon	Carbon Analyzer	O	235	55.1	mg/l	10.3	19. - 81.
Total Carbon	Carbon Analyzer	O	235	61.4	mg/l	11.8	31. - 85.
Carbon Dioxide	Calculated		326	11.8	mg/l	10.6	0. - 78.
Alkalinity	Titration	M	327	210	mg/l	29.2	79. - 289.
Bicarbonate	Titration	M	328	256	mg/l	35.5	96. - 352.
Carbonate	Titration	M	327	0.034	mg/l	0.430	0. - 6.
Total Hardness	Atomic Absorption	O	329	238	mg/l	24.9	78. - 310.
Non Carbonate Hardness	Calculated		328	28.1	mg/l	16.3	0. - 80.
Calcium	Atomic Absorption	O	329	89.4	mg/l	8.88	30. - 120.
Magnesium	Atomic Absorption	O	329	3.25	mg/l	1.01	.9 - 8.0
Dissolved Strontium	Atomic Absorption	O	329	804.	ug/l	116.	360. - 1200.
Dissolved Sodium	Atomic Absorption	O	329	18.6	mg/l	6.25	2.6 - 35.
Dissolved Potassium	Atomic Absorption	O	329	3.13	mg/l	1.42	.2 - 5.7
Dissolved Lithium	Atomic Absorption	O	34		mg/l		-
Chloride	Mercurometric	MO	328	27.6	mg/l	8.81	2. - 50.
Sulfate	Spectrophotometric	O	329	26.4	mg/l	10.2	.0 - 42.
Fluoride	Colorimetric	O	329	.250	mg/l	.107	.0 - 1.1
Silica	Atomic Absorption	O	329	4.60	mg/l	1.79	.0 - 9.7
Dissolved Manganese	Atomic Absorption	O	235	17.0	ug/l	26.1	.0 - 210.
Dissolved Iron	Atomic Absorption	O	277	1910.	ug/l	4510.	.7 - 36000.
Color	Color Disks	O	328	47.3	Pt-Co Std.	86.9	0. - 850.

* Median pH value
M Miami Subdistrict laboratory
O Ocala District laboratory

(table 6). Also listed are summary statistics for the 42 monitor wells used in this investigation. Individual analytical results are available for inspection at the U.S. Geological Survey, 901 S. Miami Avenue, Miami, Florida.

Natural Ground-Water Constituents

The quality of the ground water in Dade County differs from place to place (fig. 17). Dissolved calcium and bicarbonate are the major ions. These ions are dissolution products of the limestone. Solution of native rock is also responsible for the observed magnesium. Sodium, potassium, chloride, and sulfate are naturally present in water. These ions are also a useful index of septic-tank effluent and are discussed in the section on septic-tank related parameters.

Many parameters in natural ground-water systems are controlled by or are influenced by the calcium carbonate equilibrium system. This equilibrium system can be represented by the following series of reactions:

1. $CO_2 + H_2O \rightleftharpoons H_2CO_3$
2. $CaCO_3(s) + H_2CO_3 \rightleftharpoons Ca^{++} + 2HCO_3^-$
3. $HCO_3^- \rightleftharpoons H^+ + CO_3^=$
4. $H_2O \rightleftharpoons H^+ + OH^-$

The list of chemical and physical properties commonly determined in a chemical analysis which are directly affected by changes in this equilibrium system includes dissolved Ca^{++}, HCO_3^-, $CO_3^=$, CO_2, inorganic carbon and pH. Due to the abundance of limestone dissolution products in the Biscayne aquifer several parameters in table 5--alkalinity total

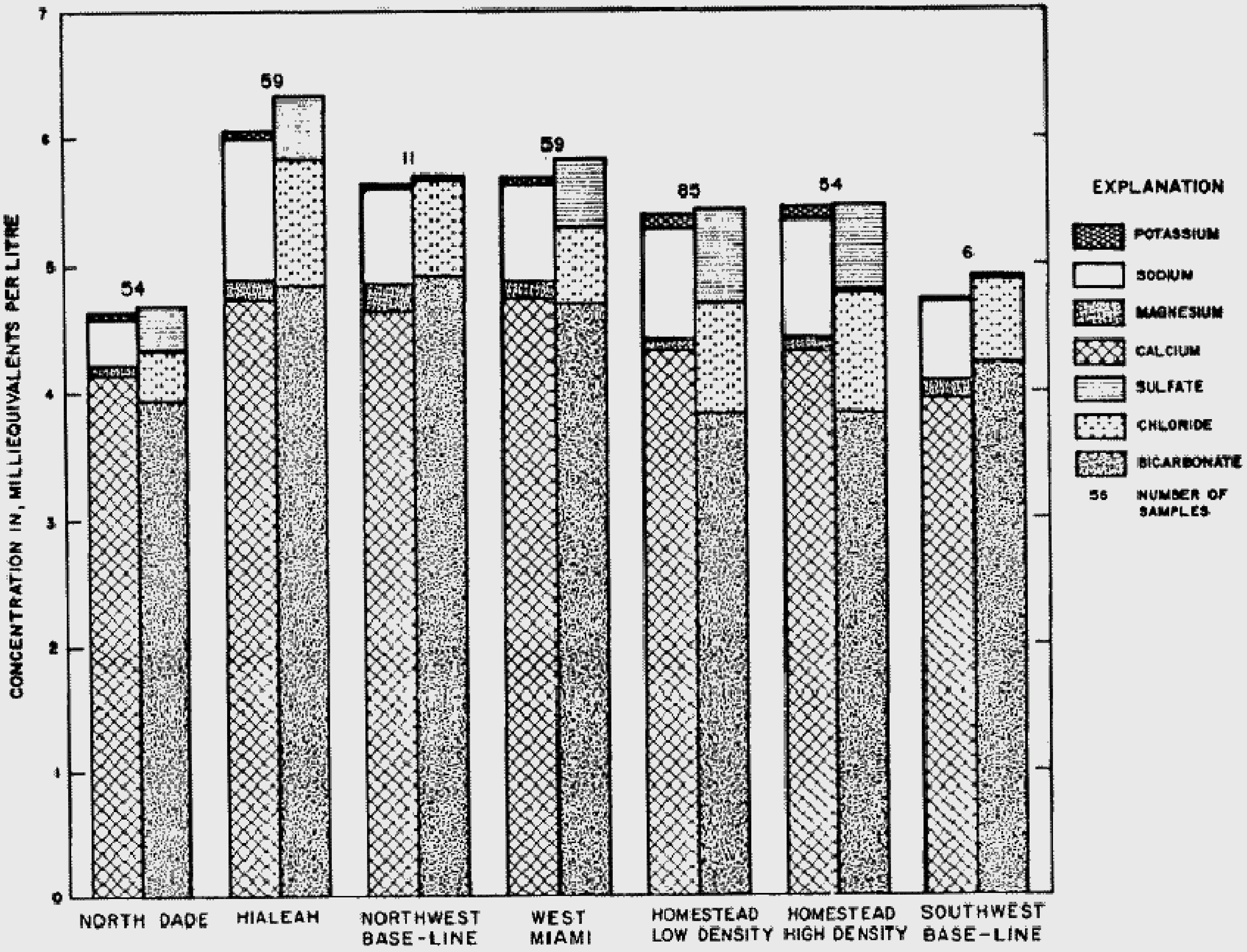


FIGURE 17.--Average concentrations of major cations and anions in ground water at seven sites.

TABLE 6.--*Septic tank related parameters in samples from the septic-tank test sites.*

Parameter	Analytical Technique	Lab	Number of Samples	Average	Units	Standard Deviation	Range
Specific Conductance	Wheatstone bridge	M	329	541	mmho	67.4	182- 694
Sodium	Atomic Absorption	O	329	18.6	mg/l	6.25	2.6- 35
Potassium	Atomic Absorption	O	329	3.13	mg/l	1.42	0.2- 5.7
Chloride	Mercurometric	M	328	27.6	mg/l	8.81	2- 50
Sulfate	Titrametric	O	329	26.4	mg/l	10.2	0- 42
Ortho Phosphate	Auto Analyzer	O	322	0.020	mg/l	.067	0.0- 0.8
Total Phosphorus	Digestion, Auto Analyzer	O	323	0.032	mg/l	.081	0.0- 0.8
Total Nitrogen	Calculated Sum		323	2.02	mg/l	1.30	0.2- 12
Organic Nitrogen	Digestion, Auto Analyzer	O	322	0.48	mg/l	.53	0.0- 6.0
Ammonium	Auto Analyzer	O	323	0.64	mg/l	1.12	0.0- 6.0
Nitrite	Auto Analyzer	O	323	0.00	mg/l	.026	0.00- 0.4
Nitrate	Auto Analyzer	O	323	0.900	mg/l	1.06	0.0- 4.0
Organic Carbon	Infrared Analyzer	O	285	6.50	mg/l	7.12	0.0- 47
BOD	5-day incubation	DM	318	1.22	mg/l	1.84	0.0- 24
COD	Titrametric	EO	323	19.1	mg/l	16.9	0.0- 94
Oil and Grease	Extraction, Gravimetric	W	289	10.9	mg/l	7.64	0.2- 100
Detergents	Spectrophotometer	O	306	0.077	mg/l	0.087	0.0- 0.7
Total Coliforms	Filtration, 24 hr. incubation	DM	267	53.1	colonies/100 ml	217.	0.0-1800
Fecal Coliforms	Filtration, 24 hr. incubation	M	213	10.1	colonies/100 ml	110.	0.0-1600
Fecal Strep	Filtration, 48 hr. incubation	M	235	17.1	colonies/100 ml	114.	0.0-1600

D, Dade County Laboratory; E, Environmental Protection Agency Laboratory; M, Miami Subdistrict Laboratory; O, Ocala District Laboratory; W, Washington Organics Laboratory.

hardness, dissolved solids sum, dissolved solids residue--strongly reflect changes in the calcium carbonate equilibrium system. Two other components, magnesium and strontium, are also associated with this equilibrium. These are divalent cations (like calcium) and have similar geochemical behavior and are present with the calcite lattice. Average concentrations of the various physical and chemical parameters for each of the seven sites are summarized in table 7.

A simple, and useful, measure of dissolved ions is the specific conductance of water. This test measures the ability of water to conduct an electric current and is a function of the number (concentration) and charge of the ions present. As with dissolved solids, the conductance of fresh ground water in Dade County is strongly influenced by the amount of calcium and bicarbonate ions in solution. A strong association with sodium and chloride is also apparent and therefore specific conductance reflects both natural and man-made ion enrichment.

Iron and manganese are commonly detected constituents in ground water. Under reducing conditions iron and manganese are readily soluble. As shown in table 7 soluble iron and manganese are present in unusually high concentrations at north Dade and Hialeah and are not representative of the iron and manganese typically reported for other south Florida wells. Since the wells have black iron casings the abnormally high iron and manganese are probably due to dissolution of the casing.

TABLE 7.—*Summary of natural constituents in ground water at the seven sites*

LOCATION	WELL Nº	TEMPERATURE (DEG C)	TURBIDITY (JTU)	SPECIFIC CONDUCTANCE (MICROMHOS)	DISSOLVED SOLIDS (RESIDUE AT 180 C) (MG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	TOTAL INORGANIC CARBON (C) (MG/L)	TOTAL CARBON (C) (MG/L)	PH* (UNITS)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	CARBON DIOXIDE (CO2) (MG/L)	ALKALINITY AS CACO3 (MG/L)	HARDNESS (CA+MG) (MG/L)	NONCARBONATE HARDNESS (MG/L)
NORTH DADE PRIMARY	G-1630	27.2	35	424	302	241	53	75	7.2	250	0	29	205	216	14
	G-1631	26.9	16	422	289	246	55	71	7.3	243	0	17	199	221	21
	G-1632	26.7	17	425	279	244	50	62	7.6	242	0	9.2	199	218	19
	G-1633	26.3	26	515	334	288	52	62	7.7	241	0	7.8	198	234	37
	G-1634	26.0	10	527	335	302	57	68	7.5	265	0	10	217	251	33
NORTH DADE SECONDARY	G-1643	29.1	112	387	254	239	58	73	7.1	217	0	26	178	197	26
	G-1644	27.5	8	369	245	217	44	56	7.5	217	0	10	178	196	16
HIALEAH PRIMARY	G-1610	27.5	25	624	355	343	67	77	7.7	287	0	16	236	247	13
	G-1611	27.1	42	603	348	336	63	74	7.4	289	0	20	237	254	15
	G-1612	26.6	31	606	362	336	66	78	7.6	295	0	11	242	256	16
	G-1613	26.3	67	638	367	352	68	78	7.7	307	0	16	251	262	11
	G-1614	26.1	16	635	368	353	68	77	7.6	309	0	18	253	261	10
HIALEAH SECONDARY	G-1645	27.3	20	633	379	346	66	77	7.7	295	0	13	242	270	28
	G-1646	26.2	13	594	340	331	57	66	7.6	278	0	11	228	239	11
NORTHWEST CONTROL	G-3025	25.1	23	517	312	284	62	76	7.4	283	0	15	232	247	14
	G-3026	24.3	9	567	353	321	66	81	7.3	321	0	19	263	276	13
WEST MIAMI PRIMARY	G-1605	26.5	19	571	342	324	69	71	8.0	289	0	13	237	260	21
	G-1606	25.4	15	564	333	320	66	67	7.8	287	0	13	235	257	18
	G-1607	25.0	12	560	329	315	64	66	7.8	289	0	12	237	253	14
	G-1608	24.8	16	548	318	307	65	67	7.8	282	0	9.0	231	252	19
	G-1609	24.8	23	537	313	302	64	67	7.7	284	0	12	233	262	20
WEST MIAMI SECONDARY	G-1647	25.5	24	530	315	308	63	66	7.6	277	0	14	227	248	19
	G-1648	25.1	22	574	337	333	68	69	7.7	299	0	15	245	269	20
HOMESTEAD LOW DENSITY PRIMARY	G-1615	25.1	10	519	297	241	49	53	7.8	241	0	6.9	196	231	34
	G-1616	24.8	6	556	317	304	46	49	7.6	232	0	14	190	230	40
	G-1617	24.5	6	568	314	300	45	49	7.6	228	0	8.5	187	226	39
	G-1618	24.5	5	542	317	296	46	49	7.7	221	0	8.0	181	223	42
	G-1619	24.3	7	546	321	305	45	49	7.7	226	0	7.9	185	231	45
HOMESTEAD LOW DENSITY SECONDARY	G-1625	25.2	5	514	302	284	47	50	7.8	222	0	6.8	182	226	43
	G-1626	24.4	7	551	323	303	47	49	7.7	227	0	7.1	186	231	44
	G-1627	24.5	6	552	316	302	47	49	7.8	227	0	8.0	187	231	45
	G-1628	24.5	4	554	319	306	45	48	7.8	229	0	8.7	188	231	44
	G-1629	24.4	5	542	316	300	45	48	7.8	224	0	6.3	183	230	48
HOMESTEAD HIGH DENSITY PRIMARY	G-1620	25.1	5	540	313	299	53	53	7.8	246	0	8.3	201	236	36
	G-1621	24.7	9	545	315	302	47	49	7.7	231	0	7.1	189	228	38
	G-1622	24.6	9	543	314	300	47	49	7.7	229	0	7.3	188	228	40
	G-1623	24.5	7	549	308	301	47	50	7.8	229	0	6.9	188	228	38
	G-1624	24.4	8	544	313	301	46	49	7.7	229	0	7.0	188	226	37
HOMESTEAD HIGH DENSITY SECONDARY	G-1649	25.3	7	552	319	305	49	52	7.7	241	0	7.8	198	233	34
	G-1650	24.8	13	544	315	303	47	50	7.7	231	0	8.7	189	229	40
SOUTHWEST CONTROL	G-3023	24.0	7	453	273	253	54	63	7.8	252	0	7.8	207	213	7
	G-3024	24.0	16	465	285	265	54	64	7.8	263	0	7.9	215	223	9

TABLE 7.--Cont.

LOCATION	WELL NO	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED STRON-TIUM (SR) (UG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	DIS-SOLVED LITHIUM (LI) (UG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	COLOR (PLAT-INUM-COBALT UNITS)
NORTH DADE PRIMARY	G-1630	82	1.8	717	4.2	1.4	10	7.9	.2	11	3.2	78	8862	355
	G-1631	85	1.7	824	4.4	1.7	0	10	.4	12	4.8	21	5000	225
	G-1632	81	3.4	759	5.2	3.1	0	13	.2	10	4.8	13	1204	161
	G-1633	88	3.2	754	15	2.8	0	25	.2	30	5.0	20	2029	128
	G-1634	95	2.4	894	14	.4	0	24	.2	24	6.4	8	1467	135
NORTH DADE SECONDARY	G-1643	75	2.5	680	5.8	2.9	0	10	.2	18	2.2	126	25640	159
	G-1644	75	1.6	751	4.6	.3	0	9.5	.2	9.4	4.8	26	3833	148
HIALEAH PRIMARY	G-1610	91	4.1	882	28	4.0	0	40	.4	22	7.7	27	1182	37
	G-1611	94	4.0	769	24	3.1	0	34	.2	23	6.0	40	5775	59
	G-1612	97	3.3	864	23	1.1	0	33	.2	24	6.6	38	3487	72
	G-1613	97	4.5	998	26	2.2	0	37	.2	23	7.9	28	1687	52
	G-1614	97	4.6	869	26	1.9	0	37	.2	22	8.0	21	2276	58
HIALEAH SECONDARY	G-1645	101	4.1	869	21	3.5	0	31	.3	30	7.2	14	247	48
	G-1646	87	4.0	817	27	3.8	0	41	.3	20	7.3	20	2478	44
NORTHWEST CONTROL	G-3025	88	6.1	738	16	.5	--	24	.3	1.7	6.5	--	2300	111
	G-3026	98	7.0	898	17	.7	--	29	.3	1.3	7.1	--	2900	67
WEST MIAMI PRIMARY	G-1605	96	3.5	777	18	3.0	--	22	.3	29	5.6	10	1331	18
	G-1606	95	3.6	728	16	2.8	0	22	.4	28	5.1	10	1362	8
	G-1607	96	3.6	711	18	2.6	0	21	.2	24	5.0	11	1159	11
	G-1608	93	3.9	684	16	2.1	0	19	.2	24	4.9	11	1421	10
	G-1609	95	3.7	719	14	1.4	0	19	.2	20	4.9	12	1525	12
WEST MIAMI SECONDARY	G-1647	92	3.3	786	16	2.6	0	21	.3	26	4.9	12	887	15
	G-1648	99	3.7	751	18	2.7	0	22	.2	28	5.1	18	2033	18
HOMESTEAD LOW DENSITY PRIMARY	G-1615	88	2.5	942	15	4.2	0	24	.2	29	2.4	11	110	9
	G-1616	87	2.7	844	21	4.8	0	31	.2	36	3.0	5	45	2
	G-1617	88	2.8	840	21	4.8	0	32	.1	36	3.1	2	70	1
	G-1618	83	2.7	838	21	4.8	0	32	.2	35	3.0	5	173	2
	G-1619	87	2.7	850	20	4.6	0	33	.1	38	3.1	5	160	3
HOMESTEAD LOW DENSITY SECONDARY	G-1625	86	2.4	844	18	4.2	0	27	.2	31	2.7	3	35	3
	G-1626	87	2.7	870	21	4.9	0	31	.1	37	3.1	3	98	4
	G-1627	87	2.7	851	21	4.8	0	31	.1	37	3.1	1	93	2
	G-1628	87	2.7	831	21	4.8	0	32	.1	37	3.1	1	150	5
	G-1629	87	2.7	867	20	4.6	0	31	.1	37	3.2	6	237	3
HOMESTEAD HIGH DENSITY PRIMARY	G-1620	90	2.6	860	16	3.5	0	24	.1	28	2.9	1	36	3
	G-1621	86	2.7	851	22	4.0	0	34	.2	33	3.9	3	143	3
	G-1622	86	2.7	820	22	4.0	0	34	.2	33	3.2	5	134	5
	G-1623	85	2.7	810	22	4.8	0	34	.1	33	3.2	5	143	3
	G-1624	85	2.7	824	21	3.9	0	33	.1	34	3.4	10	261	4
HOMESTEAD HIGH DENSITY SECONDARY	G-1649	88	2.8	877	21	3.8	0	32	.2	32	2.9	4	65	2
	G-1650	88	2.8	848	22	4.0	0	33	.2	34	3.0	8	212	2
SOUTHWEST CONTROL	G-3023	77	3.8	613	14	.4	--	23	.2	2.6	5.5	48	1267	30
	G-3024	81	4.1	613	14	.3	--	25	.2	.9	5.3	30	2900	40

Septic-Tank Related Parameters

Sodium

Sodium is a potential candidate for detecting septic-tank effluent. Pruel (1965) reported an average sodium concentration of 100 mg/l for septic-tank effluent.

Sodium is a major cation that is reliably detected in standard chemical analyses. Dissolved sodium is a naturally occurring ground-water constituent that remains in solution. This conservative behavior is especially true in Dade County due to the virtual absence of clay minerals which might adsorb or exchange sodium for other adsorbed species. Treated drinking water is slightly elevated in sodium content by the addition of sodium silicate and sodium silico-fluoride. Table 8 shows chemical analyses for raw and treated water at the two major water-treatment plants in Dade County. Additional sodium in effluent would also be introduced as waste by-products, the exact concentration depending on the dietary habits of the contributing households.

The average concentrations of sodium in ground water from the monitor wells at north Dade, Hialeah, West Miami, and the northwest base-line sites are shown in figure 18. Concentrations of sodium at the northwest base-line site indicate a natural or background level of approximately 16 mg/l (milligrams per litre). Raw water at the Orr water plant, near Snapper Creek Canal, (table 8) is similar with respect to sodium. However, sodium in the raw water at the Hialeah-Preston plant near Miami Canal, is greater. Concentrations of sodium at north Dade and West Miami at 40 ft and below are similar and slightly less than the concentrations observed at the northwest base-

TABLE 8-- *Typical average analysis of raw and treated water at the city of Miami water treatment plants (1972-73).*

	HIALEAH & PRESTON				ORR PLANT			
	Well Water		Treated Water		Well Water		Treated Water	
Alkalinity ($CaCO_3$)	0.	ppm*	4.	ppm*	0.	ppm*	3.	ppm*
Phenolphthalein	230.	"	40.	"	205.	"	44.	"
Methyl Orange								
Hardness ($CaCO_3$)								
Non-Carbonate	20.	"	35.	"	35.	"	36.	"
Total	250.	"	75.	"	240.	"	80.	"
Carbon Dioxide, Free (CO_2)	25.	"	0.	"	20.	"	0.	"
Chlorine Residual, (Cl_2)	0.	"	1.5	"	0.	"	1.0	"
Nitrates (NO_3)	0.5	"	0.5	"	0.5	"	0.5	"
Chlorides (Cl)	40.	"	54.	"	26.	"	28.	"
Fluorides (F)	0.2	"	1.00	"	0.2	"	1.00	"
Sulfates (SO_4)	24.	"	24.	"	32.	"	32.	"
Calcium (Ca)	88.	"	23.	"	90.	"	25.	"
Iron (Fe)	0.8	"	0.02	"	0.5	"	0.01	"
Magnesium (Mg)	7.0	"	4.2	"	4.0	"	3.6	"
Sodium & Potassium (as Na)	29.	"	32.	"	16.	"	19.	"
Silica (SiO_2)	8.0	"	9.	"	5.0	"	6.3	"
Turbidity	Nil.		Nil.		Nil.		Nil.	
Total Solids	350.	"	205.	"	300.	"	160.	"
Electrical Conductivity, (Micromhos/cm @ 25°C.)	580.		305.		500.		245.	
Color	50.		6.		7.		4.	
pH	7.3		8.8		7.3		8.6	

* parts per million; analyses by City of Miami.

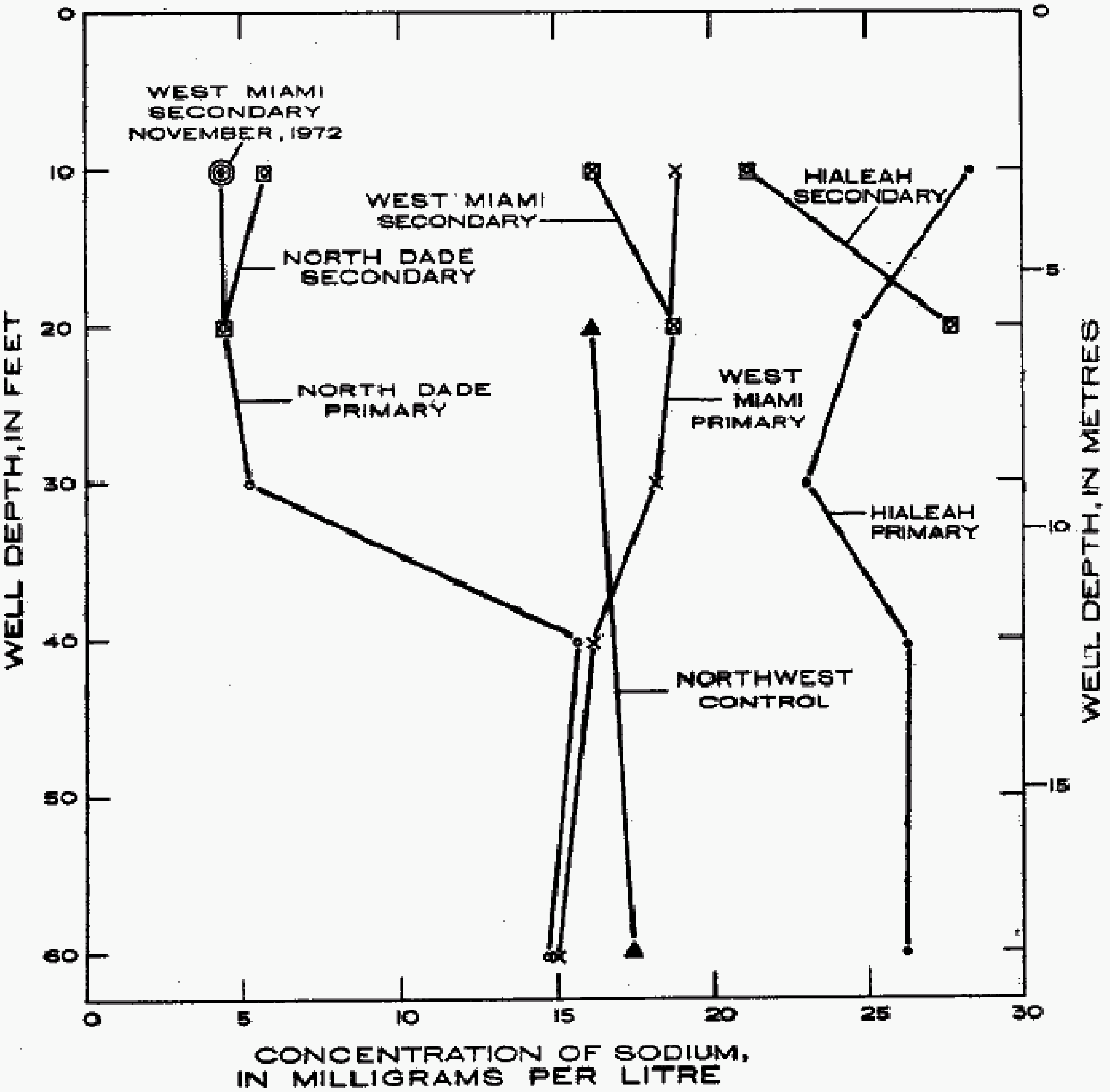


FIGURE 18.--Average concentration of sodium versus well depth at four sites.

line site. The higher concentrations at depth are close to observed concentration at the Hialeah and Preston water plants and are apparently representative of expected concentrations (about 26 mg/l) for that part of Dade County.

The observed sodium concentrations of ground water at and above 30 ft are markedly different from those of water at greater depth (fig. 18). A sample collected on November 7, 1972 at the 10-foot secondary well (G-1647) at West Miami (sodium concentration, 4 mg/l) illustrates what is probably rainfall that infiltrated rapidly to the water table with little or no mixing within the saturated zone. Sodium concentrations in the five primary and secondary wells, 30 ft deep and less at the north Dade site are similarly low. Results obtained from these five wells probably indicate storm-water leachates rather than septic tank effluent. Also shown in figure 18 is the relatively low sodium content of the 10 ft Hialeah secondary well.

Figure 19 shows the seasonal change in sodium concentration for secondary shallow well G-1645 at Hialeah, secondary well G-1647 at West Miami, primary shallow well G-1630 at north Dade, and primary shallow well G-1610 at Hialeah. Several things are evident. A seasonal trend of dilution occurs at the shallow secondary wells in West Miami and Hialeah during the rainy season. In contrast, the higher sodium concentrations and more variable behavior of the shallow primary well in Hialeah indicates an effect of septic-tank effluents. The lack of a seasonal trend in the north Dade primary well may indicate an area-wide low concentration of sodium. The common use of soakage pits or galleries to dispose of low sodium rainfall-runoff may explain

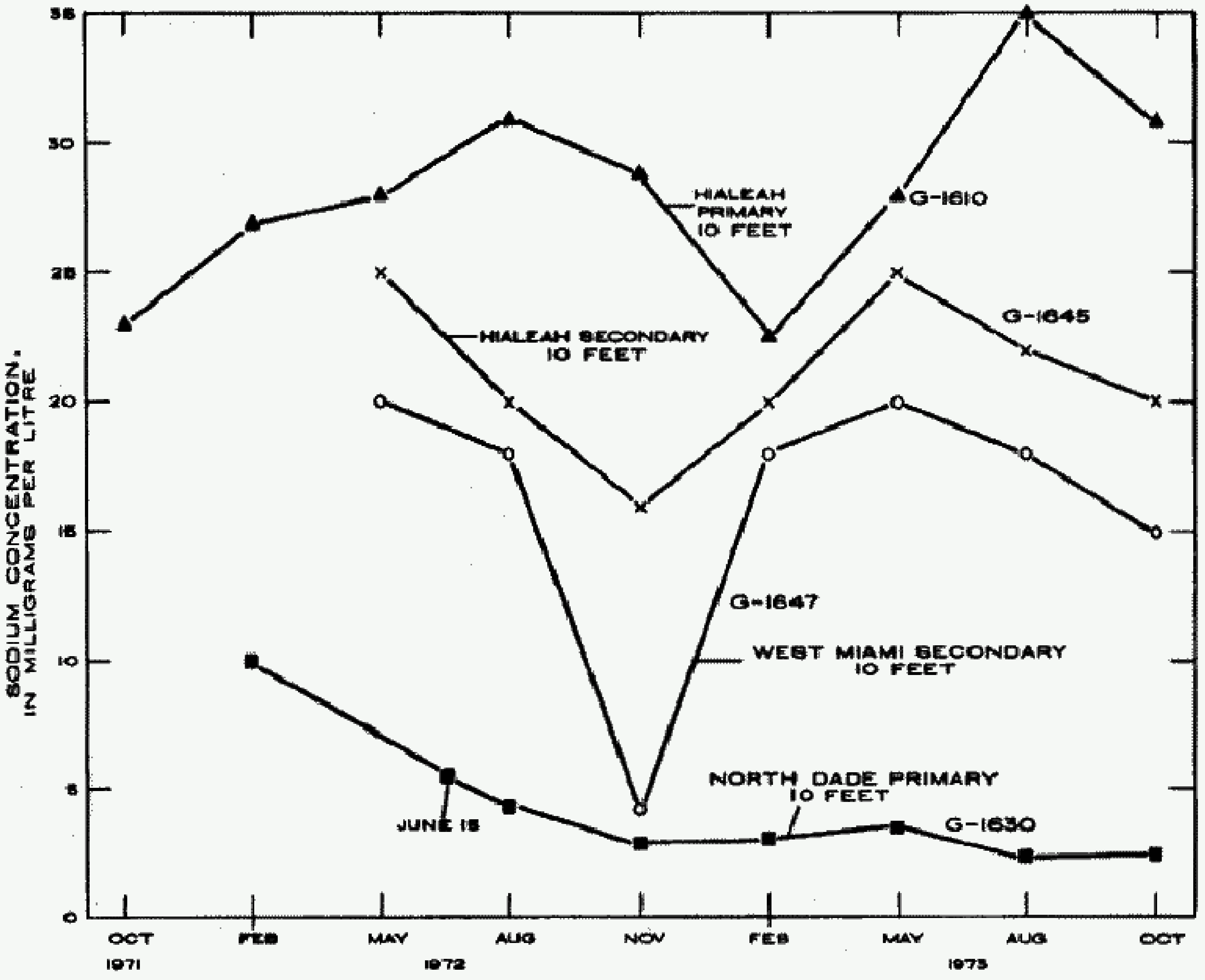


FIGURE 19.--Seasonal changes in sodium concentration in ground water from four monitor wells.

the consistently low sodium concentration.

The average sodium concentrations in the two Homestead sites and the southwest base-line site are shown in figure 20. The 10-ft wells contain less sodium than wells 20 ft and deeper, indicating the influence of rainfall leachates but no noticeable effect of septic-tank effluents. The sodium in excess of background in the deeper Homestead wells, 21 mg/l versus 14 mg/l at the base-line site, is apparently related to past agricultural practices, when the use of sodium nitrate fertilizers was common. Table 9 shows that three other substances, potassium, sulfate, and nitrate, are consistently higher than in water from wells at more northern sites.

Nitrogen

The radical differences in nitrogen chemistry of water from the seven sites in Dade County are related to the nature of the soil cover, the proportion of sand to limestone in the subsurface, the internal drainage of the sediments, the proximity to agriculture, and septic-tank effluent. The general chemistry of nitrogen is governed by bacterial reaction rates and available oxygen, and is basically:

$$\text{Organic Nitrogen} \rightarrow \text{Ammonia} \leftrightharpoons \text{Nitrite} \leftrightharpoons \text{Nitrate}$$

The sum of the four species is termed total nitrogen. The relative proportions of the various nitrogen phases at each site (primary and secondary wells) are summarized in figure 21. Average concentrations of the separate species and of the total nitrogen in water from each well are listed in table 9.

Muck soils in Conservation Area 3 and the interior undeveloped

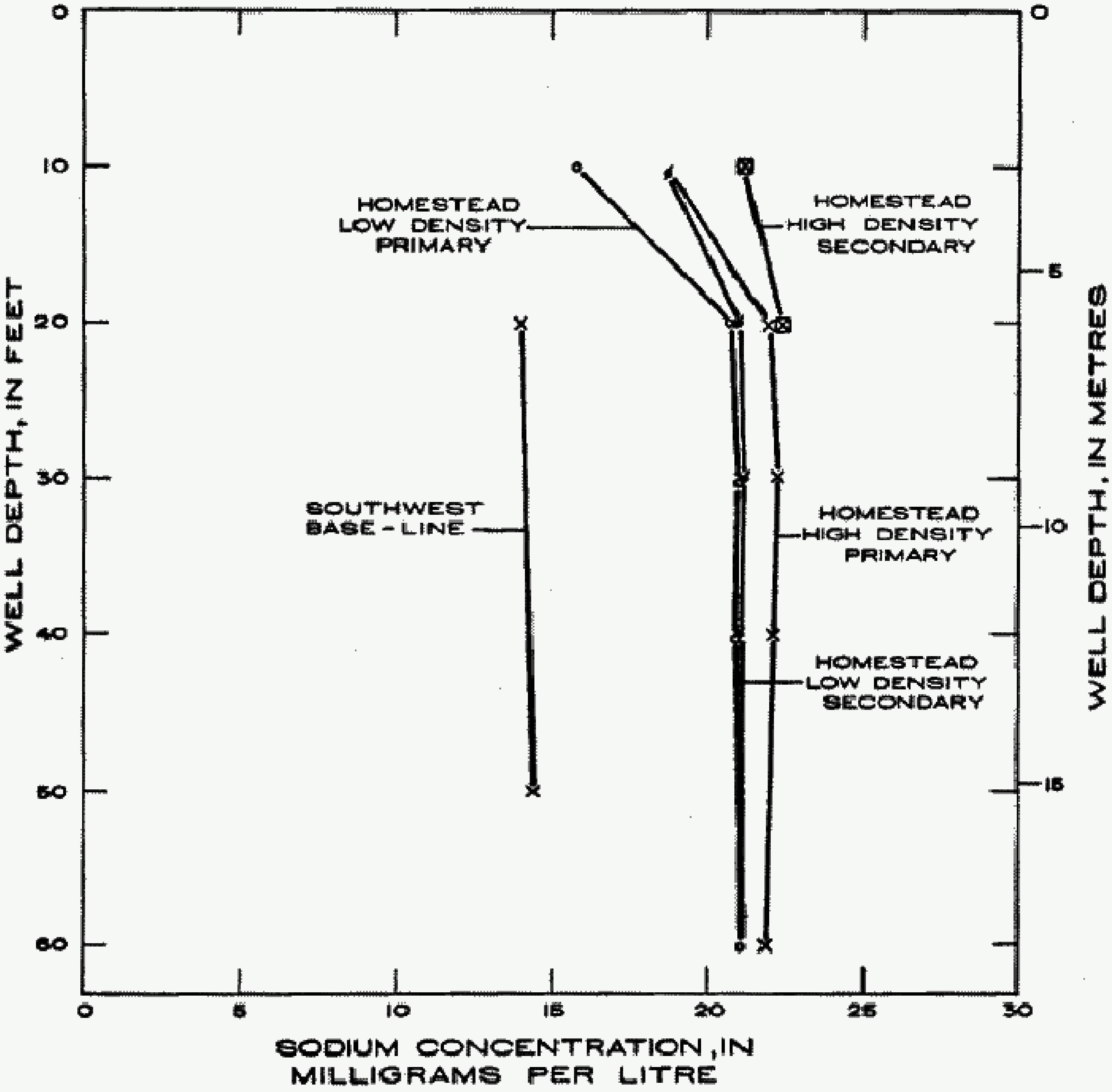


FIGURE 20.--Average concentration of sodium versus well depths at the Homestead sites and the southwest base-line site.

TABLE 9.--*Average concentrations of septic-tank related constituents*

LOCATION	WELL NO	SPECIFIC CONDUCTANCE (MICROMHOS)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	TOTAL ORTHO PHOSPHORUS (P) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	TOTAL NITROGEN (N) (MG/L)	ORGANIC NITROGEN (N) (MG/L)
NORTH DADE PRIMARY	6-1630	424	4.2	1.4	7.9	11	.01	.02	1.0	.74
	6-1631	422	4.4	1.7	10	12	.01	.01	.86	.68
	6-1632	425	5.2	3.1	13	16	.05	.17	.56	.39
	6-1633	515	15	2.6	26	30	.02	.02	.75	.66
	6-1634	527	14	.4	24	24	.01	.01	.81	.55
NORTH DADE SECONDARY	6-1643	387	5.6	2.9	18	16	.00	.00	.82	.60
	6-1644	369	4.6	.3	9.5	9.4	.00	.01	1.1	.92
HIALEAH PRIMARY	6-1610	624	28	4.8	40	22	.32	.34	5.7	1.1
	6-1611	603	24	3.1	34	23	.00	.04	2.6	.54
	6-1612	606	23	1.1	33	24	.01	.01	2.0	.96
	6-1613	638	26	2.2	37	23	.04	.06	3.8	.57
	6-1614	635	26	1.9	37	22	.00	.01	3.2	.52
HIALEAH SECONDARY	6-1645	633	21	3.5	31	30	.08	.10	3.4	.70
	6-1646	594	27	3.8	41	20	.00	.01	3.2	.39
NORTHWEST CONTROL	6-3025	517	16	.5	24	1.7	.00	.01	2.2	1.2
	6-3026	567	17	.7	29	1.3	.00	.02	1.7	.55
WEST MIAMI PRIMARY	6-1605	571	18	3.0	22	29	.05	.09	1.6	.39
	6-1606	564	18	2.8	22	28	.00	.01	1.1	.46
	6-1607	560	18	2.6	21	24	.00	.01	1.0	.51
	6-1608	548	16	2.1	19	24	.00	.00	.88	.47
	6-1609	537	14	1.4	19	20	.00	.00	.79	.42
WEST MIAMI SECONDARY	6-1647	530	16	2.6	21	26	.03	.06	1.0	.48
	6-1648	574	18	2.7	22	28	.00	.02	.93	.44
HOMESTEAD LOW DENSITY PRIMARY	6-1615	519	15	4.2	24	29	.00	.01	1.7	.25
	6-1616	556	21	4.8	31	36	.00	.00	2.6	.31
	6-1617	548	21	4.8	32	36	.00	.00	2.5	.30
	6-1618	542	21	4.4	32	35	.00	.00	2.7	.27
	6-1619	546	20	4.6	33	38	.00	.00	2.3	.37
HOMESTEAD LOW DENSITY SECONDARY	6-1625	514	18	4.2	27	31	.00	.01	2.3	.24
	6-1626	551	21	4.9	31	37	.00	.00	2.8	.27
	6-1627	552	21	4.6	31	37	.00	.00	2.8	.40
	6-1628	554	21	4.8	32	37	.00	.00	3.0	.53
	6-1629	562	20	4.6	31	37	.00	.00	2.5	.40
HOMESTEAD HIGH DENSITY PRIMARY	6-1620	540	18	3.3	29	29	.00	.00	1.7	.28
	6-1621	545	22	4.0	34	33	.00	.00	2.0	.22
	6-1622	543	22	4.0	34	33	.00	.00	2.2	.17
	6-1623	549	22	4.8	34	33	.00	.00	2.0	.22
	6-1624	544	21	3.9	33	34	.00	.00	1.7	.24
HOMESTEAD HIGH DENSITY SECONDARY	6-1649	552	21	3.6	32	32	.00	.00	1.0	.14
	6-1650	544	22	4.0	33	34	.00	.00	1.4	.13
SOUTHWEST CONTROL	6-3023	453	14	.4	23	2.6	.00	.01	1.1	.67
	6-3024	465	14	.3	25	.9	.00	.00	1.3	.89

TABLE 9.--Cont.

LOCATION	WELL NO	AMMONIA NITROGEN (N) (MG/L)	TOTAL NITRITE (N) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	BIOCHEMICAL OXYGEN DEMAND (MG/L)	CHEMICAL OXYGEN DEMAND (HIGH LEVEL) (MG/L)	OIL AND GREASE (MG/L)	METHYLENE BLUE ACTIVE SUBSTANCE (MG/L)	IMMEDIATE COLIFORM (COL. PER 100 ML)	FECAL COLIFORM (COL. PER 100 ML)	STREPTOCOCCI (COLONIES PER 100 ML)
NORTH DADE PRIMARY	G-1630	.24	.02	.05	22	1.6	64	24	.1	11	0	1
	G-1631	.16	.00	.00	15	3.4	52	10	.0	3	0	1
	G-1632	.15	.00	.00	12	4.2	42	9	.0	5	0	1
	G-1633	.07	.01	.00	10	2.5	36	10	.0	5	0	5
	G-1634	.25	.00	.00	11	1.9	35	11	.0	41	0	20
NORTH DADE SECONDARY	G-1643	.17	.00	.04	17	8.0	39	12	.0	9	0	21
	G-1644	.17	.00	.00	11	6.1	33	10	.0	22	0	7
HIALEAH PRIMARY	G-1610	3.9	.01	.04	10	1.6	22	9	.1	22	2	8
	G-1611	2.2	.00	.00	9.6	1.1	27	16	.1	7	0	4
	G-1612	1.1	.00	.00	11	1.5	27	7	.2	7	1	1
	G-1613	3.3	.01	.00	9.2	1.5	28	8	.1	1	0	19
	G-1614	2.7	.00	.00	8.8	1.0	24	10	.2	9	0	1
HIALEAH SECONDARY	G-1645	1.4	.03	1.2	12	1.3	22	12	.0	244	16	26
	G-1646	2.8	.01	.00	8.4	1.5	15	11	.2	258	9	13
NORTHWEST CONTROL	G-3025	.47	.00	.00	22	.2	50	5	.0	229	0	0
	G-3026	1.2	.00	.00	15	.2	48	7	.1	12	0	1
WEST MIAMI PRIMARY	G-1605	.93	.01	.34	2.1	1.5	17	9	.0	366	15	14
	G-1606	.63	.00	.00	5.0	.7	13	9	.0	2	0	10
	G-1607	.51	.00	.00	2.4	.9	13	11	.0	3	2	8
	G-1608	.36	.00	.00	2.8	.9	17	10	.1	4	1	1
	G-1609	.36	.00	.00	2.6	.7	16	8	.0	3	1	41
WEST MIAMI SECONDARY	G-1647	.34	.07	.11	3.0	1.1	12	10	.0	36	288	235
	G-1648	.44	.00	.00	1.0	1.0	11	13	.0	9	0	0
HOMESTEAD LOW DENSITY PRIMARY	G-1615	.03	.01	1.4	2.8	1.1	7	11	.0	15	10	2
	G-1616	.09	.00	2.2	3.1	.8	7	9	.0	23	4	3
	G-1617	.01	.00	2.2	3.1	1.4	4	11	.0	30	2	4
	G-1618	.02	.00	2.4	2.8	1.1	8	19	.0	5	1	1
	G-1619	.02	.00	1.9	3.0	.7	5	11	.0	6	1	0
HOMESTEAD LOW DENSITY SECONDARY	G-1625	.02	.01	2.1	2.5	.8	7	11	.0	229	4	21
	G-1626	.03	.00	2.4	1.7	.4	5	10	.0	45	2	1
	G-1627	.02	.00	2.4	2.4	.8	8	10	.0	2	1	1
	G-1628	.02	.00	2.5	3.2	.8	3	11	.0	3	6	4
	G-1629	.03	.00	2.1	2.8	.9	8	10	.0	12	8	5
HOMESTEAD HIGH DENSITY PRIMARY	G-1620	.01	.00	1.4	.5	.7	5	7	.0	81	0	2
	G-1621	.02	.00	1.7	1.8	.8	8	10	.0	17	0	0
	G-1622	.03	.00	2.0	2.1	.5	7	10	.0	29	6	1
	G-1623	.03	.01	1.7	2.2	.5	10	10	.0	6	0	5
	G-1624	.02	.01	1.4	2.7	.6	9	10	.0	2	0	0
HOMESTEAD HIGH DENSITY SECONDARY	G-1649	.02	.01	1.6	2.7	.5	5	9	.0	12	1	79
	G-1650	.02	.00	1.8	2.5	.5	12	11	.0	35	0	1
SOUTHWEST CONTROL	G-3023	.46	.00	.00	6.6	.0	28	17	.0	101	0	0
	G-3024	.40	.00	.00	9.3	.0	27	11	.0	14	0	0

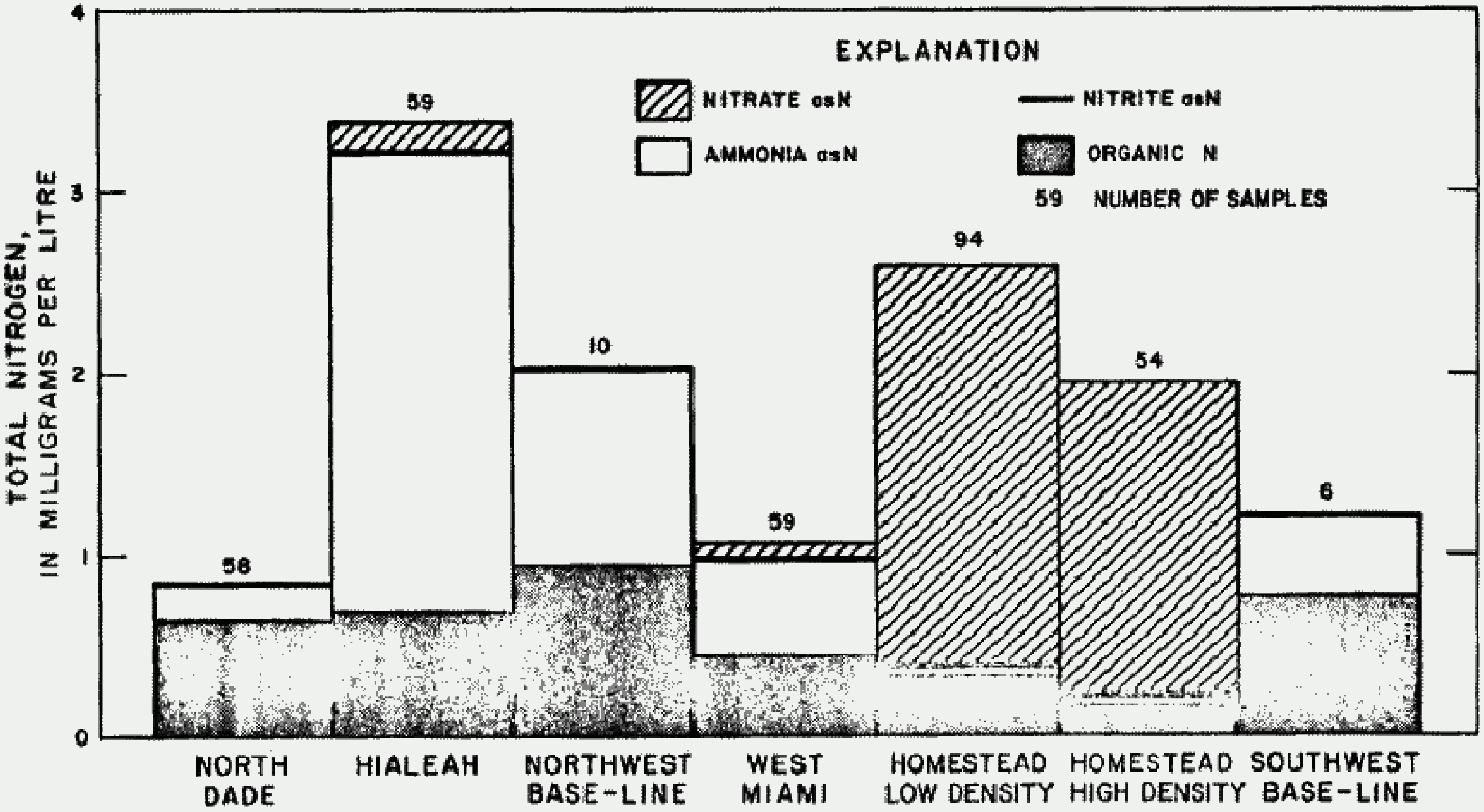


FIGURE 21.--Average nitrogen specie concentrations at the seven sites (primary and secondary wells).

marshlands produce high organic nitrogen and ammonia values in water. The two base-line sites are relatively high in organic nitrogen and ammonia. The microbial oxidation of ammonia nitrogen to nitrite and nitrate does not occur because oxygen is unavailable.

The only water samples in the north Dade, Hialeah, and West Miami sites that contain nitrate were collected from shallow wells that showed lower values of sodium than samples from deeper wells at the same sites. Rainfall leachates providing oxygen necessary for bacterial nitrification reactions to occur, or lawn fertilizers high in nitrate may be the causes of the changes in species.

The uniformly high nitrate observed in all the Homestead wells is probably related to the extensive agricultural activity. The virtual absence of ammonia in Homestead indicates that the cavernous nature of the aquifer allows rapid infiltration of rainfall carrying dissolved oxygen, permitting nitrification of any background ammonia.

Phosphorus

Analyses of two phosphorus phases were determined on unfiltered ground-water samples at all of the seven sites (table 9). Trace amounts of total phosphorus are commonly observed in well-water samples due to suspended particulate and organic matter. Total phosphorus was detected in 60 percent of the 326 ground water samples. Orthophosphate-phosphorus was present in 33 percent of the samples. The most frequent occurrences of orthophosphate-phosphorus were observed in the northern four sites (fig. 22).

Water from the northwest base-line wells was consistently low in

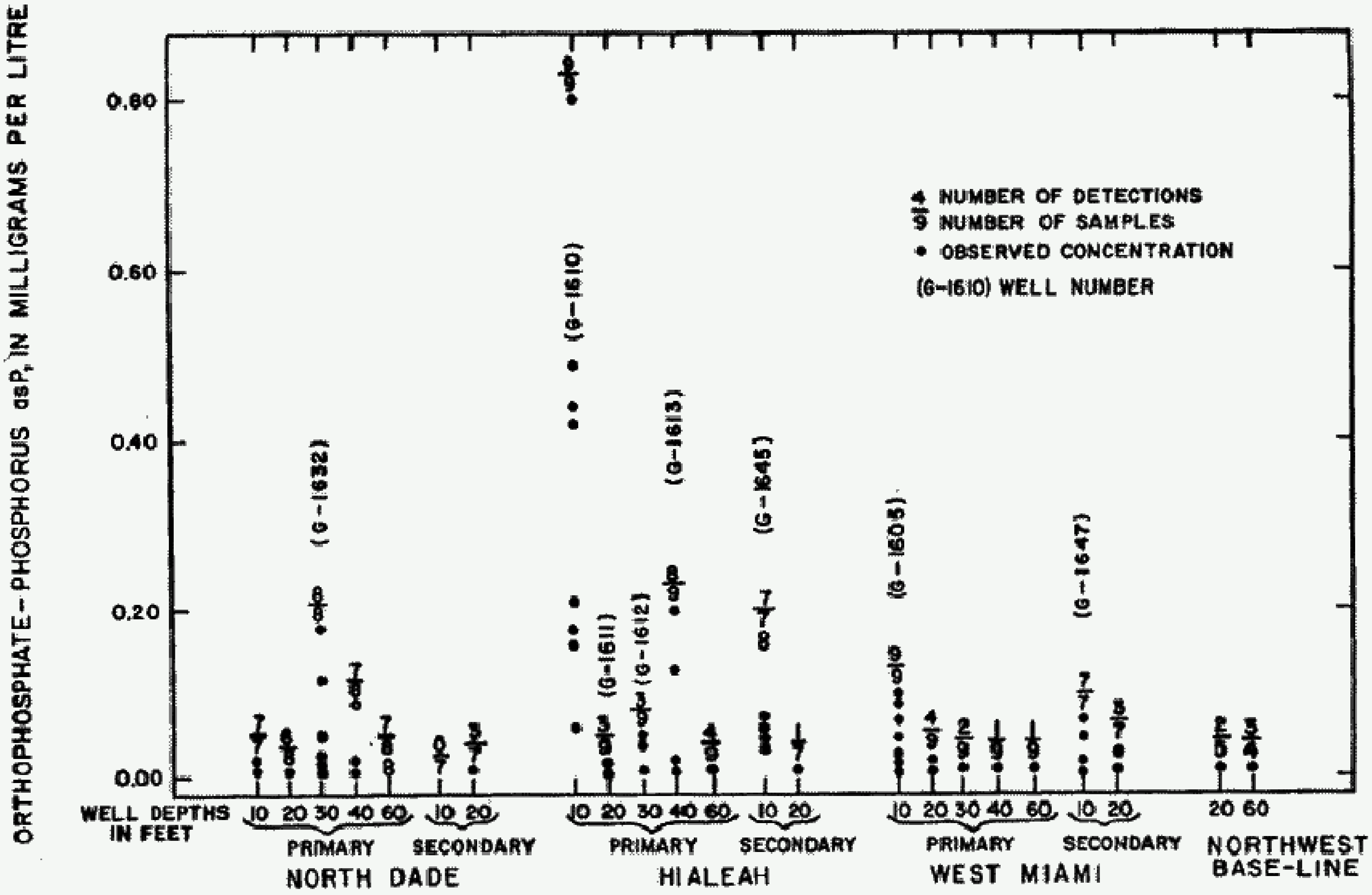


FIGURE 22.--Concentration and frequency of orthophosphate-phosphorus in four sites.

concentrations of orthophosphate-phosphorus. Most other test wells showed similar low concentrations. Well G-1632 in north Dade yielded water with anomously high levels of phosphorus, considering the low observed concentrations of phosphorus in the shallower wells at the same site. Other constituents of interest in well G-1632 are the lower organic nitrogen and higher potassium concentrations than other wells in north Dade. Sodium is also low in well G-1632. This combination of chemicals suggests the influence of lawn fertilizers rather than septic-tank effluent. The lower concentrations of potassium and phosphorus at shallower depths indicate that vertical percolation of water is not the source of these constituents, but that they have moved laterally from an upgradient source. Another possible source of introduction of surface water at depth in the aquifer is stormwater drainage wells which are common in north Dade County.

The 10-ft primary well in Hialeah (G-1610) is definitely enriched in orthophosphate-phosphorus which can be attributed to septic-tank effluents. The frequency and concentrations of detectable phosphorus at the 20 and 30-foot wells (G-1611 and G-1612) in Hialeah are very low by comparison. However, in the 40-foot well (G-1613) more frequent detection and higher concentrations of orthophosphate and the relatively high ammonia concentrations suggest that septic-tank effluent from an upgradient area is moving through the aquifer at this depth.

The 10-foot secondary well in Hialeah (G-1645) contains considerable (0.08 mg/1) orthophosphate-phosphorus. Coincidentally, sodium, chloride, and ammonia are relatively low compared to other Hialeah wells. Potassium is slightly higher and nitrate nitrogen is considerably enriched in well G-1645 (table 9). These associations indicate infiltration of fertilizer-enriched storm water rather than downgradient migration of septic-tank effluent.

Concentrations of orthophosphate-phosphorus at West Miami are higher and more common in the shallow wells (G-1605, G-1647) than in deeper wells, but there was no clear indication of the relative importance of septic-tank effluent versus storm-water infiltration.

All Homestead test wells show trace amounts of total phosphorus on several occasions. Orthophosphate-phosphorus, however, was observed in only 4 of 139 samples analyzed. Two of the four detections were at well G-1625, the shallow primary well at the Homestead low-density site. In view of the pervasive agricultural enrichment of nitrate, potassium, and sulfate, the virtual absence of orthophosphate in water from any of the Homestead wells appears contradictory. Dissolved phosphorus reacts readily with calcium to form insoluble hydroxyapatite precipitates. Additionally, when iron hydroxide precipitates, the precipitate scavenges dissolved phosphorus. The cavernous limestone in Homestead allows a good circulation of oxygen-rich water which encourages iron hydroxide precipitation. Whether the greater proportion of limestone to sand within the aquifer in the Homestead area or the formation of iron hydroxide precipitates is responsible for the absence of phosphorus is unclear. In either case, phosphorus is not mobile in the south Dade area.

Carbon

Carbon is reported as, inorganic, organic and total. Total and inorganic carbon are determined analytically. The organic carbon is reported as the difference between total carbon and the inorganic carbon. This difference method for organic carbon does not work well for ground-water samples high in inorganic carbon. Where several samples have been analyzed the average value may show trends between areas that are, in fact, different. Average carbon analyses for each of the test wells are listed in tables 7 and 9.

Organic carbon is derived from decaying organic matter. Contributions to the ground-water system are generally highest in the interior marshes. Litter on urban streets contains a fairly large quantity of readily-soluble organic waste products. The shallow primary well in Hialeah (G-1610) is rich in ammonia nitrogen and soluble phosphorus but unaffected with respect to organic carbon. Organic carbon appears to be a poor indicator of septic-tank effluent due to the fairly high natural concentrations in the ground water.

A consistent pattern of decreasing organic carbon content southward in Dade County is apparent. However, this general relation probably reflects the overall distance from organic-rich marshlands where concentrations in ground-water are high and the distance over which lower organic carbon surface water infiltration can dilute this component. Another factor of possible importance is the relative flushing rate of the aquifer which would allow more rapid infiltration of oxygen-rich rainfall permitting oxidation of organic carbon to inorganic carbon by facultative aerobic bacteria.

Sulfate

The chemistry of sulfur is controlled by bacteria, plant utilization, natural rock materials, dissolved ions in solution, pH, and availability of oxygen. The base-line sites are characterized by low dissolved sulfate concentrations (table 9). These sites are located in relatively undisturbed areas of heavy vegetation and generally characterized by reducing conditions. Although much sulfur might be available in the environment, the reduction of sulfate to sulfide by obligate anaerobic bacteria can lower the sulfate concentrations in the ground water. The low sulfate concentrations at the base-line sites are probably the result of this process.

The highest concentrations of dissolved sulfate are in the Homestead area. The combined effect of agricultural enrichment of sulfates and the oxidizing conditions found in the permeable aquifer are probably responsible. The general decrease in dissolved sulfate concentrations northward coincides with the lower aquifer permeability and concomitant reducing conditions.

Oxygen Demand

Two measures of the amount of oxygen consuming material contained in a water sample are COD (chemical oxygen demand) and BOD (bio-chemical oxygen demand). BOD values indicate the probable amount of oxygen consumed under natural conditions within the 5-day span. COD is an approximation of the readily oxidizable material irrespective of time. Both are influenced by organic material and reduced chemical species.

BOD is consistently low (less than 2.0 mg/l) in Dade County ground waters. Nearly half of the samples in which BOD was greater than 2.0 mg/l are from the north Dade wells. Increases in BOD above natural levels appear to be related primarily to infiltration of storm water.

COD is generally higher in the base-line sites than in the septic-tank areas. In order of decreasing COD concentrations the pattern,

North Dade > Hialeah > West Miami >
Homestead Low Density > Homestead High Density,

is particularly strong (table 9). Only the north Dade site shows any increase in COD due to cultural factors. The very low sodium observed in the water in the shallower wells (30 ft and above) at the north Dade site indicates that the increased oxygen demand is related to infiltration of storm water. County-wide, a lower COD is related to a higher permeability in the aquifer. As more oxygen is available to react with organic material and reduced chemical species the oxygen demand is satisfied and the COD decreases.

Bacteria

The three most common characterizations of biological purity in water samples are total coliform, fecal coliform, and fecal streptococci. Total coliform include a wide spectrum of bacteria from soils, septic tanks, storm-water leachate and many other sources. Fecal coliforms are derived solely from warm blooded animals, especially man, dogs, and cats. Fecal streptococci are derived primarily from other vertebrates and insects.

Total coliform bacteria were present in one or more samplings from every monitor well. Fifty three percent of the 322 samples collected during the study contained total coliform bacteria. Figure 23 summarizes the distribution of positive detections by site. The frequency of positive detections decreases with depth (fig. 24), and is a reflection of the distance from the surface source and the length of time in the subsurface environment.

Fecal coliform were detected most frequently in the primary shallow wells at Hialeah (G-1610), West Miami (G-1605), and Homestead low density (G-1615). The total detections of fecal coliform were 37 of 312 samples, or 12 percent. Surprisingly, north Dade and the two base-line sites had no fecal coliform detections.

Fecal streptococci bacteria detections were twice as frequent as fecal coliform detections, 83 of 309 samples (fig. 23). Only two monitor wells at the Homestead high density site and three of the four base-line wells failed to show one or more detections of fecal streptococci.

Two factors that tend to encourage the growth of bacteria in the aquifer are the absence of light and the nearly constant temperature. Among the factors which tend to retard the development of bacterial populations in ground water, are the low levels of dissolved oxygen, the large proportion of solid surfaces which would adsorb bacteria, and the virtual absence of phosphorus and trace metals essential to their growth. Overall, the dieoff rate of introduced bacteria is very rapid. The highest concentrations of fecal coliform and fecal streptococci (1,600 colonies/100 ml) occurred on November 7, 1972 in the shallow secondary well at West Miami (G-1647). This sample was abnormally low in sodium because of storm-water infiltration. Three

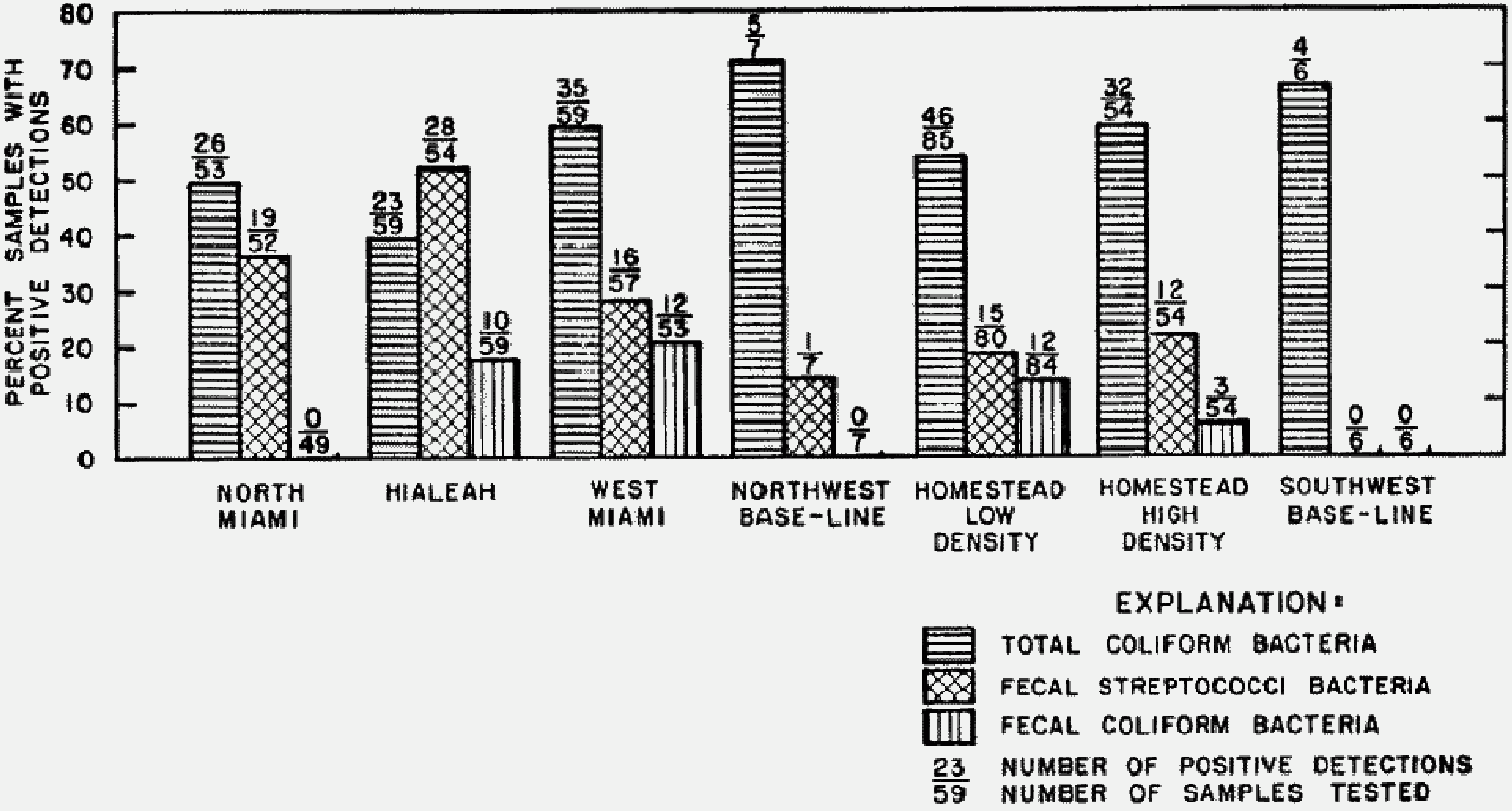


FIGURE 23.--Frequency of positive bacterial identifications at seven sites.

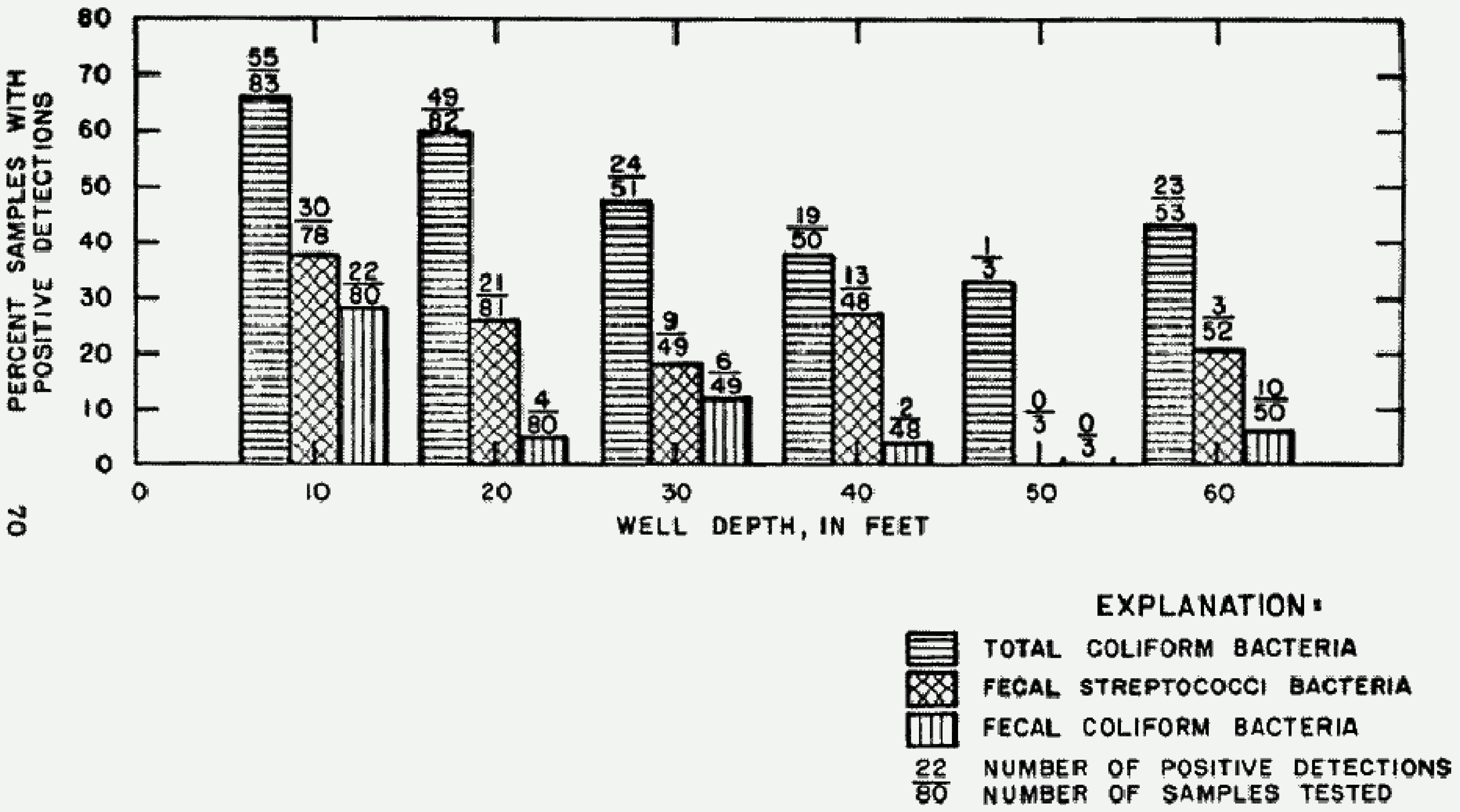


FIGURE 24.--Frequency of positive bacterial identifications versus well depth.

months later no bacteria were detected.

Metals

The twelve chemical elements listed in table 10 have a strong affinity for oxygen and form oxides insoluble in water. Cadmium and lead are commonly referred to as heavy metals. The other ten elements are similar in chemical properties. The twelve elements are commonly called trace metals because of their generally low solubility in aqueous solutions. A trace is generally considered to be less than 1 ug/g for a solid or 1 mg/l for a solution. Only iron is naturally present in concentrations greater than trace amounts in Dade County ground water.

The concentrations in table 10 are the maximum observed. Dissolved iron, manganese and zinc were analyzed each sampling time. The other elements were analyzed once or twice for each well. Generally the total, unfiltered sample is higher in concentration than the filtered sample. The few reversals (dissolved concentration greater than the total concentrations) occur when the two or more samples were collected at different times during different samplings. Average dissolved iron and manganese concentrations are listed in table 8 and were discussed as natural ground-water constituents.

Aluminum is a common component of many rock forming minerals that is very insoluble in water. The few detections of dissolved aluminum are near the detection limit of the analytical technique.

Boron is common in marine waters and in marine sediments. Both quartz and organic matter contain several micrograms per gram of boron.

TABLE 10.--*Maximum observed metal concentrations*

LOCATION	WELL Nº	DIS-SOLVED ALUM-INUM (AL) (UG/L)	TOTAL ALUM-INUM (AL) (UG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	DIS-SOLVED BORON (B) (UG/L)	TOTAL BORON (B) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	TOTAL CAD-MIUM (CD) (UG/L)	HEXA-VALENT CHRO-MIUM (CR6) (UG/L)
NORTH DADE PRIMARY	G-1630	0	800	0	10	1100	630	0	0	0
	G-1631	100	400	0	10	700	50	1	--	0
	G-1632	0	100	0	0	750	50	0	0	0
	G-1633	0	4	0	10	600	60	0	0	0
	G-1634	0	100	0	10	700	50	0	0	0
NORTH DADE SECONDARY	G-1643	100	100	--	20	--	70	0	0	0
	G-1644	0	100	--	10	--	50	0	0	1
HIALEAH PRIMARY	G-1610	0	0	20	10	1200	120	0	1	0
	G-1611	0	0	10	10	0	110	0	0	0
	G-1612	0	1400	10	0	350	50	0	0	0
	G-1613	0	1500	0	10	700	100	0	0	0
	G-1614	0	0	0	0	500	70	0	0	0
HIALEAH SECONDARY	G-1645	0	0	--	0	--	100	0	0	0
	G-1646	0	100	--	20	--	100	0	0	0
NORTHWEST CONTROL	G-3025	--	50	--	27	--	80	--	2	0
	G-3026	--	60	--	26	--	60	--	3	0
WEST MIAMI PRIMARY	G-1605	0	0	0	10	750	60	0	0	0
	G-1606	0	0	10	10	750	70	0	0	0
	G-1607	0	0	0	10	0	60	0	0	0
	G-1608	0	0	10	10	550	50	0	0	0
	G-1609	0	0	0	11	350	40	0	0	0
WEST MIAMI SECONDARY	G-1647	100	100	--	10	--	60	0	0	0
	G-1648	0	0	--	10	--	60	0	0	0
HOMESTEAD LOW DENSITY PRIMARY	G-1615	0	0	10	0	150	40	0	0	0
	G-1616	0	0	0	0	350	30	0	0	0
	G-1617	0	0	10	0	250	30	0	0	0
	G-1618	0	100	0	0	200	30	0	0	10
	G-1619	0	100	0	0	400	60	0	0	0
HOMESTEAD LOW DENSITY SECONDARY	G-1625	0	100	0	0	250	40	0	0	0
	G-1626	0	100	0	0	200	40	0	0	0
	G-1627	0	100	0	0	150	30	0	0	0
	G-1628	0	100	0	0	250	30	0	0	0
	G-1629	0	0	0	0	400	40	0	0	0
HOMESTEAD HIGH DENSITY PRIMARY	G-1620	0	0	0	0	0	20	0	0	1
	G-1621	0	0	0	0	500	30	0	0	10
	G-1622	0	0	0	0	200	30	0	1	0
	G-1623	0	0	0	0	350	20	0	0	0
	G-1624	0	0	0	0	250	20	0	0	1
HOMESTEAD HIGH DENSITY SECONDARY	G-1649	100	100	--	0	--	20	0	0	1
	G-1650	100	0	--	0	--	30	1	0	0
SOUTHWEST CONTROL	G-3023	--	--	--	--	--	--	--	--	0
	G-3024	--	--	--	--	--	--	--	--	0

TABLE 10.--*Cont.*

LOCATION	WELL NO	DISSOLVED COBALT (CO) (UG/L)	TOTAL COBALT (CO) (UG/L)	DISSOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)	DISSOLVED IRON (FE) (UG/L)	TOTAL IRON (FE) (UG/L)	DISSOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	TOTAL MANGANESE (MN) (UG/L)	DISSOLVED NICKEL (NI) (UG/L)	TOTAL NICKEL (NI) (UG/L)	DISSOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)
NORTH DADE PRIMARY	G-1630	0	0	0	--	17000	2100	2	5	210	20	1	--	12000	10000
	G-1631	0	0	10	--	11000	3400	3	4	40	--	0	--	3300	--
	G-1632	0	0	0	0	2300	1200	2	2	30	10	0	--	600	280
	G-1633	0	0	10	--	2400	2300	0	3	30	20	0	--	150	--
	G-1634	0	0	0	--	2500	1	0	2	10	10	0	--	90	50
NORTH DADE SECONDARY	G-1643	0	--	10	--	36000	8900	2	7	140	80	1	--	9000	12000
	G-1644	0	0	10	--	4500	2500	0	1	40	10	0	--	840	880
HIALEAH PRIMARY	G-1610	0	0	0	10	3300	1700	0	7	40	30	0	--	40	50
	G-1611	0	0	0	30	9600	5700	6	--	40	50	1	--	3700	600
	G-1612	1	--	0	0	4800	4900	5	--	40	--	0	--	1300	330
	G-1613	0	0	0	20	2400	4300	4	25	30	30	1	--	20	60
	G-1614	0	0	0	--	2500	2700	0	4	30	20	0	--	70	50
HIALEAH SECONDARY	G-1645	0	0	0	10	710	14000	0	0	20	20	0	--	30	50
	G-1646	0	0	0	0	4000	690	0	0	20	--	0	--	2800	2800
NORTHWEST CONTROL	G-3025	--	2	--	10	2300	6100	--	33	--	40	--	10	40	40
	G-3026	--	5	--	3	2900	4800	--	36	--	50	--	17	10	80
WEST MIAMI PRIMARY	G-1605	0	0	20	--	2500	1300	10	3	20	10	0	--	90	40
	G-1606	0	0	10	--	1400	1900	2	5	20	10	0	--	30	40
	G-1607	0	0	10	0	1700	1100	4	2	20	10	0	--	60	--
	G-1608	0	0	10	0	1900	1500	2	4	20	10	0	--	30	50
	G-1609	0	0	0	0	2400	2000	10	2	20	20	0	--	110	70
WEST MIAMI SECONDARY	G-1647	1	2	0	10	1600	1700	2	4	20	20	0	--	40	80
	G-1648	0	0	0	10	3400	1400	0	3	30	10	0	--	30	50
HOMESTEAD LOW DENSITY PRIMARY	G-1615	0	0	10	--	180	720	0	0	20	10	0	--	160	--
	G-1616	0	0	10	--	160	140	30	0	10	10	0	--	40	20
	G-1617	0	0	10	--	150	470	0	1	10	10	0	--	50	40
	G-1618	0	0	0	0	340	910	0	2	10	10	0	--	30	40
	G-1619	0	0	0	20	290	4100	2	1	10	40	0	--	20	50
HOMESTEAD LOW DENSITY SECONDARY	G-1625	0	0	0	0	60	1400	0	2	10	10	0	--	20	40
	G-1626	0	0	0	0	160	910	0	3	10	10	0	--	20	20
	G-1627	0	0	10	--	140	210	2	--	10	10	0	--	30	30
	G-1628	0	0	10	--	440	2100	0	3	10	10	0	--	20	50
	G-1629	0	0	10	--	290	2100	0	2	10	20	0	--	20	20
HOMESTEAD HIGH DENSITY PRIMARY	G-1620	0	0	0	0	70	300	1	3	10	10	0	--	70	--
	G-1621	0	0	0	10	330	2000	1	3	10	10	0	--	30	40
	G-1622	0	0	0	0	230	970	3	2	10	0	0	--	30	20
	G-1623	0	0	0	0	260	800	4	10	10	10	0	--	20	20
	G-1624	0	0	0	10	410	690	2	2	20	10	0	--	50	20
HOMESTEAD HIGH DENSITY SECONDARY	G-1649	0	0	0	10	140	580	0	7	10	10	0	--	60	40
	G-1650	0	0	10	10	290	3600	3	5	20	10	0	--	300	40
SOUTHWEST CONTROL	G-3023	--	--	--	--	1400	--	--	--	40	--	--	--	240	--
	G-3024	--	--	--	--	3400	--	--	--	40	--	--	--	50	--

Dissolved boron is appreciably greater than total boron, apparently due to contamination from the filter pads. Total boron is generally low except for the shallow primary well (G-1630) at the north Dade site. This well shows the highest average organic carbon (table 9), and the boron is probably related to natural organic materials.

Cadmium, chromium, cobalt, copper, lead, and nickel are present in trace amounts close to the detection limits of the respective analytical techniques. Zinc is very high in eight wells, G-1630, G-1631, G-1632, G-1643, G-1644, G-1611, G-1612, and G-1646. These were the only wells finished with sand points. The bronze filter screen on the sand point has a soldered seam which has several percent by weight of zinc. Considering the lead content of the solder, the very low concentrations of dissolved lead indicates the very low solubility of lead in the groundwater system. Zinc is readily soluble by comparison.

Pesticides

Pesticides is a general term for insecticides, herbicides and rodenticides. The toxicants listed in table 11 are all synthetic organic compounds which are analyzed according to techniques described by Goerlitz and Brown (1972). All the compounds listed in table 11 are only slightly soluble in water and are readily adsorbed by soils and sediments.

Five detections of chlorinated hydrocarbon insecticide were made. Only DDT and DDE in the shallow primary well (G-1605) in West Miami were present in concentrations above 0.01 ug/l. Dieldrin, a common toxicant for termites, was present in two other shallow wells. Aldrin was the

TABLE 11.--*Pesticide concentrations*

LOCATION	WELL Nº	ALDRIN (UG/L)	LINDANE (UG/L)	CHLORDANE (UG/L)	DDD (UG/L)	DDE (UG/L)	DDT (UG/L)	DIELDRIN (UG/L)	ENDRIN (UG/L)	ETHION (UG/L)
NORTH DADE PRIMARY	G-1630	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1631	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1632	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1633	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1634	--	--	--	--	--	--	--	--	--
NORTH DADE SECONDARY	G-1643	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1644	.00	.00	.0	.00	.00	.00	.00	.00	.00
HIALEAH PRIMARY	G-1610	.00	.00	.0	.00	.00	.00	.01	.00	.00
	G-1611	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1612	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1613	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1614	.00	.00	.0	.00	.00	.00	.00	.00	.00
HIALEAH SECONDARY	G-1645	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1646	.01	.00	.0	.00	.00	.00	.00	.00	.00
NORTHWEST CONTROL	G-3025	.00	.00	.0	.00	.00	.00	.00	.00	--
	G-3026	.00	.00	.0	.00	.00	.00	.00	.00	--
WEST MIAMI PRIMARY	G-1605	.00	.00	.0	.00	.03	.08	.00	.00	.00
	G-1606	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1607	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1608	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1609	.00	.00	.0	.00	.00	.00	.00	.00	.00
WEST MIAMI SECONDARY	G-1647	.00	.00	.0	.00	.00	.00	.01	.00	.00
	G-1648	.00	.00	.0	.00	.00	.00	.00	.00	.00
HOMESTEAD LOW DENSITY PRIMARY	G-1615	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1616	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1617	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1618	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1619	.00	.00	.0	.00	.00	.00	.00	.00	.00
HOMESTEAD LOW DENSITY SECONDARY	G-1625	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1626	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1627	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1628	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1629	.00	.00	.0	.00	.00	.00	.00	.00	.00
HOMESTEAD HIGH DENSITY PRIMARY	G-1620	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1622	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1623	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1624	.00	.00	.0	.00	.00	.00	.00	.00	.00
HOMESTEAD HIGH DENSITY SECONDARY	G-1649	.00	.00	.0	.00	.00	.00	.00	.00	.00
	G-1650	.00	.00	.0	.00	.00	.00	.00	.00	.00

TABLE 11.--Cont.

LOCATION	WELL Nº	TOX-APHENE (UG/L)	HEPTA-CHLOR (UG/L)	HEPTA-CHLOR EPOXIDE (UG/L)	PCB (UG/L)	MALA-THION (UG/L)	PARA-THION (UG/L)	DI-AZINON (UG/L)	METHYL PARA-THION (UG/L)	2,4-D (UG/L)	2,4,5-T (UG/L)	SILVEX (UG/L)	TRI-THION (UG/L)	METHYL TRI-THION (UG/L)
NORTH DADE PRIMARY	G-1630	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1631	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1632	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1633	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1634	--	--	--	--	--	--	--	--	.00	.00	.00	--	--
NORTH DADE SECONDARY	G-1643	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1644	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
HIALEAH PRIMARY	G-1610	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1611	--	.00	--	.0	.00	.00	.00	.00	--	--	--	.00	.00
	G-1612	--	.00	--	.0	.00	.00	.00	.00	.04	.00	.00	.00	.00
	G-1613	--	.00	--	.0	.00	.00	.00	.00	.01	.00	.00	.00	.00
	G-1614	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
HIALEAH SECONDARY	G-1645	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1646	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
NORTHWEST CONTROL	G-3025	--	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	--	--
	G-3026	--	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	--	--
WEST MIAMI PRIMARY	G-1605	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1606	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1607	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1608	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1609	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
WEST MIAMI SECONDARY	G-1647	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1648	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
HOMESTEAD LOW DENSITY PRIMARY	G-1615	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1616	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1617	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1618	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1619	--	.00	--	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
HOMESTEAD LOW DENSITY SECONDARY	G-1625	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1626	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1627	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1628	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1629	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
HOMESTEAD HIGH DENSITY PRIMARY	G-1620	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1622	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1623	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1624	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
HOMESTEAD HIGH DENSITY SECONDARY	G-1649	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
	G-1650	0	.00	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00

only chlorinated hydrocarbon present in a well sample for greater than 10 ft., G-1646, the 20-ft secondary well in Hialeah.

The herbicide 2,4-D is used extensively in south Florida for the control of hydrilla in canals. Two detections were made at 20 and 30 ft in Hialeah (G-1612 and G-1613).

Viruses

The University of Miami conducted a virus study concurrent with this investigation (Parsons, 1973) to identify viruses that could cause cytopathic effects in Wish Amnion cells, Vero and KB cells, Rhesus monkey kidney cells, and human embryonic kidney cells. No such viruses were found in water samples from any of the wells at the five sites. That study showed that septic-tank sludge particles act like a polyelectrolyte. When viruses were added to wet sludge none appeared in the supernatant fluid from the sludge: all the viruses attached themselves to the sludge and could be removed from it only by increasing the pH of the sludge to 8.0, a condition not normal in septic tanks. A maximum pH of 7.2 was measured in the septic-tank sludge of the Homestead low-density site in November 1972 after a heavy application of alkaline cleaners by a resident, and therefore represents a special situation.

The last phase of the University of Miami study was a seeding experiment in which a known quantity of attenuated poliovirus was injected into the septic tank at the Homestead low-density site. Samples collected from the outlet and from the observation wells on subsequent days showed that no viruses were present in the effluent.

GROUND-WATER CONTAMINATION

Contamination is the addition of substances which alter the original quality of a substance, in this case the ground water of Dade County. Wells in remote inland areas were used to evaluate the natural ground-water quality. In general, the ground water there is high in dissolved substances derived from the organically rich water in the conservation areas, and constituents dissolved from the aquifer materials. As the ground water flows slowly south and east, rainfall is infiltrating periodically into the subsurface. Each pattern of land-use results in the addition of specific constituents. The Homestead monitor wells strongly reflected the effects of the extensive agricultural activity to the north and west. The data at Hialeah reflect the heavy residential and industrial development which characterizes that part of Dade County. At North Dade, which is near major water control structures, the ground-water quality reflects the effects of local recharge with urban storm water. The ground water at West Miami most nearly reflects the natural water quality.

As contaminant-laden water infiltrates the ground-water system, numerous factors or processes affect the concentration distribution. The more important include dilution, chemical precipitation, filtration, adsorption, absorption, microbial assimilation and, in the case of bacteria, dieoff. The ground water is further enriched by dissolution of aquifer materials such as organic substances, sand, and limestone. The net effect of these processes as the water migrates is that contaminants are homogenized by advective dispersion and diffusion, thereby obscuring all but the most significant additions of contaminants. Only the shallow primary well in Hialeah (G-1610) showed consistent bacterial and phosphorus encirchment attributed to septic-tank effluent. These effects apparently were not transmitted downward but laterally. The shallow secondary well in this location was immediately adjacent to paved streets and apparently reflected the influence of infiltrating storm water more strongly than that of septic-tank effluent.

The major influence on overall ground-water quality is the nature of the aquifer. The southward increase in aquifer permeability allows the relatively rapid infiltration of rainfall which develops oxidizing conditions. The oxidation of organic materials and precipitation of oxide chemical components is evident. Although the ground water quality at north Dade shows the strongest influence of storm water leachates, the high proportion of sand retards water movement allowing reducing conditions to develop. As a consequence, sulfate is low, COD, iron, manganese and other reducing condition sensitive components are high.

SUMMARY

Three hundred twenty-four ground-water samples were collected from 42 wells ranging in depth from 10 to 60 ft to monitor the ground-water quality at five sites where residences are served by septic tanks. Physical, chemical, and bacteriological analyses indicate that septic tank effluents reach the ground-water system. The shallowest wells showed the most effect whereas the effect in the deeper wells in the deeper wells was nominal. The more common indicators of septic-tank effluent were present in the 10-ft monitor wells at Hialeah, and West Miami.

Water samples from base-line wells outside the urban areas indicate that the ground water is naturally high in organic nitrogen, ammonia, organic carbon and COD. Sodium enrichment of ground water may provide a key to differentiating septic-tank effluent from other urban ground-water contaminants. High ammonia nitrogen, phosphorus, and the repetitive detection of fecal coliform bacteria were characteristic of two 10-ft monitor wells (G-1610, G-1605) that sampled ground water contaminated by septic-tank effluent. Fecal coliform bacteria were present on one or two occasions in many of the monitor wells but the highest concentration (1,600 colonies/100 ml) was related to infiltration of storm water rather than to septic-tank effluent. The persistence of these indicator bacteria in ground water is apparently very low as indicated by the infrequent detection and low concentrations. Viruses were not found in the ground-water at any of the five sites.

Areal variations in the hydraulic conductivity of the sand and limestone aquifer had the most noticeable influence on the overall ground-water quality. In north Dade County, where the aquifer is less permeable and reducing conditions prevail, the ground water was highest in dissolved iron, manganese, COD, and organic carbon. The ground water in the more permeable limestone in south Dade County near Homestead was low in these components but higher in dissolved sulfate and nitrate.

Dispersion, dilution, and various chemical processes presumably obliterate any direct evidence of septic tank effluent at depths greater than 20 ft for all the 65 types of water analyses employed in the investigation. Contamination from agricultural activities in Homestead and from storm-water infiltrate at West Miami, Hialeah, and north Dade are more readily identifiable and pervasive than that from septic-tank effluents.

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