UNITED STATES DEPARTMENT OF THE INTERIOR

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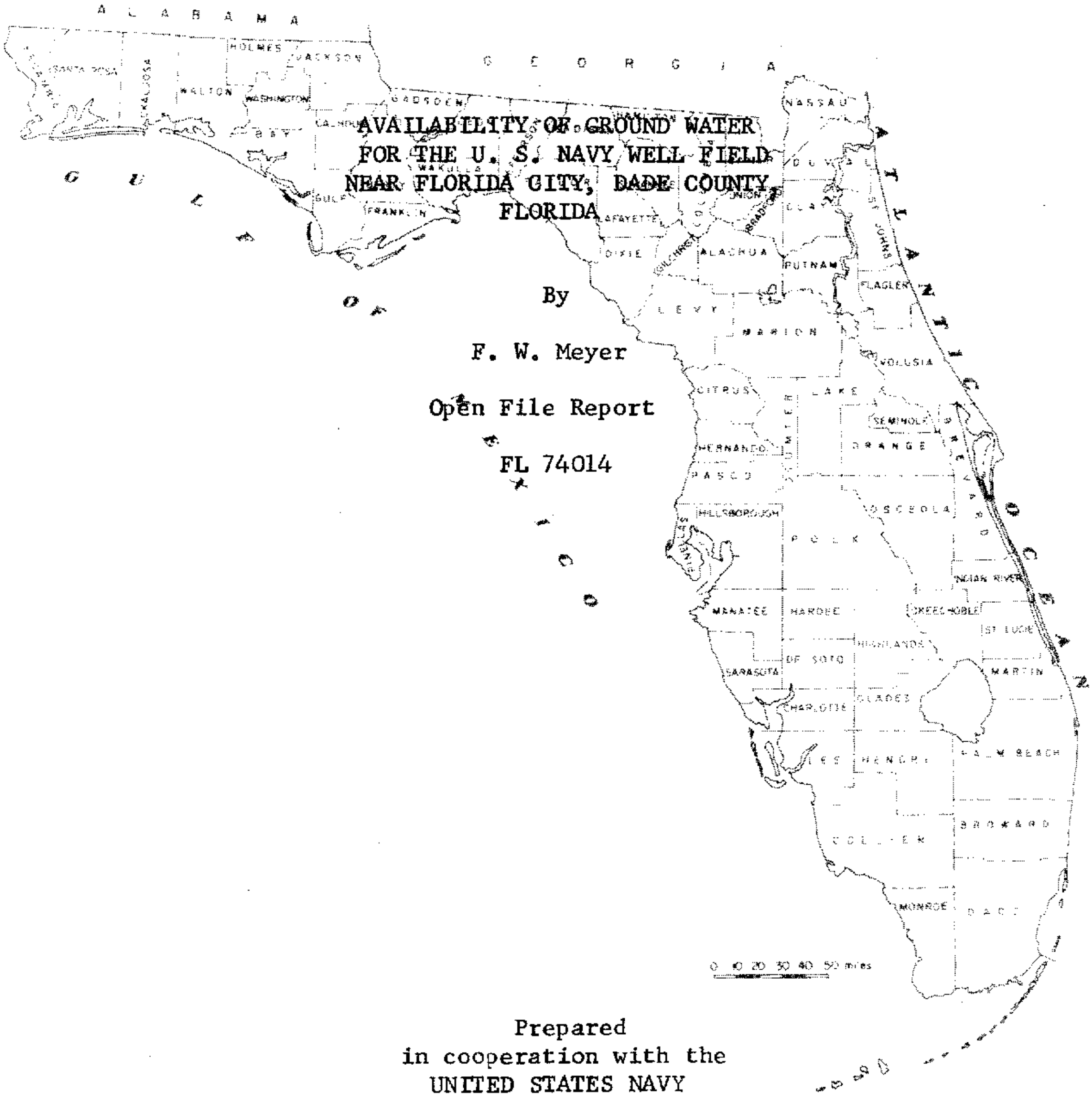

AVAILABILITY OF GROUND WATER FOR THE U. S. NAVY WELL FIELD NEAR FLORIDA CITY, DADE COUNTY, FLORIDA

By

F. W. Meyer

Open File Report

FL 74014

Prepared
in cooperation with the
UNITED STATES NAVY

Tallahassee, Florida
1974

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA
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SUMMARY

Studies described in this report indicate that enough ground water is available in southeastern Dade County so that the U.S. Navy facilities at Key West can increase its demand from 6 million gallons per day to 18 million gallons per day. It is planned that future water requirements in southeastern Dade County -- beyond the 18-million-gallon-per-day demand -- be met chiefly by recharge from a pump-equipped conveyance canal from Conservation Area 3, according to the U.S. Army, Corps of Engineers and the Central and Southern Florida Flood Control District.

INTRODUCTION

Water to supply the Department of Navy facilities at Key West and residents of the upper Florida Keys is piped from the U.S. Navy well field near Florida City in southeast Dade County (fig. 1). The demand for additional water for the rapidly developing upper Keys is becoming critical and the Navy and the Florida Keys Aqueduct Authority (FKAA) are jointly considering a plan to meet future water demands in the Keys by increasing pumpage from the Navy's wells from 6 mgd (million gallons per day) to 18 mgd and by constructing an additional pipeline from the treatment plant to the upper Keys.

The wells are far enough inland that they can yield 6 mgd without danger from sea-water intrusion. However, Navy and FKAA officials concur that there is a possibility that increased withdrawals from the Navy wells and from other wells in the vicinity of Florida City could cause sea water to move inland and contaminate the wells. Also, they concur that an assessment of the available ground-water supply is needed because of this possibility. With this in mind, the U.S. Navy entered into a cooperative agreement with the U.S. Geological Survey to determine the adequacy of the ground-water supply in the vicinity of Florida City and the effects that the proposed increase in withdrawal might have on the supply, particularly, from the standpoint of sea-water intrusion.

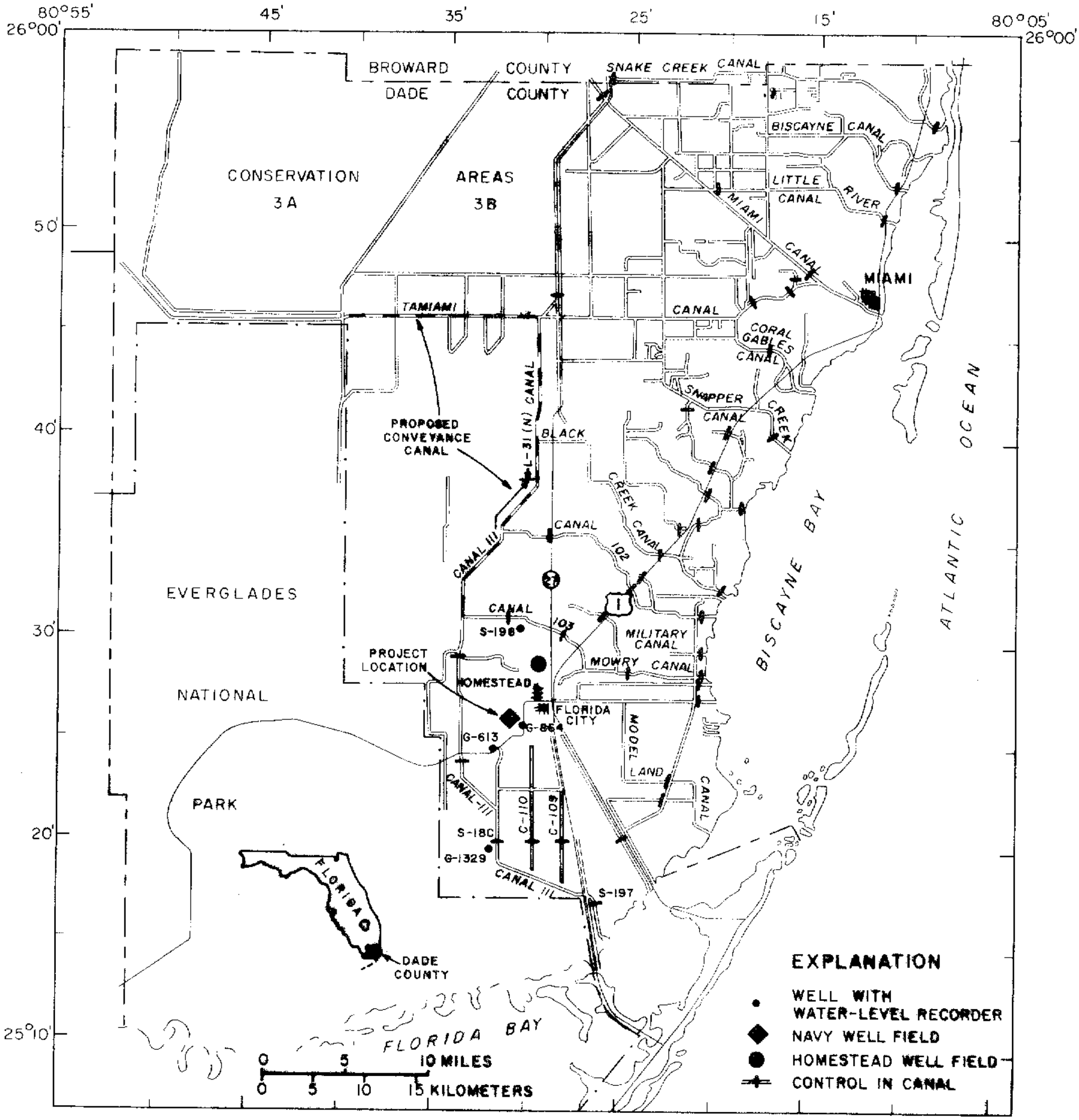

Figure 1.--Dade County showing locations of Navy well field, principal drainage, and selected observation wells.

Purpose and Scope

The purpose of this report is to indicate the effects that a 12 mgd increase in Navy well-field pumpage will have on local water levels and on the zone of sea-water intrusion in southeast Dade County. Long-term data on water levels, water use, and chloride concentrations were used to determine historic and present-day pumping effects. An electrical analog model (Appel, 1973) of the Biscayne aquifer, constructed in cooperation with the Central and Southern Florida Flood Control District (C&SFFCD), was used to predict the effects that the increased well-field pumpage would have on water levels.

Most of the data for the study, which began in July 1972 and ended in December 1972, were obtained as a part of a long-term, continuing monitoring program between the Geological Survey and the Navy. Supplemental data were obtained from long-term, continuing cooperative programs with the C&SFFCD, Everglades National Park, the U.S. Army, Corps of Engineers, and the Dade County Department of Public Works.

Drawdown and recovery data were collected at one of the Navy wells in November 1972 to determine the hydraulic characteristics of the aquifer. Valuable historic data were obtained from unpublished reports by W.P. Cross, S.K. Love, and G.G. Parker of the U.S. Geological Survey in 1941, and by W.J. Krome of the Florida East Coast Railroad in 1922. Other reports containing pertinent information are listed in the reference section.

Acknowledgments

Thanks are extended to the following people who supplied data and technical assistance during the investigation: Fred Frohock, Navy Aqueduct, Key West, Florida; Eugene Atkinson, Navy Aqueduct, Florida City, Florida; W. V. Storch, Central and Southern Florida Flood Control District, West Palm Beach, Florida; and R. J. Franz Naval Facilities Engineering Command, Charleston, South Carolina.

NAVY WELL FIELD

The Navy well field and water plant facilities near Florida City, shown on figures 1 and 2, were constructed in 1941-42 to supply water to military and civilian populations in the Florida Keys. Since then water has been pumped 130 miles through an 18-inch steel pipeline (the Navy aqueduct) from Florida City to Key West. Water is obtained from seven supply wells (table 1 and fig. 2) that range in depth from 48 to 62 feet. All wells were completed in the highly permeable limestone of the Biscayne aquifer (Schroeder and others, 1958).

Over the past 30 years the pumping capacity of the water-supply system has been periodically increased chiefly to meet the demands of the relatively slow-growing civilian population in the Keys. Pumpage increased steadily from 1.4 mgd in 1943 to 6.1 mgd in 1966 (fig. 3). In 1967 the demand declined when the FKAA desalting plant at Key West became operational. Use of desalted water at Key West resulted in a reduction in pumpage during 1967 and 1968, but developments in the upper Keys between 1968 and 1971 caused the demand to rise again, and in 1971 pumpage was 5.7 mgd. It soon became apparent to Navy and FKAA officials that the capacity of the aqueduct and supply wells was being approached and that an additional water supply and larger aqueduct would be needed shortly to prevent a water shortage. In 1972 the Navy and the FKAA began to explore the feasibility of providing the additional water by installing more wells at the water plant near Florida City, and by constructing an additional pipeline to the upper Keys.

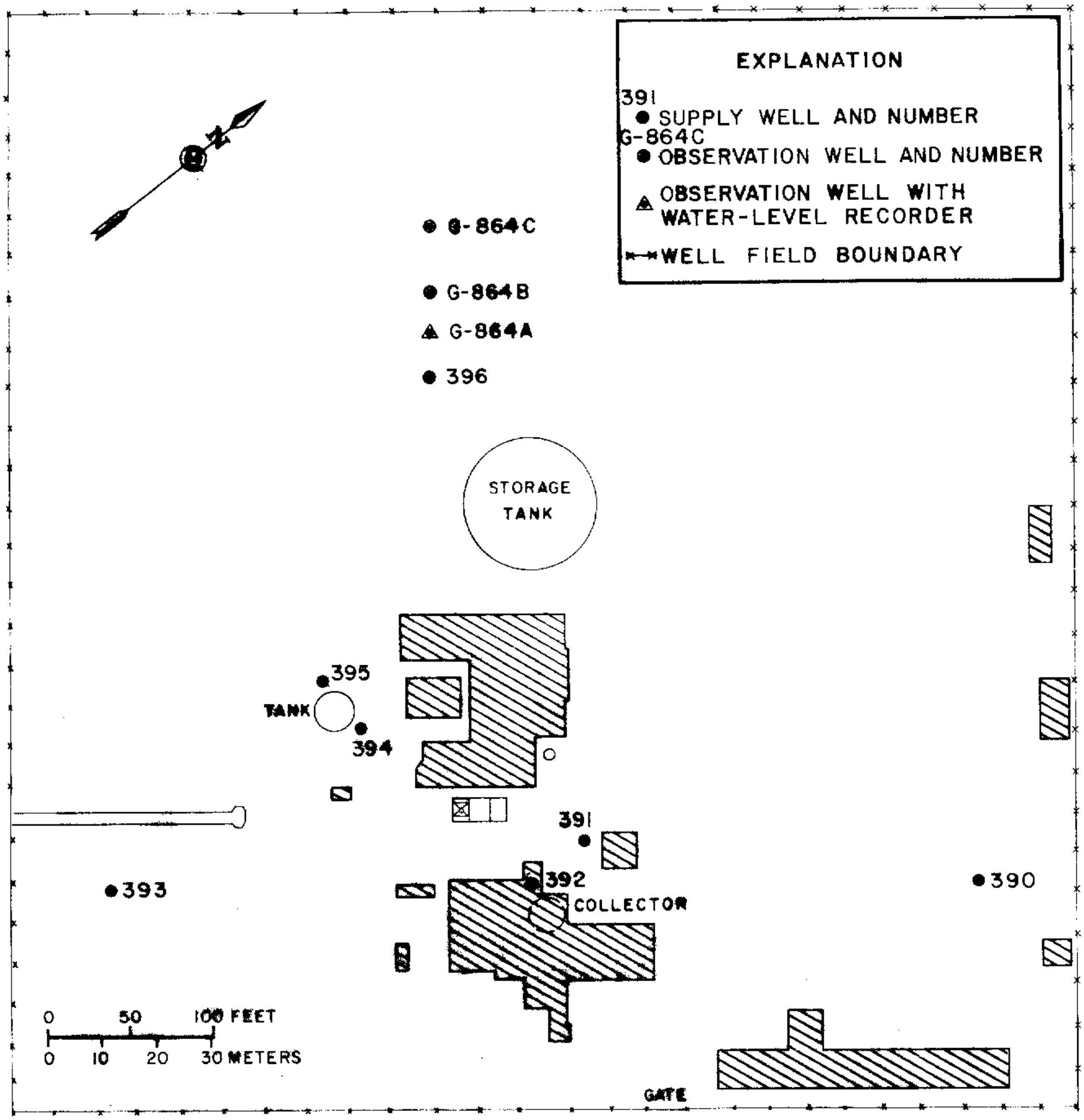

Figure 2.--The Navy well field showing location of supply wells and selected observation wells.

Table 1.--Records of Navy supply wells.

Well No.	Year Drilled	Diameter of casing (inches)	Well depth (feet)
390	1942	10	48
391	1942	10	62
392	1942	10	62
393	1946	18	55
394	1952	20	52
395	1956	16	60
396	1958	16	60

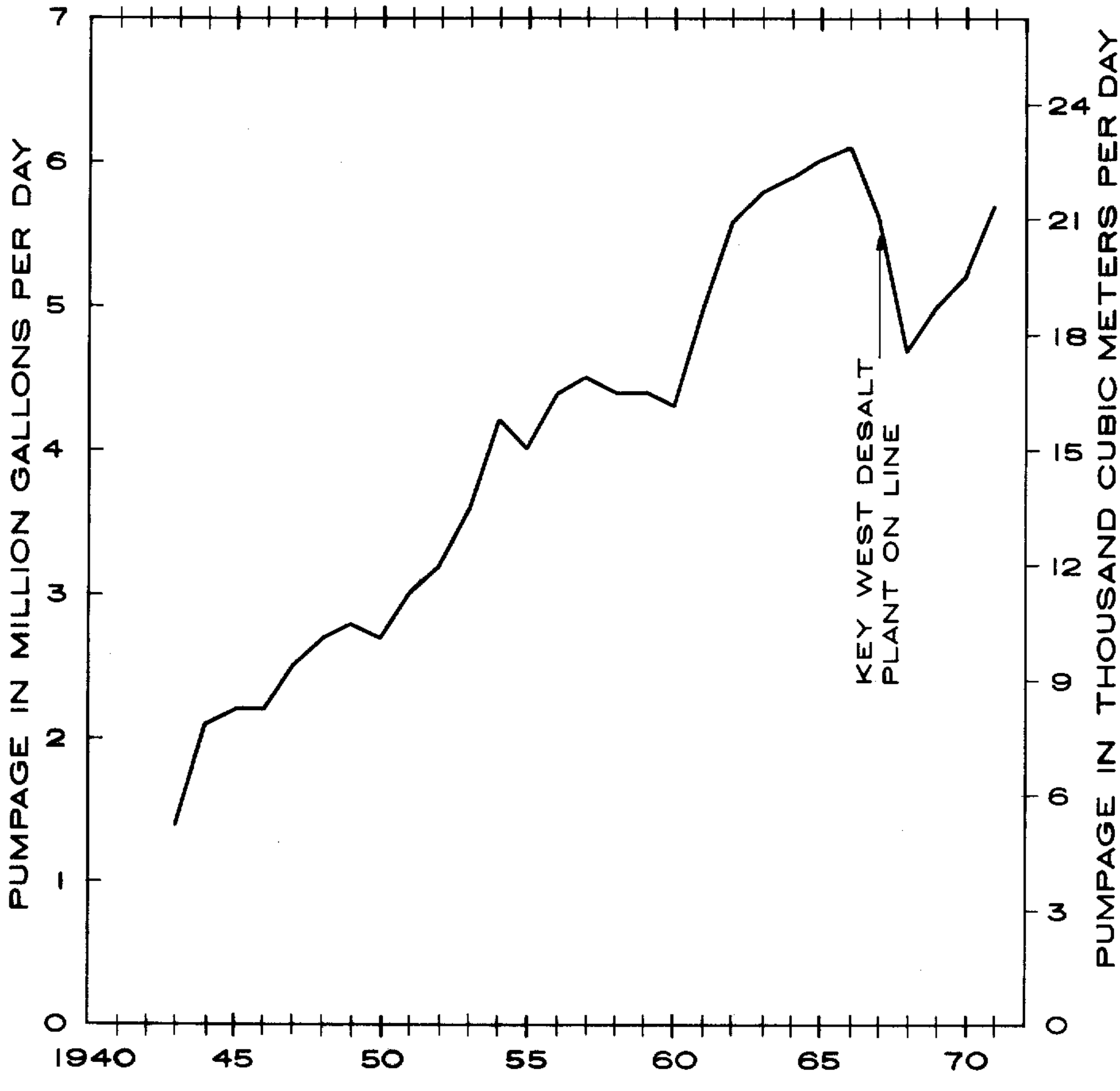

Figure 3.--Pumpage from Navy well field, 1943-71.

Population and water-use projections (Meyer, 1971 p. 30-54) indicate that additional water would be required by 1975 to supply the demand in the upper Keys. The projections suggested that pumpage from the Navy wells will average about 12 mgd by the year 2020 and that the pipelines should be designed to deliver 18 mgd, assuming that the maximum day demand will be about 150 percent of the yearly average. The effects of the increased pumpage will be evaluated in the following sections.

SOURCE OF WATER SUPPLY

Biscayne Aquifer

The Biscayne aquifer is the chief source of fresh water for municipal, domestic, industrial, and agricultural supplies in southeast Dade County. The Biscayne aquifer (Parker and others, 1955, p. 160-162; and Schroeder and others, 1958), a section of highly permeable limestone, underlies most of Dade and Broward Counties (fig. 4). The aquifer increases in thickness toward the Atlantic Ocean, and it is about 75 feet thick at the Navy well field. The aquifer is recharged by local rainfall and at times by seepage from canals; aquifer storage is depleted by evapotranspiration, seepage to drainage canals, seepage to the ocean, and by consumptive use; that is, water that is withdrawn for use and is no longer available for reuse.

In southeast Dade County, the aquifer is replenished chiefly by local rainfall; aquifer storage is depleted chiefly by evapotranspiration and to a minor extent by drainage, by seepage to Florida and Biscayne Bays, and by consumptive use.

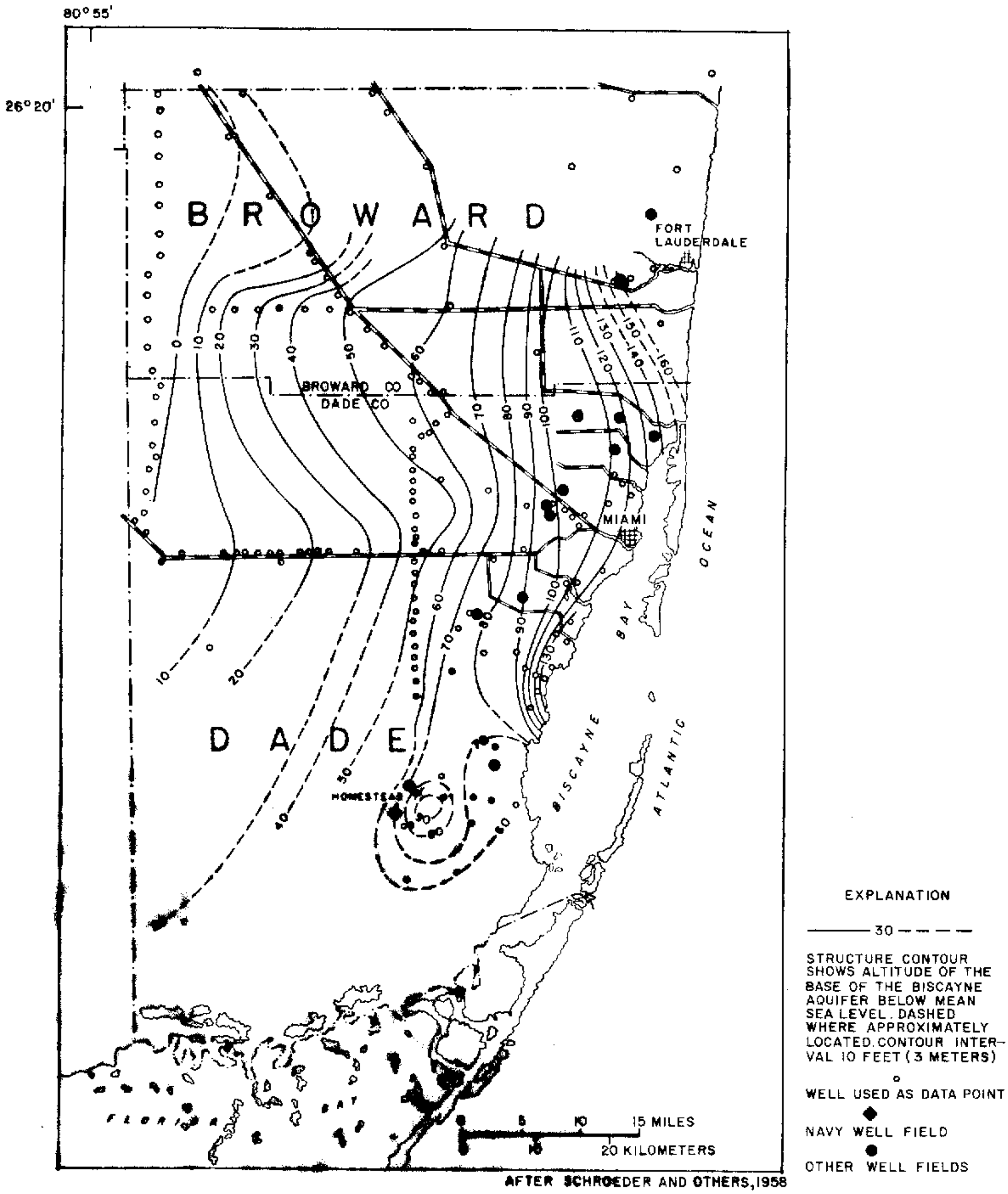

Figure 4.--Configuration of the base of the Biscayne Aquifer in Dade and Broward Counties.

Water Levels

Until the mid 1960's, south Dade County was drained by only a few small canals in the agricultural area east of Homestead, and seasonal torrential rains accompanying hurricanes caused flooding in the relatively low-lying, flat, coastal region.

In the mid 1960's drainage was improved by completion of several primary canals of the C&SFFCD (Canals 111, 102, and 103 on fig. 1). Each canal was gated at strategic points to prevent sea-water intrusion and to regulate water levels in the interior. The effectiveness of the improved drainage is indicated by the reduction in peak water levels since the mid 1960's. For example, the peaks for 1968 and 1969 in well S-196 about 2 miles north of Homestead, as shown on figure 5, were between 1 and 3 feet lower than the peaks for 1947 and 1960 although rainfall for those years was about the same.

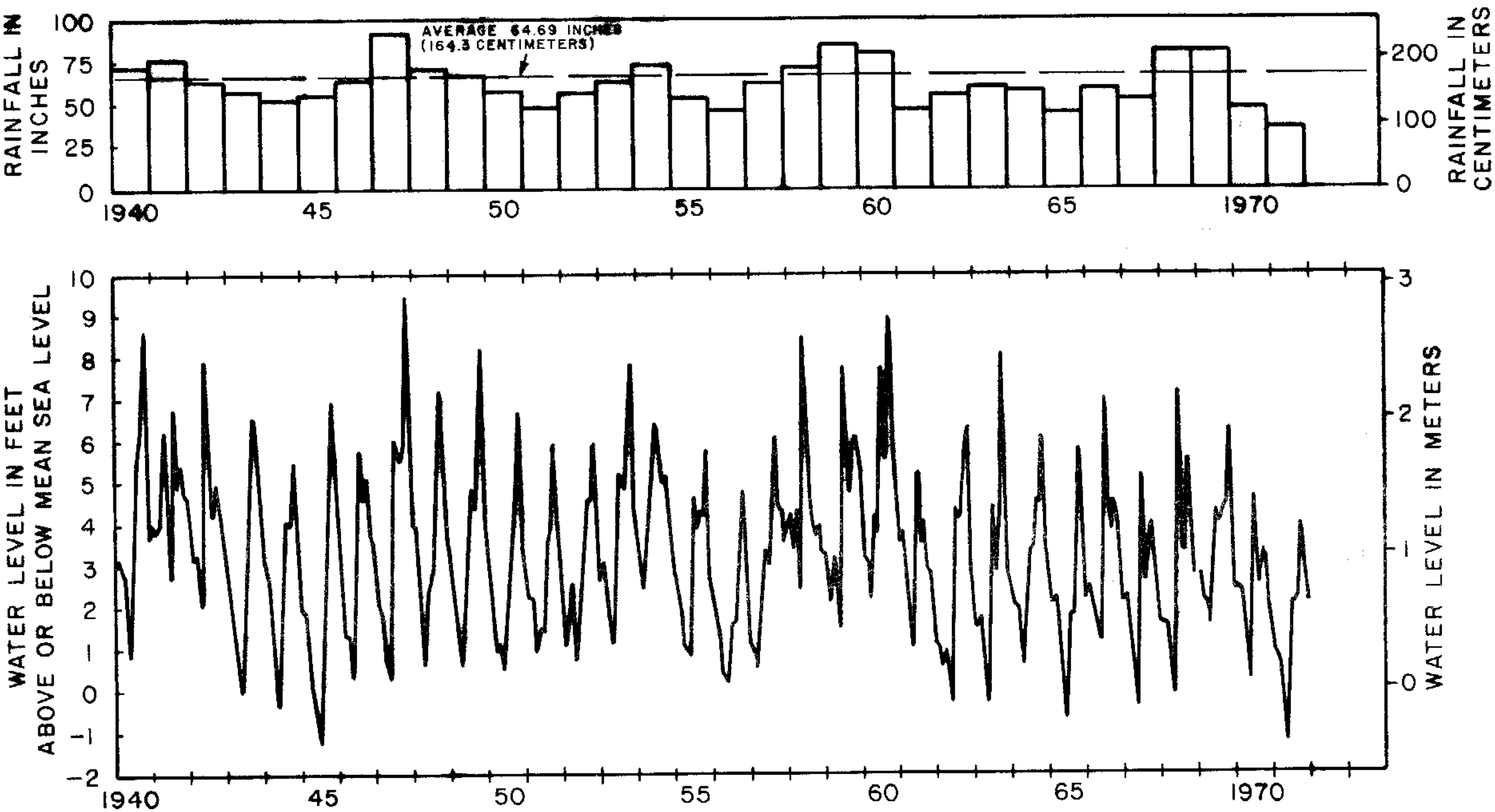

Figure 5.--Well S-196 and rainfall at Homestead experiment station, 1940-71.

Drainage improvements during the 1960's have, however, caused a slight lowering of annual low water levels in the Homestead area because of increased seepage losses to downgradient areas. The hydrograph of well S-196 shows for the 6 years since 1961, that yearly low levels were generally below those for 1947-66. Severe droughts since 1961, however, have not caused excessive declines in water levels. For example, water levels in well S-196 were lowered about equally during the 1945 and 1971 droughts, which suggests that the rates of evapotranspiration and seepage to downgradient areas diminished when water levels declined several feet below land surface, and that ground water inflow to the area, although probably small, then was about equal to losses by evapotranspiration, and ground-water outflow.

Water levels at the Navy well field averaged about 2.5 feet above msl (mean sea level) during 1960-71 (fig. 6), a level that, according to the Ghyben-Herzberg principle, is sufficient to prevent intrusion of sea water. The average yearly lowest water level at the Navy well field during 1960-71 was slightly below mean sea level (fig. 7), and the average yearly highest was just above 5 feet above msl (fig. 8).

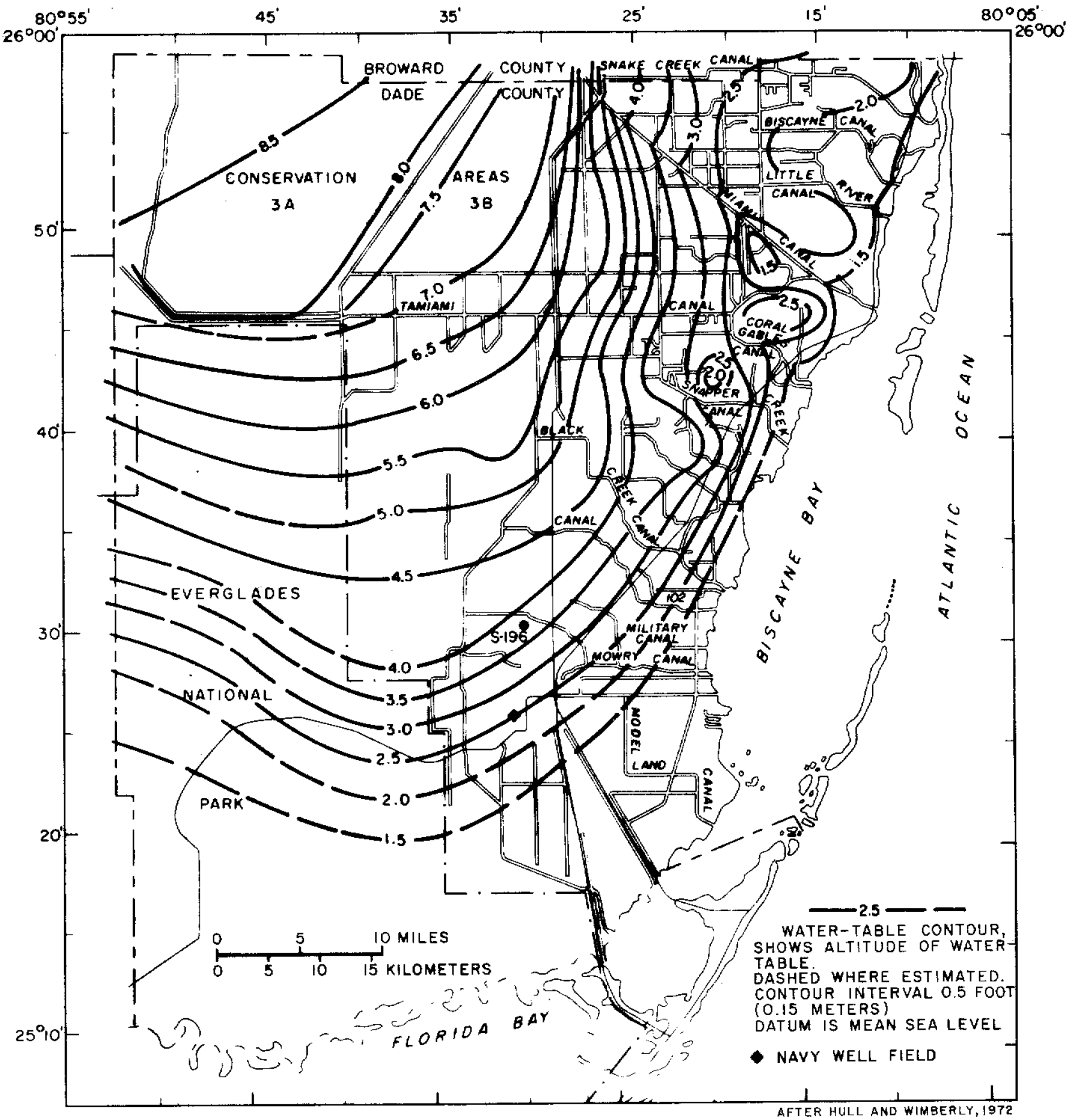

Figure 6.--Configuration of the average water table, 1960-71.

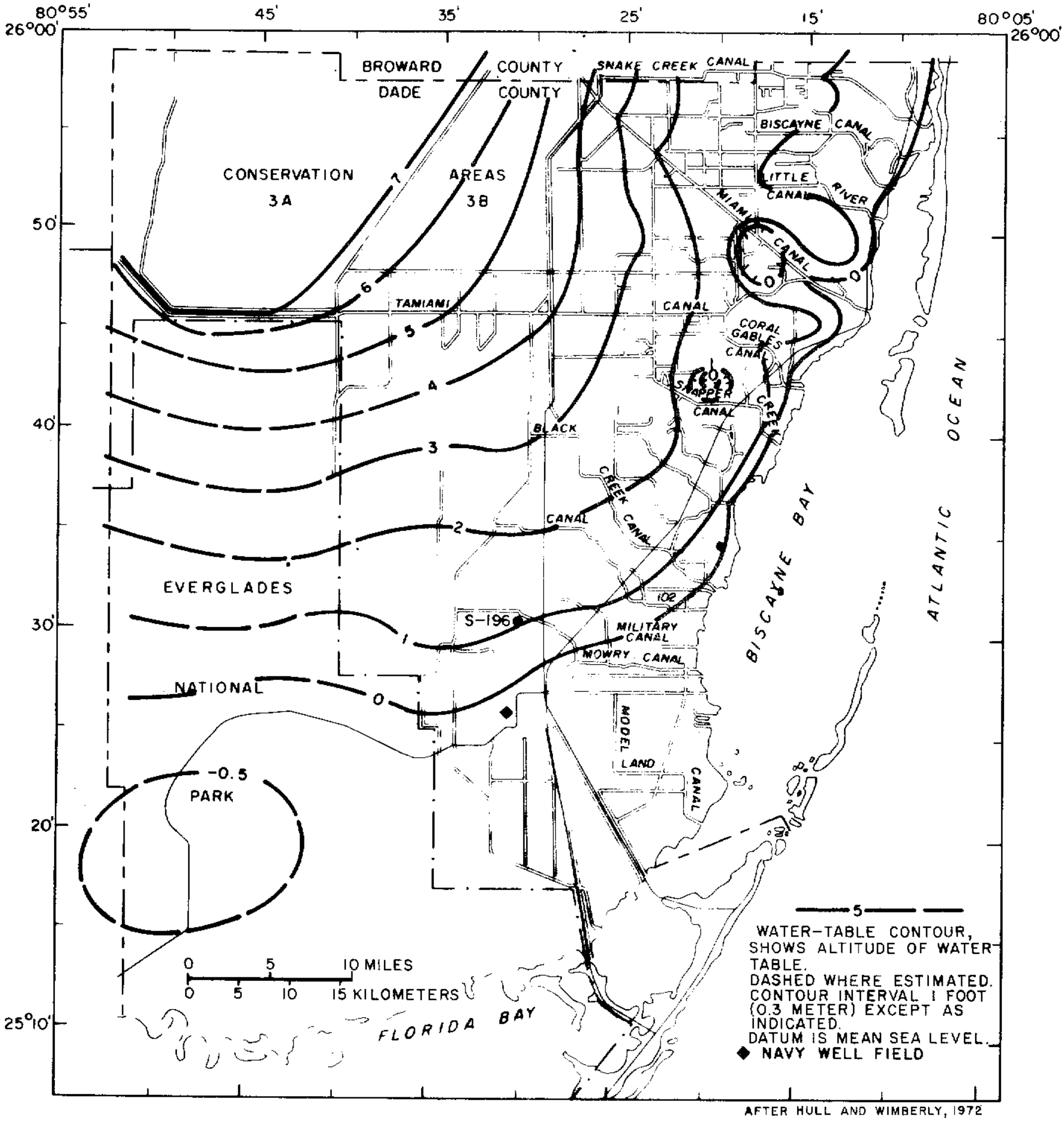

Figure 7.--Average yearly lowest ground-water levels, 1960-71.

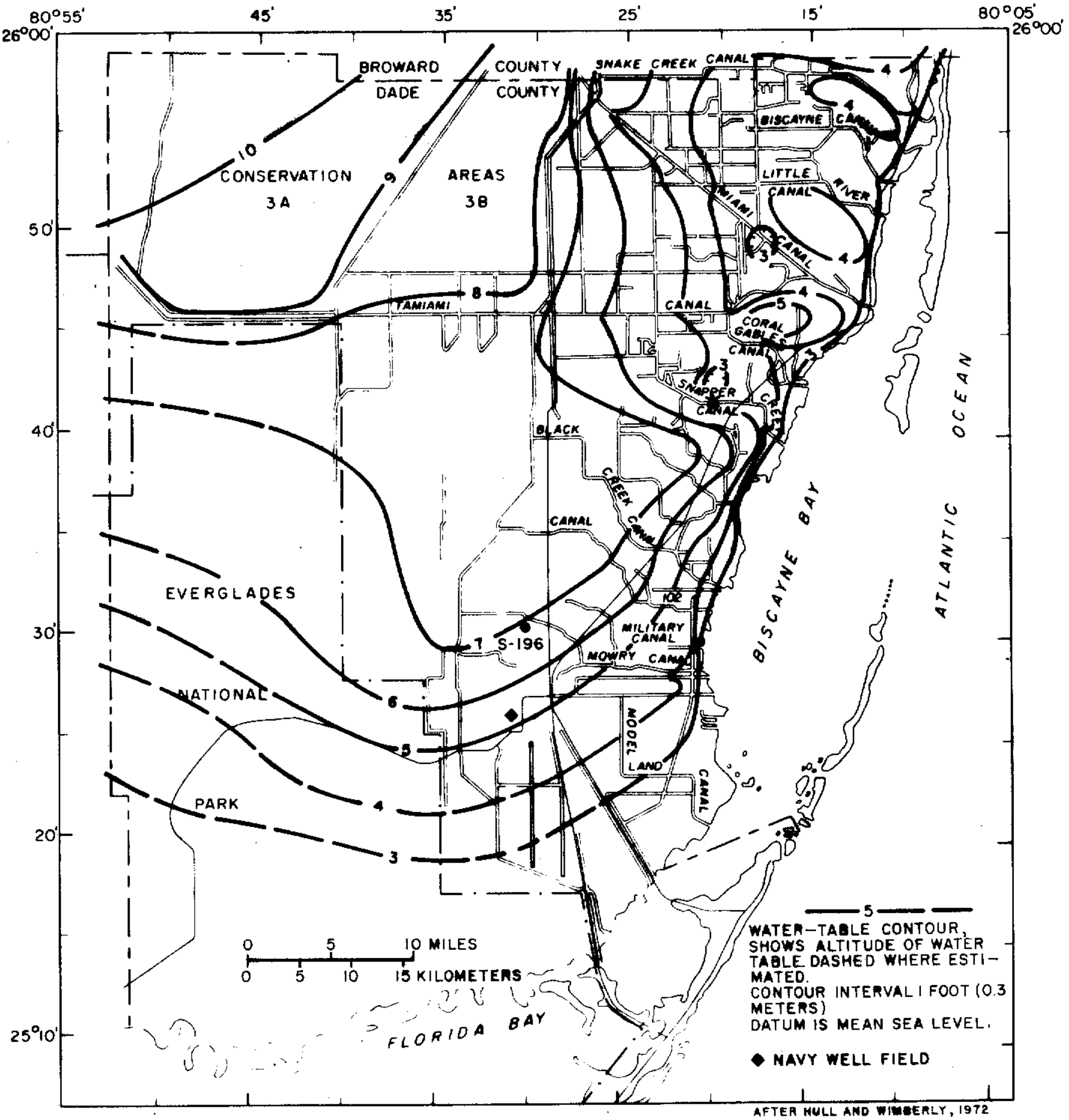

Figure 8.--Average yearly highest ground-water levels, 1960-71.

During the 1971 drought, water levels in a 160-square mile area southwest of the Navy well field declined to about 1.5 feet below msl (fig. 9); and in the southern half of Dade County, water levels generally declined below sea level. The water-level depression was caused chiefly by evapotranspiration. The total evapotranspiration from the area of the water-level depression includes the depletion of ground water in storage and ground-water inflow from upgradient areas. Estimates of evapotranspiration have been reported by Klein (1965, p. 11) and by Hull and Meyer (1973, p. 21-23, 30-31). At the Navy well field, ground water was flowing generally southward toward the water-level depression. Plans to raise water levels in south Dade County during the annual dry season will be discussed in the following sections.

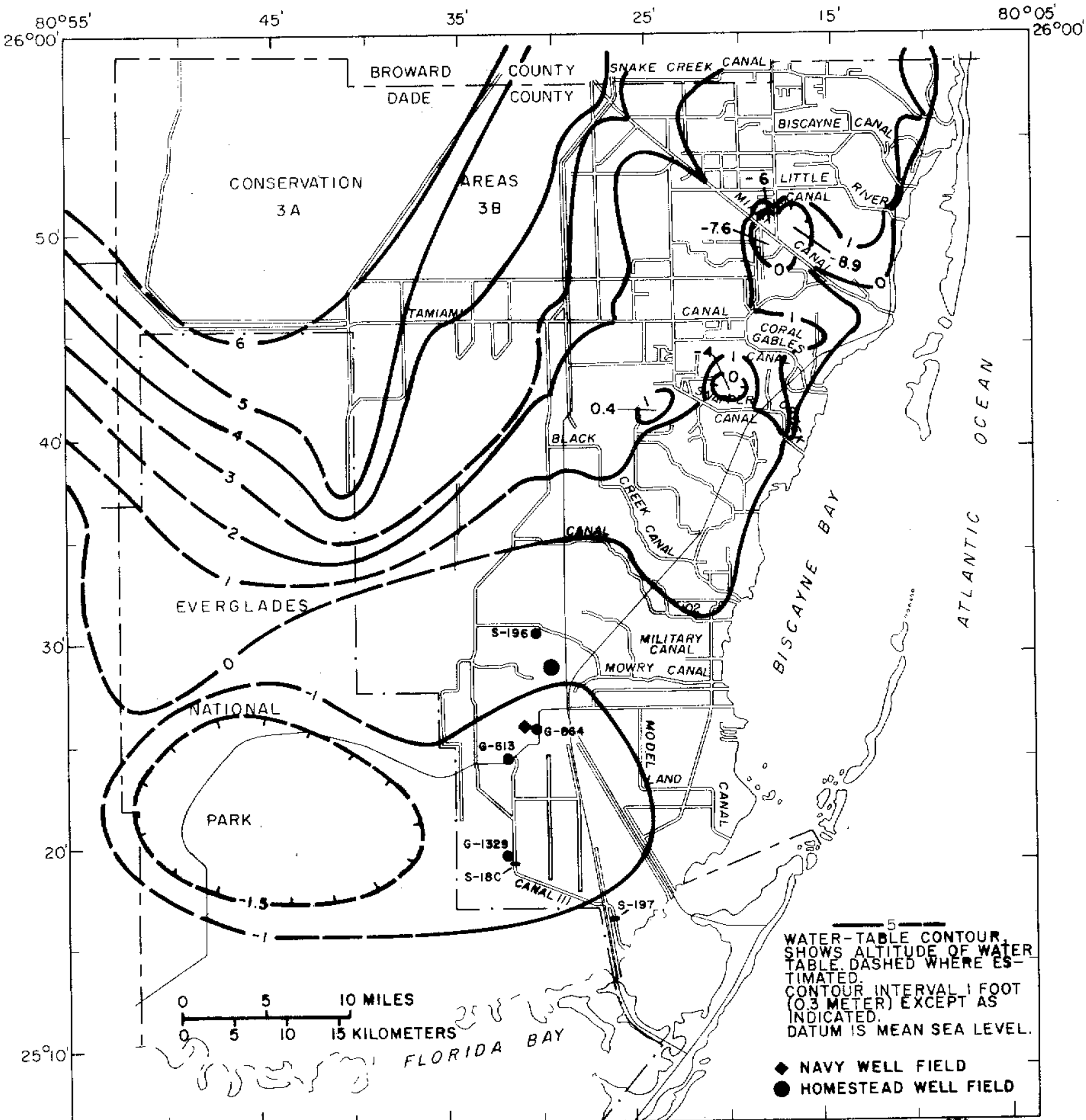

Figure 9.--Ground-water levels during May 3-5, 1971.

Sea-Water Intrusion

Sea-water intrusion has historically been the main threat to water supplies in Dade County. The chief causes of intrusion are uncontrolled canals and low water levels. Occasional inundation by hurricane-driven tides also caused intrusion in low-lying unprotected areas such as south Dade County. The intrusion of sea water into the Biscayne aquifer has been described in detail by Parker and others (1955, p. 571-712). Pertinent information on sea-water intrusion in the Homestead area in 1941 was collected by W. P. Cross, S. K. Love, and G. G. Parker, of the U.S. Geological Survey for the Navy.

The maximum inland extent of sea-water intrusion in Dade County for 1946, 1970, and 1971 is shown on figure 10. The area of intrusion has been mapped on the basis of the position of the 1,000-mg/l (milligrams per liter) line of equal chloride concentration at the base of the Biscayne Aquifer. Chloride concentrations are highest at the base of the aquifer nearest the coast where the concentration is about equivalent to that in sea water (19,300 mg/l chloride). The intruded zone is wide in southeast Dade County because water levels there are often below sea level at a considerable distance inland from the coast.

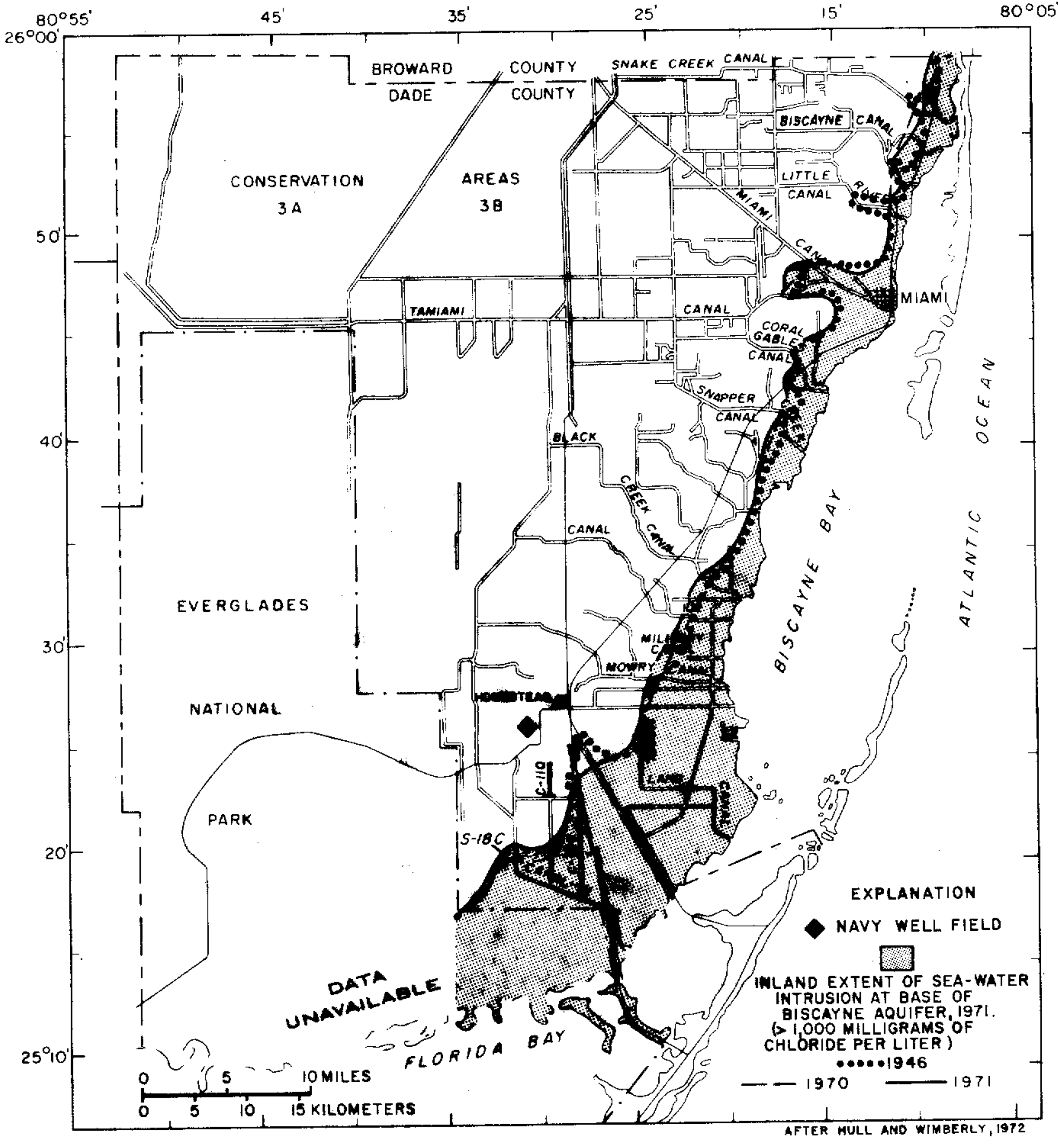

Figure 10.--Inland extent of sea-water intrusion for 1946, 1970 and 1971.

In extreme south Dade County the zone of sea-water intrusion is about 8 miles wide (fig. 10). A comparison of the positions of the 1,000-mg/l lines for 1946, 1970, and 1971, indicates that no major advances have occurred since 1946, despite the lowering of peak water levels after the mid 1960's by improved drainage. The 1,000-mg/l line was about 4 miles southeast of the Navy well field during 1970-71.

A short-term intrusion problem occurred in 1965 when construction of Canal 111 and associated control structure S-18C were completed. According to theCorps of Engineers, the canal was planned to provide flood control, drainage, and navigation benefits for a large part of south Dade County. Structure S-18C, designated as the coastal salinity control, was constructed in 1964, and the canal was excavated in 1965 incrementally northward and southward from S-18C. Prior to construction of the reach from S-18C to the bay the chloride concentration in ground water was about 20 mg/1 at a depth equivalent to that of the bottom of the canal. As the canal was excavated southward then eastward from S-18C in early 1965, the canal intersected the part of the aquifer that was intruded by sea water. At the same time, inland water levels were low owing to normal seasonal rainfall deficiency, and the salty water moved inland from the zone of intrusion through the newly excavated canal to S-18C. In May 1965 the chloride concentration in canal water immediately upstream from S-18C peaked at 2,400 mg/1 (fig. 11). Rains during June through August caused the canal to freshen, but in September 1965 the chloride concentration peaked at 13,370 mg/1 as a result of tidal inundation during Hurricane Betsy. Upstream from S-18C about 2 miles a concurrent sample of canal water contained a chloride concentration of 10,000 mg/1. Subsequent rains flushed the salty water downstream and the chloride concentration upstream from S-18C was 50 mg/1 in early 1966.

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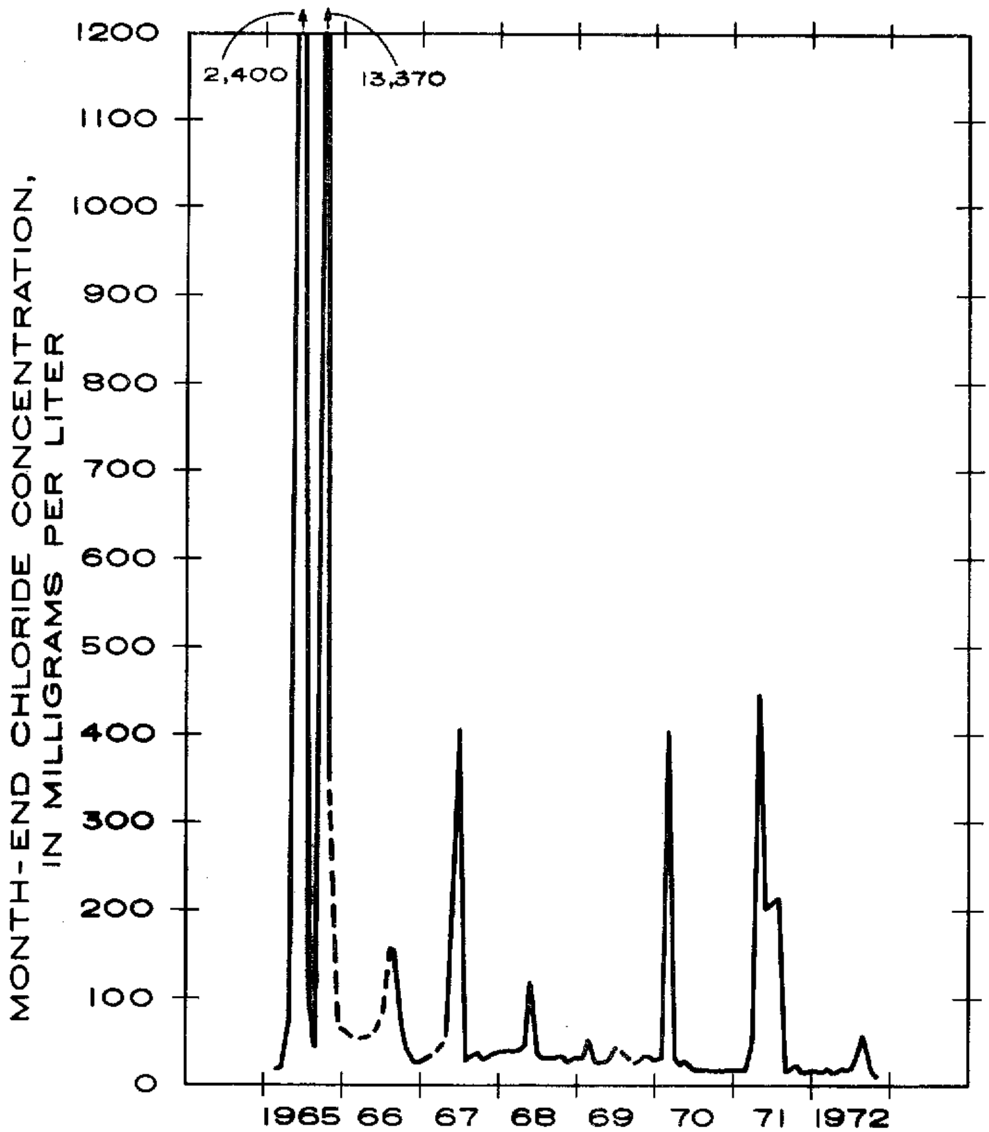

Figure 11.--Chloride concentration in water from Canal 111 upstream from S-18C, 1965-72.

As a result of the short-term intrusions and predictions by Klein (1965) and Barnes and others (1968) that serious sea-water intrusion would result from the uncontrolled reach below S-18C, a plug of earth was left in the canal at the intersection with U.S. Highway 1 and excavation of the canal continued downstream from the plug to the bay. The plug was left in the canal to prevent salt water movement upstream to S-18C and to divert fresh water southward through lowlying glades to Everglades National Park by bank overflow. Despite the plug, the salt water moved upstream during dry periods as shown by the chloride peak for 1967 on figure 11. In February 1969 the limestone plug was removed and control structure S-197, a temporary earthen dam equipped with control gates, was installed a few hundred feet downstream from U. S. Highway 1 (fig. 1). Details of the hydrologic effects of Canal 111 during 1967-69 are contained in a series of 15 open-file data reports by Meyer and Hull (1973), copies of which are available from the District office, Tallahassee, Florida, upon request.

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Sea water migrated upstream to S-18C during dry periods of 1970 and 1971, as shown by peak chloride concentrations for those years on figure 11, thereby indicating that control S-197 was not completely effective in keeping salt water out of the reach below S-18C. However, without S-197 sea water would have moved inland several miles upstream from S-18C during the same dry periods. It can be concluded that seepage at controls in south Dade County is high, but that controls such as S-197 are needed to retard the inland movement of sea water during dry periods even though earthen dams are less than completely effective.

In 1970, the U.S. Army Corps of Engineers began to excavate tributary Canals C-109 and C-110 northward from Canal 111 (fig. 1). Plugs were left in the canals near the intersection with Canal 111. When, in 1970-71, samplings indicated that salt water migrated 2-3 miles, upstream in these canals, excavation was halted. As a result, the Corps of Engineers reappraised the need for draining low-lying areas south and east of Homestead and construction of canals C-109 and C-110 and other proposed canals was halted. As of 1973, the Corps of Engineers does not plan to remove the plugs. Long-term effects of existing canal construction on the zone of intrusion can be determined by recurrent sampling.

ADEQUACY OF EXISTING SUPPLY

The adequacy of a water supply can be evaluated on the basis of the effects that changes in pumping rates have on nearby water levels and on the quality of the water. The rate and amount of water-level changes depends upon the rate and duration of pumping, the hydraulic characteristics of the aquifer (transmissivity and storage coefficient), and the proximity of hydraulic boundaries. For a given pumping rate, water levels are usually lowered the least where the hydraulic characteristics of the aquifer are high, and recharge is readily available. Conversely, water levels are lowered the most where the hydraulic characteristics of the aquifer are low and recharge is not available. Lowering water levels to or below sea level in aquifers that are connected with the ocean often results in sea-water intrusion. Therefore, pumping of wells in coastal aquifers should not be increased to the rate where the pumped ground water contains significant amounts of salt water.

Pumping Effects

In 1922, an aquifer test was conducted for the Florida East Coast Railroad at Florida City by W.J. Krome (written commun., 1922 to Mr. J.P. Beckwith); and the results indicated that pumping a well at a rate of 3.7 mgd continuously for 5 days produced no measurable drawdown in a well one-half mile away. Krome also reported that increasing the pumping rate to 5 mgd had no noticeable effect on the drawdown in the pumped well.

Studies of the hydrology of the Dade County area by W.P. Cross, S.K. Love and G.G. Parker in 1941 (unpublished data for the Navy Department) indicate that the Biscayne aquifer is more permeable in Homestead than in Miami. They observed that a withdrawal of about 1 mgd from the Homestead well field had no measureable effect on nearby water levels, and that the quality of the water there had not varied in 18 years.

Records of water levels in the vicinity of the Navy well field since 1959 suggest that the aquifer is highly permeable there because water levels in nearby observation wells are not noticeably affected by the well-field pumping. For example, a comparison of the hydrographs for wells G-864A (fig. 12) and G-864 (fig. 13) shows that the water levels in the two wells were nearly identical during the 1972 water year although well G-864A is only 20 feet from Navy supply well (396) and well G-864 is about 2,500 feet from it. (See locations on figures 2 and 1 respectively).

A comparison of the long-term hydrographs of well G-864 (fig. 14) with well G-613 (fig. 15) which is 2 miles southeast of the well field and affected chiefly by rainfall and evapotranspiration, shows that the seasonal patterns were generally the same although well G-864 is near the Navy well field. An inspection of the records for wells G-613 and G-864 showed that the water levels declined chiefly in response to daily evapotranspiration.

Studies by Hull and Meyer (1973) and by Klein (1965) show that evapotranspiration is high in the lowlying marshes along the southern coastline of Dade County. Measurements of evapotranspiration in southern Florida for varying water-table depths, and varying amounts of crop cover were found to be significant according to Stewart and Mills (1967).

The apparent lack of drawdown (pumping effects) in wells G-864 and G-864A indicates that present (1973) pumping has not produced a significant decline in local water levels. Therefore, it could be concluded that the 1973 rate of ground-water withdrawal by the Navy wells is insignificant compared to the amount of ground water lost to the atmosphere by evapotranspiration in downgradient areas.

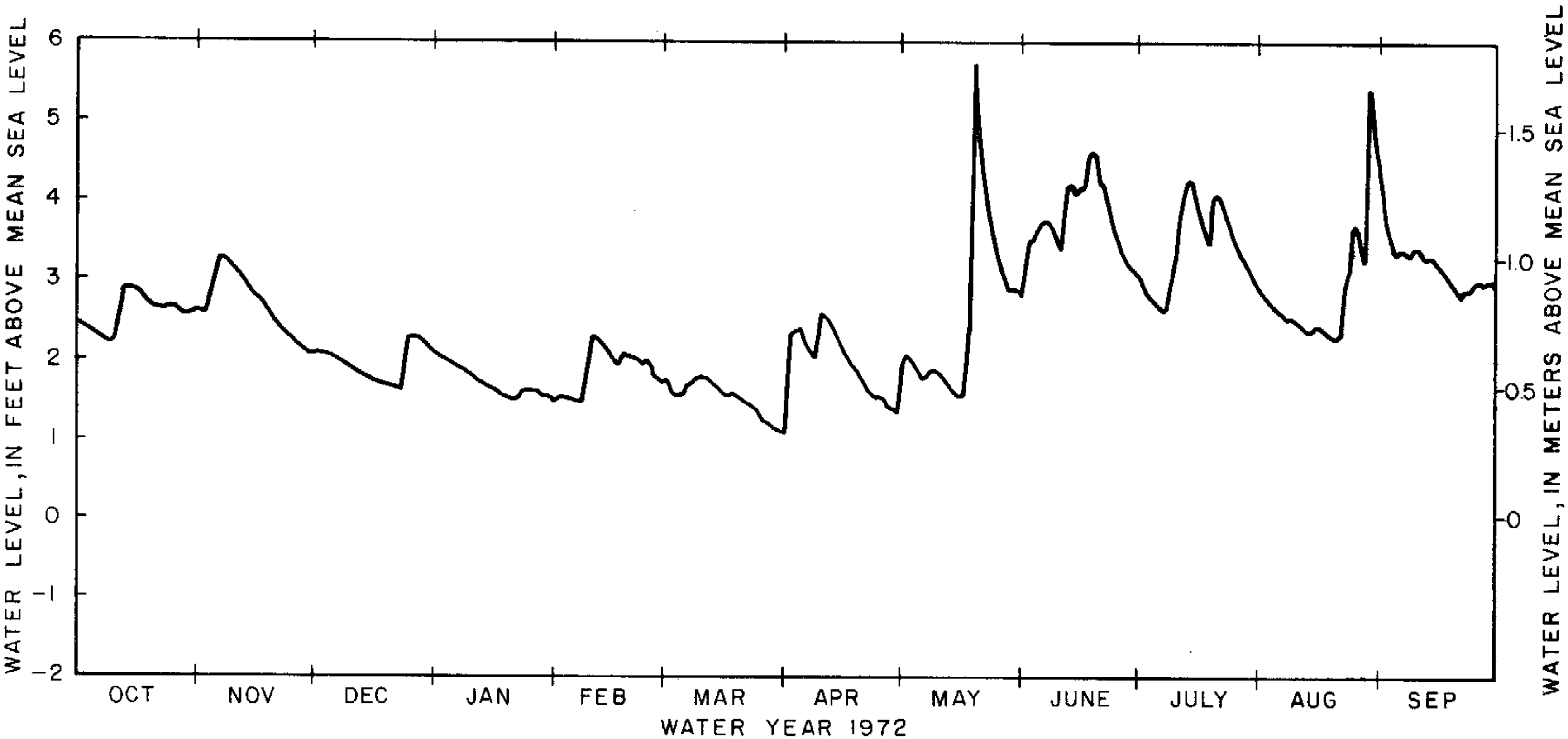

Figure 12.--Well G-864A, October 1971 - September 1972.

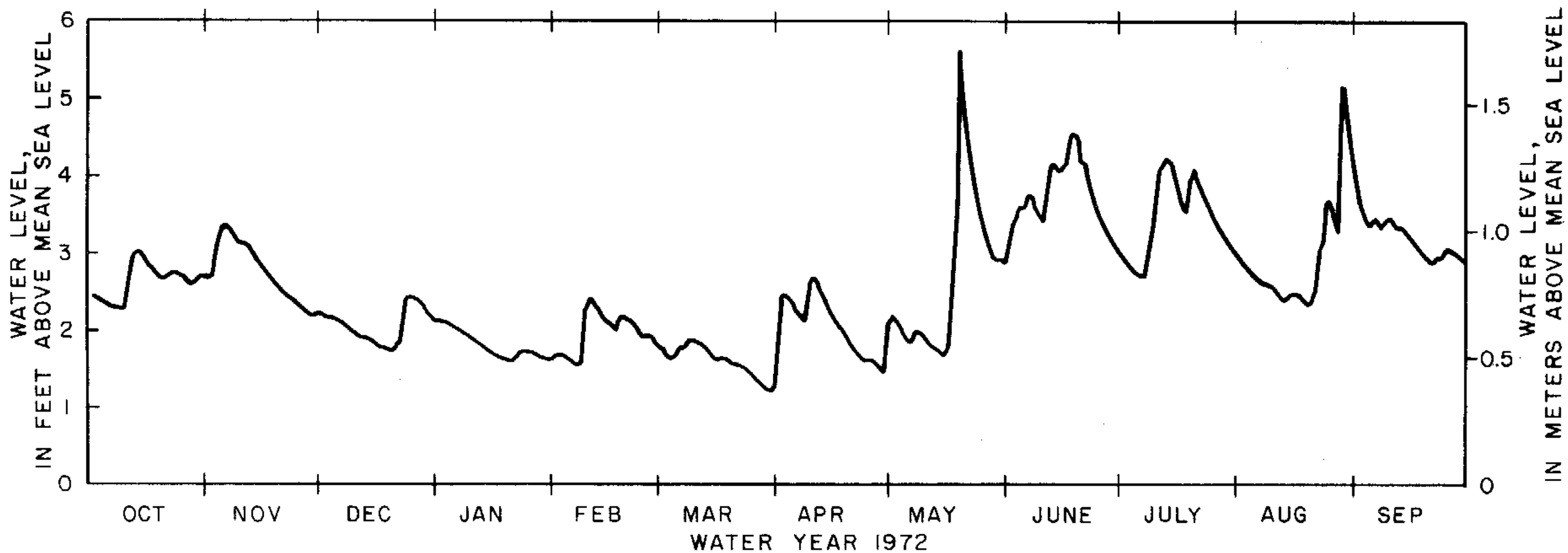

Figure 13.--Well G-864, October 1971 - September 1972.

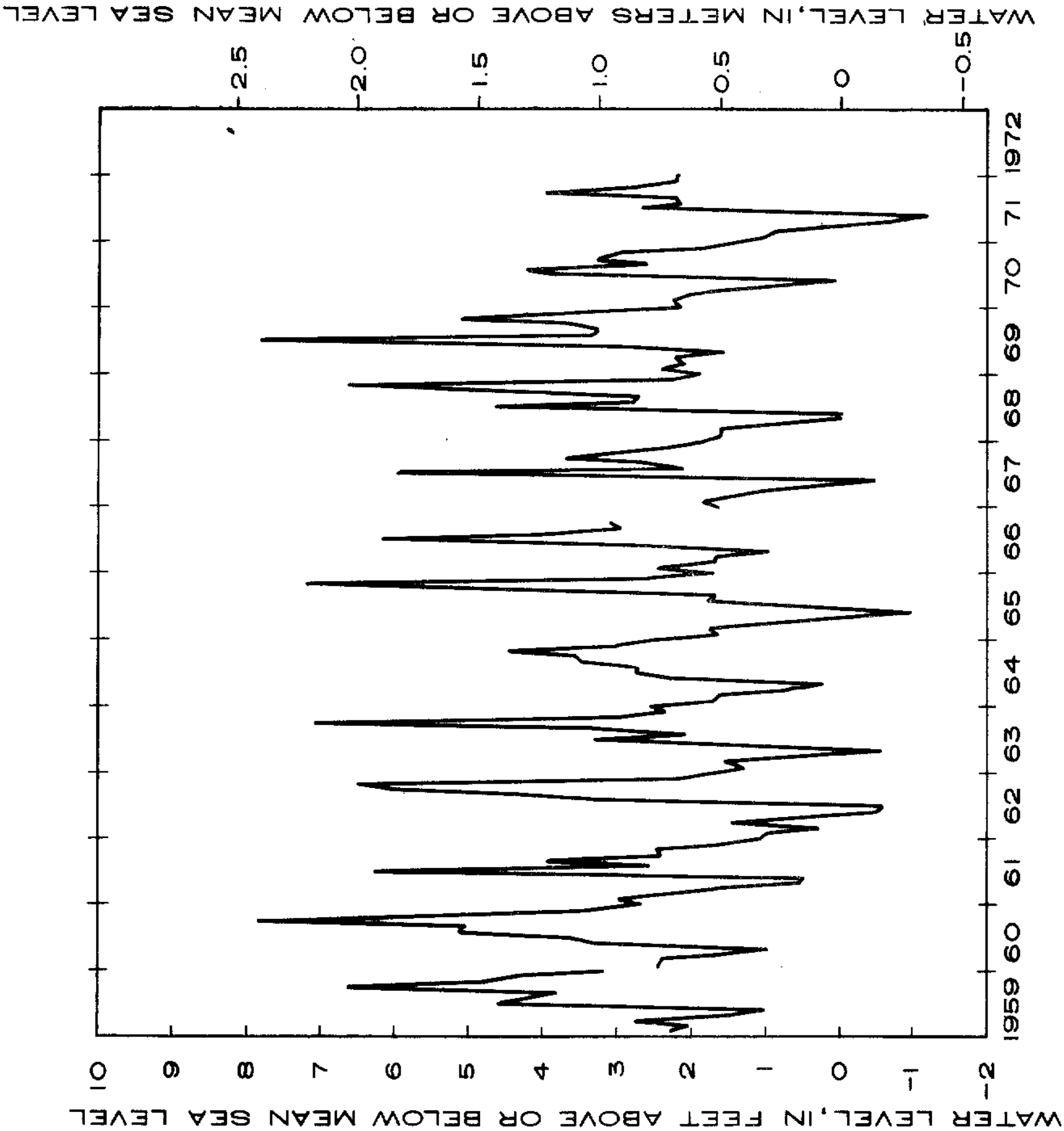

Figure 14.--Well G-864, 1959-71.

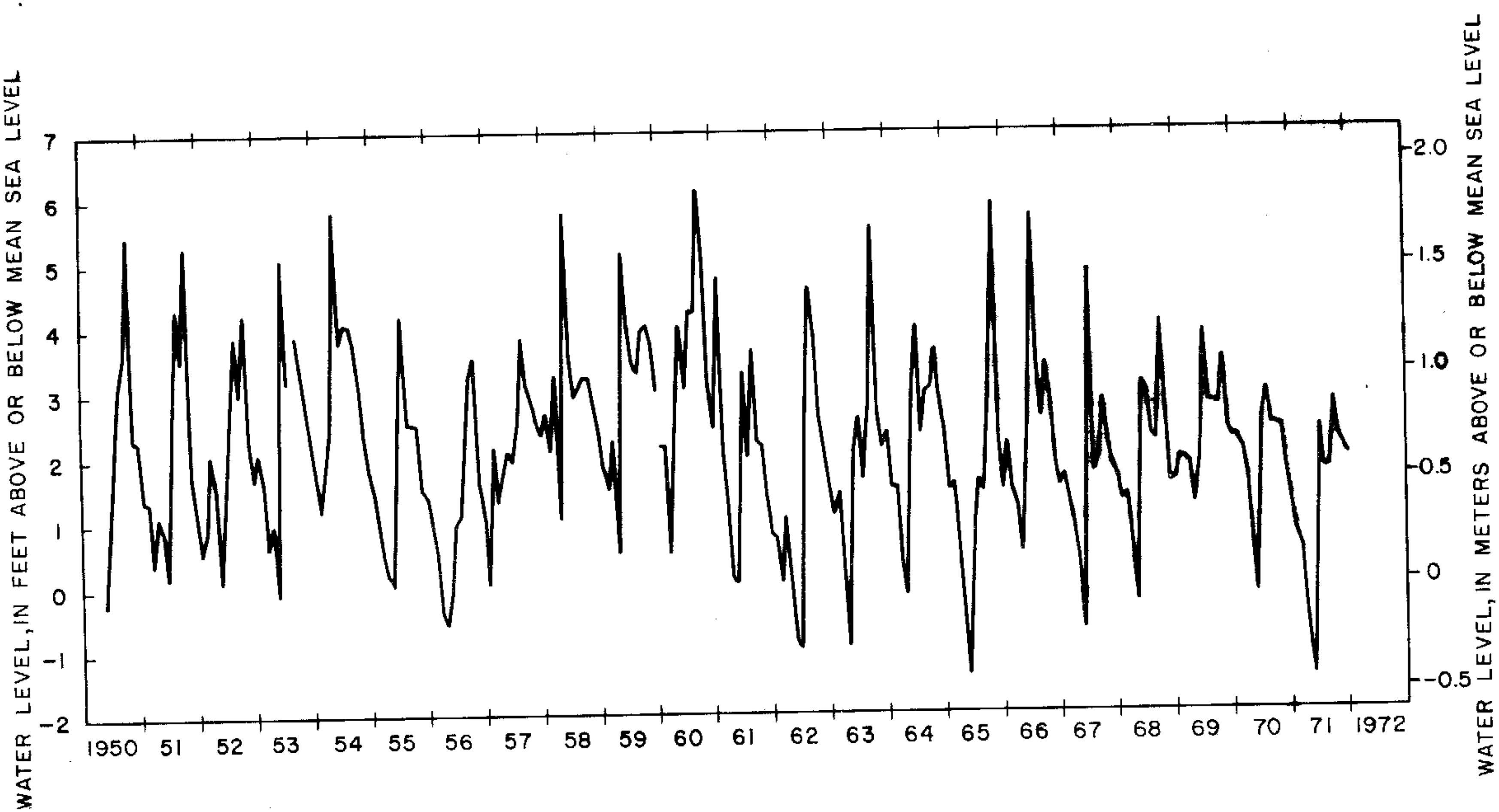

Figure 15.--Well G-613, 1950-71.

The lack of drawdown in and near the pumping wells is therefore a good indication of high aquifer transmissivity. This conclusion is supported by the results of a short-term aquifer test by the author. On November 21-22, 1972, Navy supply well 396 was pumped at 1,400 gpm (gallons per minute) and water levels were measured in observation wells G-864A, G-864B, and G-864C and in the supply well (locations on fig. 2). Well 396 was then shut off and the measurement of water levels in the observation wells was continued. As shown in figure 16, the water level in well G-864A, 20 feet northwest of the pumped well 396 rose 0.05 foot when the pump on well 396 was shut off. The water level in well G-864B, located 50 feet from the pumped well, rose 0.03 foot. When well 396 was started again it produced a drawdown of about the same magnitude (0.05 foot) in well G-864A. The water levels in the three wells responded almost instantaneously to the pumping, and they appeared to reach equilibrium very quickly. The transmissivity of the aquifer was estimated to be about 15 million gallons per day/ft, based on the water level fluctuation in observation wells G-864A and G-864B, and the Thiem formula.

On the other hand a large part of the pumped water is derived from water that would normally be lost to the atmosphere by evapotranspiration. Normally this water would seep southward through the aquifer and through the canals that intersect the aquifer to the lowlying sawgrass marshes near the coast where most of it would be evapotranspired. The pumping wells, however, intercept a small part of this seepage which in turn lowers water levels in the sawgrass marshes thus reducing evapotranspiration there. Therefore, it could be concluded that Navy wells are, at the present rate of pumping, indirectly salvaging some water from evapotranspiration.

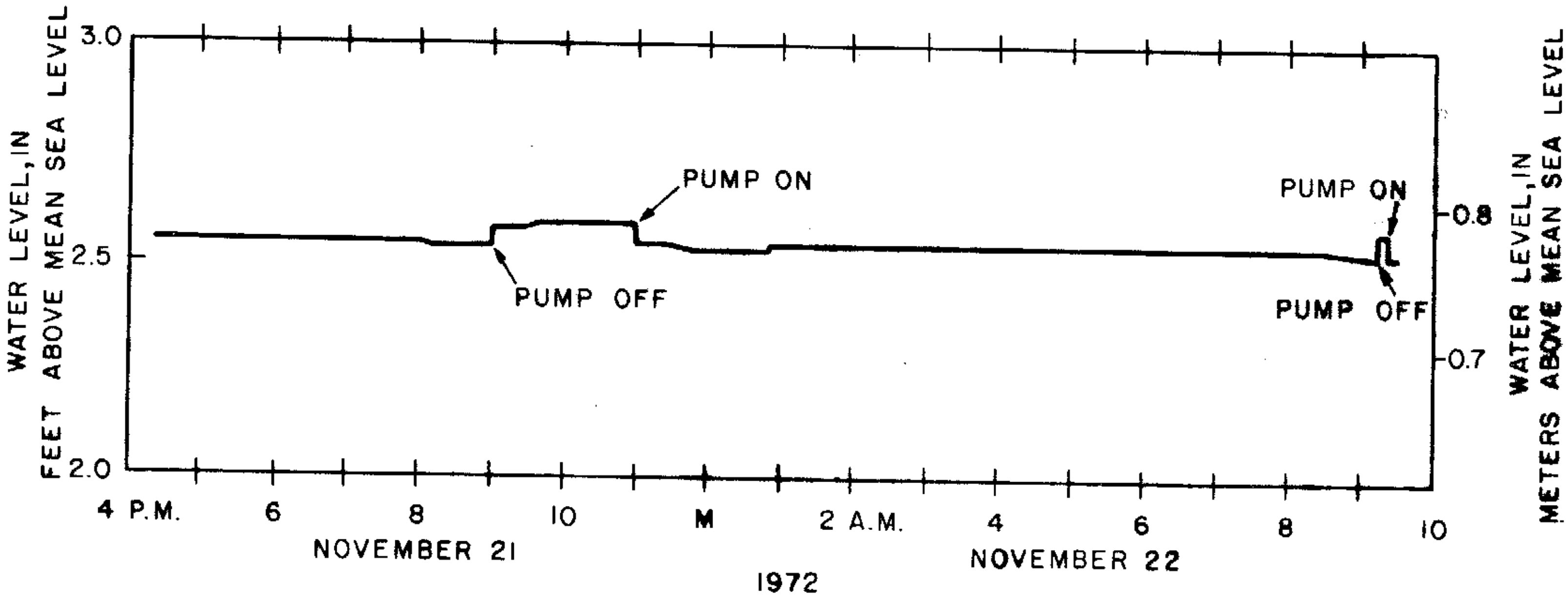

Figure 16.--Well G-864A, November 21-22, 1972.

Water Quality

The quality of water from the Navy's wells has changed only slightly since pumping began in 1942. The chloride concentration has increased about 20 mg/l over the past 30 years (fig. 17). On the basis of analyses of water samples from the Navy wells and from the Homestead city well collected during 1941-64, the chloride concentration in ground water in the Homestead-Florida City area ranged from 9 and 16 mgl. During 1964-67 the chloride concentration of water from the Navy wells increased from 12 to 32 mg/l. Since 1967 the chloride concentration of water from the Navy wells has changed only slightly owing to annual variations in rainfall, averaging about 32 mg/l. The increase in chloride concentration in water from the Navy's wells since 1964 is apparently related to the construction of Canal 111 during 1964-65 and to tidal incursions during hurricane Betsy in September 1965 (Meyer and Hull, 1973). This is supported by the fact that increase in chloride concentration in water from well G-1329 near S-18C (location on fig. 1) in 1965 coincided with the rise in concentration of chloride in the water from the Navy's wells. The chloride concentration in water from the Homestead well field has reportedly increased slightly in the past few years (1965-73) (written commun., Mr. Olaf Pearson, City Manager, Homestead, Florida, November 20, 1972). A sample of water obtained in October 1971 from one of the city wells contained 28 mg/l chloride.

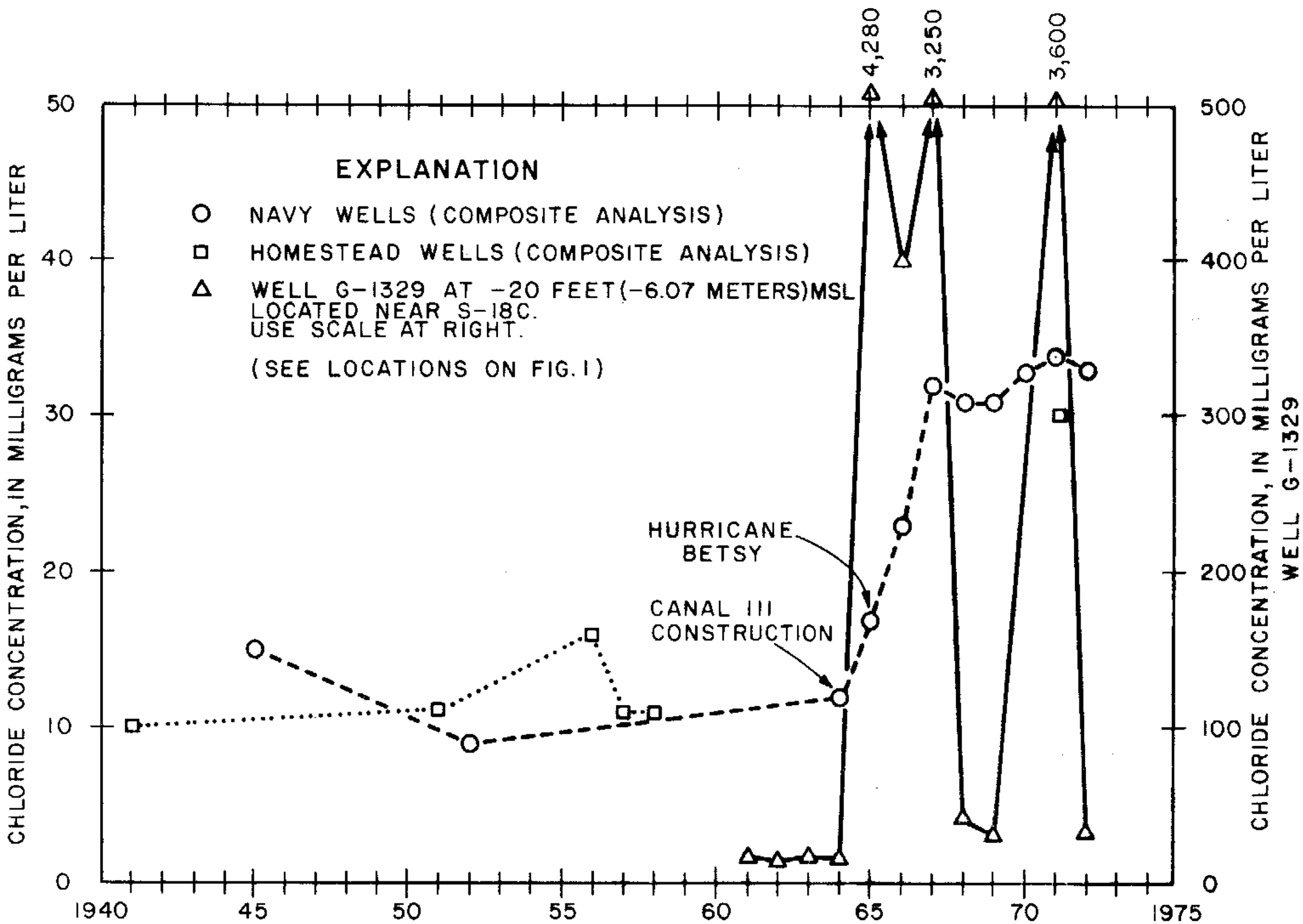

Figure 17.--Chloride concentration in ground water from the Navy and Homestead well fields and from well G-1329, 1941-72.

The concentration of chloride in water from well G-1329 increased from 17 mg/l in 1964 to 4,280 mg/l in 1965 as a result of tidal inundation during Hurricane Betsy and inland movement of salt water from the coastal part of Canal 111 during construction. Wide ranges in chloride concentration occurred in well G-1329 during 1966-72 as a result of flushing during wet years and sea-water intrusion from Canal 111 during dry years (Meyer and Hull, 1973). Therefore, it appears that the increase in chloride concentration in ground water in the vicinity of the Navy well field was caused chiefly by tidal inundation and by changes in the drainage, and not by pumping the wells. Also, as previously stated in the section on sea-water intrusion, the position of the 1,000-mg/l line of equal chloride concentration (fig. 10) indicates that there has been no major advance of the salt front despite increased drainage and water use in south Dade County since 1946.

Additional increases in chloride concentration in ground water in the Homestead-Florida City area can be abated by maintaining higher water levels in canals upstream of coastal controls, by constructing a conveyance canal to link Canal 111 to Conservation Area 3, and by curtailing excavation of additional drainage works.

At the present rate of pumping (6 mgd), there appears to be no threat to any of the Navy's wells from sea-water intrusion other than by the remote possibility that sea water might move inland through Canal 111 undetected to the well field during an extreme drought, or by tidal inundation. Expanding the existing monitoring network to include canals 109 and 110 would provide sufficient warning in the event of serious sea-water intrusion.

As the south Dade area develops and water use increases, there is a possibility that water from some wells near the zone of sea-water intrusion will increase in chloride concentrations. To offset this possibility the Corps of Engineers and the C&SFFCD plan to construct a conveyance canal from Conservation Area 3A to Canal 111 in order to replenish the aquifer in south Dade County during dry periods (written Commun., W.V. Storch, C&SFFCD, May 18, 1972). They will size the conveyance canal to supply sufficient water to meet projected water needs in south Dade County until the year 2020. Included in their plans are the Navy's plan to drill enough wells near Florida City to supply 18 mgd to the Navy - FKAA pipeline.

ADEQUACY OF SUPPLY FOR

WELL-FIELD EXPANSION

Effects of Increased Pumping

Increasing the yield of the Navy's well field from 6 to 18 mgd is expected to have only a slight effect on local water levels and on the chloride concentration in the pumped ground water. The additional water-level decline near the center of the well field should be less than 1 foot, and the chloride concentration of the pumped ground water should range from 30 to 40 mg/l.

Natural loss of water by evapotranspiration is expected to continue to dominate the seasonal decline in local water levels despite the increased pumping. A large part of the pumpage will be derived from water infiltrating the aquifer from nearby reaches of Canal 111 and tributary canals. At present (1973) there is sufficient seepage from the canals to supply both the increased pumpage and the dry weather needs; however, additional recharge will be required to meet projected needs in south Dade County for the next 50 years -- that is, beyond the 12-mgd increase. The Corps of Engineers proposes to furnish the additional recharge to south Dade County by connecting the north end of Canal 111 to Conservation Area 3 by a conveyance canal.

Recharge From Conveyance Canal

Additional water to recharge the aquifer in south Dade County during the annual dry period (November-May) will be supplied by a pump-equipped conveyance canal linking Canal 111 to Conservation Area 3A, according to the C&SFFCD and the U.S. Corps of Engineers (1968). An electric analog model of the Biscayne aquifer, constructed by the U.S. Geological Survey (Appel, 1973), was used to simulate the flow of water from the conservation area through the canals to the bay and pumping centers to meet the dry weather needs of a 1 in 10 year drought in the year 2020 (written commun., C.A. Appel, April 6, 1971). Consumptive use of water (water that is used once and not returned to the aquifer for reuse) for south Dade County is expected to reach 490 mgd by 2020. Consumptive use for the Homestead-Florida City area, including that for the Navy, is expected to reach 93 mgd by 2020. Also considered in that analysis was recharge by rainfall and loss by evapotranspiration and seepage to the bays. The predicted water levels for the year 2020 (fig. 18) are based on the premise that the conveyance canal is functioning, and that pumpage patterns and rates will be the same as that known.

The capacities of the canal and pump were determined jointly by the Geological Survey, the Corps of Engineers, and the C&SFFCD in 1971-72. The canal and pump will furnish 872 mgd to meet demands in south Dade County and 152 mgd to Everglades National Park (written commun., U.S. Corps of Engineers, C&SFFCD, September 19, 1972).

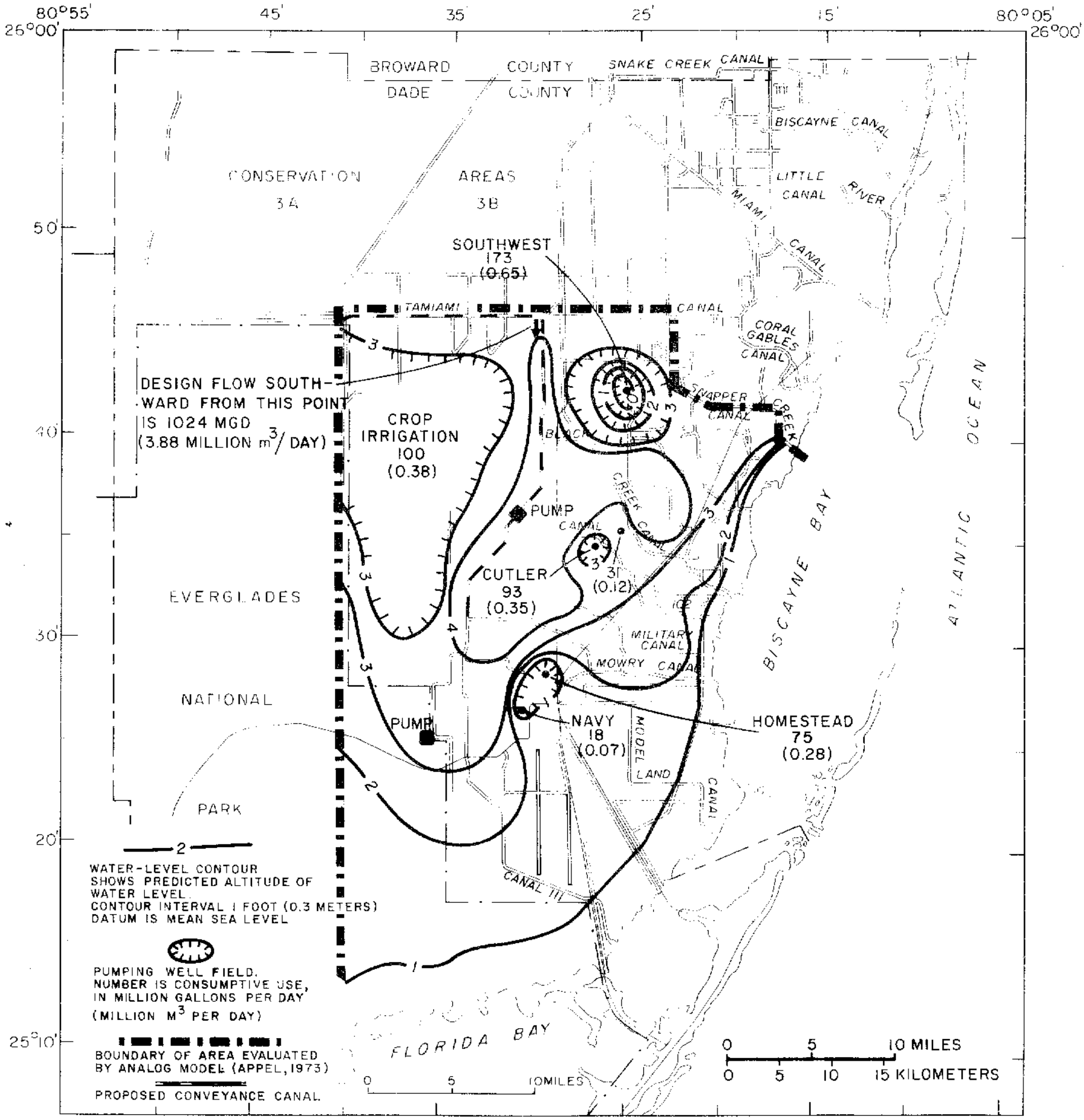

Figure 18.--Predicted water levels in southeastern Dade County in the year 2020.

A comparison of the predicted water levels with those in May 1971 (fig. 9) shows that water levels would be raised significantly in the vicinity of the Navy well field as a result of the conveyance canal recharge and that infiltration to the well field would be greater from the northwest as a result of steeper hydraulic gradients. According to the predicted water levels a sufficient quantity of ground water could be pumped without undue stress, but there is a possibility that curtailment of water use might be necessary under extreme drought conditions. However, the likelihood of periodic curtailment of pumping is not sufficient to discourage development of public water supply in south Dade County.

CONCLUSIONS

Under the existing conditions there is ample fresh ground water in the Homestead-Florida City area to supply the present capacity of the Navy well field. It is expected that the yield from the Navy's well field can be increased at this time from 6 to 18 mgd by additional wells without significantly lowering regional water levels and increasing the chloride content in the raw water. Expanding the existing monitor network to include Canals 109 and 110 should provide sufficient warning in the event of serious threat of sea-water intrusion resulting from extreme drought or tidal inundation.

Consumptive use of water by municipalities in the Homestead-Florida City area, including that for the Navy, is expected to reach 93 mgd by 2020. Deficits during drought will be met by pumping water from Conservation Area 3A through a conveyance canal to south Dade, according to the Corps of Engineers. The canal and pump capacities will be capable of supplying sufficient water to south Dade County to meet the needs of a 1 in 10 year drought in the year 2020. Recharge from the conveyance canal should maintain water levels well above sea level in the Navy's wells and provide additional safety to this vital supply system.

During extreme droughts it might be necessary to curtail pumping to protect coastal wells from sea-water intrusion. However, periodic curtailment of pumping is not sufficient reason to discourage development of public water supply in south Dade County.

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Table 2 -- FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

The following factors may be used to convert the English units published herein to the International System of Units (SI). Subsequent reports will contain both the English and SI unit equivalents in the station manuscript descriptions until such time that all data will be published in SI units.

Multiply English units	By	To obtain SI units
	Length	
inches (in)	25.4	millimeters (mm)
	.0254	meters (m)
feet (ft)	.3048	meters (m)
yards (yd)	.9144	meters (m)
rods	5.0292	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
acres	4047	square meters (m^2)
	.4047	*hectares (ha)
	.4047	square hectometer (hm^2)
	.004047	square kilometers (km^2)
square miles (mi^2)	2.590	square kilometers (km^2)
	Volume	
gallons (gal)	3.785	**liters (l)
	3.785	cubic decimeters (dm^3)
	3.785×10^{-3}	cubic meters (m^3)
million gallons (10^6 gal)	3785	cubic meters (m^3)
	3.785×10^{-3}	cubic hectometers (hm^3)
cubic feet (ft^3)	28.32	cubic decimeters (dm^3)
	.02832	cubic meters (m^3)
cfs-day (ft^3/s-day)	2447	cubic meters (m^3)
	2.447×10^{-3}	cubic hectometers (hm^3)
acre-feet (acre-ft)	1233	cubic meters (m^3)
	1.233×10^{-3}	cubic hectometers (hm^3)
	1.233×10^{-6}	cubic kilometers (km^3)
	Flow	
cubic feet per second (ft^3/s)	28.32	liters per second (l/s)
	28.32	cubic decimeters per second (dm^3/s)
	.02832	cubic meters per second (m^3/s)
gallons per minute (gpm)	.06309	liters per second (l/s)
	.06309	cubic decimeters per second (dm^3/s)
	6.309×10^{-5}	cubic meters per second (m^3/s)
million gallons per day (mgd)	43.81	cubic decimeters per second (dm^3/s)
	.04381	cubic meters per second (m^3/s)
	Mass	
ton (short)	.9072	tonne (t)

*The unit hectare is approved for use with the International System (SI) for a limited time. See NBS Special Bulletin 330, p.15, 1972 edition.

**The unit liter is accepted for use with the International System (SI). See NBS Special Bulletin 330, p. 13, 1972 edition.