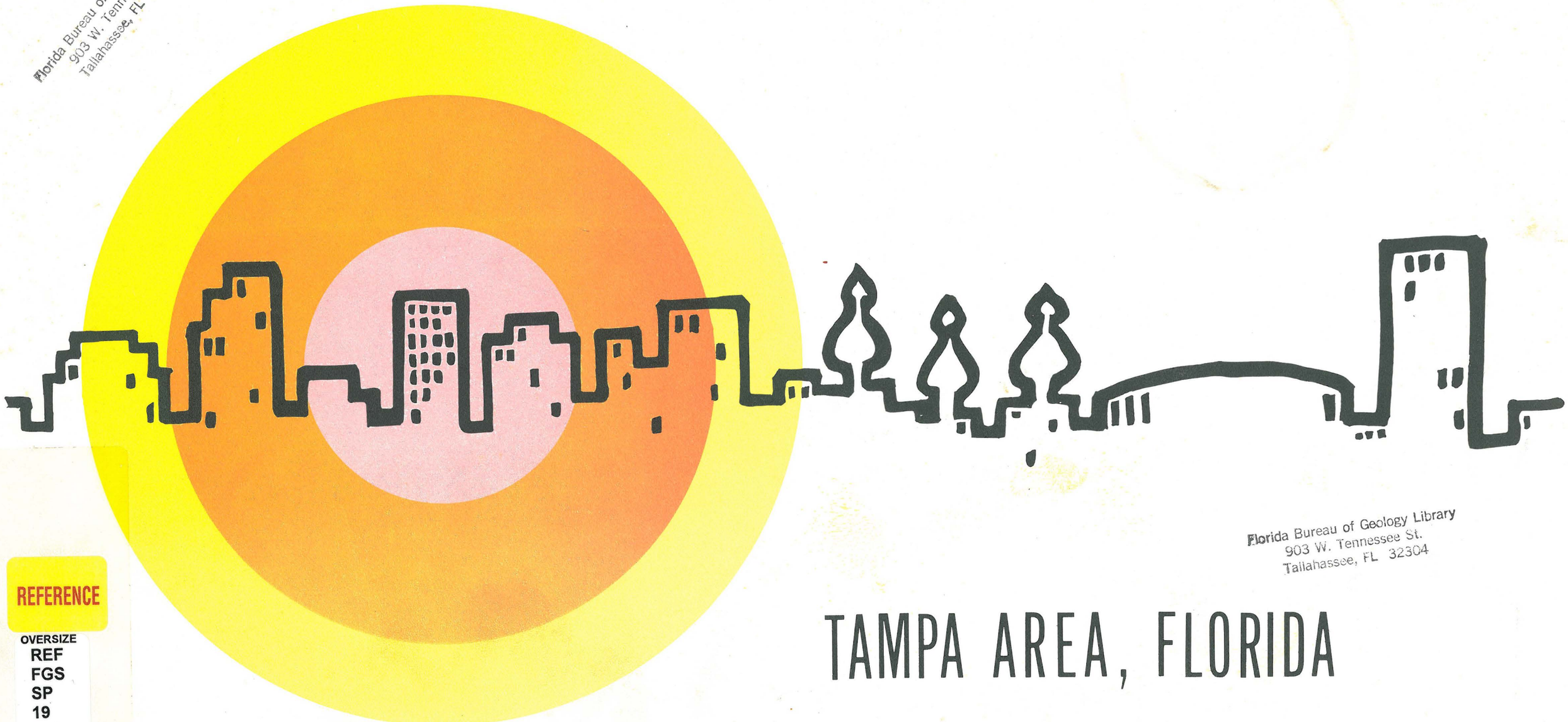
ENVIRONMENTAL GEOLOGY AND HYDROLOGY



TAMPA AREA, FLORIDA

STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES

Harmon Shields, *Executive Director*

DIVISION OF INTERIOR RESOURCES
Robert O. Vernon, *Director*

BUREAU OF GEOLOGY
C. W. Hendry, Jr., *Chief*

SPECIAL PUBLICATION NO. 19

ENVIRONMENTAL GEOLOGY AND HYDROLOGY TAMPA AREA, FLORIDA

by Alexandra P. Wright

Prepared by the
BUREAU OF GEOLOGY
DIVISION OF INTERIOR RESOURCES
FLORIDA DEPARTMENT OF NATURAL RESOURCES

TALLAHASSEE, FLORIDA
1974

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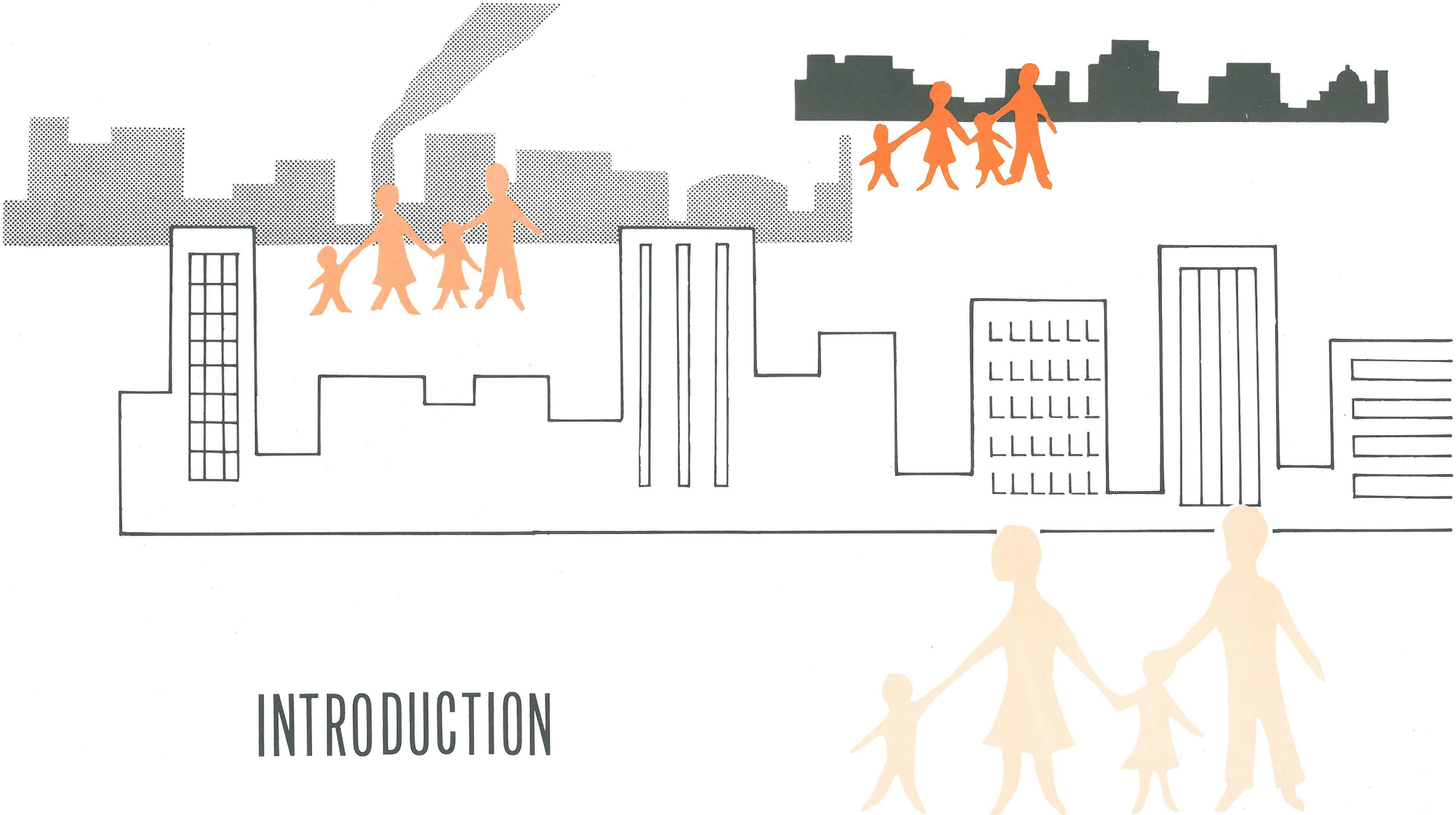
PREFACE

"Environmental geology. The collection, analysis, and application of geologic data and principles to problems created by human occupancy and use of the physical environment, including the maximization of a rapidly shrinking living space and resource base to the needs of man, the minimization of the deleterious effects of man's interaction with the Earth, and the accommodation of the exponentially increasing human population to the finite resources and terrain of the Earth. It involves studies of hydrogeology, topography, engineering geology, and economic geology, and is concerned with Earth processes, Earth resources, and engineering properties of Earth materials. It involves problems concerned with construction of buildings and transportation facilities, installation of utility facilities, safe disposal of solid and liquid waste products, development and management of water resources, evaluation and mapping of rock and mineral resources, and overall long-range physical planning and development of the most efficient and beneficial use of the land." So states the Glossary of Geology, published by the American Geological Institute, and to this end this publication is presented.

To accommodate the exponentially increasing human population to the finite resources and terrain of the earth has become the foremost responsibility of government officials, planners and technical researchers within the last two decades. In the not too distant past, it seemed we had inexhaustible supplies of clean air, potable water, energy and other mineral resources, but such excesses are no longer assured. We have entered the era of shortages and recycling which has resulted in the reestablishment of priorities and the sequential uses of our resources in order to insure our survival.

This publication is presented not as the answer to any of the monumental problems facing those with the responsibility of planning for the future, but as a tool to help those with such responsibilities.

Charles W. Hendry, Jr.



INTRODUCTION

POPULATION

Although Tampa's first incorporation occurred in 1849 with a population of 185, Tampa officially became a city after a second incorporation in 1855. Since that time Tampa and its surrounding suburbs have experienced a population explosion. To put Tampa's growth into perspective, the following table provides a summary of census facts:

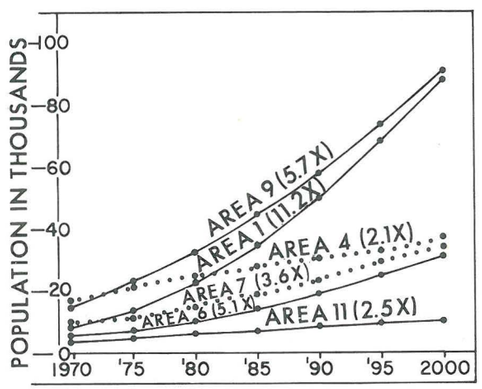
	1870 pop.	1970 pop.	% increase
U. S.	38,558,371	203,184,772	427
Florida	187,748	6,789,443	3,516
Hillsborough County	3,216	490,265	15,144
Tampa	796	277,767	34,795

Population figures alone have little environmental significance. The statistic that probably relates most directly to the physical setting is population density, or the number of people per acre of land. Based on 1970 census data, figure one shows population densities within the Tampa area.

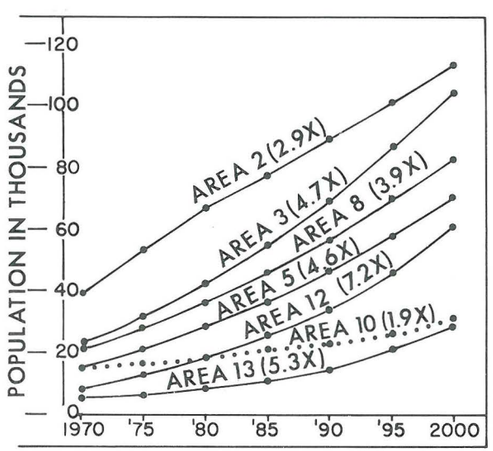
Obviously, the individual requires a certain minimal space for life, work and leisure and it seems reasonable to assume that creature discomfort and environmental damage can result from overcrowding. Establishing an optimum space requirement for the individual is an interdisciplinary problem and no reliable estimate can be given here.

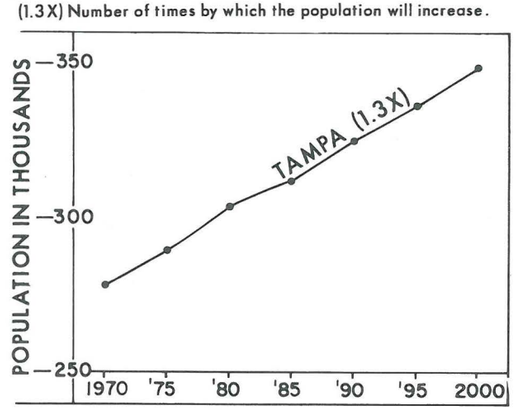
Attention can be paid, however, to future growth patterns and specific areas in which accelerated population increases are anticipated. For this purpose, the graphs below exhibit population projections through the year 2000 for the fourteen areas outlined on figure one. These graphs indicate that the population of some areas will increase by many times during the next 30 years. It is these areas which are prime candidates for the environmental damages that have historically accompanied indiscriminant development.

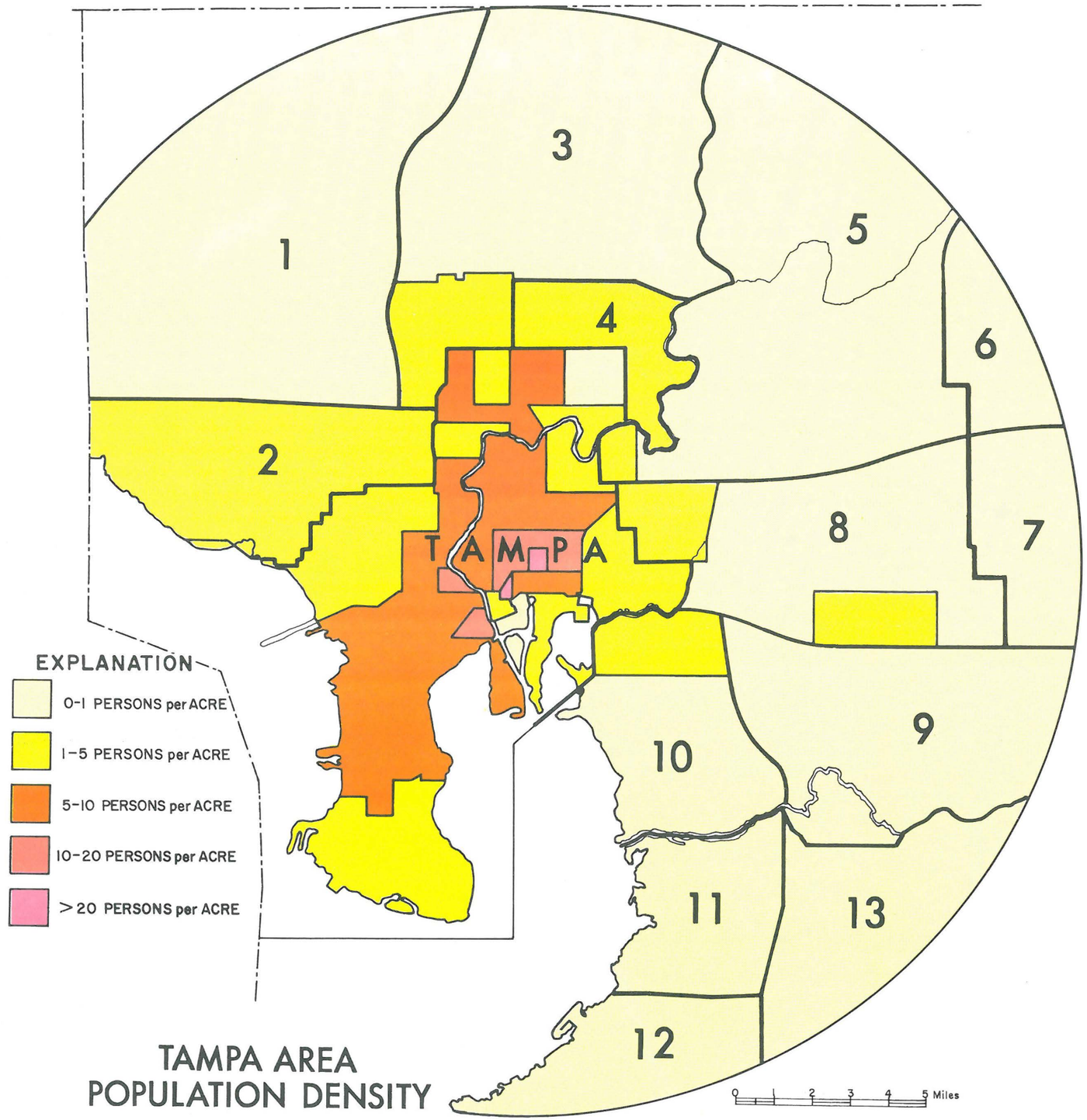
Prudent planning must keep pace with development in these areas and such planning must be based on thorough knowledge of both physical and biological environ. It is the job of scientific agencies to provide planners with such information if environmental crises are to be avoided as more and more people populate the Tampa area.



POPULATION PROJECTIONS BY CENSUS AREA
(SOURCE: TAMPA BAY REGIONAL PLANNING COUNCIL)
(1.3X) Number of times by which the population will increase.







TAMPA AREA
POPULATION DENSITY

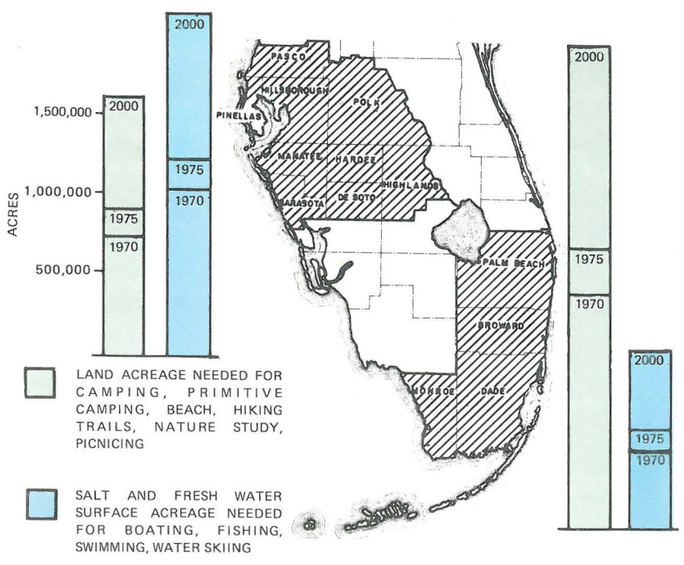
RECREATION

Recreational facilities are a significant asset to any area in both the intangible enjoyment they provide and the role they play in the local economy. Due to the great influx of tourists to the area as well as the accelerated resident population increases, Tampa's recreational demands are especially high. In fact, according to the Division of Recreation and Parks, current and projected demands for recreational facilities in the Tampa region[1] are the highest in the state.

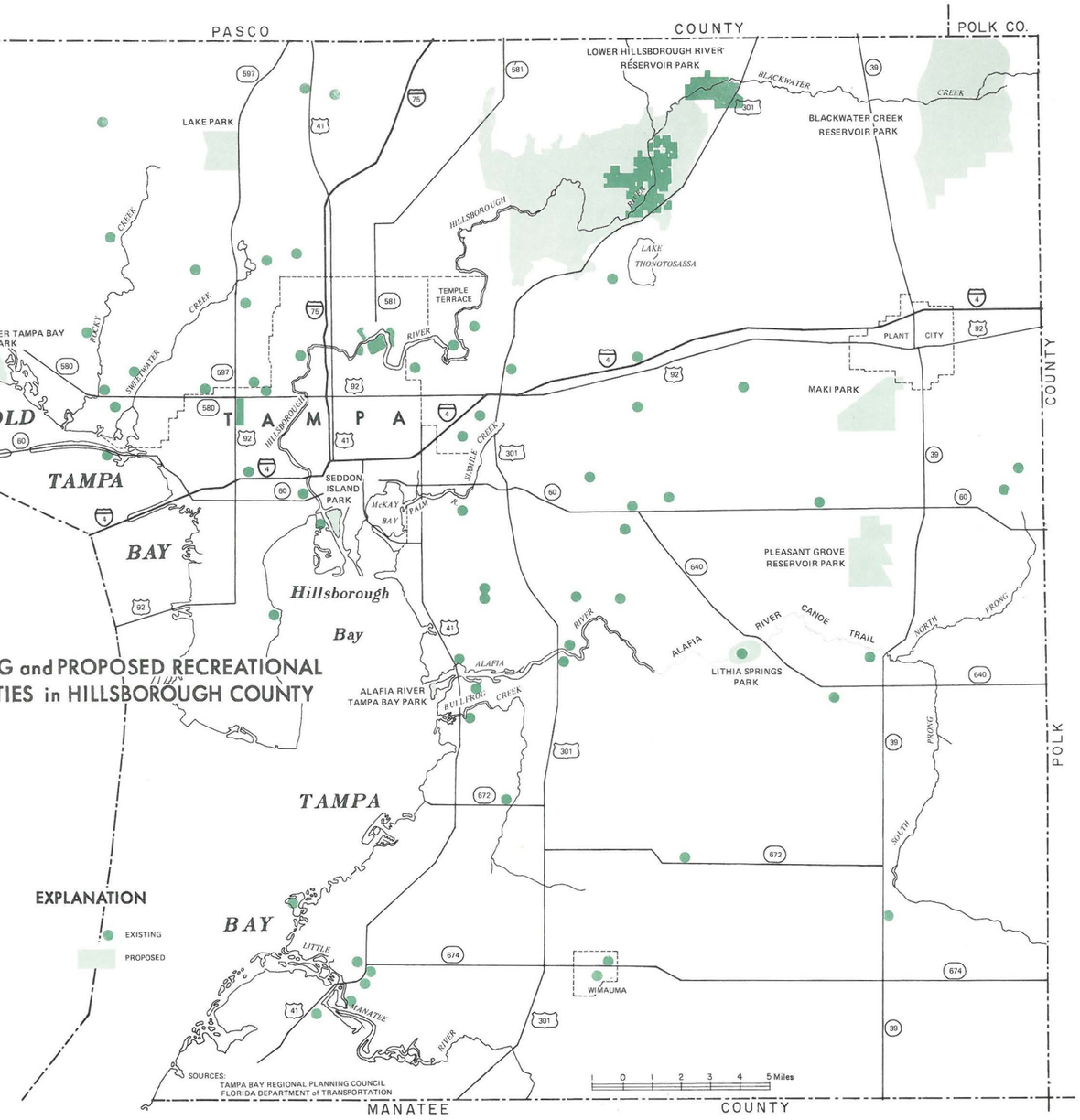
Fortunately, the area is endowed with many natural resources which are the crux of outdoor recreation. Geologic features frequently provide the focal point for recreational facilities in the Tampa area. Springs, for example, are a main attraction of many local parks. Another example of a unique natural feature can be found in Hillsborough River State Park where the occurrence of a rock outcrop in the river provides a scenic stretch of rapids. A primary natural asset of the Tampa Bay area is the Bay itself. Although the Bay has not been as significant a recreational resource as it might have been, several proposed recreation sites are located on the Bayfront.

The map shows existing and proposed recreational facilities within the Tampa area. The status of proposed facilities varies from the "drawing board stage" to "development near completion". Tampa's current and projected recreational demands are great, and the proposed recreation areas will not meet all of the needs. The task of the recreation planner, however, is simplified by the fact that any site distinquished by its natural or historical elements has potential for recreational development. The important point is that the creation of a list of potential recreational lands and acquisition of those lands should be done now. This is necessary for two reasons: the rising costs of real estate, and the need to preserve the lands' natural resource assets until such time as the sites can be developed for recreation. The fact that demands for water related recreation are greatest further emphasizes the necessity of properly managing the regional water resources.

[1]includes Hillsborough, Pinellas, Pasco, Polk, Manatee, Hardee, DeSoto, Sarasota and Highlands counties.



RECREATIONAL NEEDS OF THE TAMPA AREA CONTRASTED WITH THOSE OF THE MIAMI AREA (DATA SOURCE; DIVISION OF RECREATION AND PARKS, 1971)



TRANSPORTATION

Historically, transportation in the Tampa area has been vitally linked with the expanding population of the area. The existence of the natural estuary (ideally suited for the development of a port), played an important role in the location and subsequent growth of the City of Tampa.

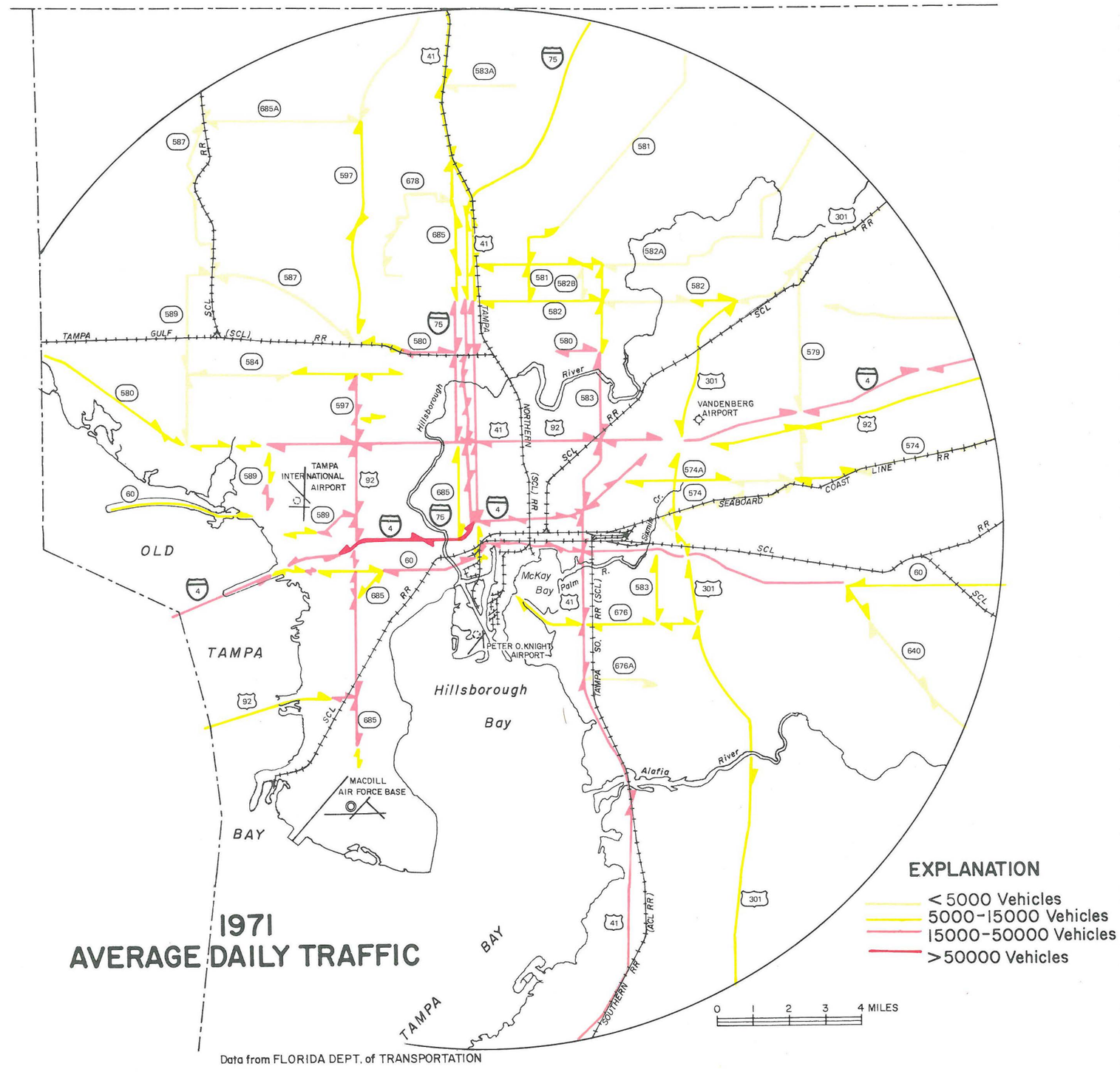
Tampa channel was initially dredged in the late 1800's, and has since been deepened several times to accomodate larger ships and cargo. The port was first used for shipping cattle to Cuba in the 1800's. Later, with the discovery of phosphate in the area, a prosperous future for the port was assured. Currently, phosphate is the leading product shipped from Port Tampa, and many area residents depend directly or indirectly on the port for their livlihood.

Whereas the port is a key to the economy of the Tampa area, the supporting role of the railroads for carrying goods to the port cannot be ignored. Like the shipping industry, the rail industry was initiated in Tampa during the late 1800's. In 1883, the railroad stretched eastward toward Plant City and by 1885 it was linked with the north. With the expansion and diversification of industry in the area, rail trade continued to grow.

A benchmark in transportation history was the completion of Gandy Bridge in 1924, then the world's longest auto toll bridge. Today's impressive network of highways reflects local and regional growth patterns in the Tampa area. Tampa is served by U. S., state and interstate highways.

The airline industry was born in 1914 in the Tampa area when Tony Janus made the first regularly scheduled flights from St. Petersburg to Tampa in an airboat. Tampa's new International Airport is a monument to the spectacular growth of air travel.

Tampa's transportation facilities are an important asset to the area. They provide convenience to residents, in addition to facilitating the flow of tourists to the area. Many transportation planning studies, now underway, incorporate environmental considerations to insure that future development of transportation facilities will have minimal environmental repercussions.



WATER

In 1971, Port Tampa handled over thirty six million tons of cargo. This is the largest tonnage handled by any port in Florida. Further, the port ranks eighth in the nation in total tonnage handled, and fourth in export tonnage. With the proposed deepening of the channel, the projected tonnage may reach sixty million tons by 1985, and one hundred million tons by the year 2000.

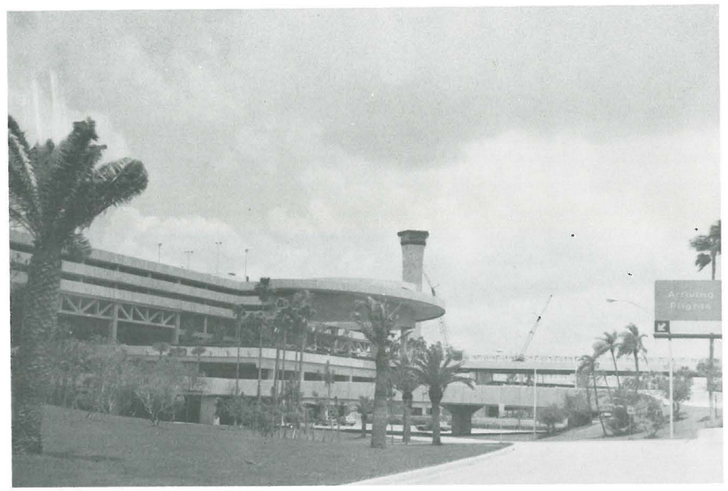
At the present time, the U. S. Geological Survey and the Tampa Port Authority have undertaken an estuarine hydrology and environmental study of Tampa Bay, to insure the wisest environmental and commercial management of the Bay. The present status and the fate of Tampa Bay have long been subjects of heated controversy. The comprehensive Bay study will provide a plethora of data including:

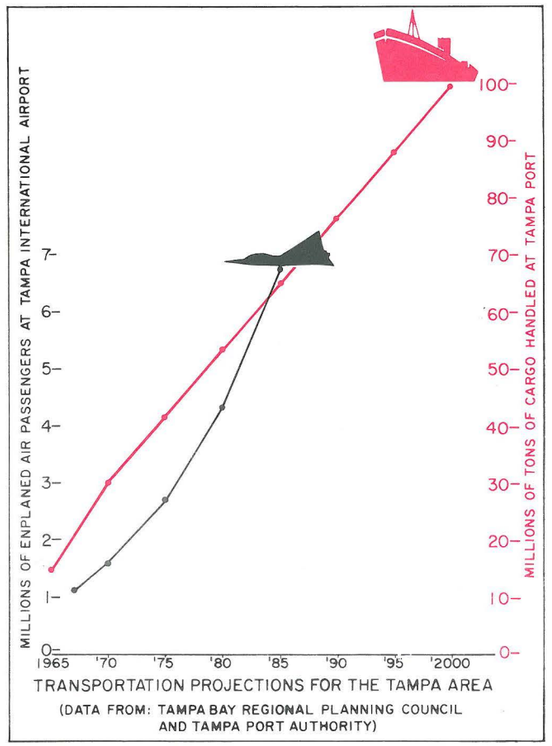
--the quality of Bay waters and sediments
--the quality of inflow to the Bay
--flushing mechanisms
--circulation patterns
--characteristics of bottom and sub-bottom deposits.

Among the most sophisticated estuarine investigations ever undertaken, the Tampa Bay study will entail development of a computer model which will provide accurate predictions of changes in the Bay environment so that improvements in the ship channel can be planned and designed to minimize environmental effects.

The deepening project is necessary to accommodate the larger new ships which the phosphate industry (the largest user of port facilities) will be using. The dredging operation will increase the channel depth to forty-seven feet. The actual desired depth is forty-three feet, but two foot allowances must be made for error and for slumping of the sediment after dredging is completed. It is expected that fifty million cubic yards of sediment will be removed under the supervision of the Army Corps of Engineers, which is the agency responsible for maintenance of the channels. Some sediments removed from the Bay will be used for construction purposes. The remainder will be used in spoil areas.

Photo by R.C. Reichenbaugh





TRANSPORTATION PROJECTIONS FOR THE TAMPA AREA

(DATA FROM: TAMPA BAY REGIONAL PLANNING COUNCIL AND TAMPA PORT AUTHORITY)

AIR

The new Tampa International Airport has been designated an intercontinental facility and jet terminal by the Federal Aviation Authority, and its runways and terminal complex are designed to accommodate all commercial aircraft including the 747 and SST. Currently, ten major scheduled airlines operate from Tampa International. Completed in 1971, the airport features four levels: baggage claim, ticketing, transfer (landside-airside shuttle), and parking. The multi-level concept and radial design minimize walking distance from automobile to aircraft seat and maximize efficiency.

The remainder of the airports in the area (exclusive of Macdill) are for private use. They offer flight schools, aircraft sales, service and leasing, or some combination of these.

SURFACE

Hillsborough County is served by interstate highways 4 and 75. On completion, I-75 will enable driving from Tampa to Saulte Ste. Marie, Michigan on the Canadian border. Interstate 4 provides easy access to Florida's east coast, and in Daytona Beach it connects with I-95 which runs along the entire eastern coast of the United States.

With regard to rail transportation, the Tampa area is served by Seaboard Coastline, the eighth largest railroad in the nation. Seaboard is primarily a carrier of phosphate, and to a lesser degree, citrus products and passengers. Seaboard is also a feeder line to junctions where goods are transferred to other railroads and carried to more distant destinations.

TOPOGRAPHY

TOPOGRAPHIC MAPS

Topography (or the shape of the land surface) is of great significance to virtually every aspect of land use planning. The relationship of relief to geography and physiography, location and thickness of mineral resources, drainage patterns, climatology, vegetative patterns, occurrence of natural disasters, soil development, physical aesthetics, etc. points up the value of a familiarity with the topography of the study area. The shape of the land, portrayed by contour lines (lines of equal elevation), is the distinctive feature exhibited on topographic maps, however, a wealth of information about the area is also shown on the maps.

The Tampa area encompasses all, or portions of sixteen quadrangle maps, each showing an area of 7.5 minutes latitude by 7.5 minutes longitude. The scale on these maps is 1:24,000 - that is, one inch on the map equals 24,000 inches or 2000 feet on the ground. The contours are imaginary lines following the land surface at a constant elevation above sea level. The contour interval (given at the bottom of each map) is the vertical difference in elevation between adjacent contours on the map. In flat areas such as Tampa, the contour interval is generally small so that contour lines are not far apart.

Several characteristics of contour lines are noteworthy:

1) Contour lines never cross or intersect one another, nor do they split.
2) Every contour line closes on itself either within or beyond the limits of the map.
3) The closer the spacing of contour lines, the steeper the slope.
4) Contour lines curve upstream, but cross the stream at right angles to its course.

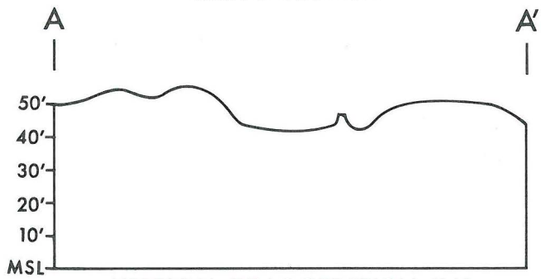
Topographic maps are ideal for pinpointing exact locations, as they are referenced to latitude-longitude, and contain a sectional gridwork within each township. Township is given on the sides of each map, and range on the top and bottom. Each of the 36 sections within a township represents one square mile, and each section number is shown in red on the map.

Color coding and numerous map symbols indicate a variety of physical and cultural features. Black is used for man-made features (roads, buildings, etc.), blue for water, brown for contour lines, mines, etc., green for vegetative cover, and red for urban areas, section lines, etc. In addition, lavendar is used on photorevised maps to show new features.

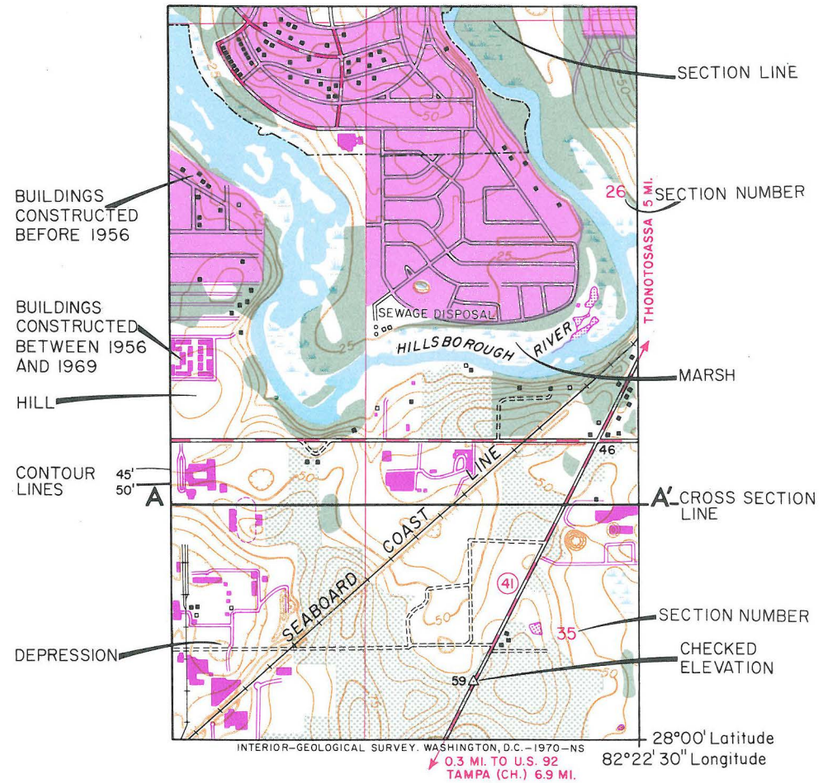
Cross sections (as shown in the diagram) can easily be constructed from topographic maps and are useful in representing cross country relief or slope of the land surface.

Topographic maps covering the Tampa area are available through the U. S. Geological Survey in Washington, D. C.

CROSS SECTION



VERTICAL EXAGGERATION X40



ROAD CLASSIFICATION

Heavy duty..... Light duty.....

Medium duty..... Unimproved dirt.....

Interstate Route U.S. Route State Route

SULPHUR SPRINGS, FLA.

N2800–W8222.5/7.5

1956

PHOTOREVISED 1969

AMS 4540 III SW–SERIES V847

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

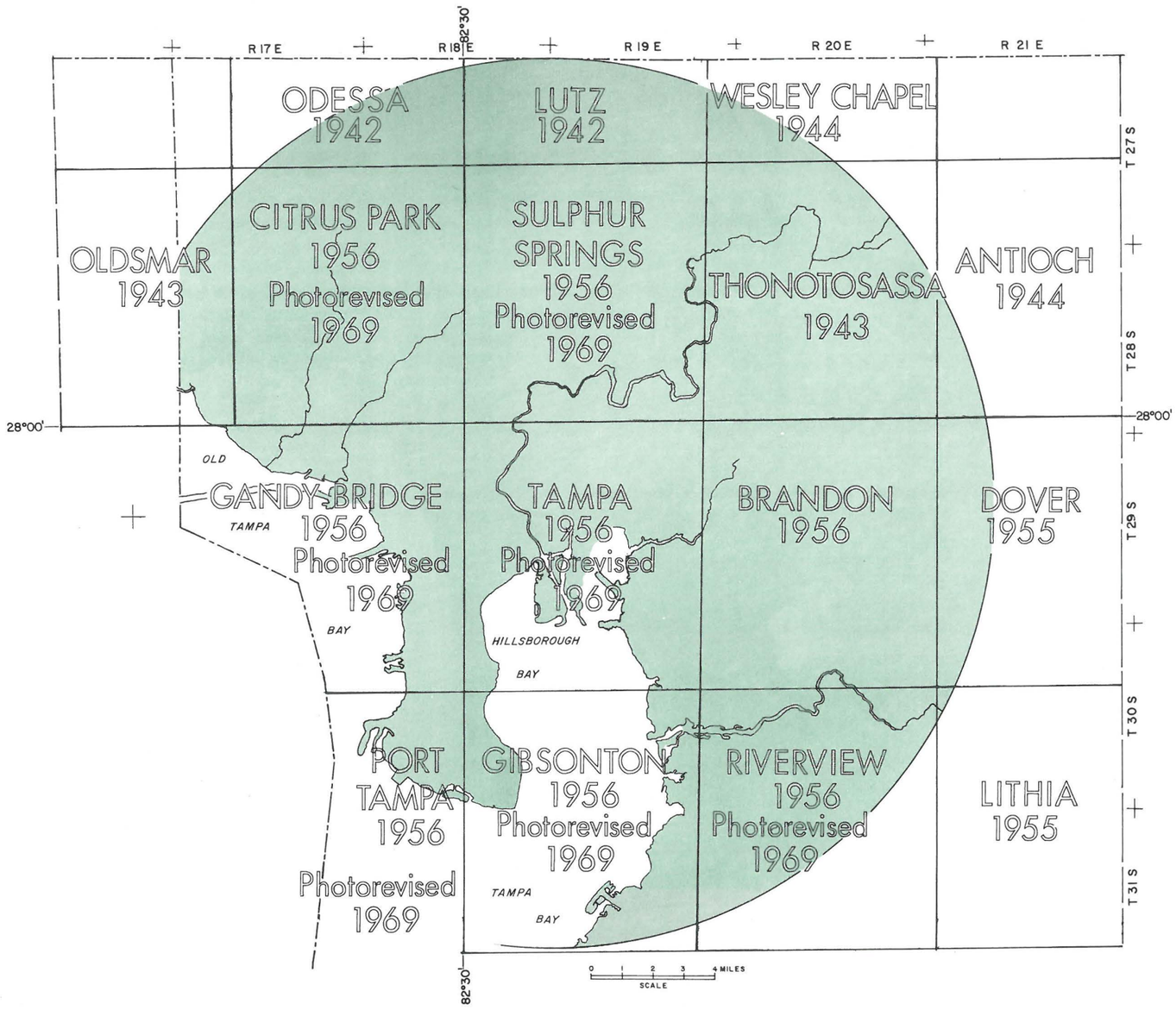
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 5 FEET

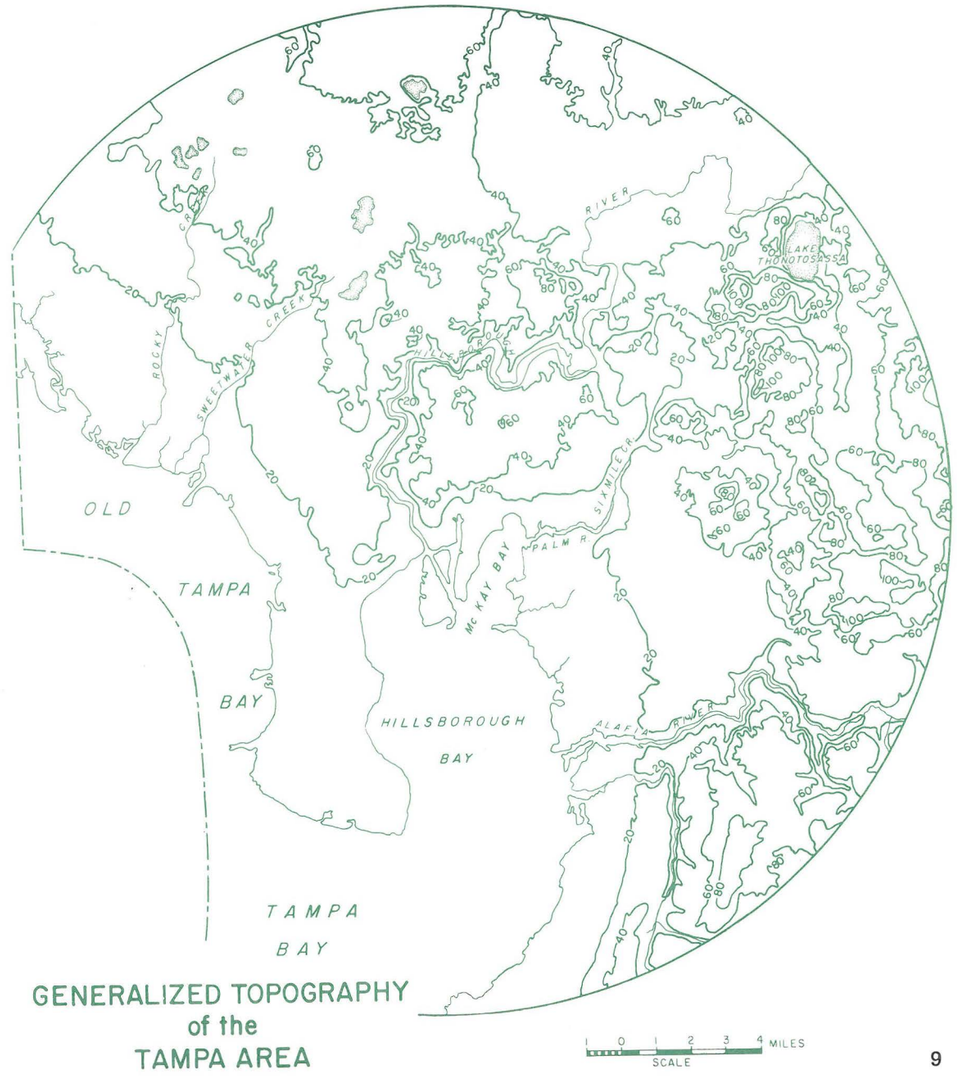
DATUM IS MEAN SEA LEVEL

TOPOGRAPHY OF THE TAMPA AREA

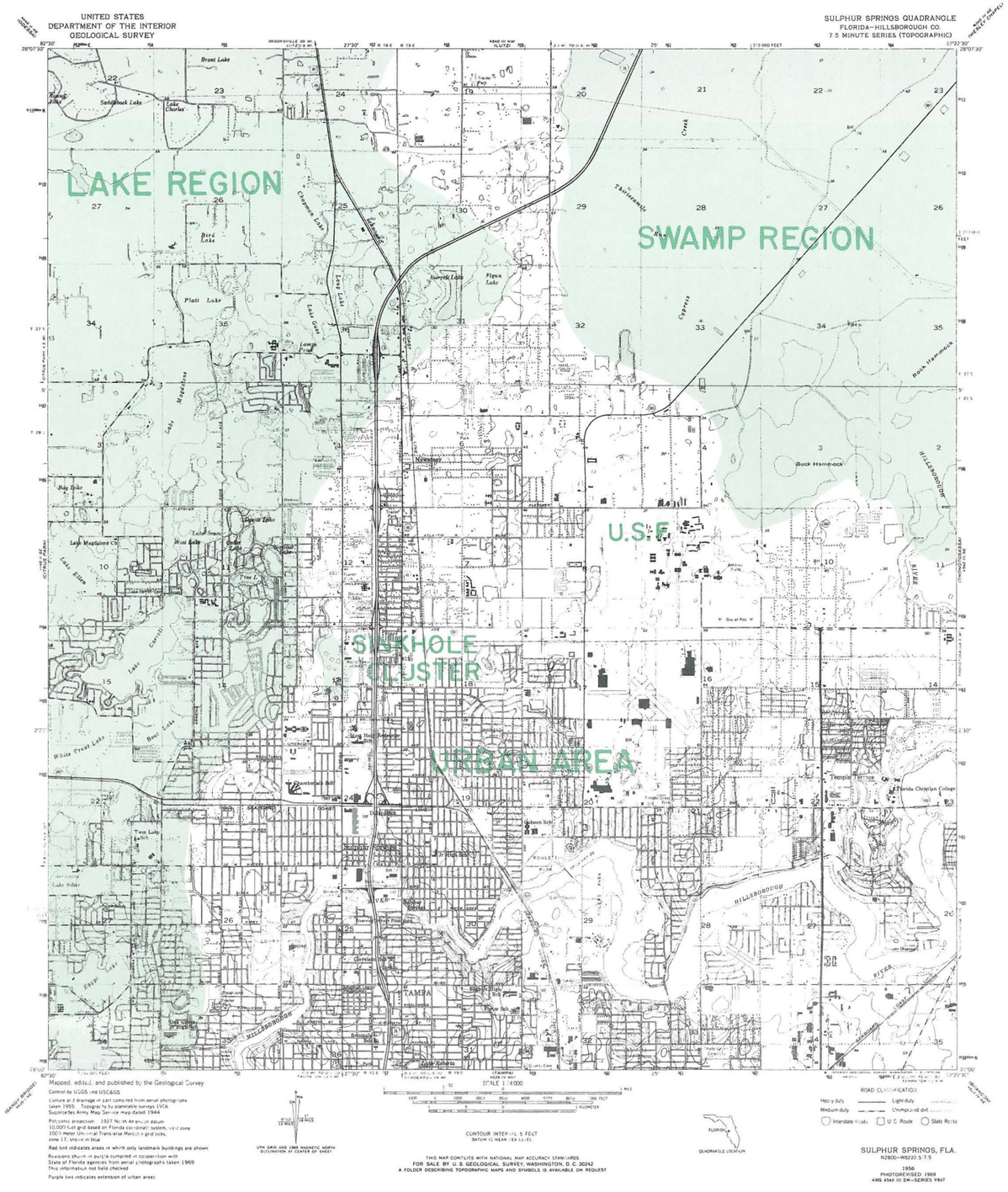
The index map on this page shows the boundaries of the sixteen 7.5 minute topographic quadrangles which encompass the Tampa area. Seven of them have been photorevised. Space does not permit reproduction of each quadrangle, however, the Tampa, Gandy Bridge, and Sulphur Springs quads are discussed on subsequent pages.



The simplified contour map presented here portrays the general topography of the Tampa area. The interbay peninsula, and the coastal strip (which ranges from about 1 to 3 miles wide) are characterized by elevations rarely exceeding 20 feet above sea level. Low relief extends inland for some distance from the mouths of the river channels. The area gradually slopes upward to the north and east. Highest elevations are found within the Polk Upland (see Physiography Section) in the eastern part of the area.



GENERALIZED TOPOGRAPHY of the TAMPA AREA



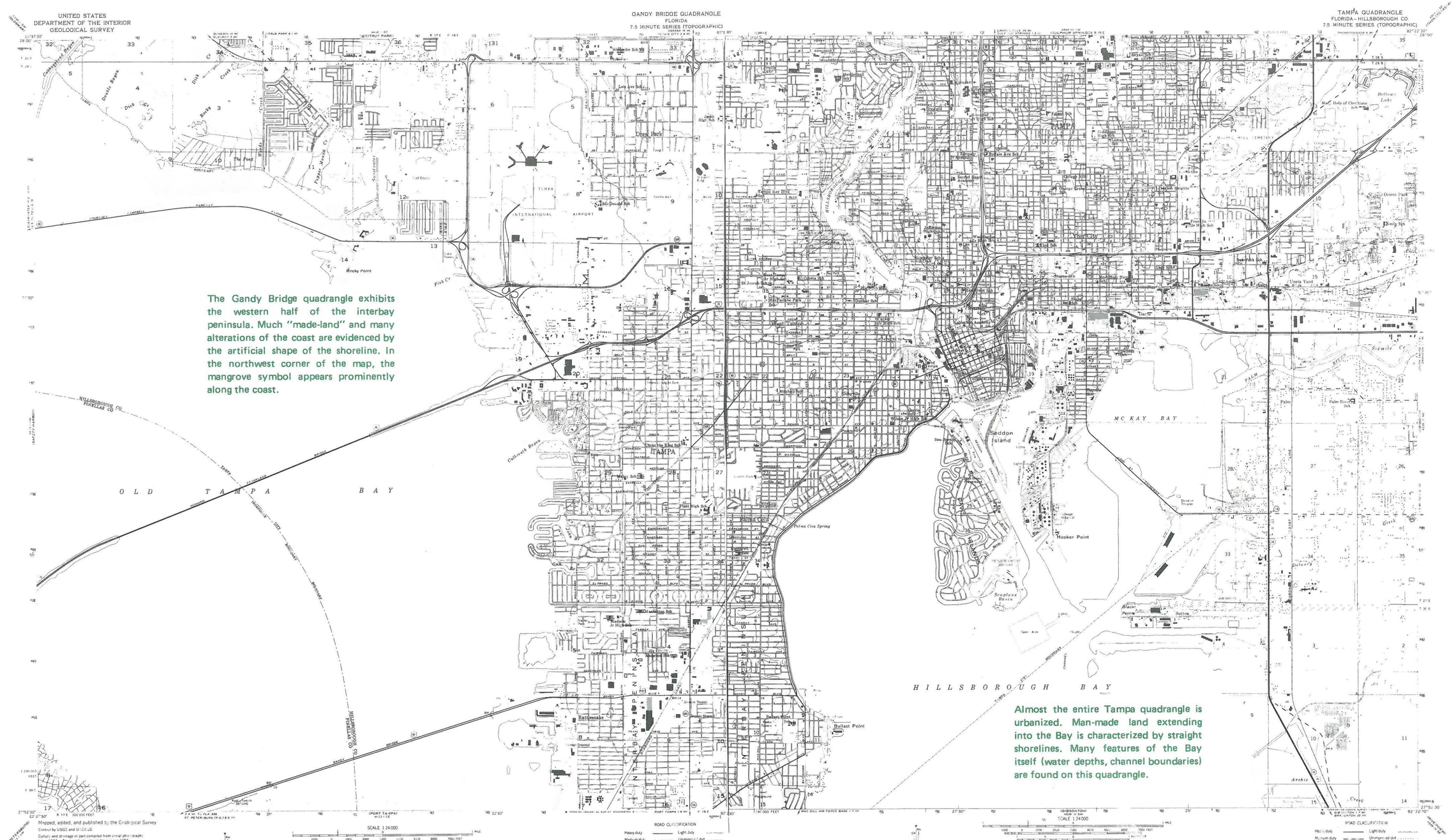
Sulphur Springs Quadrangle

The southern half of this quadrangle is highly urbanized. Physically, two distinctive regions are evident - a lake region and a swamp region. The western part of the map exhibits a preponderance of lakes, whereas the eastern half contains almost none. The elevations of most lakes are printed on the map within the surface area of the lake.

The northeastern quarter of the map is covered by wooded swamp, which accounts for the lack of development in that area. With the continued growth of the University of South Florida community, it is conceivable that urbanization may push its way toward the swamps as developers attempt to overcome the limitations of this hitherto low-priority land.

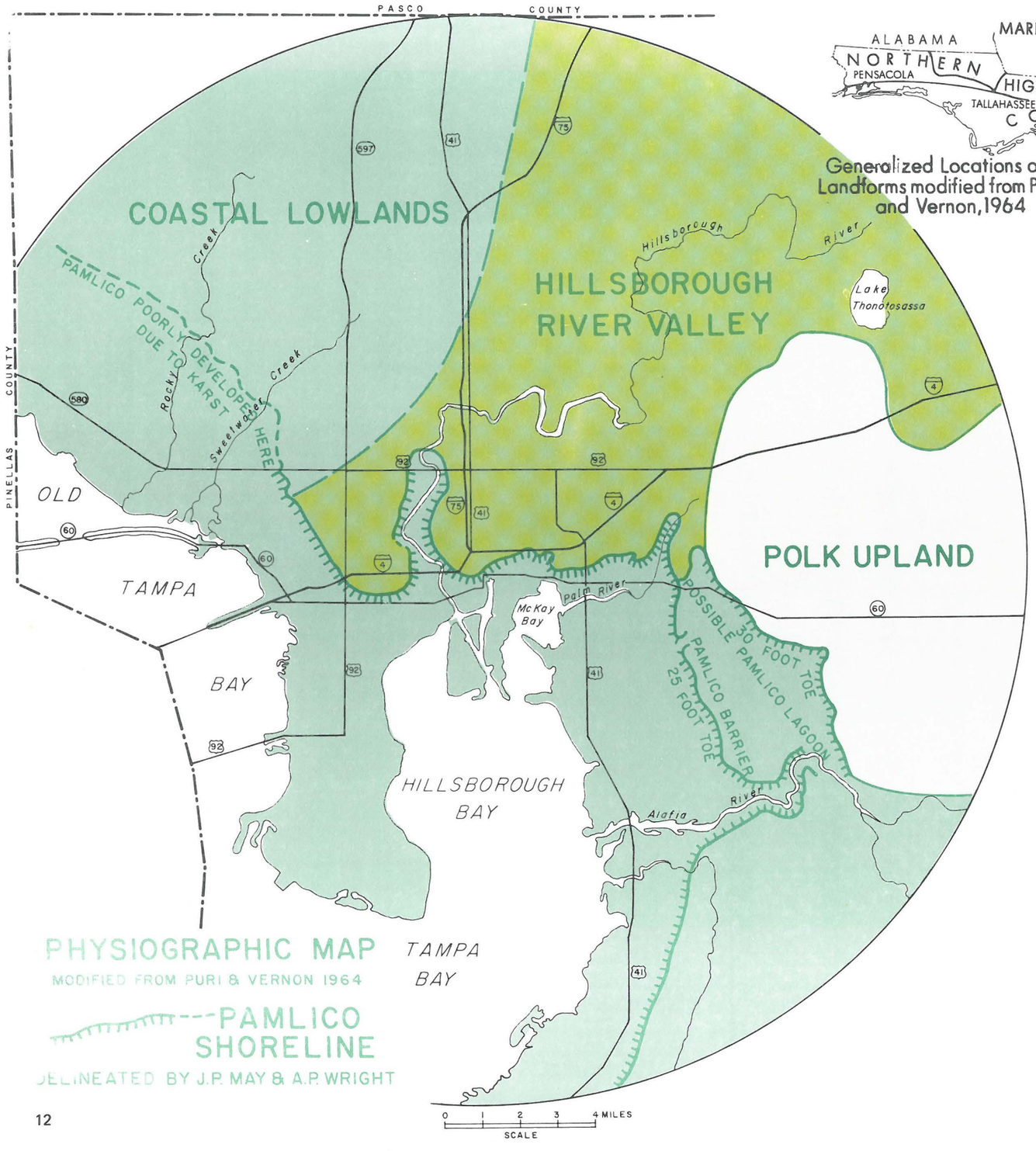
Another interesting feature of the map is the cluster of sinkholes near 109th Street and Florida Avenue. These appear as series of concentric circular contour lines with hachure marks indicating a drop rather than a rise in elevation. The blue symbol for water appears in the center of the sinkholes on the original map, but cannot be seen on this reproduction.

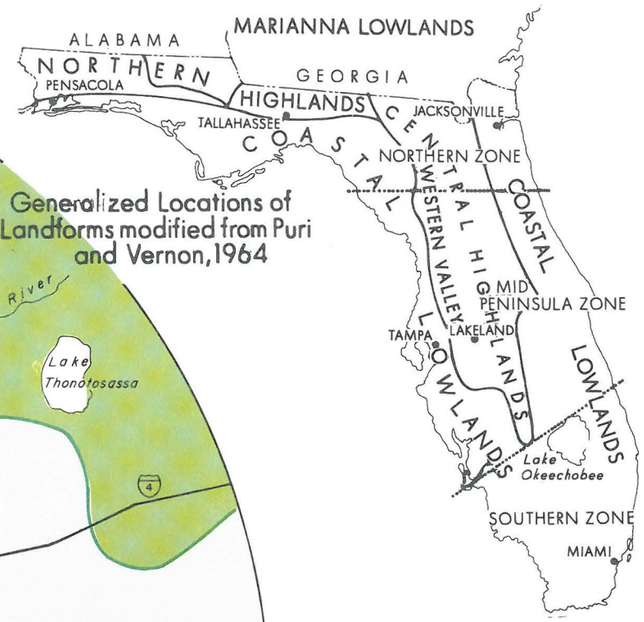
Lake Magdalene



The Gandy Bridge quadrangle exhibits the western half of the interbay peninsula. Much "made-land" and many alterations of the coast are evidenced by the artificial shape of the shoreline. In the northwest corner of the map, the mangrove symbol appears prominently along the coast.

Almost the entire Tampa quadrangle is urbanized. Man-made land extending into the Bay is characterized by straight shorelines. Many features of the Bay itself (water depths, channel boundaries) are found on this quadrangle.





PHYSIOGRAPHY

The Tampa area lies within the major physiographic subdivision known as the Gulf Coastal Plain and in general exhibits little variation in physiography.

The terrain is flat and low-lying, reflecting the relatively low relief of the bedrock. In the eastern part of the area, the land surface becomes gently rolling with smoothly rounded hills and shallow depressions.

On the basis of local physiographic features, the area can be divided into regions. These regions have been discussed in detail by White (1970).

Notable physiographic features within the area are related to the marine origin of the region. Traces of ancient stands of sea level are found in parts of the study area where the landscape has not been greatly altered by fluvial processes.

GULF COASTAL LOWLANDS

The western part of the Lowlands is very swampy and many lakes are present. Relict marine features, such as bars, barrier islands, etc., formed during ancient stands of sea level are found in the Gulf Coastal Lowlands. The area is largely covered by somewhat poorly drained sands with an organic pan and is characterized by flat topography and swamps. Sinkholes are scattered in the northwest area and will be discussed in greater detail later.

Each of the Pleistocene glacial stages was followed by an interglacial stage during which the ice melted and the seas encroached on the land. Each encroachment reached successively lower levels and consequently the remnants of interglacial shorelines can still be identified on land. These remnants provide clues to paleogeography. The Pamlico shoreline represents an advance of the sea to an elevation of about 25 feet above present sea level. From the configuration of the Pamlico shoreline in the Tampa area, it can be deduced that this area was occupied by a large and more open estuary during late Pleistocene time. Several islands also existed, primarily in the area of what is now Pinellas County. Relict sand dunes are found in the Temple Terrace area.

The extent of the Pamlico shoreline is shown on the map. This is the only Pleistocene shoreline that is well preserved in the Tampa area.

THE CENTRAL HIGHLANDS

The Central Highlands comprise a number of upland areas within mid-peninsular Florida. Among these is the Polk Uplands which is of considerably less elevation and local relief than many of the other Upland features. The general Central Highlands also encompasses several lowlands including the Western Valley. These lowland and highland features can be attributed to differential erosion which reduced unprotected soluble areas to lower elevations, leaving residual remnants of former regional upland areas.

The Hillsborough River Valley: The Hillsborough River Valley trends northeast-southwest through the central portion of the area and represents the southern end of the Western Valley which includes both the Hillsborough and Withlacoochee Rivers. There is evidence that the Western Valley may have once held only one long stream. Periodically, the Withlacoochee overflows into the Hillsborough River via a topographic saddle.

The Hillsborough River Valley has gently sloping to flat relief and is dissected by the Hillsborough River and its numerous tributaries. The size of Hillsborough Bay into which the river flows, coupled with the fact that a Pleistocene shoreline can be traced part way up the river valley suggests that the Hillsborough River has existed for some time. The river's broad, swampy flood plain is also indicative of an older river. Although well drained, deep sands cover much of the area, portions of the River Valley are swampy, and relatively few lakes are present.

The Polk Upland: The eastern part of the study area encompasses a small portion of the Polk Upland. This area is topographically higher than the surrounding Coastal and River Valley lowlands and attains elevations of 100 to 130 feet. The terrain is gently rolling and bounded on the west by a scarp whose slope steepens toward the Hillsborough River. The area is covered by well drained sands which are mixed with phosphatic material in places.

TOPOGRAPHY AND LAND USE PLANNING

Because of the detail and accuracy of topographic maps and the relevancy of topography to land use, planners can utilize topographic maps for myriad purposes. Some examples are given below:

Locating and Evaluating Mineral Resources

Valuable mineral deposits are often associated with physiographic features (arches, relict beach dunes, etc.) that are revealed on topographic maps. In addition, if the elevation of the top of an economic mineral deposit has been mapped, this map can be superimposed on a topographic map of the area and the land surface elevation minus the deposit elevation is equal to the thickness of overburden that will have to be removed prior to mining.

Selecting Industrial and Residential Sites

Topographic maps provide information that is useful in selecting industrial and residential sites. Topographic maps can be used as base maps for showing utility lines, access roads and waterways, zoning boundaries, potential water supply and the present industrial-residential pattern of the community.

Planning Recreation Areas

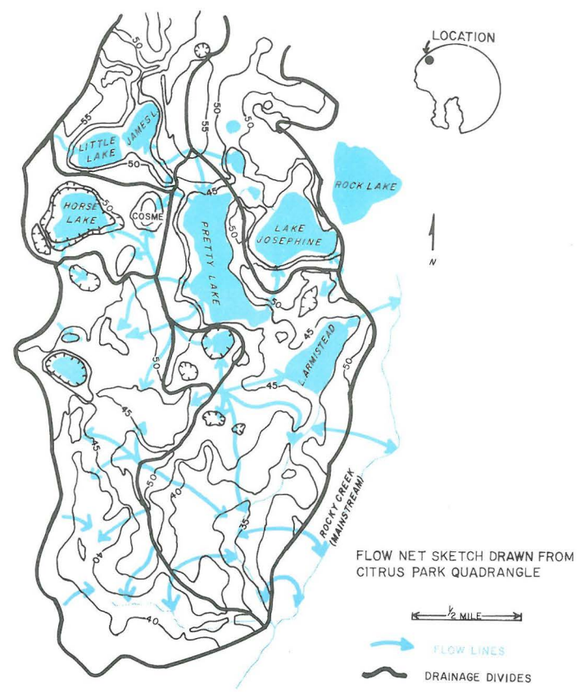
Topographic maps are ideal for locating areas with unique physical attributes that may be suitable as recreation areas. Potential hiking and canoe trails can be sketched on topographic maps, then evaluated in the field. Lack of urbanization is often a primary criteria for recreation areas, and undeveloped land can be spotted at a glance on topographic maps.

Defining and Evaluating Water Resources

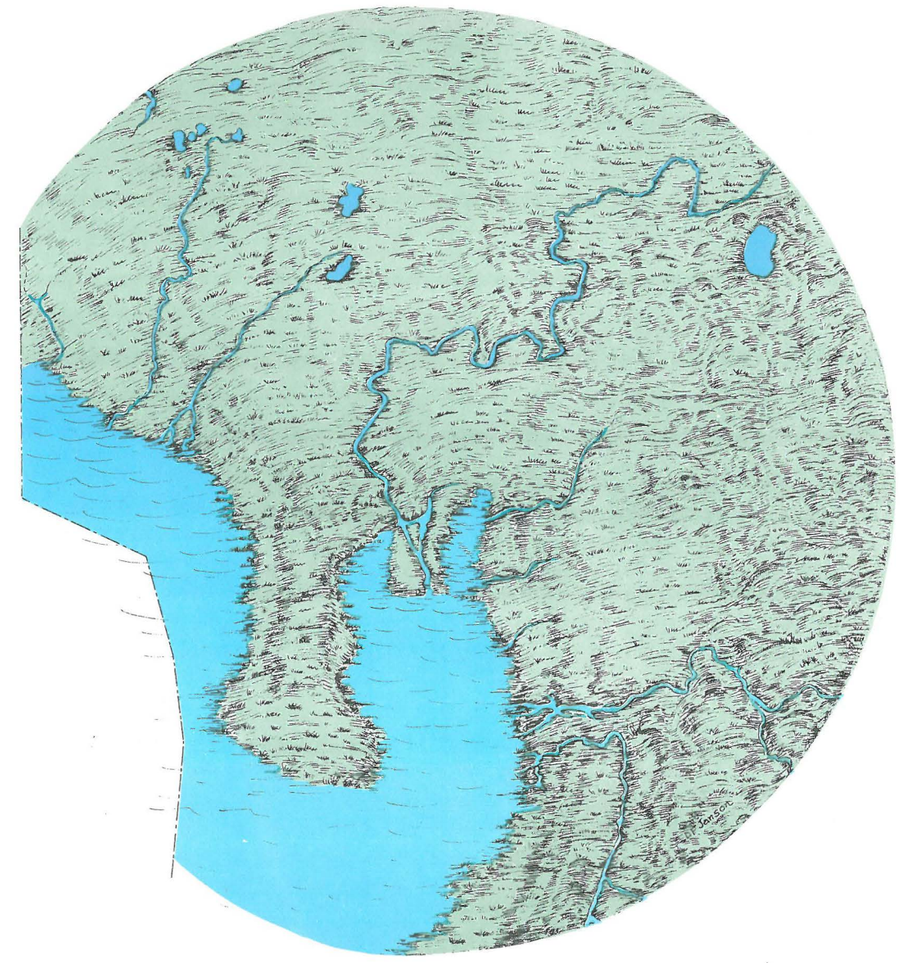
Topographic maps serve as a tool for planning watersheds, recharge areas, well fields, surface water supply sources, flood control structures, reservoirs, etc. Indeed their applications to hydrology are almost limitless. The map illustrates how surface drainage patterns and drainage basin boundaries can be delineated on a topographic map. Such flow nets are used in planning flood control and drainage projects and in correlating climatological conditions with surface water flow.

Incorporating Physical Aesthetics in the Regional Plan

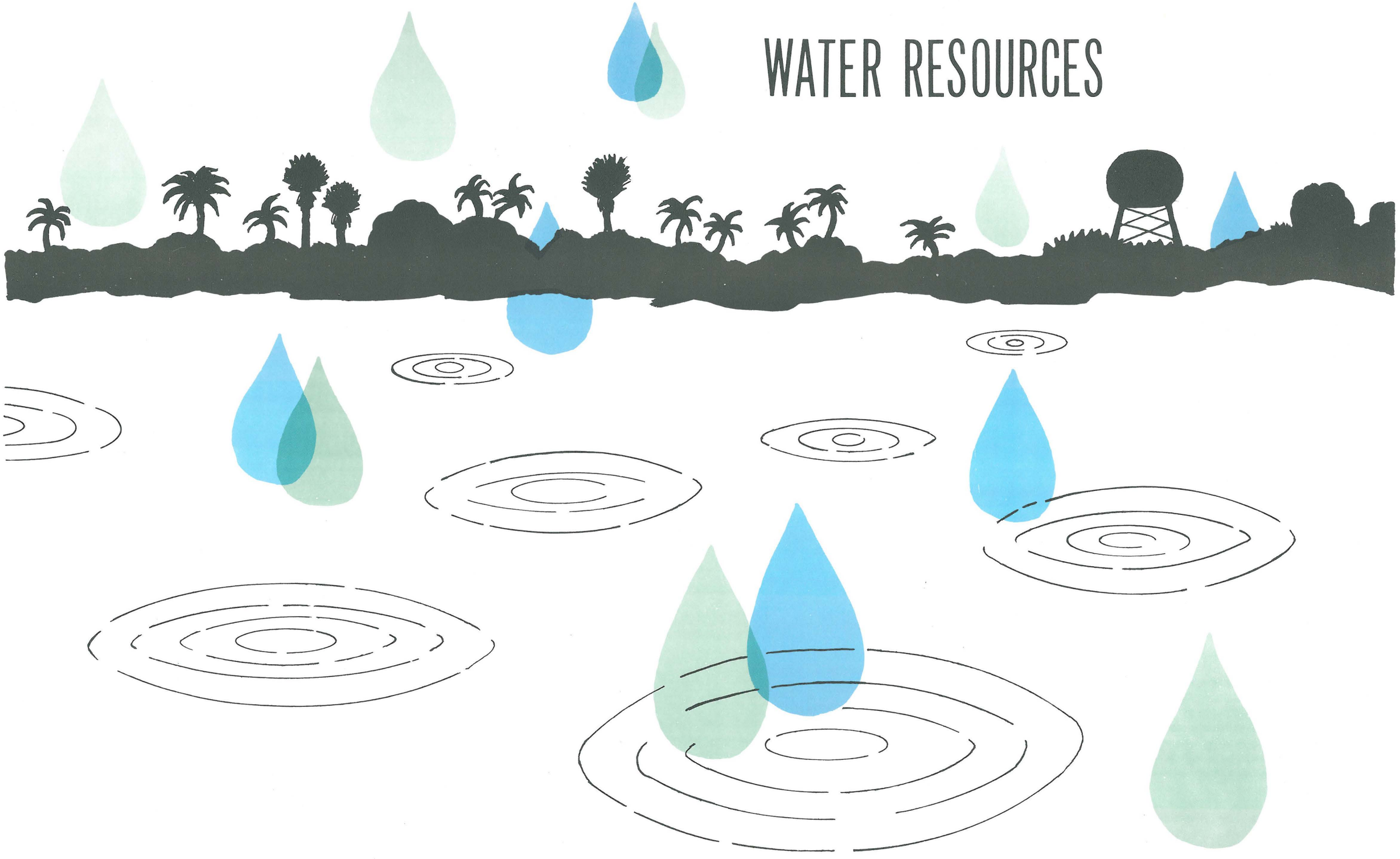
In many areas there is an aesthetic quality to the "lay of the land". Creative planners can sometimes capitalize on inherent physical appearances by emphasizing the natural landscape in the land use plan. Topographic maps can be a starting point from which a land use design that is harmonious with natural features can be developed.



FLOW NET SKETCH DRAWN FROM CITRUS PARK QUADRANGLE



WATER RESOURCES



WATER CYCLE

One of the consequences of urbanization is an increasing demand upon available water resources for public supply, recreation, industry and other purposes.

As the competition for water intensifies, hydrology becomes a more prominent aspect of planning, and sound and equitable water management becomes a necessity. The hydrologic cycle is a fundamental concept in understanding, planning for and managing water resources.

Fresh water on land is derived from ocean water evaporated by the sun's heat. Evaporated water in vapor form is transported by convective air currents through the atmosphere to inland areas, where part of the vapor condenses and precipitates.

Rain that reaches the land returns either to the ocean by gravity flow or to the atmosphere by evaporation from land, water and plant surfaces. Before the basic cycle is completed, however, much interchange of water may take place between lakes, swamps, streams and the ground. Time required for a water particle to complete the cycle may vary from an instant to many years, depending on the path it takes.

Once rain reaches the land surface its path depends on the terrain. Two important characteristics are the slope of the land surface and the permeability of the surficial and underlying materials.

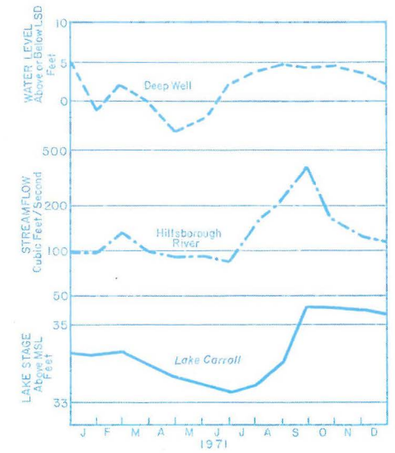
Steep slopes and low permeabilities promote the runoff of rainfall to streams or to lakes, swamps, and sinkholes which may or may not connect to streams leading to the ocean.

Gentle slopes and high permeabilities promote the infiltration of rainfall into the ground. Much of the water that infiltrates is stored in a soil zone, serving to supply water for vegetation, but part of it moves down to the water table, ultimately to emerge at some lower level, usually in areas that contain or adjoin streams, lakes and swamps.

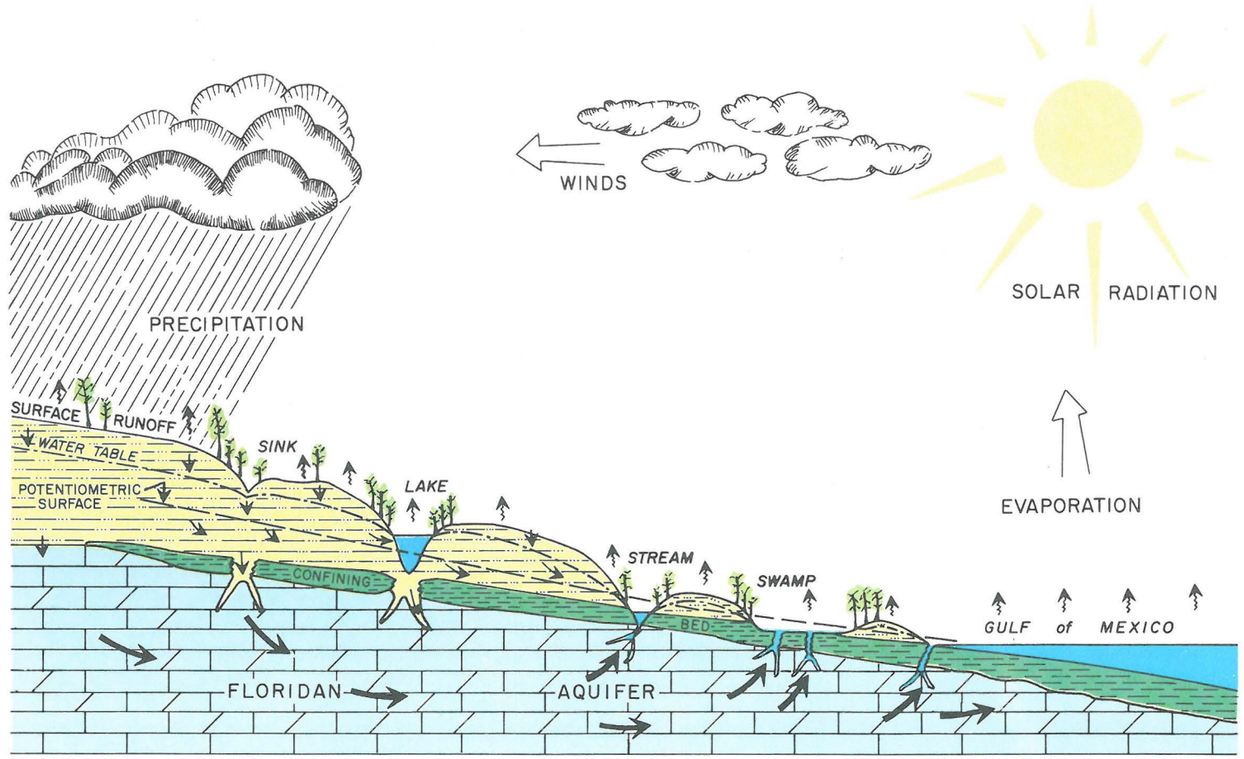
In Hillsborough County water may also move downward into the Floridan aquifer, which underlies the water table aquifer and is generally separated from it by a layer of relatively impermeable material called a confining bed. Sinks in the bottoms of some streams and lakes may connect directly with the Floridan aquifer. Water in the Floridan aquifer eventually emerges as springflow in streams, lakes, swamps, or the ocean.

Recharge to and discharge from the Floridan aquifer are dependent on the relative position of the waters involved and the fact that water always moves from higher to lower elevations. Because water in the Floridan aquifer is confined, its potential elevation is represented by an imaginary surface, called the potentiometric surface, which is determined by the level at which water freely stands in tightly cased wells that penetrate the aquifer. Given the necessary openings in the confining bed, water can move into the Floridan aquifer from water bodies which stand above the potentiometric surface; conversely, the Floridan aquifer can discharge water into water bodies whose levels stand below the potentiometric surface.

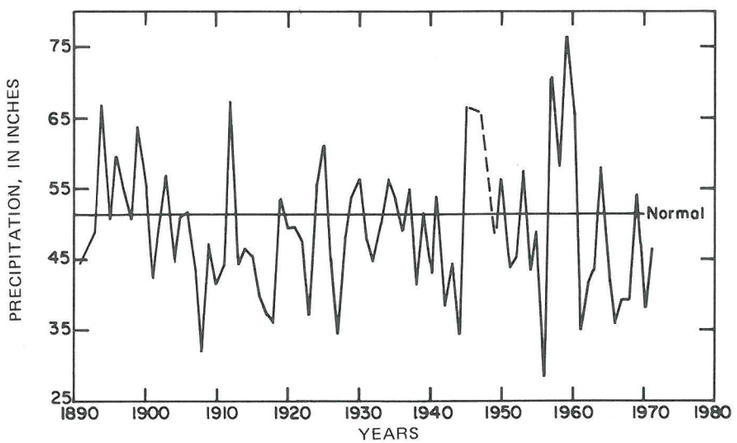
It is evident that all components of the hydrologic system are interrelated to form a delicate balance, and when one component of the system fluctuates, other components fluctuate similarly. This can be illustrated by the relationship between streamflow, lake and well levels. These levels respond to both natural and artificial alterations in the quantity of water within the system. Projects involving water withdrawal, addition, or diversion should be evaluated in terms of possible effects on the entire hydrologic system.



WATER LEVEL AND STREAMFLOW RECORDS INDICATING RELATIONSHIP BETWEEN COMPONENTS OF THE HYDROLOGIC SYSTEM



PRECIPITATION AND EVAPOTRANSPIRATION



YEARLY PRECIPITATION, IN INCHES, AT TAMPA, FLORIDA

Replenishment of lakes, streams, and aquifers in the Tampa area is largely dependent on precipitation. Normal annual precipitation at Tampa is 51.57 inches, however, total yearly precipitation fluctuates widely. The lowest yearly total recorded was 28.89 inches in 1956, and the highest recorded was 76.57 inches in 1959.

Monthly variations in precipitation are important to farmers, construction companies, homeowners, etc. Two wet seasons are defined by the graph of monthly precipitation in Tampa: a pronounced one during the summer, and lesser one early in spring. Most rainfall occurs between June and September as a result of thunder storms, tropical depressions or hurricanes. During these months, outdoor activity is often restricted by frequent showers, and local flooding may occur.

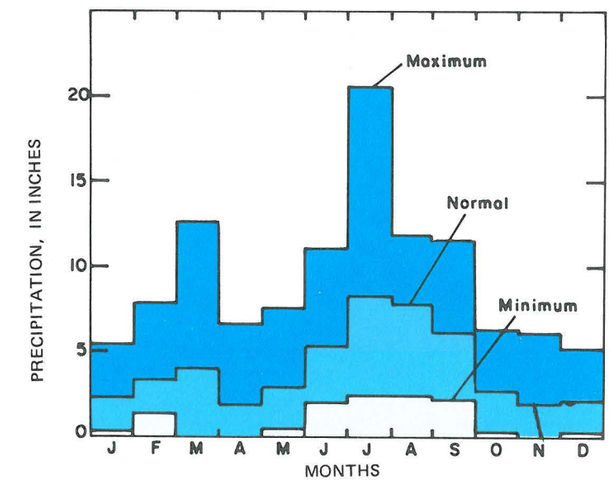
Lack of precipitation in late spring may bring about regional drought which causes the vegetation to experience moisture stress. At this time, there are critical demands on water resources for irrigation and sprinkling, and restrictive measures are sometimes imposed.

Whereas precipitation is the primary source of replenishment of the water resources in the area, the amount of water that actually enters the hydrologic system is sharply reduced by evapotranspiration (ET).

Potential monthly ET can be calculated on the basis of mean monthly temperatures and sunlight duration. During months when precipitation exceeds the potential ET value, all potential ET can take place. If the precipitation is less than the potential ET, actual ET consumes all precipitation plus some of the moisture stored in the soil, and the actual ET is less than the potential ET. This leaves a moisture deficit.

During rainy months there may be a moisture surplus. This is equal to the precipitation that remains after all potential ET has taken place and the soil moisture retention has been restored to full capacity (about 4 inches per foot in the Tampa area). Each month when there is a moisture surplus, about half of the accumulated excess water leaves the area as runoff.

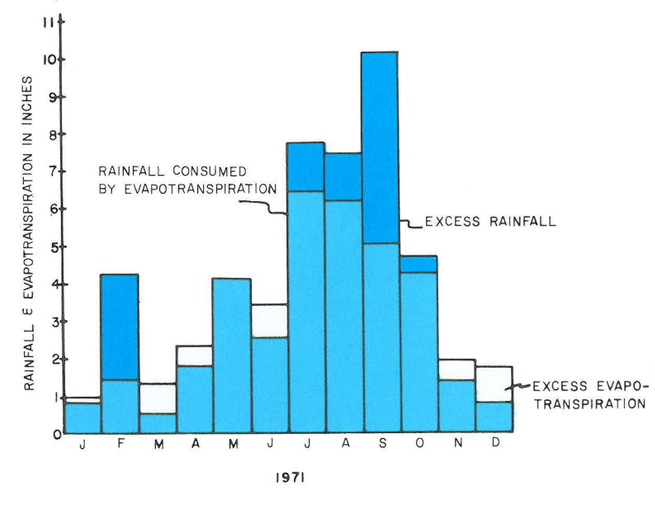
It is easy to see that evapotranspiration takes a heavy toll on precipitation, and the "leftovers" must be carefully managed. Although drainage is essential to optimum land use in many locations within the Tampa area, the consequences of drought can be lessened by retaining as much excess water in the area as is feasible.



MAXIMUM, MINIMUM, AND MEAN MONTHLY PRECIPITATION, 1952 – 1971

WATER BUDGET—TAMPA, FL., 1971
(methodology from Thornwaite & Mather, 1957)

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
PRECIPITATION (INCHES)	.86	4.25	.54	1.80	4.09	2.54	7.74	7.46	10.16	4.70	1.40	.79	46.33
POTENTIAL EVAPOTRANSPIRATION (INCHES)	.99	1.44	1.41	2.63	4.47	6.02	6.45	6.18	5.07	4.28	1.97	2.21	43.12
ACTUAL EVAPOTRANSPIRATION (INCHES)	.99	1.44	1.34	2.42	4.33	3.92	6.45	6.18	5.07	4.28	1.94	1.86	40.22
MOISTURE DEFICIT (INCHES)	0	0	.07	.21	.14	2.10	0	0	0	0	.03	.35	2.90
MOISTURE SURPLUS (INCHES)	0	2.68	0	0	0	0	0	1.28	5.09	.42	0	0	9.47



DRAINAGE

On one hand, the Tampa area is facing ever-increasing demands for water, which are difficult to meet with present supply sources...

A critical need exists to retain water on or below the land surface.

On the other hand, many acres of valuable land are flood prone and many additional acres are swampy and unusable throughout most of the year...

A critical need exists to dispose of, or provide facilities for the disposal of excess water.

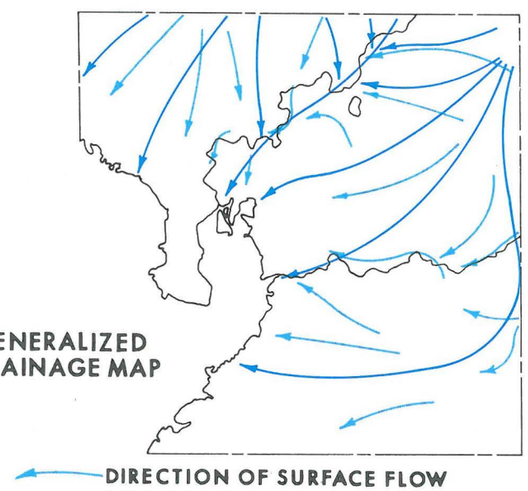
The polarity of these problems provides the greatest challenge to water management efforts.

Ideally, projects which deal with one problem can be planned so as not to intensify the other; or water management can be directed toward alleviating, in part, both problems simultaneously.

Water management projects in the Tampa area are currently underway by the U. S. Army Corps of Engineers and the Soil Conservation Service.

UPPER TAMPA BAY WATERSHED
Soil Conservation Service

The watershed includes about 103 square miles in which the two principal problems are flood damage and drainage. The objectives of the SCS watershed project are 1) to protect improved pasturelands, citrus groves and other agricultural developments from flood water damage (2) to provide drainage outlets, and 3) to conserve water during the dry season.



GENERALIZED DRAINAGE MAP

DIRECTION OF SURFACE FLOW
DIRECTION OF GROUND WATER FLOW

These objectives will be accomplished by land treatment measures, channel construction and improvement and installation of channel control structures.

The average annual cost of the project ($160,000) compared to the average annual benefits ($212,340) places the benefit: cost ratio at 1.33 to 1.

The main objective of SCS is to improve agricultural land, however, when lowlying areas are drained, they become suitable for other land uses which may have higher economic priority. Consequently, as land values increase the ownership and use of the land may gradually change.

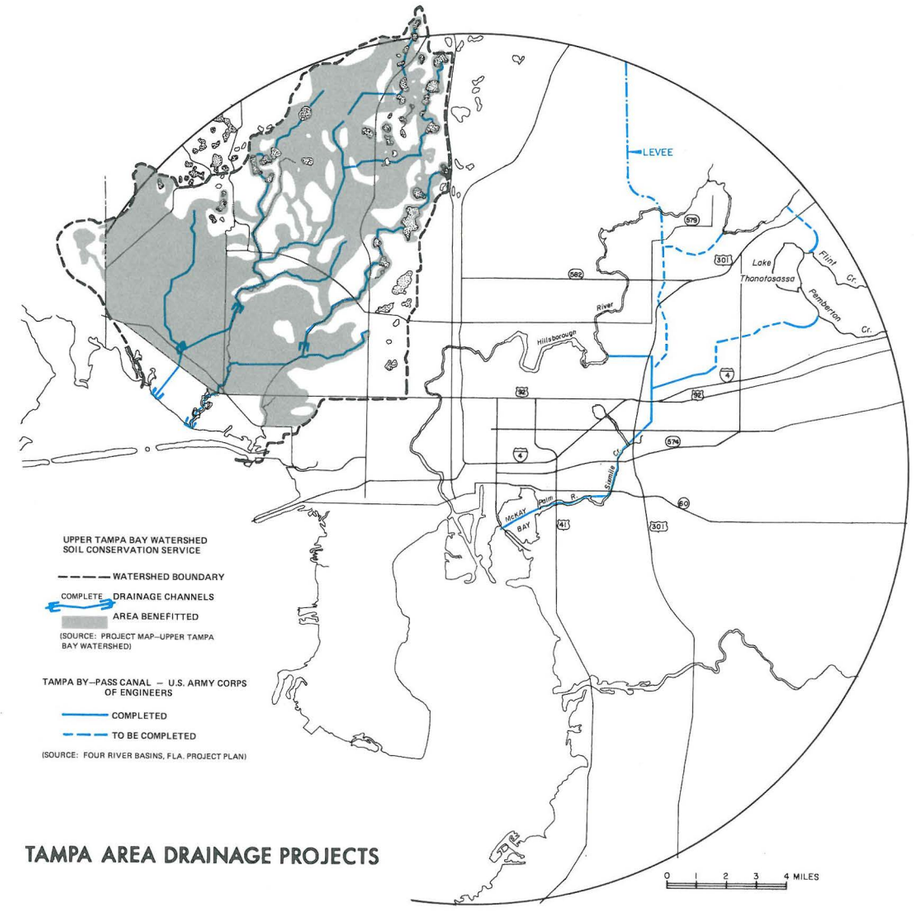
Although SCS proposes to retain much of the drainage and flood water, evapotranspiration losses will be high, as all retention areas will be above ground. If the excess water could be rapidly recharged to the Floridan aquifer, more could be conserved and the raised potentiometric surface would reduce the threat of salt water encroachment. (One of the SCS structures can be seen in the soil portion of this study.)

FOUR RIVER BASINS PROJECT
U. S. Army Corps of Engineers

The objective of the total project is to deal with the following items: flood control, major drainage, navigation, recreational boating, water conservation, pollution abatement, and salt water intrusion. Several works of improvements are slated for the Hillsborough River. Of special importance to the Tampa area are the lower Hillsborough River "Detention Area" (discussed previously) and the Tampa Bypass Canal.

The Canal, when completed, will lead south from the Lower Hillsborough Reservoir and pass east of urban Tampa. During time of flood, it will divert water from the Hillsborough River directly to the bay. It is designed to give urban Tampa maximum protection from floods - including one so severe, its likelihood of occurrence is once in about 200 years.

The benefit: cost ratio of the entire Four River Basins project is estimated at about 1.5 to 1.



TAMPA AREA DRAINAGE PROJECTS

Sections of the Canal have been excavated below the top of the Floridan aquifer and below the level of the potentiometric surface. Here, newly made springs are discharging into the canal and the potentiometric surface is being lowered. It is hoped that an adequate number of control structures will be installed to raise the water levels in the Canal and thereby prevent a large decline in the potentiometric surface, excessive drainage from the aquifer, and salt water encroachment. (A view of the Canal can be seen in the Geology section of this study.)

WATER QUALITY

A variety of chemical and biological constituents are present in water sources in varying amounts, and the quality of any water sample reflects many factors, including:

1) source of the sample
2) season during which the sample was taken
3) time of sampling
4) specific location and depth of the sample
5) nature of soils, rocks and vegetation that the water has contacted
6) kind and amount of matter that has been introduced to the water source by man.

Water quality standards have been established for public water supply, shellfish harvesting, recreation, agriculture, industry, navigation and utility. In addition, quality standards have been set for specific water uses such as production of carbonated beverages, pulp, canned foods, etc. These standards necessitate the following considerations in planning:

-- is the existing quality of the available water source suitable for a given use, or will extensive treatment be necessary?

Since all water "used" is actually "borrowed" and will eventually be returned to the environment in some form, a second consideration is important:

-- will the use add detrimental constituents to the water in such quantity that treatment will be necessary before the water can be returned to the environment?

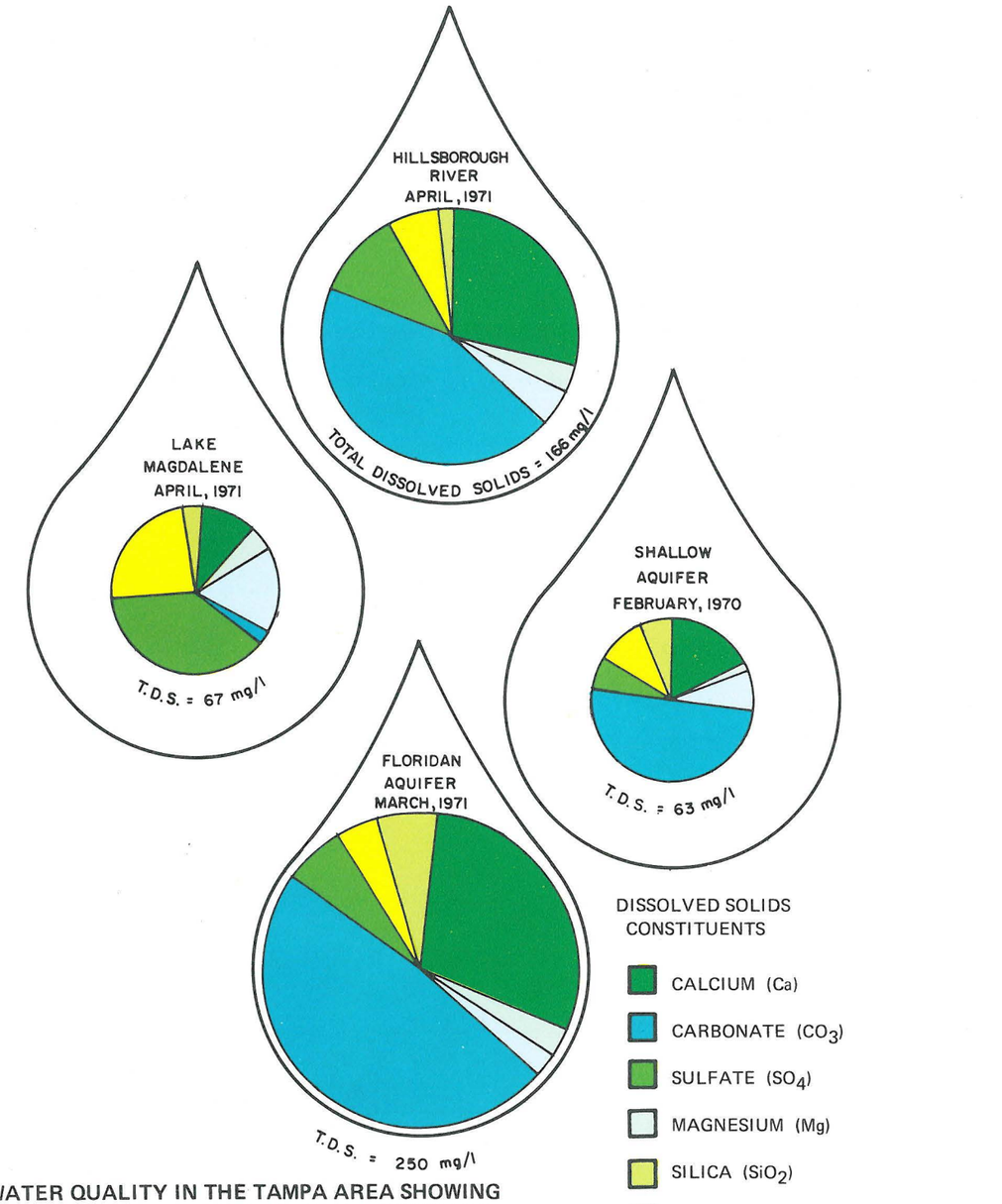
Discharge of noxious liquid effluents is only one means of fowling a water body. Alteration of the land surface or landscape may also have detrimental effects on water quality. For example, removing vegetation from a construction site may accelerate erosion and increase turbidity in a nearby stream or lake.

Detriment to the water resources may not be readily evident after a project has been completed, but it may be avoided if the possibility is considered during the planning phase of the project.

SOURCE & SIGNIFICANCE OF CHEMICAL CONSTITUENTS IN WATER

Constituent or property	Source or Cause	Significance. Maximum tolerable concentration for public water supply is shown in parentheses.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Produced by reaction of atmospheric CO_2 with water. Dissolved from carbonate rocks such as limestone and dolomite.	HCO_3 and CO_3 produce alkalinity. In combination with calcium and magnesium, cause carbonate hardness.
Calcium (Ca) and Magnesium (Mg)	Dissolved from most soils and rocks, especially limestone, dolomite, and gypsum. Magnesium is present in large quantities in seawater.	Cause most of the hardness and scaleforming properties of water; consumes soap.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and abundant in ancient, and industrial brines and seawater.	About 300 mg/l in combination with sodium gives salty taste to water. Increases the corrosiveness of water. (250 mg/l).
Dissolved solids (TDS)	Chief mineral constituents dissolved from rocks and soils.	Water containing more than 1,000 mg/l of dissolved solids are unsuitable for many purposes (500 mg/1).
Fluoride (F)	Dissolved in small quantities from most rocks and soils. Enters many water from fluoridation of municipal supplies.	Fluoride in drinking water can reduce tooth decay but may cause mottling of teeth depending on concentration and other factors (1.4 to 1.6 mg/l depending on air temperature).
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentrations much greater than the local average may suggest pollution. Nitrate encourages growth of algae and other organisms which produce undesirable tastes and odors.
Phosphate (PO4)	Dissolved from many rocks and soils. Some from fertilizers, detergents, domestic and industrial wastes.	Phosphates stimulate the growth of algae. Excessive amounts may indicate pollution from phosphate mining or domestic wastes.
Silica (SiO_2)	Dissolved from most rocks and soils, usually in small amounts from 1-30 mg/l.	Forms hard scale in pipes and boilers. Inhibits deterioration of zeolite-type water softeners.
Sodium (Na) & Potassium (k)	Dissolved from most rocks and soils. Found in ancient brines, seawater, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. High sodium content may limit the use of water for irrigation.
Specific conductance ($K \times 10_6$)	Measure of the ability of water to conduct electrical current.	Specific conductance is directly proportional to dissolved mineral content of water. Can also be related to individual constituents in water.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in sewage, mine waters and some industrial waters.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water (250 mg/l).

Modified: M. E. Beard, 1969, The Florida District Water Quality Laboratory:



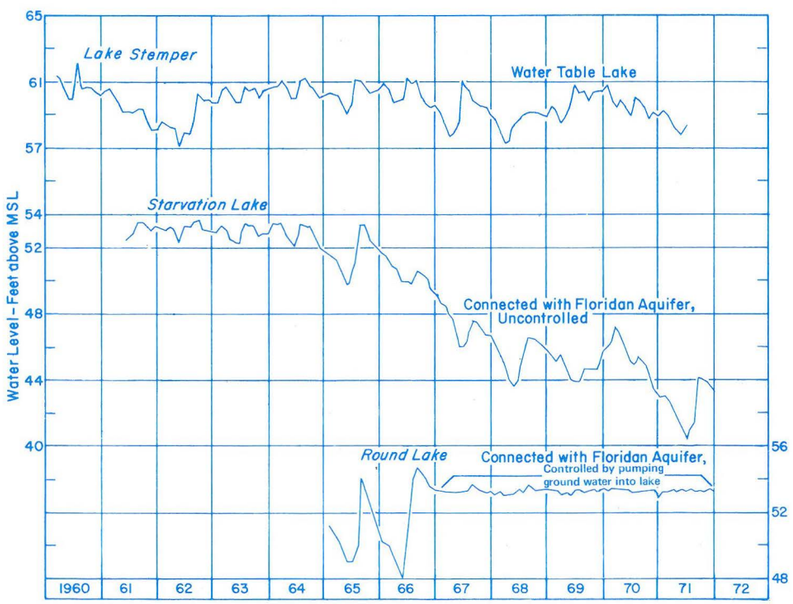
WATER QUALITY IN THE TAMPA AREA SHOWING RELATIVE PROPORTIONS OF TOTAL DISSOLVED SOLIDS AND CHEMICAL CONSTITUENTS OF TOTAL DISSOLVED SOLIDS.
(Data from: U.S.G.S. Provisional records)

LAKES

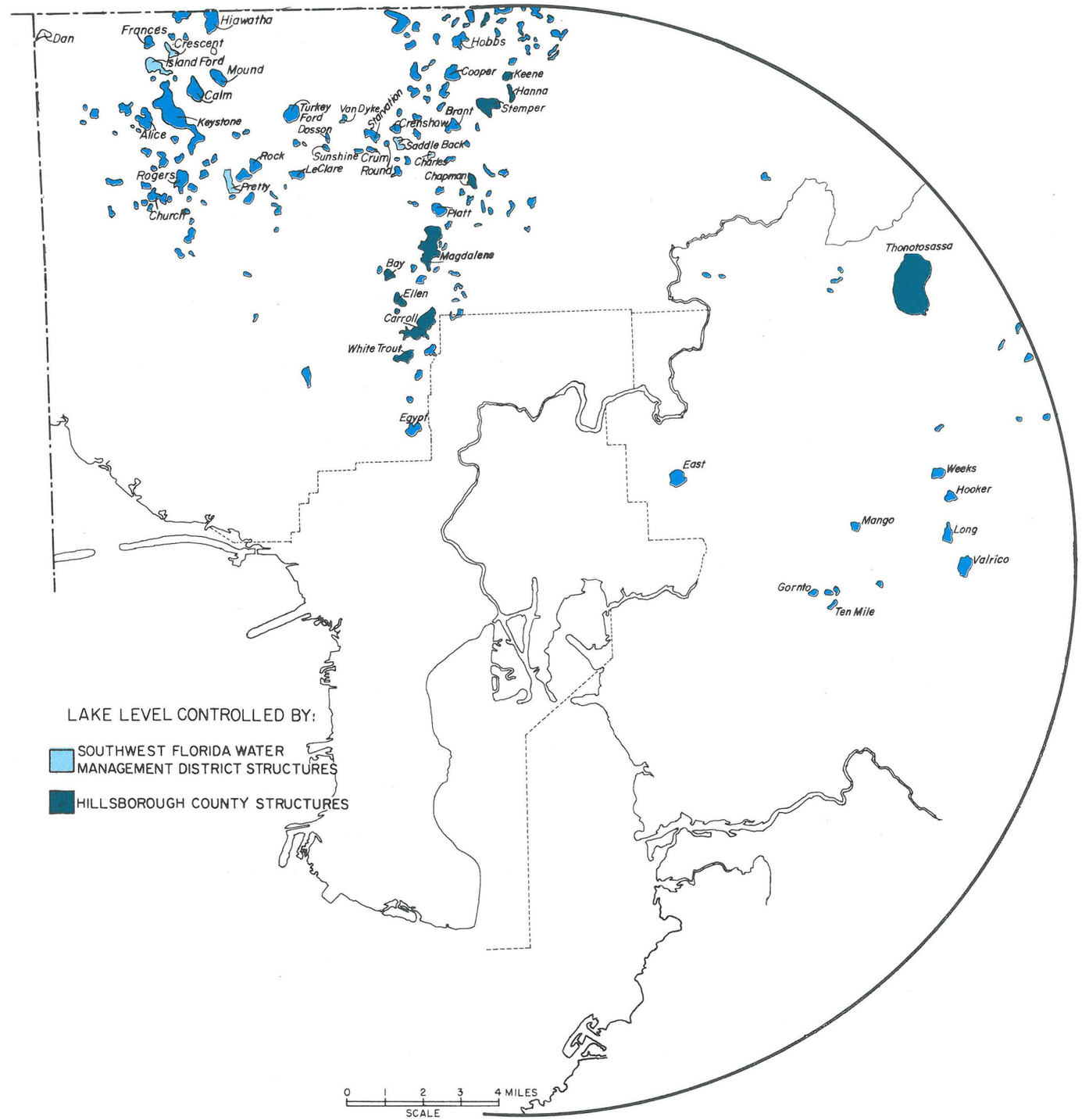
The Tampa area is dotted with numerous lakes which are especially abundant north of the city (see map). Here, lakes are concentrated on a low sandy ridge which is 20 to 40 feet higher than adjacent poorly drained swamplands.

Some lakes occupy depressions that intersect the shallow water table. Water levels in these lakes respond to changes in water table elevation. Other lakes occupy partly filled sinkholes or cavities connected to the Floridan artesian aquifer, and fluctuate with the potentiometric surface. A third lake type is found in depressions lined with relatively impermeable material perched above the water table. Although water levels in all lakes are affected by rainfall and evaporation, perched lakes depend almost entirely on rainfall to maintain their levels. It is doubtful that perched lakes in the Tampa area would have any permanence, as such lakes in the Tampa climate would soon be filled with vegetation.

Underground movement of water to or from a lake depends on the relationship between lake level, water-table level, potentiometric surface, and the nature of the deposits underlying the lake. J. W. Stewart (1968, p. 118) has found that the decline in levels of some lakes near the well fields in northwest Hillsborough County was in part due to the cumulative effects of well pumpage. In order to prevent large fluctuation in water level, control structures have been installed at many lakes in the Tampa area.



HYDROGRAPHS OF SELECTED LAKES IN THE TAMPA AREA



DISTRIBUTION OF LAKES IN THE TAMPA AREA
(INFORMATION FROM S.W. FLA. WATER MANAGEMENT DISTRICT)

The chemical quality of lake water is an important factor in the continued use of lakes in the area. Although the quality of lake water is generally good, the total dissolved solids in several of the larger, more urbanized lakes in the area are increasing with time. Conductance and turbidity of several local lakes are shown in the graph.

A decrease in the quality of lake water may reflect either the direct addition of contaminants to the lake water such as by surface drainage or indirect addition by seepage. Lands with high animal populations, septic tank fields, or receiving high pesticide applications may indirectly contribute contaminants to a nearby lake.

Eutrophication is another factor which threatens lakes. This is the enrichment of water with nutrients that promote excessive plant and animal growth. Eutrophication accompanies the natural aging process of a lake, but may be greatly hastened by the activities of man. Study is essential to determine which lakes are under accelerated enrichment before any corrective measures can be employed.

During the developments of subdivisions, dredging of lake bottoms is sometimes undertaken to increase the size or depth of a lake and provide fill material to adjacent property. Such projects have the potential to disturb the ecology of the lake basin, change the drainage area, remove impermeable material from the lake bottom with consequent altering of lake level characteristics, and render the lake highly turbid. Extremely fine particles suspended in lake water may not settle for many years.

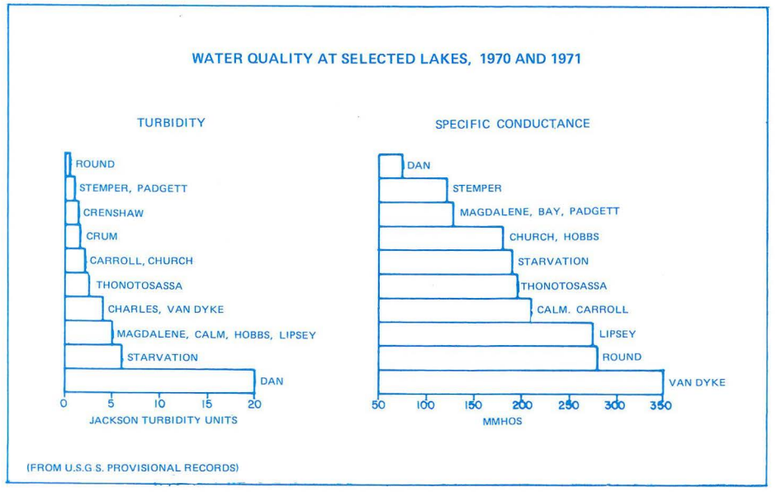
In some areas, new man-made lakes have been created. It is clear that a thorough investigation of the geology and hydrology of the area must precede such a project. With careful planning, some borrow pits may be reclaimed and converted to lakes bordered by attractive landscaping.

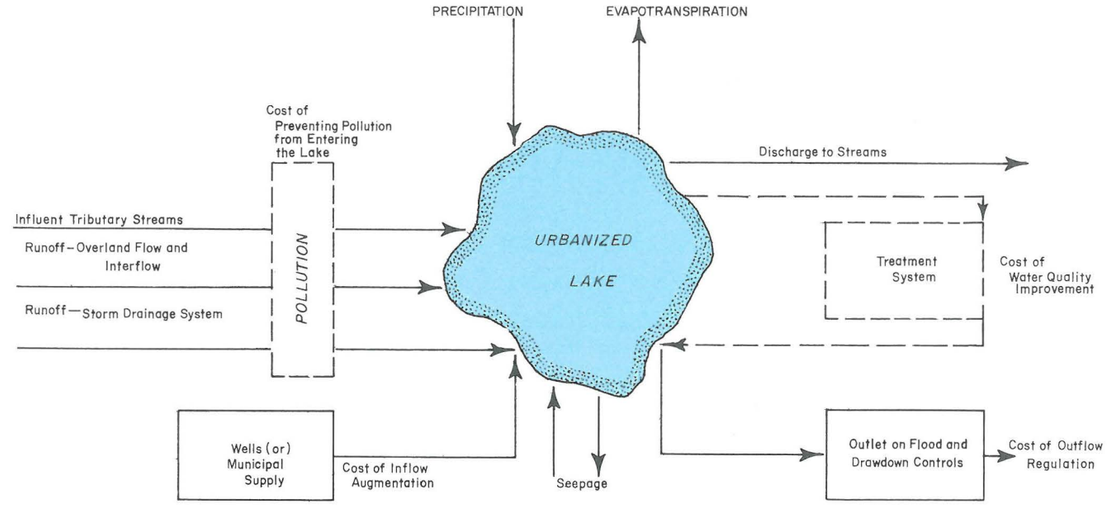
Lakes in the Tampa area are utilized largely for recreation and residential focal points. Property values usually increase with proximity to a lake. Continued recreational and residential benefits hinge on maintaining adequate chemical quality, and reasonable water level fluctuations. Some range of fluctuation in lake level is conducive to the health of the lake.

Some of the potential lake problems which should be considered in developing and managing lakes and adjoining property are:

1) lakefront flooding
2) abnormal recessions in lake levels
3) sedimentation caused by stripping nearby terrain (a special threat during the rainy season)
4) contamination from:
   a) septic tanks
   b) outboard motor oil
   c) storm runoff from urban areas
   d) runoff from agricultural or farm-lands (pesticides, nutrients).

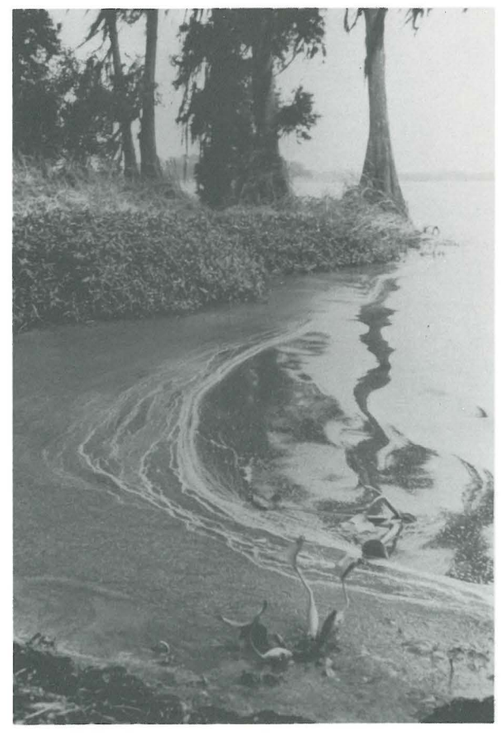
A lake planning and management model is presented on this page.





From: U.S.G.S. Circular 601-G, Real Estate Lakes, D.A. Rickert and A.M. Spieker

SCHEMATIC DIAGRAM OF A BASIC LAKE PLANNING AND MANAGEMENT MODEL.



Shoreline of Lake Thonotosassa. (photo by R.C. Reichenbaugh)

Typical circular collapse structure.
(photograph by J.W. Stewart)

"To improve lake quality three major things must be accomplished:

1. The nutrients must be reduced in the lake and future sources of input reduced or stopped.
2. A significant zone of rooted aquatic vegetation must be maintained.
3. The lake must be allowed to fluctuate in a manner similar to the historical natural fluctuation of the lake."

Southwest Florida Water Management District Hydroscope, Vol. 3, No. 11.

STREAMS

Excluding the Hillsborough River, which will be treated separately, there are four major streams within the Tampa area which discharge into Tampa Bay. Streamflow is highly variable seasonally as well as annually due to climatological conditions.

Water in the four streams is generally not of the highest quality because of the addition of urban wastes to streams within the Tampa area and contamination from upstream sources which may be outside the County. The ultimate recipient for all streamflow from the area, Tampa Bay, receives 328,400 pounds of suspended solids per year from sewage treatment plants alone. Some important points, regarding streams, that should be land use planning considerations include:

- *Any development which alters the topography will likely alter the drainage pattern in the area.*
- *Any emplacement of contaminants in a stream may endanger the downstream uses of the water.*
- *The lower the flow in a stream, the greater the chances for salty bay water to move upstream.*

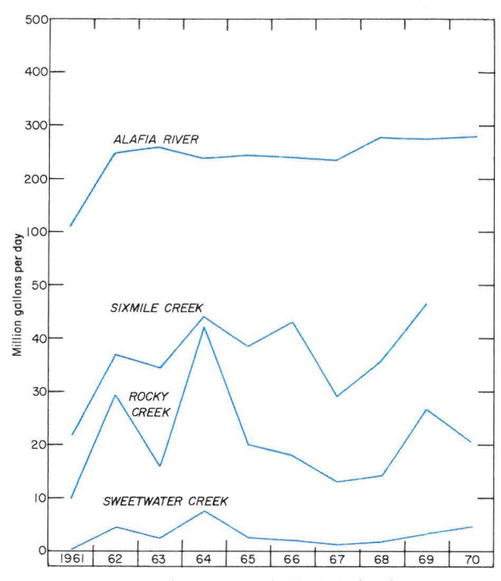
Two consequences of the movement of bay water inland during low flow are: mineralization of the stream itself, and seepage of brackish water into the aquifer.

Competent and effective drainage basin management is mandatory if the effects of drought, flood and pollution are to be minimized and stream channel aesthetics maintained.

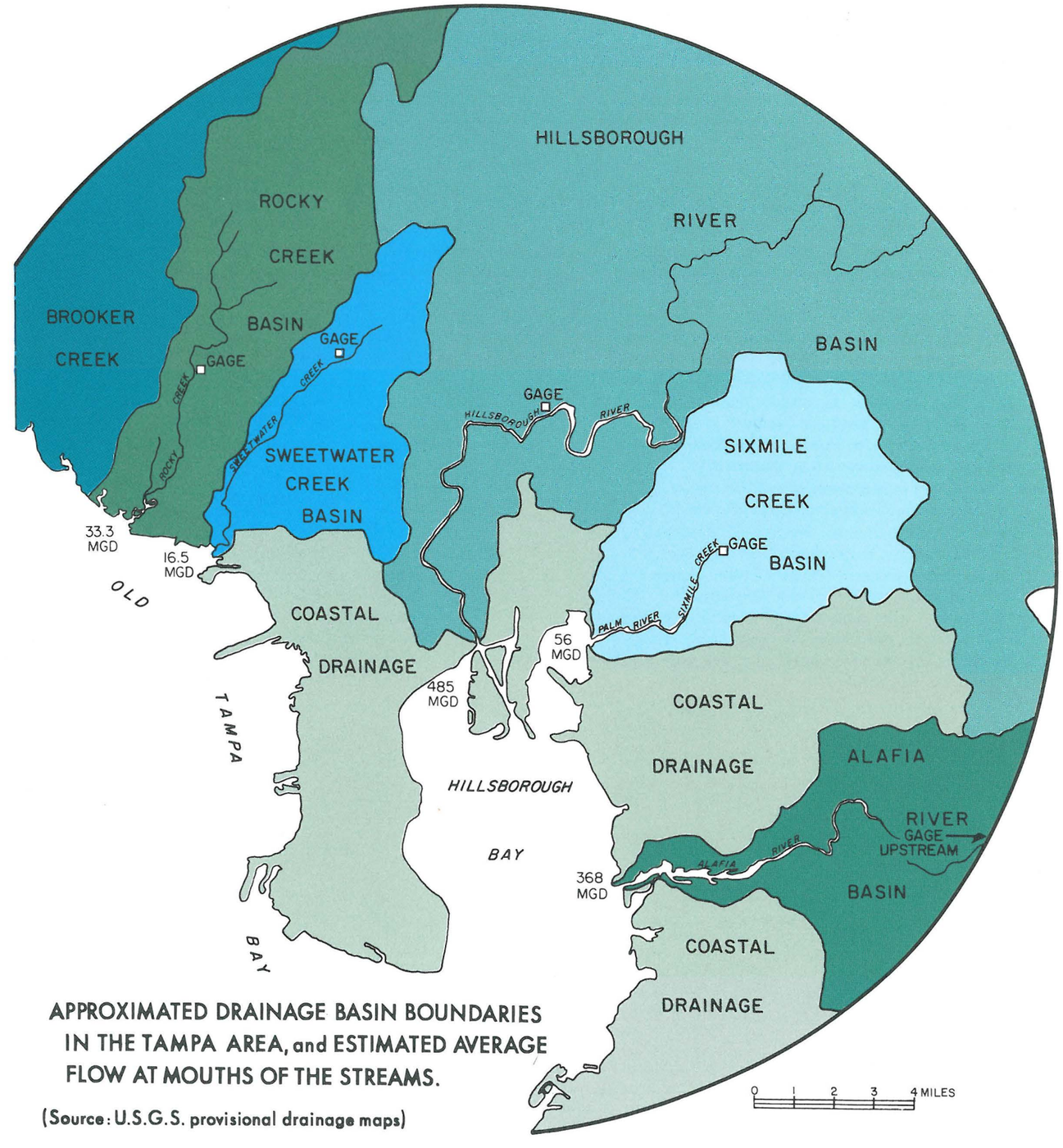
Land use planning for riverfront areas must be prudent. An assessment should be made of present riverfront land use, and existing physical, chemical, and biological conditions of the stream. In addition, an order of priorities (or a downstream order) for use of the water and waterfront lands should be established.

Stream channel segments may be designated as:

--sites for historic monuments or archaeological sites,
--sites for scenic or aesthetic natural areas,
--sites for water supply plants, dams, bridges, canals,
--recreational sites,
--low or high density residential sites;
--industrial sites



MEAN STREAMFLOW AT GAGING STATIONS 1/61 – 9/70



APPROXIMATED DRAINAGE BASIN BOUNDARIES IN THE TAMPA AREA, and ESTIMATED AVERAGE FLOW AT MOUTHS OF THE STREAMS.

(Source: U.S.G.S. provisional drainage maps)

Sweetwater Creek

Alafia River

Rocky Creek

STREAM CHARACTERISTICS

Stream	Total Drainage Basin Area	Average Discharge at gage[1] / Period of Record	Estimated Average Flow at Mouth[2]	Maximum Flow / Date	Minimum Flow / Date
Alafia River	460 mi.^{2}	249 mgd / 38 yrs.	369 mgd	29,651 mgd / 9/7/33	4.26 mgd / 6/5,6/45
Sixmile Cr. (Palm River)	40 mi.^{2}	39 mgd / 13 yrs.	56 mgd	833 mgd / 9/11/60	2.8 mgd / 5/27/62
Rocky Cr.	45 mi.^{2}	25.8 mgd / 17 yrs.	33.3 mgd	1835 mgd / 7/29/60	NO FLOW / 4/7-5/5/67
Sweetwater Cr.	25 mi.^{2}	4.9 mgd / 19 yrs.	16.5 mgd	283 mgd / 3/17/60	NO FLOW / Often

CHEMICAL QUALITY[3] (Samples taken at gage)

Stream	Total dissolved solids mg/l[4]	Chloride mg/l	pH units	PO_4[5] mg/l	Date Sampled
Alafia River	457	80	7.6	25	4/26/71
Sixmile River (Palm River	269	17	7.9	0.21	5/22/70
Rocky Cr.	150	23	7.3	0.13	5/13/71
Sweetwater Cr.	138	24	6.6	0.94	5/9/70

Pollution Loads discharged To Tampa Bay (lbs/day)

Stream	Sewage Plants Discharging to Stream	Total Filterable Residue	$NH_4 + NO_2 + NO_3$	Total PO_4
Alafia River	5	16,760	6870	43,470
Sixmile River (Palm River	2	3570	170	100

Discharge from treatment plants (lbs./days)

Stream	BOD	SUSPENDED SOLIDS
Rocky Cr.	3	31	38
Sweetwater Cr.	4	385	580

[1] Gaging station locations shown on may on preceding page.
[2] Discharge at gage times basin factor (ratio of total drainage area to area above gage) plus any springflow downstream from gage
(Data from:

[3] From U.S.G.S. provisional water quality data
[4] Residue at 180 C
[5] Orthophosphates as PO_4

HILLSBOROUGH RIVER

The Hillsborough River rises in the Green Swamp area south of the Withlacoochee River. Crystal Springs, Sulphur Springs and numerous small springs feed the river. The channel is about 54 miles long and flows through Polk, Pasco and Hillsborough Counties.

Tampa has acquired the majority of its water supply from the Hillsborough River since the mid twenties. The water treatment plant, located at the dam near twenty-second Street, has a capacity of 60 million gallons a day (mgd). The "firm flow" of the river is estimated to be 50 mgd. During 1971, pumpage averaged 49 mgd (see figure 1).

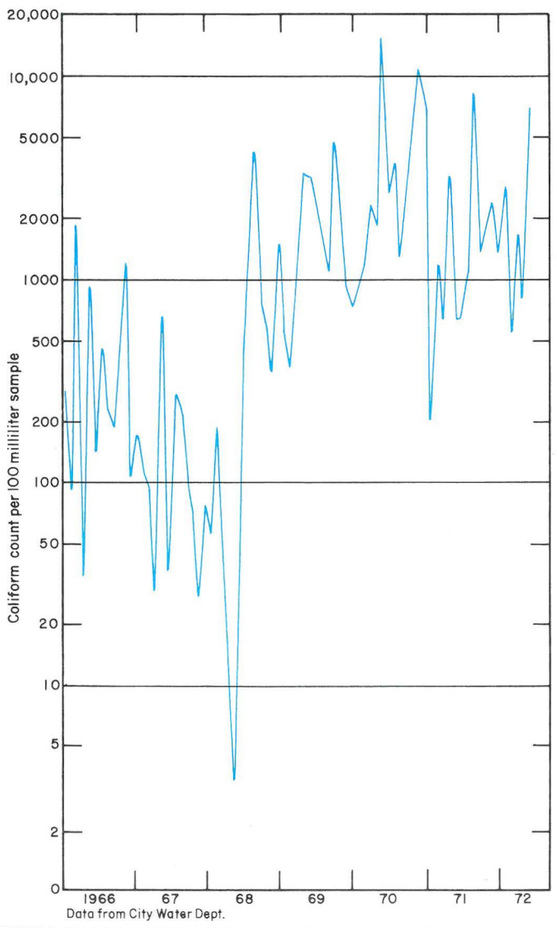


FIGURE 2. COLIFORM CONTENT AT PLANT INTAKE CITY WATER WORKS AT HILLSBOROUGH RIVER DAM

In 1964, the Tampa water supply was augmented by flow from Sulphur Springs. During periods of low flow in the river, 20 mgd have been diverted from the Spring to the Reservoir. Currently, the firm available supply of the Hillsborough Reservoir does not meet the water needs of the City, and plans for development of well fields are being implemented.

The quality of water from the Hillsborough River is not ideal. High values are obtained for turbidity, settleable solids, color, odor, and taste. Treatment by the city water plant includes flocculation, sedimentation, filtration, chlorination, algae control, coagulation, stabilization, clarification, pH control, and taste and odor control.

Hillsborough River

Total drainage basin area	690 square miles
Average discharge at gage/period of record	*428 mgd/32 years
Estimated average flow at mouth	485 mgd
Maximum flow/date	*9432 mgd/3-21-60
Minimum flow/date	*none/ 11-30 to 12-2-45
CHEMICAL QUALITY	SAMPLED 5/15/69.
	(Data from U.S.G.S. water quality records)
Total dissolved solids (mg/l)	195
Chloride (mg/l)	16
pH (units)	8.5
Nitrate (mg/l)	1.7
Sewage plants discharging to stream	6 (4 in Polk County)
POLLUTIONAL LOADS discharged TO BAY	
Total filterable residue	11,470 lbs./day
$NH_4 + NO_2 + NO_3$	250 lbs./day
Total phosphate	630 lbs. /day

*these figures do not include water diverted for use by the City of Tampa

A notable problem in water quality is the presence of a disturbing number of coliform bacteria[1] (figure 2). Only one of 13 samples taken from the swimming area of the Hillsborough River State Park between January 14 and July 27, 1971 by the Hillsborough County Health Department was found to have less than 1000 bacteria per 100 milliliters (ml) (the upper limit for public water supply, according to state law). 2400 bacteria per 100 ml were found in water samples collected from the stream from the dam upstream to the Polk County line. The effluent of at least six sewage treatment plants finds its way to the Hillsborough River--four of these plants are in Polk County.

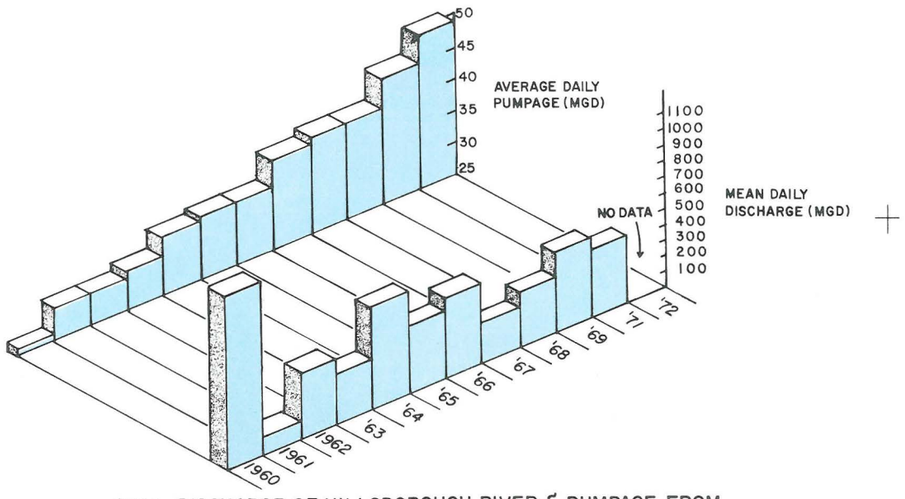


FIG. I DISCHARGE OF HILLSBOROUGH RIVER & PUMPAGE FROM RIVER BY CITY OF TAMPA WATER DEPARTMENT.

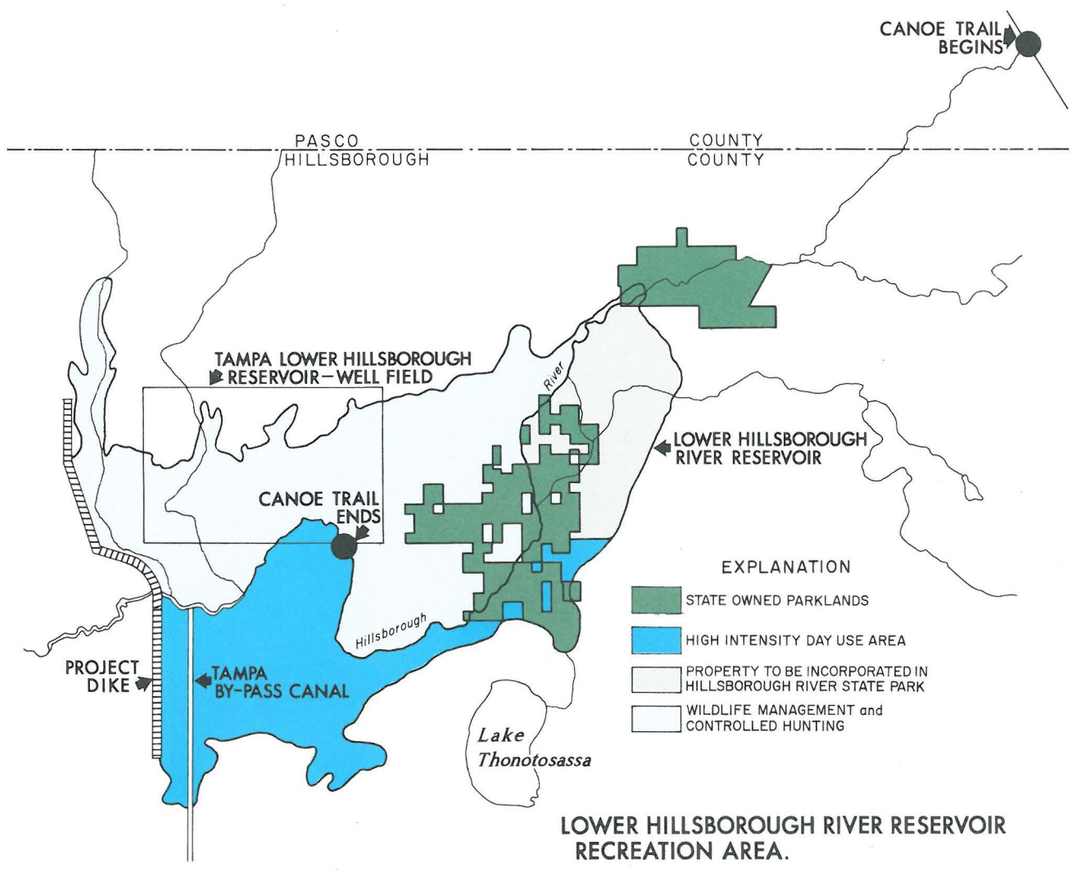
Another problem is the presence of water hyacinths, which at times cover Tamps's entire water supply reservoir. Hyacinths are treated with a chemical herbicide (2-4 D) and sink to the bottom of the Reservoir or are discharged downstream. The hyacinths are a hindrance to recreational uses of the river. Also when they are discharged to Tampa Bay and decompose, each acre of hyacinths can contribute 200 pounds of nitrogen and 26 pounds of phosphate (Florida State Board of Health. 1965).

[1]Source-intestinal tract of warm blooded animals; significance--general indicator of pollution.

Much of the land adjacent to the Hillsborough River is being acquired for construction of the Lower Hillsborough River Flood Detention area in Hillsborough County and the Upper Hillsborough River Flood Detention area in Pasco and Polk Counties. These areas will be set aside for temporarily detaining flood waters during extreme high flow conditions.

The multi-use concept will be employed in the Lower Hillsborough River Detention area. Much of the area is still in a wilderness state and lends itself to recreation and conservation. Exclusive of the primary purposes of the reservoir (prevention of flood damage and improvement of ground water levels), land-use plans for the reservoir area include:

1) development of a well field in the western portion
2) establishment of a high intensity day use recreation area to be leased to local agencies, The University of South Florida, and Tampa University
3) incorporation of a portion of the reservoir in the existing program of Hillsborough River State Park
4) leasing of lands to the Florida Game and Fresh Water Fish Commission for management purposes and limited hunting.



LOWER HILLSBOROUGH RIVER RESERVOIR RECREATION AREA.

Source: S.W. Florida Management District

In addition, over seventeen miles of the river channel in Hillsborough and Pasco Counties has been proposed for designation as a scenic river and canoe trail by the Florida Division of Recreation and Parks. This means that the natural environment of this segment of the river will be preserved for public enjoyment.

The Hillsborough River is a tri-county resource. Regional planning is obviously the basis for successful maintenance and management of the river channel.

SCENES AT HILLSBOROUGH RIVER STATE PARK

WATER TABLE

The sandy surface deposits in Hillsborough County generally contain water. The upper surface of the saturated zone is the water table. Water table contours generally follow topographic contours with the water surface lying a few feet below land surface. The level of the water table fluctuates primarily in response to rainfall, which is the principal source of recharge to the shallow aquifer.

Discharge of water from the aquifer is by seepage into lakes and streams, drainage from canals and ditches, evapotranspiration, pumpage from wells, and natural drainage from springs.

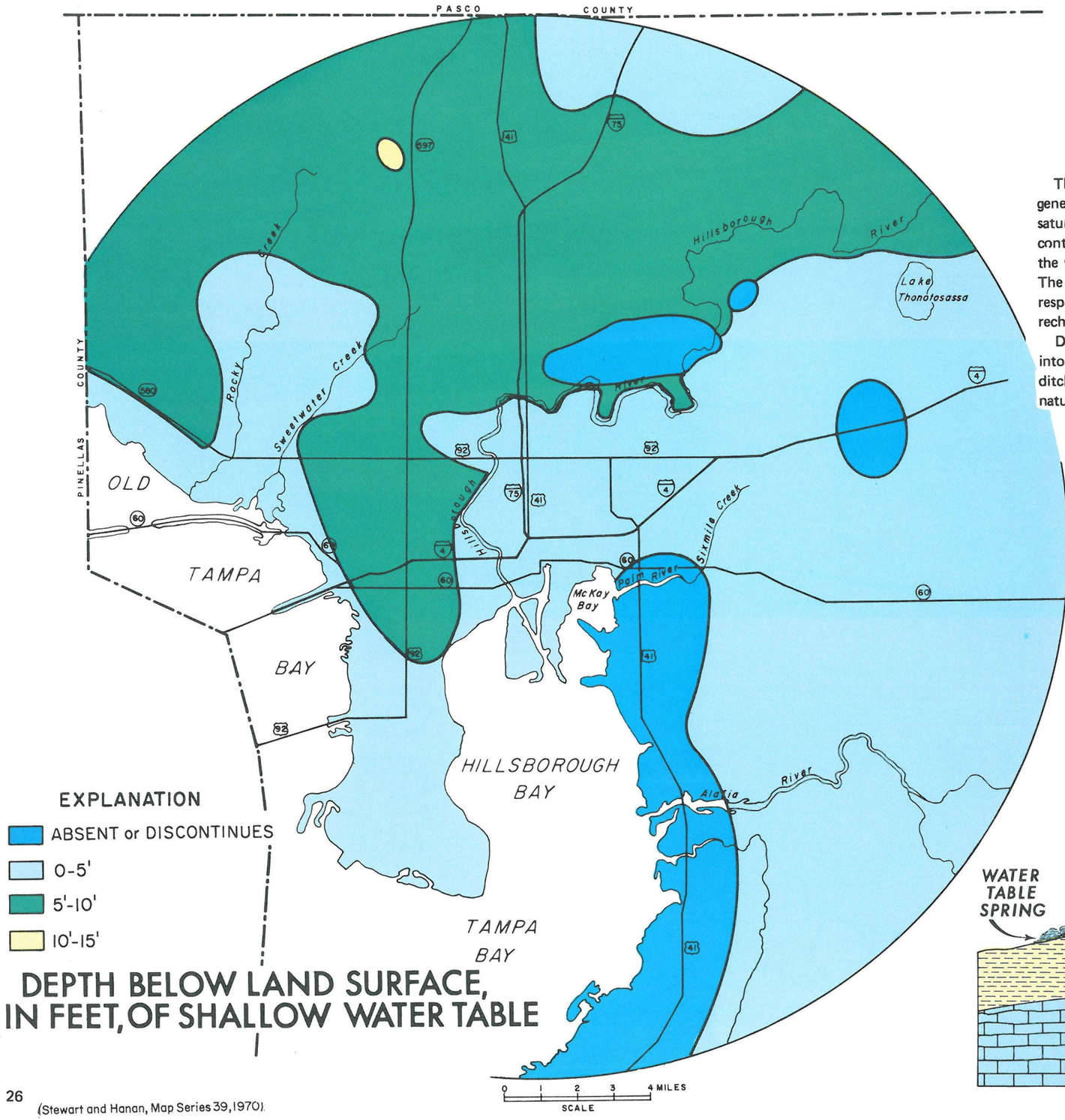
In some places, the water-table aquifer is hydraulically connected to the underlying artesian aquifer. The primary uses of the shallow aquifer are:

1) as a source of recharge to the Floridan aquifer

2) as a source of water for lawn irrigation.

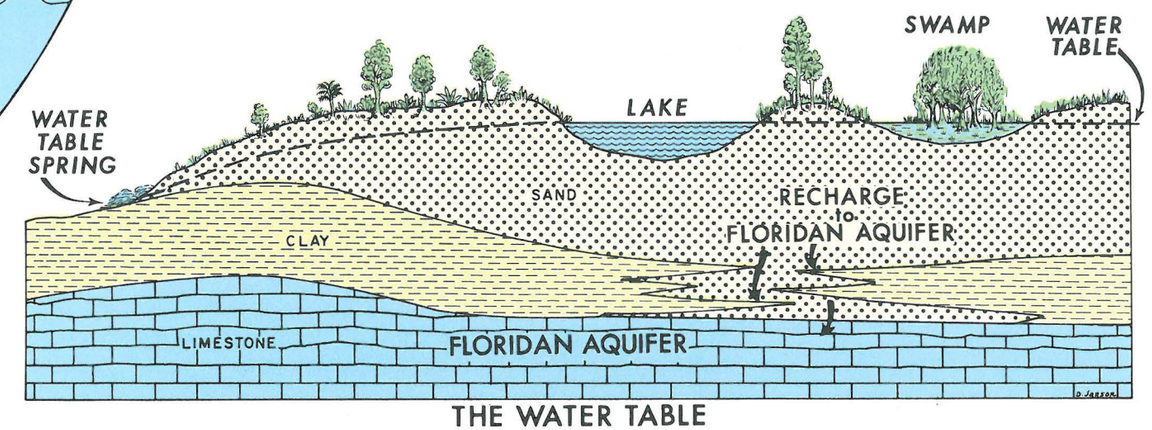
Wells can be driven or drilled into the water table aquifer easily and inexpensively, but because the water produced is small in quantity and of poor quality, it is not useful as a source of public supply. Since the water table lies so close to land surface, the shallow aquifer is suspectible to pollution.

Pollution of the shallow aquifer should be carefully avoided in areas where it rapidly recharges the Floridan aquifer, perhaps our most valuable water resource.



DEPTH BELOW LAND SURFACE, IN FEET, OF SHALLOW WATER TABLE

(Stewart and Hanan, Map Series 39, 1970).



THE WATER TABLE

AND SWAMPS

The type and abundance of native vegetation present in an area is in part dependent on the position of the water table with respect to land surface.

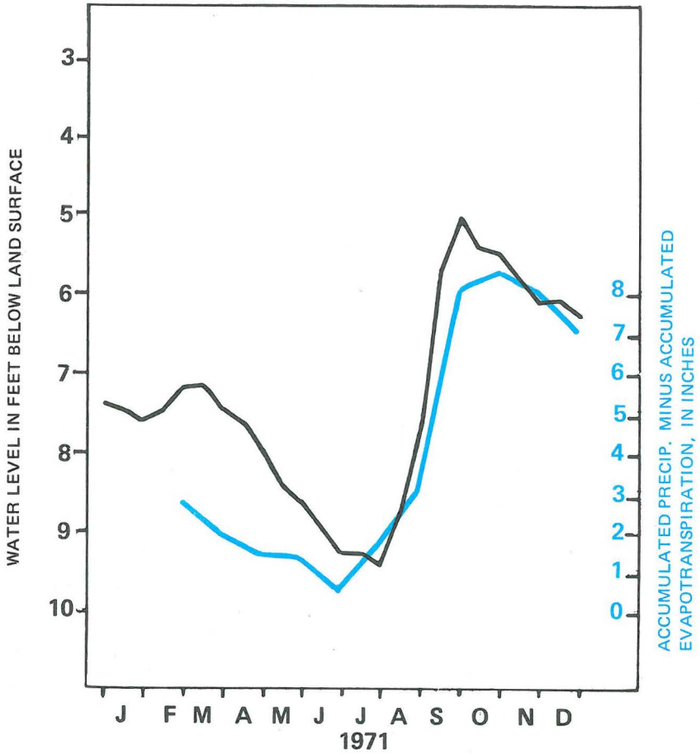
Where the water table is above land surface, lakes or swamps occur. Swamps, cypress domes or bayheads represent a distinct ecosystem in which the flora and fauna are specifically adapted to the environment. Development in low-lying wetlands is preceded by drainage, filling, or both.

Since the swampland biota is dependent on the presence of excessive water, drainage or filling results in a relatively barren landscape.

Another limitation of swamps for development is the character of the subsurface material. Many swamps are underlain by thick organic or peaty deposits which form unstable foundation conditions for many types of construction. In addition, low-lying areas are generally flood prone.

Despite the limiting factors, many swamplands have been successfully developed for a variety of land uses. Prior to developing swamplands, the potential destruction of a unique habitat should be considered.

WATER LEVEL IN WATER TABLE WELL NEAR TAMPA, AND ACCUMULATED PRECIPITATION MINUS ACCUMULATED EVAPOTRANSPIRATION AT TAMPA



Unique swampland biota (photo by J. W. Stewart)

A flourishing swamp (photo by J. W. Stewart)

FLORIDAN AQUIFER

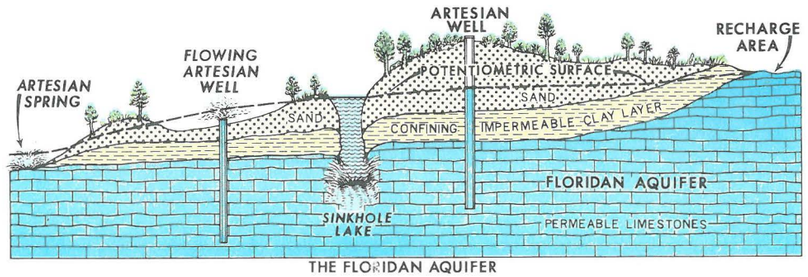
The Floridan aquifer is the principle source of ground water in the state. It includes the Lake City, Avon Park and Ocala Limestones (Eocene age), Suwannee Limestone (Oligocene), Tampa limestone and parts of the Hawthorn Formation (Miocene). It is exposed at the surface in some areas and underlies several hundred feet of sediments in others.

In the Tampa area, the top of the Tampa limestone can be considered the top of the Floridan aquifer. The aquifer is artesian, and in some places wells that penetrate it flow. An aquifer is artesian when it is confined by an impermeable layer and the water in the aquifer is under sufficient hydrostatic pressure to cause it to rise above the base of the confining bed in wells.

The level to which water will rise in wells penetrating the artesian aquifer is called the potentiometric surface. When the potentiometric surface is above land surface, the well is said to be flowing.

Water in the Floridan aquifer moves into Hillsborough County from adjacent counties and most fresh water discharge from the aquifer occurs inland of Tampa Bay. Currently, the Floridan aquifer produces a large quantity of good quality water from wells in the Tampa area, however, decline in water quality and/or severe reduction of water stored in the aquifer can result from improper land use or short-sighted planning.

Recharge or "replenishment" of water to the aquifer takes place where the confining layer is thin or absent and rain water can infiltrate permeable surficial deposits and percolate into the aquifer itself. Recharge occurs also as leakage through the confining layer wherever the altitude of the water table exceeds the altitude of the potentiometric surface of the Floridan aquifer. Recharge areas should be identified and land maintained as "open space". In addition, recharge in these areas can be accelerated by artificial means. When development occurs in recharge areas, the wastes associated with urbanization have ready access to the aquifer and can damage water quality. Likewise, pavement (the ever-present foundation of urbanization) prevents water from infiltrating the soil and greatly reduces the recharge potential of an area.



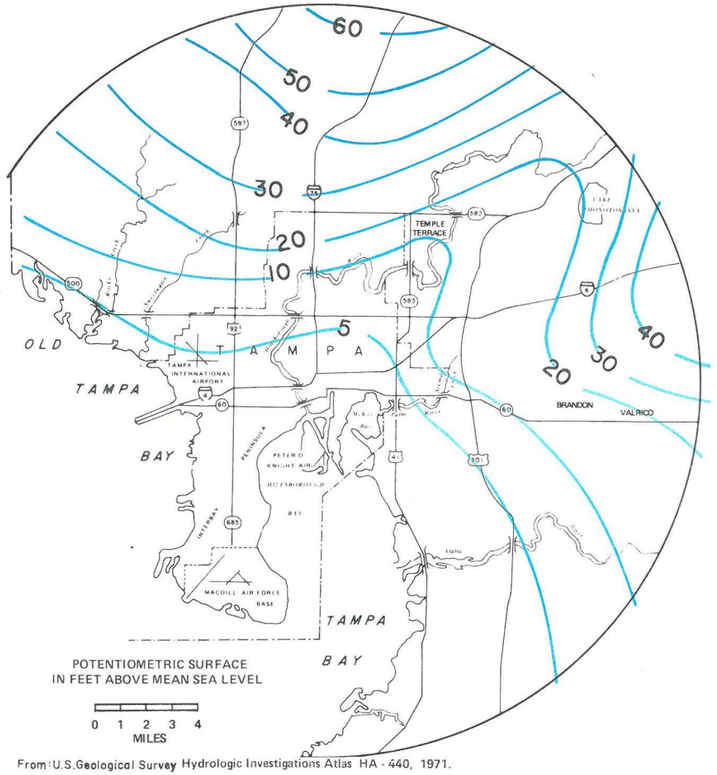
THE FLORIDAN AQUIFER

Recharge can also take place through sinkholes that breach the confining layer. Great damage to the quality of water in the aquifer can result when sinkholes are used as dumps or waste basins.

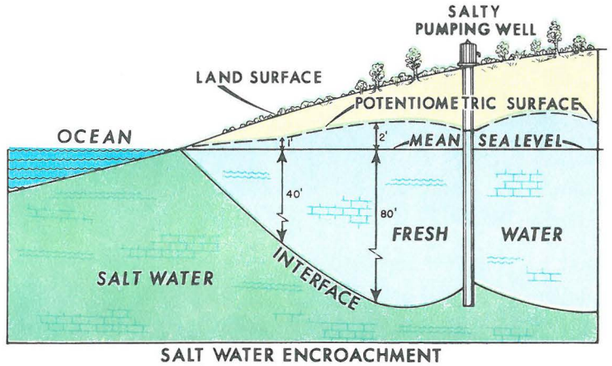
Another threat to the aquifer in any coastal area is salt-water encroachment. At depth saline water underlies the fresh water in the aquifer. Theoretically, the depth below sea level to the top of this salt water is forty times the height of the potentiometric surface above sea level. Or, for every foot that the potentiometric surface is lowered, salt water moves forty feet upward in the aquifer.

During the twenties, public supply wells for the City of Tampa were abandoned due to ever increasing salinity in the water. This is the result of drilling wells too close to the coast, too deep, or overpumping them.

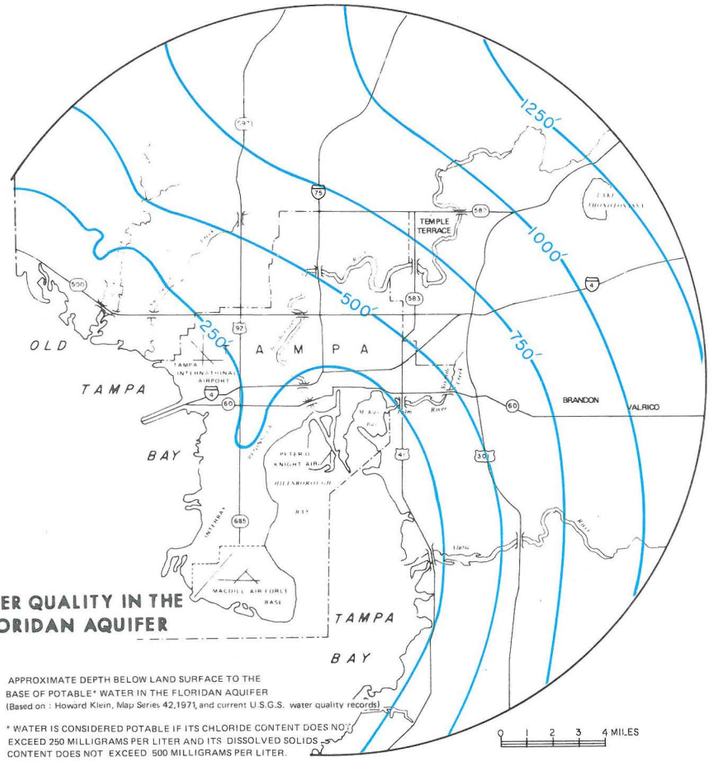
Salt-water encroachment can also take place when canals are dredged inland from the coast. If the aquifer is exposed by the excavation, the potentiometric surface would be lowered as fresh water was drained to the ocean. During periods of low water levels and high tides, salt water in the canals can move inland and contaminate the aquifer. Construction of dams or water level control structures near the coast can reduce potential salt water encroachment in such canals by maintaining a higher fresh water level.



From: U.S. Geological Survey Hydrologic Investigations Atlas HA - 440, 1971.



SALT WATER ENCROACHMENT



WATER QUALITY IN THE FLORIDAN AQUIFER

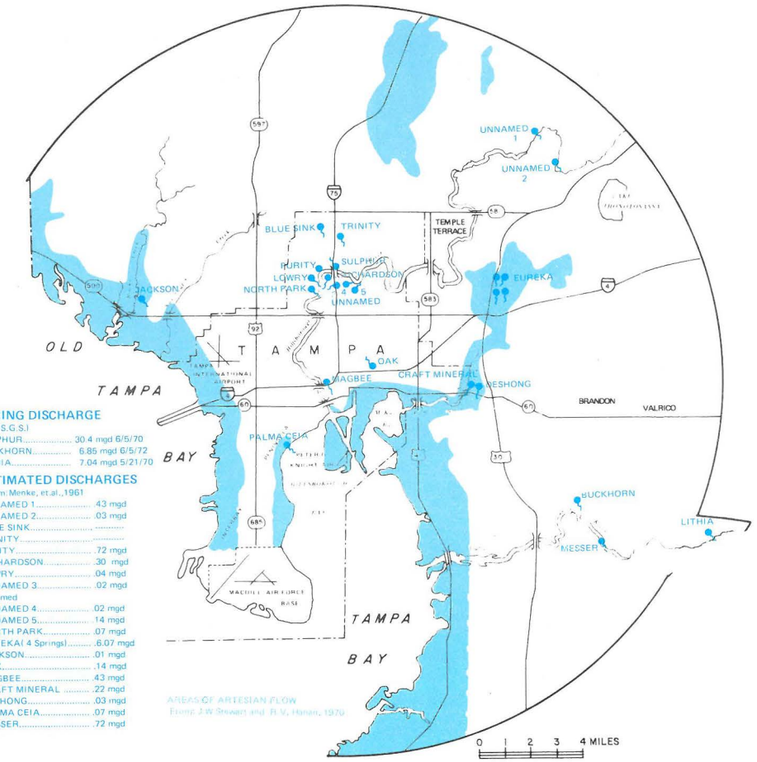
APPROXIMATE DEPTH BELOW LAND SURFACE TO THE BASE OF POTABLE* WATER IN THE FLORIDAN AQUIFER
(Based on : Howard Klein, Map Series 42,1971, and current U.S.G.S. water quality records)

* WATER IS CONSIDERED POTABLE IF ITS CHLORIDE CONTENT DOES NOT EXCEED 250 MILLIGRAMS PER LITER AND ITS DISSOLVED SOLIDS CONTENT DOES NOT EXCEED 500 MILLIGRAMS PER LITER.

AND SPRINGS

Water table springs generally occur where the permeable material in the water table is exposed or crops out in a ditch or along the side of a steeply sloping bank. Artesian springs are found where the limestone aquifer lies at or near land surface and the potentiometric surface is higher than land surface. There are five large springs in the Tampa area and these have been studied by the U. S. Geological Survey. In addition, there are innumerable small springs in the area that have been flowing for years.

Springs can be used to supplement water supply and are a valuable asset to recreation areas. Continued use of springs for these purposes is dependent on maintenance of water quality through wise management of recharge areas which supply the springs.

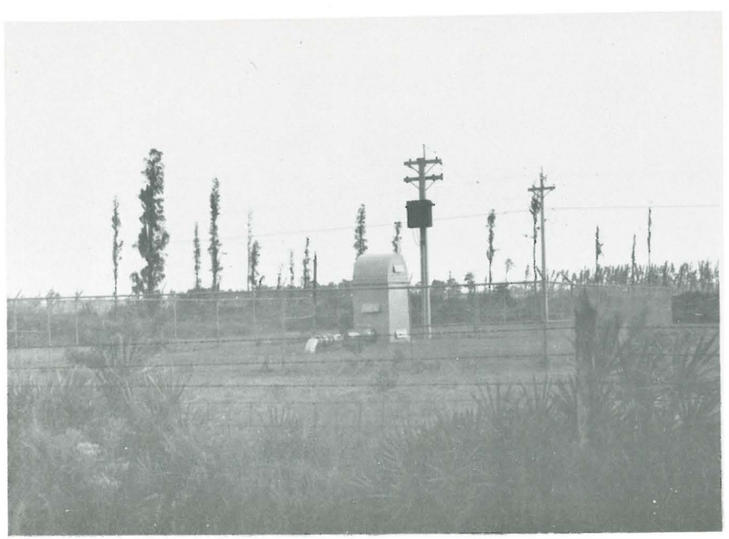


SPRING DISCHARGE
(U.S.G.S.)

SULPHUR	30.4 mgd 6/5/70
BUCKHORN	6.85 mgd 6/5/72
LITHIA	7.04 mgd 5/21/70

ESTIMATED DISCHARGES
From Menke, et.al.,1961

UNNAMED 1	.43 mgd
UNNAMED 2	.03 mgd
BLUE SINK	.....
TRINITY	.....
PURITY	.72 mgd
SULPHUR	.....
LOWRY	.04 mgd
RICHARDSON	.30 mgd
NORTH PARK	.07 mgd
UNNAMED 3	.02 mgd
unnamed	
UNNAMED 4	.02 mgd
UNNAMED 5	.14 mgd
EUREKA(4 Springs)	6.07 mgd
JACKSON	.01 mgd
OAK	.14 mgd
MAGBEE	.43 mgd
CRAFT MINERAL	.22 mgd
DESHONG	.03 mgd
PALMA CEIA	.07 mgd
MESSER	.72 mgd



Wells and a storage tank in a northwest Hillsborough County well field. These wells pump large amounts of potable water from the Floridan aquifer.

Scenic Lithia Springs, a popular recreation area.

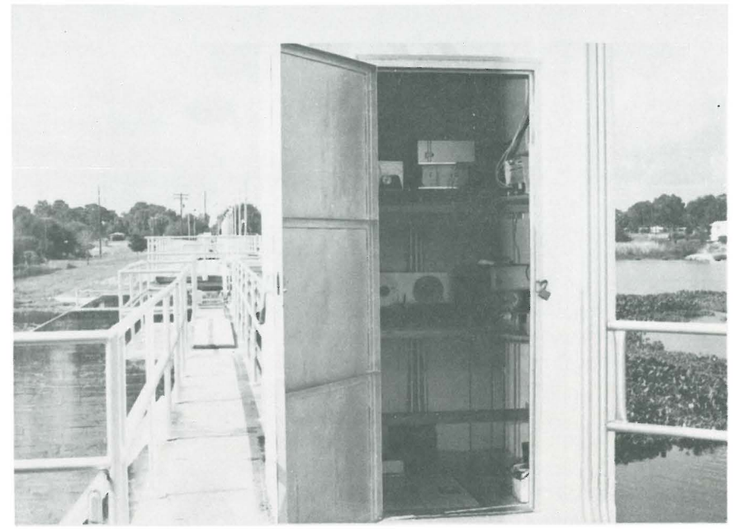
WATER USE

Water in Hillsborough County is mainly used for irrigation, industry, and public supply. In 1970, about 69 mgd was used for irrigation and 56 mgd for industry. Most of this water was self-supplied. Twelve of the major public supply systems are shown on figure 1. Their combined pumpage for 1971 (or 1970, as indicated on the map) was 33,933 million gallons or 93 mgd. About a third of this water was removed from Northwest Hillsborough County for use in Pinellas County.

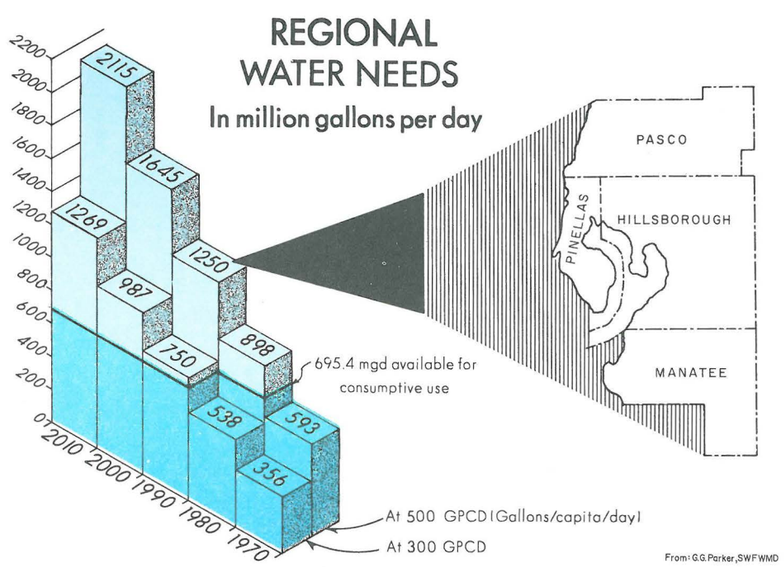
There is a vast quantity of fresh water within the Tampa Bay region, however, only a portion of it can be withdrawn from the hydrologic system without creating serious environmental repercussions (declining lake levels, parched vegetation, etc.)

G. G. Parker (1972) states that "If we can capture for our consumptive use more than one-third of runoff, we will be fortunate indeed." For the Tampa Bay region (Hillsborough, Pinellas, Pasco, and Manatee counties), Parker estimates one-third of the runoff to be on the order of 254 billion gallons per year or 695.4 mgd. Projected water needs for the Tampa Bay region are illustrated on this page. The figures are based on population projections in "Florida Land and Water Resources, Southwest Florida, 1966", and the assumption that 300 and 500 gpcd represent reasonable minimum and maximum figures for regional needs. Although the picture apparently looks grim (interpolation indicates that water demand will equal water supply in 1973 at the 500 gpcd rate of withdrawal or 1987 at the 300 gpcd rate), two factors should be borne in mind as the illustration is examined: 1) The figures are based on the assumption that the water withdrawn is permanently consumed. They do not take into account the fact that much water that is withdrawn is re-cycled or at some time returned to the hydrologic cycle and therefore, much is not permanently consumed. 2) As time goes by, greater sophistication in water management will improve the outlook.

A water use projection for Hillsborough County is also shown on this page. This graph applies Parker's per capita water use rates (300 and 500 gallons/day) to the population projections for Hillsborough County published by the Hillsborough County Planning Commission in April, 1972.



Water stage recorder at Hillsborough River dam. (photo by W. M. Woodham)



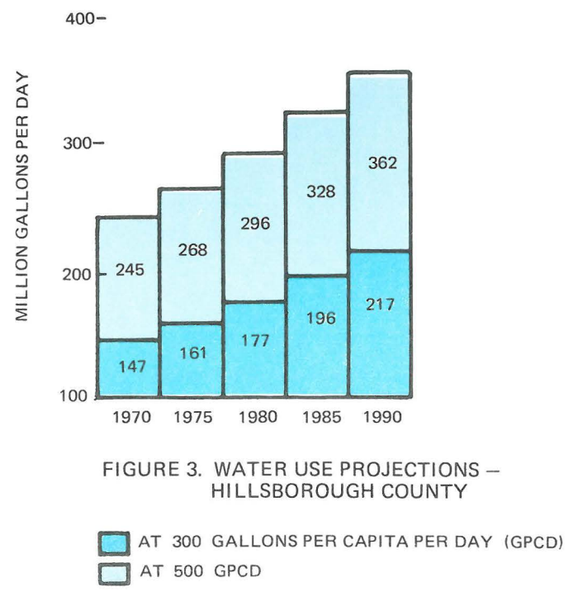
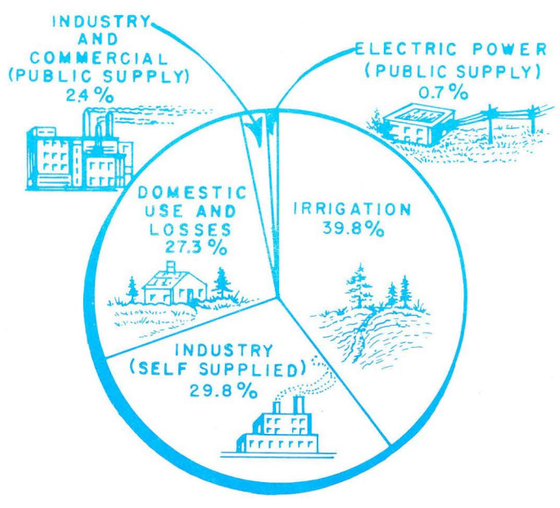


FIGURE 3. WATER USE PROJECTIONS – HILLSBOROUGH COUNTY

The water problems of Hillsborough County have been widely publicized. Much of the problem can be attributed to the inadequacy of the facilities rather than the sources.

Governmental agencies and private consulting firms have submitted innumerable recommendations for remedial actions to alleviate the City's and County's water problems. Some of the measures suggested include:

1) establish flood retention reservoirs
2) develop the Lower Hillsborough River Reservoir well field immediately
3) establish control structures on dams and streams to reduce salt-water encroachment
4) supplement the water supply by pumping water from sinkholes
5) investigate the possibility of acquiring springs in neighboring counties
6) create recharge facilities for rapid replenishment of water to the aquifer
7) reduce waste of water by plugging abandoned flowing wells, and encouraging re-use of water by industry and agriculture
8) treat and re-cycle waste waters



HOW FRESH WATER IS USED IN HILLSBOROUGH COUNTY

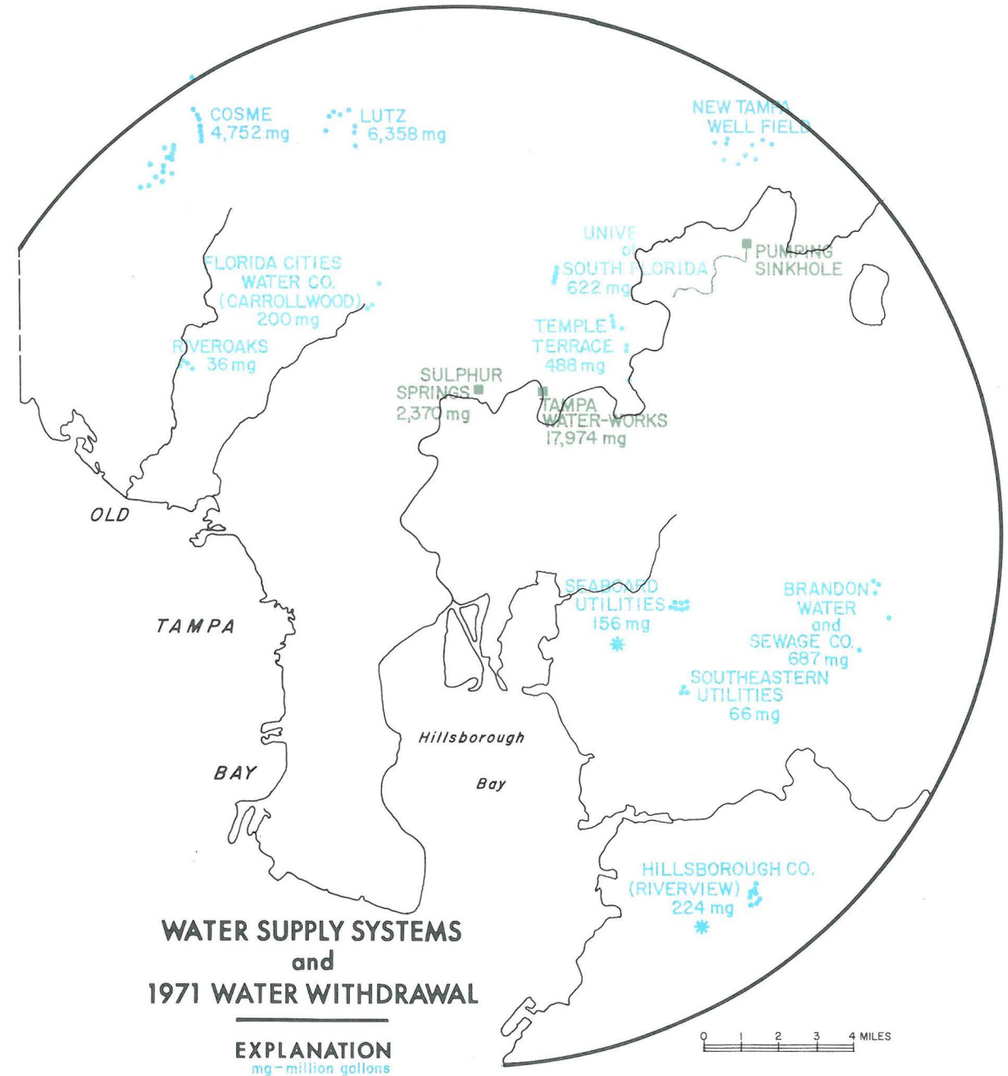
Many of these plans are now being implemented. The seriousness of the water situation and the suggested courses of action highlight the role that hydrology must play in land use planning.

Hillsborough River dam. (photo by W. M. Woodham)

WATER USE FACTS

Number of industries in Hillsborough County[1]	650
Number of electrical power plants[1]	3
Population served by public supply[2]	370,000
Population served by ground water[2]	65,000
Population served by surface water[2]	305,000
Number of acres irrigated[2]	47,000
Saline water (self-supplied)[2]	
Used by industry	86.4 mgd
Used for thermoelectric power	1899 mgd
Cost of water[1]	
From Hillsborough River	$92.74/million gallons
From Lower Hillsborough Reservoir Well Field	$31.71/million gallons

[1] 1971 Data
[2] 1970 Data



WATER SUPPLY SYSTEMS and 1971 WATER WITHDRAWAL

EXPLANATION
mg – million gallons
✱ – 1970 Data
• – Well

FLOODING

"Those of us who work in the water management field know that some of the multimillion dollar public works projects that we are now constructing could have been prevented if the citizens had simply not been allowed to construct their houses, businesses and developments on land that is often flooded by the stream, creek, river or lake that it abuts. Yet, day after day, we see more and more marginal and submarginal land being developed and sold -- often times to unwary buyers -- who after the first normal rainy season or two, come to us and demand flood control. We believe that much of their anquish and heartache -- and lots of public works money -- could be saved if the construction process included a requirement for full knowledge of the historic or predictable water conditions at that site so the proposed construction could be accommodated to the conditions, or be prevented altogether."

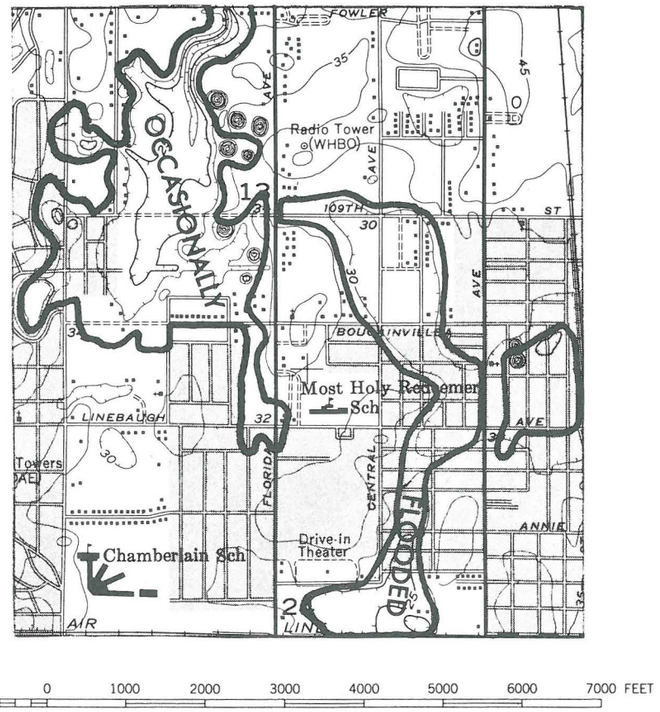
Dale Twachtmann
Ex-Executive Director
Southwest Florida Water Management District

Everyone is aware of the loss of life and property often associated with floods, but unfortunately, not everyone is aware of the flooding potential of the area in which they reside.

Many flood prone areas have already been developed, and others are in the path of urban expansion. Now is the time to strengthen controls on flood prone land and provide 1) a zoning classification which would prevent development in these areas, and/or 2) guidelines for construction in flood prone areas where development is allowed.

Additional drainage projects could provide even more widespread flood protection, but such projects are costly and may tend to diminish regional water resources.

Results of Hurricane Agnes, June, 1972. (photo by Bill Wood)



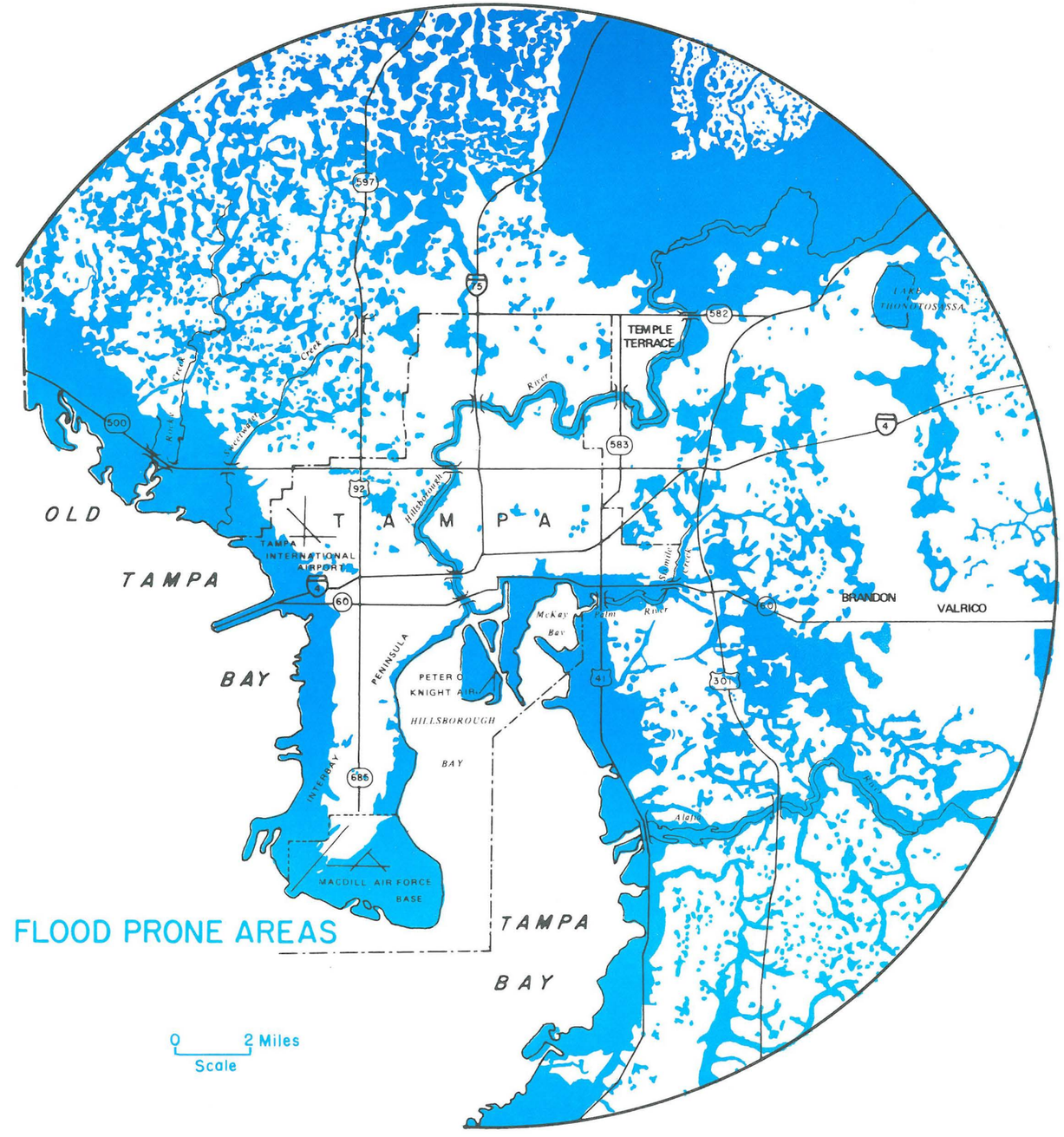
The large map presented here was constructed by compiling and reducing all the 1:24000 scale flood prone quadrangle maps of the Tampa area which were completed by the U.S. Geological Survey. The detail above shows a small area at the actual scale of the 1:24000 maps. The following explanation appears at the base of each quadrangle map of flood-prone areas, and is quoted verbatim:

The purpose of the flood-prone area maps is to show to administrators, planners, and engineers concerned with future land developments those areas that are occasionally flooded. The U.S. Geological Survey was requested by the 89th Congress to prepare these maps as expressed in House Document 465. The flood-prone areas have been delineated by the Geological Survey on the basis of readily available information.

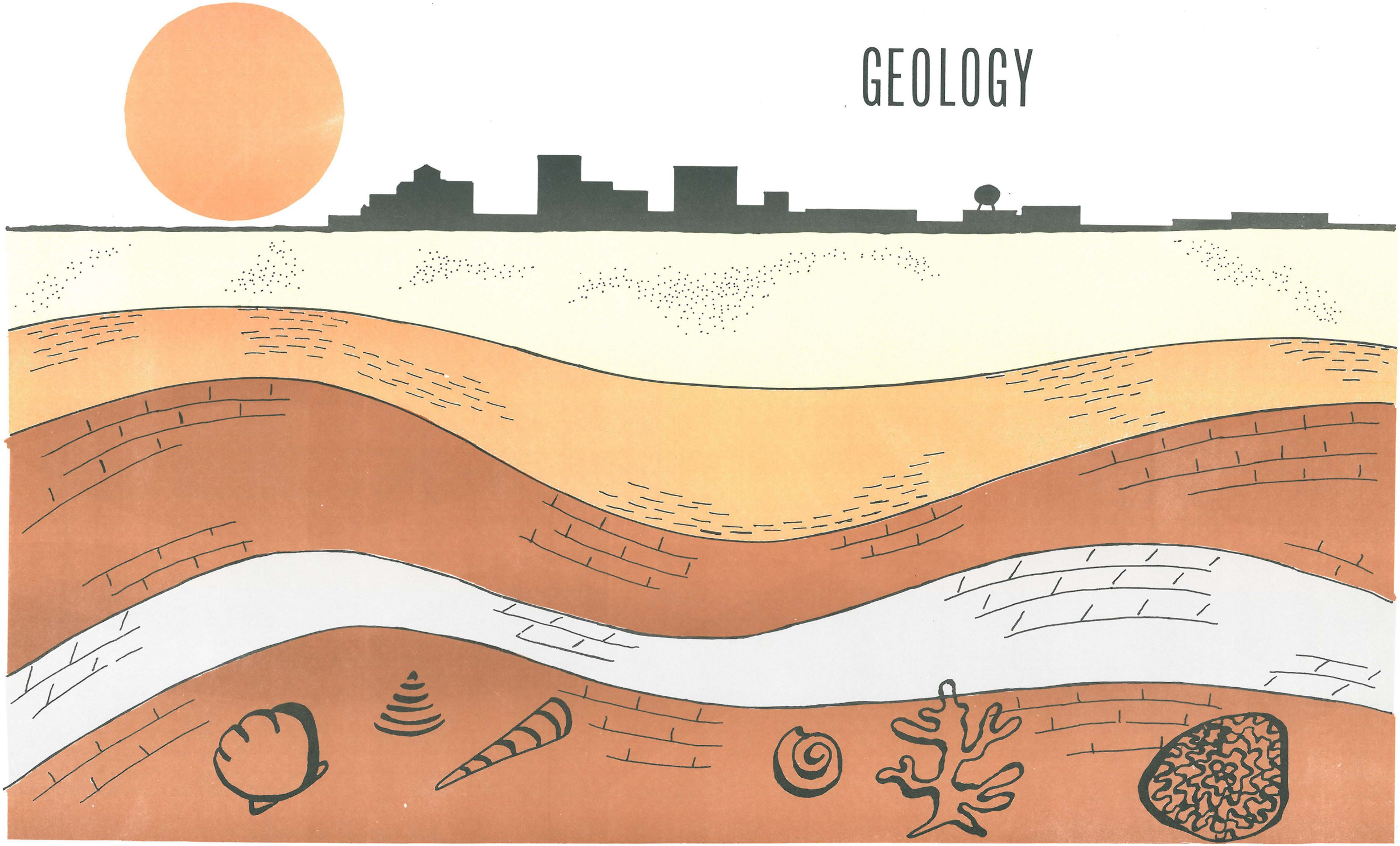
Flood-prone area maps were delineated for those areas that meet the following criteria: (1) Urban areas where the upstream drainage area exceeds 25 square miles, (2) rural areas in humid regions where the upstream drainage area exceeds 100 square miles, and (3) rural areas in semiarid regions where the upstream drainage area exceeds 250 square miles.

This map indicates only areas that may be occasionally flooded, and provides no information on the frequency, depth, duration, and other details of flooding. Larger areas than those shown on the map may be inundated by less frequent floods.

Flood-hazard reports provide the detailed flood information that is needed for economic studies, for formulating zoning regulations, and for setting design criteria to minimize future flood losses. When detailed information, such as that contained in the flood-hazard reports, is required, contact the U.S. Army, Corps of Engineers; the U.S. Geological Survey; or the Tennessee Valley Authority in the areas of their jurisdiction.



GEOLOGY



GEOLOGIC HISTORY

Depending on the depth, temperature, and circulation of the water, varying assemblages of organisms flourished and their skeletal remains make up much of the sedimentary sequence. The physical characteristics of the rocks and the fossils they contain enable the geologist to reconstruct a picture of the ancient geography and environment.

During Paleocene and Eocene time, the Tampa area was covered by open ocean in which layers of limestone were deposited. Intermittently, the seas regressed and the limestone was subjected to weathering. As sea level fluctuated, the local environment changed and limestones with slightly different physical characteristics and dissimilar fossils were deposited in succession. At the close of Eocene time, the seas retreated from the Tampa area and did not return until later in Oligocene time.

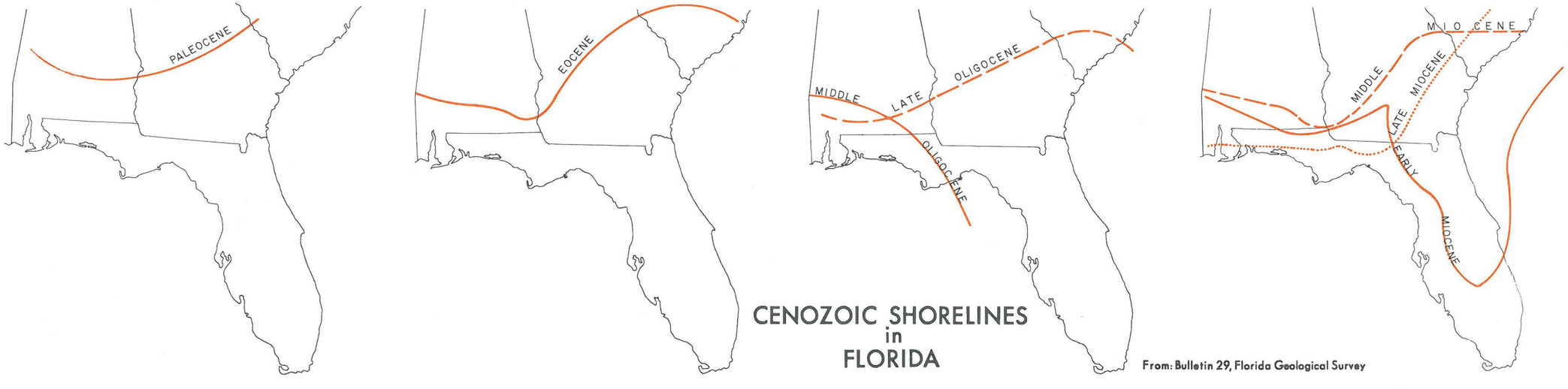
The nature of local late Oligocene sediments indicates that they were laid down in a warm, quiet, shallow sea in which mollusks and micro-organisms flourished. The limestones are relatively pure and of economic value in those parts of the state where they are available to surface mining.

The geology of Florida is reflected in the topography of the state, the nature and occurrence of water resources, the character of soils, and the type and extent of valuable minerals. As all of these are important factors in land use planning, the planner should be knowledgeable about what lies below the land surface.

Beneath the Tampa area, there are several thousand feet of carbonate rocks (chiefly limestones) which were deposited during Cenozoic time. These rocks overlie sandstones, shales and igneous rocks of Mesozoic and Paleozoic age.

The thick carbonate sediments were deposited in the warm, shallow seas that covered all of peninsular Florida at one time or another during the Cenozoic era. Accumulation of these sediments was accompanied by subsidence of the land surface with numerous transgressions and regressions of the sea. When sea level was low the emerged land areas were exposed to erosion; consequently, the rock record is not complete.

Photo by R.C. Reichenbaugh



CENOZOIC SHORELINES in FLORIDA

From: Bulletin 29, Florida Geological Survey

Throughout Miocene time, more and more rocks eroding from the highlands north of Florida were washed southward and deposited in the Tampa area. Due to the great distance of transport, these minerals were abraded and broken into sand and clay size particles. Considerable quartz sand is found in the last consistent limestone deposit of the area. The Miocene and Oligocene limestones of the Tampa area are generally permeable and yield substantial quantities of water to wells.

During late Miocene time, sand and limy, phosphatic clays were deposited in the very shallow, sometimes stagnant seas, estuaries and swamps of the Tampa area. As the shoreline migrated, islands, lagoons and lakes developed in various locations. Marine, fresh water and land fossils have been found in Miocene deposits around Tampa.

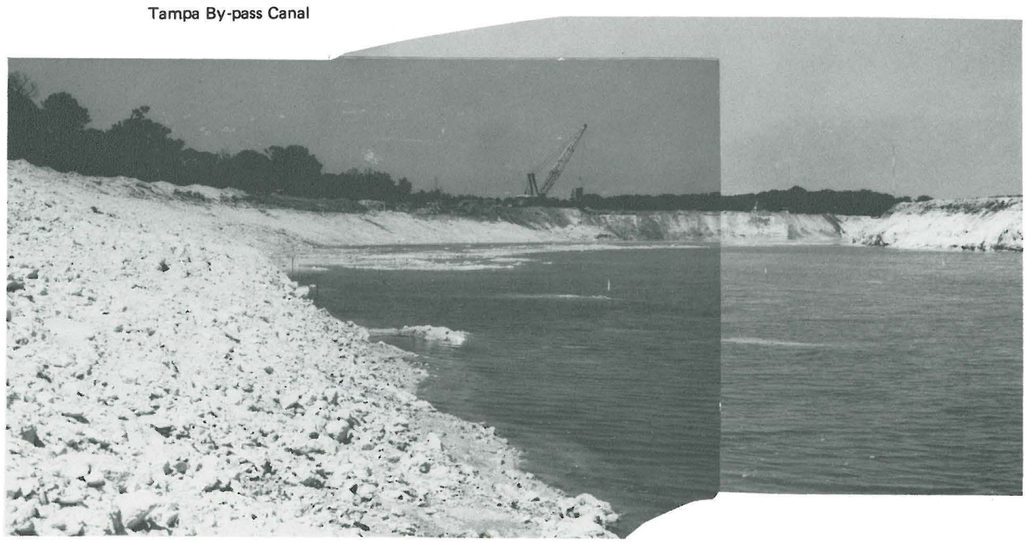
Pliocene sediments similar to late Miocene sediments, are scanty and difficult to differentiate from late Miocene sediment in the vicinity of Tampa. In eastern Hillsborough County, sands and clays containing abundant phosphate nodules are presumed to be Pliocene in age and may have been weathered from older deposits. In Polk County, these phosphate-bearing sediments are mined extensively.

Throughout Pleistocene time, the alternate formation and melting of glaciers caused sea level to move back and forth over the Tampa area and seas washed quartz sand over Tampa and much of the state several times. These fluctuations left behind terraces which are still evident today and record ancient sea level stands. The mantle of quartz sand covering the area served as parent material of many of the soils which later developed. In areas where the sands are thick and pure, they are of economic value.

Well developed stream channels in Tampa, and relict dunes on the campus of the University of South Florida reflect the effect that wind and water had on the sandy deposits. Gradually, a landscape with abundant vegetation developed.

Throughout the Cenozoic history of Tampa, deposits accumulated essentially as horizontal blankets of sediment which dip slightly to the southwest. This is reflected in the gently sloping land surface, and pronounced local relief can largely be attributed to recent fluvial processes and underground solution activity.

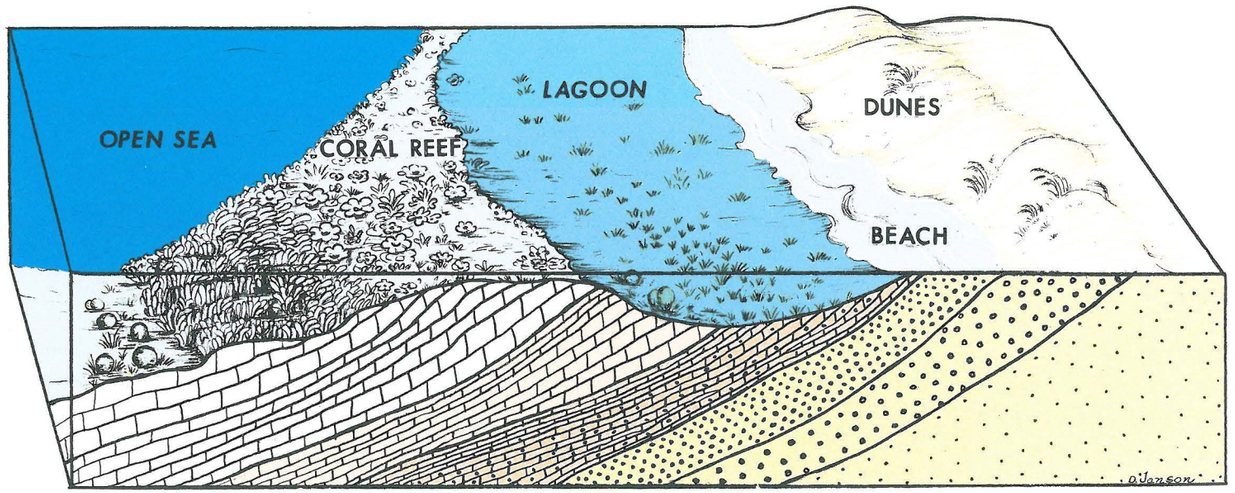
Tampa By-pass Canal



GEOLOGIC TIME SCALE

ERA	PERIOD	EPOCH	APPROXIMATE RADIOMETRIC DATES
CENOZOIC	QUATERNARY	RECENT	5000 YEARS B.P. *
		PLEISTOCENE	2 MILLION YEARS B.P.
	TERTIARY	PLIOCENE	12 MILLION YEARS B.P.
		MIOCENE	25 MILLION YEARS B.P.
		OLIGOCENE	38 MILLION YEARS B.P.
		EOCENE	55 MILLION YEARS B.P.
		PALEOCENE	65 MILLION YEARS B.P.
MESOZOIC			225 MILLION YEARS B.P.
PALEOZOIC			600 MILLION YEARS B.P.

* Before Present



ARTIST'S RECONSTRUCTION OF HOW THE TAMPA AREA MAY HAVE APPEARED DURING TERTIARY TIME

GENERAL GEOLOGY

The thick carbonate rock sequence underlying the Tampa area has been divided into lithologically similar, mappable units or formations. These formations are generally bounded above and below by ancient erosion surfaces.

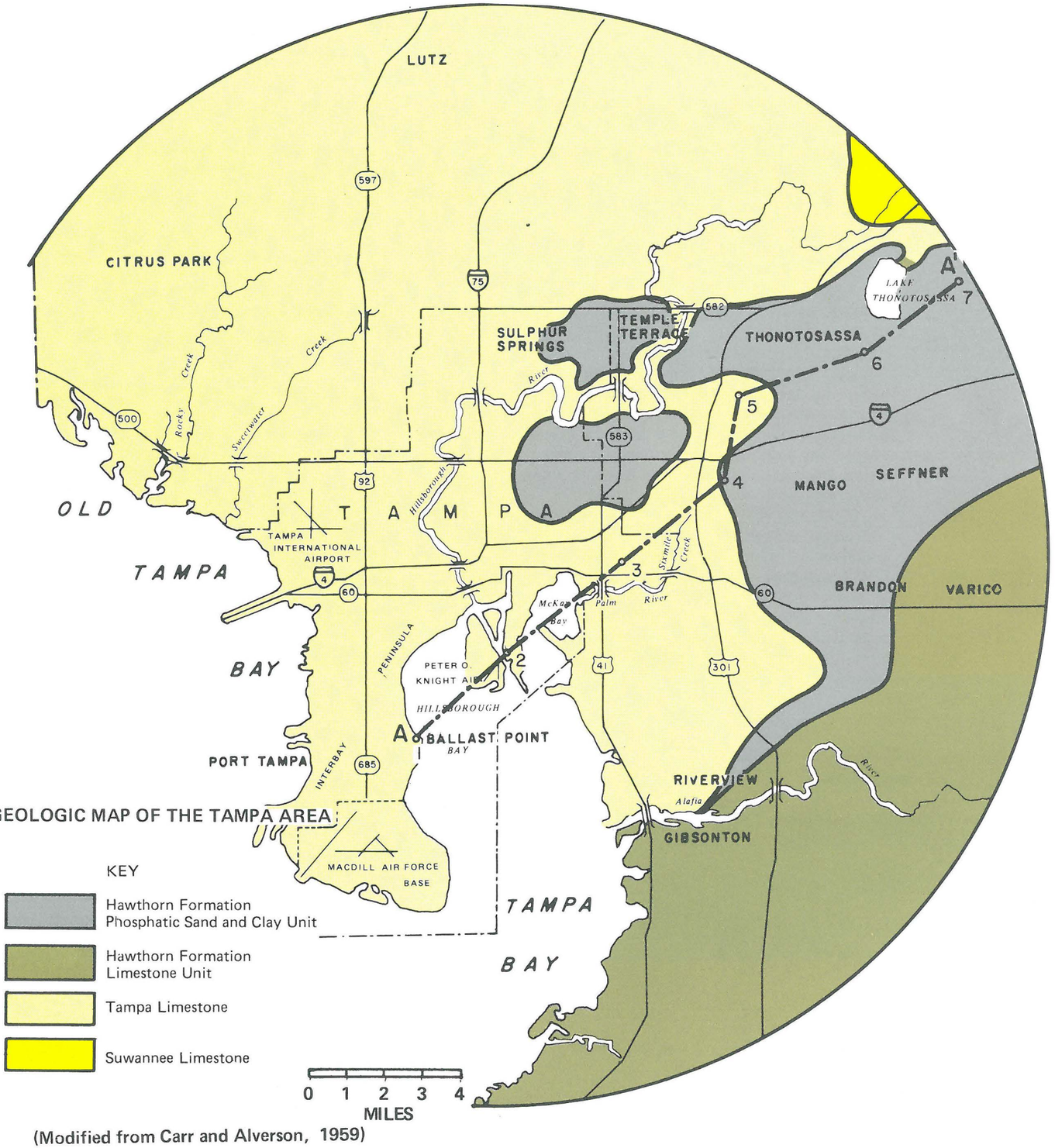
Formations can be mapped on the basis of rock exposures at land surface (outcrops), and from samples retrieved during the drilling of water wells or core-test holes.

An examination of the surface geology in the Tampa area reveals that rocks of Tampa age outcrop in several locations along the banks of the Hillsborough River and can be seen in other stream channels, sinkholes, roadcuts, etc. Ballast Point was considered a classic locality for studying Tampa sediments during the late 1800's and early 1900's, but now the exposures are limited and inaccessible at high tide.

The Hawthorn Formation, which occurs east of Tampa, can also be studied in a number of exposures. Much of the Tampa area is covered by a veneer of Pleistocene and Recent sandy deposits. In the map, these deposits have been stripped away to reveal what lies directly beneath them.

Because each formation has distinct physical attributes, mapping and cross-sections of these units provide some key to the depth and extent of economically valuable deposits, highly productive water bearing zones, and zones susceptible to subsurface solution which could manifest on the land surface as sinkholes.

Florida Bureau of Geology drilling rig



GEOLOGIC MAP OF THE TAMPA AREA

(Modified from Carr and Alverson, 1959)

Crystal River Formation (Eocene)

The Crystal River Formation is a granular, white to tan limestone which, in part, is largely made up of fossil fragments cemented by a calcareous matrix, giving it the appearance of coquina rock. Due to its porosity, some portions have been washed out and filled with clay. Masses of chert also occur within the formation.

The limestone was studied and named in a quarry in Citrus County. Here, and in adjacent counties where it lies near the surface, the formation's overall purity and uniform texture make it economical to mine. In the Tampa area, the Crystal River is generally deeply buried and of no economic importance at present.

Suwannee Limestone (Oligocene)

In general, the Suwannee Limestone is a pure, very fossiliferous limestone of variable hardness. It contains a minor amount of fine quartz sand cemented among the abundant fossil fragments and imprints. The formation was named for exposures that occur along the Suwannee River. Much of the Suwannee Limestone has been altered by ground water since its deposition. This accounts for some of the differences in texture, hardness and porosity within the formation.

The base of the Suwannee Limestone in the Tampa area is marked locally by clay lenses. Some core samples from Tampa reveal the presence of peat in varying amounts in the lower portion of the formation.

The Suwannee, like the Crystal River Formation, is mined for crushed stone in counties north of the Tampa area where it occurs near the surface. In the Tampa area, the Suwannee is a principal source of water to many supply wells.

Tampa Stage (Miocene)

In the Tampa area, rocks of Tampa age are soft, white, impure limestones averaging between about 40 and 160 feet in thickness. It can be seen from both the map and cross-section that the Tampa limestone is absent in the northeast portion of the study area. In some localities, the upper portion of the deposit is composed of calcareous sands and clays grading downward into unconsolidated or loosely cemented lime mud. Chert layers and silicified fossils are also common to the upper portion of the deposit. In a few locations, phosphate nodules or pebbles occur within the Tampa limestone. The base of this unit is frequently marked by beds of clay and clayey sand. Although the sediments are generally not as fossiliferous as the underlying Suwannee Limestone, there are zones within the Tampa that are consequently highly porous. This is because the fossil fragments are generally coarse grained and irregularly shaped and thus do not pack together as tightly as the finer calcium carbonate grains. Most of the Tampa limestone is very sandy and crumbly. Due to the sand content of the rock and the occurrence of lenses of clay and sand within the limestone, the formation is not quarried for crushed stone. The Tampa limestone is valuable, however, as a source of water and yields large quantities to many wells in the Tampa area. The loose cementation and high porosity of portions of the Tampa limestone make it susceptible to weathering and dissolution by ground and surface waters. Many solution cavities, sinkholes and collapse structures occur in the formation, especially where it lies near the surface.

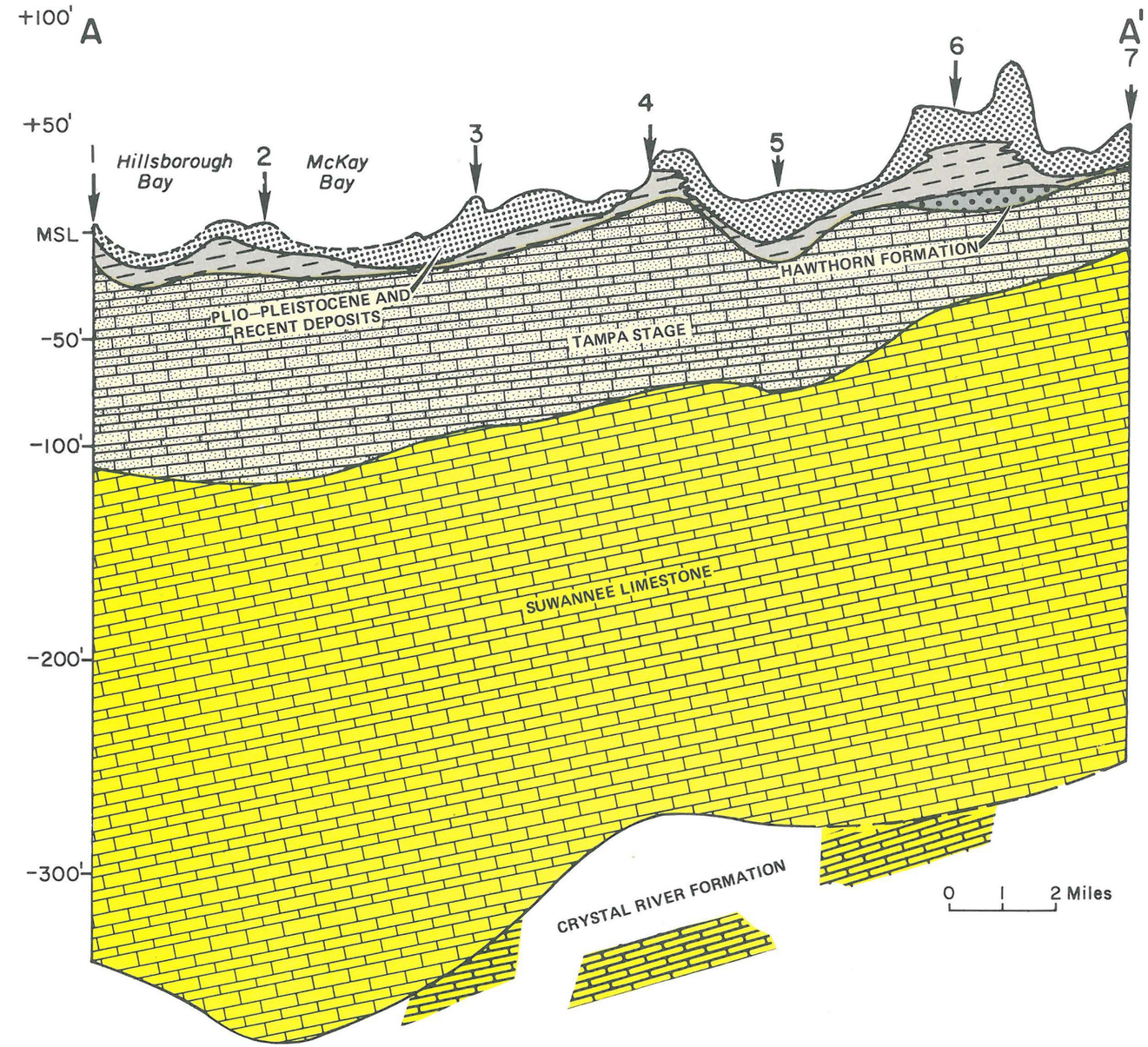
Hawthorn Formation (Miocene)

This formation exhibits a great variation in composition and physical properties. In general, the formation in the Tampa area consists of an upper sand unit, a phosphatic clay unit, and a lower limestone unit. These layers occur in varying thicknesses and tend to interfinger. In most of the Tampa area, the formation is absent, and where it does occur, frequently only one or two of the units are present. Maximum thickness of the formation in Hillsborough County is about 250 feet. Fossils are rare in Hawthorn deposits. The formation thickens to the east and becomes a significant deposit in Polk County, where it is overlain by the Bone Valley Formation, which is thought to be residual material from the weathering of the upper parts of the Hawthorn Formation. It is this residuum that contains the rich concentrations of phosphate so extensively mined in Polk County.

In the Tampa area, the clays of the Hawthorn Formation, along with clays in the upper part of the Tampa Limestone, make up the impermeable confining layers overlying the limestones of the Floridan aquifer.

Undifferentiated Plio-Pleistocene and Recent Deposits

These deposits cover most of the Tampa area and vary from a few inches to many feet thick. They are predominantly fine grained quartz sands which contain varying amounts of organic material. Some of these deposits are of economic value and are discussed further in the Mineral Resources section.



GEOLOGIC CROSS SECTION showing SOUTHWESTERLY DIP OF STRATA in the TAMPA AREA

SINKHOLES

Sinkholes exhibit varying characteristics in the Tampa area and are difficult to classify. There are two basic sink hole types: 1. Collapse sinks produced by collapse of the limestone roof above an underground void. 2. Solution (funnel) sinks developed slowly downward by dissolution beneath a soil mantle without rupture of the rock in which they develop.

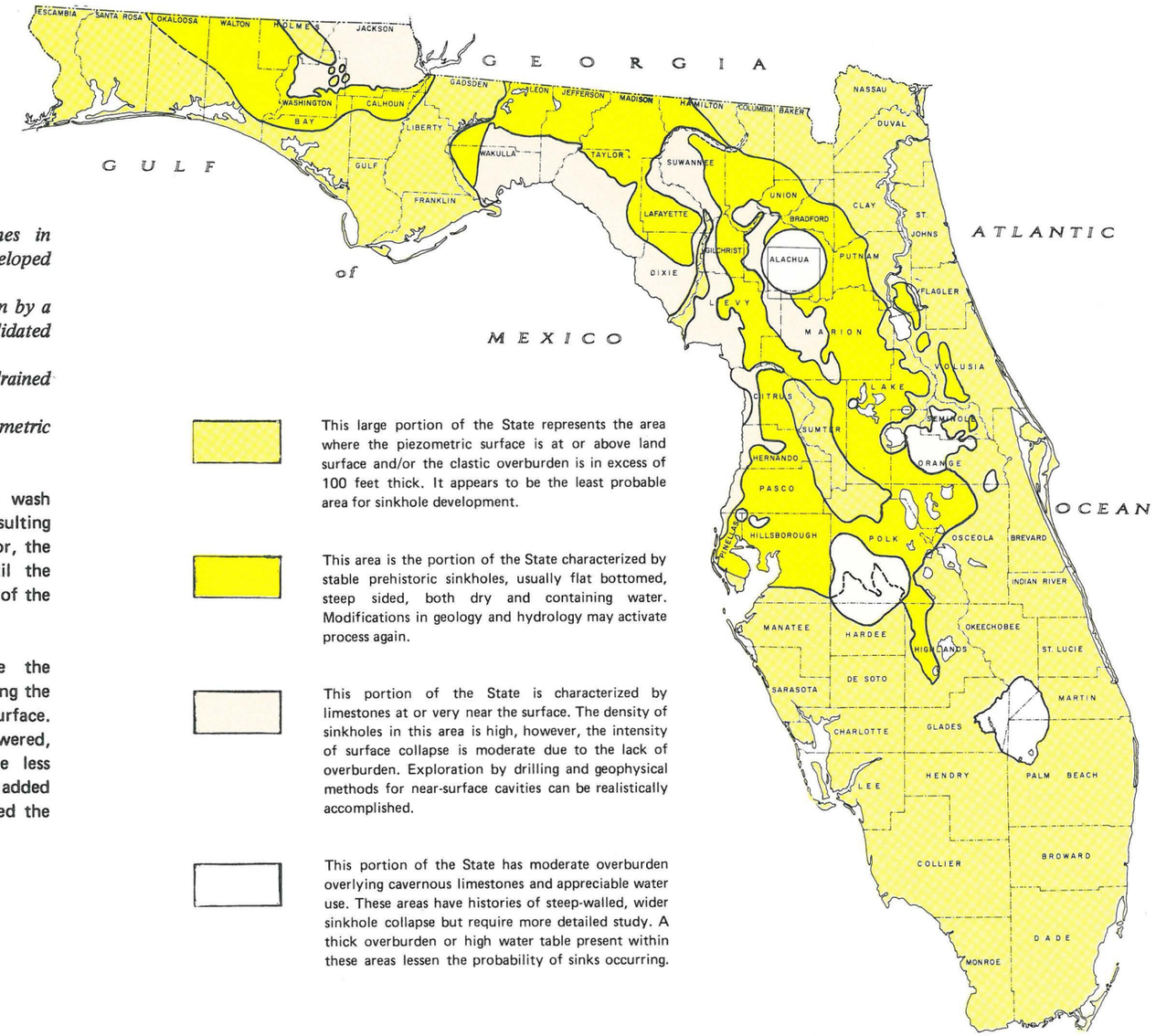
Collapse sinks are normally steep sided, rocky and abruptly descending. Formation of collapse sinks is unpredictable and often instantaneous, thus they constitute the greater threat to land development. Solution sinks may be funnel-shaped depressions broadly open upward, or pan or bowl-shaped. They develop slowly and are usually heralded by the formation of a radial fracture pattern in the soil or even in concrete or asphalt overlying them. Though their formation may not have the devastating effect of a collapse sink, their occurrence can equally limit land use.

Sinkholes in the Tampa area may be of either type, or some variety and are commonly formed in an environment with the following physical characteristics:

1) occurrence of permeable limestones in which a cavity system has been developed through dissolution by ground water
2) these limestones are generally overlain by a relatively thin layer of unconsolidated sediments
3) overlying sediments are usually well drained and permeable
4) a water table higher than the potentiometric surface of the artesian aquifer

Overlying sediments may slowly ravel or wash downward, filling in the cavity system and resulting in a structural sag reflected at the surface; or, the cavity system may continually enlarge until the cavern roofs are too thin to bear the weight of the overburden, resulting in catastrophic collapse.

Two activities which tend to increase the likelihood of sinkhole occurrence are dewatering the aquifer and increasing stresses on the land surface. When the potentiometric surface is lowered, dewatered cavities in the limestone provide less support to overburden layers. Similarly, the added weight of buildings or fill material may exceed the strength of underlying cavernous limestones.

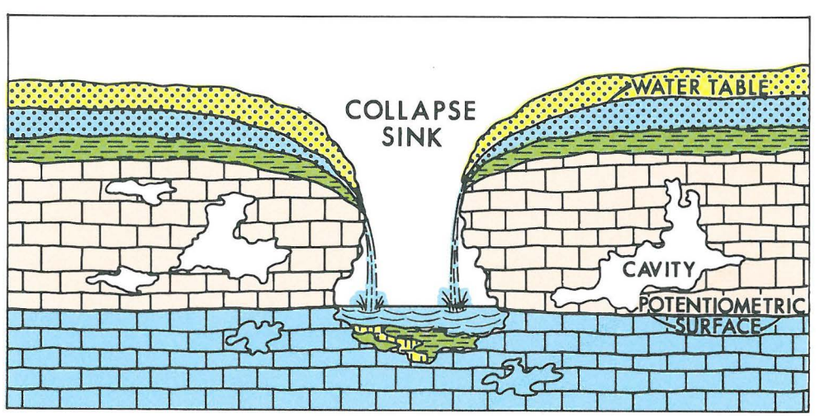


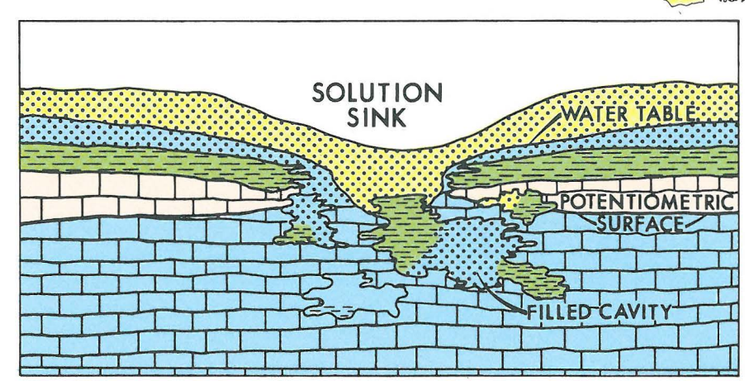
This large portion of the State represents the area where the piezometric surface is at or above land surface and/or the clastic overburden is in excess of 100 feet thick. It appears to be the least probable area for sinkhole development.

This area is the portion of the State characterized by stable prehistoric sinkholes, usually flat bottomed, steep sided, both dry and containing water. Modifications in geology and hydrology may activate process again.

This portion of the State is characterized by limestones at or very near the surface. The density of sinkholes in this area is high, however, the intensity of surface collapse is moderate due to the lack of overburden. Exploration by drilling and geophysical methods for near-surface cavities can be realistically accomplished.

This portion of the State has moderate overburden overlying cavernous limestones and appreciable water use. These areas have histories of steep-walled, wider sinkhole collapse but require more detailed study. A thick overburden or high water table present within these areas lessen the probability of sinks occurring.





Sinkholes in the Tampa area may or may not be filled with water. Sinkhole lakes are characteristically circular and deep. Unless sinkholes have been filled with impermeable material, they are directly connected to the Floridan aquifer and provide a rapid means of recharge. Such direct recharge is not conducive to the removal of contaminants from water by filtration or chemical reaction. It is therefore essential to safeguard the quality of water entering sinkholes.

Sinkholes in the Tampa area generally occur in a wide northwest-southeast trending band. There is a concentration of them in the northwest area, but their apparent predominance here is partially due to more detailed mapping in this section (see map).

Although existing sinkholes can be mapped, predicting specific areas of potential collapse is difficult. No particular pattern to the cavity system in limestones has been discovered.

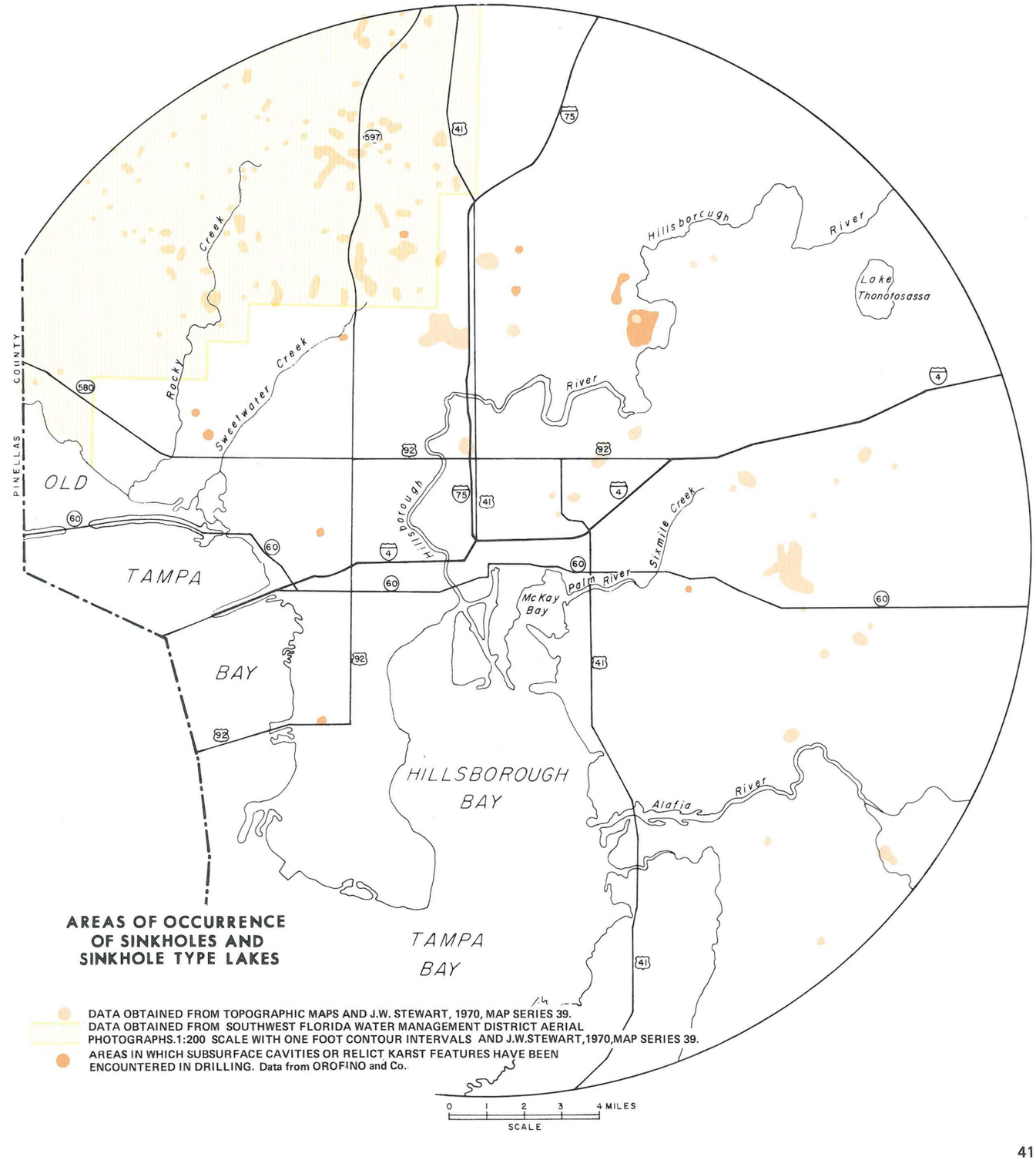
The most widely used method for detecting sub-surface cavities is drilling bore holes. This approach has the obvious disadvantage of producing little data for the amount of effort expended. Other new procedures have been used experimentally in an attempt to identify sub-surface cavities, but the results are not foolproof.

Victor Stringfield (U.S.G.S.) examines sinkhole near Lake Magdalene. (photo by J.W. Stewart)

One method utilizes airborne remote sensing devices. Computer processed imagery obtained from flights over a test area reveals thermal and apparent moisture-stressed vegetative patterns that may be associated with sub-surface cavities.

Additional data collection and refinement of techniques are necessary before the effectiveness of this method can be evaluated.

Another experimental method of identifying sub-surface cavities is gravity mapping. A gravity meter records, on the land surface, local differences in gravity which, after correction factors have been applied, are directly related to differences in density of the underlying rocks. Areas underlain by cavernous limestones produce lower gravity readings than areas underlain by limestones containing fewer voids. Gravity surveying as a means of detecting subsurface voids has certain limitations. The smaller the cavity and the more deeply it is buried, the less detectable it is by gravity methods. A cavity with a diameter equal to or greater than its depth of burial is readily detectable because the gravity anomaly is great. Small gravity anomalies can be produced by a variety of subsurface conditions and therefore may or may not be indicative of small and/or deeply buried subsurface cavities.



AREAS OF OCCURRENCE OF SINKHOLES AND SINKHOLE TYPE LAKES

DATA OBTAINED FROM TOPOGRAPHIC MAPS AND J.W. STEWART, 1970, MAP SERIES 39.
DATA OBTAINED FROM SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT AERIAL PHOTOGRAPHS.1:200 SCALE WITH ONE FOOT CONTOUR INTERVALS AND J.W.STEWART,1970,MAP SERIES 39.
AREAS IN WHICH SUBSURFACE CAVITIES OR RELICT KARST FEATURES HAVE BEEN ENCOUNTERED IN DRILLING. Data from OROFINO and Co.

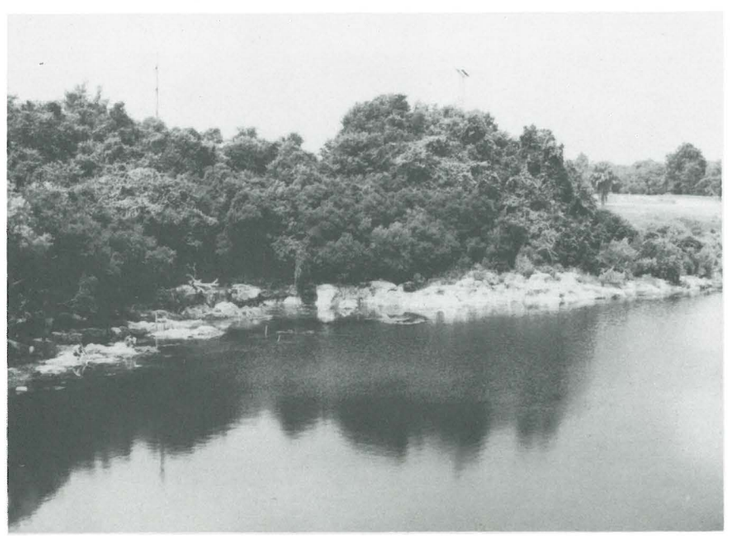
STRUCTURE

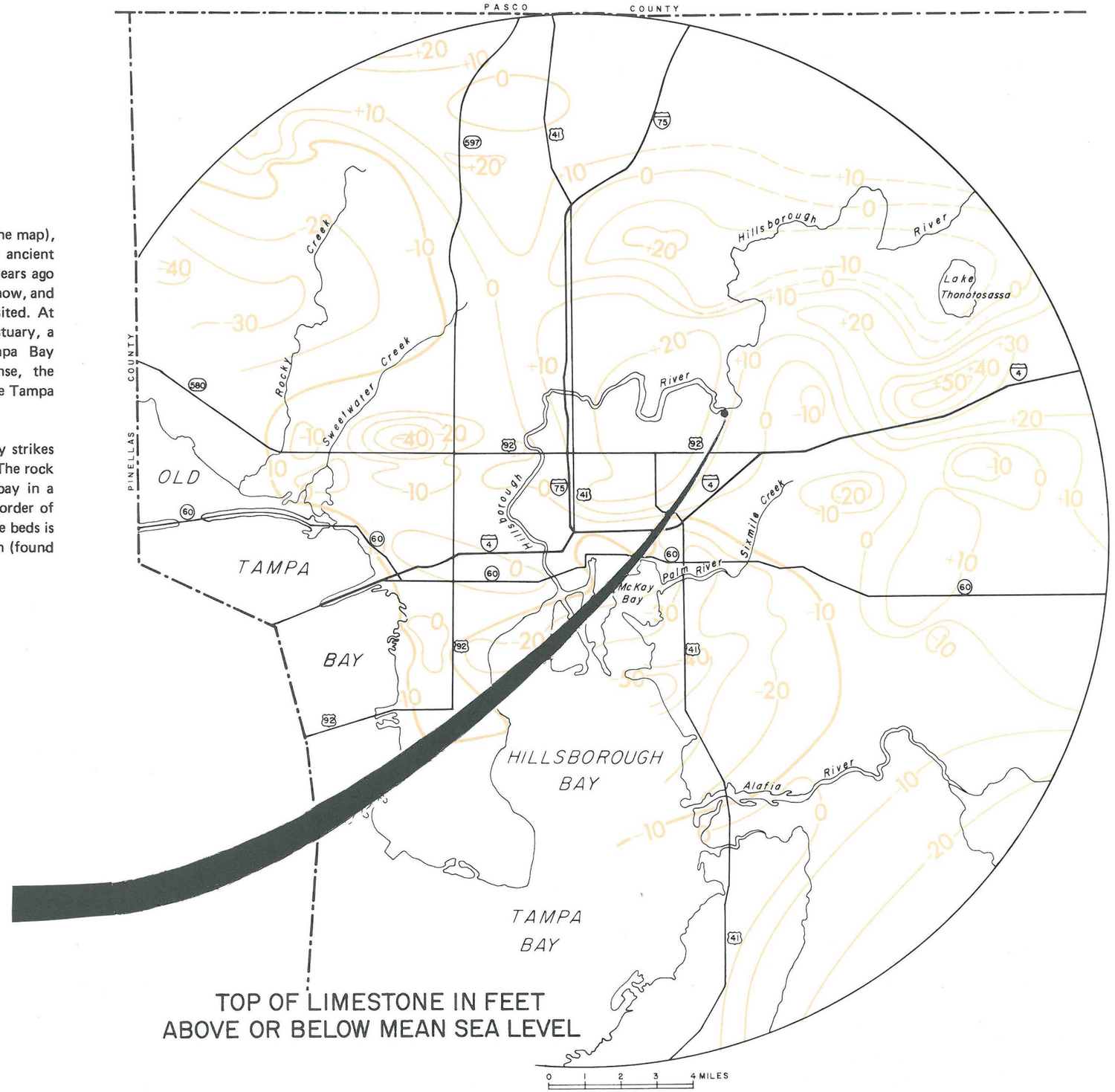
The map presented on this page shows the top of the first consistent limestone. The data is referenced to mean sea level, therefore the contours reflect the actual topography of the bedrock surface. Knowledge of this bedrock surface is important in understanding surface features which are often genetically related to the underlying rock.

The complexity of the contours is due, in part, to post-depositional alteration of the rock. This could include shifting and settling, differential compaction of the limestone strata at some time after deposition, erosion of the rock surface between depositional cycles, and solution weathering of the limestone by ground water.

The contours, however, do reveal something about ancient paleogeography. For example, the minus ten foot contour line (shown as a bold line on the map), can be considered an approximation of an ancient shoreline that occurred here some million years ago when sea level was ten feet lower than it is now, and before surficial sands and clays were deposited. At this time, the Tampa area had a broader estuary, a smaller interbay peninsula and Old Tampa Bay extended further inland. In a broad sense, the topography of the present land surface in the Tampa area reflects bedrock topography.

The bedrock underlying the area generally strikes or trends in a northwest-southeast direction. The rock surface dips gently downward toward the bay in a southwesterly direction with a slope on the order of 0.1% or about 5 feet per mile. The dip of the beds is perhaps better illustrated on the cross section (found on another page in this section).





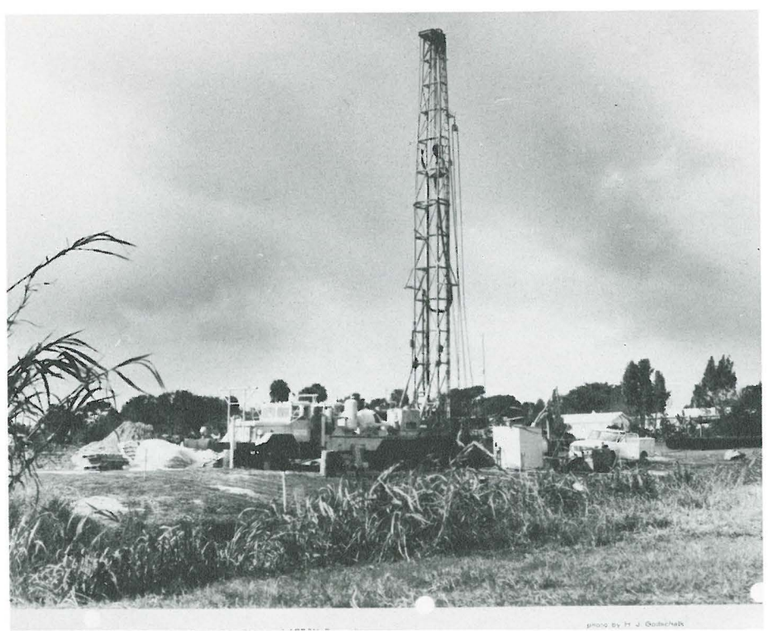
GEOLOGY AND URBAN PLANNING

Two of the more severe problems associated with urbanization are proper waste disposal and adequate water supplies during periods of water shortage. Recent investigations indicate that in some areas there are possibilities for simultaneous alleviation of both problems by utilizing the technique of deep well injection. Successful application of this technique hinges on a good knowledge of subsurface stratigraphy and hydrology.

The method of deep well injection involves injecting treated wastewaters and/or storm runoff into subsurface permeable zones that do not otherwise lend themselves to water supply or mineral production. Many factors, however, must be carefully evaluated before such a project can commence. Further, according to Garcia-Bengochea, et. al.(1973, p. 5-6), Underground disposal of wastewater by wells "... can be achieved successfully if five general requirements are fulfilled. These are:

1. There is a stratum or strata (aquifer) which can accept the waste.
2. The hydraulic and structural characteristics of the aquifer will not be changed significantly by the disposal of the waste.
3. The disposal of such waste will not impair the present or future use of the water in such aquifer.
4. The disposal of such waste will not impair the present or future use of the water in adjoining aquifer or surface-water supplies.
5. The installation is designed properly, with consideration of the physical, chemical, and biological characteristics of the waste and the hydrogeological characteristics of the receiving aquifer and confining strata."

"Present hydrological knowledge indicates that the treated fresh water effluent should not readily mix with the saline waters of the aquifer but would create a large fresh water bubble in storage at the top of the aquifer which could be partially recovered at a later date for low quality uses (irrigation) or for further specific treatment and reuse." (Garcia-Bengochea, et. al., 1973, p. 4-5)



Deep well injection is being carried on in several areas in Florida and additional sites are being evaluated. Several sites currently under investigation are within the geological realm of the Tampa area. These include a site to the east of the Tampa area in Mulberry and several sites in Pinellas County.

According to Wilson, Rosenshein and Hunn (1973, p. 1, abstract), an injection well in Mulberry was completed in 1972 at a chemical plant which produces a liquid waste from phosphate processing that has a high chloride content and high acidity (pH generally less than 2). This effluent is injected into several permeable zones penetrated by the well between 4040 and 4984 feet deep. Tests performed at the Mulberry well provided not only information about the characteristics of the injection zones, but also suggested additional evaluative techniques that might be employed at other sites.

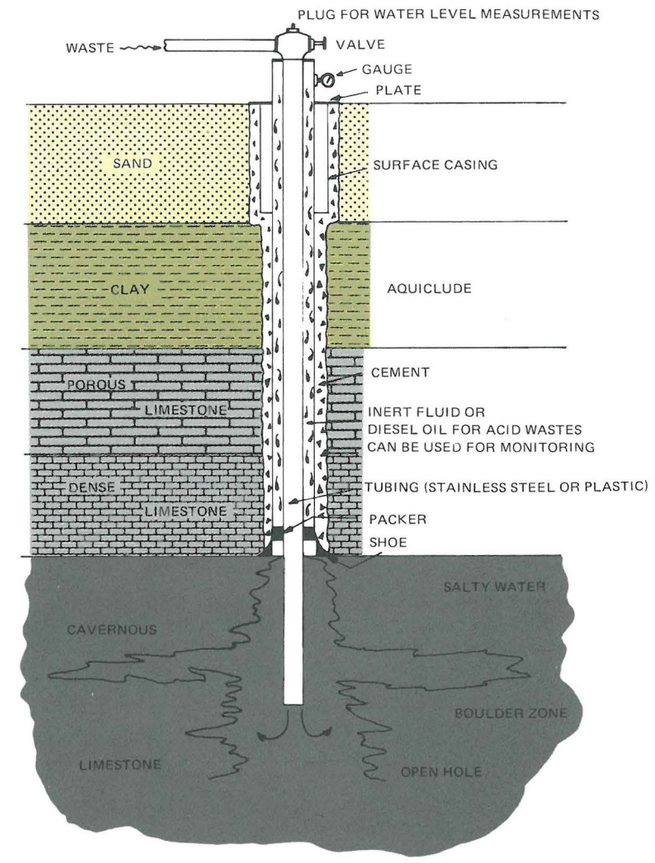
Mr. H. J. Woodard, Geologist with the Department of Natural Resources, is supervising a pilot hole in St. Petersburg which is a cooperative effort by the Division of Interior Resources and the City of St. Petersburg. The project is to study the feasibility of injecting excess surface water into a saline aquifer and recovering it for subsequent use.

According to Garcia-Bengochea, et. al., 1973, p. 27, the objectives of the project are to determine:

1. the characteristics of the deep underground formation at that site;
2. the quality of the deep ground water;
3. the injection rate capacity and associated increase in pressure;
4. ratio of the amount of fresh water that could be subsequently recovered to the amount injected; and
5. quality of the recovered water.

According to H. J. Woodard, as of July, 1973, the pilot hole is completed to a depth of 3500 feet. One injection test was performed at a depth of about 850 feet, and two additional tests are slated for zones that appear promising. One shallower, less saline zone may be suitable for stormwater disposal, and a second deeper zone (greater than 3000 feet deep) may be found satisfactory to receive secondarily treated sewage.

TYPICAL WELL
for
DISPOSAL of TREATED WASTES



(from: R. O. Vernon, 1970, p. 4)

The deep well injection technique has the potential to provide some relief to the waste disposal and water shortage problems of urban centers such as the Tampa Bay area. At present, the need to continue basic geologic and hydrologic data collection cannot be over-emphasized. If deep, permeable zones could be identified and mapped, and their geohydrologic properties and stratigraphic relationships studied, determination of the feasibility of subsurface storage of waste in this area could be greatly facilitated.

Deep well injection studies serve to further illustrate the integral role that geology plays in many phases of urban planning.

MINERAL RESOURCES

PHOSPHATE

INTRODUCTION

During 1970 mineral resources valued at slightly more than 20 million dollars were produced from Hillsborough County, giving it a rank of third among all Florida counties, as shown in Table 1. The figures, however, do not give insight into the impact on Tampa of massive phosphate operations and the mining of construction sands in adjacent Polk County, nor of the quarrying of limestone in Sumter and Hernando counties and the extraction of clay in Citrus County. Practically every aspect of our modern way of life depends in some way on mineral resources. Mineral resources are necessary for building homes, constructing and maintaining roads and highways, manufacturing automobiles and planes, and for producing food crops to feed the people of the world. No one can question that our society depends upon mineral resources. Furthermore no one can question that mineral resources are finite; they are exhaustible. If they are not mined where they occur, they are lost to society.

In recent years it has become evident that mining, especially of mineral resources near the land surface, can result in extensive environmental damage. Air may be polluted. Stream life may be partially or totally destroyed. Land may be left in a state no longer useful. However, it also has been shown that with planning and controls, mining can take place with minimal environmental damage. The necessity of mining and the necessity to minimize environmental damage and reclaim mined-out land has led some investigators to emphasize the need for leadership in undertaking mineral evaluation studies on large land areas *prior to* development. Then, when socially necessary mining operations have been completed, leadership is again appropriate for reclaiming the land mined. The need for planning is most pressing in areas of rapid population growth.

Mineral resources in the general vicinity of Tampa include phosphate, sand, clay, limestone, cement, oyster shells and peat. These products will be considered separately.

TABLE 1

Value of Mineral Production in Florida for Leading Counties [1]

Year	County	Value (Thousands)	Minerals Produced in Order of Value
1970	Polk	$140,598	Phosphate rock, sand and gravel, peat
	Dade	35,184	Cement, limestone, sand and gravel
	Hillsborough	20,041	Cement, phosphate rock, sand and gravel, oyster shell, peat
	Broward	11,930	Limestone, sand and gravel
	Sumter	Withheld	
	Marion	2,562	Limestone, fuller's earth, sand and gravel, phosphate rock
1969	Polk	137,696	Phosphate rock, sand and gravel, peat
	Dade	33,953	Cement, limestone, sand and gravel
	Hillsborough	22,555	Cement, phosphate rock, oyster shell, sand and gravel
	Broward	11,187	Limestone, sand and gravel
	Sumter	3,741	Limestone, lime, peat

[1] Data from Bureau of Mines Minerals Year Books, 1969 and 1970.

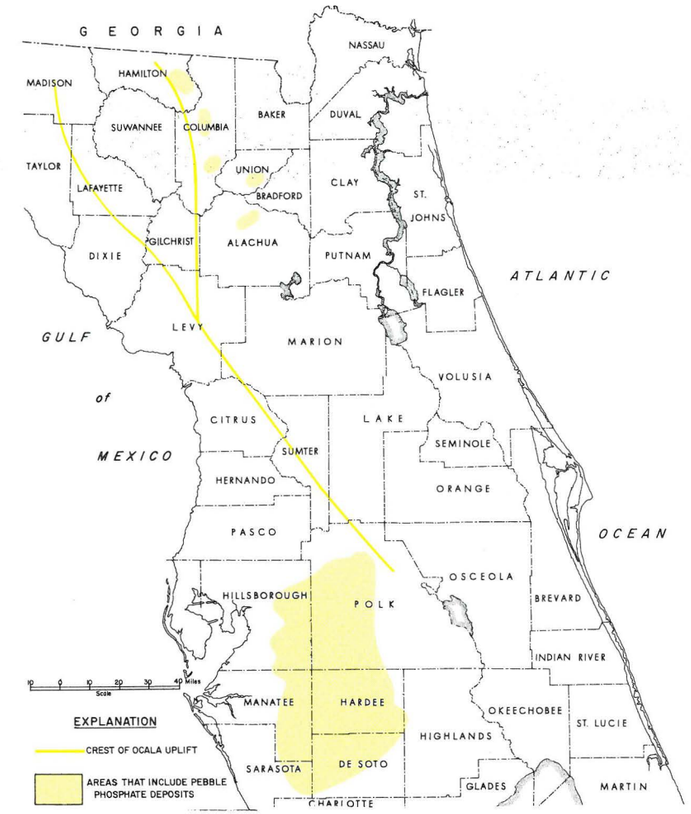


FIGURE 1. PEBBLE PHOSPHATE DEPOSITS OF FLORIDA. THE CREST OF THE OCALA ARCH IS INDICATED BY A HEAVY DARK LINE. MODIFIED FROM PIRKLE ET AL. (1967, FIG. 1, P. 238).

PHOSPHATE

Although phosphate is used in the manufacture of a wide variety of products, including well-known detergents, water softeners and metal polishes, most phosphate is used in the manufacture of fertilizers. The importance of fertilizers in feeding the people of the world would be difficult to exaggerate, and Florida has long been a world leader in supplying phosphate. It is evident, therefore, that the needs of the world, not Florida alone, must measure the impact of Florida's phosphate.

Location and Regional Significance of Pebble Phosphate Deposits

By far the greatest production of phosphate rock in Florida is of the type called "pebble phosphate." The deposits consist of phosphate particles mixed with varying amounts of quartz sand and clay. The phosphate particles usually range from colloidal size to pebbles an inch or more in diameter. Figure 1 shows locations of known pebble phosphate deposits on the Florida peninsula. An examination of the figure reveals that the deposits occur along the flanks or fringes of the Ocala Uplift, an upwarped area cresting in eastern Citrus and Levy counties along the western side of the peninsula. Knowledge of this relationship has been useful in exploration programs.

Some phosphate rock is produced from Hamilton County in the northern part of the peninsula (Fig. 1), but most of Florida's phosphate rock is mined east of Tampa from the large area known as the "Bone Valley District." During 1970 phosphatic sediments produced from the Bone Valley District had a value of approximately 150 million dollars and accounted for almost three-fourths of our domestic needs and one-third of the world's needs. Most of the rock in one form or another is shipped through the port of Tampa. In fact, phosphate is responsible for nearly 50 per cent of the tonnage entering and leaving this important port. Obviously the mining of phosphate rock has an enormous influence on the economy of the Tampa area and the State of Florida (Table 2).

The Bone Valley phosphate field of central Florida is shown on Figure 2. The northern part of the region contains the highest grade phosphate rock and has been mined most extensively. If mining continues it must spread into the southern part of the area.

TABLE 2

FLORIDA PHOSPHATE INDUSTRY*

Item	1971	1970	1969	1968	1967
Employees	6,662	7,563	7,464	9,060	10400
Payroll	$ 59,000,000	$ 59,061,293	$ 59,093,035	$ 68,848,000	$ 69,000,000
Production of marketable rock (short tons)	30,500,000*	29,300,000*	29,900,000*	33,000,000*	31,900,000*
	(*Includes N.C. production—U.S. Bureau of Mines)				
State ad valorem taxes paid	$ 5,215,968	$ 5,996,090	$ 5,882,553	$ 5,856,154	$ 6,326,018
Polk County ad valorem taxes paid	$ 3,619,312	$ 4,635,566	$ 4,577,014	$ 4,627,404	$ 4,583,587
State sales taxes	$ 3,135,273	$ 3,129,152	$ 2,836,648	$ 2,385,727	$ 2,112,112
New construction expenditures	$ 30,000,000	$ 22,189,867	$ 18,227,300	$ 35,420,585	$ 56,827,650
Expenditures for raw materials, equipment, supplies	$174,764,731	$161,192,084	$181,658,064	$175,487,087	$175,086,157

*Data furnished by the Florida Phosphate Council. Five-year comparison.

Nature of Sediments in the Bone Valley District

Three types of sediments are encountered in the phosphate mines (Fig. 3). From the land surface downward these materials are: (1) loose quartz sands and clayey sands (top soil and sand overburden), (2) phosphate beds of the Bone Valley Formation (leached zone and ore zone or matrix), and (3) bedrock (limestone) or bedclay of the Hawthorn Formation. The mixture of phosphate particles, sand and clay of the Bone Valley Formation is the material mined for its phosphate content. Data illustrating various characteristics of the overburden sediments, the phosphate beds, and the underlying bedrock or bedclay are given in Table 3. These data are of samples collected from a test hole drilled on the Lakeland Ridge between the towns of Bartow and Mulberry.

Surface Sands:

The overburden of top soil and loose to slightly hardened quartz sand and clayey sand (Fig. 3) ranges in thickness from a few feet to more than 50 feet (Spls. A through H, Table 3), and typically from 5 to 25 feet. Some investigators believe these surface sands

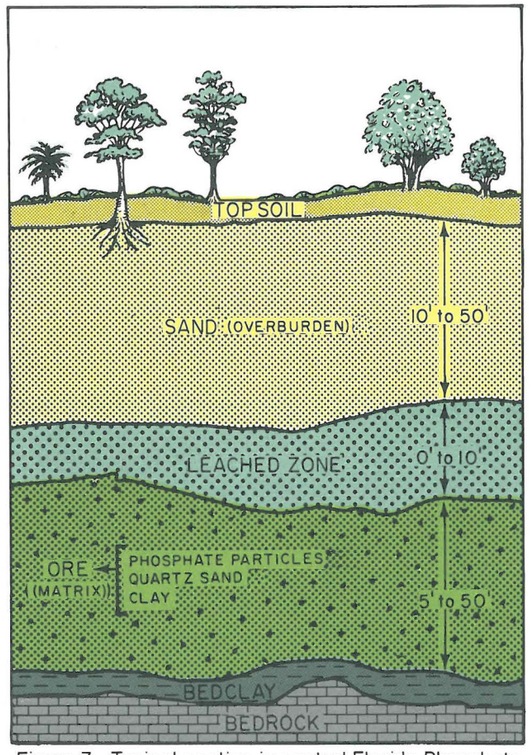


Figure 3. Typical section in central Florida Phosphate district. Modified from Fountain and Zellers, Fig. 2, 1972.

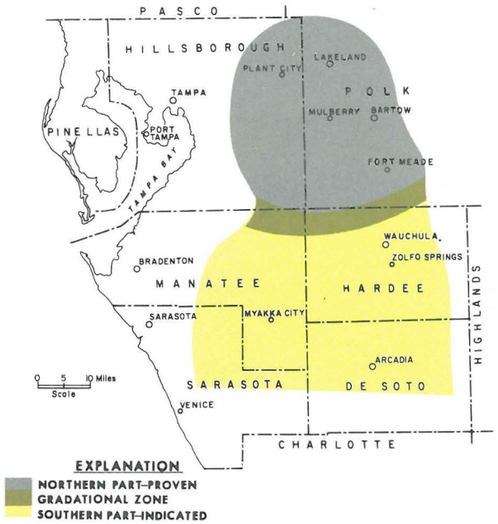


FIG. 2 BONE VALLEY PHOSPHATE DISTRICT OF FLORIDA. THE DISTRICT IS DIVIDED INTO A HIGH-GRADE NORTHERN PART AND A LOW-GRADE SOUTHERN PART.
(Map furnished by Mr. Joe Weaver of Wayne Thomas, Inc.)

were deposited under marine conditions as seas encroached and retreated from the area during Pleistocene time. Other workers consider the quartz sand blanket to represent a simple insoluble residue accumulated on-site from the weathering of underlying sediments.

TABLE 3*
Channel Samples from Grace Drill Hole
SW ¼, Section 4, T.30S., R.24 E., Polk County, Florida
Approximately 4 Miles West of Bartow
Surface Sands and Phosphatic Sediments of the Bone Valley District

Spl.	Depth in feet	Insoluble Residue: Quartz Sand in %	Insoluble Residue: Clay (−325 mesh) in %	Total Soluble in %	P_2O_5 in %	Total Heavies in %
		Overburden Sands and Clayey Sands				
A	0-10	97.01	1.70	.20	.18	1.14
B	10-15	95.52	2.39	.20	.16	1.07
C	15-20	86.47	9.49	2.50	.22	1.17
D	20-30	78.95	19.68	.70	.70	.77
E	30-33	79.86	18.41	.60	1.26	1.06
F	33-40	91.33	7.50	.50	1.10	1.12
G	40-47	83.96	13.33	1.20	.68	.71
H	47-51	96.00	3.40	.10	.22	.77
		Matrix (Commercial Zone)				
I	51-60	35.62	11.08	52.72	15.88	.26
J	60-69	27.68	12.50	59.22	15.66	.10
		Bedrock				
K	69-80	26.23	10.24	63.19	6.68	.05
L	80-87	17.44	7.99	74.50	3.64	.08

*Modified from Pirkle et al. (1967, Table 11, p. 253)

Phosphate Beds of the Bone Valley Formation:

Phosphate beds (Fig. 3) beneath the surface sands consist of varying mixtures of phosphate particles, quartz sand and clay (Spls. I and J, Table 3). The phosphate particles, often referred to as phosphorite, range in color from white or cream to dark gray or black and assay from less than 65 per cent to as much as 80 per cent bone phosphate of lime (BPL) or tricalcium phosphate, $Ca_3\ (PO_4)_2$. The unweathered phosphate mineral is apatite, more specifically carbonate-fluorapatite. In the upper parts of the phosphate beds, where the sediments are more subject to weathering processes, much of this apatite changes to various aluminum phosphate minerals, partly through reactions with surrounding sediments. This upper zone containing the aluminum phosphate minerals is called the aluminum phosphate zone or, locally, the leached zone (Fig. 3). Its thickness usually is between 5 and 10 feet. During mining this upper zone normally is stripped off and discarded as overburden.

The "matrix" or commercial zone of the phosphate beds (Fig. 3) occurs beneath the upper weathered aluminum phosphate zone. Its average district-wide composition according to Altschuler et al. (1964, p. 25) has the following range:

Apatite (carbonate-fluorapatite) . . 35-40 per cent
Clay (montmorillonite) . . . . . 20-25 per cent
Quartz sand and some chert . . . . . 25-40 per cent

This lower zone may be more than 50 feet in thickness, but commonly is between 10 and 20 feet, with an average for the district of approximately 15 feet.

Hawthorn Bedrock or Bedclay:

The commercial phosphate beds or matrix rests either on bedclay or on bedrock (Fig. 3). The bedclay is a phosphatic, impure clay, sandy clay or clayey sand and the bedrock is a pale yellow, impure, phosphatic limestone (Spls. K and L, Table 3). Neither bedclay nor bedrock carries sufficient phosphate content to be commercial. Characteristics of the overburden sands, the phosphate beds and the underlying bedclay or bedrock are summarized on Figure 4.

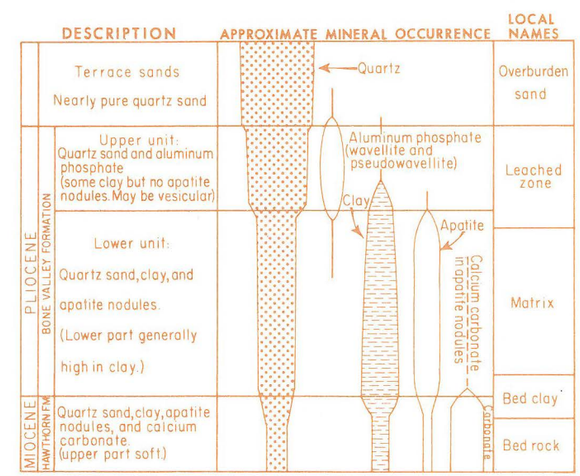


FIG. 4 STRATIGRAPHIC RELATIONS, LOCAL TERMINOLOGY AND MINERAL COMPOSITION OF THE OVERBURDEN SANDS, THE LEACHED ZONE AND MATRIX OF THE PHOSPHATE BEDS, AND THE UNDERLYING BEDCLAY AND BEDROCK. MODIFIED FROM CATHCART et al. (1953, Fig. 3, p. 82).

History of Mining

Pebble phosphate was originally discovered in the Bone Valley District along the Peace River in 1881 by Captain J. Francis LeBaron of the Army Engineers (Davidson, 1892), and mining of the river-pebble deposits began in 1888. In 1891 production from land-pebble deposits was initiated as mining activities began to shift from the irregularly distributed deposits of river beds and flood plains to the more continuous ores beneath the surface sands of the region. Since this early beginning, approximately 97,000 acres of phosphate land have been mined. It is estimated that today an average of 6,500 tons of marketable product are produced from each acre of phosphate land mined. In the early days, however, a large volume of the smaller phosphate particles that are removed today could not be extracted from the sediments. In fact, in recent years some of the waste from these earlier operations has been remined to recover the small phosphate particles.

Mining and Land Reclamation

Difficult environmental problems result from any mining operation in which the top layers of the earth are removed to reach a valuable mineral product, or in which the top layers of the earth are stripped off as the valuable mineral product. This type of mining, called strip mining, is practiced in the Bone Valley District. Overburden sands and clayey sands are removed by giant, electric-powered draglines to uncover the valuable phosphate beds (Fig. 5). The phosphate beds in turn are removed by draglines, one of which can pick up as much as 49 cubic yards of sediments at a time. The phosphatic sediments are dumped by the draglines into sumps where the ore is mixed with water and then pumped to recovery plants.

During the early days of mining, no thought was given to restoring the mined-out land to useful purposes. An area, after mining, was left turned up-side-down with man-made ridges and hills composed mostly of sand and clayey sand interspersed with low areas and filled sludge ponds or settling ponds which take many years to dry sufficiently to permit any type of beneficial use. With changing times it has become evident that such valuable land cannot be left in an unreclaimed, unuseable state. In 1961 the mining companies agreed among themselves to restore to useful conditions as much of the mined-out land as they could afford. Since that agreement the Florida phosphate industry has reclaimed an average of approximately 1,500 to 2,000 acres of mined-out land each year. Additional incentives to reclaim land stem from the mineral severance tax law passed by the Florida Legislature in 1971. Furthermore, Polk, Manatee and Sarasota counties have zoning ordinances requiring a certain amount of phosphate land reclamation.

Nearly all of the phosphate companies have reclaimed significant land areas. Some of the projects are tabulated on Table 4. Current projects include Lakeland Skyview Mobile Home area and golf course, Sanlan Ranch Campgrounds, and simultaneous mining and reclamation on Lake Parker in Lakeland.

However, major reclamation problems exist. These problems are complex and to the present are largely unsolved. A clay-water slurry (slime) is produced in the processing of the phosphate rock. This slurry dries very slowly and after standing for many years still has a volume nearly 6 times greater than the original clay volume. In fact the volume is about twice as great as the original volume of the matrix mined. Slightly more than two-thirds of the land mined must be used as settling areas for these slimes. Therefore a substantial amount of the mined-out land is not readily available for reclamation. Much study has been directed toward this problem of the slimes with encouraging results (Timberlake, 1969). Undoubtedly such studies will continue to demand a high priority until the slime problem is solved.

Figure 5. Mining with giant dragline.

TABLE 4
Examples of Land Reclamation Activities of Various Phosphate Companies*

Example	Company	Description of Project
1	IMC	Southwest Bartow—100 acres—A tract adjoining IMC's Bartow offices. Mined 1965-66. Residential sites.
2	IMC	U.S. 17 strip—135 acres—South of Bartow. Right-of-way for anticipated four-lane road. Good for commercial.
3	IMC	West Mulberry—31 acres—2,500 ft. frontage on Fla. 60. Sold to out-of-state industrial firm.
4	IMC	Noralyn recovery plant site—20 acres—office, lab, on reclaimed land.
5	IMC	Mulberry area—1,000 acres—North, south and south east of Mulberry; all acreage fronting on a highway. One part recreational, another agricultural, rest of reclaimed area for residential or commercial uses.
6	(Armour)	West Bartow Elementary School—Dedicated in May, 1966; Deeded to city in 1960.
7	(Armour)	Clark Property—170 acres—Swampland prior to mining. A real estate subdivision after reclamation.
8	(Cyanamid)	Saddle Creek Park—740 acres—Originally a swamp; land has been donated to people of Polk County for recreational area. Swimming, fishing, picnicing, and other activities. East of Lakeland.
9	(Cyanamid)	Orange Park, north of Lakeland—2,224 acres reclaimed—mining and simultaneous reclamation. Reclamation completed within a month after mining.
10	(Cyanamid)	315 acres—east of Lakeland—donated to Florida Audubon Society as a wildlife sanctuary. Largest reserve owned by society in state.
11	(Mobil)	Peace River Park—donated to city of Bartow (east of city limits) as recreational area.
12	(Mobil)	Christina Park—1,100 acres—Large area south of Lakeland. Sold to private interests for housing development.
13	(Cyanamid)	Pleasant Grove Fish Management area, east of Tampa—1,160 acres—Under supervision of Fla. Game and Fresh Water Fish Commission.
14	(IMC)	Bartow Civic Center—10 acres—1966, land was donated to city for civic center.
15	(Cyanamid)	Sydney—1,613 acres reclaimed—15 miles east of Tampa. Sold portion of reclaimed land for 18-hole golf course.
16	(W.R. Grace)	Sylvester Shores—Fashionable residential subdivision built on reclaimed land in southeast Lakeland. Mined in 1955. Reclaimed in 1960.
17	(W.R. Grace)	North Mulberry area—367 acres fronting on SR 37 and Carter Road. Potential commercial and residential property. 2,600 ft. reclaimed on SR 37.
18	(W.R. Grace)	East Mulberry area—155 acres with 4,400 ft. on SR 60. Potential commercial property.

*Data furnished by the Florida Phosphate Council and phosphate companies.

Pollution Control and Water Conservation

The phosphate producers also have been concerned with problems of air and water pollution. During the past 10 years more than 40 million dollars have been spent by the phosphate companies to install equipment to reduce emissions to the air of fluorides, sulfur dioxide, and dust. Furthermore, an amount in excess of 30 million dollars has been spent during the same period of time for water quality control, with phosphorus and nitrogen discharges receiving much attention. In addition, millions of dollars have been spent to install and operate water conservation systems. The magnitude of the efforts expended toward the control of air and water pollution and for the conservation of water is suggested by the vast expenditures directed toward these ends. Expenditures for the past 5 years are summarized on Table 5.

Substantial progress has been realized. The recirculation of water is much above the national industry average. Airborne fluoride emissions were reduced about 90 per cent during the period from 1959 to 1966. Likewise discharges of phosphorus and nitrogen into local streams have been reduced almost 90 per cent during recent years.

Interesting Elements and Minerals

At one time or another, interest has been expressed in the presence of various materials in the phosphatic sediments of the Bone Valley District or in the tailings left after the processing of phosphate rock. For example, more than one-third of the phosphate values mined can not be extracted profitably and must be discarded with waste materials. Therefore the waste contains a relatively high per cent of unclaimed phosphate. Also, the phosphatic sediments of the district contain minor amounts of uranium. With such tremendous volumes of phosphate rock being mined, the minute amount of uranium in individual phosphatic particles adds up to an impressive quantity of uranium handled in the mining operations. During World War II, studies were made on extracting the uranium from the phosphatic sediments and several plants were constructed in which small amounts of uranium were recovered on a pilot scale.

Furthermore, the Bone Valley sediments contain traces of heavy minerals such as ilmenite, rutile, zircon and monazite. Rutile and ilmenite are important source materials for titanium which has many uses such as a whitener in paper and cloth, a white paint pigment, and a source for titanium metal. Zircon is used in molds in making castings and as a source of zirconium metal. Monazite is a source of rare elements. Also the phosphate rock contains 3 to 4 per cent fluorine, and the district has interest as a possible source of vast quantities of this element. Partly as a result of pressure from air pollution laws and as a result of a shortage of the principal mineral source of fluorine, plants to recover fluorine from phosphate rock have been planned for the Bone Valley District, and some have become realities. Investigations indicate that phosphate rock may eventually become a significant source of aluminum fluoride, according to some estimates by the mid-1970's.

TABLE 5

EXPENDITURES FOR AIR AND WATER POLLUTION CONTROLS AND FOR WATER CONSERVATION PRACTICES*

Item	1971	1970	1969	1968	1967
Expenditures to install air pollution controls	$5,532,090	$2,850,370	$1,925,330	$5,173,066	$9,079,869
Expenditures to install water pollution controls	$3,353,867	$2,136,658	$2,544,587	$2,832,692	$4,822,825
Expenditures to install water conservation systems	$2,528,070	$ 892,400	$1,276,970	$ 729,575	$3,530,218
Expenditures to operate air pollution controls	$4,591,511	$4,111,540	$4,365,305	$3,981,000	$4,040,120
Expenditures to operate water pollution controls	$3,354,340	$3,000,902	$5,592,750	$4,830,500	$5,569,370
Expenditures to operate water conservation systems	$2,623,739	$2,035,770	$2,417,492	$2,530,900	$1,848,020

*Data furnished by the Florida Phosphate Council.

SAND

Construction Sands

The costs of homes, buildings, roads and highways reflect the availability and quality of such common construction sands as concrete sand, plaster sand and mortar sand. All commercially useful sands contain grains of various sizes (diameters). Concrete sand is a clean, relatively coarse sand graded to contain grain sizes within specific ranges (Table 6). Plaster and mortar sands are finer than concrete sand, but like concrete sand, must be clean and graded to specifications (Table 7).

Because much of the surface of Florida is covered with a blanket of quartz sand it might seem that concrete sand could be produced at almost any site. Nothing could be farther from the truth. The median diameters of surface sands collected along east-west traverses crossing the Florida peninsula are given on Figure 6. From this figure it can be seen that the coarsest surface sands in peninsular Florida occur near the center of the peninsula, trend in a nearly north-south direction, and coincide with the general area of Trail Ridge and the Lake Wales Ridge. A comparison of the median diameter (Md) of the surface sands (Fig. 6) with the median diameters (Md) of concrete sand (Table 6) shows that most surface sands collected along the traverses are too fine to serve as a source for quality concrete sand.

In order to obtain large quantities of concrete sand in the peninsula it has been found necessary to extract coarse sands from sediments occurring beneath the surface sands. These underlying coarse sands are present only in the area of the Lake Wales Ridge (Fig. 7). There sand is mined from the Citronelle Formation which locally contains concentrations of very coarse sand grains, quartz granules, and small quartzite pebbles. These localized concentrations of coarse sediments are the materials from which construction sands are produced.

At some localities the surface sands must be removed as overburden before mining the deeper, coarser sands; in other areas, however, surface sands can be mined with the underlying Citronelle sediments. In either case open pit mining methods are used, utilizing draglines in those pits which are dry, and dredges with barge-mounted pumps in those pits which are partly water-filled. Sand removed from the pits is washed and sized by screens to meet required specifications of concrete and plaster sands and then shipped by truck or rail to the market area.

Because transportation is a major cost factor in the sand and gravel industry, various population centers in the peninsula receive their construction sand from pits in that part of the Lake Wales Ridge area closest by road or rail. For example, Jacksonville receives its quality construction sands from mines in Clay and Putnam counties in the northern part of the ridge area. Orlando receives its coarse construction sands from mines in Lake and Polk counties. The Tampa area receives a major part of its quality construction sand from the Lake Wales Ridge area in Polk County. However, some production for the Tampa market has come from other localities, such as sites on the Lakeland Ridge southwest of Bartow (Fig. 7).

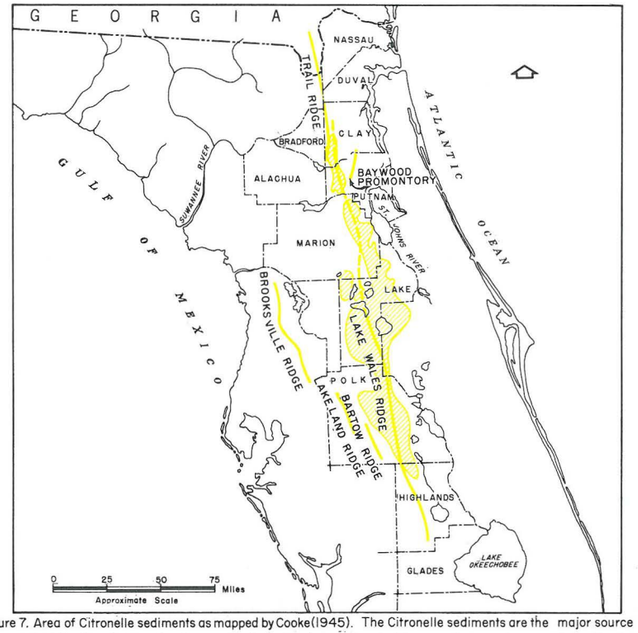


Figure 7. Area of Citronelle sediments as mapped by Cooke (1945). The Citronelle sediments are the major source materials of quality construction sands in the Florida peninsula. These sediments also contain kaolin clay.

TABLE 6

Screen Analyses by Weight of Finished Concrete Sands Collected at Major Producing Mines within the Area of the Lake Wales Ridge

Sieve Size	Florida State Road Specifications % Cumulative	Site A Putnam County	Site B Lake County	Site C Polk County	Site D Polk County
4	0- 5	0.00	0.00	0.0	0.0
8	0- 15	3.2	1.2	1.0	0.3
16	3- 35	12.6	10.8	13.2	6.3
30	30- 75	39.3	39.7	50.4	30.0
50	65- 95	69.9	81.1	73.0	64.5
100	95-100	94.5	99.5	93.6	97.5
FM*		221	232	231	199
Md.**		.47	.52	.60	.39

*Sum of cumulative values for samples. Expression of coarseness.

**Median diameter (mm).

TABLE 7

Grading of Sands for Masonary and Mortar Uses*

Sieve Size	Percentage Passing each screen by weight
4	100
8	95 to 100
16	60 to 100
30	35 to 70
50	15 to 35
100	0 to 15

*Recommendations of the American Society for Testing Materials

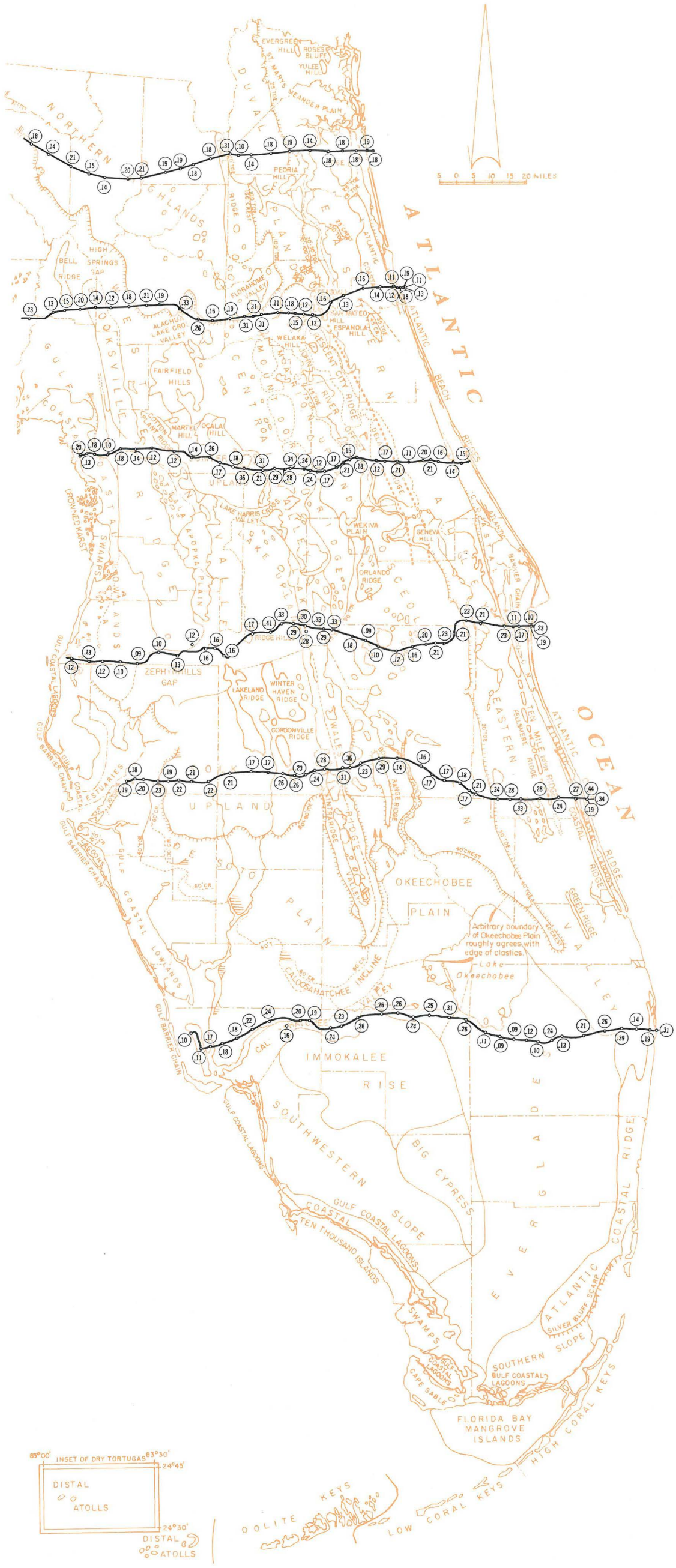


FIGURE 6. SITES AT WHICH SURFACE SAND SAMPLES WERE COLLECTED ALONG EAST-WEST TRAVERSES CROSSING THE FLORIDA PENINSULA. THE VALUE GIVEN AT EACH SITE IS THE MEDIAN DIAMETER IN MILLIMETERS OF THE QUARTZ SAND COLLECTED AT THAT LOCALITY.

A Specialty Sand

Glass sand, an important specialty sand, is produced in both Polk and Hillsborough counties. The glass sand from Polk County is mined in the Lake Wales Ridge area near Davenport where the sands are separated from the same sediments from which concrete and plaster sands are produced. Special processing, including flotation to remove heavy minerals and other impurities, is required to obtain a high quality product.

The glass sand from Hillsborough County is presently produced from surface sands in the Plant City area. Parts of this deposit contain a very high-grade glass sand which in its natural state meets high quality requirements, both texturally and chemically. There are very few natural deposits of glass sand anywhere that meet the quality of these Plant City sands for manufacturing glass. Prior to 1970 flotation was not used in processing the sand. Since that date, however, flotation has been used to remove heavy minerals and other impurities to ensure a reliable product.

Glass sands must be of very high purity; even a fraction of a percentage of some impurities, such as iron, will color the glass produced. Table 8 illustrates the allowable percentages of certain of the more common impurities found in sand deposits. Furthermore glass sand must have a uniform grade-size distribution of sand particles with most of the grains having diameters falling within a range of approximately 0.840 to 0.149 mm (-20 mesh to + 100 mesh).

Glass manufacturers differ somewhat in the details of their specifications for glass sands. Requirements quoted by one major manufacturer for a high-grade glass sand are given below.

1. Chemical Composition - The glass sand shall be composed of the following oxides in the following percentages by weight as determined by analysis based on ignited samples.

Oxide	Percent
SiO_2	not less than 98.500
Al_2O_3	not more than 0.500
Fe_2O_3	not more than 0.035
CaO, MgO	not more than 0.200

2. Grain Size - The glass sand shall conform to the following requirements with respect to grain size:

percent remaining on 16 mesh screen	none
percent remaining on 30 mesh screen	0-20
percent remaining on 60 mesh screen	40-80
percent remaining on 120 mesh screen	15-30
percent passing through 120 mesh screen	0-10

Some of the glass sands in Hillsborough County and similar deposits in Manatee County in their natural state regularly approach these specifications for high purity glass sand. Analyses of a sample of Plant City sand as taken from the ground are given on Table 9.

The value of the deposits near Plant City as a glass sand was recognized in 1961 (Pirkle et al., 1963, p. 128). Since that time studies have been undertaken to locate additional deposits. During one study the following procedure for locating deposits of the Plant City type was followed by the authors. At the outset, all areas of St. Luci sands were plotted from soil maps onto topographic maps of Hillsborough and Manatee counties. Field checks of these areas were then made to determine which of the regions of St. Luci sands support a true scrub vegetation. Holes were drilled in the sands supporting a true scrub growth, and the sands taken from the holes were analyzed for texture (sand size), heavy mineral content and iron content. From the analyses it was found that the sand in many of the regions is too fine for glass purposes. However, sands from some areas were found to be of the same quality as the Plant City deposits. The final result of the study was the location of new resources of glass sand of the Plant City type. It must be added, however, that this procedure for locating glass sands will not work in other parts of Florida. Different methods of exploration must be devised for other areas.

TABLE 8*

Specifications for Chemical Composition of Glass Sands
Percentage composition based on ignited samples

Qualities	SiO_2 Minimum	Al_2O_3 Maximum	Fe_2O_3 Maximum	CaO+MgO Maximum
First quality, optical glass	99.8	0.1	0.02	0.1
Second quality, flint-glass containers and tableware	98.5	0.5	0.035	0.2
Third quality, flint-glass	95.0	4.0	0.035	0.5
Fourth quality, sheet glass rolled and polished plate	98.5	0.5	0.06	0.5
Fifth quality, sheet glass, rolled and polished plate	95.0	4.0	0.06	0.5
Sixth quality, green glass containers and window glass	98.0	0.5	0.3	0.5
Seventh quality, green glass	95.0	4.0	0.3	0.5
Eighth quality, amber glass containers	98.0	0.5	1.0	0.5
Ninth quality, amber	95.0	4.0	1.0	0.5

*Taken from Fettke (1926, p. 400).

TABLE 9

Plant City Glass Sand

Site	Accumulative percent retained on mesh 12	16	20	30	50	60	100	140	Heavy Minerals in %	Fe_2O_3 in %
Plant City	0.0	Tr.	0.4	3.6	41.3	58.3	87.0	93.9	0.154	0.016

Sand mine at Plant City.

CLAY

Among the most interesting Florida clays from the commercial viewpoint are kaolinitic clays for ceramic purposes, fuller's earth clays for their adsorbent properties, and bloating clays for their use in making lighweight aggregate. None of these clays is currently mined in Hillsborough County. However all are mined in the Florida peninsula and are a part of the mineral environment of Tampa.

Kaolinitic Clays of the Citronelle Formation

The north-south trending Lake Wales Ridge area which divides the Florida peninsula into an eastern and western part (Fig. 7) is underlain by Citronelle sands that contain varying amounts of kaolinitic clay. These, usually assigned a late Miocene or Pliocene age, are the materials previously discussed as the source sediments for quality construction sands of the peninsula. The kaolinitic clay occurs disseminated throughout the sands, usually constituting from 2 or 3 per cent to as much as 25 per cent of the beds.

The kaolinite of the Citronelle Formation is a high quality ceramic clay. It has been mined at one time or another in Clay, Lake and Putnam counties, the production from Putnam County being continuous since 1892. In addition to its value as a ceramic clay, the kaolinite of the Citronelle Formation may have potential as a future source of aluminum. Citronelle clays are not present in Hillsborough County, but they do occur in the eastern, central and northern parts of adjacent Polk County.

Fuller's Earth Clays of the Hawthorn Formation

The Hawthorn Formation contains fuller's earth clays, utilized for their adsorbent properties. The dominant clay minerals are montmorillonite and attapulgite. Extensive mining of the clays is carried out in Gadsden County northwest of Tallahassee and in southwestern Georgia. The production of the adsorbent clays closest to the Tampa area is at Lowell in Marion County. Clay from that site is shipped to the Tampa market for use as an adsorbent cat litter, as a pesticide carrier, and as an inter-caking agent for fertilizers. Although Hawthorne sediments are present in the subsurface of Hillsborough County, no extensive occurrences of fuller's earth type clays suitable for mining have been reported.

Bloating Clays

Some clays will expand or bloat when heated, often taking on the appearance of a burned, porous or cellular cinder rock. The expanded or bloated material is relatively light and if sufficiently strong is ideal as a lightweight aggregate for use in the production of concrete and concrete products.

Clays Along the St. Johns River:

The only site from which bloating clays currently are mined in Florida is near Russell just west of the St. Johns River in Clay County. However, there are other occurrences of similar clays known to be present along the St. Johns. These clay bodies apparently are confined to the general vicinity of the river valley.

Deposits of Clayey Sediments in West-Central Peninsular Florida:

Within the past few years massive bodies of clayey sediments possibly useful as a bloating clay have been found in northern Pinellas County (west and southwest of Lake Tarpon) and in the vicinity of Telegraph Swamp in Charlotte County. These clays have been drilled and studied by members of the Florida Bureau of Geology, the Geology Department of the University of Florida, and the United States Bureau of Mines Laboratories (Wahl and Timmons, 1972). Figure 8 is a fence diagram showing the stratigraphic position of the clay body near Lake Tarpon. Wahl and Timmons (1972, p. 109) report that the large clay deposit probably is Miocene in age, consists of montmorillonite type clays, has an average thickness of 25 to 35 feet, and is overlain by unconsolidated Pleistocene sands. The clays have good bloating characteristics across an acceptable temperature range and develop a good cellular structure with a fairly thick and apparently tough wall structure. However the deposit is in an area of rapid population growth and mining may not be feasible. In regard to this problem Wahl and Timmons (1972, p. 112) state:

"It is possible that development of the Pinellas County deposit to its maximum potential might already be prohibited by urbanization, for the Pinellas-Hillsborough County area is one of the fastest growing regions in the state at the present time. It is, indeed, imperative that other similar deposits throughout the state be located and their potential for development be realized so that land-use planning and resource development can be coordinated."

In light of these comments by Wahl and Timmons it is of interest to note that extensive deposits of clayey sediments that may have potential as a base material for the manufacture of lightweight aggregate are present in a number of other counties in west-central peninsular Florida, including Pasco, Polk and Hillsborough. In evaluating these clayey sediments a number of economic factors must be considered. Obviously the overburden covering the clay deposits should be as thin as possible so that the cost involved in its removal is not substantial. Also, the moisture content of the clay should be low. Every bit of moisture present is significant in that it increases processing costs. It is desirable that the clay be a natural bloating clay; however, coal or fuel oil can be used to make the clay bloat if the melting range of the clay is over a sufficient temperature span. In addition to these factors, transportation costs and problems related to the environment and to the restoration of mined-out land must be given serious consideration.

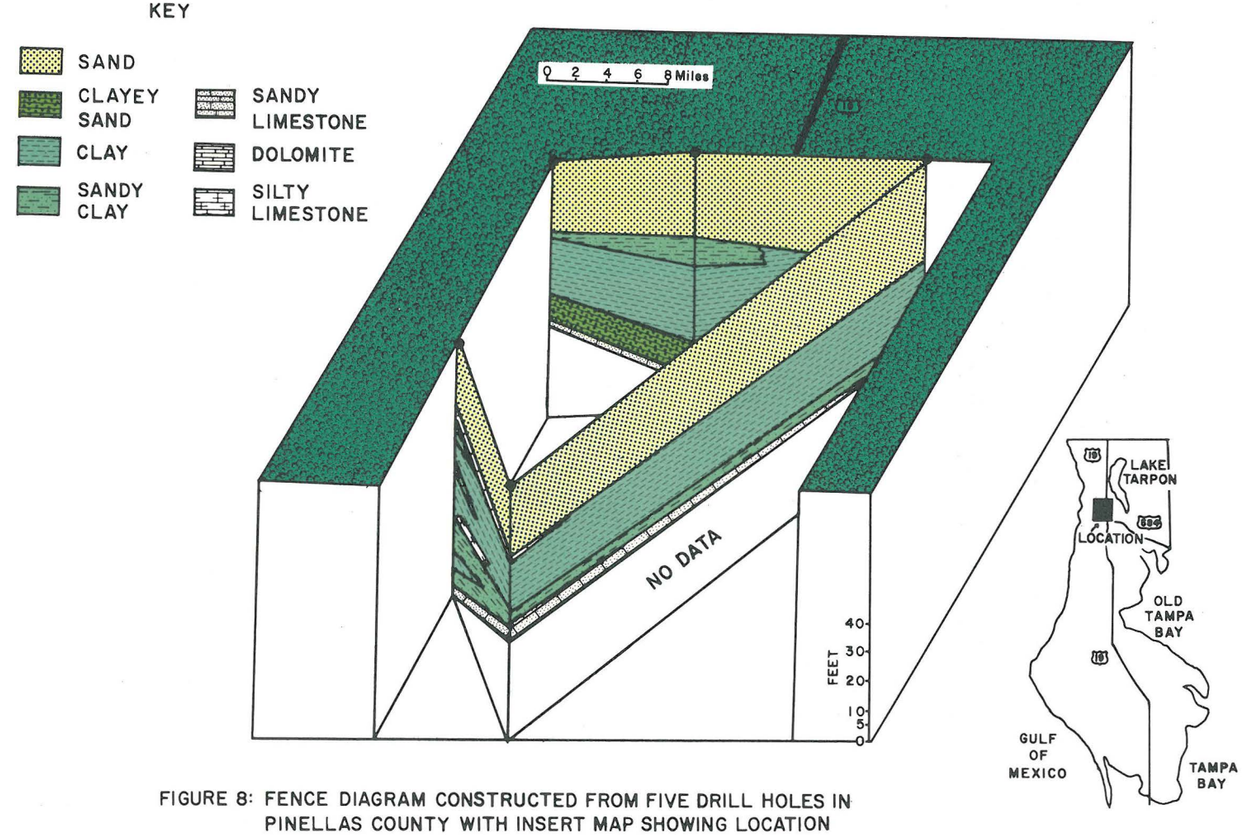


FIGURE 8: FENCE DIAGRAM CONSTRUCTED FROM FIVE DRILL HOLES IN PINELLAS COUNTY WITH INSERT MAP SHOWING LOCATION OF DRILLED AREA. MODIFIED FROM WAHL AND TIMMONS (1972, FIG. 5).

There are different methods that could be used in attempting to locate and pinpoint deposits of these clays. To illustrate, Figure 9 shows a section through Pasco, Sumter and Lake counties. From this section it is clearly seen that the Ocala Arch crests beneath Sumter County (holes 3, 4 and 5). The near-surface sediments on the flanks of the arch are shown to be sandy clay (yellow color with dashes and dots). These sandy clays flanking the crest area of the Ocala Arch grade away from the arch into sediments containing less clay (yellow color). Clearly the sediments closest to the crest area are the highest in clay content and should be considered as broad targets for possible clay deposits.

Figure 10 is a map of the same general area showing the depth to the top of the Floridan aquifer (usually limestone). By combining information from this figure with information from Figure 9 the target areas for the clays flanking the Ocala Uplift can be further localized. That area colored dark yellow on Figure 10 marks the crest area of the uplift. Limestone is within 10 feet of the land surface and a thick deposit of clay would not likely be present over the limestone. Beneath the area colored light yellow the limestone is at a depth of 10 to 25 feet. Again the closeness of the limestone to the land surface would tend to preclude the presence of a massive deposit of thick, clayey materials between the land surface and the limestone, although the occurrence of a potential clay body could not definitely be ruled out. Throughout the area colored yellow-green the limestone is from 25 to 50 feet below the land surface. This depth to the limestone should be sufficient for clay occurrences and for clay mining. Thus on the basis of the work of Pride, Meyer and Cherry (1966) the yellow-green area on Figure 10 of this report should be considered as areas in which clays of interest for their bloating qualities may be present.

Additional information of significance in speculating on the possible occurrences of bloating clays is given in the work of Ketner and McGreevy (1959, Plates 3 and 4). Information from their plates has been selected and reproduced here as Figure 11. This figure shows subsurface sediments along a line from Brooksville southeastward through Dade City into Polk County. In this section the materials marked by dashes are designated by Ketner and McGreevy as the clay unit of the Tampa Formation. In Pasco County this clay unit is shown to be near the land surface along the flanks of the Brooksville Ridge as indicated by holes 5 and 9 on Figure 11. Therefore another broad target area for possible clay deposits would be along the flanks of the Brooksville Ridge where clayey sediments are not covered by thick overburden sands. Obviously these published reports by the Florida Bureau of Geology and the United States Geological Survey can be used as starting points in planning for exploration programs directed toward the recognition of potential clay resources in the general area of Tampa.

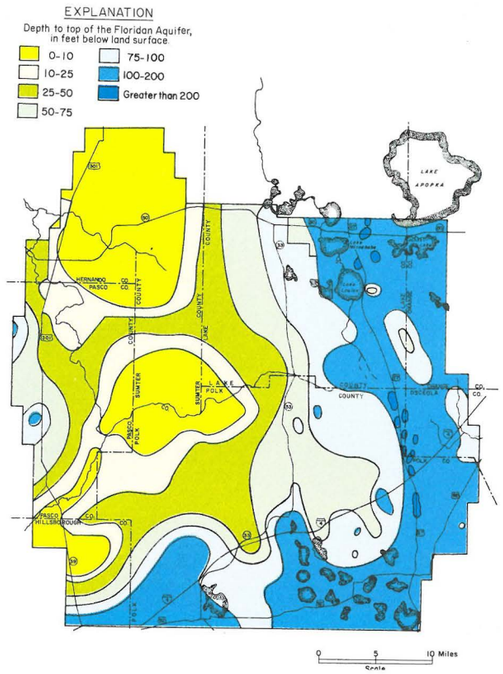


Figure 10. Green Swamp and surrounding areas showing thickness of sediments over the Floridan aquifer. (Reproduced from R. Pride et al. 1966, Fig. 3)

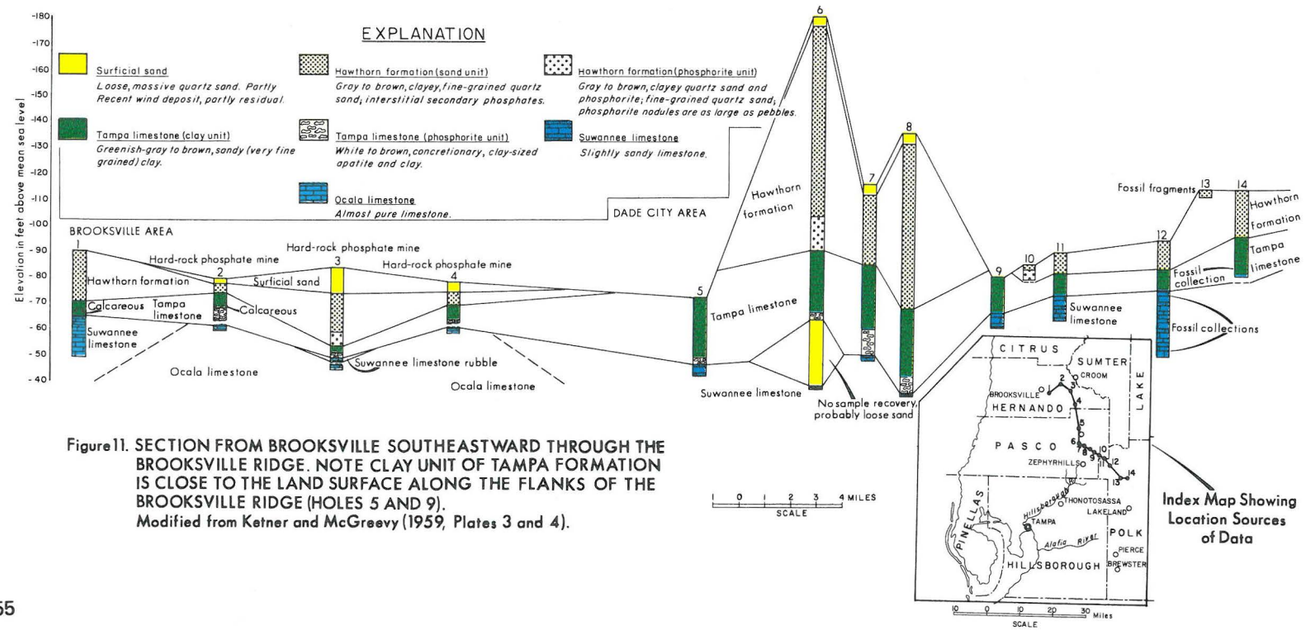
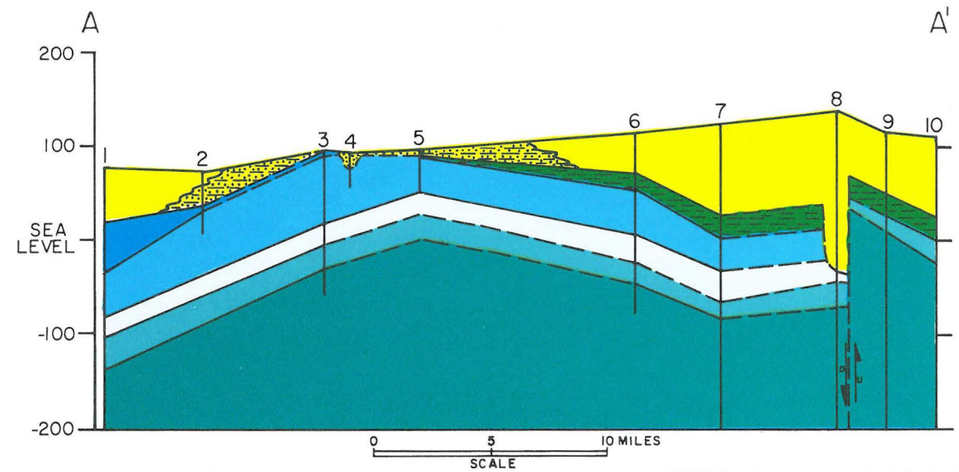
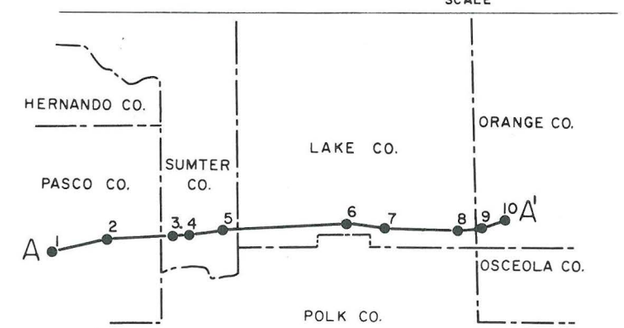


Figure 11. SECTION FROM BROOKSVILLE SOUTHEASTWARD THROUGH THE BROOKSVILLE RIDGE. NOTE CLAY UNIT OF TAMPA FORMATION IS CLOSE TO THE LAND SURFACE ALONG THE FLANKS OF THE BROOKSVILLE RIDGE (HOLES 5 AND 9). Modified from Ketner and McGreevy (1959, Plates 3 and 4).





Sketch Map Showing Location of Cross-Section

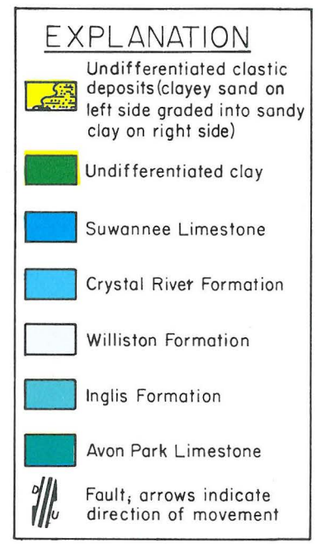


Figure 9. SECTION THROUGH PARTS OF PASCO, SUMTER AND LAKE COUNTIES. THE CREST OF THE OCALA ARCH IS IN THE VICINITY OF SUMTER COUNTY NEAR CORE HOLE NO.4. NOTE THE CLAY CONTENT OF SEDIMENTS IS HIGHEST AROUND THE FLANKS OF THIS ARCH (YELLOW COLOR WITH DASHES). MODIFIED FROM PRIDE ET AL. (1966, FIG. 8).

LIMESTONE

Centers of Limestone Production

During 1970 slightly more than 40 million tons of crushed limestone valued at 55.2 million dollars were produced in Florida from 90 quarries in 23 counties (Table 10). The producing areas can be grouped into two major centers of limestone production, one north of Tampa in the area of the Ocala Uplift (Fig. 12), and the other in the southeastern part of the peninsula in Dade and Broward counties. All of the Florida peninsula can be supplied with limestone products from these two centers.

Of most direct interest to Tampa is the center in the Ocala Uplift area. There limestones arched upward from depth are now exposed or covered by only a thin veneer of overburden sediments. They are accessible for mining by open pit methods and may be removed with draglines, power shovels, front end loaders and bulldozers.

TABLE 10*

Florida: Crushed limestone sold or used by producers, by counties (Thousand short tons and thousand dollars)

County	Number of quarries	1970 Quantity	Value
Alachua	4	1,744	$ 1,335
Broward	16	6,924	11,303
Collier	6	1,679	2,502
Dade	14	11,134	13,356
Hernando	6	7,719	13,023
Levy	2	249	155
Marion	10	924	2,121
Monroe	2	917	615
Palm Beach	2	W	W
Sumter	3	2,604	2,456
Undistributed[1]	25	6,316	8,310
Total[2]	90	40,210	55,176

W Witheld to avoid disclosing individual company confidential data; included with "undistributed."

1 Includes Charlotte, Citrus, Lee, St. Lucie, Suwannee, Taylor, and Palm Beach counties.

2 Data may not add to totals shown because of independent rounding.

*Bureau of Mines Minerals Yearbook, 1970.

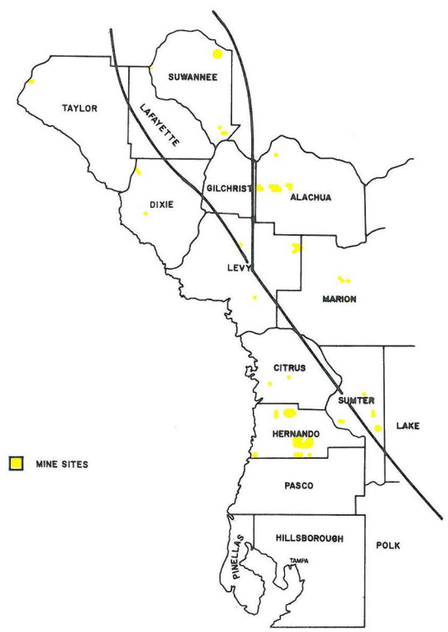


Figure 12. Center of limestone production north of Tampa. The crest of the Ocala Uplift is indicated by a heavy black line. Areas in which active limestone quarries are present are shown in color. Note their correlation with the area of uplift.

Uses of Limstone

Limestone mined in Florida is used principally as a roadbase, as concrete aggregate, and in the manufacture of cement and lime (Table 11). The loose, granular "Ocala Lime Rock," mined extensively within the Ocala Uplift area in many counties including Alachua, Marion, Levy and Sumter, is used as a roadbase material and in the manufacture of lime. A crystalline limestone called "Brooksville stone," mined primarily in Hernando County, is marketed as a concrete aggregate, although some is used for railroad ballast and for agricultural purposes. During the past, much of the limestone used in making cement for the Tampa market came from mines in Citrus and Hernando counties. Now, however, limestone sediments are being imported from the Bahamas for the Tampa cement market.

Some carbonate rocks have a relatively high content of magnesium. These rocks, often called dolomites or dolomitic limestones, are used mainly as fertilizer filler and for soil improvement. They are mined north of Tampa in some parts of the uplift area and south of Tampa in Manatee and Sarasota counties.

TABLE 11*

Florida: Crushed limestone sold or used by producers, by uses (Thousand short tons and thousand dollars)

Use	1970 Quantity	Value
Concrete aggregate	9,824	$16,302
Dense graded roadbase stone	15,232	20,398
Other roadstone[1]	2,820	4,214
Unspecified aggregate and roadstone	2,866	2,788
Agricultural purposes[2]	375	1,353
Fill	3,373	2,651
Railroad ballast	120	165
Other uses[3]	5,600	7,306
Total[4]	40,210	55,176

[1]Other roadstone includes bituminous aggregate, macadam aggregate, and surface-treatment aggregate.
[2]Data include stone used in poultry grit.
[3]Includes asphalt filler, cement, chemical stone, other filler, lime, stone sand.
[4]Data may not add to totals shown because of independent rounding.

*Bureau of Mines Minerals Yearbook, 1970.

Limestone Reserves

Like many other low unit-value mineral resources, limestone deposits must have natural purity and be easily accessible for mining in order to be economically important. Although the Tampa area is underlain by vast quantities of limestone, the thickness of overburden coupled with the impure nature of the limestone renders the sediment throughout most of the area insignificant as economic deposits. However, about 10 miles northwest of Lakeland there is a large region in which limestone is close to the land surface (Fig. 10, yellow-green color). That area, partly in Hillsborough County, has potential as a source region.

Florida's reserves of limestone are monumental. Reves (1962, p. 7) states that in the northern half of the peninsula alone, the amount of limestone which has less than 15 feet of overburden, if mined to a depth of 40 feet, would approach 4.2 trillion tons. A vast amount is a very high calcium limestone, ranging from a minimum of 95 per cent calcium carbonate to as much as 99.8 per cent calcium carbonate. Furthermore there is a great deal of dolomitic limestone. For example, Vernon (1951, p. 218) reports more than 100 square miles underlain by dolomitic limestone in Citrus and Levy counties alone. Other occurrences of dolomitic limestone are known in Florida, including deposits along the Gulf Coast in Dixie, Taylor, Jefferson and Wakulla counties (Reves, 1962, p. 12) and in Pasco, Hernando, Suwannee, Manatee and Sarasota counties (Maxwell, 1970, p. 26).

Potential Deposits of Crystalline Limestone

Recently Yon and Hendry (1972) investigated the occurrences of crystalline limestone in Hernando and Pasco counties. Limestone products from these counties, just north of Tampa, would have a marked impact on the Tampa market. Yon and Hendry determined that crystalline limestone suitable for concrete aggregate is associated with an elongated subsurface high extending from Pasco County northwestward into Hernando County (Figs. 13 and 14). They interpreted the buried "ridge" of limestone as a possible carbonate bank built during Oligocene time in a warm shallow sea.

The highs and lows of the upper surface of this buried limestone "ridge" conform in general with the highs and lows of the land surface. To prospect in that area for limestone suitable for aggregate, one may superimpose contour maps of land surfaces onto Yon and Hendry's contour map of the upper surface of the limestone high (Fig. 13). The crystalline limestone should be close to the land surface at those sites where the two sets of contour lines show nearly the same elevations (Yon and Hendry, 1972, p. 40). These correlations brought out by Yon and Hendry constitute a vivid illustration of the significance of basic geological studies in pointing to occurrences of accessible mineral resources.

Limestone mine in Sumter County.

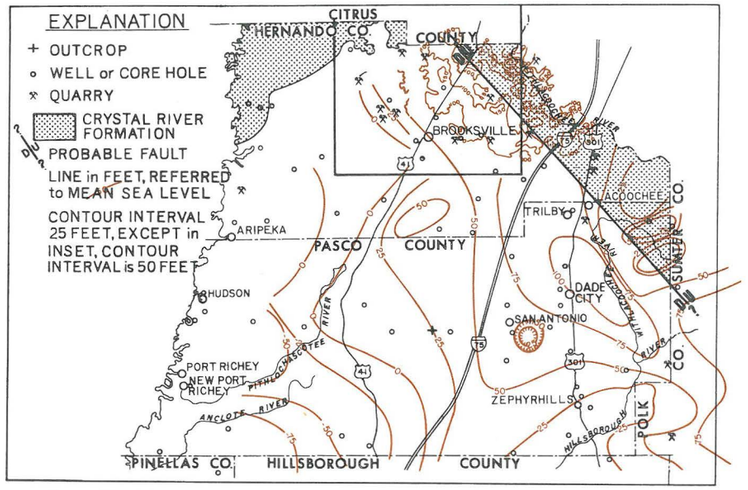


Figure 13. CONTOURS DRAWN on the TOP of the SUWANNEE LIMESTONE in HERNANDO and PASCO COUNTIES. A HIGH, ELONGATED AREA JUST WEST of DADE CITY is CLEARLY SHOWN. ITS TREND is NORTHWEST-SOUTHEAST. (FROM YON and HENDRY, 1972, Fig.5, p.12).

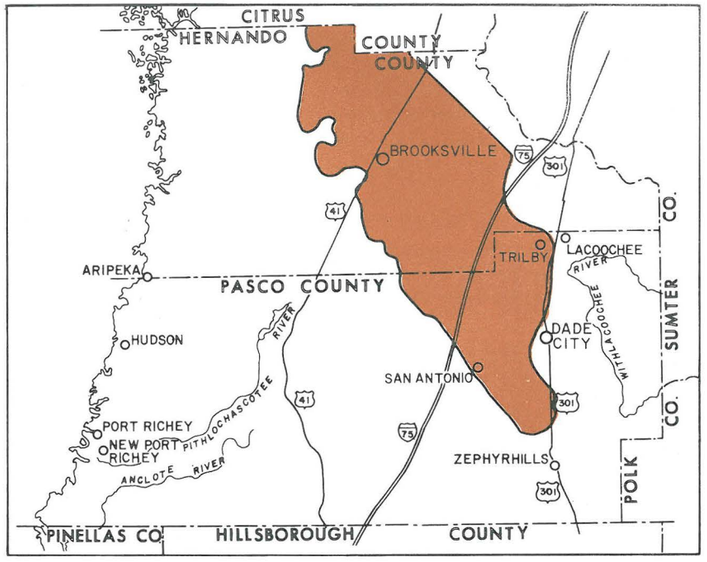


Figure 14. AREA of POTENTIAL LIMESTONE AGGREGATE in HERNANDO and PASCO COUNTIES is SHOWN in COLOR. THIS AREA CORRESPONDS to the HIGH on FIGURE 13. (FROM YON and HENDRY, 1972, Fig.16, p.39.)

CEMENT, OYSTER SHELL, & PEAT

Cement

Cement itself is not a mineral but normally is considered a mineral resource. The raw materials needed in its production are lime or limestone and minor amounts of silica, alumina, and iron oxides. In manufacturing portland cement the raw materials are crushed, then proportioned under strict chemical controls, ground to a powder or slurry and fed into an inclined rotary kiln. The powdered material moves under gravity from the upper toward the lower end of the rotating kiln where intense heat is produced. The heat fuses the powdered charge to a glassy clinker composed of calcium silicates and aluminates. The clinker is then mixed with a small amount of gypsum, which later helps regulate setting time, and the mass is ground to a fine powder. This powder is portland cement.

The limestone used in producing portland cement must not contain more than 3 per cent magnesia. This is a stringent requirement that eliminates many potential limestone sources. Part of the small amounts of silica, iron oxides, and alumina needed may be present in the limestone as impurities. Additional amounts usually are added by introducing clays or other materials containing these substances. Staurolite from the heavy mineral operations near Starke has been used to some extent in Florida as a source of iron and aluminum.

Factors important in establishing a cement plant include the availability and quality of deposits of limestone and the other raw materials. In addition, a satisfactory source of fuel for the rotary kilns must be considered. Most important, however, is the location of the market area. The plant should be established as close as possible to major population centers to reduce costs of transportation.

At present there are four plants producting cement in Florida. Three are in the Dade County or Miami area and one is in the Hillsborough County or Tampa area. The Tampa plant, with an annual capacity of 6 million barrels of cement, is by far the largest in the state. Nevertheless, a cement shortage exists in the Tampa region and cement is being imported into the area. One of the new sources is Honduras in Central America.

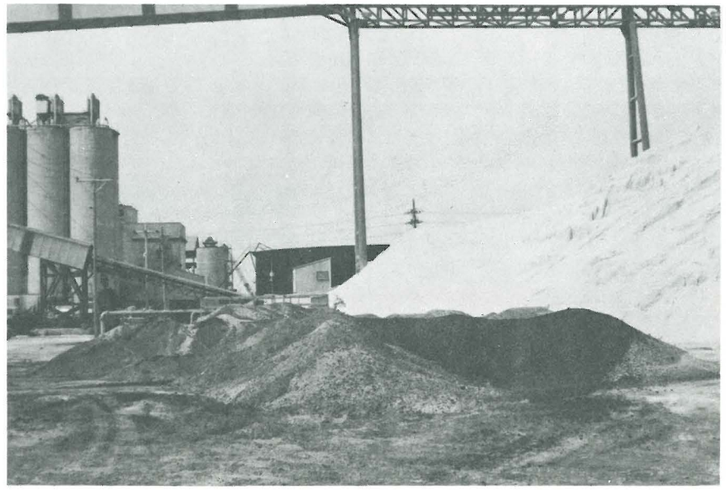
Approximately 87 per cent of the cement produced in Florida during 1970 went to building material dealers, concrete products manufacturers, and ready-mix concrete manufacturers (Minerals Yearbook, 1970). Much of the remainder was used by highway contractors and government agencies.

Limestone for the cement plant in the Tampa area was mined for years at sites in Citrus and Hernando counties. Now limestone sediment (aragonite) is being dredged near Bimini in the Bahamas and shipped to the Tampa plant. The clay needed to furnish small amounts of iron oxides and alumina is mined in Citrus County. Soon, however, clay for the Tampa operation will be mined from a new pit to be opened in Hernando County.

The quantity of raw materials consumed in the production of cement at the Tampa site is enormous. Dust from the clinker burning process makes for a significant problem which currently is of a crisis nature at the Tampa plant. A new cement plant is in the planning stage for Manatee County just south of Hillsborough County. This will reportedly be a pollution-free plant, but resistance to its construction is already substantial.

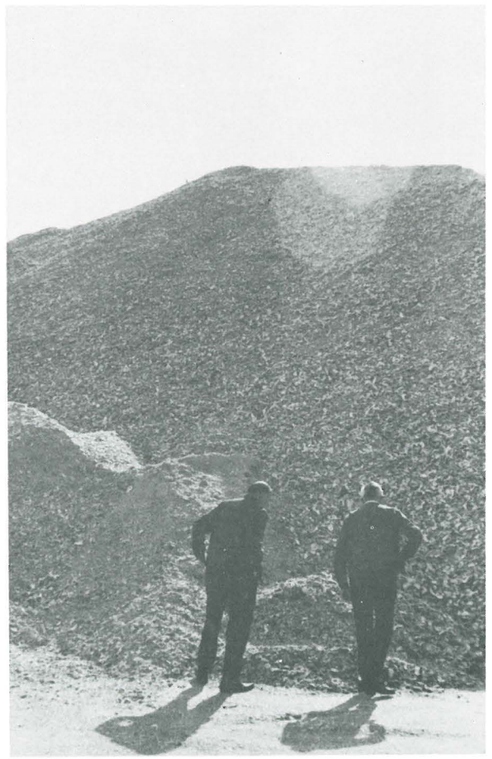
If a population center is to thrive it must have cement and other construction materials, and it must be able to obtain them at a reasonable cost. Raw materials necessary for the production of cement are available to the Tampa region. However, as illustrated by the Tampa plant, cement manufacturing can be plagued by pollution problems. The need for cement, when considered with problems associated with its production, serves as a striking illustration of the need for informed leadership in planning for the economical and popularly acceptable manufacture of a product necessary for a thriving and expanding population center.

Scenes at cement plant in Tampa



Oyster Shells

For years oyster shells have been dredged from Tampa and Hillsborough Bays, with an estimated tonnage of slightly more than one-half million cubic yards now being produced annually. The sites of current dredging operations are shown on Figure 15. Most of the oyster shells are used for road base materials, the city of Tampa being among the largest of the consumers. According to Mr. E. Medard of Bay Dredging and Construction Company (personal communication), the shell layer being mined in the bay ranges in thickness from 2 to 20 feet, approximately, and is overlain by 4 to 15 feet of overburden. The amount of reserves is unknown.



Mountain of oyster shells at Bay Dredging and Construction Co.

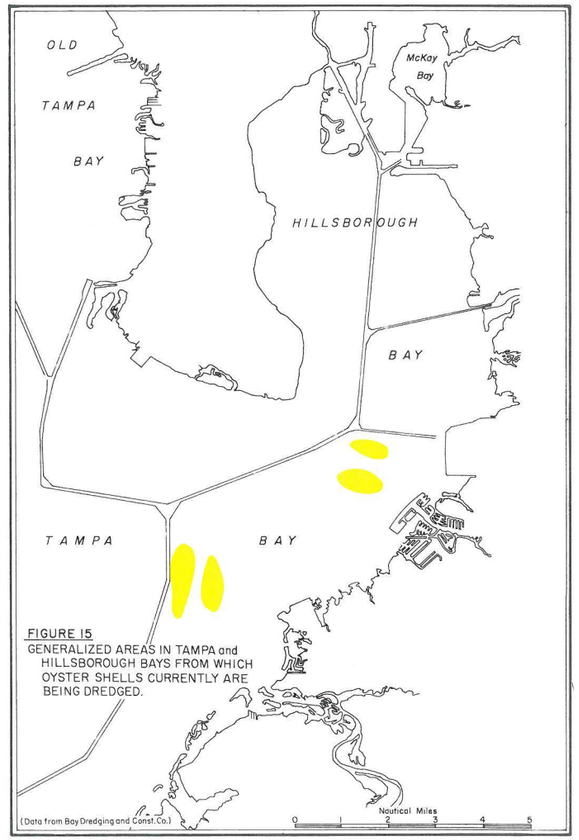


FIGURE 15
GENERALIZED AREAS IN TAMPA and HILLSBOROUGH BAYS FROM WHICH OYSTER SHELLS CURRENTLY ARE BEING DREDGED.

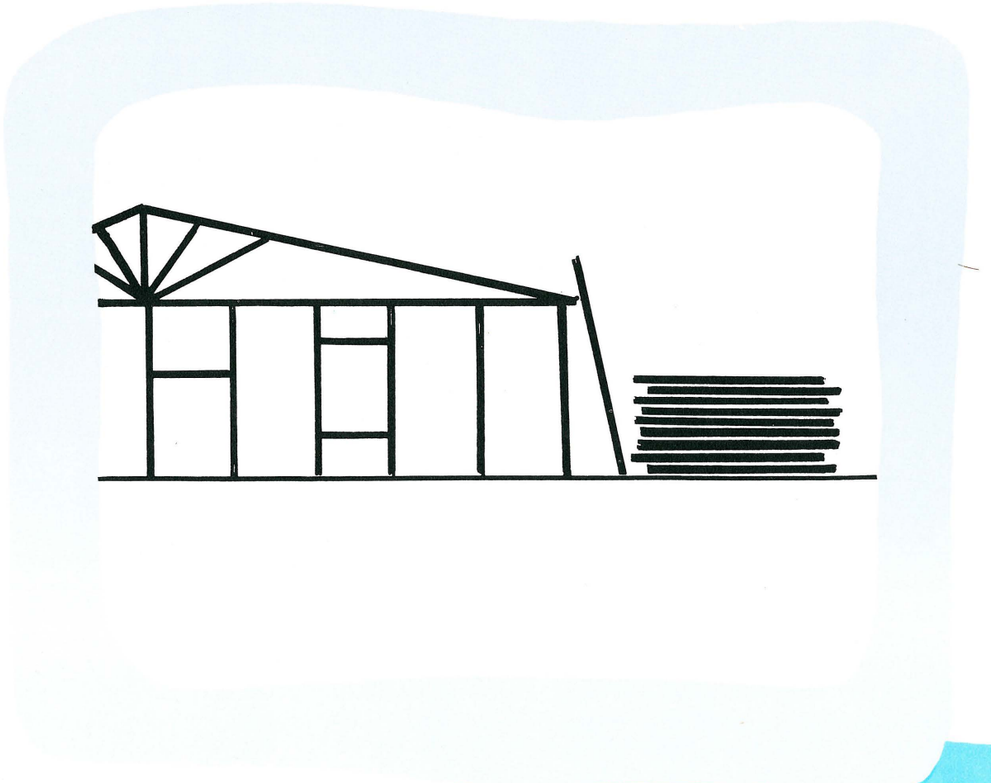
Dredging of these shells in the bay area has been the subject of much concern during recent months. The problems include possible destruction of marine life and biological resources and possible adverse effects on local water quality. Again there is insufficient data to evaluate all aspects of these concerns intelligently and effectively, and clear-cut recommendations or decisions cannot be drawn with comfort and conviction. To illustrate the dilemma, late last year when the Florida Cabinet considered requests for renewal of permits to continue dredging operations for oyster shells in Tampa and Hillsborough Bays, it was faced with different opinions from different individuals, institutions, and state agencies. The consensus was that further study was needed.

Peat

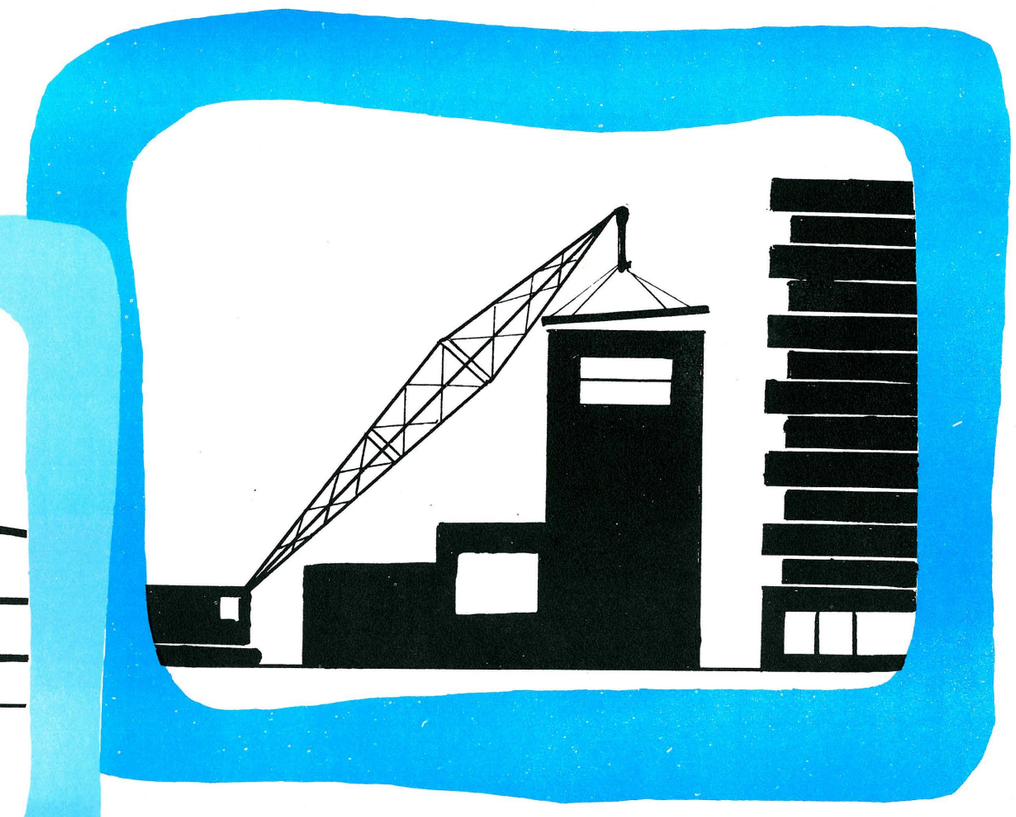
During 1970 peat was produced in Florida from 8 plants in 6 different counties including Hillsborough. Total production from the entire state amounted to approximately 46,000 tons valued at slightly more than 300,000 dollars (Minerals Yearbook, 1970). Most of the peat is used for improving the physical character of soil. The production in Hillsborough County is largely for local needs and comes from sites near Mango. Davis (1946) has made a thorough study of Florida's peat deposits. That work can be consulted for discussions of the various kinds of peat and mucks, their distribution, origins and characteristics.

CONCLUDING REMARKS

This brief discussion of mineral resources of the Tampa area touches upon interesting and crucial environmental and land-use problems. Some of the problems can not be evaded and will become more and more pressing with time. They are both philosophical and practical. It is evident that among the most significant needs for understanding any of the problems are reliable, basic data. These data can not be accumulated in a few days or in a few months; their accumulation takes years. A strong case can be built that one of our most severe deficiencies in preparing for the land-use and environmental problems that face us today has been our lack of support for those studies and for the work of those agencies which supply basic data. Where and when plans and decisions can be based by competent leadership upon reliable data, socially beneficial solutions to these challenging problems will be more easily obtainable.



ENGINEERING GEOLOGY



FOUNDATIONS

Introduction

Engineering geology may be defined as: "The application of the geological sciences to engineering practice for the purpose of assuring that the geologic factors affecting the location, design, construction, operation, and maintenance of engineering works are recognized and adequately provided for"[1]. As such, engineering geology is concerned with the physical characteristics of earth materials and deals with quantitative data obtained from testing the suitability of those materials for specific uses or roles.

In the Tampa area, construction planning perhaps most frequently demonstrates the simultaneous use of engineering and geological concepts. Likewise, soils studies incorporate engineering and geological principles. This phase of the report will deal with the use of engineering geology techniques applied to construction planning and the study of soils.

In planning the construction of any building, of primary consideration is the character of the earth materials upon which the building will rest. Various physical properties of these materials determine how much weight they can bear and, in turn, how a given building must be supported.

Three factors are involved in the selection of an appropriate foundation design:

1. The nature and competency (strength and compressibility) of the subsurface materials.

   Incompentent (weak and/or compressible) subsurface materials may necessitate special site preparation prior to construction and/or a complex foundation system.

2. The size and type of building.

   The size of the building is important in that small, light buildings such as residences obviously require less support than heavy multi-story structures; and likewise low-rise structures, such as shopping malls, generally require less support than heavy high-rise buildings. The type of building construction, such as steel, concrete, masonry or wood, determines the building's adaptability and tolerance to settlement and its effects.

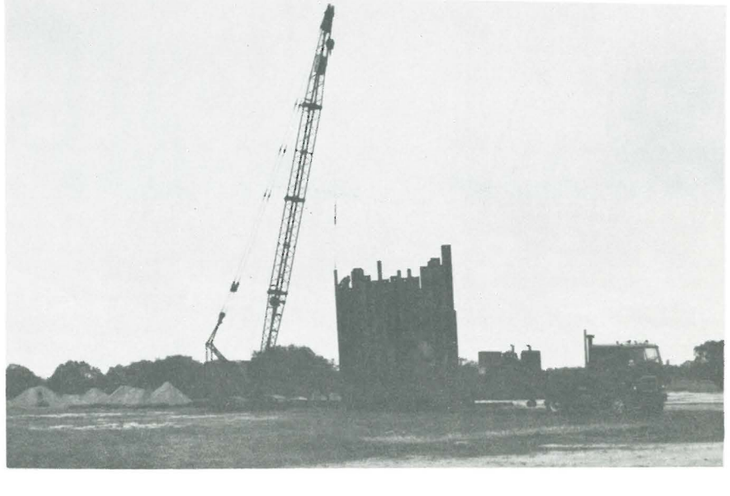
3. Economics.

   The cost of constructing a feasible foundation system should be in balanced proportion to the cost or value of the structure itself.

All three factors must be weighed in determining the suitability of a site for construction. It may also be pointed out that the same three factors listed above also determine the scope and extent of the subsurface investigation and study which is required for a building site.

The thickness and character of surficial soil deposits and the depth to rock often are of prime importance in the selection of a building site and development of construction plans. Probably the most accurate statement that can be made about the surficial soil deposits and the depth to the rock surface in the Tampa area is that they are characterized by their inconsistency. The thickness and extent of the cohesionless and cohesive soils—that is, the sands and clays—can vary greatly, even among the borings made at one site. In addition, soils intermediate in nature between the noncohesive sands and the cohesive clays, such as sandy clays and clayey sands are quite common. In some instances, sands grade slowly downward into clayey sands and then sandy clays and then relatively pure clays. In other instances, clayey lenses are found within the sands; and sand lenses within the clays. Consequently, accurate mapping of the thickness of the cohesive and non-cohesive soils in the Tampa area is very difficult.

In addition to the areal extent and thickness of the cohesionless sands and cohesive clayey soils; the strength and compressibility of these soils is a vital parameter. Standard penetration tests provide some indication of both the relative strength and relative compressibility of soil deposits. The specific procedures for performing this test and obtaining soils samples is comprehensively presented in American Society for Testing and Materials specification D 1586. In general, this procedure involves driving a 2 inch split spoon sampler 18 inches into the soil by means of the energy imparted by a 140 pound drop hammer falling 30 inches. The number of blows required to drive the sampler the last foot into the soil is the standard penetration resistance, commonly called the 'blow count'. Other supplemental investigative procedures, such as the auger borings or cone penetrometer borings are sometimes used to obtain additional information regarding the nature of the surficial soil deposits; but the standard penetration test is the most widely used method of determining and evaluating the nature of the subsurface conditions. However, it should be noted that the data obtained from this procedure is rather limited and more qualitative than quantitative in nature. More specific and quantitative information regarding shear strength and compressibility of soils is generally obtained by laboratory testing of undisturbed soil samples. Sometimes field load tests are necessitated because of the nature and geology of the soil deposits.



Subsurface conditions which limit the suitability of a site for construction can generally be overcome by the use of certain site preparation techniques or special foundation design, or both. Before subsurface problems and their solutions can be discussed, some pertinent terms need defining:

Shallow Foundation Systems

This type of foundation bears at a very shallow depth and imparts the foundation loads to the shallow subsoils. There are a number of types of shallow foundations, all of which are used to spread the superimposed loads over a sufficient area so that the safe bearing capacity of the foundation soils are not exceeded. The type that is best suited for a particular site depends upon the subsurface conditions. The following are the three major types of shallow foundation systems listed in the order of least costly to most costly.

Individual or Continuous Foundations—Individual spread footings are utilized to support columns; whereas continuous spread footings are used to support load carrying walls. These are normally the least costly type of foundation systems and are utilized where good subsurface conditions exist.

Strap Foundations—This type of foundation is utilized to support a row of two or more columns. The foundation strap is structurally designed with sufficient stiffness and rigidity to function as a single unit. This type of foundation system is used where somewhat poor subsurface conditions exist and when it is desirable to reduce subsurface stresses and minimize potential settlement between columns.

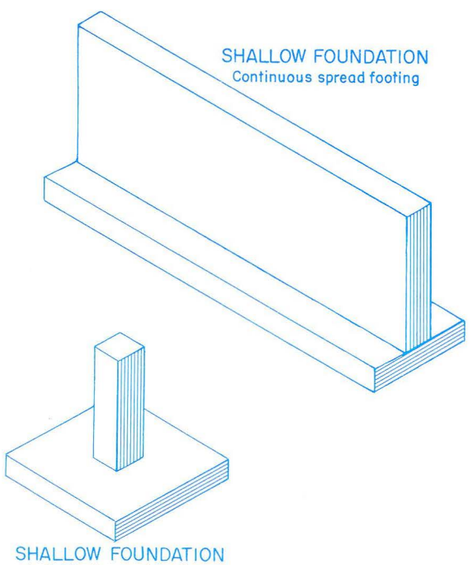
Mat Foundations—A mat or raft foundation, commonly called the floating foundation, encompasses the entire base of the structure and spreads the building load over the entire building area. The main functions of such a foundation system are to reduce subsurface stresses in compressible soils, bridge weak zones or possible subsurface cavities, and reduce total and differential settlement. This is generally the most costly of the various types of shallow foundation systems.

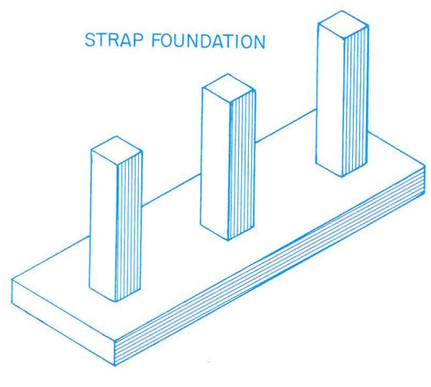
Deep Foundation Systems

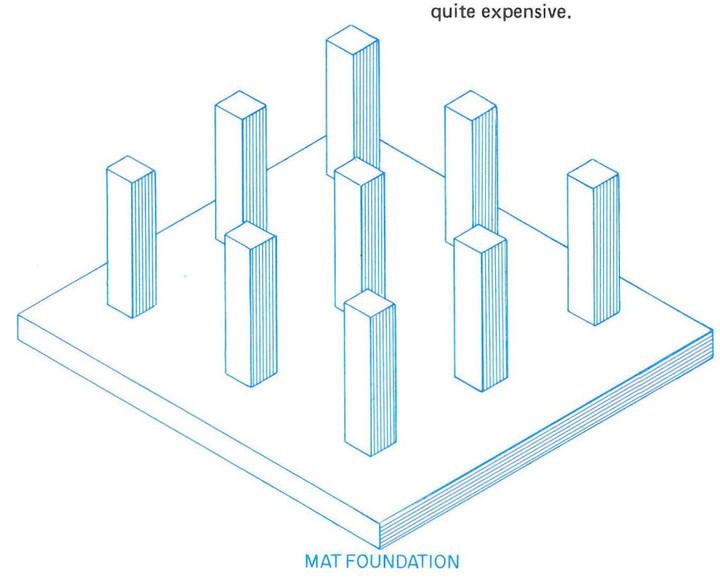
Piles or caissons are the most common type of deep foundations. Their purpose is to transfer a load which cannot be supported at a shallow depth to a greater depth where adequate support is available. Caissons are rarely used in the Tampa area because of installation difficulties imposed by the general geology of the area; whereas timber, steel and/or concrete piling are commonly used. Because of the variable and unreliable nature of the clayey subsoils, the piling are usually end-bearing on the limestone bedrock. The cost of piling can vary widely, depending upon their length and capacity.

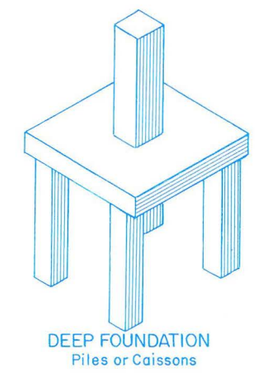
Subsurface Grouting

This generally refers to the pumping of sand-cement mixtures or chemical grouts into weak porous permeable zones and/or underground cavities or networks of cavities in order to strengthen and stabilize the subsurface strata. This procedure, although not commonly used, is frequently necessitated in certain areas within the Tampa area because of the geological conditions. The cost of this type of site preparation work is extremely variable and can be quite expensive.









SANDS

Foundation problems common to the Tampa area can be dealt with in a variety of ways depending on the severity of the problem and the nature of the structure. Four fundamentally undesirable site conditions include: loose sands, compressible clay, organic materials, and sinkholes.

LOOSE SANDS

Structures built on loose sands may settle and crack if the sands densify or compress. Densification can result from the imposed load, changes in ground water levels, or from vibration of the ground due to traffic, sonic booms, machinery, etc.

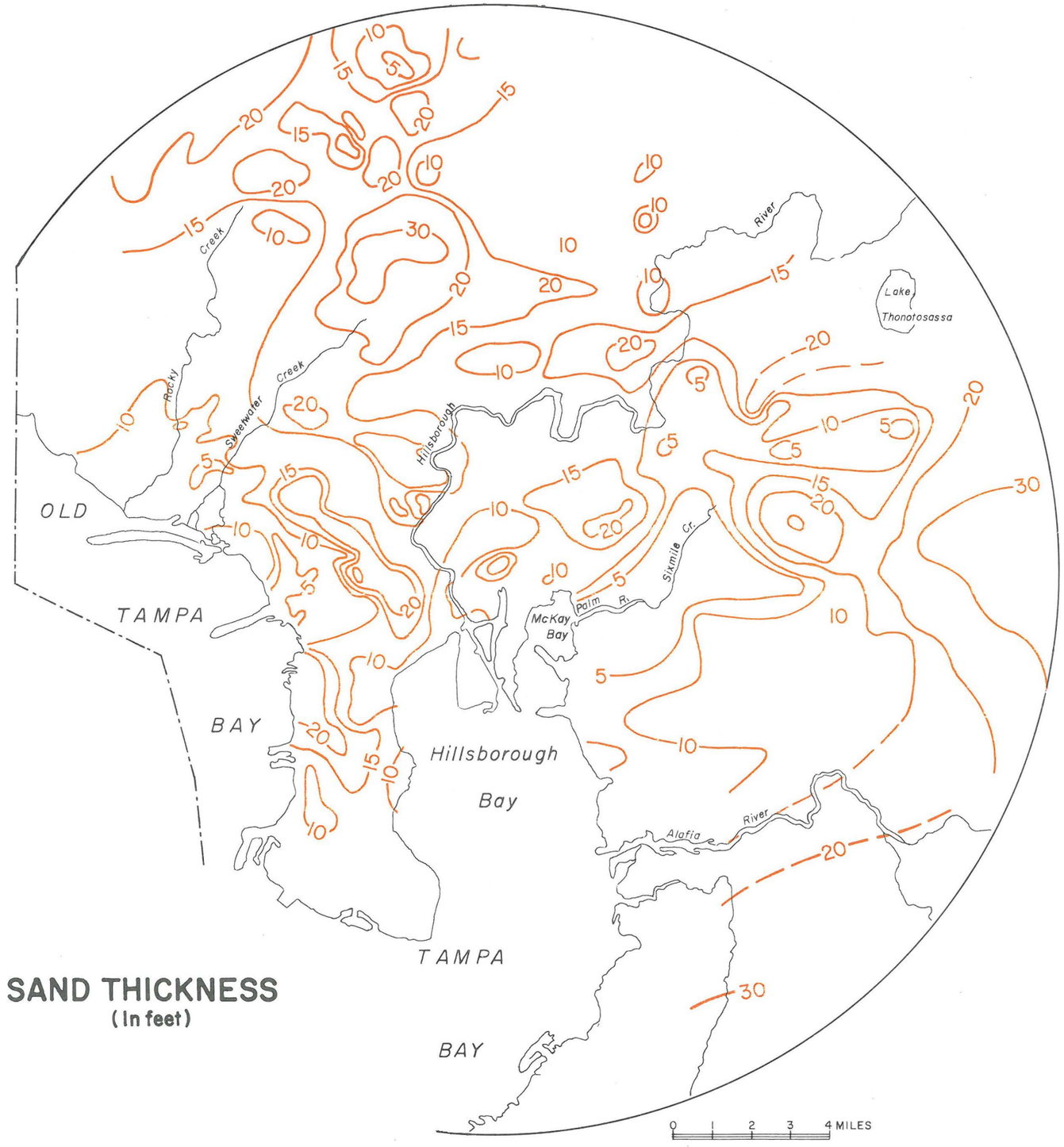
In order to prevent settlement, three alternatives are possible: 1) loose sands can be removed and replaced, 2) pilings can be utilized for support, or 3) the sands can be densified.

Even for high rise buildings, excavation of loose sands for foundations rarely exceeds depths of ten feet. With deeper excavations, costs are higher, and the water table becomes a problem. If the entire ground floor area of a building must be excavated, every foot of material removed results in a significant increase in cost. Following removal of loose sands, the site is back filled and properly compacted.

In-place densification of loose sand is usually the least expensive means of adequately preparing the site for buildings. The older method of densifying loose cohesionless soils was to excavate it, replace it in thin layers and compact it. However, modern compaction equipment and techniques now make possible the densification or appreciable thicknesses of sand without excavation. If surface deposits of loose cohesionless soils are only moderately thick, the use of large heavy vibratory compaction equipment usually will adequately densify the soils; whereas if the loose sands are either very thick or buried, a process called "Vibroflotation"[1] can be utilized. This latter system utilizes water and vibration to compact the sand. All methods of in-place densification are reasonable in cost.

In the Tampa area, pure quartz sands and sands with minor amounts of silt, clay, and organic material generally range from a few inches to more than 30 feet thick. The sands tend to thin toward the Bay. The meandering contour lines on the map partially reflect the effects of stream channel development and the erosion of sands by streams. The reaches of the river channels exhibit thinner sand than adjacent areas.

[1] Trademark



SAND THICKNESS
(In feet)

SAND SUITABILITY AS A FOUNDATION MATERIAL

The map presented here incorporates both thickness and compressibility of the relatively pure surface sands and outlines the areas or problem sands and satisfactory sands. It must be borne in mind that the map has been compiled from data currently available and is thus generalized. Close spacing of "good" and "poor" sands bears witness to the local variability of sand characteristics.

It can be seen from the map that thick loose sands are especially prevalent in the Temple Terrace-University of South Florida area and around Brandon. Firm sands are fairly well scattered but appear to be concentrated in the downtown and interbay areas.

With regard to site suitability for construction, this map illustrates one of the many aspects which must be considered, and it will be utilized as an overlay in the Land Use section of the report.

Good: Firm sands five feet or greater in thickness have been encountered in these areas. These sands are capable of supporting many types of structures with no pre-construction site preparation.

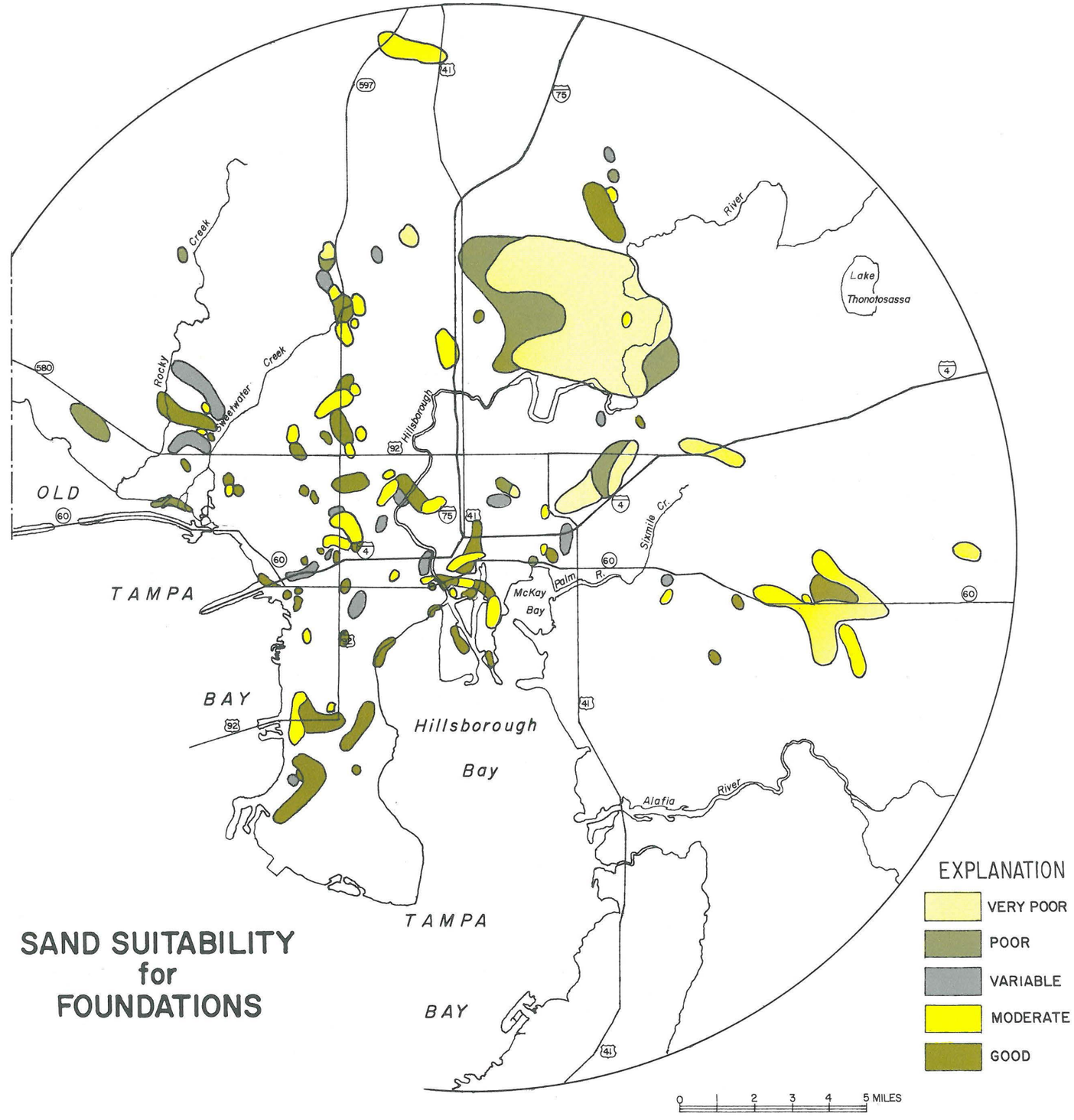
Variable: These areas have been found to contain varying thicknesses of sand that exhibits eradic compressibility. Because of their unpredictable nature pre-construction treatment for the sands may be required.

Moderate: This includes areas in which sands are predominantly firm but contain compressible lenses and areas in which less than five feet of loose sand lies at the surface and is underlain by more than five feet of firm sand. Depending upon the type of construction proposed, very little treatment may be necessary to render these sands suitable to provide adequate foundation support.

Poor: Included are areas in which sands are 10 feet or greater in thickness and are predominantly loose, but contain lenses of firm sand. Also, included are totally loose sands five to ten feet thick. These two conditions have been grouped as "poor" because some preconstruction site preparation would probably be required but may not be as extensive as in the areas labeled "very poor".

Very Poor: This includes areas in which loose sands ten feet or greater in thickness have been encountered, areas in which firm sands less than five feet thick are underlain by loose sand greater than five feet thick, and areas in which sands containing organic deposits have been found. All of these conditions would likely necessitate treatment prior to construction.

It should be noted that sands less than five feet thick have been omitted from consideration in this map. When very thin sands are encountered, the material underlying them is generally of equal or greater importance in foundation planning. These areas will be brought to light in the discussion of clays.



CLAYS

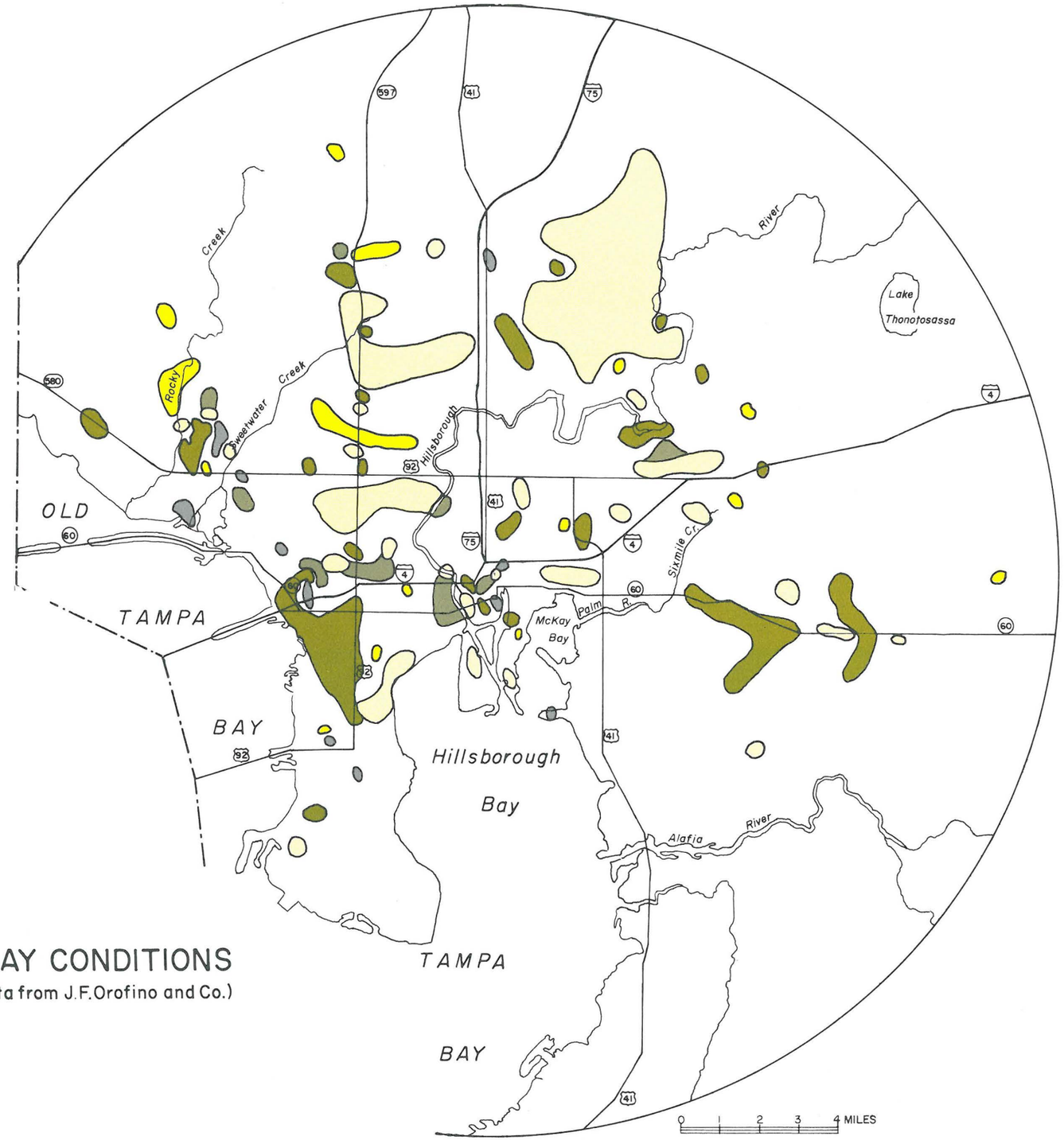
The presence of clays at or near the surface presents a problem to many types of construction. This is due to the low shear strength of many clays as well as their compressibility. To compound the problem, compressibility and shear strength of the clays in the Tampa area are very variable and inconsistent. Furthermore, clays or cohesive soils cannot normally be mechanically improved.

One method of treatment is to remove the weak, compressible, cohesive soils and replace them with properly compacted competent materials. Unfortunately, this is only feasible when they lie at or near the surface; which in the Tampa area they rarely do. Where they are deeply buried, the soils overlying them may be sufficiently thick and competent to adequately support a structure. However, when the weak clays are shallow, they generally necessitate some special attention in foundation design. If the underlying limestone is also shallow, piling can be used to transfer the foundation loads through the weaker compressible clays to bedrock. However, since piling is an expensive means of supporting small structures, shallow weak clays can be a bigger stumbling block to small construction projects than to large ones.

The map on this page shows the areas in which firm clays have been found underlying surface sands, and areas in which soft clays or clays containing soft lenses have been encountered beneath the sands. In addition, areas are shown in which clay occurs only as thin lenses within the sand or mixed with sand as a minor constituent. Like the map illustrating sand conditions this map is generalized on the basis of the network of known values. The thickness and compressibility of clay and cohesive soils varies as much as if not more than the sands. It is virtually impossible to predict the conditions that will occur at a specific site without performing a subsurface investigation at the site.

On the map, soft clays have been shown according to thickness ranges (less than five feet, five feet to ten feet, and greater than ten feet). If the soft clays are of significance to a particular construction project, then the greater their thickness, the more of a problem they become. No attempt has been made however, to categorize the clays according to the severity of the problem they may cause. Whether or not the clays will be a problem at all, largely depends on their depth and thickness, and thickness and competency of the overlying soils, the magnitude of the building loads to be imparted and the structure tolerance to settlement.

This map will be used in the Land Use section in combination with other maps to indicate land suitability for construction.



CLAY CONDITIONS

(Data from J.F.Orofino and Co.)

CLAY CONDITIONS

Areas in which soft clays greater than ten feet thick are found to occur. This includes soft clays with interspersed lenses, clays containing peat layers and karst areas with greater than ten feet of clay.

Areas in which five to ten feet of soft clay have been encountered.

Areas in which soft clays less than five feet thick occur.

Areas in which clays occur only as thin lenses within the sand, or as a minor faction mixed with sands.

Areas in which firm clays containing no soft lenses occur. These clays are of varying thickness.

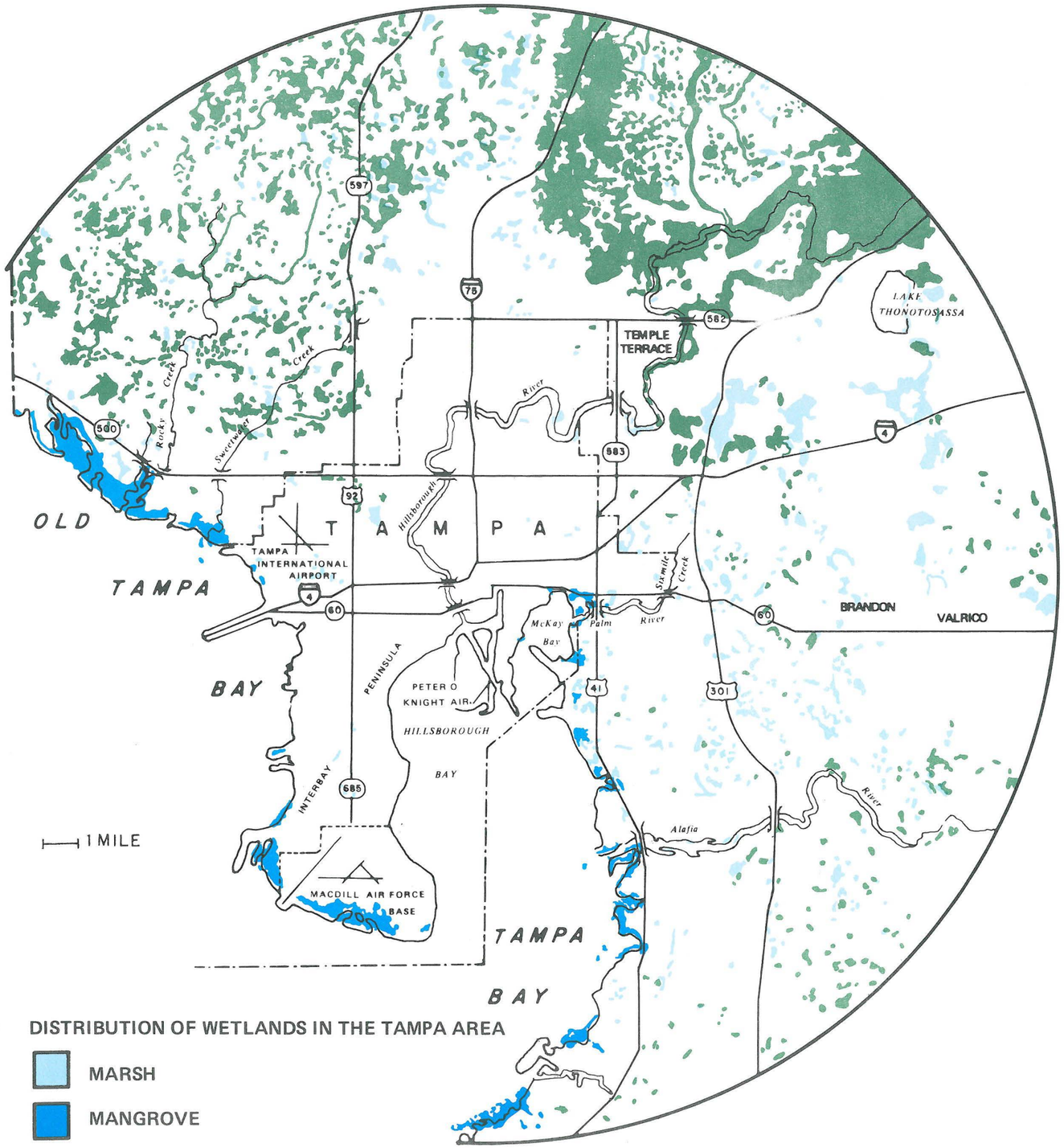
ORGANICS

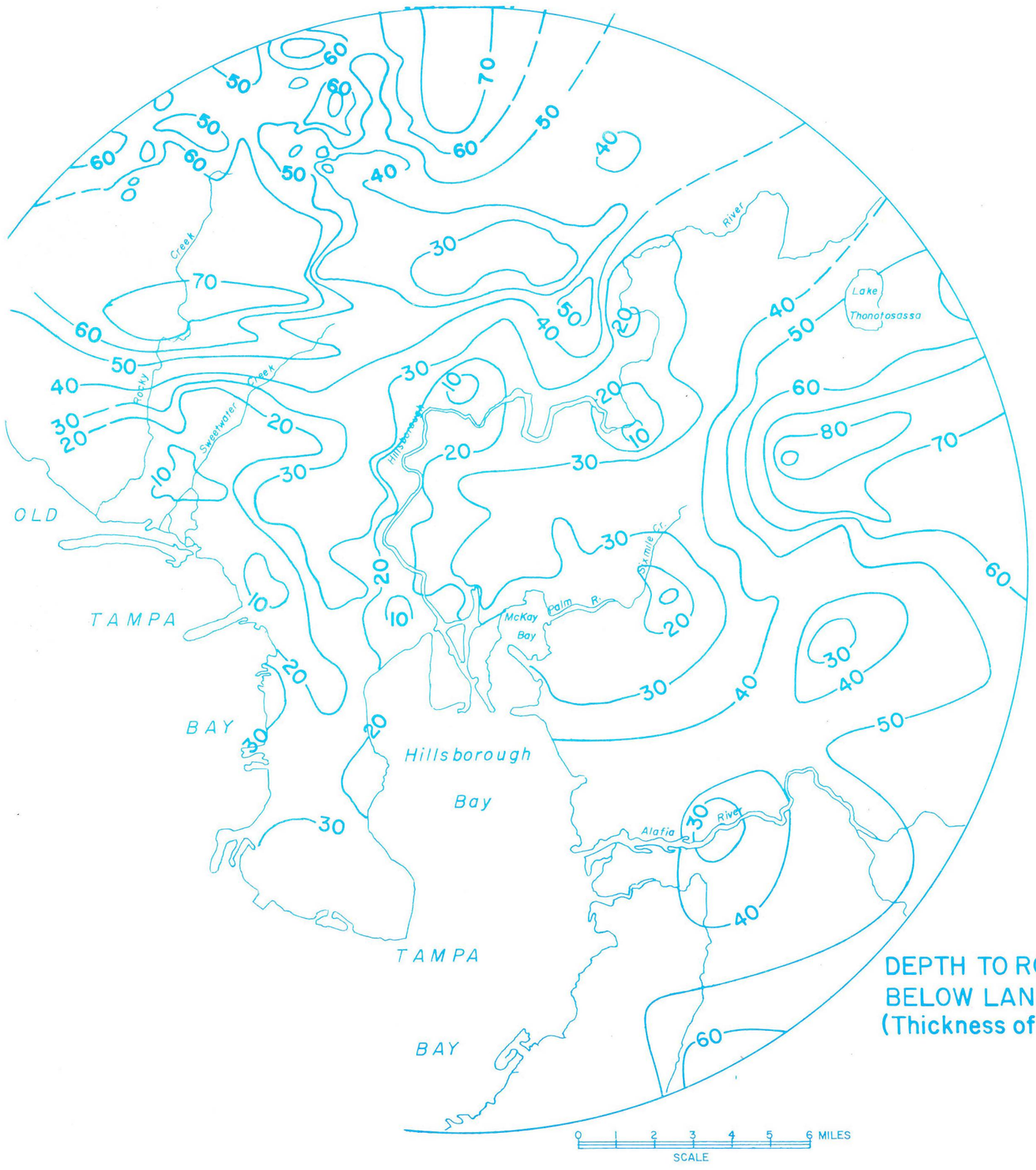
ORGANIC MATERIALS

Deposits of organic soils, including peat and muck are undesirable for almost all construction. Like clays, they cannot be mechanically improved and in most cases, must be removed and replaced with suitable fill.

Since areas where organic deposits occur are generally swampy or lowlying, such sites have other disadvantages imposed by the high ground water table. Many swampy areas, however, have been excavated, filled and compacted to provide acceptable building sites.

The map shows areas which are designated as marshes or swamps on the topographic maps of the Tampa area. In many instances, these swamps were filled after the topographic maps were compiled but all of the areas designated on the map can be expected to contain organic deposits. While these areas need not be eliminated from consideration as potential building sites, it should be realized that their surficial deposits may limit land use or impose additional expense for pre-construction site preparation.





DEPTH TO ROCK (in feet)
BELOW LAND SURFACE
(Thickness of overburden)

POTENTIAL COLLAPSE

Areas underlain by cavernous limestones present special foundation problems especially for heavier buildings. Stronger foundations for high rise structures are a necessity in such areas and inexpensive spread foundations are usually not adequate. If the problem is not severe, strap foundation (which is the next least expensive) may be adequate, but in many cases more costly mat foundations must be used. A pile foundation is not generally a satisfactory alternative; since when sinks develop, slumping of sediments creates lateral pressure which may cause standard piling to fail.

Other steps which may be taken in order to minimize the potential risk of loss of foundation support include proper site drainage and design of the structure to minimize the net increase in stress on the subsurface deposits. Stress increases can be minimized by placing a basement beneath a structure and in this way the total weight of the building may not be substantially greater than the weight of the soils excavated for the basement.

A last resort in dealing with the problem of collapse is subsurface grouting. However, this is very expensive and the amount of grouting required is unpredictable. When grouting is undertaken, the final cost and success of the effort is unknown.

An alternative action, though not necessarily a solution to the problem is to move the location of the building to a different position on the site where cavities in the limestone have not been encountered in the subsurface investigation.

It is difficult to assess the risk involved in constructing in an area of potential collapse. Although imminent risk of collapse can be minimized by site treatment and careful foundation design, there is still a potential risk of loss of foundation support due to cavities which may not have been revealed by the subsurface investigation.

"The final decision as to the type of foundation system to utilize will be dependent upon the owner's willingness to incur certain costs and assume certain risks. These must be balanced against one another in view of the type structure, intended use and consequence of problems which might develop if the risk becomes a reality."[1]

Areas in which collapses have occurred in the past are shown on a map in the Geology section of the report with the discussion of sinkholes.

DEPTH TO ROCK

A map showing the position of the rock surface relative to mean sea level is presented in the Geology section. Whereas that map is prerequisite to understanding subsurface relationships, the matter of concern in construction planning is the depth to rock measured from land surface as illustrated on this page. The contour lines reflect not only variations in the bedrock surface, but also variations in local topography. This map can also be considered a map of the thickness of surficial deposits and is a useful tool in construction planning. When the surficial deposits are incompetent as a support material, it is vital to know how deeply buried the rock surface is so that a decision can be made as to whether it would be more economical to improve the surficial deposits or to utilize piling for support.

This map is an important component of land suitability for construction as presented in the Land Use section of the report.

[1] James F. Orofino, Orofino and Company, (Personal Communication).

SOILS

Soils are an integral aspect of both geology and land use planning. The mantle of sand deposited in Hillsborough County during Pleistocene time is the parent material for many of the soils which developed in the area. Drainage, climate, vegetation, and topography have also played roles in the formation of local soil types.

The Soil Conservation Service (S.C.S.) has identified and mapped the soils of Hillsborough County on the basis of their characteristics as determined in the field and lab. These include color, texture, structure, consistence, depth of soil over bedrock or compact layers, steepness of slope, degree of erosion, nature of underlying parent material, acidity or alkalinity of the soil, etc. The soil layer studied and described by the S.C.S. ranges from 40 inches to 72 inches thick.

On the basis of observed analytically determined characteristics, soils are classified into phases, types and series. "The soil type is the basic classification unit. A soil type may consist of several phases. Types that resemble each other in most of their characteristics are grouped into soil series."[1]

Detailed maps of soil phases in the Tampa area are presented in the Hillsborough County Soil Survey. In addition, a County map showing soil associations is included and a revised map is presented in the Supplement to the Soil Survey. Part of this map is reproduced here and the major characteristics of each association are given.

Soils that occur together in a regular pattern in the landscape have been grouped into soil associations. The individual soils within each association may or may not have similar properties and interpretations.

POMELLO-ST. LUCIE ASSOCIATION: Areas dominated by nearly level to gently sloping, nearly white, excessively to somewhat poorly drained, strongly acid, deep sands. The native vegetation consists of scrub oak, slash pine, saw palmetto and sand pine. Soils in this association are low in organic matter and fertility and are very droughty, hence they are poorly suited to cultivated crops and citrus.

LAKELAND-ARREDONDO ASSOCIATION: Areas dominated by nearly level to gently sloping, well to somewhat excessively drained, slightly to very strongly acid, deep, brownish colored phosphatic and non phosphatic sands. The native vegetation consists primarily of turkey oak, pine, shrubs, grasses, and a few palmettos. The soils in this association are low in organic matter content and fertility and have a low available water capacity.

BLANTON-LEON ASSOCIATION: Areas dominated by nearly level to gently sloping, moderately well drained, deep sands. Native vegetation includes pine, oaks, grasses and palmettos. The soils have low organic matter content, low natural fertility, and low available water capacity.

LEON-PLUMMER ASSOCIATION: Areas dominated by nearly level, very strongly acid, deep, somewhat poorly drained sands with an organic stained subsurface layer. The native vegetation includes slash pine, saw palmetto, runner oak, gallberry, woody shrubs, and various grasses. The soils are low in organic matter content, natural fertility and available water capacity.

ONA-SCRANTON-LEON ASSOCIATION: Areas dominated by nearly level to gently sloping, somewhat poorly drained, strongly acid, deep sands on broad, low flatland. The natural vegetation consists of pine, turkey oak, live oak, saw palmetto, woody shrubs, and grasses. Most soils in this association have moderately high to high organic matter content, and are moderately low in natural fertility.

RUSKIN-SUNNILAND-BRADENTON ASSOCIATION: Areas dominated by nearly level, somewhat poorly drained, sandy soil with loamy to clayey subsoils. The native vegetation is pine, cabbage palmetto trees, saw palmetto, runner oak, woody shrubs, and grasses. The soils have low organic matter content, and low to moderate natural fertility and available water capacity.

RUTLEDGE-FRESH WATER SWAMP-PLUMMER ASSOCIATION: Areas dominated by nearly level, very poorly drained, deep, strongly acid to medium acid sands in low wetland. Native vegetation is mainly water-tolerant grasses and sedges, pickerelweed and St. Johnswort, with cypress, bay, gum and occasional pine trees in swampy areas. Soils have low to high organic matter content and low fertility. Wetness is an outstanding limitation for many uses of these soils.

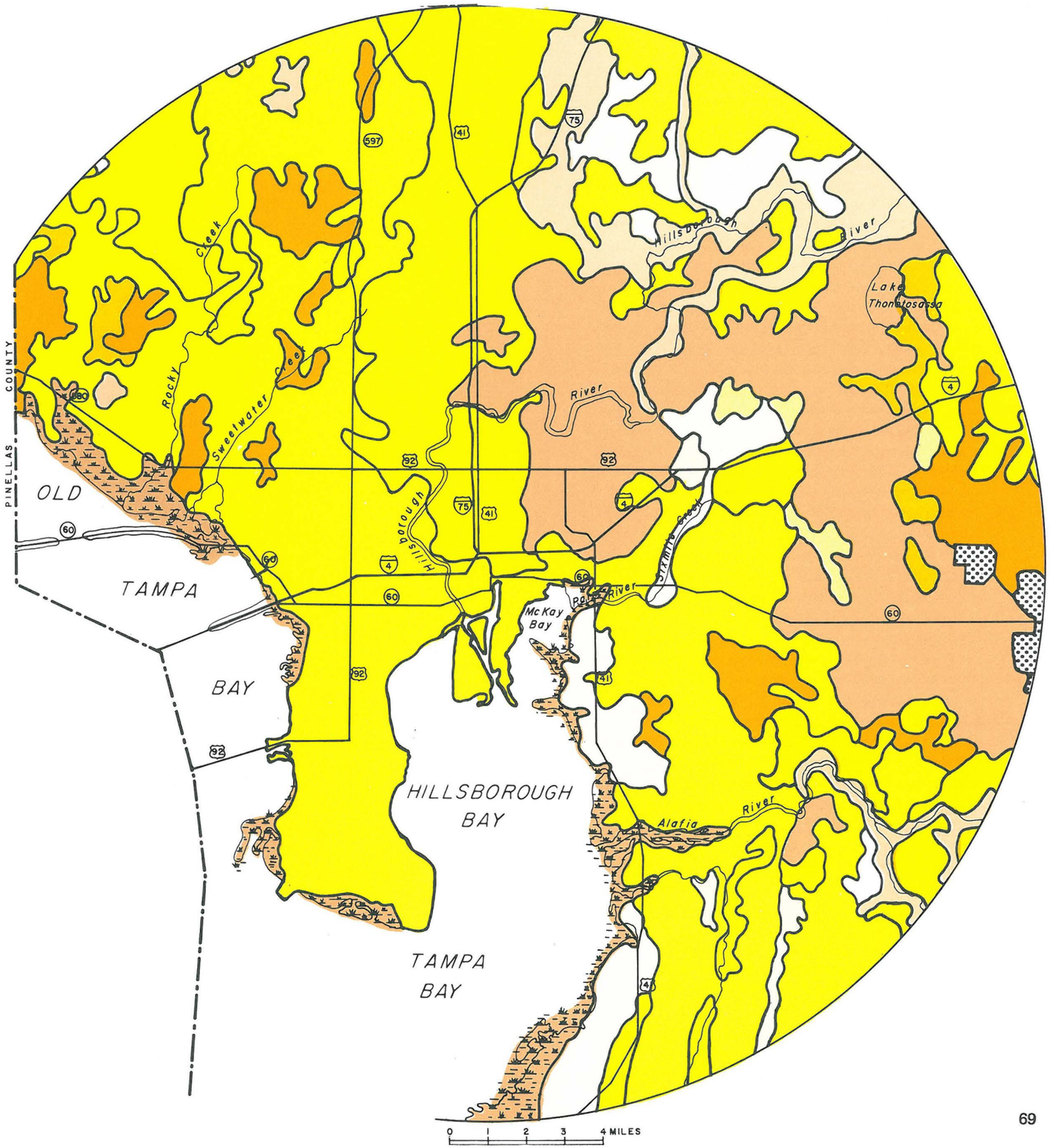
BRIGHTON-TERRA CEIA ASSOCIATION: Areas dominated by nearly level, very poorly drained, shallow to moderately deep, acid to neutral organic soils in marshes and swamps. Native vegetation consists of sawgrass and various other sedges and grasses. Organic soils in this association are high in nitrogen but low in all other plant nutrients. Excessive wetness is characteristic.

FRESH WATER SWAMP: Areas dominated by nearly level, very poorly drained mineral and organic soils in stream bottoms and swamps. Native vegetation consists of hardwoods, cypress, bay, cabbage, palmetto, pines, shrubs, vines, ferns, and grasses.

SALT WATER SWAMPS AND MARSHES: Areas dominated by nearly level, very poorly drained, saline soils lying adjacent to and affected by salt water tidal action. Native vegetation includes salt-tolerant grasses and mangrove trees.

MINE PITS AND DUMPS: Areas dominated by large open pebble phosphate mines and adjacent spoil mounds.

[1] Soil survey, Hillsborough County, Florida, 1958, p. 58.



SOIL RELATIONSHIPS in URBAN PLANNING

Soil data can be utilized in a variety of projects which are of concern to local and regional planners. In addition, the S.C.S. can provide technical assistance on water management, soil erosion and stabilization, agronomy, biology, etc.

"One of the most talked about concepts in recent years is the idea of spreading the effluent from municipal sewage treatment plants on the land to eliminate the discharge of the effluent into surface waters in the state."[1] Soil properties and plant relationships play a vital role in land renovation of waste water. The cation exchange capacity of the soils (especially clayey soils) is a most important soil property. This soil property along with plant nutrient removal and denitrifying bacteria can very effectively remove certain constituents of waste water. "Any design of a system for land spreading of waste materials must consider the soil system and its relation to the local landscape, which includes the stratigraphy, geomorphology, and hydrology of the area under consideration."[2]

The local Soil and Water Conservation District has expended a good deal of effort toward solving drainage problems in the Tampa area. Although much of this effort has involved agricultural lands, the drainage principles have been applied to urban lands as well. For example, shortly after the completion of Tampa Stadium, it was found that the parking area became flooded and unusable after rains. Using the standard soil survey in conjunction with field investigations, the S.C.S., working through the Hillsborough Soil and Water Conservation District, designed a subsurface drainage system for the parking areas, and the flooding problem was eliminated.

Soils data can and should be used along with geologic and hydrologic data as an input source for environmental planning.

[1] Livingston, J. B., *Land Renovation of Waste Water,* p. 1 from: Workshop Proceedings-Use and Interpretations of Soil Surveys and Engineering Principles of Water Management, 1972, Soil Conservation Service.

[2] Daniels, R. B., *Water Movement in Soils,* p. 7, from Workshop Proceedings—Use and Interpretations of Soil Surveys and Engineering Principles of Water Management, 1972, Soil Conservation Service.

Shallow excavation showing a soil profile.

Soil Conservation Service control structure in northwest Hillsborough County.

Tampa Stadium parking area after installation of the subsurface drainage system.

Many land uses are essentially "surface" uses and consequently, soil characteristics are the most important geohydrologic consideration in planning. The land use most vitally linked with soils is agriculture or agronomy. Land areas in which the soils are particularly productive warrant consideration for designation as agricultural lands. The S.C.S. has compiled detailed information on the productivity of various soils with regard to assorted crops.

Other land uses in which surficial materials (soils) are of primary concern include recreational areas, highway and airport sites, cemeteries, golf courses, single story buildings, etc.

Shown on this page is Table 5 from the *Supplement to the Soil Survey: Hillsborough County,* Florida. This lists the degree of limitations, restrictions and hazards for various land uses by soil associations.

Two factors should be borne in mind when this table is examined:

1) This generalized table is derived from more detailed S.C.S. tables and maps. Final evaluation of a specific site for a proposed use must be supported by detailed on-site investigations.

2) The limitations listed in the table are based on the characteristics of only the top 40-72 inches of material.

The Rating System

None to slight: Soils have properties favorable for a particular use. Limitations are so minor that they can be overcome easily. Good performance and low maintenance can be expected from these soils.

Moderate: Soils have properties moderately favorable for a particular use. Limitations can be overcome or modified with planning, design, or special maintenance.

Severe: Soils have one or more properties unfavorable for a particular use. Limitations are difficult and costly to modify or overcome, requiring major soil reclamation, special design, or intense maintenance.

Very severe: Soils have one or more properties so unfavorable for a particular use that overcoming their limitations is very difficult and costly. Reclamation is extreme, requiring the soil material to be removed, replaced or completely modified.

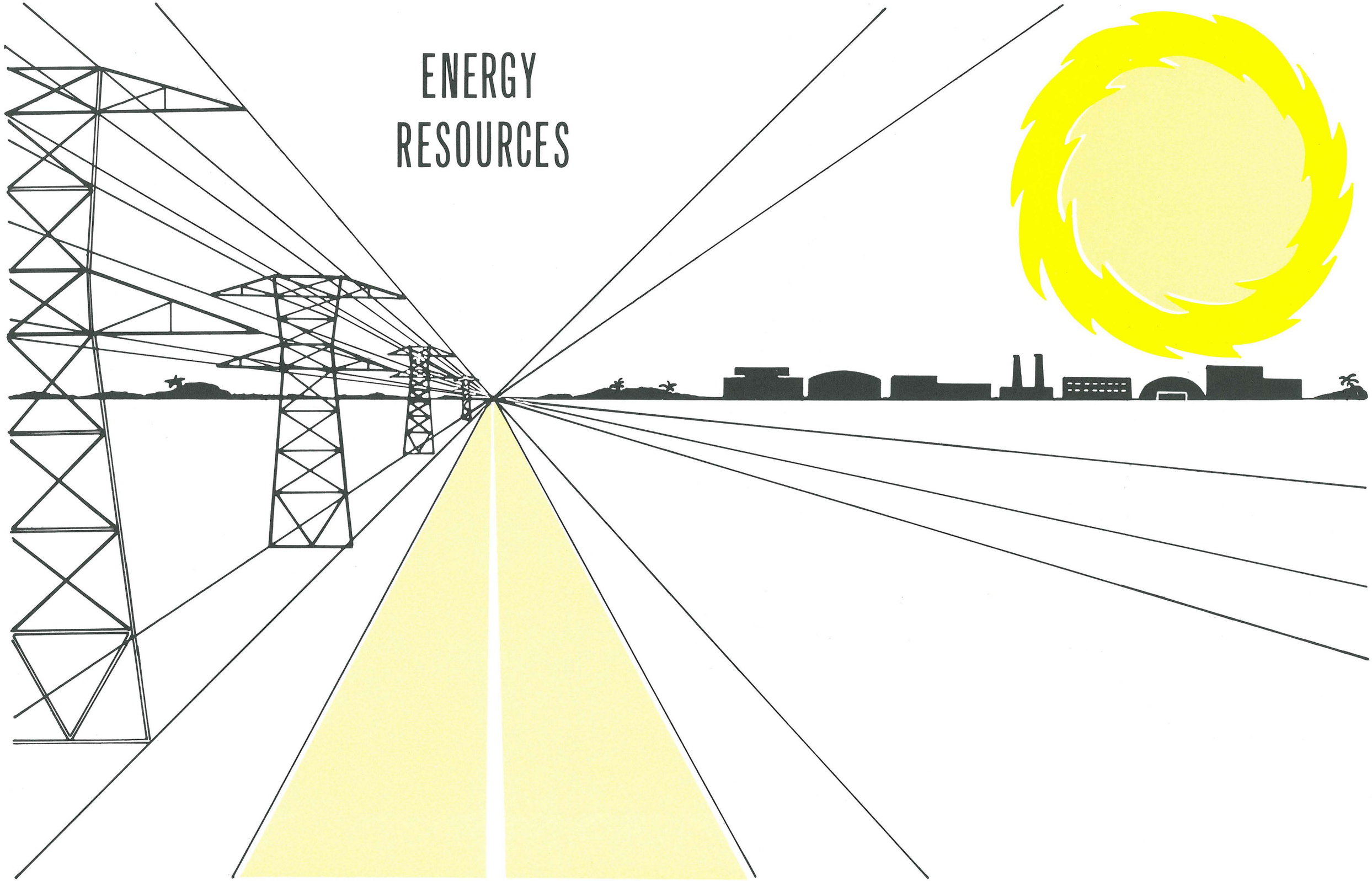
The rating provided for each association is for the predominant soil in the association. Other soils in the association may have different ratings. These ratings are actually measures of "degree" or "intensity" of soil limitations, restrictions, or hazards for a certain use. Most soils are suitable for all uses if provisions can be made to overcome or eliminate the problems.

DEGREES OF LIMITATIONS, RESTRICTIONS AND HAZARDS FOR SELECTED USES BY SOIL ASSOCIATIONS, HILLSBOROUGH COUNTY, FLORIDA (MODIFIED FROM SOIL CONSERVATION SERVICE, 1969, TABLE 5)

NAME OF ASSOCIATION WITH COMPONENT SOILS AND PERCENT OF EACH	FOUNDATIONS FOR LOW BUILDINGS	HIGHWAYS, AIRPORTS, STREETS, PAVED ROADS AND PAVED PARKING AREAS	DIRT ROADS UNPAVED STREETS AND PARKING AREAS	CAMP SITES, PICNIC AREAS AND PLAYGROUNDS	GOLF COURSES	FALLOUT SHELTERS AND BASEMENTS	CEMETERIES
POMELLO–ST. LUCIE POMELLO 31 ST. LUCIE 24 OTHERS 45	MODERATE WT	SLIGHT	SEVERE TRAF	SEVERE TRAF, PROD	SEVERE PROD, AWC	MODERATE WT	MODERATE WT, PROD, AWC
LAKELAND-ARREDONDO LAKELAND 41 ARREDONDO 23 OTHERS 36	SLIGHT	SLIGHT	MODERATE TRAF	SEVERE TRAF	MODERATE PROD, AWC	SLIGHT	SLIGHT
BLANTON–LEON BLANTON 24 LEON 23 OTHERS 53	MODERATE WT	MODERATE WT, FL	MODERATE TRAF, WT, FL, SL	MODERATE WT, FL, TRAF, SL	MODERATE WT, AWC	MODERATE WT, FL	MODERATE WT, FL, PROD
LEON–PLUMMER LEON 61 PLUMMER 9 OTHERS 30	SEVERE WT, FL	MODERATE WT, FL	MODERATE TRAF, WT, FL	MODERATE WT, TRAF, FL	MODERATE WT, FL	SEVERE WT, FL	SEVERE WT, FL
ONA–SCRANTON–LEON ONA 30 SCRANTON 21 LEON 16 OTHERS 33	SEVERE WT, FL	SEVERE WT, FL	SEVERE TRAF, WT, FL	MODERATE WT, TRAF	MODERATE WT	SEVERE WT, FL	SEVERE WT, FL
RUSKIN–SUNNILAND–BRADENTON RUSKIN 40 SUNNILAND 30 BRADENTON 15 OTHERS 15	SEVERE WT	MODERATE WT, SH–SW	MODERATE WT, TRAF	MODERATE WT, TRAF	MODERATE WT	SEVERE WT, FL	SEVERE WT, FL
RUTLEGE–FRESH WATER SWAMP–PLUMMER RUTLEGE 25 FRESH WATER SWAMP 24 PLUMMER 10 OTHERS 41	SEVERE FL, WT	SEVERE WT, FL	SEVERE WT, FL	SEVERE WT, FL	SEVERE WT, FL	SEVERE WT, FL	SEVERE WT, FL
BRIGHTON–TERRA CEIA BRIGHTON 34 TERRA CEIA 30 OTHERS 36	VERY SEVERE WT, FL, PBV	VERY SEVERE TSC, WT, FL	VERY SEVERE TRAF, WT, FL	VERY SEVERE TRAF, WT, FL	VERY SEVERE TRAF, WT, FL	VERY SEVERE WT, FL	VERY SEVERE WT, FL
FRESH WATER SWAMP	VERY SEVERE FL, WT	VERY SEVERE WT, FL	VERY SEVERE FL, WT	VERY SEVERE FL, WT	VERY SEVERE FL, WT	VERY SEVERE FL, WT	VERY SEVERE FL, WT
SALT WATER SWAMPS & MARSHES	VERY SEVERE WT. FL, PBV	VERY SEVERE FL, WT, TSC	VERY SEVERE FL, WT, TSC	VERY SEVERE FL, WT, TRAF	VERY SEVERE WT, FL, TRAF, SALINITY, PROD	VERY SEVERE WT, FL	VERY SEVERE WT, FL
MINES, PITS AND DUMPS	(VARIABLE)	(VARIABLE)	(VARIABLE)	(VARIABLE)	(VARIABLE)	(VARIABLE)	(VARIABLE)

ABBREVIATIONS: WT–WATER TABLE, TRAF-TRAFFICABILITY, FL-FLOOD HAZARD, AWC-AVAILABLE WATER CAPACITY, PROD-PRODUCTIVITY, PBV-PRESUMPTIVE BEARING VALUE, SL-SLOPE, TSC-TRAFFIC SUPPORTING CAPACITY, PERM-PERMEABILITY, ORG-ORGANIC

ENERGY RESOURCES



PRIMARY ENERGY SOURCES

For purposes of this energy discussion, the Tampa Bay Area will be assumed to include Hillsborough, Pinellas, Pasco, Polk and Manatee Counties.

Adequate supplies of primary energy sources, at reasonable costs, are essential to modern living. Without such supplies every facet of our way of life is handicapped. Growth of industry and of population is dependent upon the relative cost of such supplies.

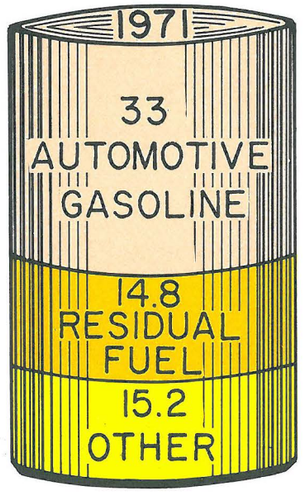
Historically and right up to the end of 1972, the area is 100% deficit in internal primary energy supplies. All primary energy used in the area, both directly and through conversion to secondary energy (electricity), is imported. Most is "domestic", imported from other parts of the United States, some is foreign, imported from other countries.

This complete dependence upon imports may change in the future. It is now suspected that there may be petroleum deposits in the area. It is known that uranium (the fuel source of nuclear power plants) exists in connection with the phosphate deposits in the eastern portion of the area. Development of this resource may become economically feasible in the future. More detailed discussion of these possible future energy sources will be found in other sections of this report.

Primary energy is imported to the area in the forms of liquid petroleum products, natural gas and coal.

Table "A" lists the various primary energy sources brought into the area during 1971 and illustrates the growth for 12 months ending October 31, 1972. For ease in comparing utilization value, tons of coal and MCF (million cubic feet) of gas have been converted to "equivalent barrels" of oil.

Some indeterminate portion of the liquid products brought into the area is exported to other parts of Florida by truck, rail and pipeline. There appear to be no available statistics covering these movements but a guess is that they may amount to 15-20% of the quantities shown in the table.



PETROLEUM LIQUIDS TOTAL 63 Million Bbls.

COAL (Equiv. Bbls.)

GAS (Equiv. Bbls.)

In addition to the quantities shown in the table, 7,957,000 barrels of residual oil were brought into Port Manatee in 1972, all of which was barged up the coast to Florida Power Corporation's plant at Crystal River. All of this residual was of foreign origin.

Liquid petroleum products are, with very minor exceptions, brought in by water through the Port of Tampa (including Weedon Island in St. Petersburg) and Port Manatee. All of the crude oil, most of the residual fuel and minor amounts of the jet fuel and diesel oil are used as power plant fuel in the generation of electricity. The balance of the residual is used in industrial heating and for fueling ships in the port, while the uses of the other products are obvious.

Most of the residual is of foreign origin, mostly from Venezuela and the Dutch West Indies. (Starting in 1973 there will be substantial imports of residual from the Virgin Islands). All of the crude oil is imported from Libya. The balance of the liquid petroleum products is of domestic origin, principally from the refineries along the Texas and Louisiana coasts of the Gulf of Mexico.

As an approximation, the cost of transportation of petroleum products and of coal, in large quantities by ocean vessel, is about 1/30 of the cost of moving the same quantity overland by truck. Specifically, at this writing, a barrel of residual oil moves 2,000 miles from the refinery in Venezuela to the Port of Tampa for about 30 cents. It costs over 50 cents more to then move the same barrel 100 miles by truck from Tampa. There are no more than three other ports in Peninsular Florida which can handle ships as large as can be handled in Tampa Bay. And none of these have as extensive oil handling and terminal facilities as does the Port of Tampa (including Port Manatee). The net result is that the Tampa Bay Area can offer fuel using industries all grades of petroleum products, from more suppliers, and at lower costs than can almost any other area in Florida or for that matter, in the entire southeast.

TABLE A

Primary Energy Sources Received in Tampa Bay Area (Barrels of 42 U.S. Gallons)

	Year 1971	12 Months Ending 9/30/72	
Aviation Gasoline	1,168,000	1,597,000	
Automotive Gasoline	32,994,000	36,849,000	
Jet Fuel & Kerosene	7,253,000	6,103,000	
Diesel Fuel (No. 2)	5,944,000	6,820,000	
Residual (No. 6)	14,825,000	12,846,000	
Propane	822,000	838,000	
Crude Oil		556,000	
Total liquid	63,006,000	65,609,000	
Coal (tons)	2,845,000	3,919,000	
Coal (equiv. bbls)	10,353,000	12,343,000	(Assume 3.639 bbls/ton)
Total Water Deliveries	73,359,000	77,952,000	(Equivalent bbls.)
Gas (MCF)	21,827,000		
Gas (equiv. bbls)	3,520,000		(Assume 6.32 MCF/bbl.)
Total Primary Energy	76,879,000		(Equivalent bbls.)
Foreign Origin	11,701,000	11,396,000	(Almost exclusively No. 6 and crude)

Note: Basic data from reports issued by the Tampa Port Authority.

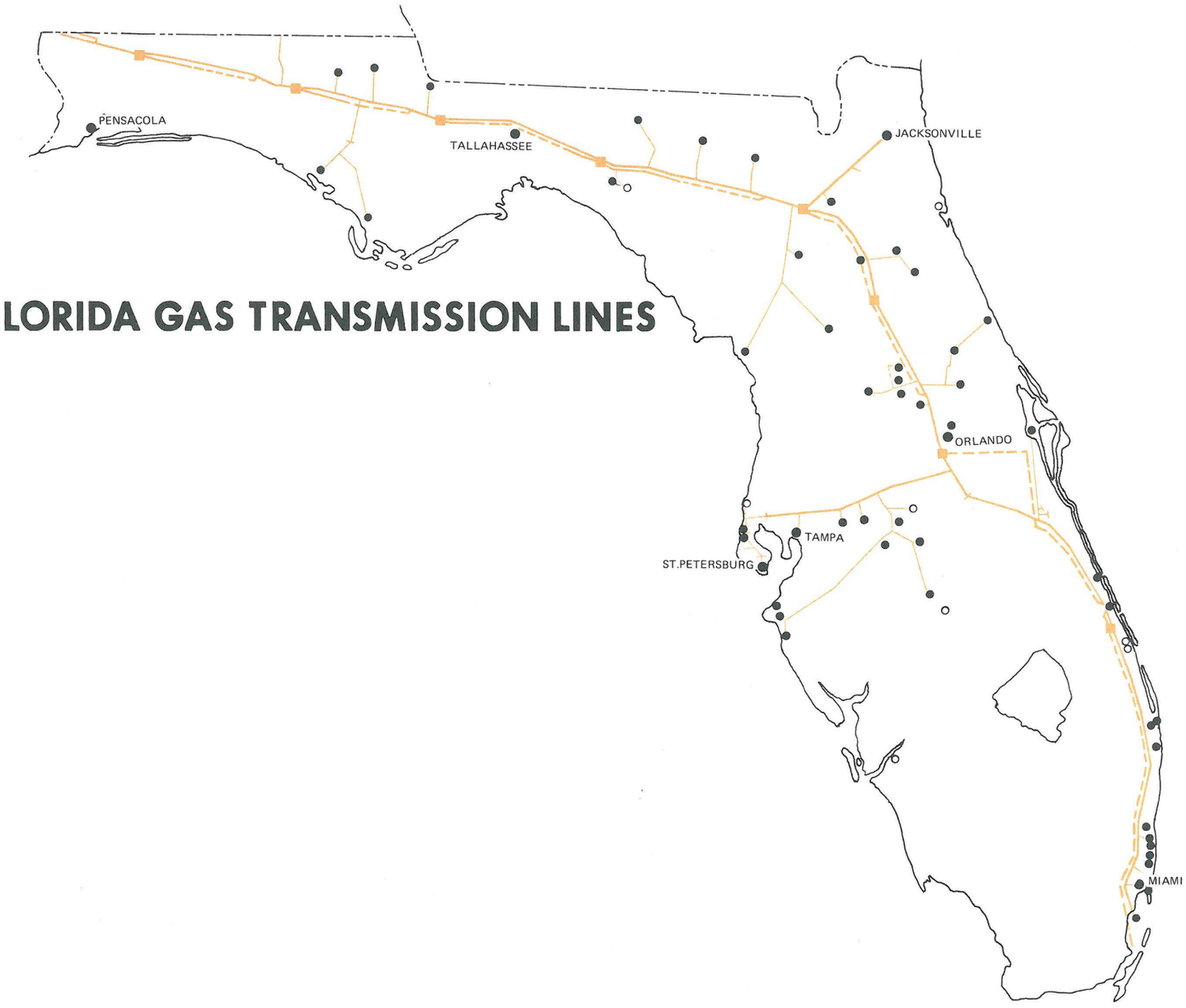
Natural gas is brought into the area by the pipeline system of the Florida Gas Transmission Company which extends from southern Texas around the Gulf into Florida. Most of the gas handled by the pipeline originates in Texas and Louisiana. Relatively small amounts are now being picked up from the new oil fields in northwest Florida.

Approximately 45% of the gas the pipeline brings into the area is used in generation of electricity. Another 30% is sold directly to large industrial users, with the balance being sold to 8 retail gas distributor systems for resale for residential, commercial and small industrial use.

The pipeline facilities of the Florida Gas Transmission Company and of the retail distribution systems supplied by it have expanded and kept pace with the demand for gas in the area. In spite of the nationwide shortage of natural gas, there has been very little curtailment, or interruption, of gas supply to industrial users, and none at all to commercial and residential users. However, at least until the nationwide gas supply picture improves, Florida Gas is accepting no new large industrial customers but to date there has been no restriction placed on serving new residential, commercial and small industrial customers.

All of the coal brought into the area is used by Tampa Electric Company for generation of electricity. This coal originates in strip mines in Western Kentucky and Southern Illinois and is moved in river barges down the Ohio and Mississippi Rivers to a transship facility below New Orleans. At this point it is reloaded into ocean going barges, holding over 20,000 tons each, for the Gulf of Mexico crossing to the Tampa Electric docks where it is unloaded by fast, automatic machines. The barges return loaded with phosphate rock, an operation which substantially reduces the transportation cost of the coal.

FLORIDA GAS TRANSMISSION LINES



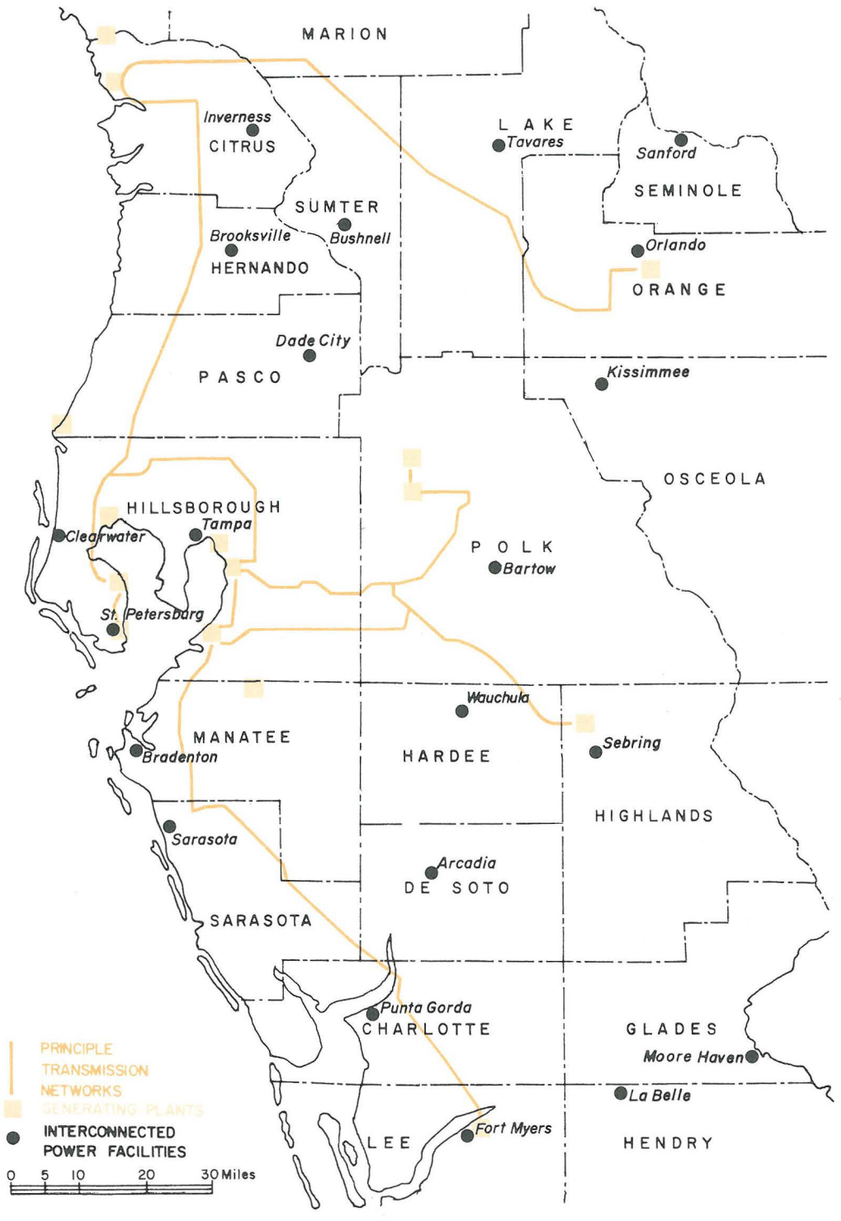
ELECTRIC ENERGY

The entire State of Florida is blanketed by a network of high voltage transmission lines which interconnect the load areas with 35 power plants of four investor owned power systems, four major municipally owned systems, several smaller municipal systems and one small federally owned plant. Additionally, the transmission network is interconnected at several points to the north and west with the country's overall network.

Various portions of the Florida network are owned by the individual power supplying systems. However, it is completely interconnected and operated substantially as though it were all under one ownership. This results in a high degree of service reliability, with every electrical load area being served by multiple sources. With rare exceptions, power plant and transmission failures do not cause interruption of electrical service anywhere in the state.

The accompanying map shows the portion of this transmission network within the Tampa Bay Area as of January 1, 1972, with most of the circuits operating below 115,000 volts omitted for clarity. Also not shown are some 50 of the small substations where power is stepped down to lower voltages for distribution to ultimate users and many of the industrial substations where power is delivered to large users at transmission voltages.

The Tampa Bay Area is served by three investor owned and one municipally owned electric utility systems. Hillsborough County, the eastern portion of Polk County, and minor portions of Pinellas and Pasco Counties are served by Tampa Electric Company. Florida Power Corporation serves, with minor exceptions, Pinellas, Pasco and the west portion of Polk County. Manatee County is served by Florida Power and Light Company. The City of Lakeland and some adjacent territory is served by the Lakeland Department of Electric and Water Utilities. Electric power distribution in some portions of the area is by municipally owned distribution systems and Rural Electric Cooperatives, all of whom purchase their power wholesale from one or another of the suppliers.



There are power plants at eight locations within the area, as detailed in Table 1, with a total capability of 2975 MW. The interconnected transmission network enables any part of the area to be served in case of need from any of the 35 power plants in the state which have a total capability of over 14000 MW.

That the electric utilities serving the area are keeping abreast of needs is shown by the fact that generating capability within the area has doubled since 1965 and that additional capability now under construction or definitely planned, will, in the next four years, more than double the present capability.

Depending on the type of generating unit and the economics of a particular situation, these power plants burn a variety of fuels—all brought into the area through the Port of Tampa (except natural gas, which is pipelined in). Table II shows the total amount of each fuel used and the percentage this represents of the total brought into the area. In summary 29% of the total primary energy sources, coal, oil and gas, brought into the Tampa Bay Area are converted by the utilities into electric energy.

TABLE I

Tampa Bay Area Power Plants (1/1/73)

Plant Name	Capability (MW)	No. Generating Units	Type	Fuel	1972 Net Output (Millions of KWH)
FLORIDA POWER CORP.					
Bartow	478	3	ST	HO-G	3,058
Bayboro	57	3	ST	HO	229
Higgins	140	3	ST	HO-G	780
Bartow	200	4	GT	CO	207
Higgins	164	4	GT	LO-G	115
TAMPA ELECTRIC CO.					
Hookers Point	201	5	ST	HO	1,079
Gannon	1,082	6	S	C	5,136
Big Bend	352	1	ST	C	1,977
Gannon	18	1	GT	LO	10
Big Bend	18	1	GT	LO	
CITY OF LAKELAND					
Larsen	127	4	ST	HO/G	444
Plant No. 3	103	1	ST	HO-G	456
Larsen	39	3	GT	LO	Included
Plant No. 3	6	2	D	LO	in S.T.
TOTAL CAPABILITY	2975 MW				13,491

Plant Types

ST . . . . . Steam Turbines
GT . . . . . Gas Turbines
D . . . . . Diesel

Fuel Types

HO . . . . . Residual (No. 6) Oil
CO . . . . . Crude Oil
LO . . . . . Light Oil (distillate)
G . . . . . Natural Gas
C . . . . . Coal

Note: Data supplied by the utilities

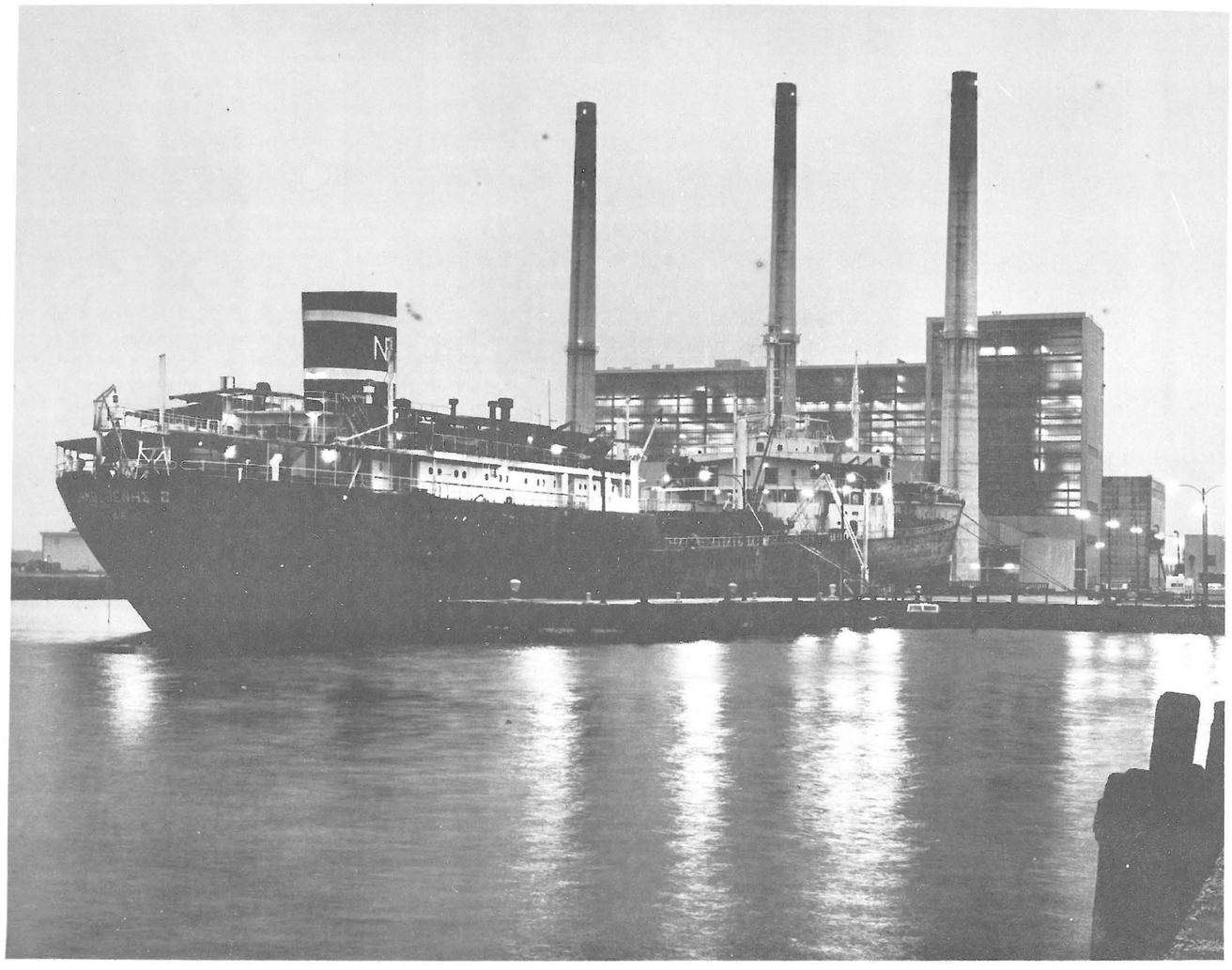
TABLE II

Tampa Bay Area Power Plant Fuel Use

(Year 1972)

Type	Quantity Used	% of Total Shipped into Area
Residual Oil	9,527,632 bbl.	74%
Gas	8,451,013 MCF (1,337,185 equiv. bbl.)	39%
Coal	3,349,724 tons (12,189,646 equiv. bbl.)	100%
Light Oils	73,101 bbls.	negligible
Crude Oil	465,075 bbls.	100%
Total Equiv. Bbls.	23,592,639	29%

Note: Data supplied by the utilities.



Greek owned tanker "Demosthenes V" discharging 140,000 barrels of Venezuelan residual oil at Florida Power Corp, Weedon Island, St. Petersburg. (photo courtesy of Florida Power Corp.)

Preliminary figures indicate that during 1972 the electric utilities supplied over 15 billion KWH of electric energy, broken down as follows:

	Millions of KWH	% of Total
Residential	6,007	39
Commercial	3,183	21
Industrial[1]	4,470	29
Other[2]	1,598	11
Total	15,258	100

[1] Approximately 50% of industrial use was in the phosphate mining and processing industries.
[2] Includes street lighting and other municipal uses, sales for resale, company's own use, etc.

Rates for electric service in the Tampa Bay Area are generally closely in line with National and Florida average rates, and far below the highest rates in the "lower 48" states. These highest rates are generally found in the New England and New York City areas. Rates lower than charged in the Tampa Bay Area are generally found in areas abundantly supplied with hydro-energy, with its zero fuel costs, or in areas within coal or gas fields where there is little or no transportation component in the utilities fuel costs.

Table III lists rates in effect on January 1, 1971. As the direct result of spiralling fuel costs, general inflation and the high costs of meeting environmental demands, most of the country's electric utilities have been forced to increase rates during the intervening two years.

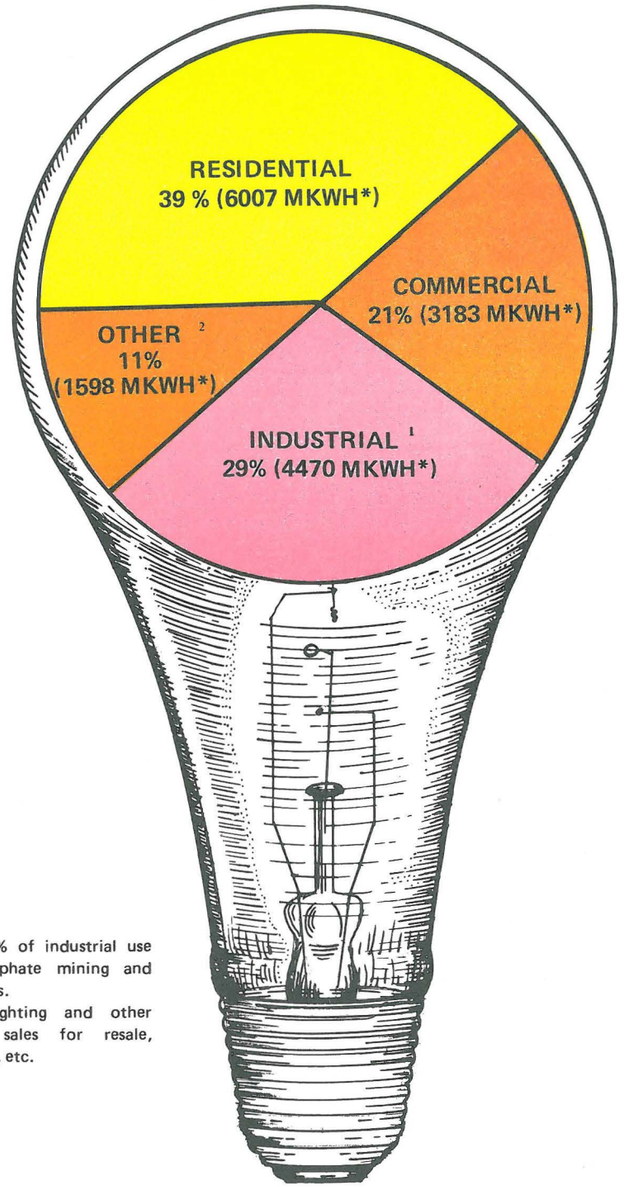
Therefore the actual rate figures given in the table are no longer applicable. However, there would be no important change in the relative positions of the various areas listed.

TABLE III

Typical Electric Bills
January 1, 1971

	Small Residential 250 kwh/mo.	Medium Residential 1000 kwh/mo.	Small Commercial 750 kwh/mo.	Large Commercial 10,000 kwh/mo.	Medium Industrial 300 kw demand 60,000 kwh/mo.
Highest in 48 States (cities of 50,000 or more)	12.78	27.66	43.07	392.80	$2,333
National Average	7.84	19.24	28.45	252.43	1,269
Florida Average	7.39	19.51	30.65	253.28	1,157
Tampa Bay Area Avge.	8.03	19.50	32.68	245.16	1,129
Tampa Bay Area Highest	8.13	19.73	36.18	275.65	1,256
Tampa Bay Area Lowest	6.93	19.27	29.19	214.68	1,002

Sources: Federal Power Commission Publication "Typical Electric Bills", December, 1971.



[1] Approximately 50% of industrial use was in the phosphate mining and processing industries.
[2] Includes street lighting and other municipal uses, sales for resale, company's own use, etc.

USE OF ELECTRICITY

*MILLION KILOWATT HOURS

ENERGY OF THE FUTURE

Modern man needs sources of energy to support his way of life. Such sources are needed to provide light, heat and cooling of his buildings; to move his automobiles, airplanes, trains, trucks, ships; to power his shops, factories and mines and for countless other uses. Without adequate supplies of energy, civilization and life would end.

For the United States, 97% of the energy used comes from the three fossil fuels, coal, oil and gas. Hydro-electric and nuclear energy supply the remaining 3%. About 26% of the fossil fuels are converted into electricity, the balance is used directly. The figures for the rest of the world are not greatly different, except that in some areas wood and other organic materials contribute to the energy supply in a small way.

The fossil fuels represent a finite resource—once used they can not be replaced. Therefore there must inevitably come a day when there are no more fossil fuels to support a civilization. Opinions vary as to when this day will come but the best estimates indicate that by the end of this century supplies of natural gas will be substantially exhausted, liquid petroleum supplies may last through the middle of the next century, coal will probably last 300 to 500 years.

In the intervening years we can expect constantly increasing costs, coupled with spasmodic but increasingly severe shortages. The local shortages of natural gas and heating oil during the winter of 1972-73 were an insignificant illustration of what will become commonplace if substitute sources of energy are not developed.

To date there appear to be two such substitutes which have reasonable hopes of being developed into practical sources of energy—nuclear power and solar power.

Nuclear power is furthest along, having been developed to the point where it is (early 1973) contributing 2% or 3% of the nation's total energy needs, all of this in the form of electric energy. Present indications are that by 1985, nuclear will be contributing between 11% and 15% of the country's energy needs.

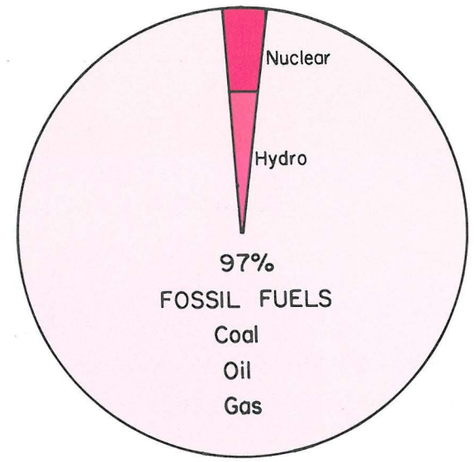
Florida's two largest utilities have been among the leaders in the nuclear field. In January 1973 they had one large nuclear generating unit operating, three in various stages of construction and one more in the advanced planning stage. All of Florida's utilities are studying the need for, and feasibility of additional nuclear units.

None of the nuclear units now definitely planned for Florida will be in the Tampa Bay Area. However, the area will probably see such units in the future since there are locations in the area which meet the rather stringent siting requirements for such generating units.

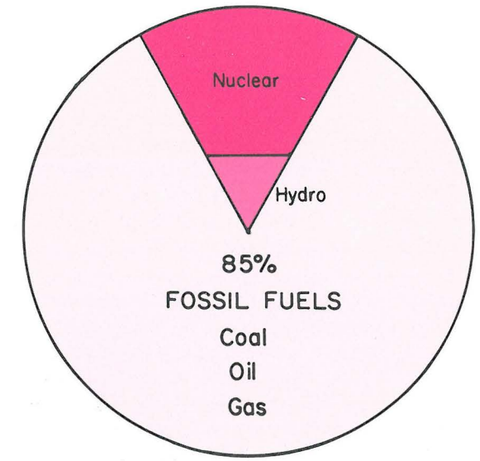
The current commercial types of nuclear generating units consume uranium as a fuel, much as a fossil unit consumes coal, oil or gas. Uranium, like the fossil fuels, is a finite resource. As available supplies are used up, the price increases.

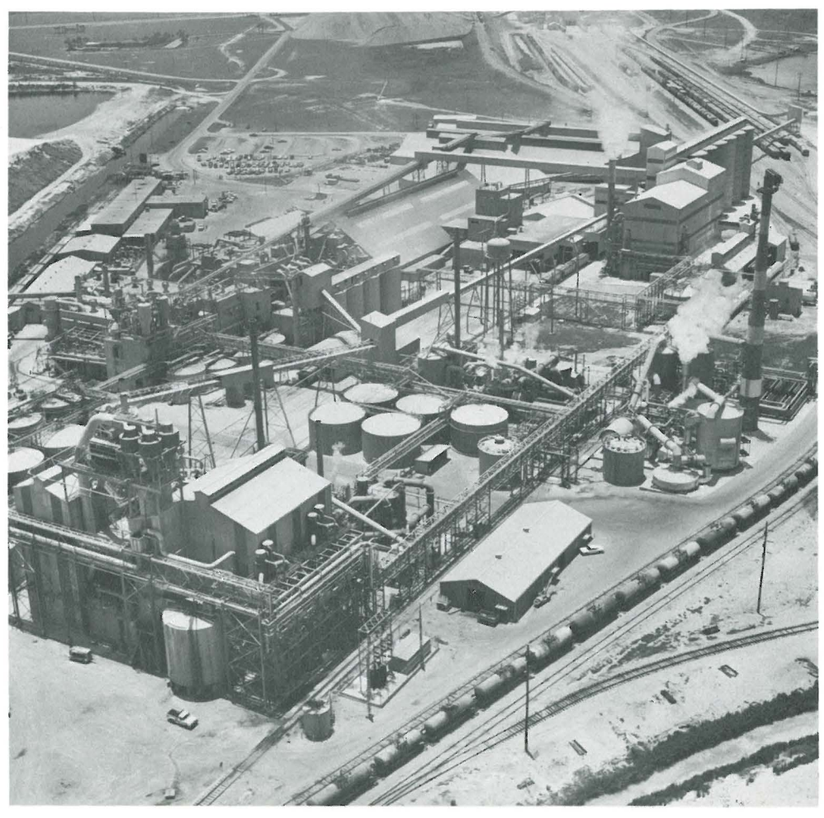
It is known that there are fairly large amounts of uranium ore in connection with the phosphate deposits in the eastern portion of the Tampa Bay Area. It is currently estimated that this ore is recoverable at costs of around $15 per pound of refined U_3O_8. The current market price of U_3O_8 is less than $8 per pound and industry sources estimate that it will be the late 1900's before market conditions will make recovery of Florida's uranium ore economically feasible. (See W. R. Oglesby's article on this subject, Page 48, Tallahassee Area study published by the Bureau of Geology in 1972.)

PRESENT
U.S. ENERGY SOURCE



U.S. ENERGY SOURCE
PROJECTED TO 1985





There are four major processing steps involved in converting the U_3O_8 to actual nuclear plant fuel. Special requirements make it most unlikely that Florida would ever be an attractive location for plants involved in the first two of these steps, conversion of the powder U_3O_8 into the gaseous UF_6, and enrichment of this gas by increasing its contained percentage of the isotope U_{235}.

However, the remaining steps, conversion of the gaseous, enriched UF_6 to the powder UO_2, pelletizing this powder, and assembling the pellets into reactor fuel assemblies are exactly the type of industries which Florida likes and which like Florida. They are light, clean, high precision industries, requiring good supplies of highly skilled labor and abundant resources of engineering and scientific manpower. Given an adequate local market for their output, which should exist by the early 1980's, it should be possible to attract this industry to Florida.

Going back now to the statement that uranium is a finite resource, it is evident that, like the fossil fuels, there must come a day when it is exhausted. Before that day comes, perhaps early in the next century, another type of energy source must have been brought to commercial practicality.

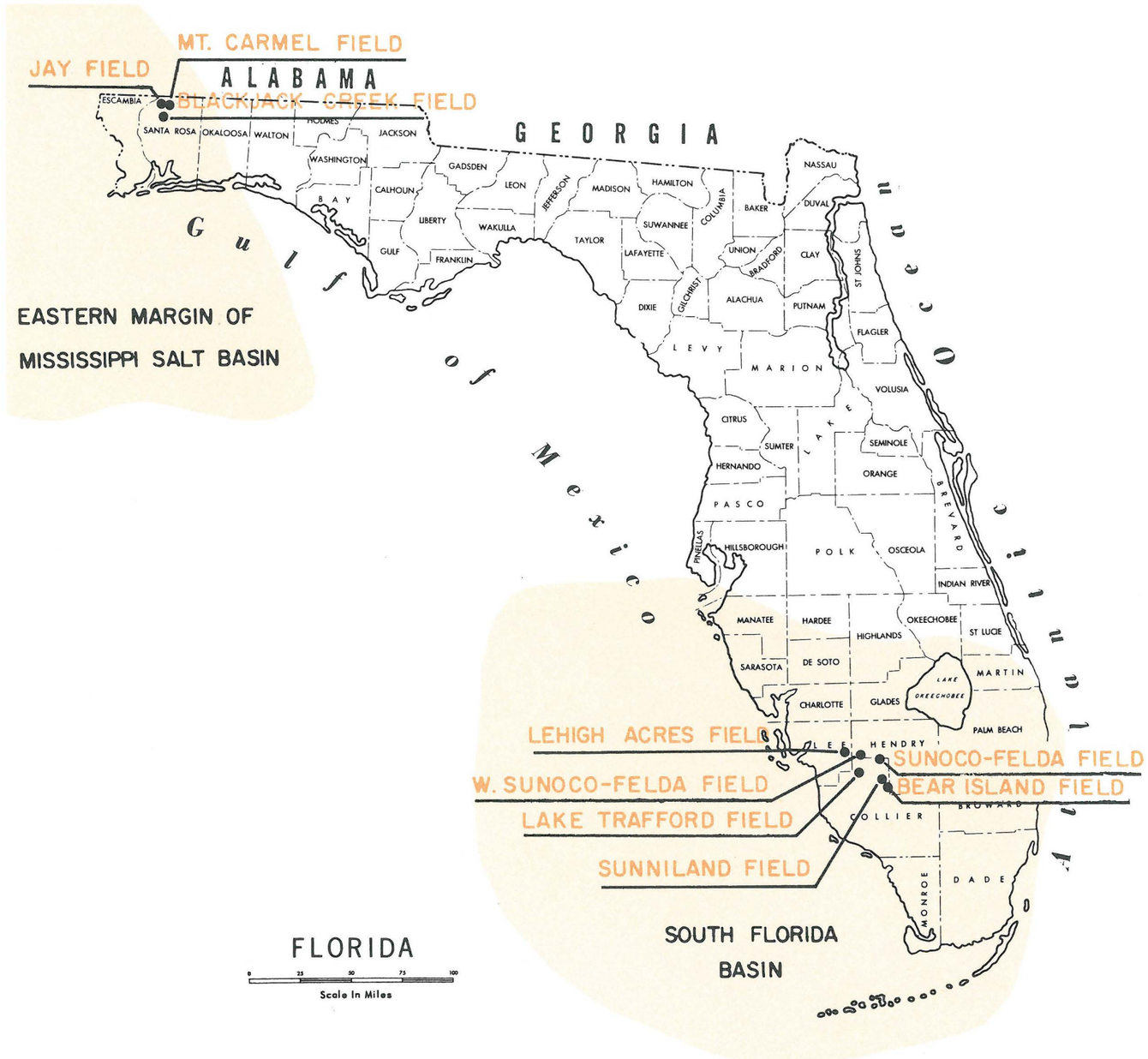
Uranium oxide could be produced from 'wet process' phosphate plants.
Photo courtesy of the Florida Phosphate Council

OIL AND GAS

The "breeder reactor" which actually can produce more fuel than it consumes, has been proven in the laboratory stage. Funded jointly by the electric utility industry and the Federal Government, the first "demonstration" plant, using the breeder process, is now in the engineering stage. Because of the problems involved in converting a laboratory process to a practical commercial power plant, many in areas of new and unknown technology, it is expected that it will be the mid 1980's before the first commercial breeder plant will be operational, at a total developmental cost of well over one billion dollars.

But, if the "breeder" or some equivalent process is not available by early in the next century, civilization as we know it must come to an end!

Solar energy research has been sadly neglected, perhaps because it does not have the glamor of nuclear and other advanced scientific development. The work which has been done in this field, largely at the University of Florida leads us to believe that if a small fraction of the money and scientific man hours which are going into nuclear development were put into solar development, then we would have the means to capture enough of the limitless solar energy to supply all of the energy needs of the world as long as it exists. And Florida, because of its unique climate, should be the center of such research.



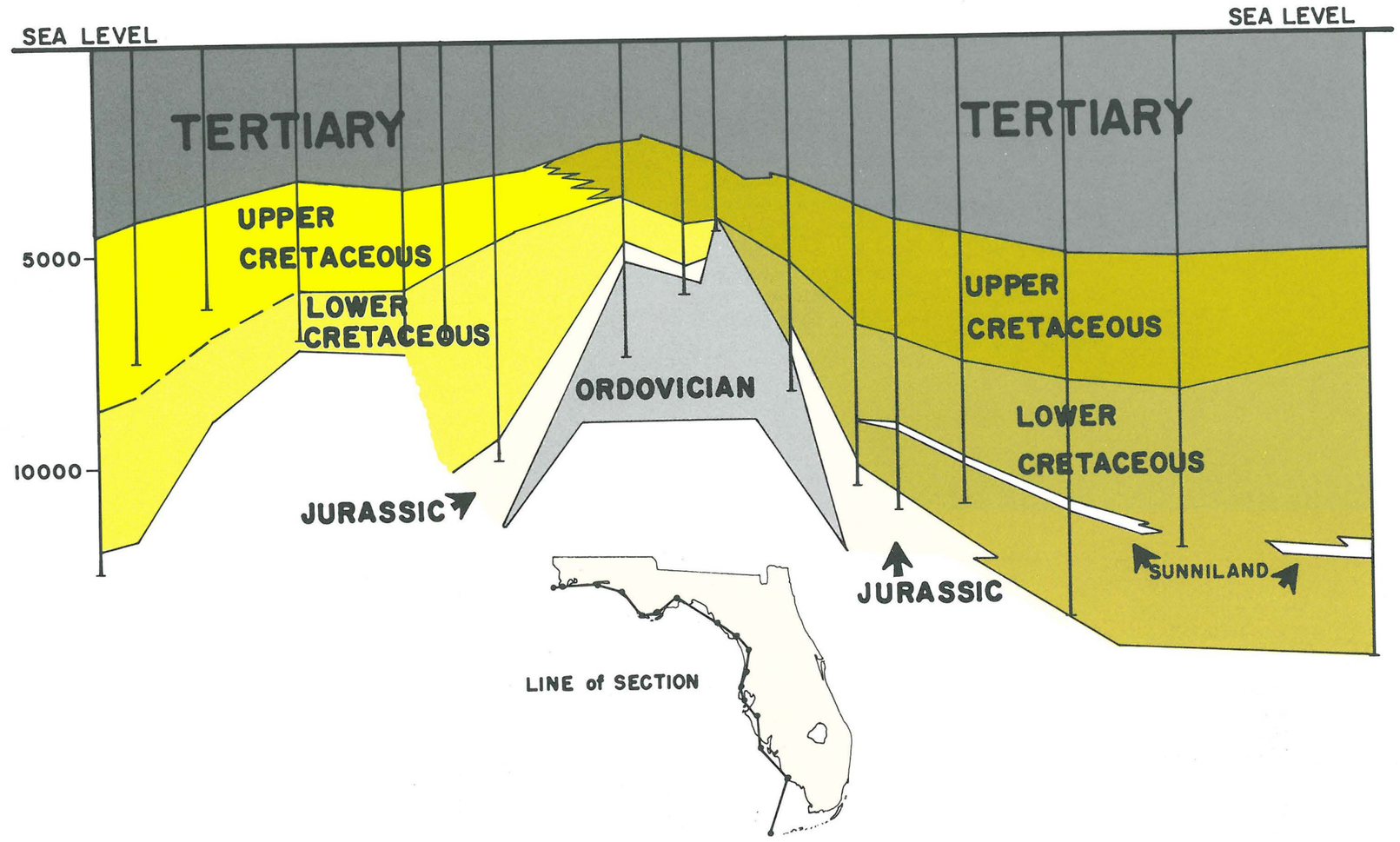
There is no oil or gas production within the Tampa Area, and no immediate prospects for such production. Hillsborough County, and the six counties surrounding it within a 50-mile radius, have had 41 oil tests drilled therein between 1900 and 1973. However, only 12 of these tests have been drilled within the past 30 years, since the discovery of Sunniland Field, in Collier County. Sunniland marked the entry of Florida into the ranks of oil producing states, and we now rank 12th out of 32 states which have petroleum production.

Many of the earlier wells in the Tampa area were not adequate to test the potential pay zones. In short, these seven counties remain in the Twilight Zone, as far as their petroleum prospects are concerned; they are possible but not probable areas from which oil or gas may be recovered some day. The preceding statement is made in light of the following considerations:

1. The known producing trend in south Florida extends along the northeastern portion of the Shelf associated with the South Florida Basin.
2. The known producing trend in northwest Florida extends along the eastern margin of the Mississippi Interior Salt Basin.
3. The Tampa Area is not located in a basin but rather on the central Florida platform, a structurally positive area. There is no particular reason to believe adequate petroleum source beds exist on or in conjunction with this central platform.

The lack of oil production in the vicinity of Tampa does not signify that the availability of gasoline or fuel oil is less here than in other metropolitan areas. Austin, the capital of Texas, experienced a dozen critical periods of petroleum shortage during 1972. The City of San Antonio, Texas, was threatened by a blackout when the municipal electric power system could not obtain natural gas to operate in the spring of 1973. No power shortages due to lack of fuel were reported in the Tampa area. Tampa, like the rest of Florida, but unlike Texas and most of the United States has no liquid petroleum products pipe lines; and hence has complete flexibility of its sources of supply. Tampa is one of four deep sea ports in the Gulf Coast of the U.S. and is open to the fuel markets of the world. On the other hand, most of the inland cities of the United States are served by product pipe lines which are inflexible. If the input supply of such pipe lines is curtailed, the output at the distribution point is likewise curtailed.

Although there is no pipe line supply of petroleum to Tampa, the city is served by the natural gas line of Florida Gas Transmission Company. Natural gas for domestic use is no real problem; the supply of natural gas for generating electricity is, unfortunately, inadequate here as in other cities. This is not due to lack of capacity of the pipe line. Its carrying capacity could be increased by the simple expedient of increased compressor capacity along the line. There is a real shortage of natural gas at the sources of supply. Company officials of Florida Gas recently have announced an intention to convert one of the parallel lines in their gas transmission system to a products pipe line. If this is done, Tampa as well as other areas of Florida served by the Florida Gas Company will enjoy lower transmission costs of fuel overland and reduced trucking on the highways. However, users of this fuel may find they have traded a flexible seaborne supply open to world markets for a rigid source controlled by the supply available at the input points to the pipeline.

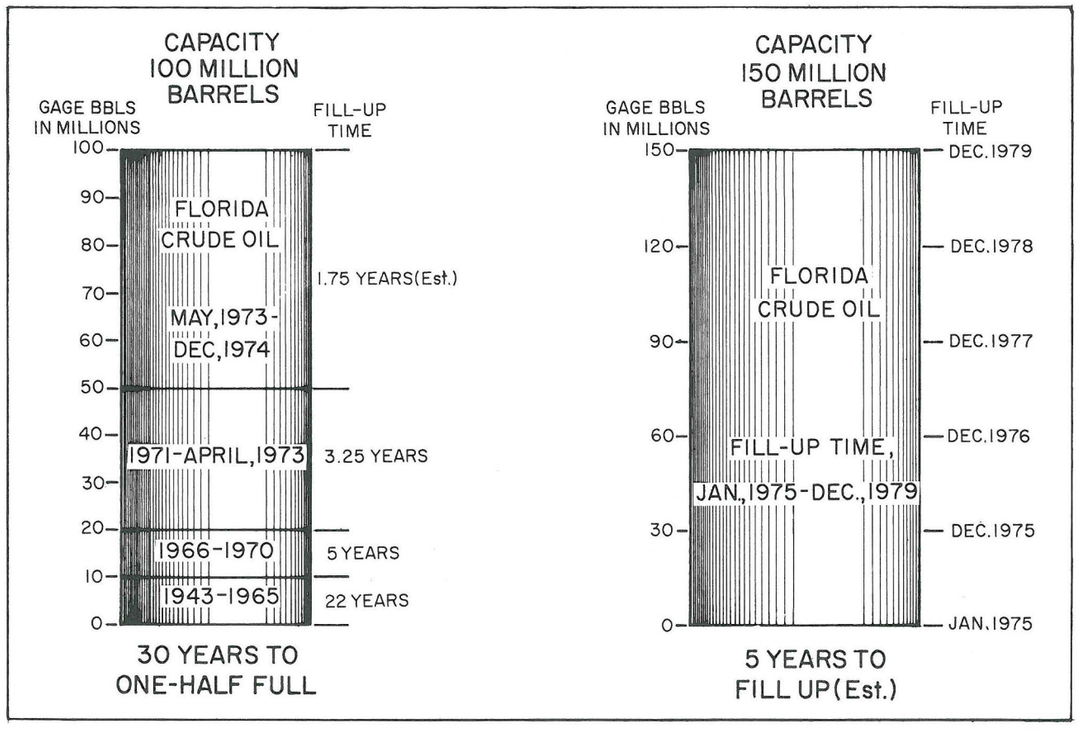


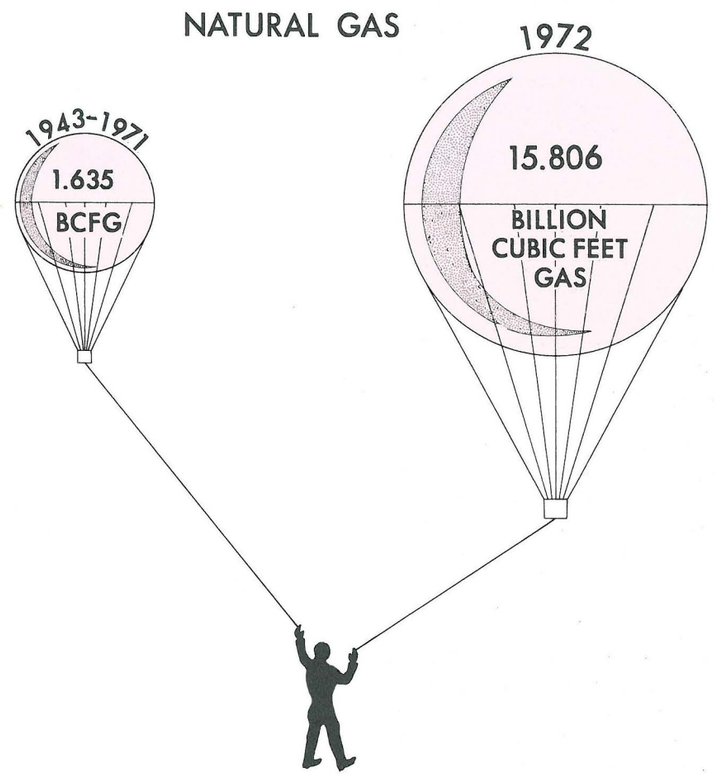
Crude oil produced in Florida is from two widely separated basins which are: The Mississippi Interior Salt Basin and the South Florida Basin, shown on **Page 80.** Production occurs below 11,000 feet in the South Florida Basin and below 15,000 feet in the Florida portion of the Mississippi Salt Basin.

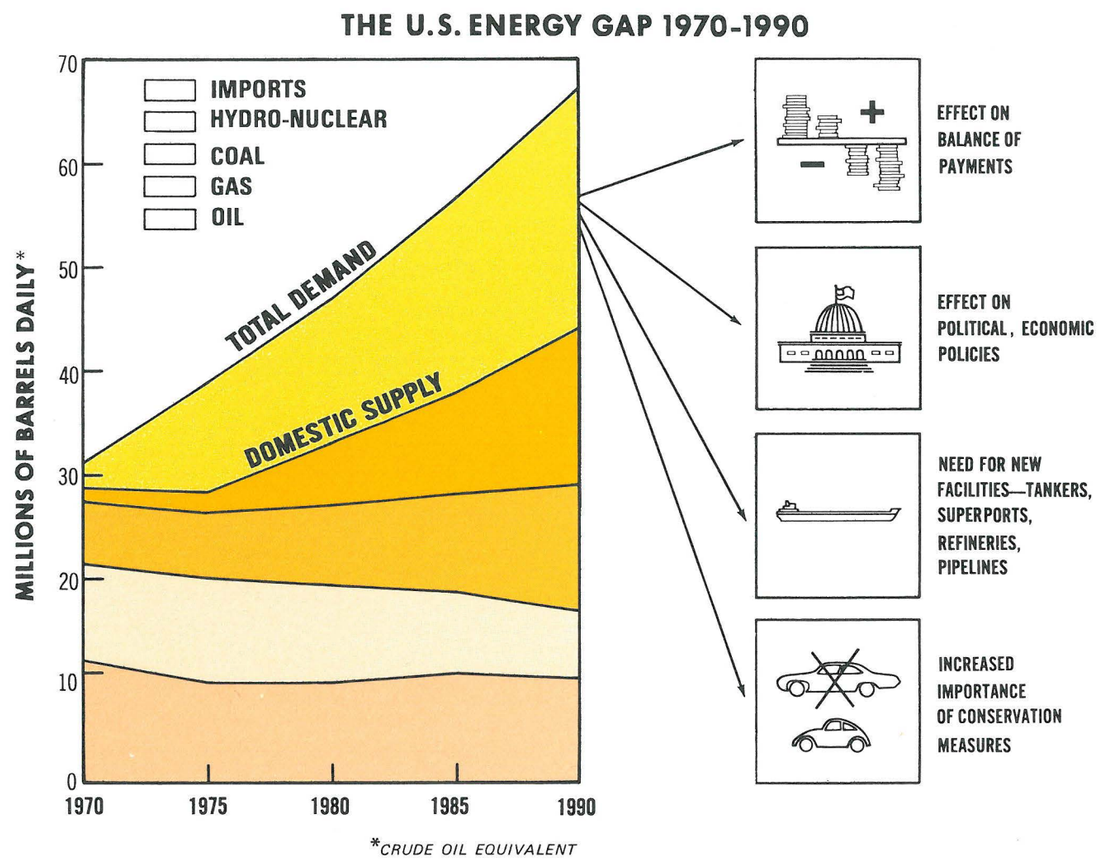
The production from Jurassic age strata in Jay, Blackjack Creek and Mt. Carmel Fields occurs in the Norphlet Sand, which immediately overlies the Louann Salt, and in the Smackover Limestone which overlies the Norphlet Sand. These three fields will produce about 100,000 barrels of oil and 100,000,000 cubic feet of gas per day, when fully developed, about 20% more than their current production rate.

The Sunniland Limestone of lower Cretaceous age supplies the balance of crude oil production from six fields centering around Immokalee, Collier County, Florida. The combined daily production from these fields is about 13,000 barrels of crude oil. No commercial amount of gas is derived from these undersaturated reservoirs.

Florida produces about 30,000,000 barrels of crude oil annually and uses about 7 times this amount of refined petroleum products. All of the crude produced in Florida is exported to refineries in other states and all its petroleum products are imported by sea. Therefore, oil production in the state has no more direct effect on Florida's petroleum products supply than it has on other areas in the United States. However in the case of gas, Jay Field produces about a tenth of the supply carried for distribution by Florida Gas Transmission pipe line to the Tampa area and around the State. Gas is a desirable, clean, and currently, low cost fuel. If enough of it is discovered in the state, we could solve the environmental problems connected with electric power generating plants while the supply lasted.







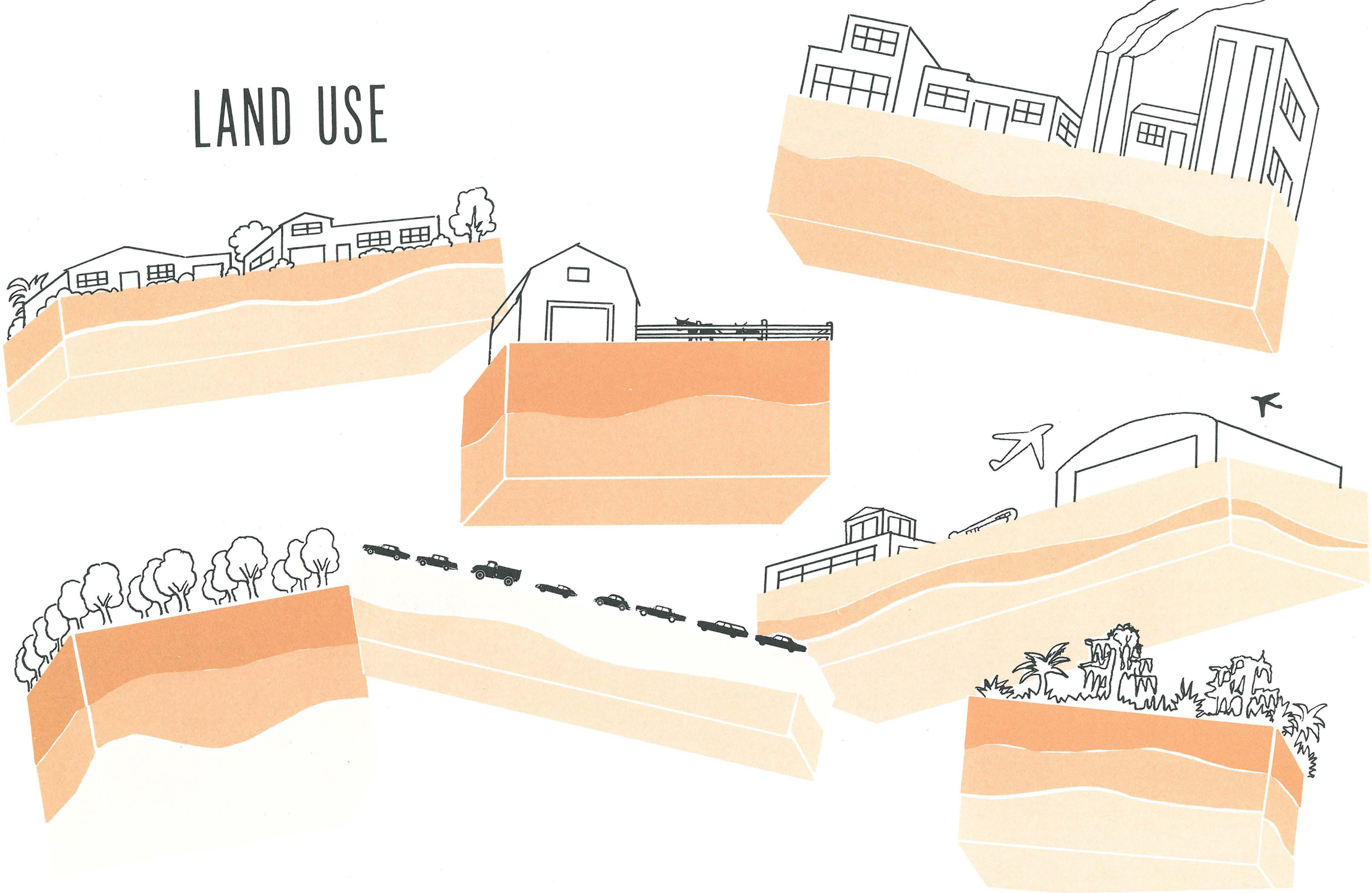
Source: SHELL OIL CO.

Ultimately, Florida, like the rest of the country, will be forced to shift to an energy base other than petroleum and natural gas, as the domestic supply becomes exhausted. The international supply can augment our own petroleum resources; but for economic, security and political reasons it is nonsense to suppose we could exist as a wholly dependent fuel imports nation.

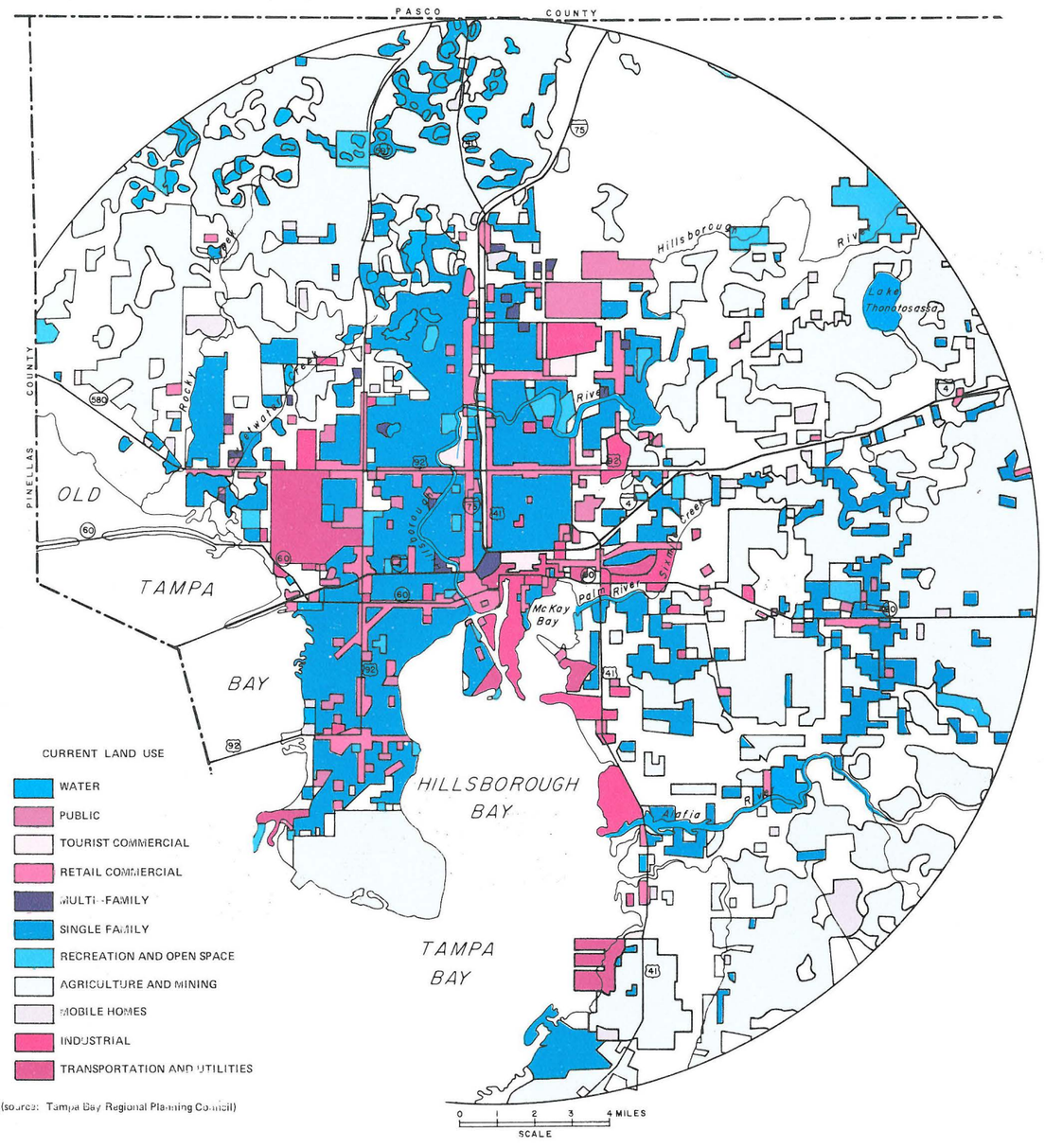
This is illustrated by a chart entitled "The U.S. Energy Gap 1970-1990" from a publication by Shell Oil Company shown in reproduction. The graph shows total oil imports of about 2½ million barrels per day (B/D) in 1970, rising to 5½ million B/D in 1975, and to 23½ million B/D in 1990. If the true cost of foreign oil in 1970 is taken at $1.00 per barrel (considering that United States companies operating abroad must pay foreign royalties and taxes, and that shipping costs are paid to foreign nationals) our trade deficit on oil was about $900,000,000. By 1975, this cost may well double, as both oil prices, royalties, and transport costs increase. Hence the 1975 deficit estimated on oil imports is 4 billion dollars. These costs will probably redouble by 1990, so that the deficit on oil imports may attain 34 billion dollars. These projections do not allow for dollar inflation which the Organization of Petroleum Export Countries insists must be adjusted with more dollars.

The chart indicates we will produce 10 million barrels of oil per day in the U.S., and import 23½ million barrels by 1990. If this occurred, the Nation would be dependent on foreign sources for the energy necessary to our military and industrial survival, for the two are interdependent. The obvious answer is that the charted projection will not occur and that we will not be using a total of 33½ million barrels of petroleum in 1990. Either we shall have adapted to such alternate sources available by reduction of coal, oil shales, and tar sands to petroleum liquids, or perhaps shifted to a hydrogen energy base through electrolysis of water in a related nuclear reactor program furnishing electric power. A third course, to reduce our total use of energy, will take place as the cost of fuel increases relative to other items in the gross national product.

LAND USE



CURRENT LAND USE

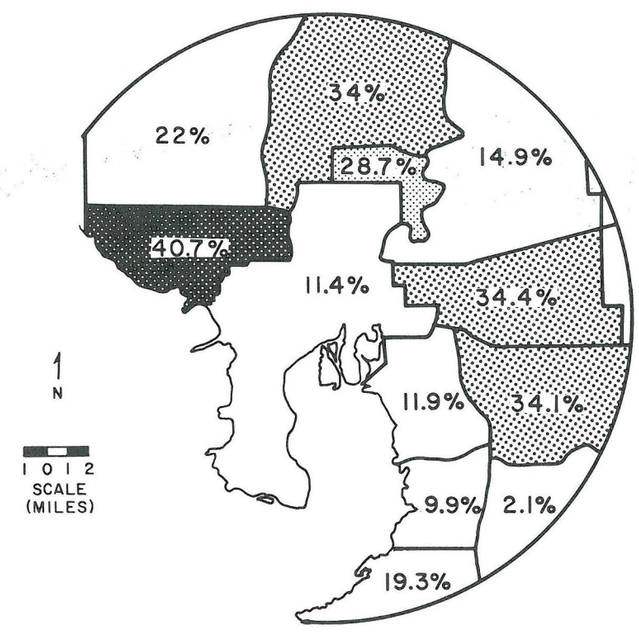


(source: Tampa Bay Regional Planning Council)

Although 86.5% of the land within the urban limits of the City of Tampa is developed, only 15.1% of the land within the Tampa area (as delineated by the map) is developed. The following table shows the percentage of land in the Tampa area that falls within each land use category:

single family residences	8.0%
multi-family residences	0.3%
mobile homes	0.6%
retail and services	0.9%
tourist commercial	0.1%
industrial	1.2%
transportation and utilities	0.9%
public and semi-public	1.6%
recreation and open space	1.6%
agriculture	39.8%
vacant and open range	43.4%
inland water	1.6%

Present land use largely reflects the "preference development" practices of the past which were essentially based on the location of certain natural and cultural features and on economic considerations. Certainly many examples of unwise land use within the Tampa area could be identified, however, it is not the purpose of this report to criticize the existing conditions that cannot be significantly altered. It should be pointed out that current land use patterns do have a marked influence on the direction that future development will take. As increasing knowledge about the area becomes available appropriate legislation and zoning designations can serve to channel development into patterns compatible with environmental considerations.



PROJECTION OF THE PERCENT INCREASE IN DEVELOPED LAND BETWEEN 1972 AND 2000.

FUTURE LAND USE

Presented on this page is the Hillsborough County Planning Commission's Provisional Plan of Development through 1990. At the time of this writing, the plan had not been finalized, and the copy shown here is subject to revision. The plan is based on existing major land use categories. Areas which are currently urbanized represented the starting point for the Planning Commission.

Preferred future expansion areas include those areas into which urbanization anticipated by 1980 and by 1990 may best be channeled. It should be pointed out that in both categories, two to three times more land has been assigned for urbanization than trends for future land consumption indicate is needed. This extra allotment is to compensate for portions of the designated land which may be found undevelopable, and to allow for additional urbanization that could not be foreseen at this time.

Around the fringes of the Tampa area, land is slated to remain undeveloped or to be used as agricultural land. According to the Planning Commission, much of this land is developable, however, it is not needed for current or projected land use requirements.

Substantial portions of land have been designated as interim or permanent open area. Included in this category are preservation and conservation areas or those lands which should experience little or no development. Riverine and swamp environments fall into this category, and it is envisioned that recreation will be the primary land use here. Also included are Southwest Florida Water Management District's existing and proposed reservoir areas.

In preparing the Plan of Development the Planning Commission has utilized a sequential approach. Initially, environmental factors were evaluated and a series of maps indicating land use suitabilities were constructed largely on the basis of geohydrologic considerations. These maps were used in conjunction with socio-economic projections in order to establish a basic pattern for growth.

In delineating specific urbanization patterns within suitable areas, several planning concepts were utilized. The concentric pattern of development (where growth takes place around the perimeter of the existing urban center) was used in combination with the radiating plan (where urbanization expands along highway routes) and the satellite cities concept (discussed on the following page) to establish what is hoped to be an equitable and environmentally compatible plan of development.

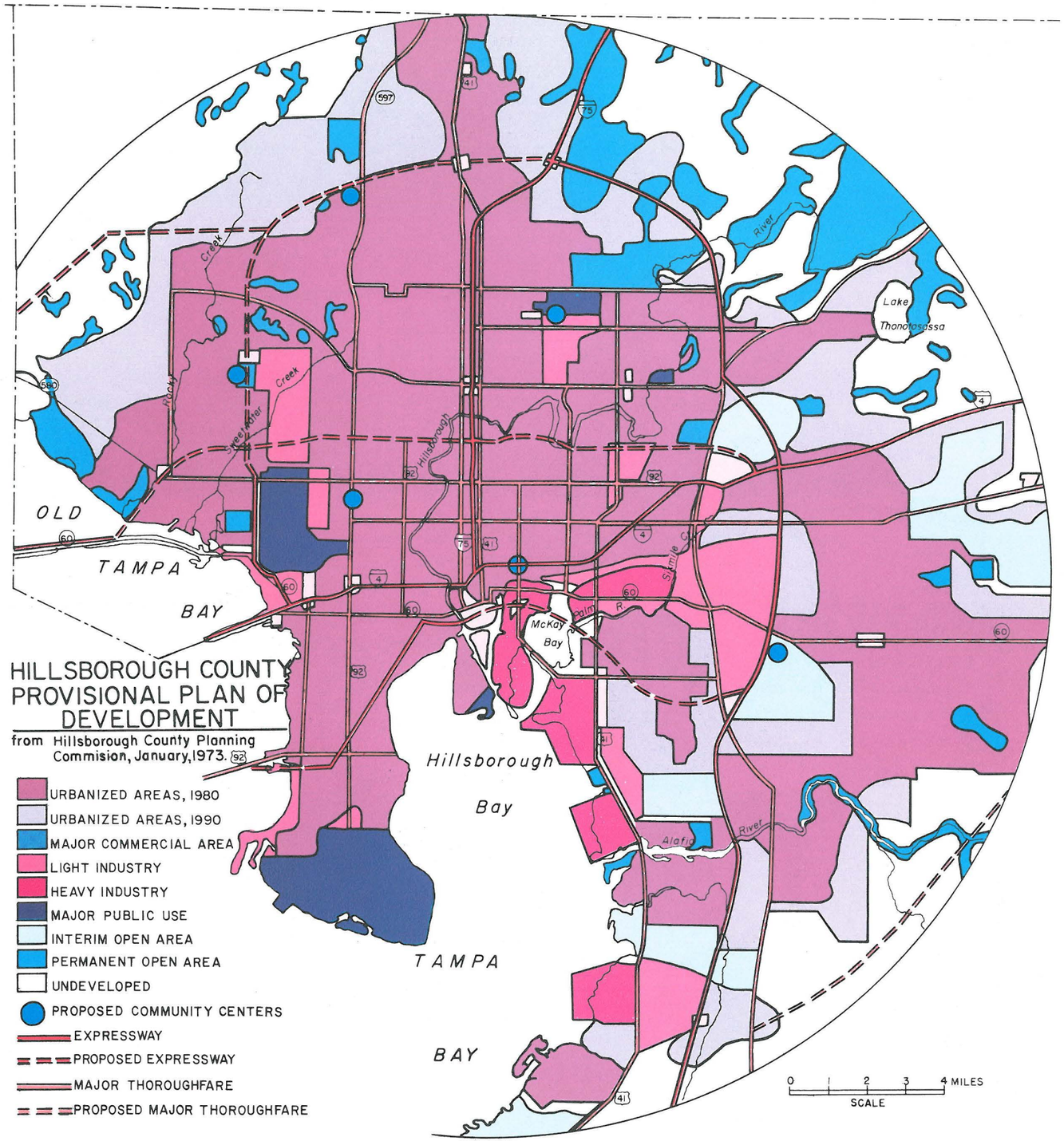
With regard to specific land uses, several noteworthy policies are employed by the Planning Commission. Because of the need to de-centralize traffic flow and diffuse pollution, planning of concentrated industrial areas is avoided. In general industrial parks help achieve the goal of diluting the problems often associated with industry. With large peripheral land areas and attractive planting, industrial parks can be a visually pleasing addition to the landscape. Busch Gardens is a notable local example.

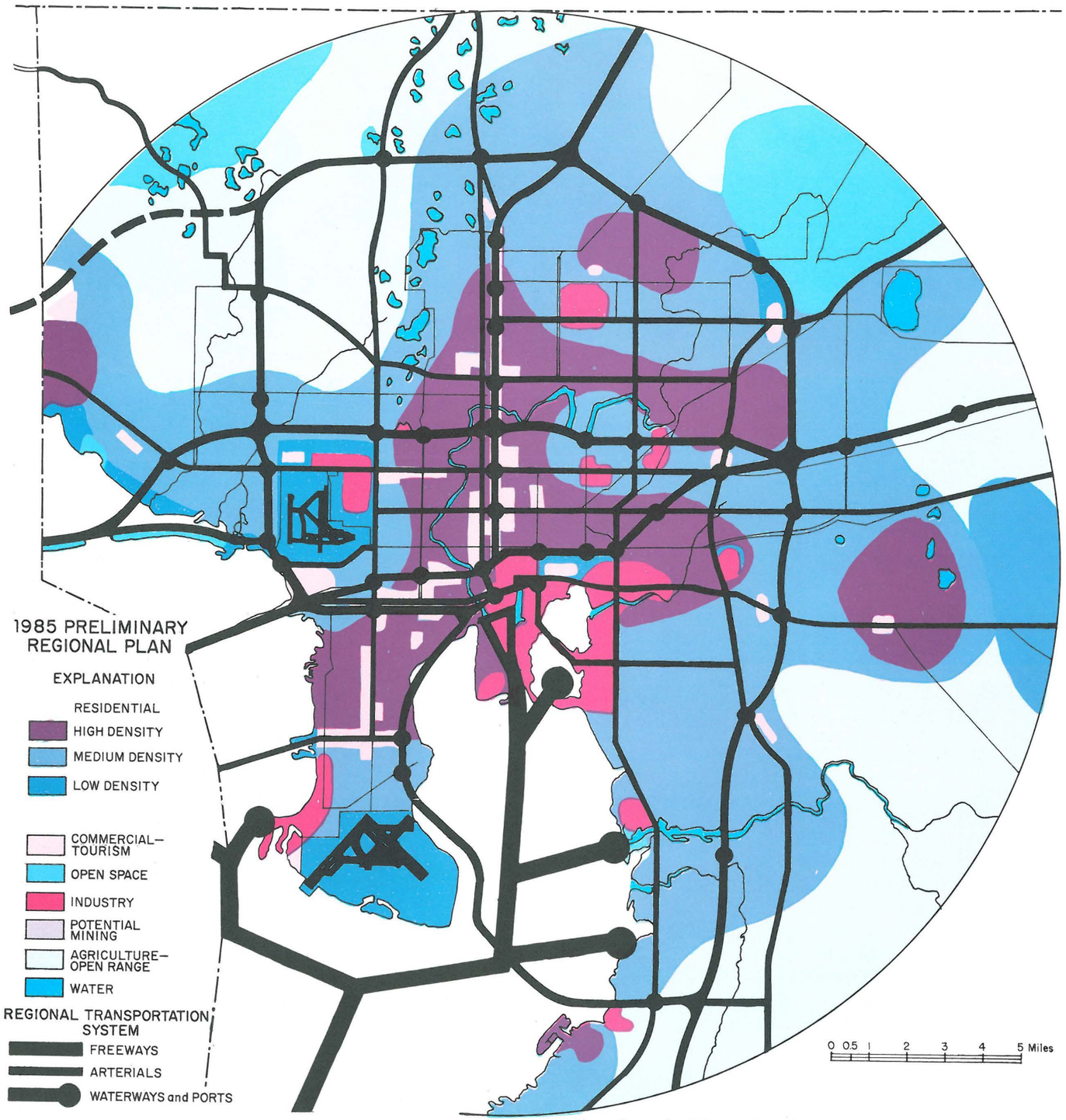
Transportation is another important consideration in planning for the growing Tampa area. The Planning Commission attempts to coordinate all phases of transportation and to incorporate highway, port and airport traffic into a single efficient network.

An additional effort of the Planning Commission is to de-emphasize development in northwest Hillsborough County in the area of the well fields.

The plan shown on this page reflects the environmental awareness of the Planning Commission. As new data becomes available and growth trends change, the plan of development will be revised and updated.

A future land use plan, by nature, constantly evolves in response to changing regional needs and increasing cognizance of local potentials. Both the Hillsborough County Planning Commission and the Tampa Bay Regional Planning Council are currently involved in updating future land use plans for the Tampa area. TBRPC prepared a preliminary plan for 1985 in 1968. A portion of that plan is presented on the following page.





From: Tampa Bay Regional Planning Council, 1985 Preliminary Regional Plan.

According to the Council,

> "The preliminary plan provides for the allocation of the region's developable land resources into patterns of use which will be required to serve the future population."

Among the objectives of the plan are the following:

LAND DEVELOPMENT – Encourage compatible land use arrangements through purposeful site planning to provide compatible, compact and diversified land development.

WATER SUPPLY – Provide a guaranteed water supply for the region through the investigation, development and preservation of all possible sources including watersheds, surface supplies, salt water conversion, and aquifers.

WATER AND AIR POLLUTION – Stop water and air pollution through better public management and control of wastes, location planning for polluting industries, the formation of effective sanitary sewer districts, the establishment of on-site treatment of industrial wastes, and the investigation of a regional solid wastes disposal system.

SHORELINE DEVELOPMENT – Discourage shoreline development in conflict with existing development, natural tidal flows and irreplaceable marine resources.

OPEN SPACE/RECREATION – Adopt a multi-use open space program for the acquisition and development of lands for recreation, conservation, cultural and scenic uses thereby protecting this economic resource which plays a major role in generating new resident and tourist growth.

It is evident that the Council has a great concern for the physical environment. In many instances the Council relies heavily on available geohydrologic information for making land use decisions. During the planning process, many specific questions arise that can best be answered by the geologist or hydrologist.

The answers to such questions are rarely readily available and must be based on careful evaluation of existing data. This illustrates the importance of continuing basic geologic and hydrologic data collection programs and expanding these programs in areas for which accelerated development is predicted.

In the Tampa area growth projections indicate that areas peripheral to urban Tampa will experience the greatest increase in development between now and the year 2000. In conjunction with future development, the Tampa Bay Regional Planning Council believes that two new concepts in urban planning might be applicable to the Tampa area. These are the "new town" policy and the "satellite city" concept. The "new town" policy involves designing small self-sustaining cities outside the realm of existing metropolitan areas. The "satellite cities" concept entails encouraging development in existing suburbs so that they could essentially function independently but would in part be dependent on the urban center. A major objective of the two concepts is to deemphasize over development of urban areas. In formulating plans for "new towns" and "satellite cities", the Planning Council will be looking first at environmental considerations.

Concern with environmental factors has also prompted state legislation. Recently, the Florida Land and Water Management Act was passed. The purpose of the Act is to permit development without destroying Florida's resources or environment and to provide for the designation of areas of critical state concern and development of regional impact.

In designating areas of critical state concern, the state or the local government will set forth developmental guidelines to insure preservation of historical and archaeological resources, and guidelines for water storage areas, significant marine resource areas and so on.

Development of regional impact is defined as any development which, because of its character, magnitude or location, would have a substantial effect upon the health, safety or welfare of citizens of more than one county. In evaluating regional impact generated by development, such things as the degree to which development would contribute to air, water and noise pollution, number of new residents, vehicular traffic and the likelihood of subsidiary development are to be regarded in establishing guidelines.

TRANSPORTATION PLANNING & GEOLOGY

Geology, engineering geology, and hydrology have long been of eminent importance to transportation planners. When new highway sites are designated, on-site soil surveys and subsurface explorations are carried out. The State Department of Transportation maintains an Office of Materials and Research which is charged with the responsibility of carrying out these investigations.

The first phase of study is an office procedure that entails gathering all available information on the soils and geologic conditions in the project area. Aerial photographs, Soil Conservation Service publications, topographic maps and geologic maps and reports published by the United States Geological Survey and Florida Bureau of Geology are utilized as primary data sources.

After the evaluation of general site conditions, a detailed field investigation follows which centers around a comprehensive test boring program. Borings are spaced according to site conditions and the requirements of the given project. Vital phases of the field exploration program are sample description and testing. Among the soil and rock properties logged in the field description are: color, principal and modifying constituents, hardness, cementation, grading, relative density, consistency, moisture content, particle shape, etc. Field tests frequently include standard penetration tests, miniature vane shear tests, etc. In addition, laboratory tests quantify various properties of samples collected at the site. Some of the common tests include the following:

Soil Tests	Rock Tests
Moisture Content	Specific Gravity
Specific Gravity	Density
Atterberg Limits & Indices	Porosity
Density	Absorption
Grain Size Distribution	Los Angeles Abrasion
Compaction Test	Sodium Sulphate Test
Permeability Test	Unconfined Compression Test
Consolidation Test	Triaxial Shear Test
Unconfined Compression Test	Qualitative & Quantitative
Direct Shear Test	Mineral Identification
Triaxial Shear Test	

1. discussions of the character and depth of soils and/or rock encountered on-site
2. the nature and severity of the problems which these materials might impose on the design or performance of the roadway
3. treatments which might be undertaken to alleviate the potential problems.
4. comments on slope erosion possibilities, occurrence of springs, swamps, seeps, and recommendations for borrow pit locations.

As with any engineering project, the transportation planning project that is most successful is the one which is based on the larger and more detailed array of basic data. The more that is known about an area geologically (i.e., the more available basic data), the fewer the problems, less the expense, and greater the accuracy in transportation planning within that area.

The recent creation of the Remote Sensing Section within the Topographic Office of the State Department of Transportation is an excellent example of current environmentally oriented thinking in transportation planning. The topic of pilot study completed in 1970 by the Remote Sensing Section is the proposed Tampa Bypass Corridor. The study area (about 40 miles long and 4 miles wide) is shown in the figure. The corridor study was based on aerial photographic interpretation with the goal of the project being to locate and identify physical and cultural features within the corridor " . . . to a degree of detail consistent with the information needs for preliminary location and design, and within a time frame . . . more realistic than that required by ground mapping methods."[1] The study includes five separate photo-map series delineating the following: land use, key features, property boundaries, drainage, and engineering soils. Except for the property boundaries series, mapping was based exclusively on air photo interpretation.

The land use maps show 53 different land uses within 12 basic categories. The key feature maps emphasize areas of special land use such as gravel, sand and clay extractive industries, outdoor museums and monuments, etc., which require special consideration during the planning phase. Property boundaries maps show the limits of individually owned land. Drainage maps outline existing drainage patterns at the time of mapping. Soils maps provide an indication of the engineering soil types within the corridor. These can be roughly correlated with the AASHO classification. A portion of one of the engineering soils maps along with the soils classification is shown on this page.

The use of remote sensing can greatly facilitate transportation planning. The potential of multiple-sensor techniques (including black and white panchromatic, black and white infrared, color, and color infrared photography; multi-band photography; and thermal and multi-spectral line scan imagery for indicating thermal properties, vegetative patterns, solution activity, permeability, physiography and potential borrow pits is being investigated. It is hoped that airborne data collection can be implemented to provide rapid, accurate, economical, and detailed information for use by transportation planners.

[1] Remote Sensing Section, Topographic Office, State of Fla. D.O.T., July, 1970, Tampa By-Pass Corridor Study, p. 1

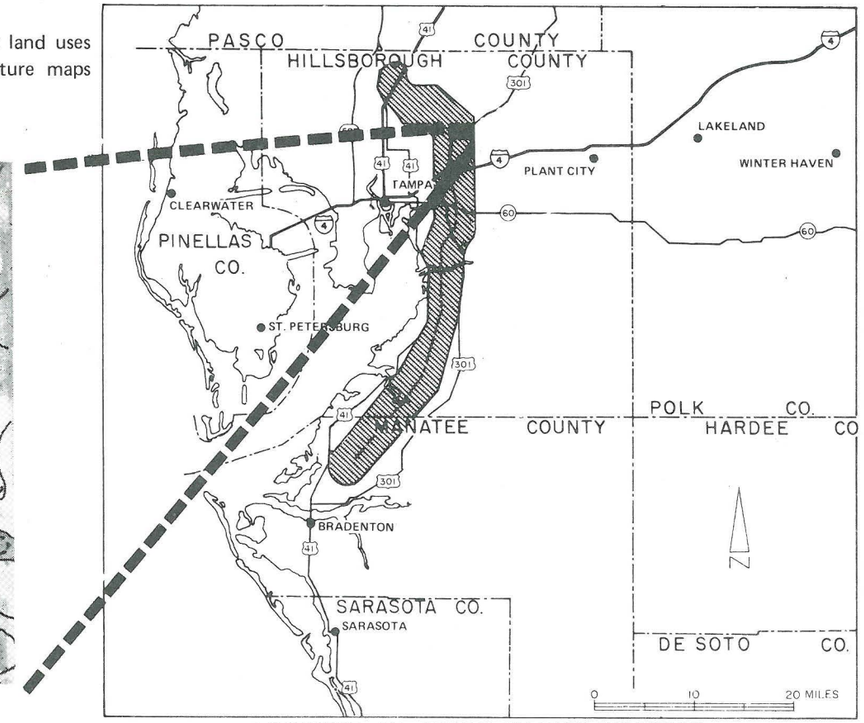
CLASSIFICATION

- C Silty or clayey sand
- R Fine sand
- P Peat and muck
- H Man-made land (filled areas)
- ◌ Sinkhole

1000 0 1000 3000 Feet

Source: DEPARTMENT of TRANSPORTATION

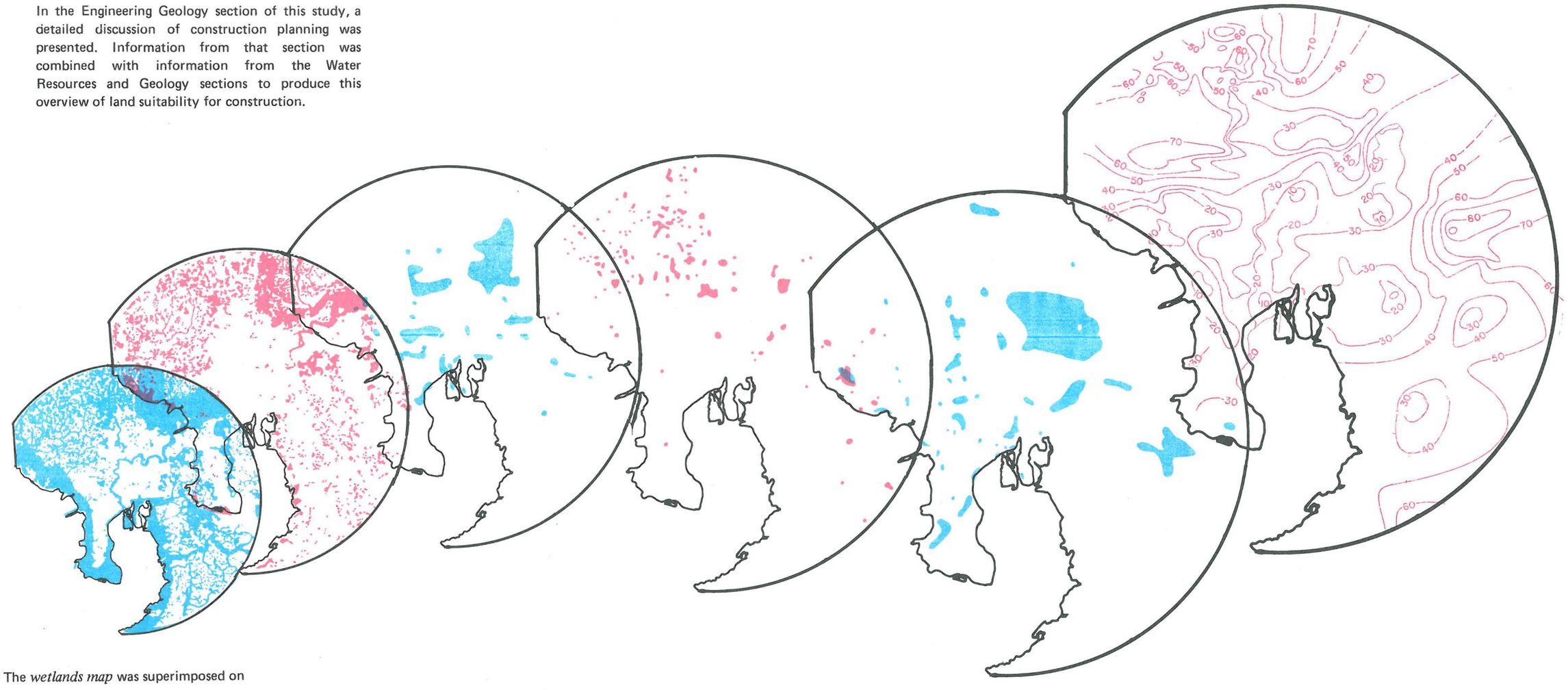
ENGINEERING SOILS MAP



LOCATION of the TAMPA BY-PASS CORRIDOR

GEOLOGIC FACTORS & CONSTRUCTION

In the Engineering Geology section of this study, a detailed discussion of construction planning was presented. Information from that section was combined with information from the Water Resources and Geology sections to produce this overview of land suitability for construction.



The *wetlands map* was superimposed on

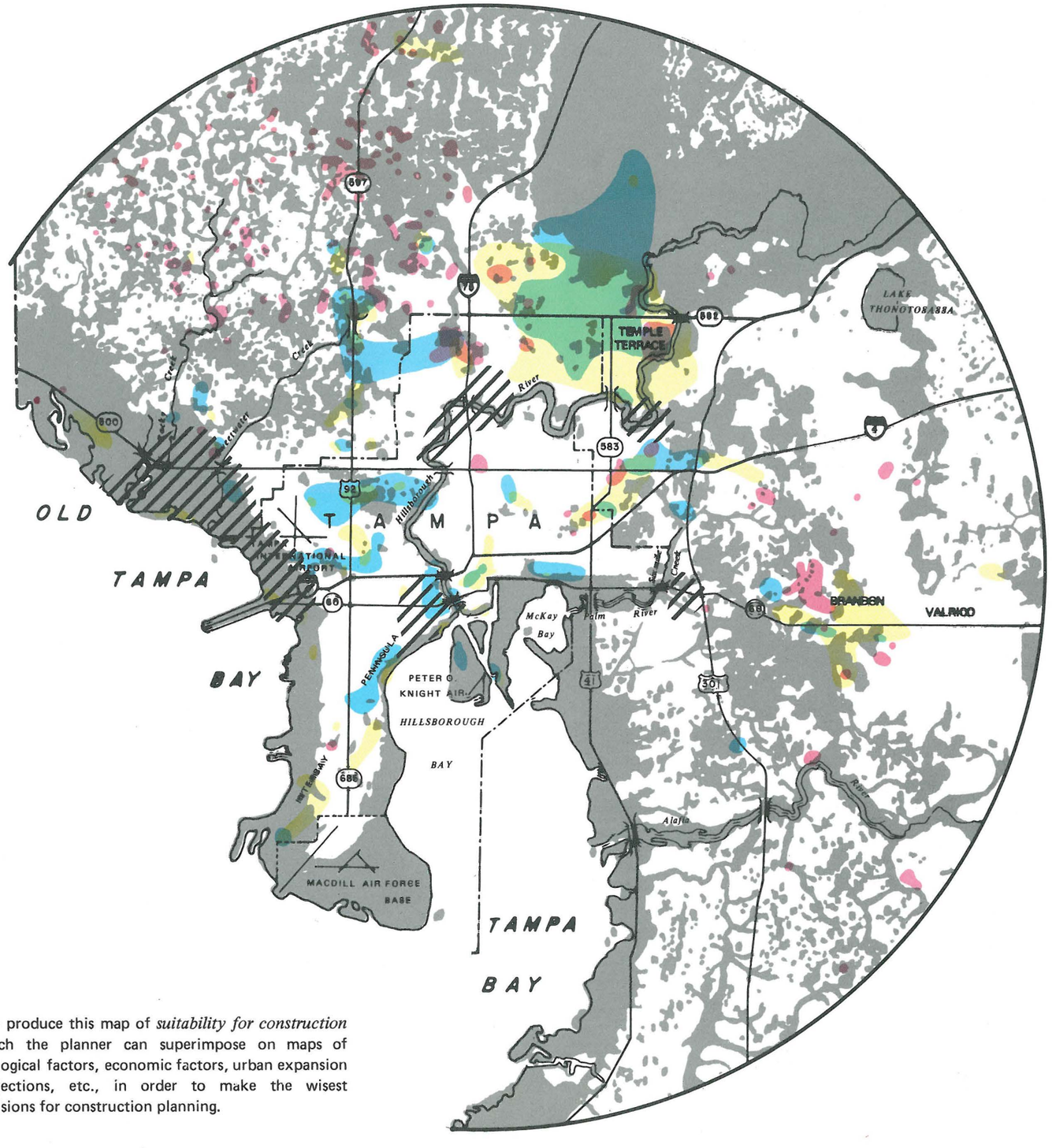
the *flood prone area map* which was superimposed on

the *clay conditions map* which was superimposed on

the *sinkholes and sinkhole-type lakes map* which was superimposed on

the *sand suitability for foundations map* which was superimposed on

the *depth to rock map*.....



...to produce this map of *suitability for construction* which the planner can superimpose on maps of ecological factors, economic factors, urban expansion projections, etc., in order to make the wisest decisions for construction planning.

LAND SUITABILITY FOR CONSTRUCTION

One unfavorable condition:

- flood prone and wetland areas
- sand poor for foundations
- clay poor for foundations
- areas of sinkhole occurence

Two unfavorable conditions:

- floodprone and wetland areas + poor sands
- flood prone and wetland areas + poor clays
- flood prone and wetland areas + sinks
- poor sands + poor clays
- poor sands + sinks
- poor clays + sinks

Three unfavorable conditions:

- flood prone and wetland areas + poor sands + poor clays
- flood prone and wetland areas + poor sands + sinks
- flood prone and wetland areas + poor clays + sinks
- poor sands + poor clays + sinks

Four unfavorable conditions

Areas where rock lies near land surface (suitable for seating piling for high rise structures)

GEOLOGIC FACTORS & SANITARY LANDFILLS

Solid waste disposal has become a topic of concern in the Tampa area where population growth has resulted in increasing production of waste and decreasing undeveloped land areas suitable for waste disposal.

In the past, few controls were placed on solid waste disposal, and site selection was based largely on convenience. Gradually, damaging environmental effects resulting from indiscriminate waste disposal become apparent and the concept of the sanitary landfill was introduced.

The American Society of Civil Engineers defines a sanitary landfill as: "A method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation, or at such more frequent intervals as may be necessary."

Essentially, a sanitary landfill consists of a series of trenches which, in the Tampa area are excavated to dimensions on the order of 400 feet long, 80 feet wide and 10 feet deep. Trash and garbage emptied into the trenches are compacted, then covered daily with a thin layer of earth in order to minimize odor, fire hazard, insect and rodent problems, etc.

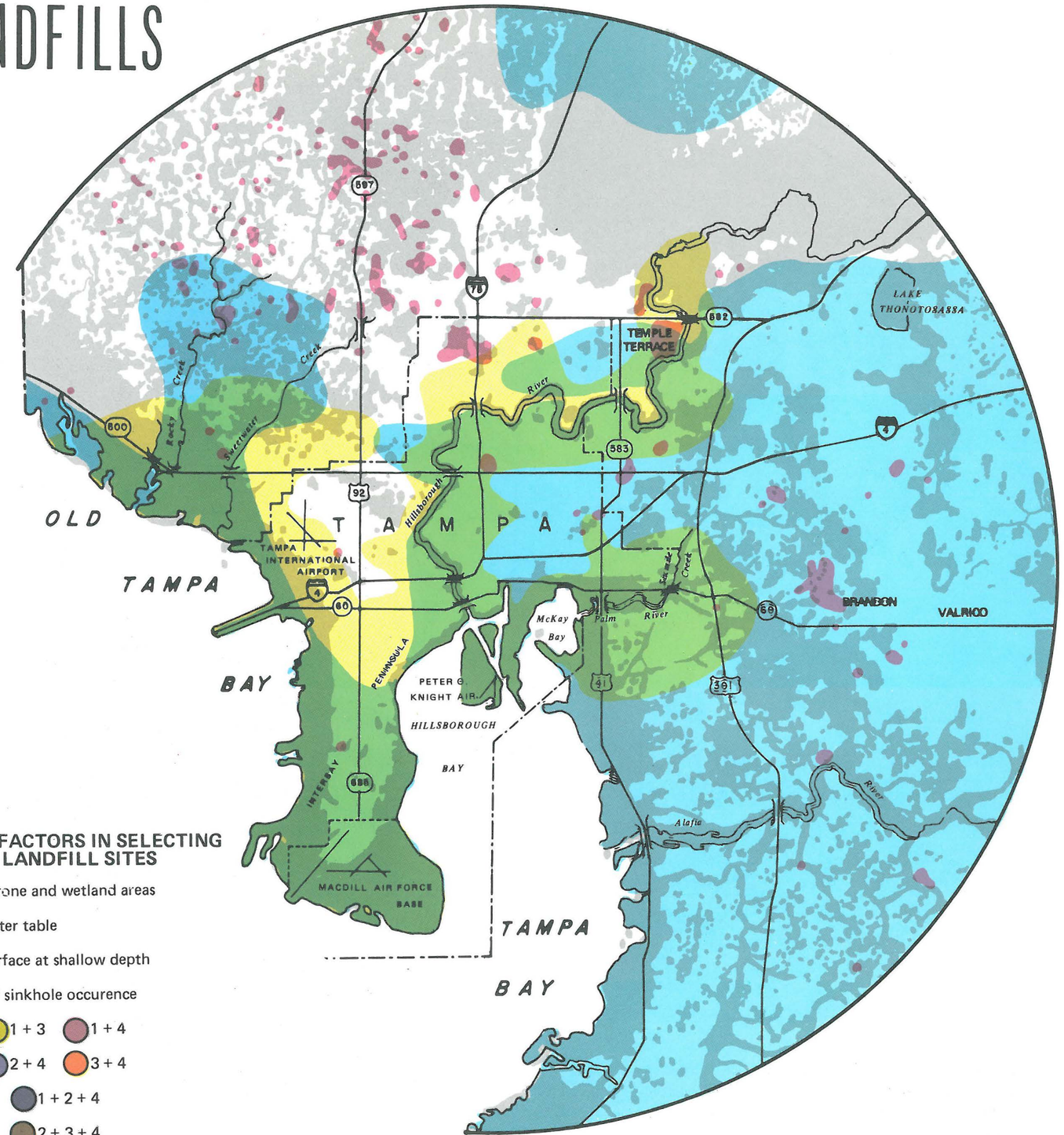
Waterborne pollutants are also a significant potential problem of sanitary landfills. Rains infiltrate the refuse in a sanitary landfill and pick up dissolved solids. Under certain conditions this "leachate" may find its way to a local water supply. For this reason, certain geohydrologic factors must be thoroughly investigated prior to selection of a landfill site.

Among other things, sanitary landfill sites should be relatively "dry" in terms of both surface and ground water conditions, and surficial sediments should be clayey and relatively impermeable. Under these conditions, flow of the leachate may be retarded and potential pollutants filtered and absorbed.

The map presented on this page is based on U.S.G.S.-F.B.G. Map Series 39 and on maps presented earlier in this publication. Rating criteria are as follows:

1. Type of unconsolidated material. Favorable: clay, silty clay, clayey silt, and silt. Unfavorable: sand.
2. Thickness of unconsolidated materials. Favorable: at least 25 feet. Unfavorable: less than 15 feet.
3. Site topography. Favorable: adequate drainage and not subject to flooding. Unfavorable: low swampy areas; areas subject to flooding; sinkholes and areas near sinkholes; along stream channels hydraulically connected with Floridan aquifer.
4. Ground-water levels. Nonartesian aquifer: Favorable: greater than 15 feet below land surface. Unfavorable: less than 5 feet below land surface. Artesian aquifer: Favorable: potentiometric surface at least 5 feet above water table. Unfavorable: potentiometric surface near or below the water table.
5. Character of limestone aquifer. Favorable: dense, unfractured. Unfavorable: fractured and cavernous.
6. Relation to public water supply wells. Favorable: at least several miles downgradient from large pumping withdrawals. Unfavorable: adjacent to or within the immediate cone of influence of large-scale pumping.

Hillsborough County sanitary landfill trench
(photo by J.W. Stewart)



UNFAVORABLE FACTORS IN SELECTING SANITARY LANDFILL SITES

- 1 flood prone and wetland areas
- 2 high water table
- 3 rock surface at shallow depth
- 4 areas of sinkhole occurence
- 1 + 2
- 1 + 3
- 1 + 4
- 2 + 3
- 2 + 4
- 3 + 4
- 1 + 2 + 3
- 1 + 2 + 4
- 1 + 3 + 4
- 2 + 3 + 4
- 1 + 2 + 3 + 4

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