THE HYDROGEOLOGY AND PROBLEMS OF PENINSULAR FLORIDA'S WATER RESOURCES

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THE FLORIDAN AQUIFER AND THE WATER CROP

One of the world's largest (213,200 km^2 or 82,000 mi^2) and most prolifically-yielding ground-water reservoirs, the Floridan Aquifer, underlies all of Florida and extends northward into Alabama, Georgia and South Carolina (14). Some wells pumping from this aquifer yield upward of 8,000 gallons per minute, but yields of 1,000 to 2,000 gpm are more common. The Floridan Aquifer is composed chiefly of limestone and dolostone (Fig. 1), with increasing quantities of evaporites (gypsum, anhydrite and halite) toward the base, and is the source of about 90% of the water withdrawn for human use in the Florida Peninsula north of Lake Okeechobee. The Floridan Aquifer is deeply buried, to depths of 600 to 800 feet (183 to 244 m) along Florida's Gold Coast south of that lake, and contains only saline water. In fact, most of the tier of eastern counties lying along the Atlantic Coast north of Lake Okeechobee to Jacksonville and beyond is also underlain by non-potable salty water in the Floridan Aquifer (5).

The Floridan Aquifer either contains or is underlain by brackish to salty water everywhere at some depth, the deeper parts of it consisting of brines many times saltier than the ocean. Such brackish water is only sparsely used at present but may be utilized in the future through desalination processes to produce potable water. Techniques are known and currently utilized in about a dozen Florida localities to produce potable water from the brackish ground water of the Floridan Aquifer. Economics will determine the future extent of such desalination projects. It is cheaper to desalinate brackish ground water in some areas even now than it is to develop fresh water many miles distant and import it through lengthy pipelines. Currently, either fresh or brackish ground water can be developed at the well head or pump orifice for less than 10 cents per 1000 gallons but to desalinate brackish water costs an additional 50 cents to $1.00 per 1000 gallons, depending chiefly upon the salinity and the process used.

The aquifer ranges in thickness from about 500 feet (152 m) in Citrus and Levy Counties to about 2,000 feet (610 m) in Duval County. Leve (9) indicated that the aquifer is deeper than 2,200 feet (671 m) in Nassau County with a fresh-water thickness of about 1,600 feet (488 m). The Floridan Aquifer extends to depths of 2,000 feet (671 m) or more in Central Florida (15) and may be filled with fresh water to about 2,500 feet (762 m) in some areas (Fig. 2). Kohout (6,7) indicated that the Floridan is about 2,500 feet (762 m) thick in the Miami area where he included the "Boulder Zone", a cavernous, caving (when drilled) dolostone containing salt water, in the Floridan Aquifer.

Recharge to the Floridan Aquifer ranges from about 250,000 gpd/mi^2 (gallons per day per square mile) to more than 1 mgd/mi^2 (million gallons per day per square mile) in the areas where recharge takes place. No recharge occurs in all of those areas of the state where the potentiometric surface of the Floridan Aquifer is higher than the land surface. The rate of recharge is largely dependent upon the permeability of geologic materials overlying the Floridan Aquifer, whether it is at or very close to the land surface or is buried more or less deeply.

Direct recharge from precipitation averages about 12 to 13 inches (30 to 33 cm) per square mile, or about 572,000 to 619,700 gpd/mi^2, in the west-central Gulf Coastal area where precipitation (P) averages about 52 inches (132 cm) a year. An average measured runoff (R) of 14 inches (34.5 cm) per year, plus an estimated 1 inch (2.5 cm) of ground-water discharge directly to the Gulf of Mexico (2), leaves only 2 to 3 inches (5.0 to 7.6 cm) of direct, overland runoff contributing to stream flow. Thus,

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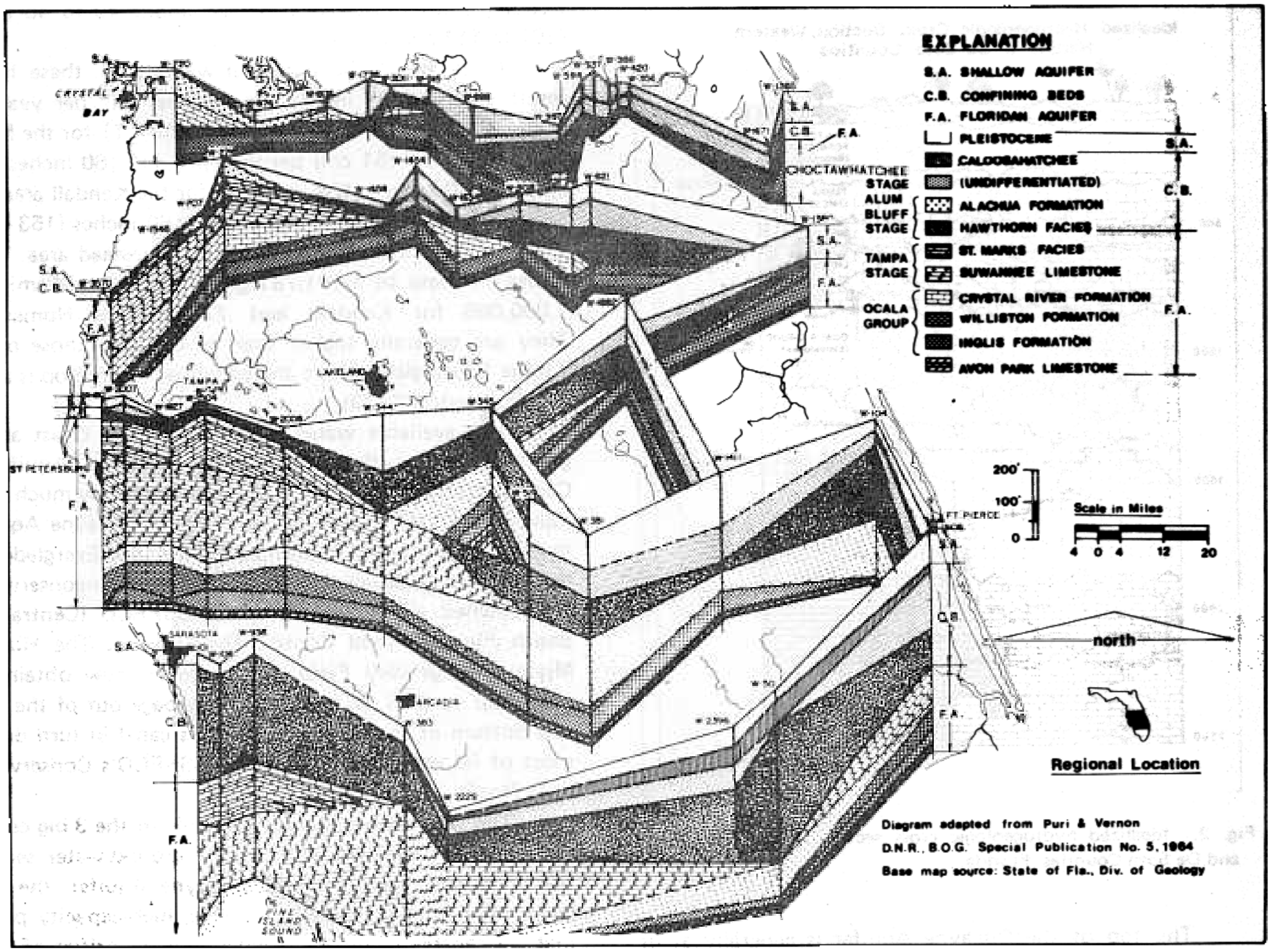

Fig. 1. Fence diagram of the Central Florida area showing the stratigraphic relations between the Floridan Aquifer, the confining beds (the Floridan Aquiclude) and the shallow water-table aquifer.

about 77 to 80% of the total discharge of 15 inches (38.1 cm) is derived from the aquifer discharge to the streams that drain the area. The rest of the long-term P value of 52 inches (132 cm), about 37 inches (94 cm) per year, is lost to evapotranspiration (ET). The water budget equation for these relationships is: $P = R + ET$.

R represents the only significantly manageable part of the water-budget equation and it also sets the upper limit of developmental water supplies. Approximately 715,000 gpd/mi^2 could be derived if *all* of R were taken for consumptive use. This is the *potential water crop*. The streams would cease flowing, lakes and swamps would dry up and the lowered water table would no longer sustain soil moisture during dry periods for most plants if this were done. This is unthinkable, so only something less than the potential water crop, *i.e.*, the *available water crop*, can be taken. This may be only 1/4 to 1/3 of the potential water crop, thus the available water crop becomes about 3.8 to 5 inches (9.5 to 12.7 cm) or 178,770 to 238,360 gpd/mi^2.

THE BISCAYNE AQUIFER AND THE WATER CROP

The southeastern Florida Gold Coast is chiefly dependent for its water supply upon the Biscayne Aquifer, a wedge-shaped ground-water reservoir about 200 to 300 feet (61 to 91 m) thick along the Atlantic Coast and thinning to a feather edge along the western margin of the Everglades where the glades abut against the higher lands of the Big Cypress and the Devil's Garden (11, 14).

The Biscayne Aquifer is one of the most highly permeable aquifers in the world, ranking with clean, well-sorted gravel in its capacity of transmitting water under water-table conditions. It has been badly abused and mismanaged in the past, however, thus leading to serious salt-water encroachment problems, among others, that are now nearing controlled management (8). Many 6-inch (15-cm) diameter wells yield 1,000 gpm or more with less than a foot (30 cm) of draw-down. Larger wells, 16 to 20 inches (40 to 50 cm) in diameter, yield 3,000 to 4,000 gpm.

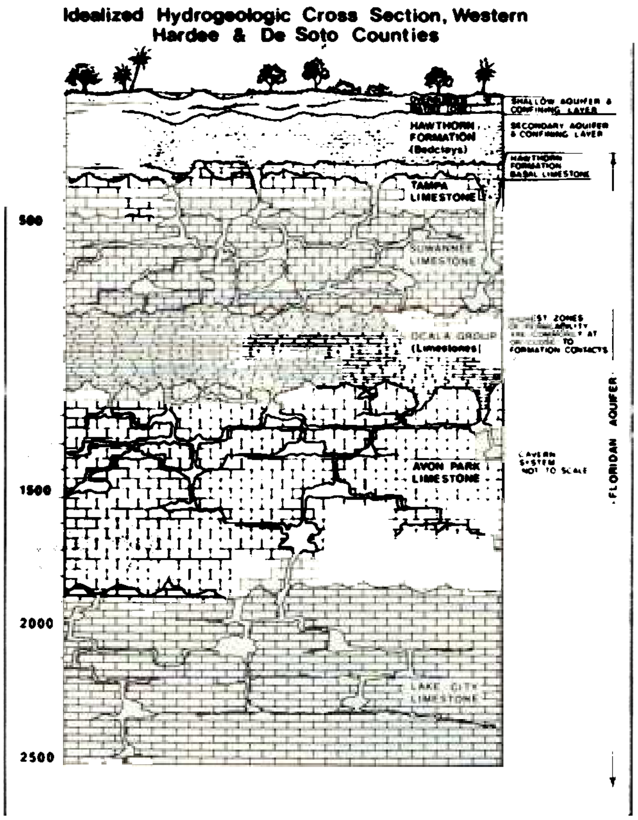

Fig. 2. Idealized hydrogeologic cross section in western Hardee and De Soto Counties, Florida.

The top of the Biscayne Aquifer is generally at or very close to the land surface with very little soil cover in Dade County, but a thickening cover of permeable sand mantles the aquifer to the north. Thus, recharge from precipitation is direct and the water table rises quickly in response to recharge from rains. Parker *et al.* (14) have shown that about 38 inches (97 cm) of an average of 60 inches (153 cm) annual average precipitation in the Miami area actually recharges the aquifer annually, thus 22 inches (56 cm) is lost to ET before reaching the water table. But 25 inches (64 cm) is discharged from the aquifer by seepage into canals and Biscayne Bay, thus 13 inches (33 cm) is discharged to ET directly from the water table. A total ET loss of 35 inches (89 cm) results by adding the 22-inch (56-cm) loss of rain not reaching the water table to the 13-inch (33-cm) loss to ET from the water table. Thirty-five to 40 inches (89 to 102 cm) of P actually reach the water table in other areas, such as Kendall and Homestead, which is not greatly different from that at Miami. About 15 to 20 inches (38 to 51 cm) of this amount is lost by ground-water discharge to canals and Biscayne Bay, while 20 to 25 inches (51 to 64 cm) is directly lost to ET from the water table. Thus, total ET losses in the Kendall and Homestead areas run about 40 to 45 inches (102 to 114 cm) a year.

In terms of the potential water crop, these figures result in about 25 inches (64 cm) per mi^2 per year [60 inches (153 cm) P – 35 inches (89 cm) ET] for the Miami area; 20 inches (51 cm) per year per mi^2 [60 inches (153 cm) P – 40 inches (102 cm) ET] for the Kendall area; and 15 inches (38 cm) per year per mi^2 [60 inches (153 cm) P – 45 inches (115 cm) ET] for the Homestead area. These values translate to 1,191,781 gpd/mi^2 for the Miami area; 1,000,096 for Kendall; and 715,068 for Homestead. They are generally higher than or equal to those of the Tampa Bay region, where the potential water crop is about 715,000 gpd/mi^2 (13).

The available water crop of the Gold Coast area is generally higher than that of the Floridan Aquifer in Central Florida. This is because of the normally much more rapid and greater direct recharge to the Biscayne Aquifer, the additional water transmitted from the Everglades by the controlled canals and the 3 huge water-conservation areas owned and operated by the CSFFCD (Central and South Florida Flood Control District) (8). The Hialeah-Miami Springs Well Field, for example, now obtains, at times, up to 90% of its water by seepage out of the sides and bottom of the Miami Canal. This canal in turn derives most of its water from storage in CSFFCD's Conservation Area No. 3.

The tremendous storage available in the 3 big conservation areas, the large amounts of ground-water seepage eastward from them into the Biscayne Aquifer, the well-regulated system of canals and huge, high-capacity pumps that are capable of moving tremendous quantities of water from places of excess to places of deficit results in water management in the Gold Coast being much simpler and more effective than elsewhere in Florida. Problems of water supply still occur there, but these problems are more related to management problems, which are rapidly being overcome, than to a dearth of available water in the KLOE (Kissimmee-Lake Okeechobee-Everglades) system (11). Thus, the current paper will delve no further into the Gold Coast as an area of critical water problems. Such problems exist mostly in the SWFWMD (Southwest Florida Water Management District) and in the adjoining, temporary RLGCWMD (Ridge and Lower Gulf Coast Water Management District).

CRITICAL WATER–PROBLEM AREAS OF SWFWMD

There are currently defined 3 principal water-problem areas: 1) The coastal strip of salt-water encroachment (Fig. 3), 2) the big well fields of the Tampa Bay area (Fig. 3) and 3) the areas of large drawdown of the aquifer water levels as shown in Fig. 4 by the hachured contours. Each of these 3 problem areas is distressed either by over-

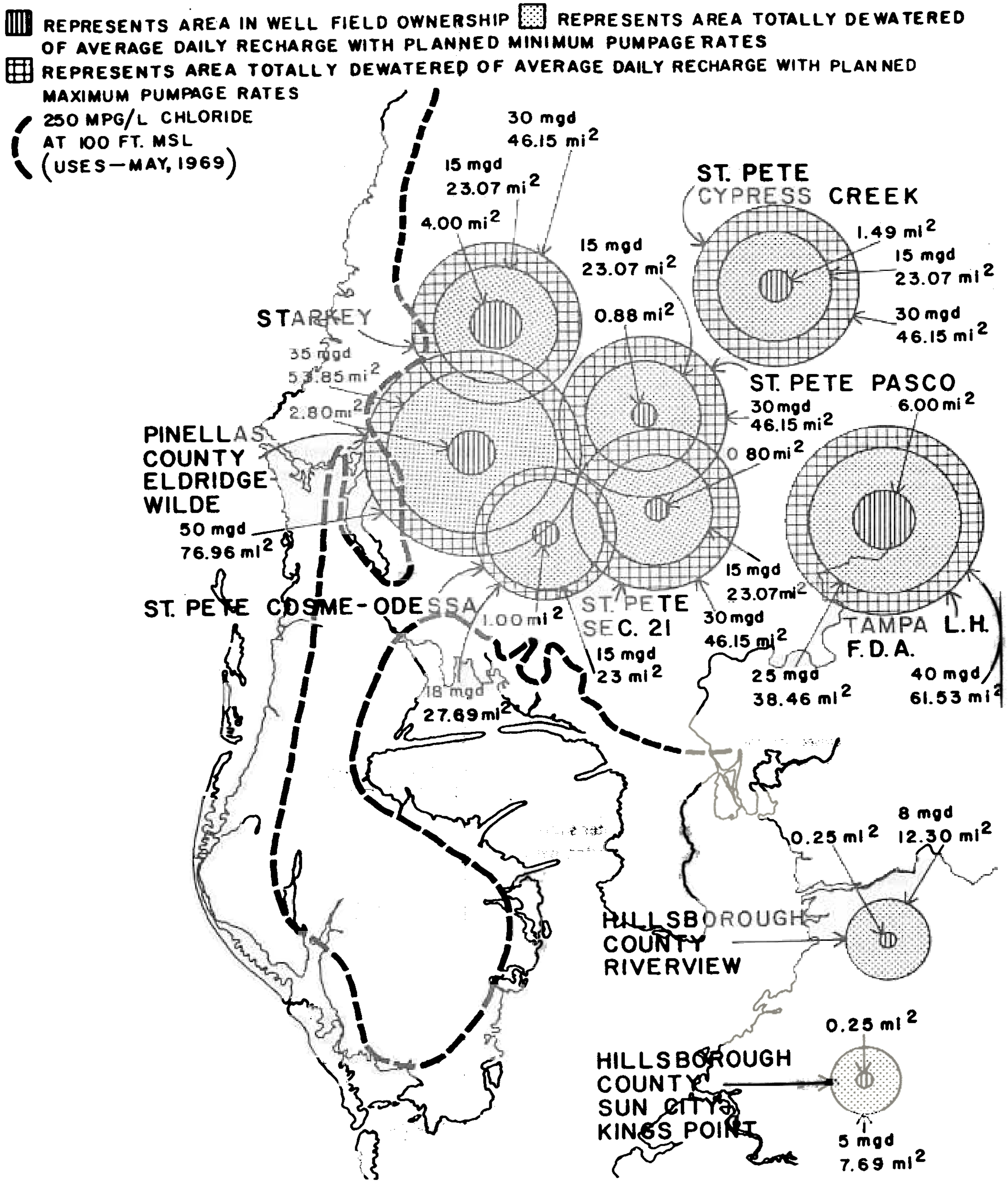

Fig. 3. Map of circular areas surrounding each large well field of the Tampa Bay Region showing areas required to produce recharge needed to supply minimum and maximum pumping rates shown.

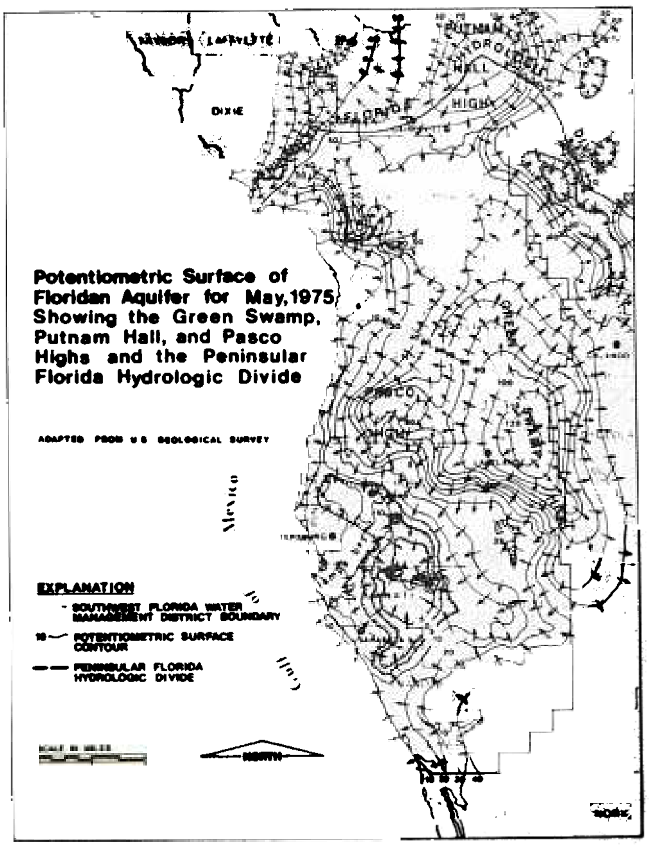

Fig. 4. Potentiometric map of Southwest Florida Water Management District and surrounding lands for May, 1975. Features shown include: Potentiometric contours; the 3 principal artesian highs; regional direction of ground-water flow through the Floridan Aquifer; and the Peninsular Florida Hydrologic Divide. Hachured lines are closed contours outlining areas of internal flow.

development of the water resources for water-supply uses or a combination of large water-supply development with tidal canals and ditches which result in salt-water encroachment.

COASTAL STRIP OF SALT–WATER ENCROACHMENT

A coastal strip of varying width containing an encroaching wedge of salt water extends along the Gulf Coast from Lee County northward. The northern part of this strip, from Tampa northward to Citrus County, has been mapped by the U. S. Geological Survey (2,16). A part of this mapping which will give an idea of the width and general inland extent of the salt-water wedge from the Gulf shore is shown in Fig. 3. The inland edge of the encroaching salt-water wedge is marked by a heavy dashed line indicating the place at which salt-water of 250 mg/1 (milligrams per liter) occurred at a depth of 100 feet (30.5 m) below msl (mean sea level) in 1969. The chloride content increases steadily below this depth. It likewise increases seaward until chloride in the ground water at or close to the shoreline, even at very shallow depths, equals that of the waters of the Gulf of Mexico, about 20,000 mg/1.

The U. S. Geological Survey has not completed its mapping of the encroaching wedge of salt water southward from Tampa, but complaints of residents in the coastal strip of western Hillsborough, Manatee and Sarasota Counties indicate that wells formerly producing fresh water have now become salty.

The phenomenon of salt-water encroachment, its causes and controls are too well known to require a comprehensive explanation here. Readers are referred to Parker (10), Parker *et al.* (14), Reichenbaugh (16) and Stringfield (18) for such information. Suffice it to say that, in a coastal area of freely permeable materials, it will be 40 feet (12.2 m) down to the salt water contact for each foot (30.5 cm) that the water table averages above sea level. Thus, it will be about 80 feet (24.4 m) to salt water where the water level averages 2 feet (61 cm) above msl and 400 feet (122 m) where the water table stands 10 feet (3 m) above msl.

The natural equilibrium between the overlying lighter, fresh water and the denser, heavier underlying salt

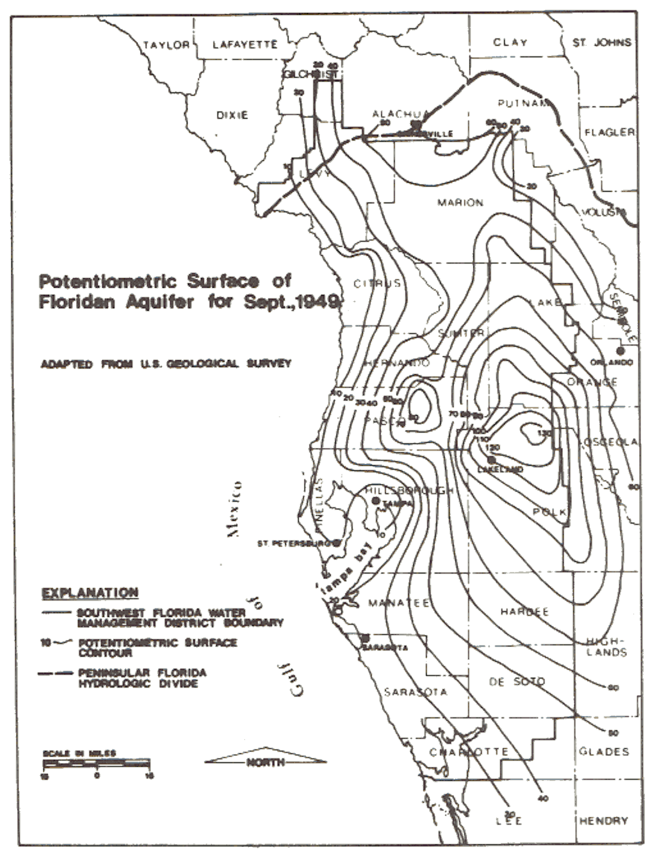

Fig. 5. Potentiometric map of Southwest Florida Water Management District and surrounding lands for Sept., 1949.

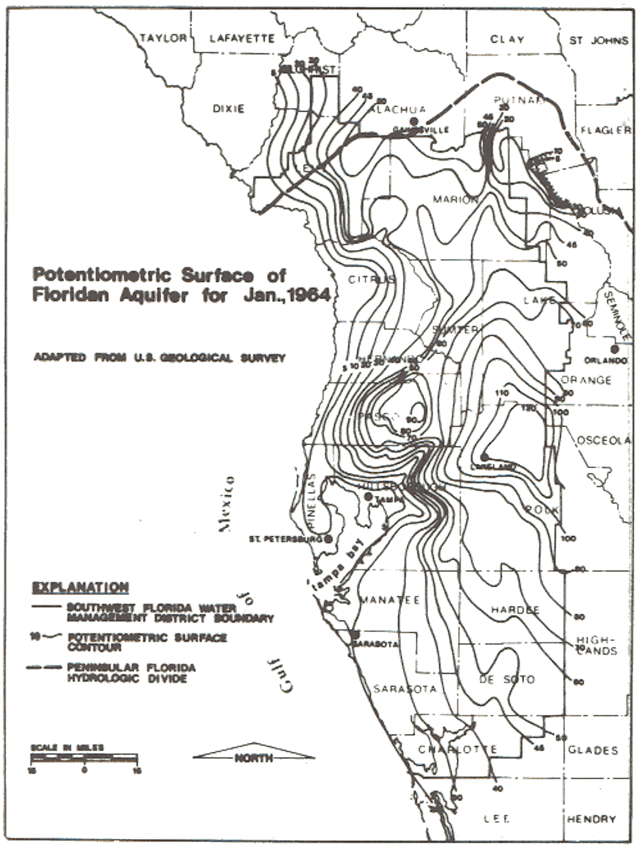

Fig. 6. Potentiometric map of Southwest Florida Water Management District and surrounding lands for Jan., 1964.

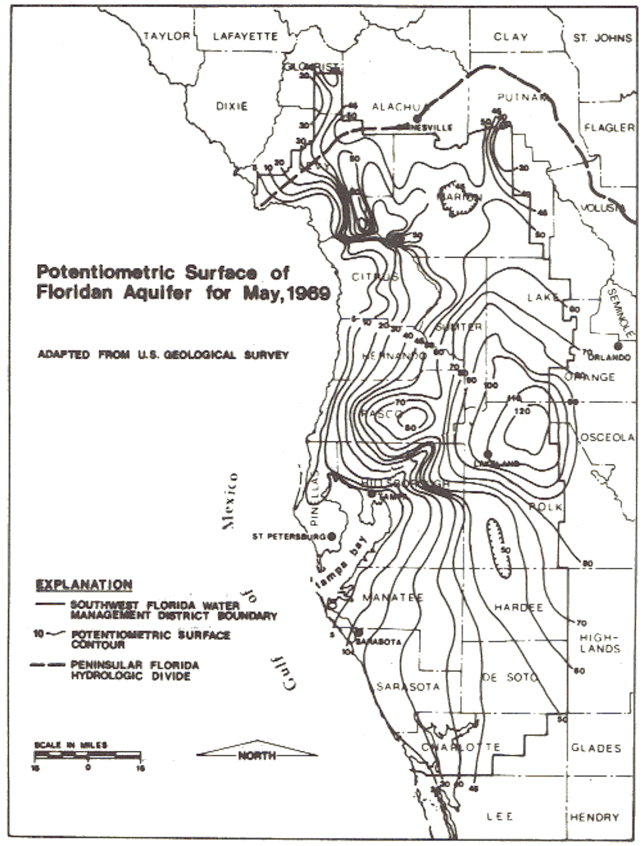

Fig. 7. Potentiometric map of Southwest Florida Water Management District and surrounding lands for May, 1969.

water becomes upset when water levels in a coastal area are lowered below their average levels of the past. Restoration of the equilibrium causes the salt-water wedge to move inland and the salt-water contact with fresh water rises.

There has been an obsession with draining the swamps and marshes to "reclaim" the land, or to build new water-front homes, or dredge natural coastal stream channels deeper for navigation or other purposes, such as flood control, since white men entered Florida. The result is the same, no matter what the purpose—salt-water encroachment.

The development of water supply wells in the coastal zone especially has had its impact in addition to drainage and the consequent lowering of water levels. Every well lowers the water level in the surrounding, generally circular area when discharging, whether by artesian pressure or by pumping. This lowering takes the form of an inverted cone with the greatest lowering of levels at the well itself and the least amount of lowering at some distance away. Hydrologists call this lowered water-level condition around a well or spring a cone-of-depression. When 2 or more wells are drilled too closely together their cones-of-development overlap, thus producing a single larger and deeper cone-of-depression.

Such conditions have happened on a larger scale where municipal, industrial or agricultural wells are crowded too closely together, thus resulting in large-area lowering of the water table or of the potentiometric surface or both. An example of this is shown in Fig. 3 where the big municipal well fields of St. Petersburg and Pinellas County have been developed too closely together. More will be said of this in a subsequent section.

The progressive lowering of the potentiometric surface with man's development of the west coastal region is shown in a series of potentiometric maps of the SWFWMD and surrounding lands (Figs. 4 through 11).

A potentiometric contour map of the Floridan Aquifer shows the height to which water rises in artesian wells penetrating the rocks of the aquifer for the time during which the water level in the wells was measured. Such a map has many uses. One can discern the directions of regional ground-water flow and determine where water comes from and where it goes by drawing arrows that cross contours *at right angles* and proceeding to the next lower contour in the *shortest distance possible* (as in Fig. 4).

One can also discover the shape of the potentiometric surface and note that there are "highs" and "lows", with ground water flowing away from the highs toward the lows.

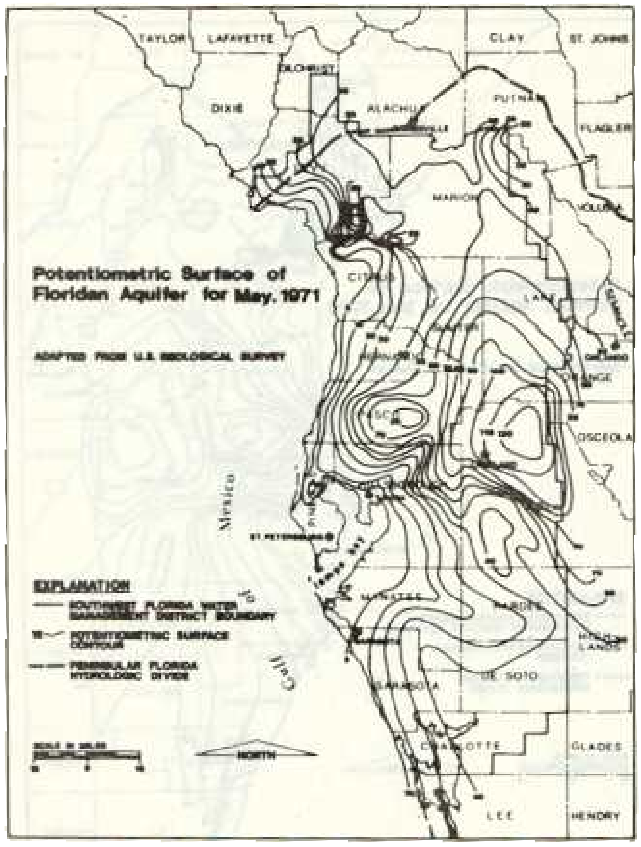

Fig. 8. Potentiometric map of Southwest Florida Water Management District and surrounding lands for May, 1971.

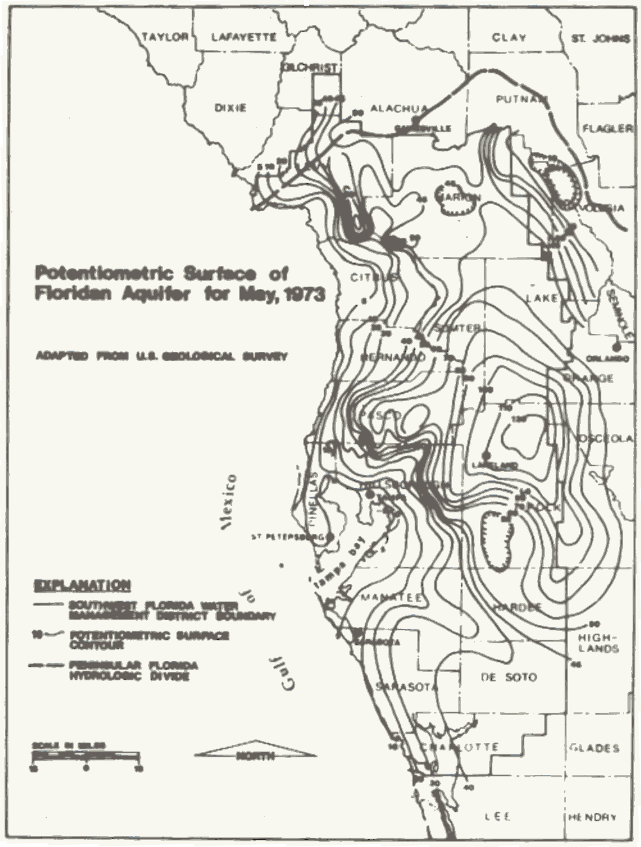

Fig. 9. Potentiometric map of Southwest Florida Water Management District and surrounding lands for May, 1973.

Three large and prominent highs dominate the potentiometric surface of the Floridan Aquifer in the Florida Peninsula: 1) the Green Swamp High, 2) the Pasco High and 3) the Putnam Hall High. Ground water continously flows centripetally outward in all directions from each of these elemental hydrologic features, indicating continuous recharge from rainfall that is required to sustain this continuous outflow.

Another important hydrologic feature is the Peninsular Florida Hydrologic Divide (12). No groundwater flow crosses this divide and no surface stream of any consequence crosses it except for the St. Johns in its tidal estuary near Palatka. Thus, water supplies in Peninsular Florida are totally dependent upon precipitation that falls on the land *south* of the Peninsular Florida Hydrologic Divide. No mysterious subterranean streams from the north flow under or over this divide. A glance at the Putnam Hall High shows the flow pattern with all flow arrows pointing away from the divide.

A comparison of potentiometric contours in Figs. 5 through 11 shows that little apparent change has taken place in the coastal zone of salt-water encroachment north of Pinellas County since 1949. The contours show only 2 km or so of eastward migration in the past 25 years. This small amount, however, involving a lowering of coastal water levels up to 5 feet (1.5 m) on the average, has been enough to cause the salt-water encroachment that brought about the loss of the St. Petersburg and Tampa well fields in the late 1920's and the gradual salinization of the New Port Richey Well Field beginning in the 1960's. Additionally, hundreds of private wells have turned salty in the urbanizing coastal strip from Pinellas County northward into Hernando County, especially since 1969 when building, dredging and filling on low lands west of US 19 began on a large scale, particularly in Pasco County.

The change of potentiometric contour conditions has been much more notable and hydrologically important in the area from Tampa southward. Perhaps the best way to see this change is to examine the change in location of particular contours, such as the 20-foot contour. The 1949 map (Fig. 5) shows it disappearing into the Gulf west of Bradenton. Presumably it turned southward and parallelled the shoreline at some distance seaward. Stringfield (18) found that water levels of artesian wells on the offshore islands of Sarasota County stood at 25 feet (7.6 m) or more in the early 1930's. Thus the 20-foot contour had to be somewhere seaward of these islands in those early days.

The 20-foot contour is noted to be gradually farther

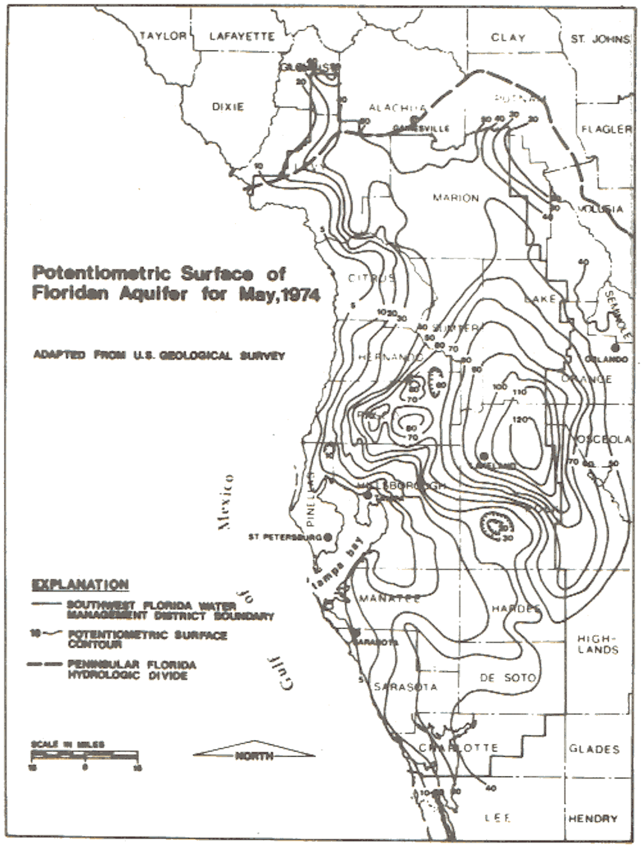

Fig. 10. Potentiometric map of Southwest Florida Water Management District and surrounding lands for May, 1974.

and farther inland as one examines subsequent maps (Figs. 6 through 11). The most notable advance is indicated on the 1971 map (Fig. 8). The 20-foot contour moved inland about 25 miles (40 km) between May, 1969 and May, 1971, a greatly accelerated rate compared with that on previous maps. It has advanced inland another 18 miles (29 km) from 1971 (Fig. 8) to 1975 (Fig. 11). A huge cone-of-depression bounded by the 5-foot potentiometric contour surrounds a greatly depressed area with water levels reaching 10 feet (3 m) below sea level in some places as much as 37 miles (59 km) from the shore in the coastal region (this shows up best in Fig. 11). These conditions are an open invitation for salt-water encroachment to occur.

Fortunately, these May conditions of greatly lowered water levels do not persist year-round. Water levels rise only a few feet near the coast and as much as 30 to 35 feet (9.1 to 10.7 m) in central and eastern Manatee and southern Hardee Counties once the rainy season sets in and irrigators turn off their pumps. Both high and low seasonal levels show a lowering trend over the years that is most accentuated inland (4,17).

Another reprehensible practice is the wastage of huge volumes of artesian water by over-irrigation. There are no large manufacturing plants or big city well fields in this area of large coastal drawdown, chiefly in southern Hillsborough, Manatee and northern Sarasota Counties (Fig. 11), but there are hundreds of large irrigation wells. These range in production during the irrigation season from about 1,000 to 5,000 gpm and a few run even higher. A 5,000 gpm well produces 7.2 mgd, at which rate 648 million gallons would be pumped during a 3-month irrigation season. Its total quantity is not known, however, nor is it known over what period of time during the irrigation season the pumping is done, as no records are kept of the pumpage. It reminds me of the young man who inherited a fortune from a deceased relative but spent his money carelessly and kept no account of his expenditures. It wasn't long before he had exhausted his inheritance and was dead broke. Counties, municipalities and even Water Management Districts can do this too, if care is not taken to see to it that proper management practices are diligently followed in the care and use of our water resources.

It was a common sight in Manatee County during the irrigation season of 1974, chiefly January through May, to see furrow-and-ditch irrigation systems with both ditches and furrows running full of water and, at the lower ends of the fields, water pouring off as wasted tail-water to fill the roadside ditches full to overflowing. Such tail-water runoff is not only direct waste of the irrigator's money but a waste of our most precious natural resource—our water. Such profligate waste of water would not be tolerated in New Mexico, Arizona, Colorado, Utah and other parts of the arid west, nor should it be tolerated here. Irrigation water should be picked up from sumps at the lower ends of irrigated fields and returned to the upper ends for recycling, thus greatly reducing pumpage from the aquifer.

Hundreds of large new wells have been drilled and pumped since 1964, with the large increase in groundwater pumpage to supply both a greatly expanding phosphate industry in the Central Florida Phosphate District (13) and a rapidly expanding citrus, vegetable and improved pasture-irrigation agribusiness. Total pumpage from southern Polk and northern Hardee Counties amounted to about 250 mgd for citrus, 350 mgd for phosphate mining and milling and 50 mgd for all other purposes, amounting to a grand total of about 650 mgd by 1970, according to Cawley (1). This is about 13 times as much water as is required by either Tampa's or St. Petersburg's municipal water-supply systems and resulted in the development of a large area of potentiometric drawdown centering in the phosphate district south of Bartow. It began showing up first on the 1964 potentiometric map (Fig. 6) as a greatly widened area, mostly in southern Polk County, between the 70- and 80-foot contours. Water from the Green Swamp High (Fig. 4) could still flow, though very slowly, to the southwest and on into southeastern Hillsborough and eastern Manatee Counties, but at a

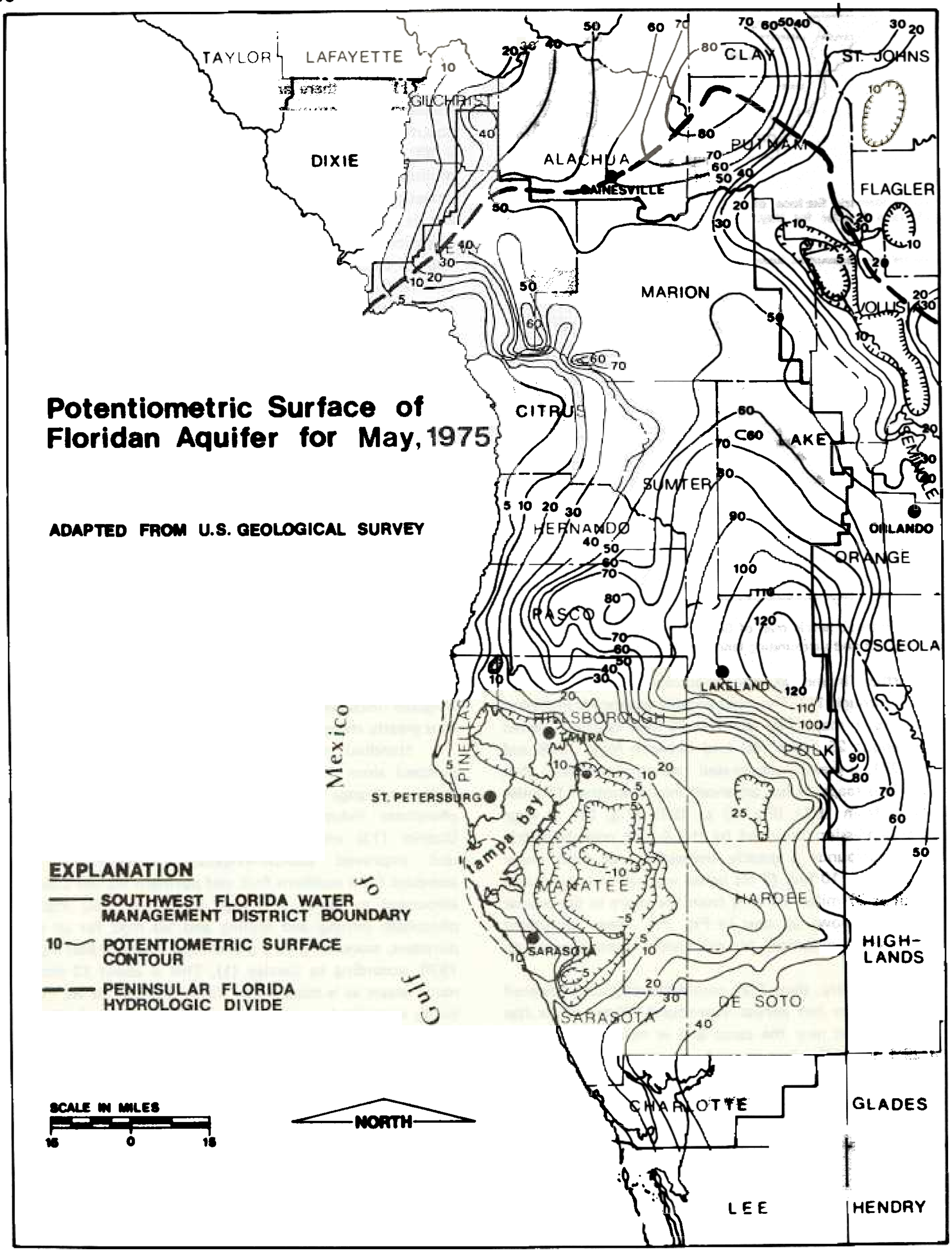

Fig. 11. Potentiometric map of Southwest Florida Water Management District and surrounding lands for May, 1975.

greatly retarded rate. Thus, ground-water flow into these 2 counties was diminished for the first time ever through ground-water developments in adjacent counties to the east.

Fig. 7 (1967) shows a 50-foot closed contour occupying the phosphate district drawdown area, and both the 60- and 70-foot contours were squeezed to the east and northeast where the 80- and 90-foot contours had existed in 1964. The development of this sump cut off the historic Green Swamp flow to the coastal areas of southern Hillsborough, Manatee and Sarasota Counties for the first time ever. This ground-water flow cutoff created a shortage of inflow and thus helped create much greater drawdowns in the coastal agriculture areas than otherwise would have occurred, even if irrigation use of water in the coastal counties remained the same as it had been prior to 1969.

Manatee and Sarasota Counties were not a part of the SWFWMD and had no hydrologic staff or consulting hydrologists to keep track of what was happening to their water supplies, hence the developing conditions of spreading ground-water lowering was not realized until the author recognized the situation from studies in the surrounding counties in late 1973. No one knows even yet how much water is being pumped annually in Manatee and Sarasota Counties—it can only be estimated. Therefore, precise analyses of the situation still cannot be derived from existing data. The best information available is from the U. S. Geological Survey potentiometric maps and related water-level data which only tell us the symptoms of the disease, not exactly what the causes are. We know that more water is being taken out of the Floridan Aquifer than Nature can put back in during a given period of time. The gut feeling is that there would be enough water for all real needs if it were not being wasted on such a colossal scale as seems evident. Intelligent use and conservation of the water supply is greatly needed.

The situation is urgent and crying for assistance. Detailed studies of the hydrogeology of both Manatee and Sarasota Counties are direly needed, as are comprehensive studies of the water use and quantities of water actually required. The Ridge and Lower Gulf Coast Water Management District should underwrite a full-scale, comprehensive, cooperative study with the U. S. Geological Survey to gain the information needed to handle this problem properly. The same kind of study is needed for Manatee and Sarasota Counties as the SWFWMD has had with the U. S. Geological Survey for Hardee and De Soto Counties (20).

THE BIG WELL FIELDS OF THE TAMPA BAY AREA

A classic case of inadequate well-field design and management exists in the Tampa Bay area. No hydrologist in his right mind would have designed and located the existing well fields where they now are, nor would he have prepared pumping schedules such as have been utilized in recent years. The well fields are too close together and they have been pumped much too heavily.

Fig. 3 is a map of the big well fields area with scale drawings of the location of each well field, the area of land held (vertically-lined inner circle) and the areas required to furnish recharge sufficient to supply minimum and maximum pumpage shown. Pinellas County's Eldridge-Wilde Well Field, for example, shows 2.80 mi^2 (7.3 km^2) in the inner, vertically-lined circle of the well field. The next circle, dotted, shows that an area of almost 77 mi^2 (200 km^2) is required to produce from recharge the pumpage taken out when the well field is producing 50 mgd. SWFWMD's water crop value of 640,000 gpd/mi^2 was used to calculate the area needed for recharge to supply any given pumpage.

It doesn't take a highly trained and widely experienced hydrologist to understand how the "water-war" between Hillsborough, Pinellas and Pasco Counties developed, or why shallow wells in this area have gone dry, lake levels have fallen and streams such as Brooker Creek, which flows westward to Lake Tarpon through the southern parts of the circles of influence of Pinellas County's Eldrige-Wilde, and St. Petersburg's Sec. 21 and Cosme-Odessa well fields, should have had its average flow about halved since 1964, even in the face of the severe drought the area has undergone since 1961.

There is no doubt that the well fields would not be where they are now if SWFWMD (Regulatory) had been in existence when these well fields were being planned. Each would have been located sufficiently far apart that no one well field's drawdown would have overlapped that of any other. The knowledge required to make these determinations of well-field spacings existed since Theis' non-equilibrium formula for evaluating effects of a pumping well was published in 1935 (19), yet these fields and almost all other large well developments in Florida, until very recent times for that matter, have been developed without a suitable hydrologic analysis having been made of the effects that the new development would have on adjacent wells, streams or the environment.

The first place in Florida where such evaluations were made was under the author's direction in the Miami area in the spring of 1947 (14). The new Miami well fields were so planned that interference with another would not occur, nor would salt-water encroachment result, nor would nearby streams or canals be harmfully affected. The same kinds of analyses are now being made under SWFWMD's direction, not only for new well fields but for any large scale diversion of ground or surface water within the District that might have potential deleterious effects upon either a neighbor's supply or the environment. I would expect no more improper well-field locations ever be made in SWFWMD in the future.

The same conclusions may be reached regarding water-supply developments in the coastal area of salt-water encroachment and in those interior areas of over-draft, such as in the Central Florida Phosphate District. The maximum water supplies for municipalities, industry and agriculture can be developed without harm to the resource, the environment or prior users, with proper application of hydrogeologic principles.

Nature gives the Florida Peninsula a larger supply of rain and natural recharge than she gives most places else-where on earth. All we need to enjoy these blessings is the intelligent management of water and related land resources. Most of the "messes" we now suffer have developed without an understanding overview of the requirements of good water-and-land management. We have these under-standings now and we need not repeat the errors of the past, given an intelligent use of the expertise and powers of the several regional Water Management Districts and the West Coast Regional Water Supply Authority and the assistance of competent consulting hydrologists to guide the development of the resources. We can, if we will, live within our individual and regional water crops and still have enough water to meet the needs of all. But, our most precious natural resource, our water supplies, can be need-lessly ruined if we continue the careless and wasteful ways of the past.

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QUESTIONS

Q: Considering the lakes you showed us and the shortage of water in them, is there some engineering principle which would prevent the drainage water in that area from being returned to the drainage field and the lakes instead of letting it run into Tampa Bay?

Parker: It's more political than anything else. The lakes are in Hillsborough County, but the water is being taken out by St. Petersburg. This conflict prevented anything from being done for a long time. However, drainage ditches were finally allowed under the road to allow the drainage water to get into the lakes again.

Q: Will that water field be restored to its original state?

Parker: Several things were done. The natural drainage system was partially restored. Local people were allowed to take water from the aquifer and put it back into the lakes. There's only a small loss of water involved, as it is more an energy loss due to the pumping. However, the latter point is only a breakeven proposition, *i.e.*, it is only partially replacing water which is seeping out of the lakes.

A third accomplishment was that a limit was placed on the amount of water St. Petersburg could take out of the lakes—cutting back from 35 to 13 million gallons per day. As a consequence, the area is being restored, the lakes are full of water again, and the situation is about at equilibrium.

Q: Will you tell us about the quality of the water going back into the drainage wells?

Parker: A drainage well will supply the same quality of water as the quality of the source of the water. Some drainage wells take water from surrounding lakes, *e.g.* the drainage well in the Orlando area. In Ocala, many of the street corners are drained into drainage wells, so sometimes the quality there is not so good. However, the water in recharge wells is not surface water, but is water in the shallow aquifer, so it is excellent water.

Q: Due to the relative density of salt water and fresh water, is it true that if you pump off 1 foot (0.3 m) of fresh water head from a source of differential salinity, the salt water will rise about 30 feet (9 m)?

Parker: I eliminated a series of slides on salt water encroachment, because I didn't think I would have time to cover it. Consider an island in the ocean. Rain falling on the land surface infiltrates the soil and builds up a fresh water table. If the fresh water level above sea level averages 1 foot (0.3 m) year-round, there will be a depth of 40 feet (12 m) of fresh water to the interface between fresh water and salt water. If the fresh water table averages 2 feet above sea level, it will be 80 feet (24 m) down to salt water. This is based simply on the equilibrium between the weight of the fresh water that's above sea level and the weight of the salt water which is holding the fresh water in below and around the island.

The interface of mixing of the 2 types of water fluctuates with the height of the fresh water table and the changing of the tides. In the Miami area, we found the interface to be 70 feet (21 m) between water that has 250 mg per liter salt and water of 1000 mg per liter. If the aquifer were not permeable, but had a dense clay layer, the interface would be much higher.

Q: You mentioned that under Florida, there's some extremely salty water—perhaps 10 times the salinity of the ocean. How does that fit into this picture?

Parker: Fortunately for us, that water occurs at great depths beneath several very dense layers of clay or other material, through which the water can't penetrate except through cracks or other openings. Nature has provided safeguards to prevent that water from being a problem to us.

Q: We have a recharge well that's putting in about 300 gpm. Are there larger recharge wells?

Parker: Yes. A well that works properly will take as much water as it will yield to pumping. Some of the wells, such as those used as drainage wells in Orlando and Ocala to keep the lake levels constant, will take 10,000 to 15,000 gpm. Many shallow wells used to drain the water table will only take 180 to 200 gpm.

However, if the well goes down into a highly permeable sand or gravel or even into a solution cavity in the limestone, it will take as much water as you can pump. The only limitation on the amount of water taken will be friction between the casing and the pipeline.