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HYDROLOGIC RECONNAISSANCE OF MARION COUNTY

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ABSTRACT

An investigation of the water resources in Marion County was conducted from June to October of 1981 in order to delineate special problems and to set objectives for future research. To achieve these objectives, data from long term records of precipitation, evaporation, stream discharge, lake stages, and ground water levels were evaluated. Departures from average levels for the various periods of record formed a basis for evaluating historic trends in fluctuations of the hydrologic systems.

Precipitation based on a 30 year average for Marion County is 53.82 inches (1951-1980). The annual average for pan evaporation is 64.9 inches based on 20 years of record (1961-1980). Annual lake evaporation for Marion County is estimated to be 45.5 inches. Annual evapotranspiration is determined to be 36.8 inches. Ground water levels measured at Sharpes Ferry for 30 years of record averaged 43.73 ft. (NGVD).

The principal source of fresh water in Marion County is the Floridan aquifer. The top of this aquifer is between +100 ft. (msl) to -250 ft. (msl). Water is confined under artesian pressure in the aquifer by clays of the Miocene age found in the Hawthorn Formation. Concentrations of chlorides in the waters of the Floridan aquifer are low, generally below 40 mg/l. Higher concentrations are observed in the Oklawaha River Valley and Salt Springs due to the result of upward leakage of highly mineralized water. Areas of potential recharge to the Floridan aquifer occur predominantly to the east and west of the Oklawaha River. Average annual recharge is estimated to be 15 inches for Silver Springs ground water drainage basin.

A water balance based on estimates of rainfall, evapotranspiration, streamflow and ground water flow was derived for Marion County. From these

estimates, the total volume of water calculated entering Marion County which includes precipitation, streamflow and ground water flow is 4,756 mgd. An equal amount was calculated leaving Marion County from spring flow, ground water flow, ground water pumpage, streamflow and evapotranspiration estimates.

ACKNOWLEDGEMENT

The author expresses his appreciation to the many individuals who aided him through his investigation, including his colleagues at the District who helped with the interpretation of data and provided helpful technical advice and comments.

Special thanks is extended to Glen Faulkner of the U. S. Geological Survey for his rewarding discussions on the geohydrology and generous contributions of data and technical advice for the preparation of this investigation.

The author also acknowledges the members of Withlacoochee Regional Planning Council for the helpful data supplied for the investigation.

INTRODUCTION AND PURPOSE

Marion County lies within two water management districts separated by Interstate 75. The eastern portion is managed by St. Johns River Water Management District and the western portion managed by Southwest Florida Water Management District. Within the western half, the Withlacoochee Regional Planning Council provides planning and technical assistance to adequately address the region's existing and future water supply needs to the Withlacoochee Regional Water Supply Authority.

The Withlacoochee Regional Water Supply Authority's responsibilities are to plan, develop, and supply water within the county for municipal purposes. The Authority is in the process of assessing the water needs of its area which includes Marion County. This report provides water resources information needed for water management decisions by state and local government agencies.

The expressed concern of the Withlacoochee Regional Water Supply Authority for the lack of a unified compilation of existing hydrologic data necessitated the present hydrologic reconnaissance of Marion County. Without such a document, the efforts of those charged with the regulation of the water resources in evaluating the capability of the system to supply future needs are hampered.

In the past, the potable water supply for the inland portions of the District was considered extremely stable. However, due to the increased growth, the demand for water supplies has also increased. Therefore, a quantitative study to better interpret the geohydrologic system was initiated. It is intended that this study will aid water managers in evaluating the hydrologic trends in Marion County.

Previous Investigations

While a comprehensive and current evaluation of the water resources of Marion County is not available, a review of the literature provides several works that detail components of the hydrologic regime. The general physiography and geomorphology of central Florida has been described by McNeil (1950) and White (1958). Vernon (1951) reported the geologic structure and stratigraphy of the central Florida region. More detailed information is available for selected areas of Marion county in reports by Espenshade and Spencer (1963), Puri (1967), Vernon and Puri (1964, 1965) and Chen (1965).

Information on the hydrologic conditions of Marion County has been presented by several authors. Anderson and Faulkner (1973) discussed the various hydrologic aspects of the surface water resources in Marion County. Studies for the proposed construction of the Cross Florida Barge Canal have provided information concerning the potentiometric surface of the Floridan aquifer and local geohydrological conditions (Springfield, 1966; Healy, 1962; and Faulkner 1973). Tibals (1975) discussed aquifer characteristics in conjunction with possible contamination from the Barge Canal in the Summit Reach. A hydrologic budget for the canal was performed by Meta Systems, Inc. (1976). Also, water resource evaluations have been performed for peripheral counties which are germane to this study. (Leve, 1958; Wyrick, 1960; and Clark, 1964; D. D. Knochenmus and G. W. Hughes, 1976).

DESCRIPTION OF STUDY AREA

Marion County is located near the geographic center of Florida (Figure 1). It is bounded by Alachua County and Putnam County on the north, Lake County and Volusia counties on the east; Lake, Sumter and Citrus counties on the south and Levy County on the west. Current population is 122,488 with Ocala the largest city.

Topography

Topographic relief in Marion County ranges from mean sea level (msl) in the northeast corner to an elevation of 215 feet above msl in the Fairfield area northwest of Ocala (Faulkner, 1973). The principal feature of the low area is the Oklawaha River which is associated with riverine swamps and marshes. To the south and east of the river, the terrain becomes gently rolling with hills generally 60 to 100 feet above msl. A significant feature of this area is the dune-like sand hill ridge in the Ocala National Forest, dominated by pine flatwood forest. To the west of Ocala the topography is dominated by gently rolling hills ranging in elevation from 100 to 215 feet above msl. A more detailed physiographic subdivision of Marion County appears in Figure 2. Shown are land forms recognized by Puri and Vernon (1964). The physiographic divisions range in altitude as does the topographic relief.

Marion County is comprised of 1,060,676 acres with forested lands (527,734 acres) the predominant land use type. An additional 28,000 acres of predominantly forest lands is present in the Fort McCoy Wildlife Management Area. Agricultural lands comprise 319,344 acres, with wetlands comprising 81,471 acres. Other major land uses include unproductive land (57,026 acres), urban development (41,809), and water-bearing impoundments (30,086 acres).

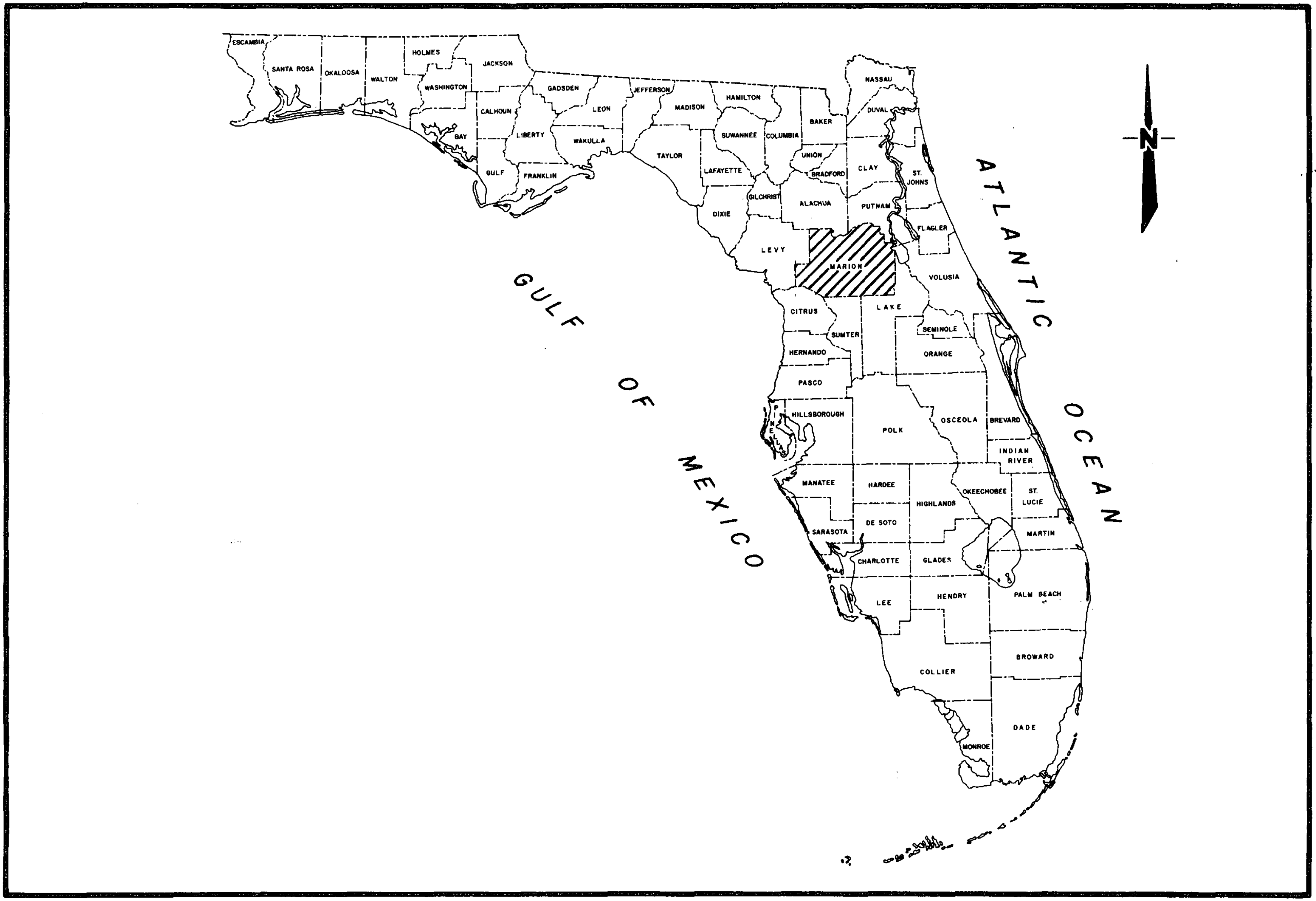

FIGURE 1. Map of Florida Showing Location of Marion County.

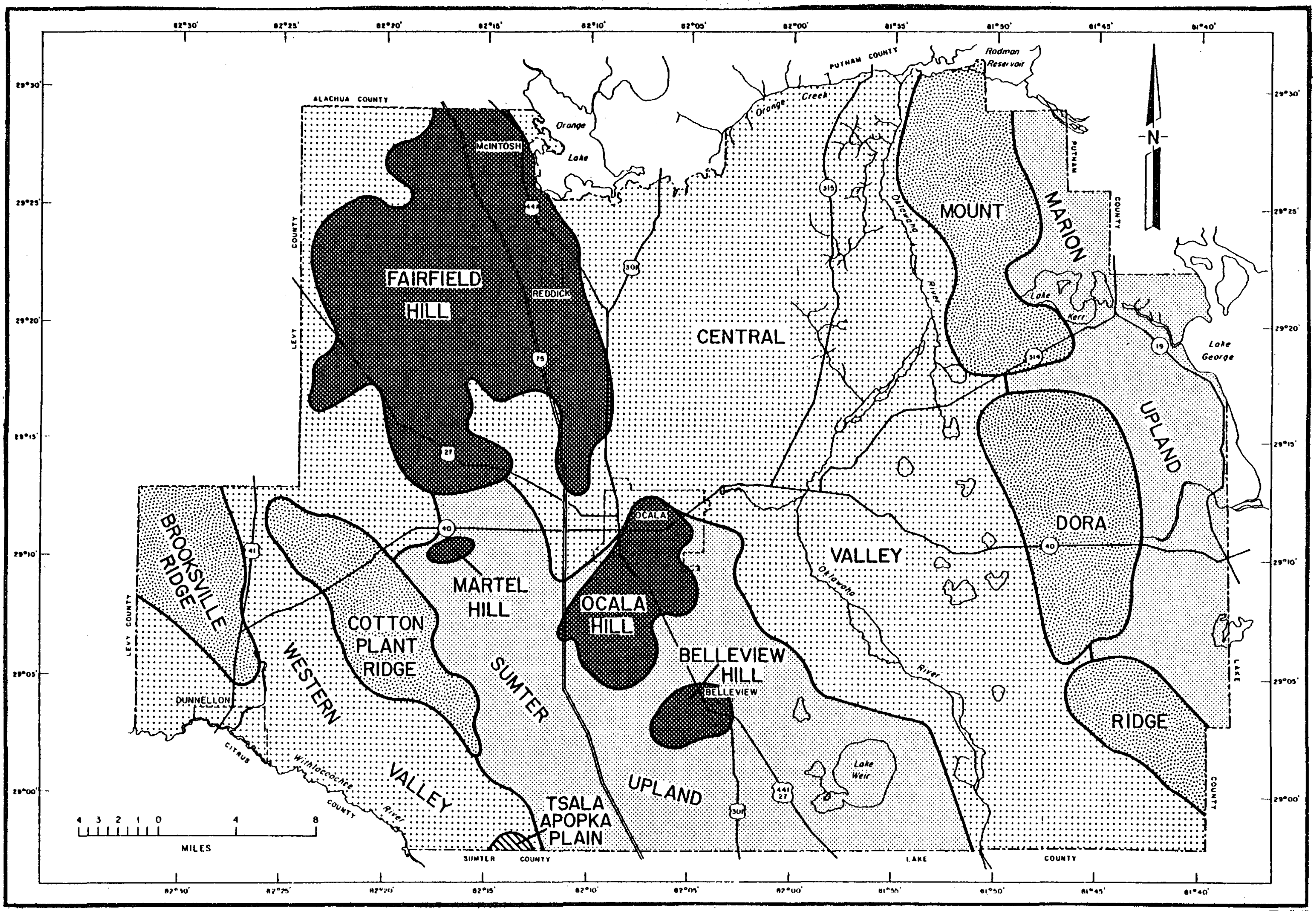

FIGURE 2. Physiographic Subdivisions in Marion County.

Marion County is spotted with lakes; the most prominent of which are Lake Kerr in northeast Marion County, Lake Weir in the southeast section. Located on the county's border are: Orange Lake to the north, and Lake George to the east. Other physiographic features include prairies such as Hopkins Prairie and Black Sink Prairie. Prairies are generally formed through solution of the underlying limestone and subsequent settling of the terrain. Major river systems include the Oklawaha River, the largest river in Marion County, flowing from south to north bisecting the county. The Withlacoochee River flowing southeast to northwest borders Citrus and Marion counties. Other streams in Marion County include a number of spring derived rivers including: Blue Run, Juniper Creek, Silver Springs Run, Salt Springs Run and Rainbow River.

Climate

As is typical of peninsular Florida, Marion County is classified as having a sub-tropical climate with two distinctive seasons. The summers are generally hot and humid with the rain events arising from convective thunder showers. The winters are mild and drier with frontal activity generally responsible for precipitation.

Precipitation

The average rainfall for the county is 53.82 inches based on 30 years of record (1951-1980). A graph of yearly precipitation for the period of record is present in Figure 3A. Annual rainfall extremes for the period of record occurred in 1971 with a low 39.3 inches and a high of 71.15 inches in 1953. Precipitation in Marion County occurs almost exclusively as rainfall and is highly spatial and temporally variable. This uneven distribution geographically and seasonally creates a degree of

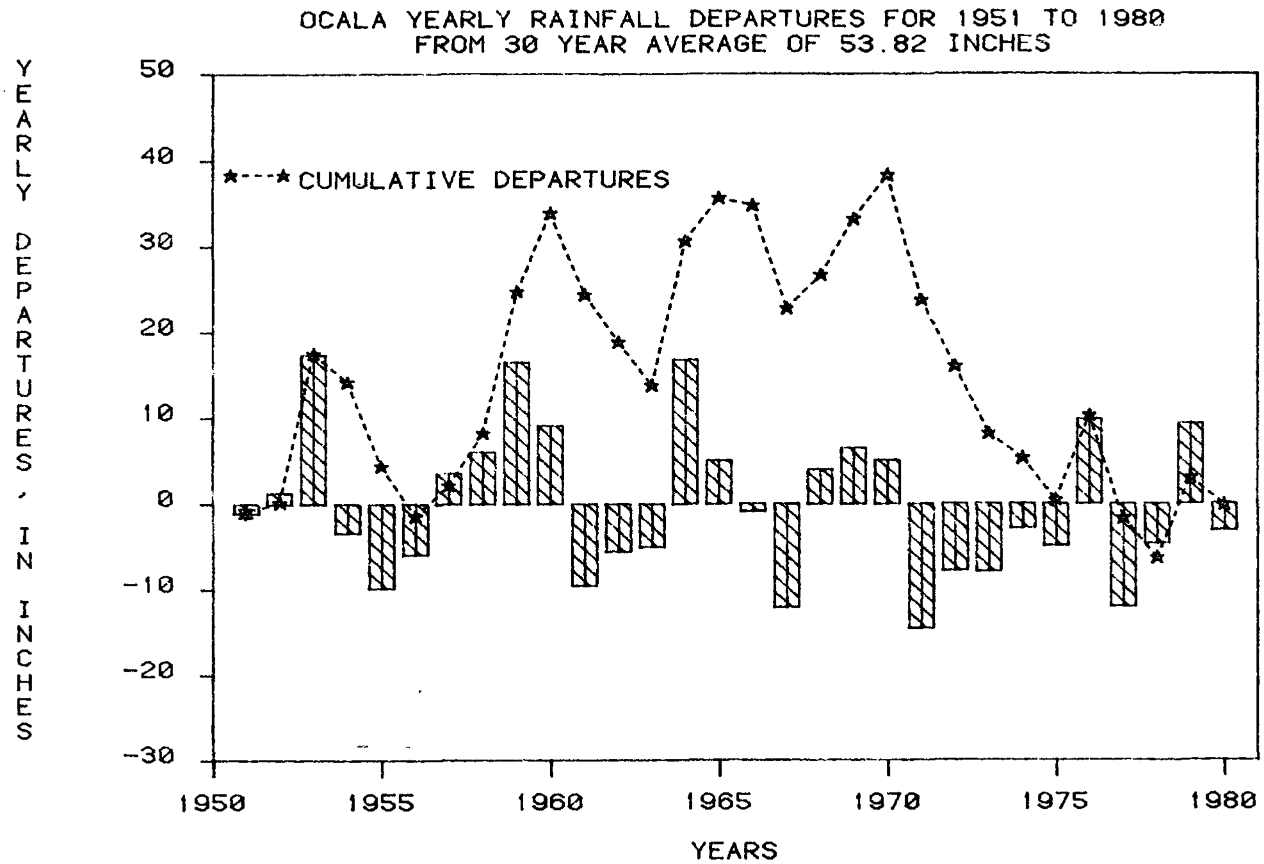

FIGURE 3A. Ocala Yearly Rainfall Departures (1951-1980).

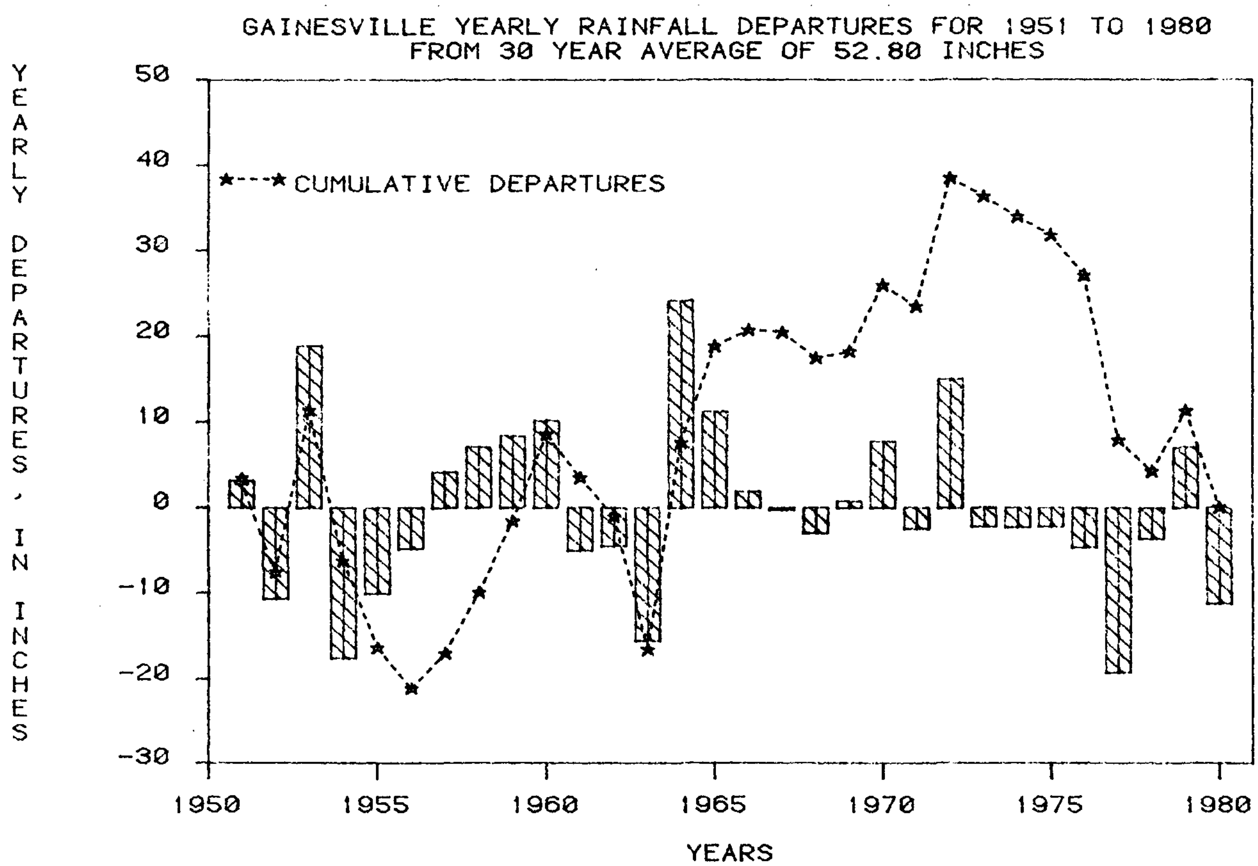

FIGURE 3B. Gainesville Yearly Rainfall Departures (1951-1980).

unpredictability in forecasting. To illustrate the uneven geographical distribution of rain, Figure 3B presents Gainesville's (Alachua County) yearly rainfall departures for a 30 year average (52.80 inches) compared with Ocala's departure from the 30 year average. The zero departure line represents the average rainfall with the height of the columns representing deviation from the average. The cumulative rainfall departures, represented by the dashed line, illustrates the summation of yearly rainfall departures from the years 1951-1980. As can be seen from the graph, yearly departures are significantly different when comparing the nearby cities.

Evaporation

Evaporation is the hydrologic process by which water is transferred from land and water masses of the earth to the atmosphere in the form of water vapor, thus affecting precipitation. The rate of evaporation is a function of solar radiation, differences in vapor pressure between a water surface and the overlying air, temperature, wind and atmospheric pressure. The annual pan evaporation data based on measurements from a Class A evaporation pan in Gainesville are illustrated in Figure 4. Annual average pan evaporation is 64.9 inches based on a twenty year record (1961-1980).

Estimates of monthly potential evaporation rates for Marion County calculated from observations of temperature and solar radiation for the years 1955-1974 are in close agreement with the measured values of Gainesville (Table 1). The data suggests that evaporation rates are greatest during spring and early summer, with 35 to 40 percent of total evaporation occurring during the winter.

Kohler, Nordenson, and Fox (1955) determined that Class A pan evaporation measurements multiplied by a coefficient of 0.70 resulted in an

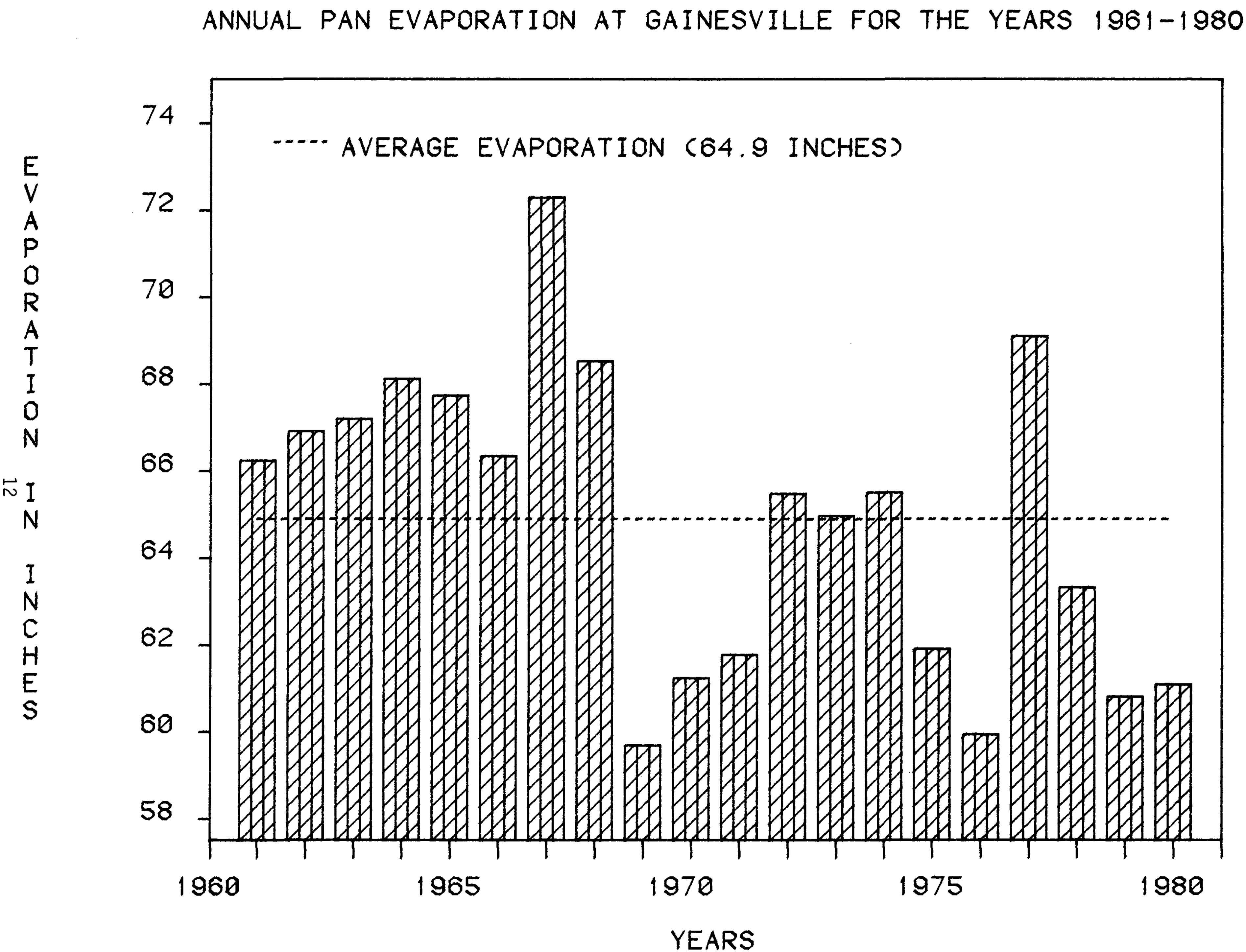

FIGURE 4. Annual Pan Evaporation at Gainesville (1961 - 1980).

TABLE 1. Potential Evaporation *(inches)

	Mean	Std. Dev.
Annual*	64.92	4.85
Monthly:		
Jan	2.37	0.47
Feb	2.96	0.40
Mar	4.71	0.68
Apr	6.57	0.58
May	7.90	0.69
Jun	7.82	0.86
Jul	7.88	0.64
Aug	7.50	0.75
Sep	6.18	0.87
Oct	5.04	0.54
Nov	3.42	0.48
Dec	2.57	0.51

*Estimated by equation $E_p = (0.014T - 0.37) R_s$

where T is mean monthly temperature, Fahrenheit

R_s is solar radiation, inches/month

Source: Meta Systems 1976

acceptable annual estimate of lake evaporation. This coefficient includes the various factors present in a natural system that additionally affects evaporation (i.e. biological activity and wind velocity). Annual lake evaporation for Marion County is estimated to be 45.5 inches.

Evapotranspiration

Evapotranspiration is the combined process by which water is transferred from the earth's surface to the atmosphere by evaporation and transpiration from the biological processes of plants. Potential evapotranspiration (PET) is the maximum rate of evapotranspiration, provided soil moisture is nonlimiting. Actual Evapotranspiration (AET) will (due to its dependence on vegetative cover and land uses), generally be less than or equal to PET. Ratios of AET to PET have been calculated for various locations in Florida and coefficient of 0.81 was interpolated for Marion County (Dohrenwend 1977). Annual evapotranspiration was then calculated from the product of annual lake evaporation and the ratio of AET to PET. Consequently, an estimated annual AET of 36.8 inches was determined for Marion County (Jenson, 1974).

GEOLOGY

The sequence of geologic rock units in Marion County is depicted in Figure 5. The oldest rocks are the Cedar Keys limestone of Paleocene Age followed by the younger Oldsmar, Lake City, Avon Park, and Ocala formations all of the Eocene series. These limestone formations make up the Floridan aquifer, the principle potable water supply for Marion County. The shallow aquifer is comprised of the Hawthorn, Fort Preston, Alachua and Jackson Bluff formations of the Miocene Age. Overlying the Jackson Bluff Formation are the Pamlico sediments of the Pleistocene series, and the unnamed aluvial lake and wind blown deposits that make up the Holocene series.

Formations

The thickness of Cedar Keys Limestone is 400-700 feet of marine dolomite, has a light gray color with considerable amount of anhydrite and gypsum. The fresh water/salt water interface is found in this formation (Faulkner 1973). Overlying the Cedar Keys limestone is the Oldsmar limestone formation with a thickness of 500-650 feet. The formation is composed primarily of marine limestone, a light brown to chalky color and fossiliferous with interbedded brown, porous, crystalline dolomite.

The Middle and Upper Eocene series initiates the collective hydrostratigraphic units known as the Floridan aquifer. The oldest is the Lake City limestone having a thickness of 600 to 700 feet, brown to light brown in color, and slightly porous to porous. Overlying the Lake City Limestone is the Avon Park limestone with a thickness of 200-400 feet. It can be identified by its fine fragmental, highly fossiliferous character and light brown to brown color. The Avon Park limestone is the oldest naturally exposed basal unit in the state of Florida, and can be seen at the surface on the crest of the Ocala uplift in the Dunnellon area

Aq.	Series		Stratigraphic Unit	Thickness (feet)	Lithology
SHALLOW AQUIFER	HOLOCENE		Unnamed alluvial lake and windblown deposits	0 to 20 FEET THICK	Alluvium, fresh water marl, peats and muds in stream and lake bottoms. Also, some dunes and other windblown sand.
SHALLOW AQUIFER	PLEISTOCENE		Pamlico and other marine and estuarine terraces	0 to 100 FEET THICK	Mostly marine quartz sand, unconsolidated, and generally well graded. Also some fluviatile and lacustrine sand, clay, marl and peat deposits.
SHALLOW AQUIFER	MIOCENE—PLIOCENE (?)	middle	JACKSON BLUFF FORMATION	0 to 75 FEET THICK	Marine sands, argillaceous, carbonaceous; and sandy shell marl. Some phosphatic limestone.
SHALLOW AQUIFER	MIOCENE—PLIOCENE (?)	middle	ALACHUA FORMATION	0 to 100 FEET THICK	Nonmarine interbedded deposits of clay, sand and sandy clay; much of unit is phosphatic, base characterized by rubble of phosphate rock and silicified limestone residuum in a gray and green phosphatic clay matrix.
SHALLOW AQUIFER	MIOCENE—PLIOCENE (?)	middle	FORT PRESTON FORMATION	0 to 100 FEET THICK	Nonmarine fluviatile sand, white to gray, variegated orange, purple and red in upper part, fine to coarse grained to pebbly, clayey, cross-bedded.
SHALLOW AQUIFER / FLORIDAN AQUIFER	MIOCENE	lower & middle	HAWTHORN FORMATION	0 to 140 FEET THICK	Marine interbedded sand, cream, white and gray, phosphatic, often clayey; clay, green to gray and white, phosphatic, often sandy; dolomite, cream to white and gray, phosphatic, sandy, clayey; and some limestone, hard, dense, in part sandy and phosphatic. Tends to be sandy in upper part and dolomitic and limey in lower part.
FLORIDAN AQUIFER	EOCENE	upper	OCALA LIMESTONE Upper Member	0 to 100 FEET THICK	Marine limestone, cream to white, soft, granular, highly porous; coquinal, often consists almost entirely of tests of foraminifers; cherty in places.
FLORIDAN AQUIFER	EOCENE	upper	OCALA LIMESTONE Lower Member	0 to 80 FEET THICK	Marine limestone, cream to tan and brown, granular, soft to firm, porous, highly fossiliferous; lower part at places is dolomite, gray and brown, crystalline, sacchoroidal, porous.
FLORIDAN AQUIFER	EOCENE	middle	AVON PARK LIMESTONE	200 to 400 FEET THICK	Marine limestone, light brown to brown, finely fragmental, poor to good porosity, highly fossiliferous (mostly foraminifers); and dolomite, brown to dark brown, slightly porous to good porosity, crystalline, sacchoroidal; both limestone and dolomite are carbonaceous or peaty; gypsum is present in small amounts.
FLORIDAN AQUIFER	EOCENE	middle	LAKE CITY LIMESTONE	600 to 700 FEET THICK	Marine limestone, light brown to brown, fragmental, highly fossiliferous, slightly carbonaceous or peaty or cherty; and dolomite, brown to dark brown with very minor amounts of gypsum and anhydrite. Unit is slightly porous to porous.
	EOCENE	lower	OLDSMAR LIMESTONE	500 to 650 FEET THICK	Marine limestone, light brown to chalky, white, porous, fossiliferous, with interbedded brown, porous, crystalline dolomite; minor amounts of anhydrite and gypsum.
		PALEOCENE	CEDAR KEYS LIMESTONE	400 to 700 FEET THICK	Marine dolomite, light gray, hard, slightly porous to porous, crystalline, in part fossiliferous, with considerable anhydrite and gypsum, some limestone.

FIGURE 5. Description of Stratigraphic Units in Marion County.

Modified from Faulkner, 1973

(Faulkner 1973).

The Ocala Limestone overlies the Avon Park Limestone, except where the Avon Park occurs at or near the surface. This is one of the most productive water bearing formations of the Floridan aquifer. For the majority of occurrence, the Ocala limestone is present near the land surface west of Silver Springs, usually covered by a thin veneer of sand and exposed on hills and upland flats. The Ocala Limestone has a lower and upper member differing in lithology and faunal differences, some authors recognize the lower group composed of the Inglis and Williston Formation and the upper member being equivalent to the Crystal River Formation. (Applin and Applin 1944 and Springfield, 1966). The lower member of the Ocala Limestone having a thickness of 80 feet or less in the barge canal area, is cream to tan and brown in color and consists of granular highly fossiliferous to coquinal with a soft to firm texture and is quite porous. The upper member can be distinguished from the lower member by the cream to white color, soft and granular texture, and is regarded to be highly porous. It often consists entirely of formanifers and usually is as much as 100 feet thick. In places the Ocala is cherty, more commonly near the upper zone, but erratic cherty zones may occur at any depth in the unit. The chert is not consistently present at any given horizon and is usually found in irregularly shaped masses or as relatively thin layers of limited areal extend (Faulkner 1973). The top of the Ocala limestone is depicted in Figure 6.

The top of the Hawthorn Formation is depicted in Figure 7. The Hawthorn Formation unconformably overlies the Ocala Limestone and is of Miocene Age. The Hawthorn formation is present in most areas east of the north-south line between Silver Springs and the Oklawaha River (Figure 8).

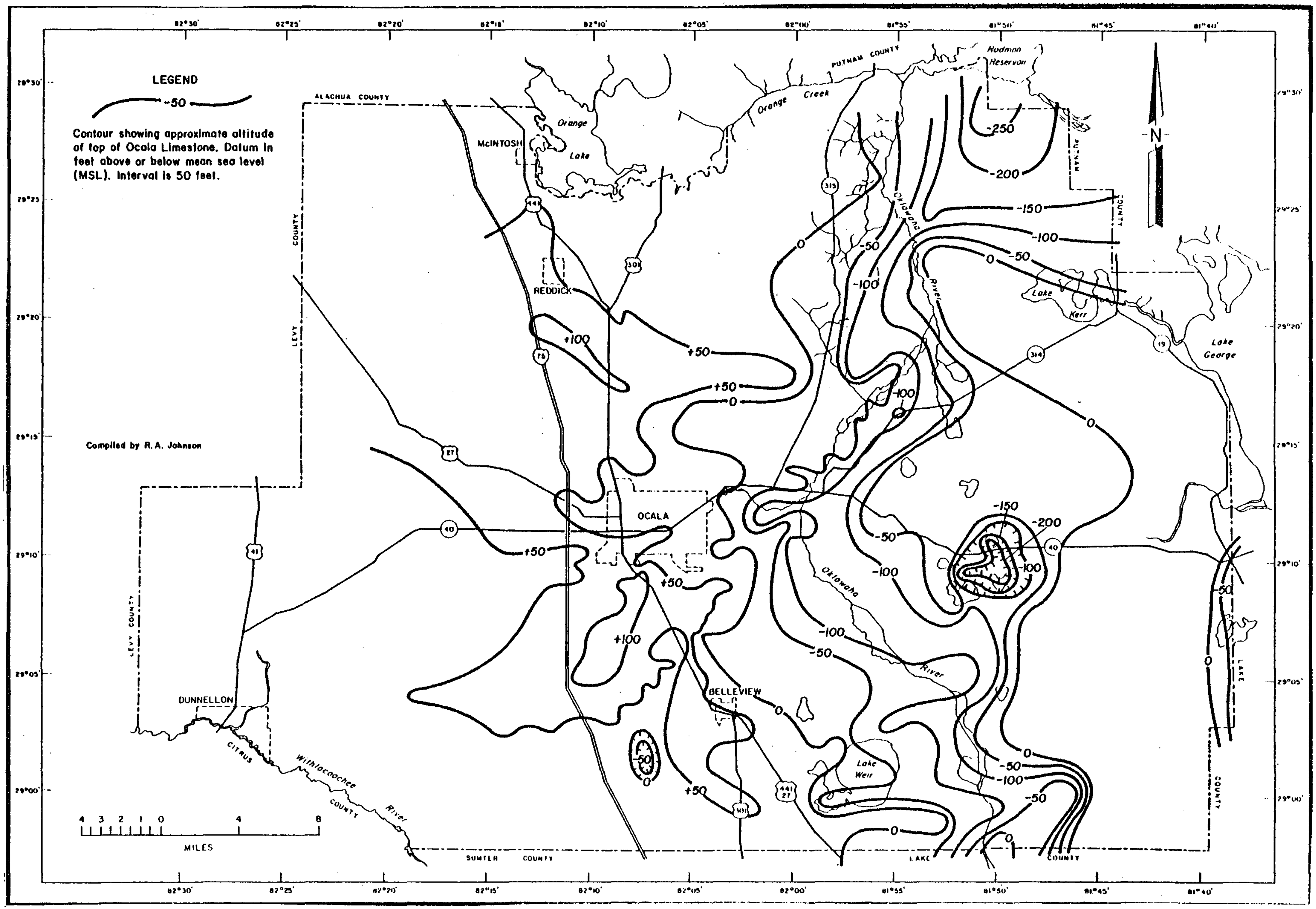

FIGURE 6. Top of the Ocala Limestone.

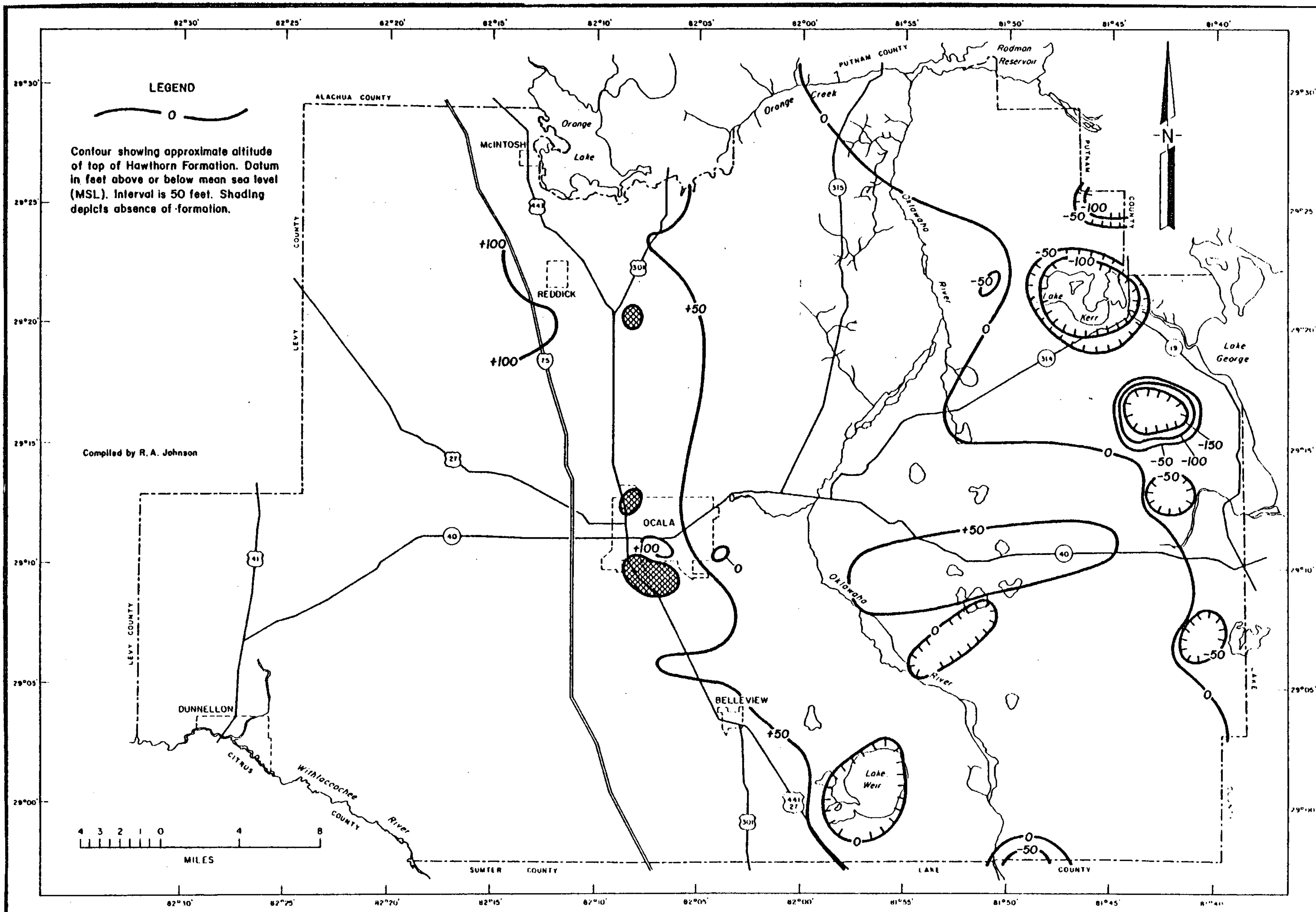

FIGURE 7. Top of the Hawthorn Formation.

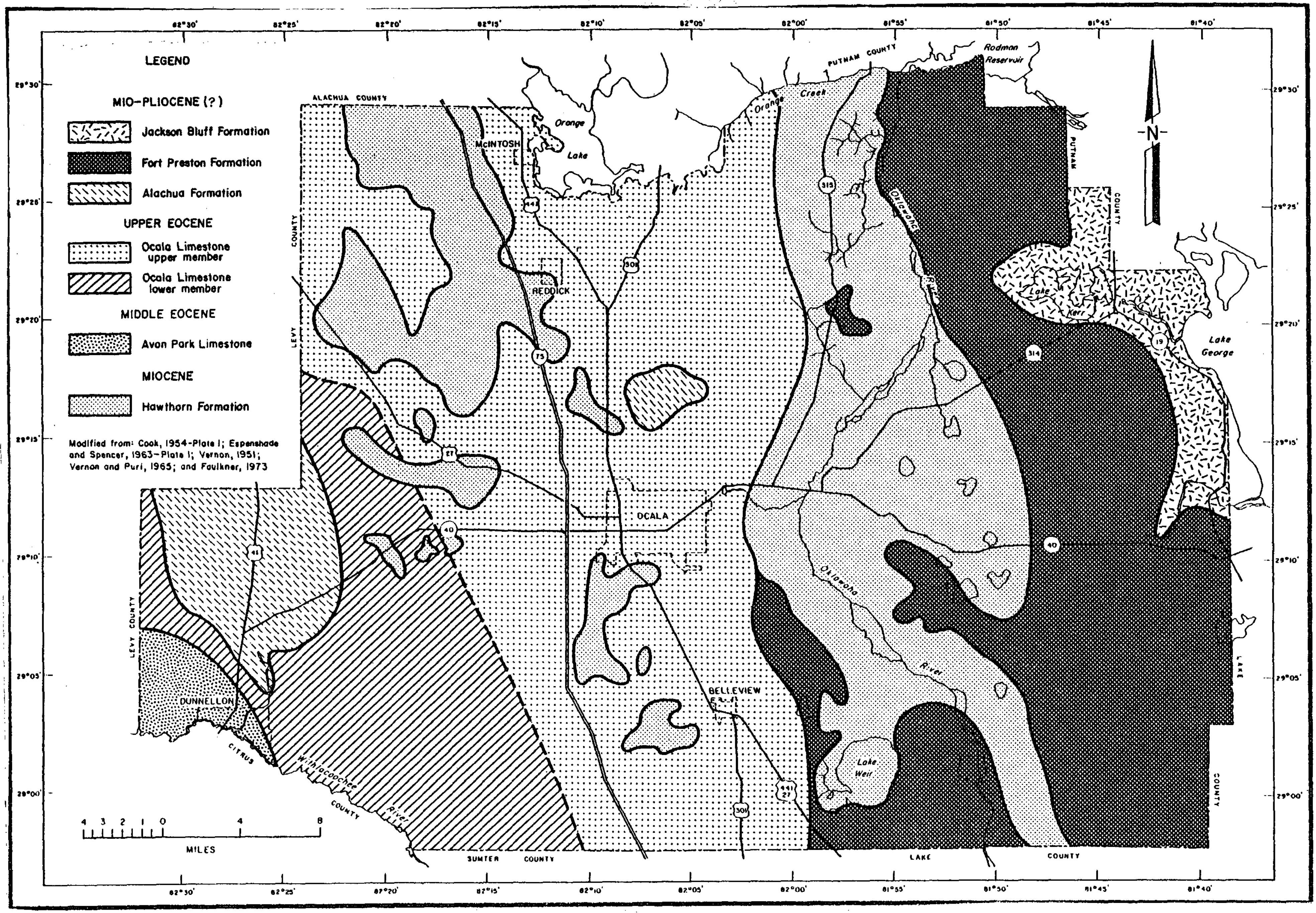

FIGURE 8. Geologic Map Showing Stratigraphic Units at or Near Land Surface.

The Hawthorn formation ranges from a few feet to approximately 140 feet thick and consists of shallow marine interbedded sand. The composition of the Hawthorn formation varies with large sections of carbonated and dolomite rock. The formation exhibits a sandy nature in the upper layers, with clays and clayey sand interspersed throughout the formation, and has a green to gray and white color. Permeable limestone and dolomites in the lower parts of the Hawthorn constitutes the uppermost part of the Floridan aquifer. The low permeability clays and clayey sands in the Hawthorn Formation comprise the confining unit of the Floridan aquifer.

The Fort Preston formation in the Lake Weir area overlies the Hawthorn formation and is interfingered with more than 100 feet of marginal, coarse marine, clastic sediments of middle Miocene age or younger. These sediments are multicolored with white, pink, lavender, tan and orange predominations and consist of poorly sorted quartz grains, that range from pebble size to fine grain. The Alachua formation is considered to be middle Miocene and possible Pliocene Age. The Alachua formation is estimated to be as much as 100 feet thick with irregularly interbedded deposits of clay, sand and sandy clay and to be interbedded by phosphate rock and silicified limestone residiuum in the lower formations. This limestone is the source of hardrock phosphate mining in the area.

The Jackson Bluff formation is present in the extreme eastern end of the County, in the vicinity of Lake Kerr, Salt Springs and Juniper Springs (Figure 8). The unit is considered younger than the lower Hawthorn and where it is present, it overlies the Hawthorn formations. The stratigraphic unit consists of argillaceous and carbonaceous sands and sandy shell marl with some phosphatic limestone or dolomite (Cook 1945), with a thickness of a few feet to 75 feet and more.

The Quaternary System of the Pleistocene Series overlies the Jackson Bluff formation. This stratigraphic unit, consists of the Pamilico and other marine quartz sand. It also contains some fluviatile and lacustrine sand, clay marl, and peat deposits. This overlying unit can be up to 100 feet thick and was developed from geologic shorelines generated by higher levels of the sea. (Cook 1945, MacNeil 1950). The unnamed alluvial lake and wind blown deposits is the youngest of basal units being laid some 10,000 years ago. The Holocene Series contains the alluvium, fresh water marl, peats and muds in streams and lake bottoms; and some windblown sand deposits, having depths up to 20 feet (Faulkner 1973).

SURFACE WATER

About 25 percent of the precipitation in Marion County contributes to surface drainage which supplies the Oklawaha River, Withlacoochee River, lakes and ponds in the county. The remainder, excluding evapotranspiration, percolates through the surficial unconsolidated material supplying the Floridan aquifer. (Anderson and Faulkner 1973). The Floridan aquifer stores and transports the water to points of major discharge, such as springs within the county.

OCCURRENCE AND MOVEMENT

The Oklawaha River is the largest river system in Marion County. It flows northeasterly bisecting the county and has major confluences at the Silver River, Eaton Creek and Orange Creek. Orange and Eaton Creeks are the major tributaries to the Oklawaha River downstream of Silver River. Eaton Creek is a slow moving stream which empties into the Oklawaha River. It is the major conveyance for the drainage of Eaton and Mud lakes. Orange Creeks headwater is located at Orange Lake and flows eastward into the Oklawaha River near Orange Springs. Discharge measurement for the Oklawaha River near Ocala were discontinued due to the construction of Rodman Dam; however, for the 19 years of available record (1950 to 1969) the mean discharge was 429.56 cfs. A minimum of 7.2 cfs and a maximum 2190 cfs demonstrates the variability of flow. The second largest river is the Withlacoochee River and flows northwesterly along the southwestern periphery of Marion County. The Withlacoochee receives discharge from Rainbow Springs by way of Rainbow River. From a fifteen year continuous record (1965-1979) the mean discharge for Rainbow Springs is 730 cfs (472 mgd). The maximum recorded discharge is 1040 cfs and the minimum is 548 cfs.

Major problems with surface water usually result from variability in stage and flow. This is due to the variability in the rate and distribution of rainfall, both seasonally and annually. Orange Creek at Orange Springs has a 26 year average of 158.33 cfs from 1950 to 1979, excluding those years data was not measured, (1953, 1954, 1955, and 1972). The Withlacoochee River, according to 10 years of record (1970 to 1979) at Inglis Dam, exhibited a mean discharge of 317.13 cfs. Figure 9A and 9B demonstrates this variability by illustrating the yearly discharge departures from normal for Orange Creek and the Withlacoochee River. The dash line illustrates the summation of cumulative departures. The variation in yearly discharge departures from the average is shown to be large. This could be in part due to the regions experiencing a severe drought during 1977. The average during this period could be significantly lower than the true average as seen in Figure 9B. Variation in the flow of streams in Marion County, except Orange Creek and the Oklawaha River upstream from Silver River, is much less than that of most other streams in Florida. This is due to the high base flow supplied by the large springs in the county. Large discharges typically result from extended periods of extreme rainfall rather than short duration events due to the large storage capacity of the swamps and lowlands. Average flows are generally less than three times the minimum flow (Anderson, Faulkner, 1973). Long term monthly variation in average stream flow is relatively low due to the low variability of average monthly rainfall, the high rate of evapotranspiration that occurs in summer and large storage volume available from lakes.

The origin of most streams in Marion County are derived from major discharge points of ground water including: Silver Springs, Rainbow

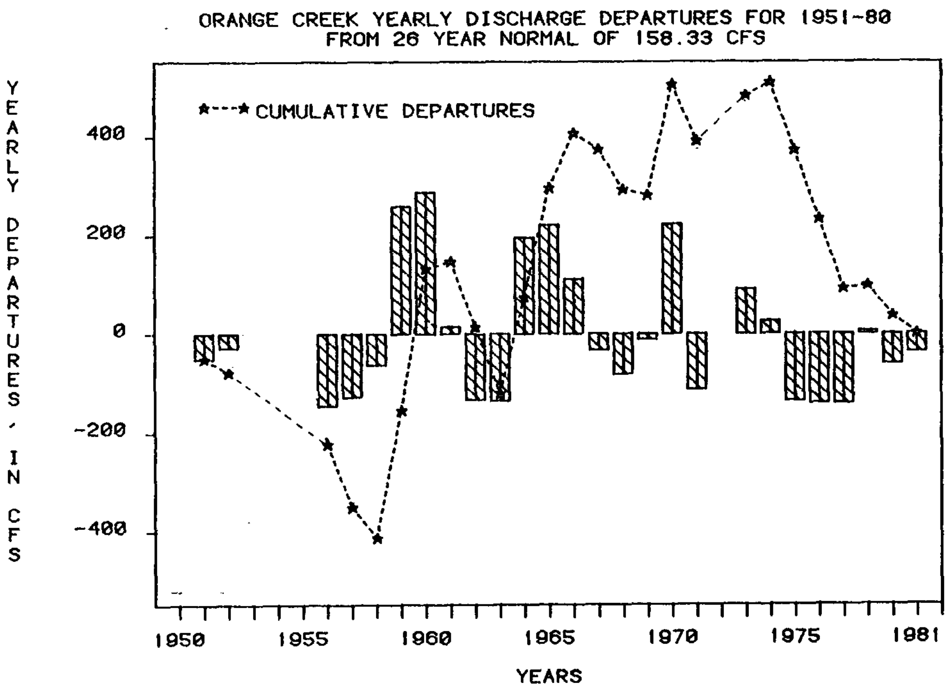

FIGURE 9A. Orange Creek Yearly Discharge Departures (1951-1980).

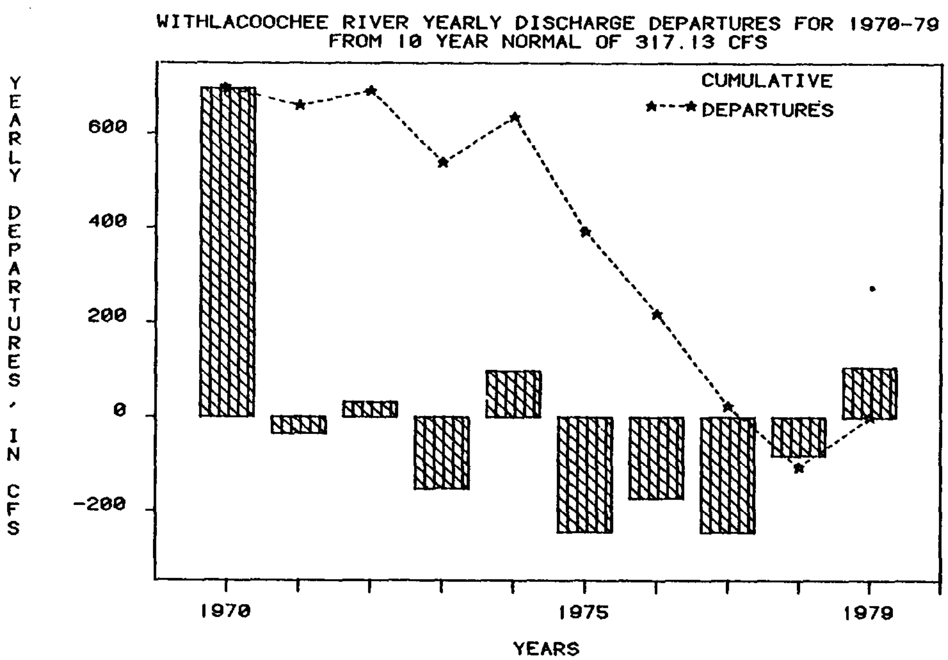

FIGURE 9B. Withlacoochee River Yearly Discharge Departures (1970-1979).

Springs and Silver Glen Springs. Figure 10A illustrates the yearly maximum, mean, and minimum discharge values for Silver Springs over thirty year period of record (1950 - 1980). A thirty year average of 800.88 cfs for the same period is shown with the cumulative departures illustrating the variation in yearly discharge. (Figure 10B).

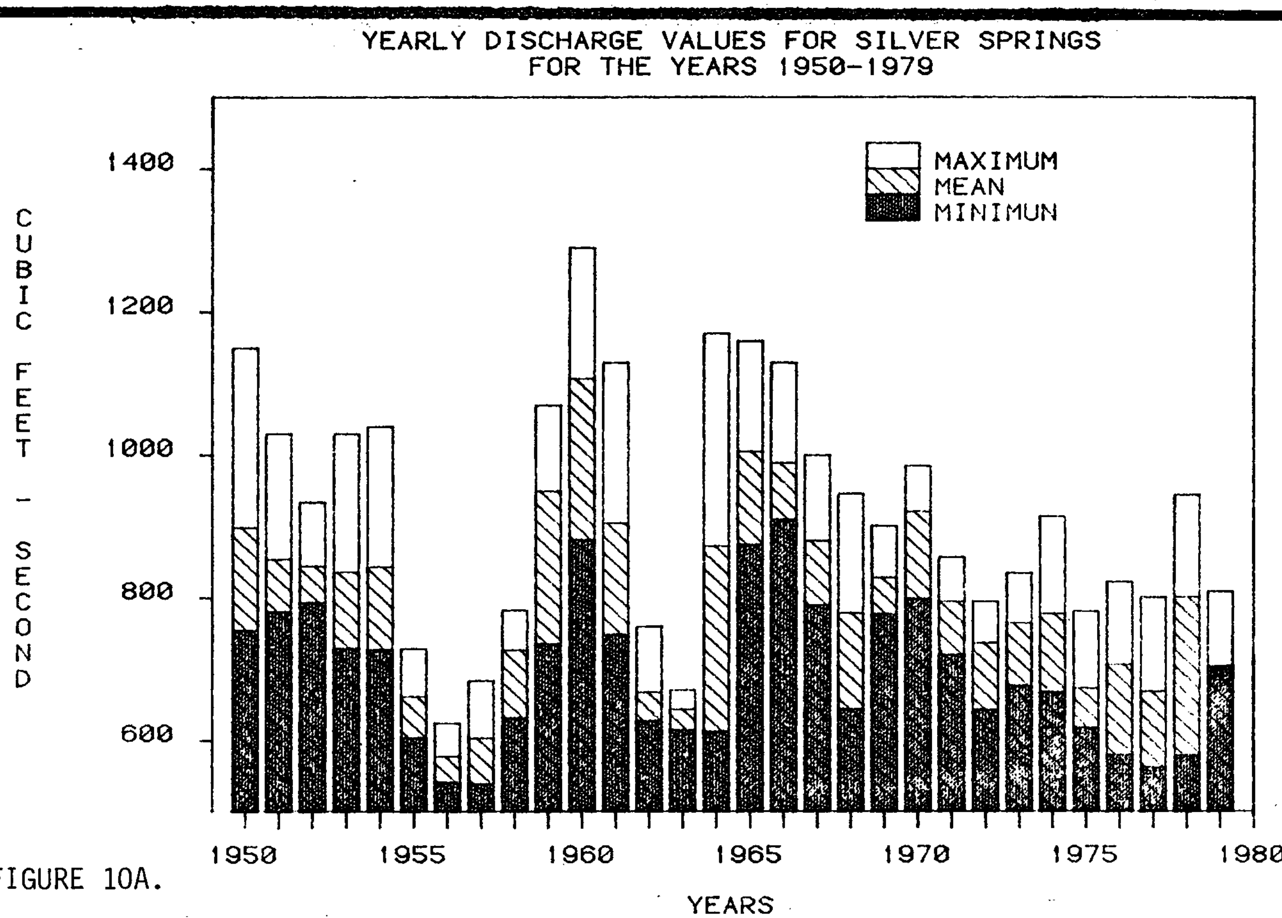

FIGURE 10A.

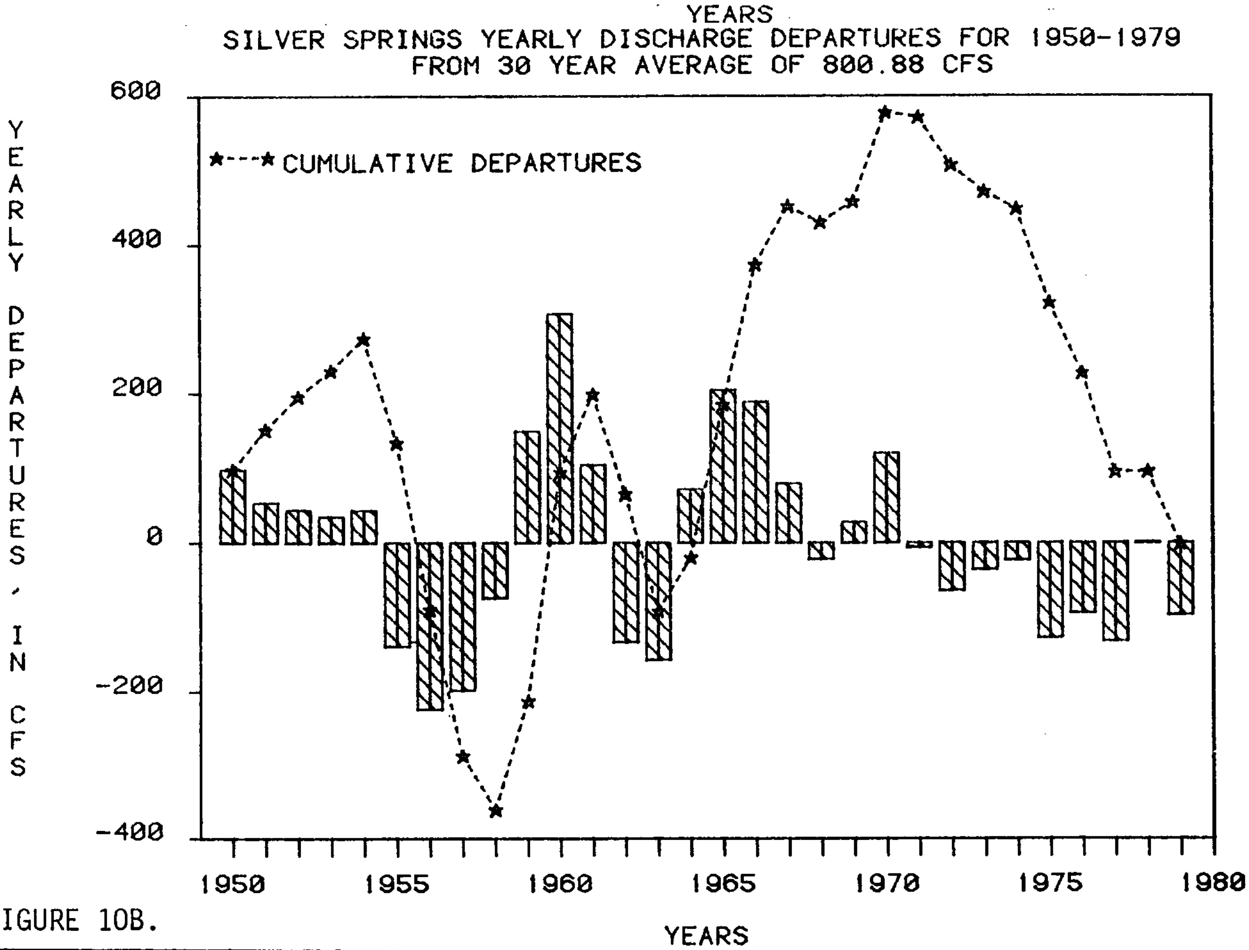

FIGURE 10B.

FIGURE 10A. Yearly Discharge Values for Silver Springs (1950-1979).
10B. Silver Springs Yearly Discharge Departures (1950-1979).

Lakes

Lakes play an important role in the surface water hydrology of Marion County. Lakes in Marion County fluctuate in response to rainfall, evaporation, surface and ground water levels. Long term monitoring of lakes indicate the net fluctuations, due to precipitation and evaporation, are similar to those found for most lakes in Florida. (Hughes 1974). Therefore, the magnitude of lake level fluctuations is due to local variations in topography, permeability and thickness of underlying geologic stratigraphy.

Most of the lakes in the county have a direct connection with the Floridan aquifer, thus recharging the aquifer when there are deficits in rainfall. The amount of leakage to the Floridan aquifer is directly proportional to the permeability of the confining layer, and to the difference between the lake level and the potentiometric level of water in the Floridan aquifer. Other major hydrologic functions of lakes are the moderating effect on the climate through the process of evaporation and possible reduction of swamps through surface storage.

Lakes in or adjacent to Marion County range in size from filled depressions to Lake George, which has a surface area of 46,000 acres. Lake altitudes range from about one foot for Lake George to more than 190 feet for those lakes located southwest of Orange Lake.

Prairies such as Hopkins Prairie and Black Sink Prairie respond typically like lakes. Prairies are generally formed through solution of the underlying limestone and subsequent settling of the terrain. Water levels in prairies fluctuate seasonally based on hydrological conditions.

Quality

Total dissolved solids are a primary water quality parameter commonly used to characterize waters. Rainfall generally contains only small amounts of dissolved minerals, whereas, streams and lakes have higher concentrations of dissolved solids when in contact with waters which are affected by the dissolution of limestone and dolomite. These greater concentrations of dissolved solids occur from contact either with the Floridan aquifer or the solution of limestone in streams where the limestone is near or at the surface. Because swift movement of surface water decreases the rate of dissolution, the concentration of dissolved solids in surface waters is comparatively lower than the more static ground water. Therefore, during low flow periods, total concentrations generally increase due to ground water inflow. Anderson and Faulkner (1973) have described the mineral (total dissolved solids) content of streams in Marion County as ranging from soft (20 mg/l) to very hard (400 mg/l). Most water in streams in Marion County and to a lesser degree in lakes, is of the calcium and magnesium bicarbonate type.

Evidence shows the mineral content of Orange Creek varies to a lesser degree than that of other streams in the county because nearly all its flow is derived from Orange Lake, direct surface runoff, or seepage from the shallow aquifer. The Oklawaha River south of Moss Bluff also has a low mineral content as its flow is derived from surface inflow and seepage from the shallow aquifer. The Withlacoochee River near Holder exhibits a higher mineral concentration during low-flow periods, which decreases during high-flow periods. This is partially due to the base flow of Floridan aquifer water from Rainbow Springs. Data also shows higher concentrations of dissolved solids at Silver Springs than at Rainbow Springs. This observation is attributed to the relative residence time of ground water in the Floridan aquifer.

Chloride concentration has been found to be negligible in lakes and most streams. Higher concentrations are found in the extreme northeast corner around Salt Springs where levels exceed 2400 mg/l. It is the opinion of the author that the high levels of chlorides are due to highly mineralized water upwelling through fracture zones within the Floridan aquifer found in this area.

GROUND WATER

Ground water in Marion County is derived from two aquifers. The most important of the two, as a source of water supply, is the Floridan aquifer. The Floridan aquifer varies considerably in porosity and permeability in both vertical and horizontal directions. The Floridan aquifer is composed almost entirely of limestone and dolomite which ranges in age from middle Eocene to middle Miocene.

Overlying the Floridan aquifer is the shallow aquifer consisting of permeable sand and shell beds. Materials composing the shallow aquifer range in age from lower Miocene to Holocene.

SHALLOW AQUIFER

The unconfined or shallow aquifer consists mainly of medium-fine sand, silt, clayey sand, and limestone. Ground water in the shallow aquifer is the sub-surface water present in the zone of saturation. Water in the zone of saturation moves both laterally and vertically under the influence of gravity to points of discharge. The shallow aquifer's main function is to act as a storage reservoir for recharge to the Floridan aquifer (Wyrich, 1960).

Recharge

Recharge to the shallow aquifer occurs directly by local rainfall which has not been intercepted by physical constraints (evapotranspiration, runoff, interception by foliage and storage). The water table in the shallow aquifer generally follows the topographic relief but to a lesser degree and is generally from 10 to 40 feet below land surface and at or near land surface at lakes and swamps. (Snell and Anderson, 1970). There is a direct relationship to rainfall fluctuations and water levels in shallow aquifers. Water levels in the Floridan and shallow aquifers generally are within three feet of each other. While in locations of higher relief, such as in the Ocala Forest, the water level in the shallow aquifer may consistently fluctuate within a range from 20 to 30 feet higher than that of the Floridan aquifer. Water levels in the shallow aquifer wells often fluctuate more rapidly and over wider ranges than that of the Floridan aquifer during periods of heavy rainfall. (Faulkner, 1973).

Water Quality

Shallow aquifers are predominantly utilized for domestic applications. In the Ocala National Forest where surficial sand deposits extend to depths of 300 feet, potable water supply from the shallow aquifer is the most cost-effective alternative. In the northern part of the Ocala Forest near the Oklawaha River, the Floridan aquifer contains high levels of chlorides, therefore, the shallow aquifer is preferred for domestic use. (Faulkner, 1973). The water quality in the shallow aquifer is generally good with TDS and hardness less than that found in the Floridan aquifer. Turbidity problems caused by suspended clay have been observed in shallow wells located in the northeast corner of the Ocala Forest. This problem can be mitigated by drilling deeper in zones of lesser clay. (Faulkner, 1973). Shallow wells located near ponds or lakes have shown problems with high iron concentrations, although this problem can be avoided by drilling deeper or relocating.

FLORIDAN AQUIFER

The Floridan aquifer is the primary supply of potable water for domestic, industrial, public and agricultural uses. The Floridan aquifer in Marion County includes the hydraulically connected permeable limestone and shell beds of the following: the Hawthorn Formation of the Miocene age, the Ocala group consisting of the Crystal River, Williston, and Inglis Formation, and the underlying Avon Park and Lake City limestones, all of the Eocene Age.

Character and Distribution

The Floridan aquifer is near land surface in the central part of the county but its depth varies considerably. It is one of the most extensive limestone aquifers in the United States with a thickness of 1,500 feet along the north and south sides of the Ocala uplift (Stringfield, 1966). Generally the thickness ranges from 1,000 to 1,200 feet along the Cross-Florida Barge Canal (Chen, 1965). In the area of the Ocala uplift much of the Floridan aquifer is unconfined and therefore under water table conditions. The aquifer is confined in areas of low depression where sediments northeast of Silver Springs underlie the Oklawaha River Valley. Along the river, artesian flow occurs from wells that penetrate the Floridan aquifer (Faulkner 1973).

Potentiometric Surface

The potentiometric surface is that surface that represents the static head or pressure of water in the aquifer. It is defined by the level in which water will rise in a tightly cased well penetrating the aquifer. The observed potentiometric levels are used to predict the direction of ground water flow, and other important geohydrologic relationships. The potentiometric surface fluctuates in response to recharge from precipitation and discharge from pumping of wells in the aquifer. Ground water moves from recharge areas toward discharge areas. The direction of flow can be traced as reflected in the slope of the potentiometric surface at right angles to the potentiometric contours. The potentiometric surface maps for September 1980 and May 1981 (Figures 11, 12) illustrate the contour patterns in Marion County. The potentiometric contour map of May 1981 is added to provide a comparison illustrating the beginning of a dry season, while the September 1980 compares the potentiometric surface, ending with a wet season. General pattern of the contours shows little variation, but does illustrate a general decline in water levels. This may result from the decline in the amount of rainfall needed to sufficiently recharge the aquifer, and/or the result of increased pumping of ground water.

Figure 13 shows a hydrograph of the Barlow (C-31) well located south of Ocala depicting the yearly ground water level departures from a 30 year average (1950-1980) of 44.79 feet (NGVD). The year 1953 was omitted from the graph because of incomplete data. The graph also illustrates the balance of deficits and surplus from the 30 year average.

Recharge

Recharge to the Floridan aquifer occurs where the potentiometric surface is at an elevation lower than the water table, provided, material covering the aquifer permits infiltration. Water is transmitted from the unconsolidated deposits consisting of sand and shell material, limey sand, silt and clay through the Hawthorn Formation. The Floridan aquifer is recharged at a rate depending upon head differences between the aquifer and its thickness and the vertical permeability of the confining unit.

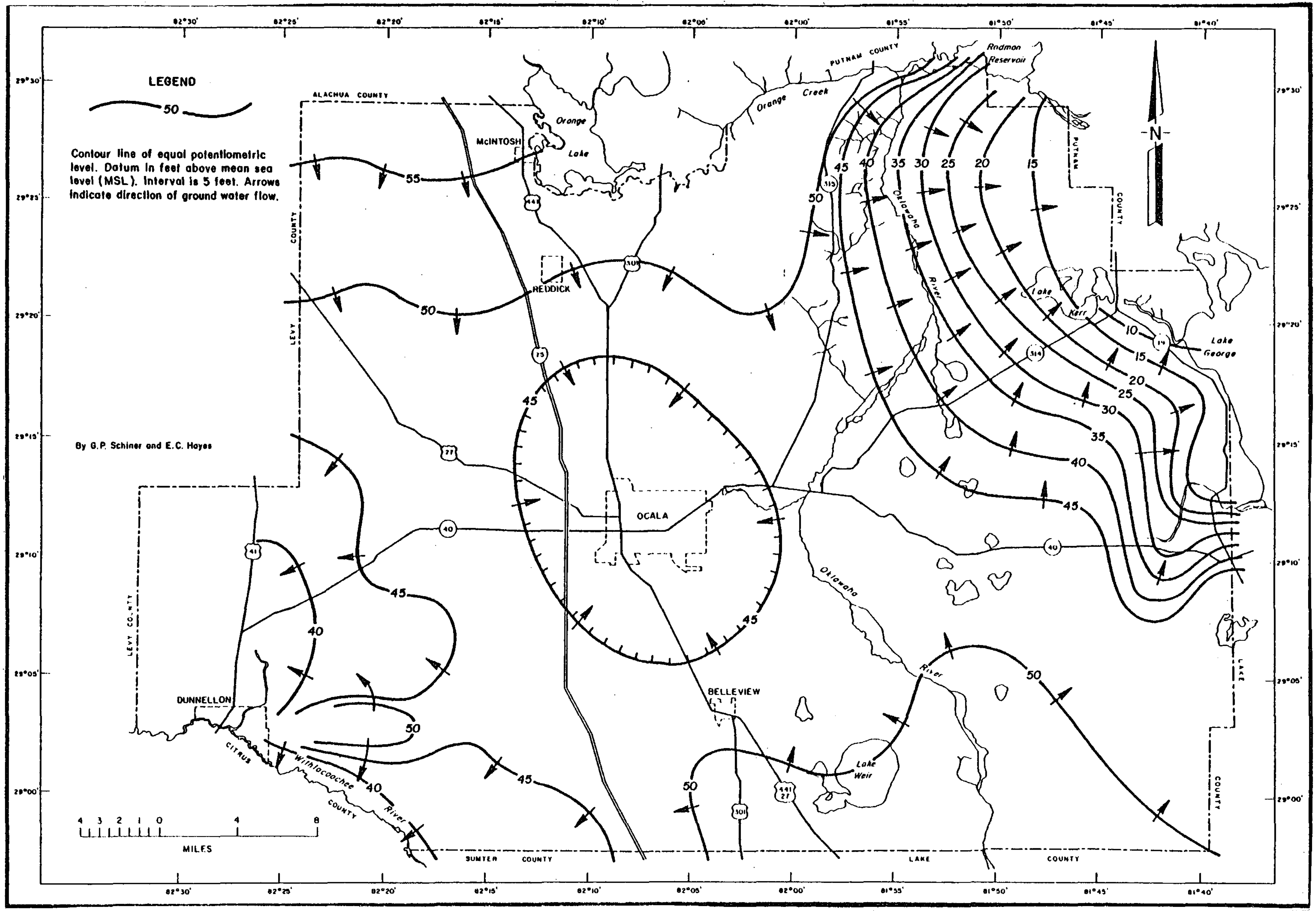

FIGURE 11. Potentiometric Surface Map of the Floridan aquifer September 1980.

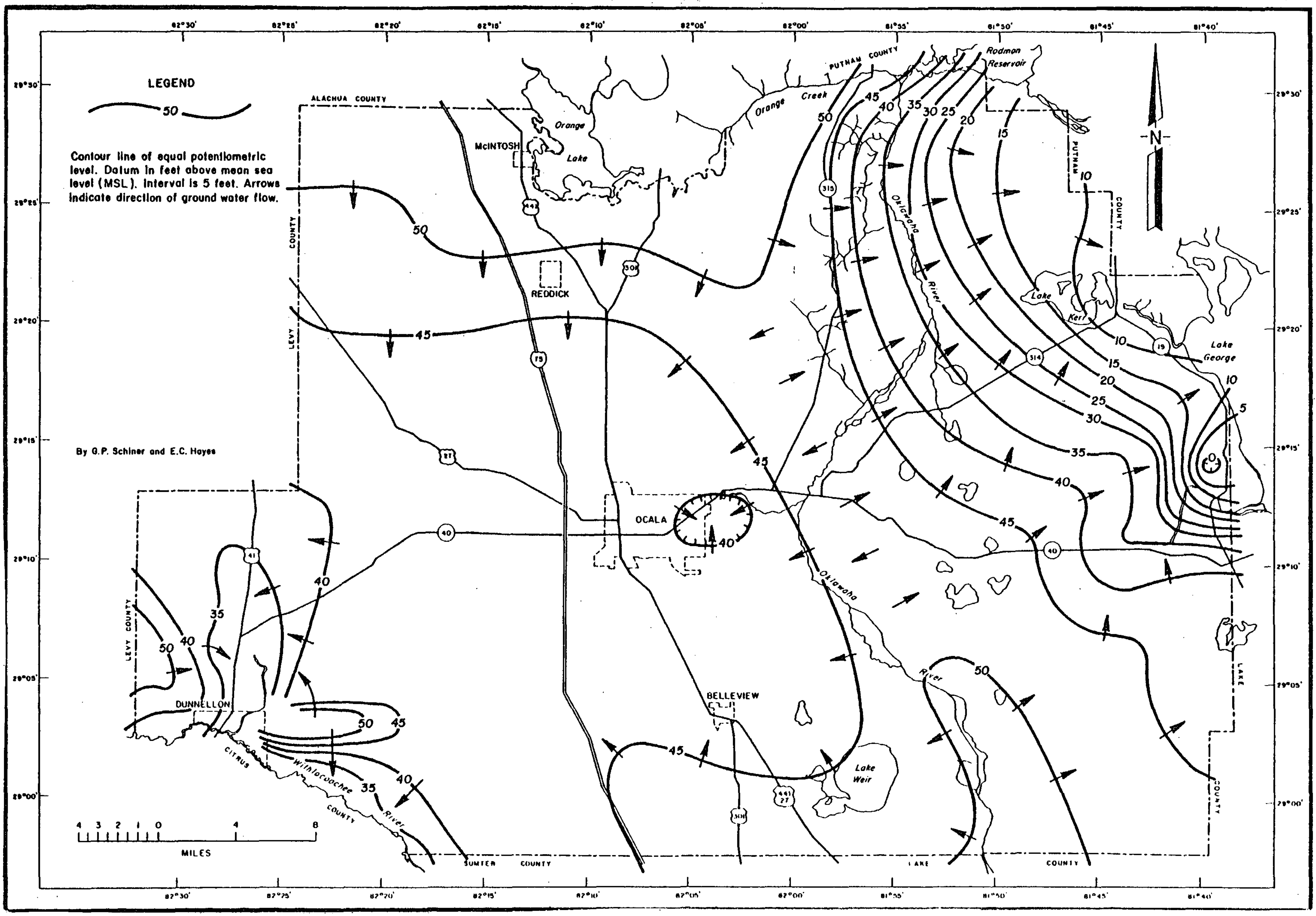

FIGURE 12. Potentiometric Surface Map of the Floridan aquifer May 1981.

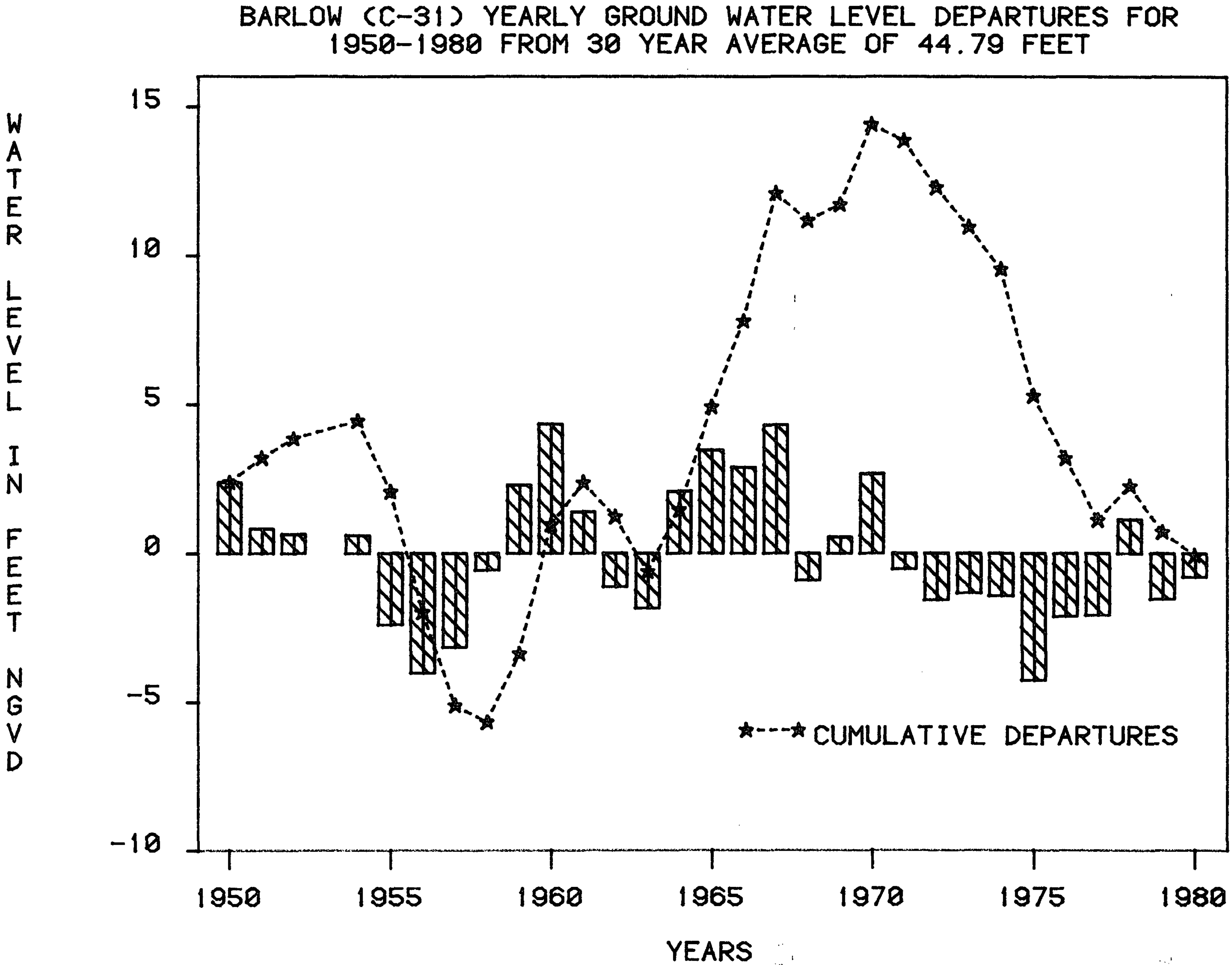

FIGURE 13. Barlow (C-31) Yearly Ground Water Departure (1950-1980).

Recharge also occurs directly through sinkholes and lakes hydraulically connected to the aquifer. Comparing hydrographs of rainfall, lake levels, ground water levels and discharge demonstrates the close inter-relationship of all the hydrologic components (Figure 14). Areas of Potential recharge to the Floridan aquifer occur predominantly to the east and west of the Oklawaha River (Figure 15). Average annual recharge has been estimated for the Silver Springs ground water drainage basin to be 15.3 inches, and 15.2 inches for Rainbow Springs east of the Oklawaha River, where surficial deposits overlie the Floridan aquifer (Faulkner, 1973). The Floridan aquifer receives little or no recharge in the Oklawaha River Valley due to the thick, overlying confining layer and the artesian flow in the valley. East of the river valley, along the Mount Dora Ridge, the top of the aquifer is higher due to uplift along normal faults. Here recharge to the aquifer occurs through sands and clayey sands of the Fort Preston formation. West of the Oklawaha River recharge is moderate due to the presence of the Hawthorn formation, which ranges in thickness from a few feet to about 140 feet.

Recharge to the aquifer in the area of Rainbow Spring occurs primarily to the south and west where the Avon Park limestone is near the surface. The permeability is somewhat lower due to the effects of sand and clay filling solution cavities, but in general, there is good recharge.

Discharge

Ground water in the Floridan aquifer moves laterally toward points of discharge, where the potentiometric surface of a confined aquifer is above land surface. The rate of discharge varies with the head difference, thickness and permeability of the confining bed. Springs are points of discharge in Marion County, of which three are classified as first

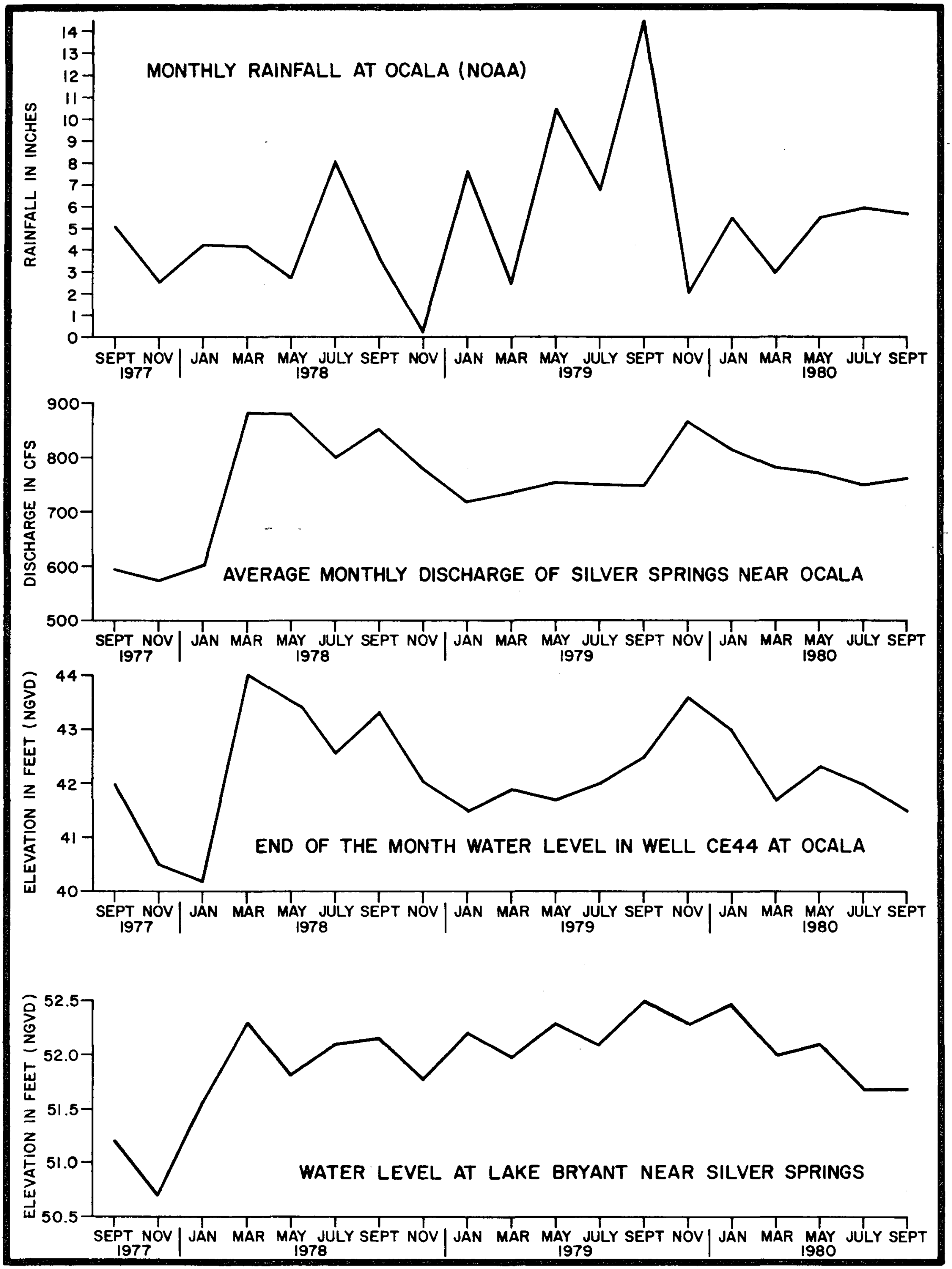

FIGURE 14. Hydrographs Showing Interrelationship of Rainfall, Water Level in Floridan aquifer, and Discharge of Silver Springs.

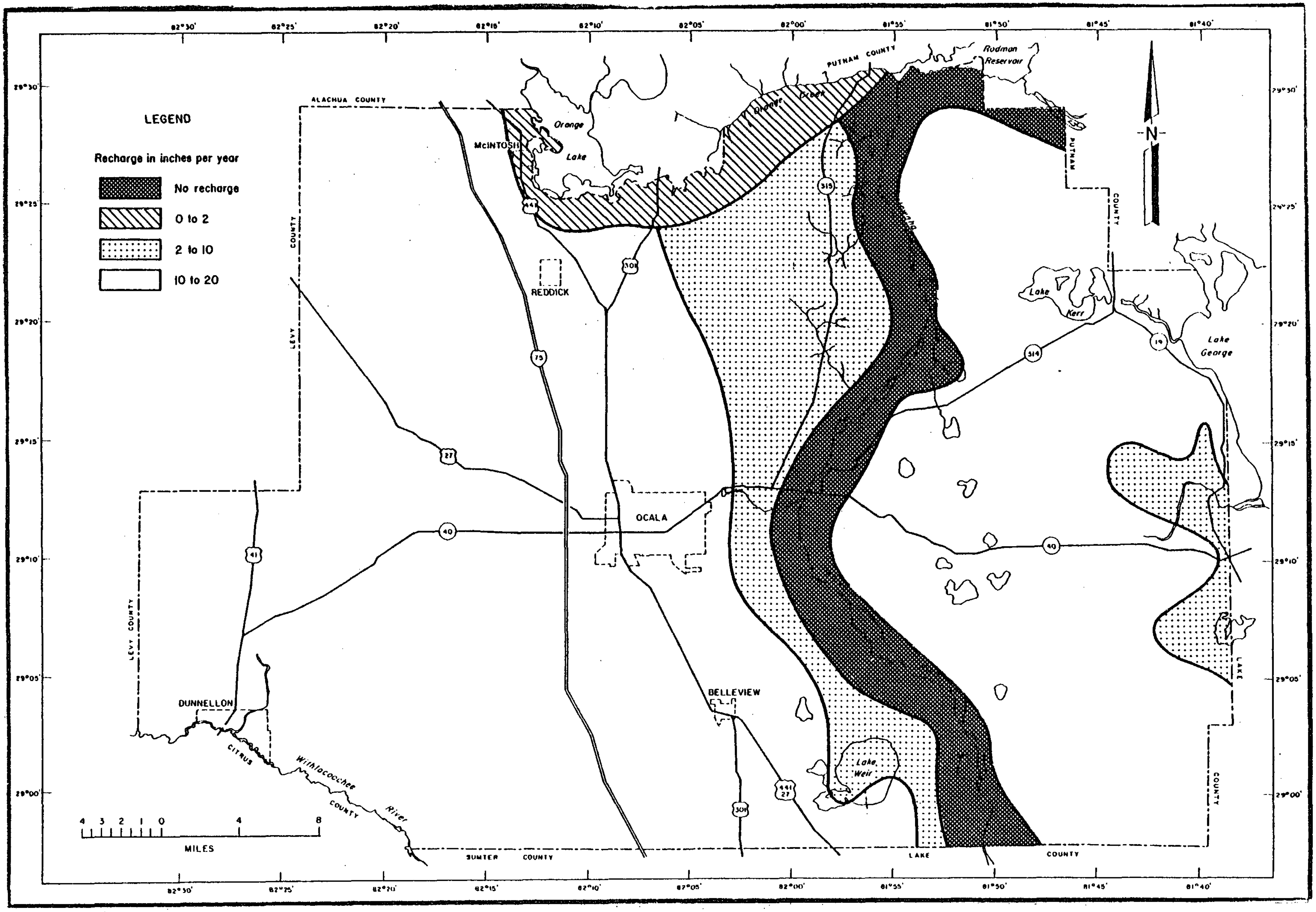

FIGURE 15. Areas of Natural Recharge to the Floridan aquifer.

magnitude having an average flow of one hundred cubic feet per second or more. They are Silver Springs (517 million gallons a day), Rainbow Springs (470 mgd), and Silver Glen (72 mgd); other points of discharge include Fern Hammock, Juniper, Orange, Salt, and Wilson Head Springs.

Water Quality

Water quality in the Floridan aquifer varies with depth and location within the county. Ground water contains less dissolved solids in recharge areas where percolation of rain directly influence the quality of water, while high concentrations of dissolved solids occur in the limestone as the result of dissolution. Chloride levels are generally low except where upwelling of connate water or overpumping has caused salt water encroachment. Figure 16 is a contour map of chloride concentrations with an emphasis in the area of the barge canal. The concentrations of chlorides are low, generally below 40 mg/l. High concentrations are observed in wells in the Oklawaha River Valley just below Silver River. This is believed to be a result of upward leakage in the Oklawaha River Channel. It is noted that chloride concentrations are observed higher in the area of Salt Springs, also due to upwelling of highly mineralized water through fractures in the limestone. The altitude of the freshwater/saltwater interface, based on the Ghyben-Hergberg principle, is more than 1,500 feet below land surface as noted by Faulkner, 1973.

Specific conductance is one of the more common types of ground water quality data collected. Specific conductance aids in the identification of areas of important recharge. Low values indicate recharge areas where high values tend to indicate slow moving older ground water and poorly permeable formations. Higher specific conductance values shown in Figure 17 occur in the area Northeast of Silver Springs where the top of the aquifer is as

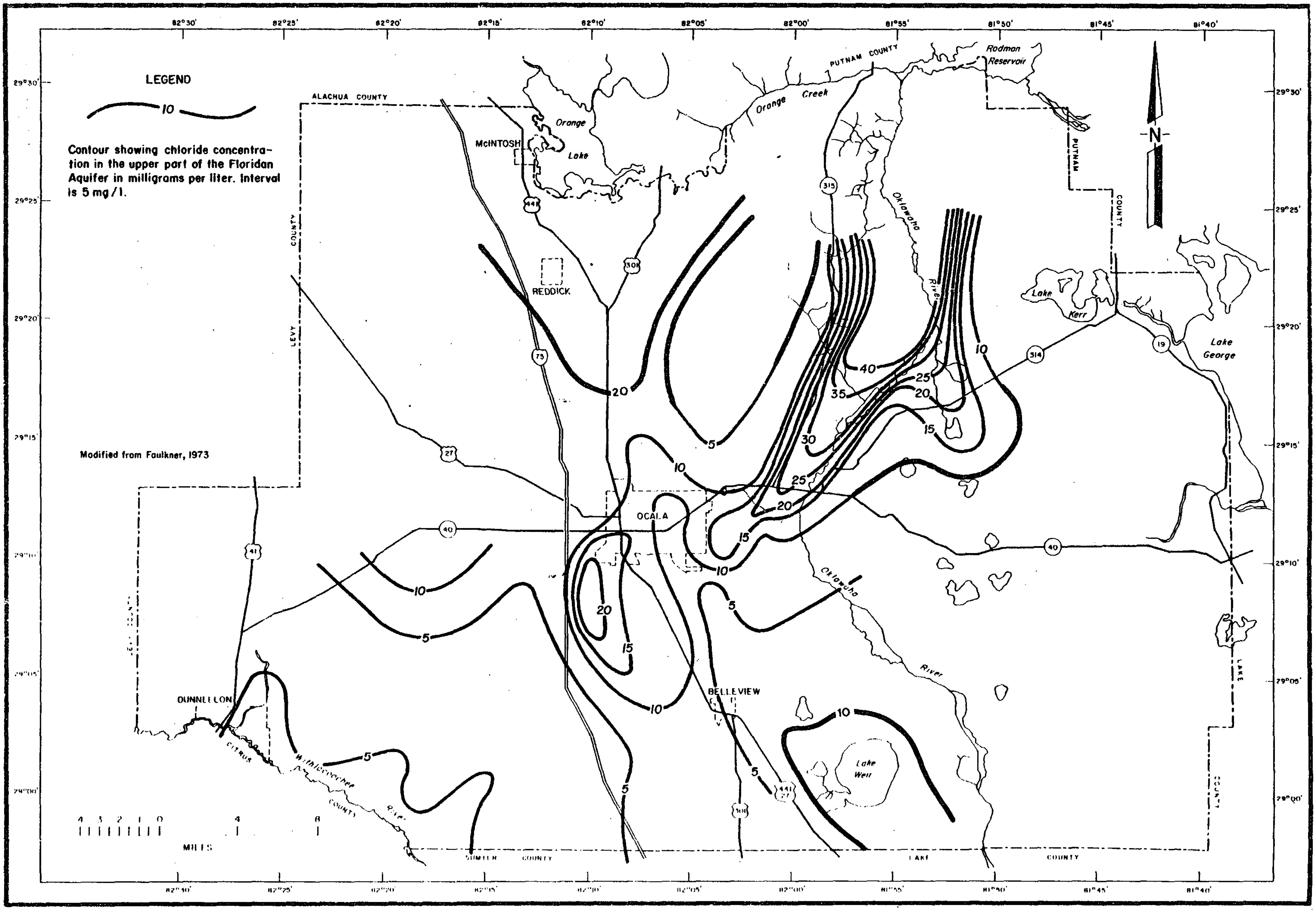

FIGURE 16. Chloride Concentration of ground water in upper part of the Floridan aquifer.

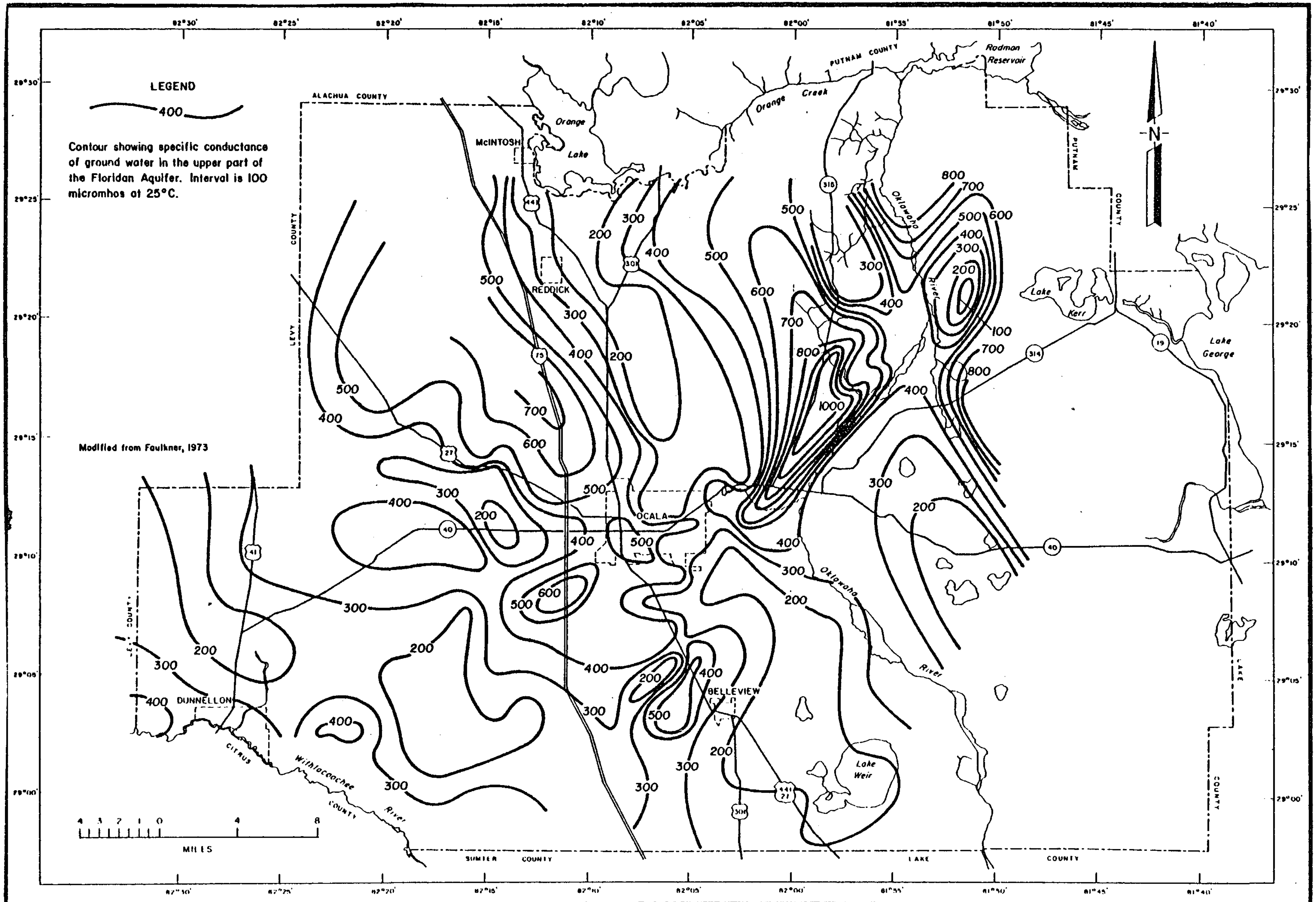

FIGURE 17. Specific Conductivity of Ground Water in upper part of the Floridan aquifer.

much as 200 feet below sea level and where it is covered by up to 250 feet of poorly permeable materials (Faulkner 1973). Areas of low specific conductance are observed in major flow zones located northwest and southeast of Silver Springs where recharge and major ground water movement is noted. Bacterial contamination is of little problem in Marion County due to the natural filtration system by sands, clayey sands or clay cover having a thickness of tens of feet. The only risk of contamination could be through natural sinkholes or drainage wells where there is recharge directly in wells having systems of well developed flow channels.

Dissolved hydrogen sulfide gas commonly causes odor problems from wells located in the river valleys and in deep wells. Relocating and using shallow wells or aerators may eliminate this problem.

Tansmissivity

Transmissivity is the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. Transmissivity values are generally greater in the area surrounding discharge points, and declines as the distance increases from the discharge point. Utilizing Darcys Law, Faulkner (1973) calculated an average transmissivity assuming a 100 foot thick aquifer in the area of Silver Springs. In this paper he calculated the flow across three closed potential contours surrounding the spring as follows:

$$T = \frac{Q-R}{IL}$$

where T = transmissivity, in gpd/ft. (gallons per day per foot width of aquifer)

Q = spring discharge in gpd

R = recharge in gpd in area enclosed by potential contour at which average transmissivity is calculated.

I = average hydraulic gradient across potential contour, in ft. per mi.

L = width of flow channel or length of closed potential contour, in miles

By treating Silver Springs as a discharging well and using a September 1968 potentiometric surface map, he evaluated the effects of the potentiometric surface using average transmissivities at the 45, 44, and 43 foot contours having 10,20, and 35 mgd/ft respectively. He calculated the average permeability to be 100,000; 200,000 and 350,000 gpd/ft^2.

Variation in transmissivity of the aquifer is very common. Such variability is due to the erosional removal of semi-confining beds and ground water movement through fracture zones (high transmissivity). Evidence of high transmissivity is indicated where potentiometric contours are widely spaced, while conversely, smaller spacing of contours indicate a lower transmissivity.

HYDROLOGIC BUDGET

A hydrologic budget can be a valuable tool to evaluate the effects of increasing population and its consequence on available water supply. Due to the growing concern to meet future water demand a hydrologic budget was constructed for Marion County so a dimensional presentation of the hydrologic regime could be evaluated.

WATER BUDGET EQUATION

The water budget equation is based on the principle of conservation of matter. The total input of water must equal total output, plus a net change in volume stored. (The change in storage volume was assumed to be negligible due to a preliminary analysis suggesting insignificant change.) The water budget equation is expressed by the following equation:

$$P + GW_1 + S_1 = ET + S_2 + P_u + GW_2$$

where P = precipitation

GW_1 = ground water inflow

S_1 = streamflow (in)

ET = evapotranspiration

S_2 = streamflow (out)

P_u = ground water pumpage (shallow and deep aquifer)

GW_2 = ground water outflow

The water budget for Marion County was estimated based on precipitation, discharge records and estimated evapotranspiration. Ground water flow within Marion County is based on recharge estimates and total area within the contributing ground water basins.

For the purpose of this report, recharge is defined as that portion of total precipitation not lost to evapotranspiration or surface runoff and is estimated for Marion County to be 17.2 inches per year.

Ground water inflows and outflows along the county periphery were estimated from the total counties areal percentage of ground water basin and estimates of recharge for neighboring counties as reported in the literature. (Clark et al., 1964; Yobbi and Chappel 1979; Knochenmus and Hughes 1976). Neighboring counties contributing ground water inflow to Marion County are shown in the ground water drainage basins depicted in Figure 18. The following table illustrates the transfers of ground water by basins and amount of recharge associated with each.

	Ground Water Contribution (mgd)		
	Recharge (inches)	Inflow	Outflow
Rainbow Springs			
a) Levy County (Basin 2)	17.2	136	
b) Marion County (Basin 2)	17.2		116
Silver Springs			
a) Alachua County (Basin 1)	10.0	65	
b) Lake County (Basin 3)	10.0	45	
Silver Glen Springs			
a) Putnam County (Basin 4)	14.3	67	
Alexander Springs			
a) Marion County (Basin 5)	17.2		69

Runoff

Runoff is the residual of precipitation after water loss through evaporation, transpiration and percolation occur. This portion eventually collects in streams and channels and drains from the area. The annual runoff is the only one of the four processes which can be measured directly and conveniently. Basin runoff (water yield) is determined by making streamflow measurements at gauging stations.

Entering from the south, the Oklawaha River at Moss Bluff has an average discharge of 303 cfs or 196 mgd for its 25 years of record. As it exits Marion County to the north at Rodman Dam, the Oklawaha River has an average discharge of 1585 cfs or 1024 mgd for its 12 years of record. In

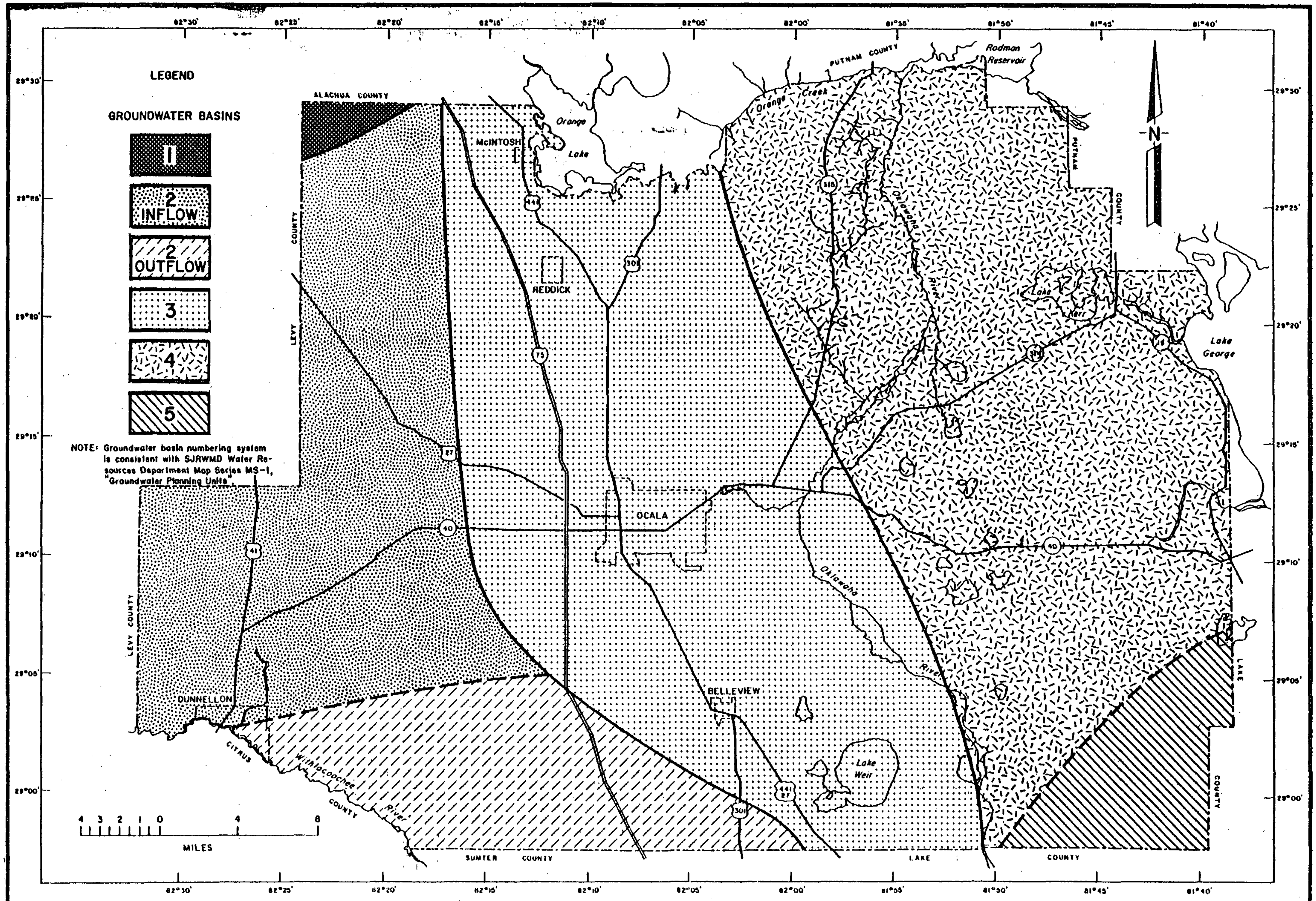

FIGURE 18. Ground Water Drainage Basins of Marion County.

addition, the Withlacoochee River average discharge of 760 mgd passes along the southwest corner of Marion County of which 472 mgd is contributed by Rainbow Springs. Along the eastern boundary, the St. Johns River has an average discharge of 6531 cfs or 4219 mgd based on a gauging station five miles southeast of Palatka with ten years of record.

Ground Water Use

Figure 19 depicts ground water use in Marion County for 1980. Agriculture irrigation represents the largest individual consumer of water (57.59%). Domestic use is the second largest use with 22.8 percent of the total. Public use (water supplied by the city) makes up 15.3 percent of the total supply. The other uses include livestock watering (2.4%) and industrial (1.8%).

A water use summary for Marion County performed by Meta Systems included projection of water withdrawn from surface and deep wells (Table 2). As indicated by the water use summary, a projected irrigational water demand of 55 percent is in close agreement with the 1980 total use graph. An estimated total water use in Marion County for 1980 was assessed at 36 mgd or 0.46 inches per year.

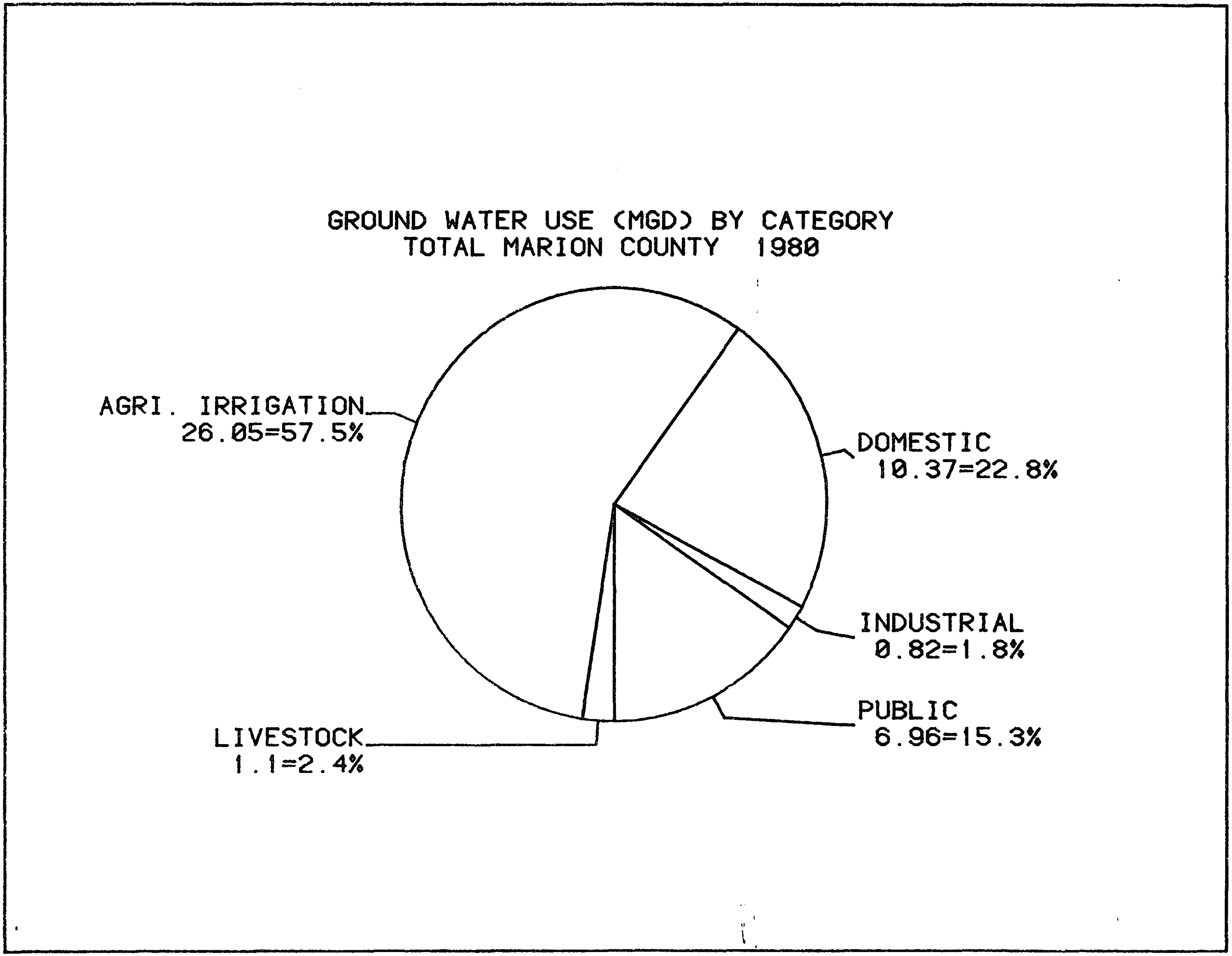

FIGURE 10. Ground Water Use Graph for Marion County

TABLE 2. Water Use Summary in Marion County

(10^6 gal/day)

	Municipalities Urban		Municipalities Rural		Irrigation		Livestock		Total	
Year	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
1980		11,123	2,685		2,627	13,797	1,474		6,786	24,921
1990		15,753	2,767		3,299	17,320	1,846		7,912	33,074
2000		18,739	2,657		3,969	20,844	2,222		8,849	39,583
2010		21,315	2,383		4,641	24,367	2,597		9,622	45,682
2020		22,822	2,438		5,326	27,967	2,973		10,737	50,789
2030		24,630	2,383		5,997	31,493	3,499		11,879	56,123

Assumption: Irrigation 16% surface
84% ground water
Irrigation acreage adjusted based upon 1969 Census of Agriculture Data.
<u>Source</u>: Meta Systems, Inc.

In summary, the estimated water budget for Marion County is depicted in Figure 20.

The following values were used to calculate the water budget:

$$P = 4247 \text{ mgd}$$

$$GW_1 = 313 \text{ mgd}$$

$$S_1 = 196 \text{ mgd}$$

$$ET = 2903 \text{ mgd}$$

$$S_2 = 1632 \text{ mgd}$$

$$P_u = 36 \text{ mgd}$$

$$GW_2 = 185 \text{ mgd}$$

Therefore: $4247 + 313 + 196 = 2903 + 1632 + 36 + 185$

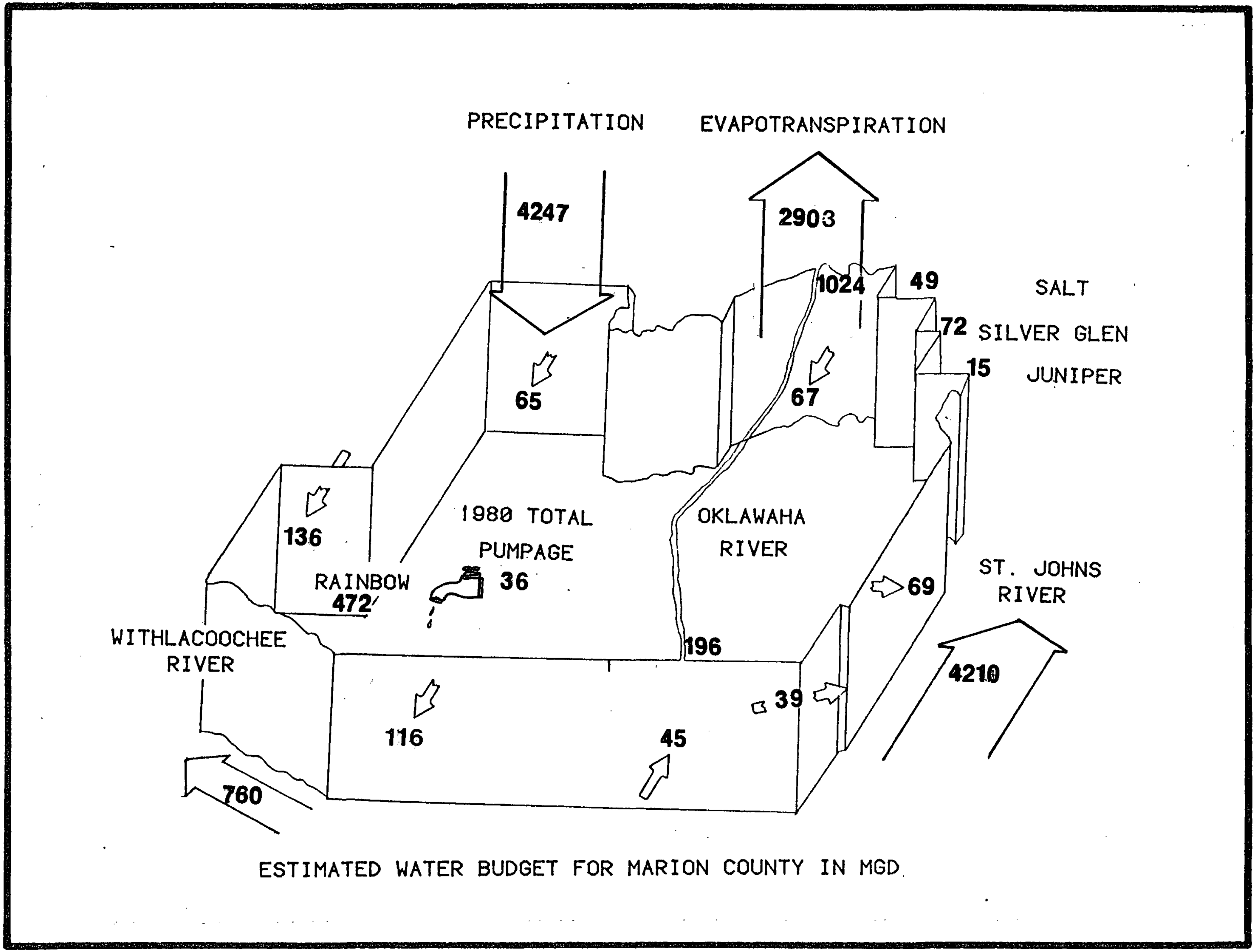

FIGURE 20. Estimated Water Budget for Marion County.

SUMMARY

The ground water in Marion County includes two freshwater aquifers. The shallow aquifer consisting of permeable sand and shell beds, and the Floridan aquifer consisting of limestone and dolomite. The Floridan aquifer is composed of all or part of three formations including Lake City, Avon Park, and Ocala Limestone. Recharge to the Floridan aquifer occurs predominantly to the east and west of the Oklawaha River at an estimated rate of 15.3 inches per year. Permeability estimates near Silver Springs range from 100,000 to 350,000 gal/day/ft.^{2}. Ground water quality is generally good, containing low levels of chlorides and total dissolved solids. Based on the potentiometric surface maps of the Floridan aquifer for September 1980 and May 1981, little change in ground water levels has occurred during the duration of observed records.

The Oklawaha River is the largest river system in Marion County, of which Orange and Eaton Creeks are major tributaries. The origin of most streams in Marion County are derived from discharge of ground water. The majority of the lakes in the county have direct connection with the Floridan aquifer fluctuating with response to ground water levels. Lakes in Marion County range in size from filled depressions to the size of Lake George which has a surface area of 46,000 acres. Surface water quality ranges from 20 mg/l (soft) to 400 mg/l (very hard) of the calcium and magnesium bicarbonate type. Due to the direct relationship of the amount of dissolved solids and the residence time, ground water from Silver Springs has a higher concentration of total dissolved solids than that found at Rainbow Springs. The highest concentrations are found in the northeast corner around Salt Springs. The chloride content in both the Oklawaha River and Withlacoochee River is generally below 5 mg/l.

Examining long-term records assisted in evaluating hydrologic trends. The records incorporate extremes, thus taking into account long term surpluses and deficits. By evidence of the graphs and cumulative departure, the hydrologic parameters appear to be cyclic, influenced by climatic conditions. Average values of the parameters aid in determining if hydrologic records for a given year deviate from the normal, providing the water management districts with a tool to base water conservation declarations.

Hydrologic parameters determined for Marion County include:

Parameter	Years of Recorded Considered	Average Value
Precipitation	30 years	53.82 inches
Pan Evaporation (Gainesville)	20 years	64.9 inches
Evapotranspiration	Annual	36.8 inches
Lake Evaporation	Annual	45.5 inches
Oklawaha River at Ocala	19 years	429.56 cfs
Withlacoochee River at Inglis Dam	10 years	317.13 cfs
Rainbow Springs	15 years	730 cfs
Orange Creek	26 years	158.33 cfs
Silver Springs	30 years	800.88 cfs
Water level Barlow (C-31)	30 years	44.79 (NGVD)

Comparing the potentiometric contour maps for September 1980 and May 1981 suggests increased withdrawals from ground water supplies in areas of concentrated populations. These areas of lower potentiometric levels have also been influenced by the deficit of precipitation for those years. Strong concern exists that increases in population, with their associated increases in water demand, may lower the potentiometric surface even further. Present water use in Marion County compared to available water supply presents no threat to increase water demand. Current conditions compared to long term records suggest a deficiency in precipitation, thus creating a deficiency in ground water levels, lake stages, and discharges from rivers. The water budget allows a 3-dimensional presentation of assembled hydrologic parameters, illustrating the hydrology and geohydrology of Marion County.

FUTURE CONSIDERATIONS

Marion County is a good recharge area and needs to ensure adequate area for maintaining maximum recharge. Monitoring water levels will also assist limiting water withdrawals during times of drought.

Suggested future research includes:

1. monitoring the recharge and discharge of ground water flow.
2. monitoring wells and lakes in order to establish a regional monitoring network for Marion County.
3. providing data on water quality.
4. plugging of free flowing wells.
5. large scale deep well pumping tests to establish quantitative characteristics of the Floridan aquifer.
6. compiling detailed information on the stratigraphy in Marion County in order to obtain precise delineation of the geologic structures.
7. deep well pump tests which may help to define routes of preferential ground water flow and to estimate drawdowns.
8. periodic monitoring of surface water discharge from local springs to get better handle of the total contribution.
9. establishing hydrologic monitoring station in key areas of the county , i.e., pan-evaporation data.
10. establishing deep well monitoring within the "no-flow boundary" located near intersection SR 14 and SR 40.

Appendix A

HYDROLOGIC DATA COLLECTION NETWORK

The hydrologic data collection network is comprised of those stations currently monitored from a state-wide network of observation wells, lake levels, and weather stations. This network is prepared by the U. S. Geological Survey in cooperation with the state and other agencies (Figure 21).

MONITORING NETWORK

Index Number	Site Number	Site ID
1	285900008207001	CE 86
2	285920081490501	CE 48
3	290223081554401	Lake Weir
4	290220081562001	CE 42
5	290455081530401	904-153-01
6	290452081525101	Oklawaha River above Moss Bluff
7	290412081592501	Smith Lake
8	290821082510301	Bryant
9	290312082190601	Well - USGS
10	290400082091001	CE 33
11	290552082044701	CE 81
12	290810082025001	CE 40
13	290953082081301	CE 79
14	291100082010001	Ocala East
15	291115081592501	Monitoring well U.S.G.S.
16	291015081385001	Juniper Springs
17	29112008202501	CE 31
18	29111008206001	CE 44
19	291139082073601	Ocala East
20	291233082082201	West
21	291310082045001	CE-45
22	291252082031501	Silver Springs
23	291244082031501	Stream gauge at Silver Spring
24	291250081591001	Oklawaha River near Conner
25	291600081550001	CE-55
26	291740081562001	CE-54
27	291750081494001	CE-56
28	2917440813906	Lake George near Salt Springs
29	29201508206501	Anthony Quad
30	2920100814600	Lake Kerr
31	2921000814350	CE-34
32	2922050820229	Fort McCoy Fire Station
33	2922000815100	CE-84
34	2925370811226	Orange Lake at Orange Lake
35	2925460815133	CE-67
36	2929330815718	Monitoring Well - U.S.G.S.
37	2930340815647	Orange Creek

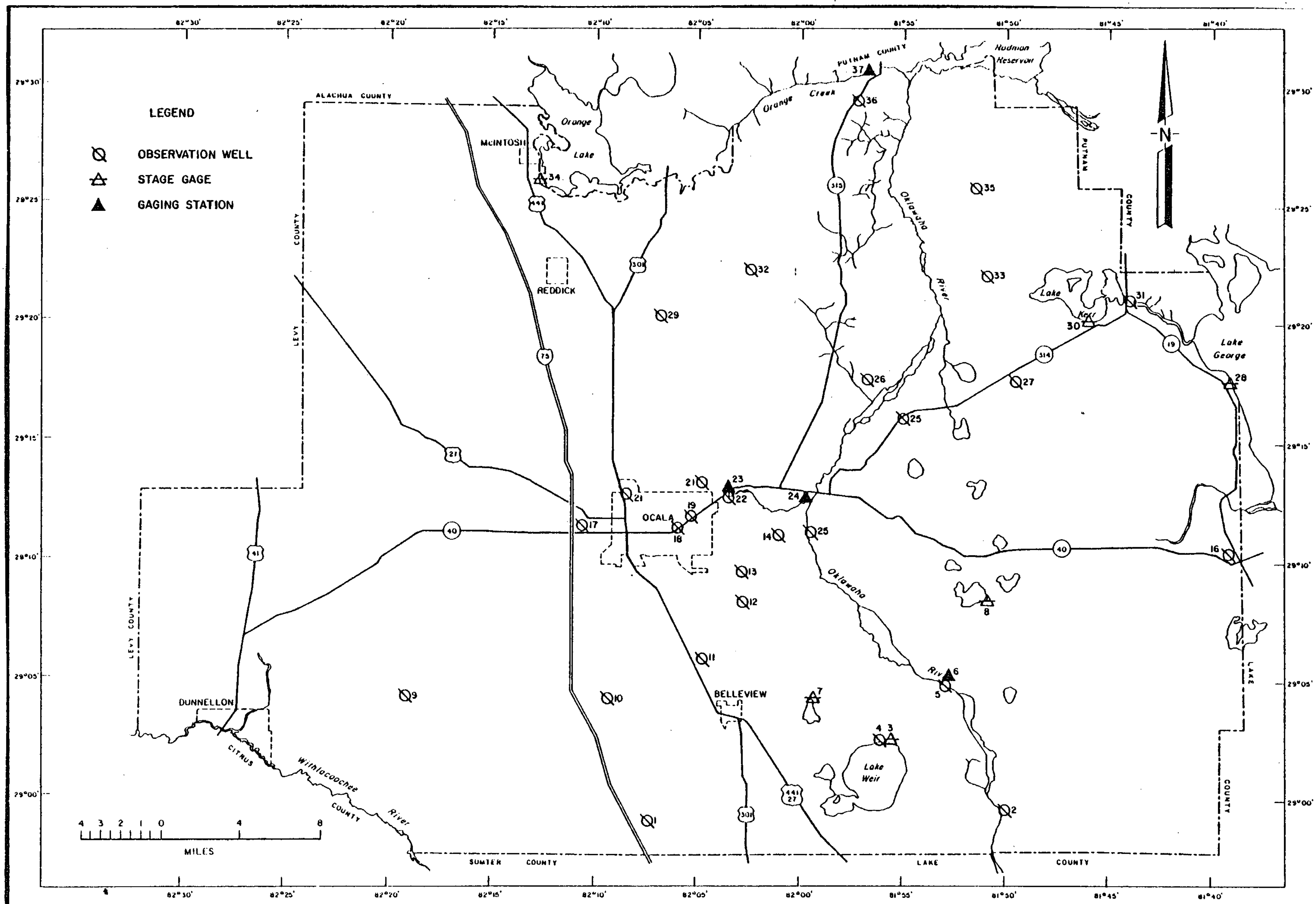

FIGURE 21. Location of Current Data Collection Stations in Marion County.

REFERENCES

Anderson, W. and Faulkner, G. L. 1973. Quantity and Quality of Surface Water in Marion County, Florida. Florida Bureau of Geology Map Series 55.

Anderson, W. 1980. Hydrology of Juniper Creek Canal Basin, Sumter County, Florida. U. S. Geological Survey Open File Report 80-208, 41 pp.

Bentley, C. B. 1977. Aquifer Test Analyses for the Floridan Aquifer in Flagler, Putnam, and St. Johns County, Florida. U. S. Geological Survey. Water Resource Investigation 77-36 50 pp.

Bermes, B. J., Leve, G. W., and Tarver, G. R., 1963. Geology and Ground water resources of Flagler, Putnam, and St. Johns Counties, Florida: Florida Geological Survey Report Investigation. Inv. 32, 97 pp.

Chen, Chih Shan, 1965. The regional lithostratigraphic analysis of Paleocene and Ecocene rocks of Florida: Florida Geological Survey Bull. 45, 105 pp.

Clark, William E., Musgrove, Rufus H., Menke, Clarence G., and Cagley, Joseph W., Jr., 1964. Water Resources of Alachua, Bradford, Clay and Union Counties, Florida: Florida Geological Survey Report Investigation 35, 170 pp.

Dohrenwend, R. E. 1977. Evaporation Patterns in Florida, Florida Scientist, Vol. 40, No. 2, pp 184 - 192.

Espenshade, Gilbert H. and Spencer, Charles W., 1963. Geology of Phosphate deposits of northern Peninsular Florida: U. S. Geological Survey Bulletin 1118, 115 pp.

Faulkner, Glen L., 1973. Geohydrology of the Cross Florida Barge Canal Area with special reference to the Ocala vicinity. U. S. Geological Survey. Water Resources Investigtion. 1-73. 117 pp.

Ferguson, G. E., Lingham, C. W., Love, S. K., and Vernon, R. W., 1947, Springs of Florida: Florida Geological Survey, Bulletin 31.

Healy, G. G., 1961. Potentiometric Surface of the Floridan Aquifer in Florida, July 6-17. Florida Division of Geology MS1.

Hughes, G. H., 1974. Water Balance of Lake Kerr; A Deductive Study of a Land Locked Lake in North Central Florida. Florida Bureau of Geology. Report of Investigation 73. pp 11-20.

Jensen, E. M., 1974. Consumptive Use of Water and Irrigation Water Requirements: American Society of Civil Engineers, pp 215.

Knochenmus, Darwin D., 1967. Tracer studies and background fluorescence of ground water in the Ocala, Florida area: U. S. Geological Survey open file report.

Knochenus, D. D., and Hughes, G. H., 1976. Hydrology of Lake County, Florida U. S. Geological Survey. Water Resource Investigation.

Laughlin, C. P., and Hayes, E. C., 1977. Potentiometric surface map of the Floridan Aquifer in the St. Johns River Water Management District and Vicinity, Florida, May 1977: U. S. Geological Survey open file report 77-257, 1 sheet.

Leve, G. W., 1958. Interim report on the ground water resources of Putnam County, Florida. Florida Geological Survey 33 pp.

MacNeil, F. Stearns, 1950. Pleistocene shore lines in Florida and Georgia: U. S. Geological Survey Professional Paper 221-F, 95-104 pp.

Meta Systems, Inc., 1976. The hydrologic budget for the Cross-Florida Barge Canal Project.

National Oceanic Atmospheric Administration, 1951 through 1980, Climatological data: Vols. 54 through 84.

Penman, H. L., 1056, Estimating evaporation: Trans. Amer. Geophys. Union, Vol. 37, No. 1, pp 43-50.

Pride, R. W., Meyer F. W., and Cherry, R. N., 1961. The hydrologic features of the Green Swamp area in Central Florida. U. S. Geological Survey Bulletin. Information Circular No. 26, pp 21-35.

Puri, Harbans S., 1957. Stratigraphy and zonation of the Ocala Group: Florida Geological Survey Bulletin 38, 248 pp.

Puri, Harbans S. and Vernon, Robert., 1964. Summary of the geology of Florida and a guidebook to the classic exposures: Florida Geological Survey Spec. Publ. 5, 312 pp.

Ross, F. W. and Munch, D. A. 1980. Hydrologic Investigation of the Potentiometric high centered about the Crescent City Ridge, Putnam County, Florida: St. Johns River Water Management District. Technical Report No. 5, 75 pp.

Schnier, G. R., and Hayes, E. C., 1980. Potentiometric Surface map of the Floridan Aquifer in the St. Johns River Water Management District and vicinity, Florida, September 1980: U. S. Geological Survey, Open File Report 81-136, 1 sheet.

Schiner, G. R., 1981. Potentiometric Surface Map of the Floridan Aquifer in the St. Johns River Water Management District and Vicinity, Florida, May 1981: U. S. Geological Sruvey Open File Report 81-1052.

Stringfield, V. T., 1936. Artesian water in the Florida Peninsular: U. S. Geological Survey Water-Supply Paper 773C, 195 pp.

Stringfield, V. T., and LeGrand, H. E., 1966. Hydrology of limestone terrances in the coastal plain of the southeastern United States: Geological Society of American Spec. Paper 93. pp 46.

Tibbals, C. H. 1975. Aquifer tests in the Summit Reach of the proposed Cross-

Florida Barge Canal near Ocala, Florida. U. S. Geological Survey. Water Resource Investigation 28-75. pp 42.

Vernon, R. O., 1951. Geology of Citrus and Levy Counties, Florida: Florida Geological Survey Bulletin 33, 236 pp.

Vernon, R. O. and Puri, H. S., 1965. Geological map of Florida: Florida Board Conserv., Div. Geology Map Ser. 18.

Yobbi, D. K. and Chappel, G. C., 1979, Summary of the hydrology of the Upper Etonia Creek Basin: St. Johns River Water Management District. Technical Report No. 4, 67 pp.

White, William A., 1958. Some geomorphic features of central Peninsular Florida: Florida Geological Survey Bulletin 41, 92 pp.

Wyrick, Granville G., 1960. The ground water resources of Volusia County, Florida: Florida Geological Survey Report Inv. 22, 65 pp.