# CHAPTER 3 EFFECTS OF DRAINAGE ON THE EVERGLADES, 1880'S TO 1940'S

## INTRODUCTION

The 1940's were a turning point in the environmental history of the Everglades. Following the initiation of anthropogenic drainage in the 1880's, large portions of the Everglades had become accessible. The overall efficacy of the canal system had been apparent for some time; in fact there was growing concern that it had been too effective and that drainage should be focused only on the parts used for agriculture. These considerations, along with a major flood during 1947, eventually led to the creation of the federal "Central and South Florida Project for Flood Control and Other Purposes" (C&SF Project), beginning in 1948. Prior to that, a number of governmental agencies collaborated on extensive studies of the Everglades (e.g., refs from Fla soil sci soc. 1943, 44; USDA-SCS 1940; Parker *et al.* 1955). Two key products of this effort were the first detailed maps of the entire region, the soil map of Jones *et al.* (1948) and the vegetation map of Davis (1943). Both provide an excellent picture of the region, a snapshot of its status in the early 1940's. However, because they are the earliest comprehensive maps, they have later sometimes been used, erroneously, as *de facto* estimates of pre-drainage conditions in the Everglades –despite the influence of nearly sixty years of water levels lowered by canal drainage.

In this chapter we combine historical and early scientific sources to examine the time sequence of Everglades drainage, and particularly to identify the physical and ecological changes that took place between the 1880's and the 1940's. Changes in the landscape were dramatic, rapid, and extensive. Enormous areas that originally had been covered by surface water much or all of the year became areas of exposed peat soil, with water tables several feet below ground surface; as much as nine feet below in some areas (Operations Dept. 1928; Clayton *et al.* 1942). Sheet flow disappeared from large areas, recurring only under particularly wet conditions. Large areas of organic soils decomposed and subsided (Clayton 1943; Stephens and Johnson 1951), or burned outright. In the northern Everglades, the resultant topographic changes were great enough to reverse the direction of surface runoff (Davis 1943). Not surprisingly, vegetation communities were also substantially altered (Baldwin and Hawker 1915; Davis 1943). In short, many of the most severe changes to the Everglades had already occurred prior to initiation of the extensive C&SF Project in 1948.

After presenting the evidence for widespread, severe hydrologic changes as a result of drainage, the remainder of this chapter focuses on four aspects of Everglades landscapes affected by these alterations: soil subsidence and topography, peat fires, soil type, and vegetation. Understanding these effects provides a means to better understand the landscapes as they were mapped in the 1940s, as well as to better understand their original, pre-drainage condition.

**PHASES IN EVERGLADES DRAINAGE HISTORY**

Anthropogenic changes in the landscapes of the Everglades can be most clearly understood by distinguishing three phases of drainage history (Light and Dineen 1994). The first two, the Lake Okeechobee Phase and the Muck Canal Phase, both lowered water depths throughout the Everglades. In contrast, the third phase, here referred to as the Impoundment Phase and initiated by the C&SF Project partially reversed the previous lowering, and actually increased water depths in the area north of Tamiami Trail. The first two phases reduced sheet flow in the Everglades simply by diminishing water depths and later also by channeling flow into canals, but few actual barriers to flow were created (**Figure 3.1**). At high water levels, water could and occasionally did flow *across* canals (Parker *et al*. 1955).

The third, Impoundment Phase was motivated in part by recognition that not all of the Everglades was suitable for agriculture, and that therefore those portions would be better left undrained (Anonymous 1938; Staff 1958). It was also recognized that these undeveloped portions of the Everglades had already suffered serious soil loss from peat fires (Anonymous 1938; Advisory Committee 1944) as well as from microbial decomposition induced by drainage (Allison *et al.* 1927; Clayton 1943). One of the goals of the Impoundment Phase was therefore to raise water levels in the undeveloped portions, keeping the soil wet and protected from further loss (Anonymous 1938; Clayton *et al.* 1942; Therkildson 1943).

The C&SF Project created an extensive system of levees, designed specifically to hold water within enclosed "Water Conservation Areas" (Light and Dineen 1994). As the levee systems were completed in the 1950s and 1960s, average water depths increased, coming closer to pre-drainage water depths. Ecologically, the Impoundment Phase generally improved average water depths, but at the expense of increased fluctuations and the elimination of the free flow of water across the remaining Everglades. Sheet flow that once occurred across the full width of the landscape was replaced by a few managed structures discharging water from one impoundment to the next.

We distinguish these different drainage phases to clarify timing as well as effect. The spatial patterns of vegetation, soils and topography mapped in the 1940s were the combined result of the original pre-drainage patterns, modified by the quite drastic effects of the first two drainage phases. The landscape conditions presently found within the remaining Everglades are an even more complex combination of the original pre-drainage patterns, modifications by the first two drainage phases, and further modifications by rewetting during the third (Impoundment) phase. The original pre-drainage patterns, the conditions mapped in the 1940s and the conditions present are considerably different. Attempts to relate them must take all phases of the water management history into account.

***Lake Okeechobee Phase***

Hamilton Disston initiated extensive drainage efforts in the Kissimmee Valley in approximately 1880. These efforts altered the timing of Kissimmee inflows into Lake Okeechobee, shortening the duration and increasing the amplitude. Alteration of the total annual volume of inflow was probably slight.

In the Caloosahatchee Valley, a reconnaissance survey by the Army Corps of Engineers in 1879 noted that residents had been flooded, that they had specifically requested a lowering of Lake Okeechobee, and that an outflow from the Lake was technically possible (Meigs 1879). At that time, prior to anthropogenic alterations, the headwaters of the Caloosahatchee River disappeared in a wide sawgrass marsh three and a half miles west of Lake Okeechobee and two miles west of Lake Hicpochee (**Fig 4.13**; Tannehill 1871; Meigs 1879; Kraemer 1892; Heilprin 1887). This extensive marsh of nearly impenetrable sawgrass (Meigs 1879; Sackett 1888) was lush: the sawgrass 10 to 15 feet tall (Meigs 1879), with peat soil from 3 to 6 feet in depth, 15 to 16 feet in the deepest portions (Wiley 1891; Kraemer 1892). In the dry season of 1879 (March-April), water, 10 to 20 inches deep, covered the marsh (Meigs 1879).

Disston sought to make the rich soils of these “Okeechobeee Muck lands” available for agriculture. To do this, he knew he would have to lower the level of Lake Okeechobee by several feet (Harney 1884; Wiley 1891). By 1884, Disston's company had excavated a canal from Lake Okeechobee to Lake Hicpochee (the "Three Mile Canal"), 22-foot wide and with a reported drop of "one foot to the mile" (Harney 1884). The Three Mile Canal passed through an area of 10 to 11 feet deep sawgrass peat (Kraemer 1892), and appears to have been cut down to bedrock:

> "The stratification as developed in the cutting beginning from the bed-rock is clay and marl under white sand, overlaid by a deep bed of muck. The depth and rankness of this superficial deposit are extraordinary." (Harney 1884, p. 604)

Also by 1884, Disston's company completed a second canal from Lake Hicpochee to Lake Flirt, thus creating a continuous connection from Lake Okeechobee to the Gulf of Mexico. After 1884, and some time prior to 1892, an additional "Nine Mile Canal" was excavated from Lake Okeechobee to Lake Hicpochee (Kraemer 1892), presumably suggesting that the Caloosahatchee River was found able to accommodate more outflow than from the Three Mile Canal alone. A 1918 map (Merriam and Frederick 1918-T42 R32) shows a one mile extension of the Three Mile Canal toward the center of Lake Okeechobee, suggesting that prior to 1918 the lake level had already lowered sufficiently to move the shoreline inward.

Firsthand observations published in the Minutes of the Trustees of the Internal Improvement Fund suggest that Disston’s canals succeeded in lowering Lake Okeechobee a number of feet, enough to draw water tables in the Okeechobee Muck lands several feet below land surface. The following, by the State Engineer, H. S. Duval, observing between July 15 and August 15, 1884, is representative:

> “On reaching the margins of the great prairies of Lake Hickopochee and Okeechobee, formerly covered with saw-grass, but now partially clothed in a new vegetation, I was surprised to see them after so much rain, otherwise than thoroughly inundated, but for miles and far away, we rode over them, dry-footed, in our two horse vehicle leaving the woods faintly outlined in the distance. …
>
> Taking a general view of the whole subject I am constrained to say from observation taken on the spot that a radical and recent change has taken place in that portion of Florida, for the vegetation is rapidly changing its character, from the aquatic to the dry land varieties. The saw-grasses are disappearing before the highland prairie grasses while the saw palmetto, fresh and new born is vigorously hurrying forward its monopoly in spreading out its meshes of concatenated roots, far and wide over the reclaimed prairies.” (Duval 1884).

Observations made between 15 October and November 26, 1884 by James M. Dancy, "appointed [by the TIIF] to examine the Southern or Caloosahatchie Division of the Drainage District," give a similar impression of the dramatic lowering of the lake and of water tables in the former sawgrass marsh:

> "4th. I traversed the Western Shore of Lake Okeechobee with the same results [as for Fisheating Creek] the lake now has a defined margin, and that margin, and prairie as far as the eye can reach is putting on a new growth both of plants and grasses and grasses which do not grow in water.
>
> 5th. I next entered the canal which is cut into Lake Hichpochee, a lake which United States Surveyors never found, taking it for granted it was all vast saw grass. This lake as Lake Okeechobee has now defined margins, the prairies at least three feet above the water level, and dry enough for cultivation. From this lake the canal has been since Col. Duval's examination partially cut to double its original width to Lake Flirt, the head of Caloosahatchee River, a distance of 22 miles, and I can assure you that at this time just at the end of a severe rainy season water can not stay in that country, with a current of from 4 to 6 miles per hour pouring through the canal and over the rock rapids at Fort Thompson. I predict that in less than one month Lake Flirt will be a lake of the past, for the dry prairie now extents at least one fourth mile out into it, and it will very soon be within the banks of the canal." (Dancy 1884).

Disston's lowering of Lake Okeechobee levels would have had great ecological significance for the Everglades as a whole, not just for the Okeechobee Muck lands bordering the southwestern border of the lake. The Okeechobee Muck lands were simply a continuation of the Sawgrass Plains portion of the Everglades. Under natural conditions prior to any drainage, the whole southern half of the Lake Okeechobee shoreline spilled into the Everglades at much the same time and same elevation (**Chapter 4**). Dancy's observation—during the late wet season—that the lake "now has defined margins" with the bordering land "at least three feet above water level" revealed that Disston's efforts had effectively eliminated all surface flows from Lake Okeechobee into the Everglades.

Firsthand observations by a steamboat and dredge captain suggest that the elimination of surface flows into the Everglades persisted for more than a decade:

> "On Sept. 23rd, 1894, Captain Menge wrote: 'I could not get any steamboat through the canals, and had to abandon my trip to Ft. Bassenger; there was only sixteen inches of water in the canal west of Hichpochee, there was seven feet when we cut it. The surface of the marsh is from 4 to 5 1/2 feet above the water in

> the canals from Lake Flirt up to Lake Okeechobee. The cattle feed all around Lake Hichpochee, and turkey, deer and hogs on Lake Okeechobee.
>
> Lake Okeechobee must be 7 feet lower than when we tapped it in 1882.'" (Disston 1895, p. 333-334).

The history of Lake Okeechobee water levels, and of outflows into the Everglades, after the collapse of Disston's company in 1895 is harder to determine. It appears likely that Disston's canals were not maintained, that their capacity decreased, and that water levels in the lake again rose. By about 1903-1905, when interest in draining the whole of the Everglades again rose, it appears that Lake Okeechobee water levels must have returned closer to pre-drainage levels and that outflows into the Everglades had resumed. Nevertheless, the ten or more years during the late 1800s when Lake Okeechobee apparently stopped flowing into the Everglades are likely to have had a lasting influence.

### *Muck Canal Phase*

The next period of drainage activity, referred to in Light and Dineen (1994) as the "Cut 'n Try Era," began about 1905 and continued into the early 1930s (**Table 3.1)**. We title it the Muck Canal Phase because four major canals built during this phase, the West Palm Beach Canal, the North and South New River Canals, the Hillsboro, and the Miami Canal, were created simply by dredging "muck," that is, peat soil, out of the Everglades. Only a short fraction of the overall length of each was dredged through rock, where the canals approached the coast. This meant that, within the Everglades, the spoil banks of these canals were just piles of peat soil. The banks appear to have disappeared, through some combination of oxidation, subsidence, fire and physical sloughing off, such that fairly quickly these canals became simple swaths, cut down through level surface of the landscape. The hydrologic and ecological significance of this is that these canals had no associated levees, meaning that (1) they drained the landscape along the full length of their passage through the Everglades, a point that will become relevant in the discussion of the later Impoundment Phase; and (2) these canals, or cuts through the landscape, did not impede sheet flow. During times when surface water was present, it could flow right across the canals with little or no limitation.

In addition to the muck canals, the major drainage-related structures built during this period were the St. Lucie Canal, the levees around the southern shore of Lake Okeechobee, and the borrow canal and levee associated with the Tamiami Trail highway. The canal connecting the

Caloosahatchee River to Lake Okeechobee was also re-dredged during this period. The focus of these efforts was two-fold: the lowering of water levels in Lake Okeechobee to eliminate outflows into the Everglades (Williams *et al.* 1911; Wright 1912); and the drainage of the Everglades themselves to make land available for agriculture. In contrast to the Caloosahatchee and the Muck Canals, which increased natural flows in approximately their original direction, the St. Lucie Canal connecting Lake Okeechobee to the Atlantic Ocean was a completely man-made watercourse; it did not follow a natural channel, nor even a natural slope.

The four muck canals were part of a larger set proposed canals, apparently envisioned to follow the original slope of the Everglades toward the original outlets. The four muck canals followed the southeasterly slope of the northern and eastern Everglades, connecting with the coastal rivers that drained Everglades water into Biscayne Bay and the Atlantic. A second, more southerly set of canals, never built, would have followed the southwesterly slope, draining into Florida Bay (FEEC 1914; Elliot 1927; **Fig. 5.9**). The construction of Tamiami Trail, which appears to have diminished southwesterly flows, and the plans for an Everglades National Park may both have been contributing reasons for not building the second set of southwesterly canals.

Three of the four muck canals, the North New River, Hillsboro, and Miami, were begun in the 1910s and opened by 1915. The fourth, the West Palm Beach Canal, was likely finished within the following five years. Contemporary accounts give a sense of the dramatic and rapid effectiveness of the Muck Canals. The following observations of the North and South New River Canals were made in the fall of 1907:

> "That the canals are a success and are reclaiming the land as the dredges progress, is thoroughly established. The canals reduce the water level from the surface to a point six feet below the surface of the ground as shown by the water in the canal, and the land for a mile on either side of the canal is entirely reclaimed, and is practically ready for preparation for cultivation, and the general influence of the drainage reaches to a much greater distance than one mile." (Jennings 1907, p. 122).
>
> "… the positive truth is that the superintendent finds it necessary to keep a sufficient quantity of water in the canal to float the dredge, while in front of the dredge the water is pouring over the front of the canal and falling six feet over a perpendicular dam to the water level of the canal and thus going on to the ocean.
>
> The result is that the reclamation of the land is fully demonstrated. We walked for a distance of half a mile or more along an Indian trail or canoe route through the saw grass, where twenty days ago the Indians traveled with their boats and

canoes, the water having all been drawn off from this territory by the cutting of the canal, thus lowering the water level." (Jennings 1907, p. 125).

**Table 3.1.** Approximate dates of initial construction and open for service of major hydraulic works affecting the Everglades. Opening dates are less well-defined as improvements, redredging, widening etc. of canals often continued for a number of years.

| Canal | Initiated | Opened | Citation |
|---|---|---|---|
| Three Mile Canal, Lake Hicpochee to Lake Flirt Can. | 1882? | 1884 | Meigs 1879, Harney (1884)<br>Harney (1884) |
| Small, local truck farming canals related to railroad | >1896 | [1897?] | Jones *et al.* (1948) |
| North New River Canal | 1906 | 1912 | Interbureau Committee (1930)<br>Clayton (1936) |
| South New River Canal | 1906-1909 | 1913 | Marston *et al*. (1927)<br>Fla. Everglades Eng. Comm. (1914) |
| Miami Canal | 1910 | 1913[1] | Marston *et al*. (1927)<br>Fla. Everglades Eng. Comm. (1914) |
| Hillsboro Canal | 1910 | [1915?] | Marston *et al*. (1927)<br>Jones *et al. (1948)* |
| West Palm Beach Canal | 1913-1917 | [1920?] | Marston *et al*. (1927) |
| St. Lucie Canal | 1916 | 1926 | Marston *et al*. (1927)<br>Elliot (1927) |
| Caloosahatchee Canal | 1915 | 1925[2] | Marston *et al*. (1927)<br>Herr (1943) |
| Lake 0. South Shore Levee[3] | 1921 | 1926 | Marston *et al*. (1927)<br>Parker *et al*. (1955) |
| Lake 0. Levee[4] | 1932 | 1938 | Parker *et al*. (1955)<br>Parker *et al*. (1955) |
| Tamiami Trail & Canal | 1916 | 1928 | Tamiami Trail Commission. (1928)<br>Tamiami Trail Commission. (1928) |

1 Dupuis (1954b), a doctor who settled in the Lemon City area north of Miami in 1898, gives 1911 as the date of opening for the Miami Canal. Gaby (1992) states March 1912.
2 According to Herr (1943), Chief Engineer of the Okeechobee Flood Control District, 1929-1943+: "The Caloosahatchee Canal had been in existence prior to that time [19251 but its capacity was small and it had little effect on Lake elevations." A second project increasing its capacities was completed in 1938.
3 This was a low muck levee. It was seriously breached during the hurricanes of 1926 and 1928.
4 This is a much more solid levee constructed by the Corps of Engineers with a top elevation of 32-34 feet above m.s.l. (Herr 1943).

A similarly dramatic decline in water levels occurred a few years later when the Miami Canal was first opened:

> "However, when the Miami Canal locks were opened in the early part of 1911, garden vegetables in the edge of the Everglades died, and some of the driven wells, 25 feet deep, went dry as far east as the Florida East Coast Railway, a distance of four miles." (Dupuis 1954b, p. 43).

Narrative observations of the dramatic lowering of water levels due to muck canal construction can be supported by a quantitative comparison of canal discharge with the pre-drainage Everglades water budget. Early canal discharge measurements do not appear to exist, but data collected during a U.S. Geological Survey study are available for the 1940-1946 period, and were considered by the authors, Parker *et al*. (1955), as likely to be representative. The land area drained by the canals shown in **Table 3.2**—the portion of the Everglades north of Tamiami Trail—was approximately 1.9 million acres. Assuming approximately 53 inches of rainfall per year (Abtew 2004) and 52 inches of evapotranspiration (Abtew 2004), net annual precipitation (runoff) for this area would have been 1 inch, equivalent to approximately 160,000 acre-feet. (Contributions from Lake Okeechobee were excluded from this calculation because lowering of lake levels and later the construction of a levee along the southern shore reportedly eliminated natural outflows into the Everglades after about 1915.) The total annual canal discharge, 1,700,000 acre-feet (**Table 3.2)**, is more than ten times this estimate of the net annual precipitation. While not all of the coastal discharge shown in Table 3.2 was derived from drainage of the Everglades—coastal uplands also contributed a portion—the Everglades certainly contributed a large fraction. It seems very likely that the Muck Canal conveyance out of the Everglades exceeded net annual precipitation, implying that these canals would also have been removing stored water. This would be consistent with the narrative accounts of water levels having been lowered, over a small number of years, from several feet above ground surface to several feet below.

**Table 3.2**. Annual canal discharge, 1940-46 (Parker *et al*. 1955). Units: 1,000 acre-feet.

| Canal | 1940 | 1941 | 1942 | 1943 | 1944 | 1945 | 1946 | Mean |
|---|---|---|---|---|---|---|---|---|
| **W. Palm Beach** | 854 | 1109 | 842 | 502 | 459 | 575 | 741 | 726 |
| **Hillsboro** | 342 | 583 | 414 | 83 | 97 | 149 | 173 | 263 |
| **No. New River** | 401 | 638 | 472 | 148 | 94 | 178 | 231 | 309 |
| **Miami** | 479 | 599 | 545 | 299 | 227 | 277 | 456 | 412 |
| **Total** | 2076 | 2929 | 2273 | 1032 | 877 | 1179 | 1601 | 1710 |

As the northern and central portions of the Everglades were being drained by the four Muck Canals, the canal and the levee associated with the Tamiami Trail highway (U.S. 41) were lowering water depths in the southern Everglades. Tamiami Canal differed from the Muck Canals in that its position and alignment had been determined almost exclusively by transportation needs, not by the natural slope of the landscape. Unlike the muck canals, which mostly ran approximately parallel to the pre-drainage flow direction (and slope), the Tamiami Canal ran almost exactly perpendicular to the flow direction. Lowering of water levels in the southern Everglades was probably more the result of partial blockage by the Tamiami Trail roadbed than it was the result of drainage by the Tamiami Canal. Captain Jaudon and other promoters of the Tamiami Trail had extensive interests in several townships of Everglades land south of the proposed Tamiami Trail and hoped to drain the lands for farming (King 1917c; 1917d; 1917e; 1917g; 1917h). Blockage of southward flow of Everglades water and diversion to the sea was an explicit goal of the Trail promoters:

> "The idea actuating the Dade County Commissioners was that the drainage of the Everglades would be promoted by the construction of the proposed road, because it was the plan to dig a canal and use the rock excavated from the canal for the road bed. The canal would constitute a waterway of value in draining the adjacent lands, and the drainage thus affected would enhance their value to the State." (Tamiami Trail Commissioners 1928).

J. H. Tatum, a Miami resident, publicly opposed the road plan because of a concern for flooding upstream from the proposed road. Tatum was apparently unconvinced that the borrow canal to be dug on the north side of the road-bed levee would successfully divert all the water coming from the north to the sea:

> "[At a Sept. 8, 1915 public meeting] Tatum claimed that the building of the road across the Everglades would flood Dade county [north of the proposed Tamiami Trail], and he was unalterably opposed to spending money to turn a deluge of water upon the valuable lands of this county." (Tamiami Trail Commissioners 1928).

Tatum's concerns apparently were well-founded. Only a few years after initiation of dredging and levee construction in 1916, upstream flooding due to blockage of southward flow across Tamiami Trail was indeed noted. In a written response to a 1923 complaint by the Pennsylvania Sugar Company ("Pennsuco"), F. C. Elliot, Chief Engineer of the Everglades Drainage District, agreed that the Tamiami Trail,

> "... act[ed] as a continuous dam across the Everglades preventing the natural flow of water and jeopardizing [by flooding] the lands East and Northwest along the Tamiami trail and Miami Canal" (June 23, 1923 letter from F. C. Elliot; in Graham 1951).

Despite this official recognition of the problem by Elliot, blockage of flow by the Tamiami Trail was still reported seven years later:

> "Federal Highway No. 94, locally known as Tamiami Trail, has been built across the 'lower glades,' ... It serves to check, to a substantial degree, the further southward movement of those waters to their ultimate outlet at the southern end of the State." (Okeechobee Flood Control District of Florida 1930).

Reduction of flow to the southern Everglades continued until sometime between 1930 and 1939, when conveyance under the Tamiami Trail roadbed was apparently increased. In 1939, the U.S. Geological Survey began measuring discharge through lateral canals extending under the Tamiami Trail (Parker *et al*. 1955). Leach, Klein and Hampton (1971) include a table showing locations of irregularly spaced bridges, apparently placed to match natural flowways.

Other drainage projects undertaken during the Muck Canal Phase include completion of the St. Lucie Canal and enlargement of the Caloosahatchee Canal in the mid 1920's, and construction of a muck levee along the south shore of Lake Okeechobee. The east-west running canals likely shifted some of the burden of keeping water levels in Lake Okeechobee low away from the Muck Canals. Ecologically, completion of the muck levee may not have had a strong effect as lowered lake levels had already eliminated most outflows into the Everglades.

The works of the Lake Okeechobee and Muck Canal Phases –hydrologic isolation of the Everglades from Lake Okeechobee, completion of the four Muck Canals, completion of the St. Lucie and Caloosahatchee Canals, and the construction of Tamiami Trail– all had strongly affected the Everglades by 1940 resulting in lowered water tables throughout the Everglades basin.

A perhaps obvious, but sometimes overlooked effect of lowering the water table below the surface of the Everglades was the elimination of sheet flow. The mechanistic relationship between the presumably low velocities of pre-drainage sheet flow and the highly directional landscape patterning of the Everglades (**Chapter 4**) is still unknown, but it appears very likely that some aspect of water flow affected the patterning. Elimination of sheet flow during much of the Muck Canal Phase, and over much of the Everglades, almost certainly has played a role in the post-drainage alteration of the original patterns.

***Impoundment Phase***

The Impoundment Phase corresponds to the extensive, federal C&SF Project, initiated in 1948. Light and Dineen (1994) chronicle the construction of this phase, primarily during the 1950s and 1960s, in detail. While detailed analysis of the hydrologic and ecological changes to the Everglades caused by this project would cover a different time period and is left to other researchers, certain comparisons with the preceding two drainage phases, and to pre-drainage conditions, can be helpfully made.

In addition to increasing flood protection for existing and projected eastern urban areas, the C&SF Project sought to shift the intensity of canal drainage away from the portions of the Everglades which were considered unfit for agriculture (but important for wildlife and recreation), and toward the still inadequately drained agricultural areas. The agricultural areas primarily surrounded the upper reaches of the Muck Canals, near Lake Okeechobee. The lower reaches of these canals passed through the portions of the Everglades assumed unfit for agriculture. Since the Muck Canals had no associated levees, as their original spoil banks had oxidized and subsided away, the efficiency of drainage of the upper, agricultural areas was compromised by the water draining into the lower reaches. At this point in time, it was becoming clear that this water should be conserved.

An important aspect of the C&SF Project was therefore to provide the lower reaches of the Muck Canals with levees, such that they could efficiently transport the water drained from the agricultural areas, without draining unwanted water from the more “natural” areas. These levees created a series of three large impoundments, called “Water Conservation Areas,” where water would be held for wildlife and recreation, as well as for flood control and water supply for the urban areas.

The setting of target water levels for these areas was intentional, and was designed to avoid hurricane tides (seiches) within the impoundments that might threaten the structure of the levees (Corps of Engineers 1957). This resulted in significantly higher water, nearing pre-drainage levels, compared to the overdrained levels associated with the Muck Canal Phase .

Botanists, including J. H. Davis, were asked to suggest water depths that would promote emergent vegetation that could act as baffles against seiches. The recommended vegetation pattern was in fact not greatly different from the pre-drainage vegetation (Givens 1957, Davis 1957, Andrews 1957).

However, these impoundments, being on a sloped surface, could not avoid creating artificial internal depth gradients: too shallow at the upstream end and too deep at the downstream end. Additionally, having been created in part for water storage, the temporal variance of water depths was *increased* above pre-drainage levels, with more water being added during the wet season and more drawn out during the dry season. In addition, the simple creation of impoundments greatly reduced sheet flow across the landscape.

These conditions were specific to the impounded areas of the Everglades north of Tamiami Trail. Conditions in the still free flowing system south of the Trail were not as extreme in terms of depth gradient disturbance, however the volume and timing of flows to Everglades National Park were altered.

**HYDROLOGIC CHANGE**

In this section, we examine the available quantitative and narrative data to assess the degree of hydrologic change caused by the Lake Okeechobee and Muck Canal Phases of anthropogenic drainage. We also use these sources to estimate how quickly the hydrologic changes occurred. While the number of different quantitative sources is small, each includes a substantial number of data points, given a good indication of spatial and temporal trends. Qualitative sources provide a way of extrapolating the quantitative data to larger areas. Two main types were found: observations from agricultural researchers working in the northern Everglades and observations from surveyors and biologists traversing the southern Everglades. Some additional information was available from the agriculturally used areas encroaching westward into the Everglades from Miami and the pinelands to the southwest. Indirect information was also available from groundwater changes observed within the coastal ridge, particularly the progress of salt water intrusion. Generally, the sources all suggest significant lowering of water levels over large areas as early as the 1920's; earlier in specific areas.

***Quantitative Sources***

**Figure 3.3**, **Figure 3.4**, and **Figure 3.5** help illustrate the magnitude of the changes between pre-drainage and post-canal (1920s-1930s) conditions. **Figure 3.3** shows 350 field measurements of water depths (distance above ground surface) in the Everglades, made in the dry season of 1915, three years after opening of the New River Canal. Points at each milepost represent the average and standard deviation of the six or eight measurements made by Baldwin and Hawker (1915) along transects perpendicular to the canal; one transect at each milepost. Clearly, drainage had already depressed the water table along the first 10 miles of each end of the canal. Nevertheless, standing water was still present along most of this transect through the Sawgrass Plains and the Ridge and Slough landscapes (See **Plate 13** for landscape locations and **Chapter 4** for landscape descriptions).  The measured depths of standing water provide an important benchmark against which to compare the later effects of canal drainage. Depths in the central portion of the canal - about one-half foot in the Sawgrass Plains and about one foot in the Ridge and Slough - constitute a lower limit for pre-drainage water depths typical for February-March in these landscapes. These depths measured in 1915 would be lower than the long-term, pre-drainage average for February-March for two reasons: the influence of canal drainage, and the below average rainfall that occurred during the previous year (Parker *et al*. 1955, pp. 36-39).

As would be expected from the pre-drainage nature of the two landscapes, the water depths measured in the Sawgrass Plains were shallower than those in the Ridge and Slough landscape. The higher variability in the Ridge and Slough area is consistent with the greater topographic variation originally present in this landscape (**Chapter 4**).

**Figure 3.4** compares the 1915 conditions shown in **Figure 3.3** with measurements made in 1939, a quarter century after opening of the major canals. The measurements were made in the spring (January to March) in both cases, and precipitation for the two years was approximately comparable. The ground surface as well as the water table near mileposts six through eight of the New River Canal had declined dramatically: the surface of the peat soil by three feet; the water table by five feet. Instead of being above ground as in 1915 and under pre-drainage conditions, by 1939 the water table was *below* ground, half way between the peat surface and the underlying bedrock.

**Figure 3.5** shows seventeen years of water table measurements from the Hillsboro Canal at Shawano. This point in the Sawgrass Plains landscape was located at mile 17 of the Hillsboro Canal; Township 45, Range 38, between Sections 13 and 14; about 5 miles NW of the border with the Ridge and Slough landscape. Parker considered these measurements to be a reliable measure of hydrologic conditions in the surrounding area, in this case the formerly inundated marsh of the Sawgrass Plains landscape:

> "Records of water levels in the Everglades are extremely useful in showing the nature and the trends in water conditions over the immediate surrounding area. When such a record is collected on a canal, the stages usually are representative of a large area. For this reason, the record of daily stage of Hillsboro Canal at Shawano, collected since January 1, 1929, is worthy of special attention because it is the longest continuous period of record known in the Everglades." (Parker *et al*. 1955, p. 371).

Two important conclusions regarding the degree and timing of drainage can be drawn from **Figure 3.5**. First, the data indicate that during the dry season, canal drainage depressed the water table to approximately three feet below ground surface. Parker states,

> "...the ground surface at Shawano was about 15 feet above mean sea level." (Parker *et al*. 1955, p. 371).

This likely applies to the early 1940s, the main period of Parker's Everglades research. Slope is estimated from Stephens and Johnson (1951) and Clayton *et al*. (1942). This strongly suggests that the similar depression shown previously in **Figure 3.4** was not unique to the two transects closer to Lake Okeechobee, but in fact typical for the post-drainage Sawgrass Plains landscape during the 1930s and early 1940s.

Second, with the exception of a dip reflecting the 1943-45 drought (Parker *et al*. 1955, p. 36-39), the measurements of elevation of the water table do not show a declining trend over the seventeen year period. During this time period, the water balance in this area included only rainfall, evapotranspiration, and lateral seepage through soils (or bedrock) to the canals; inflows from Lake Okeechobee had ceased well before 1929 with lowering of lake levels and construction of a muck levee (**Table 3.1**). The presence of the water table below ground surface means that surface runoff had also ceased. The absence of a further decline during the 1929 to 1946 period of record indicates that the dramatic drawdown of the water table already had been effectively completed prior to 1929.

***Qualitative Sources***

Soil scientists and drainage engineers working in the northern Everglades (Clayton 1936, Clayton *et al*. 1942) were well aware of the dramatic changes shown in **Figures 3.3 to 3.5**. They were particularly concerned about permanent loss of the peat soil. Lowering of the originally above-ground water table to well below ground surface had exposed the peat to oxidation:

> "The outstanding problem of the Florida Everglades is concerned with prolonging the useful life of the cultivated land and conserving the virgin lands from the destructive effects of subsidence and fires. ... A complete solution of this problem would require a return of the Everglades to their original condition, which is now impracticable. However if the available water is so distributed that a higher water table is maintained the losses from subsidence and fires can be much reduced." (Clayton *et al*. 1942, p.5-6).

Clayton *et al*. (1942) recommended specific water management improvements:

> "The useful life of the cultivated lands can be increased by maintaining the highest water table compatible with good crop yields. A water table depth of *1.5* to *2.0* feet produces the best yield for most crops now grown in the Everglades.

The water table in the virgin lands can be held somewhat higher by retarding the rate of run-off. The large diagonal canals have increased this rate of run-off and their continuous flow bleeds the Everglades of much seepage water which if retained would result in a higher water table." (Clayton *et al.* 1942, p. 6).

Hydrological and associated ecological effects were also noticed shortly after the Muck Canals opened in the southern and central Everglades. John King, civil engineer and surveyor, worked in the early 1900s for Miami developer Capt. J. F. Jaudon (Anonymous 1926), and accumulated several years of field experience in the Lower Glades west and southwest of Miami (King 1917a,b,c,d,e,f,g; Larned 1917). By early 1917, just a few years after completion of the first major canals, King had already noticed definite changes in the Everglades:

> "...the drying up of the 'Glades, due to the various canals, is playing havoc with the birds here. The finer ones are fast disappearing. They lack feeding grounds. There are, occasionally, in the southern portion, a few green leg white herons as well as small blue and Louisiana blues, but five years has made a marked change. Of the food birds, the limpkin are found only occasionally. A guide told me his record was two in a season. ...
>
> The best of [the migratory birds] is the big Florida mallard and a right prime favorite too. But his cupboard is no longer filled with food and, save in the

> surrounding country, even the mallard is migrating elsewhere." (King, quoted in Larned 1917).

King's observations suggest that canal drainage caused marked and apparently widespread changes in the Everglades. Observations by Charles Simpson, a naturalist who began exploring the Everglades in the 1880's, suggest the same:

> "During 1915 and 1916 there was a considerable shortage of rainfall in the Everglade region and this loss, further increased by water taken from the lake by three canals, so lowered the level that perhaps a hundred square miles of its western and southern part were laid bare and no water at all could be found over the general surface of the great swamp." (Simpson 1920, p.121)

The ornithologist A. H. Howell, for many years a student of Florida birds, also noted reduced water levels and their effect on birds in the Everglades:

> "The digging of numerous drainage canals on the eastern side of the Everglades has resulted in lowering the water level several feet and has permitted the use of the land for agricultural purposes. With these profound changes in the character of the big marsh, many of the birds formerly living there have been driven out. Before the Everglades were drained, they furnished a home for thousands of Florida Ducks, herons, egrets, Limpkins, and Everglade Kites, most of which have been compelled to leave the region entirely." (Howell 1932, p. 62-63).

Although initially planned, no canals were built in the portion of the Everglades south of Tamiami Trail. Lowering of water levels in this area would therefore be the result of reduced southward flows from the more northerly Everglades. A number of phenomena observed in the Lower Glades after canal construction began in 1916 would be consistent with reduced southward flows. These include frequent fires in this area in the 1920s and 1930s (Robertson 1953), Capt. Jaudon's walking trip across Shark River Slough in August of 1921 (Anonymous 1921a; Anonymous 1921b), and the observation by John Davis of being able to drive across Shark River Slough:

> "...Colonel William S. Harney ... explored the route from either Harney River or Shark River or both to Fort Dallas on the Miami River. This old route could be followed until recent years but it is seldom if at all used now because there is not sufficient water since the drainage canals were dug. In April 1943 a part of this route was so dry a truck 'glade buggy' could travel along it." (Davis 1943, p. 26).

Pre-Tamiami Trail observations of extensive and frequent boat travel west and southwest of Ft. Dallas (Miami) suggest that conditions southward were wetter prior to its construction. The Seminole Indians (Tebeau 1968; 1973), Col. Harney (Appendix D), Willoughby (Appendix G), and the township surveyor Marcellus Williams (Chapter 4, Rockland Marl Marsh section), all passed easily to and from the Miami River into the Everglades and from there on to Shark River Slough or across to Big Cypress. Further south, Glenn Simmons, an Everglades skiff builder and long-term resident of Florida City, reported that it was once possible to pass by flat-bottom skiff from Homestead through Taylor Slough into Florida Bay (Klinkenberg 1995; Simmons and Ogden 1998).

Changes in coastal groundwater also suggest a lowering of water levels within the Everglades. Parker *et al*. (1955) discuss in detail the intrusion of salt water into the Biscayne aquifer in the Miami area as pressure heads were lowered in the Everglades and in the Everglades Keys by canal drainage. Leach *et al*. (1971) discuss similar intrusion in the Fort Lauderdale area. **Figure 3.6** indicates that the intrusion began almost immediately after the start of drainage. This is consistent with the earlier conclusion that the four major canals were highly effective in rapidly lowering water levels in the Everglades.

H. Bestor, the drainage engineer for the U.S. Sugar Corporation from 1928 through at least 1943, wrote an insightful and comprehensive summary of the hydrologic condition of the Everglades by 1940:

> "The zealousness of the past has finally accomplished, in a way, the drainage of the 'Glades. In fact, the insidious loss of water through the years has virtually over-drained much of the area to a disconcerting extent. The coastal settlements, which are dependent on the back country seepage for their water supplies, are already complaining about lack of water, and large areas of idle peat and muck land have been seriously burned and the soils have generally subsided. These effects are as serious as the soil erosion problems of other states . . . . (Bestor 1942).

**SOIL SUBSIDENCE**

Under pre-drainage conditions, the peat soils (Fibric Histosols) of the Everglades were protected from rapid microbial decomposition by the anaerobic conditions created by the nearly continuous presence of surface water. With the drainage-induced lowering of water tables to below the soil surface, a portion of the soil profile became unsaturated, stimulating rapid aerobic decomposition. The ensuing subsidence of the soil surface, as much as one inch per year, provides a spatial indicator of the extent and degree of water table drawdown, particularly when contemporary researchers compared measured ground surface transects to estimated pre-drainage surfaces.

The engineer Lamar Johnson, whose childhood and working career were spent in or near the Everglades, recognized soil subsidence as a widespread problem that began immediately after opening of the first drainage canals:

> "Subsidence of organic soils is a natural result of drainage. Subsidence probably began in a relatively small area of the Everglades in about 1906. As the canals were extended into the heart of the Everglades, subsidence became more widespread.
>
> One of the paradoxical observations of Everglades history is that the early gravity drainage system of canals, while insufficient to provide the flood protection needed [for agriculture], did provide sufficient drainage to set into motion the factors of continuous subsidence." (Johnson 1974, p. 165).

Prior to drainage, the organic soils (peats) of the Everglades had been protected from aerobic decomposition by a year round or nearly year round covering of surface water. After drainage, these soils were exposed to air for progressively longer periods each year. The surface elevation of the soils of the Everglades began to subside, partly due to physical compaction and actual burning, but mostly due to microbially catalyzed oxidation (Clayton 1936).

Although some contemporary individuals were aware of peat oxidation in drained wetlands, others either were not, or possibly chose to ignore it. A 1913 assertion in an influential engineering report -- that no subsidence would occur except for 8 inches from within the top foot -- contrasts sharply with actual losses of five to seven feet by 1940:

> "...the final plans [for the major drainage canals through the Everglades] herein presented are based on the assumption that the upper foot of muck will shrink vertically 7.8 inches, while the remainder of the [soil] column down to the water table will not shrink at all." (Florida Everglades Engineering ["Randolph"] Commission 1914).

Forty years later, a comment by Stephens and Johnson (1951) gives a sense of the enormity of the early peat loss due to the lack of understanding of peat subsidence:

> "In making plans for the original drainage of the Everglades, apparently the main causes of subsidence were misunderstood. The original shrinkage of the peat due to drainage was considered, but the continuing losses by slow oxidation were not taken into account. Had the true nature and causes of subsidence losses been fully understood in the earlier days, the original plans might have been modified so as

to have saved a large portion of the waste which has occurred since that time. (Stephens and Johnson 1951).

***Quantification of Subsidence***

Extensive information exists to quantify the loss of peat in and around the Everglades. This information includes the following:

- maps of land surface elevation in the early 1940s (Jones *et al*. 1948e; Plate 10) and bedrock elevation (Parker *et al*. 1955),
- two different maps of peat thickness in the 1940s (Jones *et al*. 1948b; Davis 1946),
- a set of 300+ point measurements of peat thickness made in 1915 along the North New River canal (Baldwin and Hawker 1915),
- time series measurements from various "subsidence lines" established in 1916 (see below),
- transects of land surface elevation across the Everglades and along canal routes (Stewart 1907; Senate Doc. 89 1911; Florida Everglades Engineering Commission 1914),
- profiles of peat thickness along the proposed Tamiami Trail route (King 1917d; Wilson 1918), and
- point measurements of peat depth from township surveys conducted from 1912 to 1918 (see below).

In addition, two contour maps (Jones *et al.* 1948e; Corps of Engineers 1960) provided topographic information along the edge of the Everglades, where the peat soils were subject to subsidence and gave way to upland sand or rock of stable elevation.

Estimation of soil subsidence in the Everglades up to the 1940s was based on a synthesis of all of the above observations of land surface elevations, peat thicknesses above the bedrock, and bedrock elevations. Subsidence estimates were combined with early measurements from the 1900-1920 period to estimate the pre-drainage topography. Several key conclusions were drawn from this analysis:

- The ground surface of the pre-drainage Everglades was only slightly lower than the adjoining "upland" landscapes; in other words, the basin was filled almost to the brim with organic (peat) soil.

- Significant soil subsidence and soil loss occurred wherever organic soils were originally present in the Everglades, including in the Lower Glades south of Tamiami Trail (the present day Everglades National Park).
- A substantial fraction of the total subsidence to date had already occurred by the 1940s.
- The most severe absolute losses in elevation (subsidence) occurred in the northern Everglades: a decrease of five to seven feet.
- The most severe relative changes in elevation -- fraction of the original peat profile lost -- occurred along the eastern portion of the Everglades, from near Fort Lauderdale south to the Miami area. Here, in places, losses reached 100% of the peat profile.

***Evidence used to Determine Changes in Topography***

The range of information used to draw these conclusions and to estimate the pre-drainage topography is illustrated in **Figure 3.7**, **Figure 3.8**, **Figure 3.9, Figure 3.10**, **Figure 3.11**, **Figure 3.13**, **Figure 3.14**, **Figure 3.15** and **Plate 10**.

**Figure 3.7** shows time courses for two "subsidence lines," one representative of the northern Everglades (Sawgrass Plains; the present Everglades Agricultural Area), the other of the Davie area near Fort Lauderdale. A series of similar lines established by the U.S. Dept. of Agriculture document the progress of subsidence since initiation of drainage (Clayton 1936; Clayton *et al.* 1942; Stephens and Johnson 1951; Shih *et al*. 1979a,b,c). The lines consisted of established transects along which ground surface elevations were surveyed at multiple points. The lines were resurveyed at two to ten year intervals; the point elevations averaged and plotted versus time.

Exponential declines in soil surface elevation are typical. The rate constant was found by Clayton (1936) and by Stephens and Johnson (1951) to be a linear function of depth of the water table. Inflection points such as the one seen for the Bolles canal line reflect a change in water table, often due to a switch from gravity-driven to pumped drainage. These lines indicate that between 1912 and 1940, as much as 6 or 7 of the original 10 to 12 feet of soil was lost near Lake Okeechobee (Stephens and Johnson 1951). Across the northern Everglades as a whole, the average subsidence rate during this period was approximately one inch per year (Snyder and Davidson, 1994).

Subsidence stops only if the peat soil is resubmerged by water or when all decomposable organic matter is completely oxidized. The original caption for Line ‘D’ at Davie shown in **Figure 3.7** read as follows:

> "This line was originally laid out on Everglades peat over sand. In some places along portions of the line, the peat has entirely disappeared with only the bare sand exposed." (Stephens and Johnson 1951).

**Figures 3.8** and **3.9,** from two different researchers, depict measured cross-sectional transects of bedrock and the original ground surface elevations of the organic soils of the northern Everglades basin, as well as ground surface elevations measured in the early 1940s. Locations of the transects are shown in **Figure 3.10.**

The original pre-drainage surface was flat or even slightly convex within the Sawgrass Plains landscape, and only a few feet below the surface of the bordering sand-based flatwoods. The Ridge and Slough landscape was slightly lower than the Sawgrass Plains, and concave. By 1940, the surface along Transect A (**Figure 3.8**) had subsided approximately 4.5 feet and, in some places, by as much as 7.5 feet. Further south, along Transect B, subsidence was somewhat less, generally about 3.5 feet, with a maximum of 5.5 feet. Local "subsidence valleys," 2 to 4 feet deep, had formed along each canal, due to water table depressions which were strongest near the canals (**Figure 3.4**, **Plate 10**, **Figure 3.9**). Transect C on **Figure 3.10** shows a similar comparison of pre-drainage and 1940s elevations, and also shows the appearance of a new, drainage-induced layer of "compact peat." Both **Figure 3.8** and **Figure 3.9** indicate that by the 1940s regional drainage had caused the Everglades to become a sunken, concave basin.

Subsidence in the northern Everglades, as estimated from Transects A, B, and C, was similar to that estimated from the individual subsidence lines. A third to nearly half the depth of the original 10-12 feet of peat soil in the area directly south of Lake Okeechobee had been lost. The original topography of the sawgrass plains was profoundly altered. North of the Bolles Canal, the original slope of the land was reversed by 1940 -- descending northward toward, rather than away from, Lake Okeechobee (Stephens, 1942).

**Figure 3.10** and **Figure 3.11** provide further support for development of a basin-wide view of the Everglades by showing two snapshots of the thickness of the peat soil present in the early 1940s. For comparison, the canals present in 1940, contours of bedrock elevation, and the location of the pre-drainage Everglades boundary have been superimposed on these soil thickness maps.

The spatial patterns of peat depth shown in the southern portions of both peat thickness maps help identify the pre-drainage location of Shark River Slough. The patterns clearly reflect the presence of a flow channel, with deepest peats in the center of the channel. A diagonal NE-SW orientation is visible, particularly in Townships 54 and 55. Prior to drainage, the center of Shark River Slough crossed the future location of Tamiami Trail (Transect G) in Range 38, nine miles to the east of the future location of the L-67 Extension canal. Water management subsequent to the 1940s has pushed the location of southward water flow progressively further westward (Leach *et al*. 1971), such that it is presently restricted to Ranges 35 and 36, more than 12 miles west of the original channel center.

The pattern of peat thickness mapped in **Figure 3.11** appears to confirm the idea that Tamiami Trail restricted southward flow of water during a period before the 1940s. The abrupt ending of the 5-9 feet polygon parallel and north of the Trail would be consistent with reduced peat subsidence north of Tamiami Trail where water levels had remained higher, and more severe oxidation and subsidence on the overdrained south side of the Trail.

**Figure 3.10** is based on a less systematically gathered set of field measurements than the more precise **Figure 3.11**, but the former map provides a clearer picture of the overall patterns, particularly the pattern of peat loss caused by the canals. Comparison of these two maps with transects shown in **Figures 3.8** and **3.9** helps visualize the relation of pre-drainage topography to the topography that remained in the 1940s (**Figure 3.12**).  Estimates of pre-drainage topography from this study are presented in Chapter 5.

**Figure 3.13** is based on a unique set of data: more than 350 field measurements of peat thickness made in 1915, only three years after the opening of the North New River canal. The measurements were made by two soil scientists, Baldwin and Hawker (1915), along six or eight mile-long transects perpendicular to the North New River canal, one transect at each milepost.

**Figure 3.13** was created by combining the peat thickness data with two other data sets, a set of land surface elevations taken along the canal in 1913 (Fla. Everglades Engineering Commission 1914) and contours drawn near the canal in the 1940s (Jones *et al*. 1948e).

Polynomials were fitted to the 1915 and 1940 land surface data and to the peat thickness data (5th, 8th, and 8th order, respectively). The bedrock elevations shown were determined by subtracting the 1915 peat thickness polynomial from the 1913 land surface polynomial. The bedrock elevations shown in this figure compare favorably with other estimates of bedrock elevation. The 1940 land surface elevations were determined by sampling the 1940s contours along the same perpendicular transects measured in 1915.

The variability present in the 1915 peat thickness measurements was arbitrarily associated with the land surface. In reality the bedrock surface is quite variable and the ground surface would have been more uniform. The increased surface variability within the area of Ridge and Slough landscape relative to the Sawgrass Plains landscape may reflect actual point to point topographic variability once present in the pre-drainage Ridge and Slough landscape. The profile of soil surface and underlying bedrock surface shown in this figure is probably representative of pre-drainage conditions, as well as representative of profiles that would have been seen along the Miami, Hillsboro, and northern portion of the West Palm Beach canal.

**Figure 3.13** shows the pre-drainage nature of the Lake Okeechobee-Everglades system, and the dramatic loss of peat and elevation the system experienced. A thick wedge of peat soil tapered from ten feet thick at Lake Okeechobee to four or five feet thick near the headwaters of the New River. The north end of the wedge formed the dam that allowed water in Lake Okeechobee to reach an elevation of 21 feet above sea level before overflowing into the Everglades. It is important to note that the slope of the Everglades that provided the driving force for southward water movement was not formed by the slope of the underlying bedrock, but rather by the peat itself.

Drainage-induced subsidence strongly altered the system. By 1929 the surface elevation at a point near Lake Okeechobee had dropped by four feet (Interbureau Committee 1930). By the 1940s, more than half of the original peat profile had been lost along much of this 55 mile transect. In the area of the Everglades that extends from the southern shore of Lake Okeechobee for about 15 miles south, the land surface had become essentially flat and no longer sloped southward. By 1978, only a few feet of the original peat was left at a point four miles from the original lakeshore (Shih *et al*. 1979).

**Figure 3.14** shows two peat profiles near the southern portion of the Miami canal (Transects F and N on **Figure 3.11**). Measurements were taken from a canal survey (Ensey *et al*. 1911), township survey (Frederick 1914), and a post-drainage study (Corps of Engineers 1954). The early post-drainage (1911 and 1914) peat thicknesses of five to six feet are greater than those found further north, near the southern portion of North New River canal (**Figure 3.13**). Subsidence along these profiles was assessed by comparison with detailed, local measurements made in 1954. Subsidence was especially severe beside the canal, with loss of more than four of the original six feet of peat. The depression or "subsidence crater" formed around the lower portion of the Miami canal is clearly visible in **Plate 10**.

**Figure 3.15** shows peat thickness data for two parallel transects in the southern Everglades, one along the future route of Tamiami Trail (Transect G, **Figure 3.11**), and the second covering the same distance, but four miles further south (Transect H, **Figure 3.11**).

Two independent data sources were found for this area, Wilson (1918) and Southern Engineering Co. (1918a;b;c). Wilson's measurements were collected as part of surveys for the then proposed Tamiami and Snapper Creek Extension canals, while the Southern Engineering Co. measurements were collected at section corners as part of three government township surveys. Peat thickness remaining in the 1940s was estimated from **Figure 3.11**; bedrock elevations were obtained from Parker *et al*. (1955).

Subsidence losses along Tamiami Trail appear to have been about two feet, except to the east of the Dade-Broward Levee canal, where essentially all of the original three to four feet of peat had already been lost. Further south, along the Snapper Creek Extension, subsidence appears to have been more severe, with a loss of about three feet of peat.

**Figure 3.15** reinforces the pre-drainage location and orientation of Shark River Slough that was previously discussed in relation to 1940s peat thicknesses (**Figures 3.10** and **Figure 3.11**). Along Tamiami Trail, the center of the Slough appears to be in the middle or western side of Range 38, whereas four miles further south the center, as indicated by the thickest peat, is clearly further west, in Range 37.

With a few exceptions that are probably due to uncertainties in the estimates, peat thicknesses in the central and southern Everglades were less in the 1940s than in the period just after drainage (1911-1918).

The most severe peat losses, up to 100%, occurred along the eastern edge of the Everglades, mostly between Townships 50 and 53 (Transects E and F; Township maps I and J). The severity of losses is in part because pre-drainage peat thicknesses were less here than in the northern Everglades, and in part because the underlying sand allowed water tables to be drawn down below the peat horizon in this area. (**Figure 3.16**).

**PEAT FIRES**

In sawgrass and peat environments several types of fires are possible, distinguished by the depth of the water table: (1) leaf fires which burn sawgrass leaves without killing the culms (Forthman 1973); (2) hotter vegetation fires which do kill sawgrass culms (and therefore the whole plant); and (3) peat fires which can occur when water tables are sufficiently far below the peat surface. According to Cornwell *et al. (1974),* water tables in the peat need to be deeper than the normal annual dry season minima of 4-6 inches for peat fires to occur. Frequent and extensive peat fires occurred between the *1920s* and *1950s,* shortly after drainage began lowering water tables.

There is little doubt that leaf fires occurred in the Everglades even prior to drainage. Fires in sawgrass, one of the most ubiquitous species within the Everglades, are reported in the historical literature (e.g., Cooley, 1851 in Knetsch 1989). Modern scientific studies confirm that the periodic occurrence of leaf fires would not have destroyed the sawgrass landscape; thus leaf fires could well have been consistent with a quasi-permanent presence of sawgrass in the northern Everglades, as suggested by the deep soil profiles of sawgrass peat. Forthman (1973) found that sawgrass regenerates rapidly after fire, provided that the soil is sufficiently wet or inundated to prevent sawgrass culms from being killed. Hofstetter (1984) suggests that periodic fires may even be beneficial, reducing the build up of flammable leaf litter.

The above scenario, based on long-term coexistence of sawgrass and fire, is dependent on water levels being sufficiently high to protect sawgrass culms from burning. If water levels decline far enough below ground to dry out the surface of the organic soils, a different type of fire, the peat fire, can occur. From the post-drainage period it is known that peat fires not only kill sawgrass, but can also destroy a portion of the organic soil profile. The flammability of dry peat was recognized by early observers of the Everglades, such as Stewart (1907), an agricultural scientist, and Lupfer, an engineer involved in surveying and dredging for the North New River canal:

> "All of the marsh lands surrounding Lake Okeechobee are composed of 'peat', very similar to the world-famed Irish fuel, and when these marshes become thoroughly dry they burn with little flame but intense heat. As long as the water level is within 4 or 5 ft. of the surface there is no danger of the land burning to any great extent; and, as this question of fire is a well understood one, care will be taken not to lower the waters of Lake Okeechobee sufficiently to invite this danger." (Lupfer 1906).

Unfortunately, Lupfer significantly overestimated the water table depth needed to prevent peat fires, and was overly optimistic about the care that would be taken. Harper, who observed the eastern edge of the Everglades in 1909 and again sometime before 1927, related the peat fires to drainage:

> "...in dry seasons the drained peat [of the Everglades] sometimes catches fire, and the soil then goes up in smoke." (Harper 1927, p. 126).

> "Most of the soil is composed of decayed or partly decayed vegetation, fairly rich in nitrogen but lacking in phosphoric acid and almost wanting in potash. A vast area is half decayed vegetation; in many cases the fallen plants seem as fresh as when they were buried thousands of years ago. Whenever the whole is dried out, as it becomes when it is drained, it is ready for the fire. Careless huntsmen, tourists, even residents here are constantly setting the Glades afire and when this is done, it is well-nigh impossible to put out such fires as they smoulder and burn away below the surface, much as they do in a coal mine. Year after year we here, at and near Miami, have been almost smothered in the dry season, whenever the wind got in the northwest, by clouds of acrid, black smoke from the burning Glades, and much money and labor have been expended in fighting these fires, which burn down to bed rock or the marl and leave vast ugly lakes when the rains come. Wherever they burn, the whole thing is destroyed forever. In a very informing article in the New York Times a few years ago, it was stated that over 200,000 acres had already been burned over." (C. T. Simpson in a Nov 10, 1930 letter to H.A. Kelly, in Kelly (1931, p. 41).

Prior to this letter, Simpson in 1920 specifically describes the effect of only about five years of “partial drainage” on tree islands:

> “One of the results of partial drainage is that along this same east border [of the Everglades] numerous low, timbered "islands," which were formerly quite wet, have now been changed to dry land. A considerable part of the foundation of these groves is peat and in dry times it is very liable to fire, and once begun it is well-nigh impossible to extinguish it. These groves, despoiled of their only defense against fire, are often wholly destroyed.” (Simpson, 1920, p. 126-127).

Extensive peat fires similar to that shown in **Figure 3.17** covering tens to hundreds of square miles (Bender 1943) spread during dry periods beginning in the 1920s (Robertson 1953). These damaging peat fires continued into the 1950s (FGFWFC 1956; Wallace *et al*. 1960). Such fires could burn for months and even through the wet seasons of multiple years (Bender 1943), "destroying the upper, dry, compacted peat layers to a depth of three or four inches over large areas and up to a foot or more in localized situations" (Loveless 1959). Fires during the 1920s and early 1930s were sufficiently large and frequent to have led to the formation of a special fire control district in the Everglades. According to the district's director,

> "Previous to the creation of a fire control district by the Legislature in 1935, vast areas of the Everglades were destroyed by fire. In one county alone one-third of the muck area was totally destroyed." (Bender 1943).

***Effects of Fires on Everglades Landscapes***

Fire altered Everglades landscapes, particularly in areas where the peat soils were naturally thin prior to drainage. The location in **Figure 3.18** had been overdrained for 15 to 25 years, by the Tamiami Trail canal as well as by the Snapper Creek canal. The figure captions note the effect of fire.

Davis (1943) described the effect of lowered water levels and of burning on the Rockland Marl Marsh area:

> "Excessive artificial drainage has recently created drier conditions promoting these fires and also causing the shallow organic soils to become oxidized and subside until now some areas once soil covered are returning to rockland conditions." (Davis 1943).
>
> "Figure 21.--Rockland resulting from fires that have destroyed the shallow organic soils." (Davis 1943).

A 1944 Advisory Committee noted the distinction between vegetation fires and destructive soil fires, as well as noting lowered water tables as the cause of soil fires:

> "Such a state of saturation would prevent damage by burning to muck and peat soils swept by vegetation fires. The depth to which muck and peat soils burn by fire is conditional upon the depth of the water table below the surface. The frequent burning of muck and peat noted throughout the Everglades during the past two years reflects the low level to which the water table has fallen." Advisory Committee (1944, p. 23-24).

Robertson (1953) also remarked on areas of exposed rockland in Everglades National Park that were created by peat fires:

> "In muckland areas [of the sawgrass glades] the soil destroying effects of fire are notable. Undoubtedly some of the present rockland areas of the glades have resulted from complete removal of the soil by repeated muck fires." (Robertson 1953).

These fires affected not only the sawgrass, but the higher-lying tree islands as well. Bay heads, one of the higher elevation vegetation types, dried sufficiently in Everglades National Park to suffer repeated burns:

> "...in some places the peat is burned below general glades level so that semi-permanent ponds are established" (Robertson 1953).

Further north in Water Conservation Area 3, Loveless (1959), in a description that was very similar to the one made by Simpson (1920) almost 40 years earlier, noted similarly drastic effects of fire on the higher lying communities:

> "These [early summer of 1956] fires completely destroyed many tree island communities by burning the peat substrate out from under the tree growth. Some of these areas are now open water ponds devoid of any type of emergent vegetation while others support sparse strands of sawgrass, water-lily, floating heart and other aquatic species."

The fires that occurred in the first part of this century, after drainage had begun, had significant effects on the Everglades landscapes. It is generally accepted that the peat soils became sufficiently dry for these fires to occur as a result of the combined effects of naturally dry weather and man-made canal drainage. To estimate pre-drainage water levels it would be very helpful to know the pre-drainage frequency of fires within the Everglades.

### *Fire Frequency Prior to Drainage*

The frequency and extremity of pre-drainage fires remains uncertain (Gunderson and Snyder 1994). Cohen (1984) determined that his core studies did not reveal evidence for widespread peat fires. However, because of the intensive effort involved in microscopic studies, he was able to examine only a small number of cores. To our knowledge, there has not yet been a charcoal study of soil cores with sufficient geographic scope to reliably map the frequency and size of pre-drainage fires. In an often-referenced passage, Davis (1943) states that:

> "There were sufficiently dry conditions over large areas and some periods of time when fires became extensive, as is evidenced by layers of ashes six or more inches thick that were found under some layers of peat in some areas when the

> canals were being excavated. (Observation communicated by F. C. Elliott, former District Drainage Engineer)" (Davis 1943, p. 253).

Parker also observed ash layers in the field at two locations:

> "...Nevin Hoy and I hand-dug a number of deep pits both in the wet prairies and in the organic soils of the central glades. These pits were about 5' square and dug into bedrock... It was in the walls of at least two of these pits, one dug in the vicinity of Miami Canal's Broken Dam [NW corner of Section 10, T 52 R 39] and the other near the South New River confluence with Miami Canal, that we found ash layers up to about 2 inches thick. These buried ash layers indicate ancient, pre-historic times when there were severe droughts that dried the organic soils of the normally wet glades sufficiently to allow the soils themselves to burn as deep as the existing water table." (Parker 1974, p.30).

Several points are important to note. First, the observations are scattered. Specific, recognizable layers have not been mapped between locations, so it is unclear whether the layers do in fact represent peat fires over "large areas." Second, multiple layers are not mentioned, as would be expected if fires had recurred once every 20 or 30 years, or even once per century. The small number of layers seen within the roughly 5,000 year old profiles seem more reflective of one or two periods of climatic change, for example the Medieval Warming Period, than of regularly recurring fires. Lastly, dark layers within peat may not always reflect peat ash; microscopic studies are required for unambiguous identification of charcoal (P. J. Gleason, pers. comm., 1997).

## SOIL CHANGES

Soil oxidation caused by lowered water tables produced two major, post-drainage changes in the soil types mapped by Jones *et al.* (1948). The soil changes were paralleled by vegetation changes, so in fact the overall effect produced a complete landscape change. It will be seen in Chapter 4 that the pre-drainage landscape patterns were quite different from the altered, post-drainage landscape patterns shown in the 1940’s maps of soils and of vegetation. Fortunately, enough post- and pre-drainage information is available for these areas to make it possible to reliably “reconstruct” or hindcast the original landscape conditions. This section will present the evidence for understanding the changed as well as the original landscapes.

The first change was extensive and occurred in the middle of the Everglades. It transformed a large area of originally patterned peatland (Ridge and Slough landscape; Chapter 4) into an expansion of an unpatterned peatland, the Sawgrass Plains (Chapter 4). The second change affected the edges of the Everglades, transforming a patterned peatland into an unpatterned, primarily sand-based wetland. Both changes are the result of long periods with sufficiently dry (drained) conditions to cause lasting changes to the original vegetation, soils and microtopography.

***Loxahatchee Peats (Ridge and Slough Landscape) to Sawgrass Peats (Sawgrass Plains Landscape)***

Prior to drainage, early scientific observers of Everglades soils described peats that were only partially decomposed (Harper 1910*;* Rose 1912*;* Baldwin and Hawker 1915*;* Miller 1918*;* Dachnowski 1924*;* Allison *et al.* 1927*;* Hammar 1929*;* Waksman and Stevens 1929*).* As Harper noted in his 1910 study of Florida peat soils, peat protected from decomposition due to nearly continuous inundation, was recognizable by a fibrous, rather than amorphous texture, and by a brown rather than black color:

> "In texture, peat is more or less fibrous, being least so in the oldest and most thoroughly decomposed samples, which are rather plastic and look much like mud. The color is always some shade of brown, varying from light brown (this is usually in fresh or imperfectly decomposed peat) to nearly black." (Harper 1910, p. 210).

After drainage exposed the peat to oxidation, the soil began changing. By the *1990s*, Snyder *(1994)* records that most of the soils of the Everglades Agricultural Area (similar in extent to the pre-drainage Sawgrass Plains landscape), which were originally Fibrists, had become Saprists:

> "Histosols found in Florida are divided into Fibrist, Hemist, and Saprist suborders. Saprists are the most well decomposed and largely correspond to the term muck as defined in the 1951 Soil Survey Manual. Specifically, Saprists have a fiber content of less than one-sixth of the soil volume after rubbing and consist of almost completely decomposed plant remains. Their color is mostly black. Today, most of the soils of the EAA are Saprists." (Snyder 1994, p. 30).

Much of the change from Fibrists to Saprists occurred during the early period of drainage, from 1915 to the 1940s. Comparison of two soil mapping efforts clarifies this change. Although Jones *et al*. (1948) developed the first soil map of the entire Everglades, an earlier mapping effort described a six-mile wide transect of soils through the middle of the Everglades. The detailed work of Baldwin and Hawker (1915) mapped three miles on either side of the full length of the North New River canal, thus passing northwestward from the Atlantic Coastal Ridge to the Ridge and Slough landscape, then through the Sawgrass Plains until finally reaching the Custard

Apple Zone at the shore of Lake Okeechobee (**Figure 3.3**). The Baldwin and Hawker (1915) map -- drawn only three years after completion of the North New River Canal -- is an excellent estimator of pre-drainage conditions. Descriptions of the landscapes and their spatial extents given by Baldwin and Hawker (1915) closely match those observed by Harshberger (1912) in the year that the canal was opened.

**Figure 3.19** illustrates the principal soil profiles seen in 1915 and in 1940, as well as the extent of their occurrence along the length of the canal. The profiles were drawn from descriptions given by the two groups of soil surveyors. The extents of the soils were taken from the respective soil maps. For comparison with the soils, we also show the extent of the landscapes (vegetation) that were reported as present in 1915 and 1940. We note first an unchanging feature, which is the substrate underlying the organic soils of this transect through the Everglades. From milepost 2 through milepost 46-48, the organic material rested directly on bedrock; along the eastern edge, from milepost 46-48 to 54, a sand layer formed the substrate. From **Figure 3.19**, we make the following observations:

- In 1915, no black, non-fibrous peat was present between mileposts 2 and 54.
- In 1915, all organic soil present was uniformly a "brown, fibrous, slightly decomposed peat."
- In 1940, between mileposts 4 and 46, the subsurface remained a brown, fibrous peat, but a surface layer of "black, finely fibrous peat" had formed.
- In 1940, between mileposts 46 and 54, the brown fibrous peat was completely gone, leaving only sand with a trace of organic matter mixed into the upper layer.

In addition to these changes, the soil surface had subsided, the topography had flattened, and the vegetation had changed. In 1915, the North New River canal traversed 20 miles of Ridge and Slough landscape before reaching the Atlantic Coastal Ridge. By 1940, no Ridge and Slough landscape remained, but had been completely replaced by expansion of the Sawgrass Plains and by a short stretch of disturbed grassland towards the coast.

The widespread appearance of a new surface layer of black, finely fibrous peat (corresponding to the black surface layer of "Compact Peat" shown in **Figure 3.9**), is highly significant, particularly given that Jones *et al*. (1948) mapped it on 1 million acres -- 50% of the original organic soil portions of the Everglades.

Evidence points to post-drainage oxidation as the cause of this layer: the loss of structure, the increase in density and mineral content, and the black coloration. Soil scientists and drainage engineers at the Everglades Agricultural Experiment Station in Belle Glade who studied these soils during the 1930s make it clear that the oxidized surface layer was a result of lowered water levels:

> "By far the greater portion of the peat soils of the Everglades is composed of the partially decomposed remains of sawgrass. The marshy condition of the Glades, during the period of formation, prevented a more complete decomposition of this material. In its original condition the sawgrass peat is a brown fibrous mass in which partially decayed sawgrass roots can be readily distinguished. 20 These roots are approximately in a vertical position. After drainage, cultivation and weathering gradually transform the top soil into a condition approaching a true muck. The structure then changes into an amorphous mass, the density increases, the color becomes dark, and the rate of seepage through the soil is retarded." (Clayton *et al*. 1942).

The transformation from brown fibrous peat to black, less fibrous peat apparently did not take place immediately after drainage. Evans and Allison (1942) include a description of a characteristic Everglades Peat profile taken 15 miles south of South Bay along the North New River Canal in 1929. The description still includes brown or yellowish-brown fibrous or coarsely fibrous sawgrass peat in the upper 15 inches. The soil scientists who surveyed Dade County in the 1950s described the same phenomenon, emphasizing the role of soil oxidation under lowered water tables:

> "Near the canals, where the water table has been lowered by artificial drainage, considerable oxidation of the organic material has taken place. As a result of this increased oxidation, the remaining peat has a higher mineral content, is less fibrous, and is more nearly black." (Gallatin *et al*. 1958)

An interagency committee of agricultural scientists, inspecting the Everglades in November of 1929, also noted a contrast between the typical appearance of sawgrass peat and its appearance near canals

> "Peat is the typical saw-grass material of the Everglades. Perhaps there are one and one-half to two million acres of this material comprising the greater part of the so-called Everglades. It is a remarkably uniform body of material, consisting of brown fibrous to dark-brown, semifibrous, slightly decomposed vegetable matter, dominantly of saw-grass (Cladium effusum) composition. It varies in depth from about 4 to about 9 feet and is normally underlain by limestone. ... In the southern portion of the Everglades, along the Tamiami Trail, are extensive

> areas of black nonfibrous peat with streaks of brown fibrous peat. This is also true in places along the Miami Canal." (Interbureau Committee 1930).

We conclude that the black surface layer visible in the 1940s throughout the area of the Sawgrass Plains -- the distinguishing characteristic of the "Everglades Peats" mapped by Jones *et al*. (1948) -- reflects the effect of aerobic oxidation, caused by widespread lowering of water tables throughout the Everglades between 1915 and 1940. It follows that this black, oxidized surface layer was not originally present in the Sawgrass Plains; instead, the sawgrass originally would have been underlain by a relatively uniform profile of brown fibrous peat. This profile was uniform in the sense that there was no distinct, thick upper layer of oxidized peat. Baldwin and Hawker (1915) do note in their description of the brown, fibrous peat the presence of more and less decomposed layers deeper in the profile. These presumably reflect drier and wetter periods during the last several millennia.

It is of interest that the above description of the pre-drainage soil profile for the Sawgrass Plains -- a relatively uniform brown fibrous peat -- is similar to the description given by Jones *et al*. (1948) for the post-drainage Loxahatchee Peats, the soil associated with the Ridge and Slough landscape. The main difference would be in the fraction of aquatic, non-sawgrass species plant remains mixed with the sawgrass remains, a distinguishing character that may or may not have been used during the Jones *et al*. (1948) mapping effort. The Dade County soil surveyors were aware of this similarity:

> "[Everglades peat] is closely associated with the Loxahatchee peats but differs from them chiefly in having a black or very dark brown nonfibrous peat surface layer." (Gallatin *et al*. 1958).

The association between the Everglades and Loxahatchee Peats can be seen clearly along the Hillsboro Canal. In Township 47 Range 40, **Plate 11** shows a narrow strip of Everglades Peat along the canal, bordered on both sides by large areas of Loxahatchee Peat. The shape and position of this strip leave little doubt that, prior to drainage, it too would have been Loxahatchee Peat. Following the process described above by Gallatin *et al*. (1958), the Hillsboro canal apparently lowered the water table sufficiently to cause oxidation and the formation of a surface horizon of black, compacted, non-fibrous peat along this strip. As this surface layer had been defined as the distinguishing characteristic of the Everglades Peats, the Jones *et al*. (1948) surveyors mapped the strip as Everglades Peat, despite the surrounding Loxahatchee Peat.

A second example of a shift from Loxahatchee Peat to Everglades Peat occurred along the northeast edge of the Sawgrass Plains, parallel to what is now the L-8 canal (**Figure 1.1**). Although they mapped it as Everglades Peat, Jones *et al.* (1948a) noted that this was an old slough along the border of the Everglades, with a soil formerly similar to the Loxahatchee Peat soil:

> "Northeast of the West Palm Beach Canal from Lake Okeechobee to Twenty-Mile Bend is an old slough in which the peat was originally formed partly from water plants and was more loose than the Everglades peat. However, as a result of partial drainage for many years, it has become compacted and can scarcely be distinguished from the typical Everglades peat." (Jones *et al*. 1948a).

Figure 2 in Dachnowski-Stokes (1930) shows this slough in a peat profile cross-section as a rounded, 2-foot depression extending from West Palm Beach Canal to the edge of the Everglades (L-8 canal). The same slough is also visible as a similar, though wider depression in a 1912 peat profile given by Stephens and Johnson (1951) (Transect A, see **Figure 3.8** of this report). The shift to the Everglades Peat and unpatterned sawgrass vegetation mapped by Jones *et al.* (1948) is presumably simply the result of drainage-induced, prolonged dry conditions.

***Loxahatchee Peats (Ridge and Slough Landscape) to Davie Sands (Wet Prairies)***

The second pattern of drainage-induced change in Everglades soils occurred along the eastern and western borders of the Everglades, north of Tamiami Trail. Sand overlies the bedrock in these areas; prior to canal drainage, a layer of organic soil covered the sand (**Figure 3.8**, **Figure 3.9** and **Figure 3.19**). Water levels were sufficiently high in the central Everglades to maintain long hydroperiods in these border areas. The long hydroperiods ensured that the rate of peat accumulation exceeded or balanced the rate of peat decomposition.

With the advent of drainage, both regional and local, average water levels along the edges of the Everglades dropped and the hydroperiods shortened. Peats oxidized and, as previously noted, were mostly or completely lost along the eastern border of the Everglades by the 1940s. The soil surveyors working on the Jones *et al.* (1948) soil map of the Everglades recognized these newly exposed areas of bare or nearly bare sand as a post-drainage phenomenon. Two soil types were defined to accommodate this: "Davie mucky fine sand" and "Davie fine sand." The two soils differed primarily in the content of remaining organic matter; the subsoils were the same. The surface soil of the Davie mucky fine sand was defined as a "dark gray mixture of well oxidized organic matter and fine sand" with medium to high organic matter. The surface soil of the Davie fine sand was a "gray or light gray fine sand" with low to medium content of organic matter. The following note applies to both of the Davie soils:

> "The Davie fine sand was originally covered with from one to three feet of peat. However, this peat has shrunk or has been oxidized or burned until only a shallow covering, if any, is left. This has been or will be incorporated into the top six to ten inches of the underlying sand." (Evans and Allison 1942).

The nature of the Davie soils, deriving from drainage-induced alterations, is explicitly recognized in the 1950s "detailed reconnaissance" soil survey of Dade County Gallatin *et al*. 1958). The 1958 Dade County survey is nearly identical to the Dade County portion of the Jones *et al*. (1948) survey, so **Plate 3** will be helpful in locating the Davie and related soils. These soils are described as follows:

Davie fine sands:

> "Davie fine sand has poor to very poor natural drainage, but large areas are now overdrained."
>
> "This soil [the Davie fine sand] occurs in fairly large areas in the sandy prairies that lie between Arzell fine sand and Everglades peat in the areas northwest, west and southwest of Miami. It was originally covered with a thin layer of peat or muck. Most of the organic matter in the surface soil has been destroyed by excessive drainage, natural oxidation and shrinkage, and fires. The sand is now at the surface."
>
> "The natural vegetation was mainly sawgrass, but following drainage of adjacent areas, myrtle, groundsel, primrose-willow, and wild grasses have spread over most of the area not cultivated." (Gallatin *et al.* 1958).

Davie mucky fine sands:

> "This soil [the Davie mucky fine sand] occurs northwest and west of Miami on the edges of the sandy prairies that border the Everglades peats. The shallow peat layer of this soil has not yet been completely destroyed by fire or by slow oxidation following drainage. The soil is poorly to very poorly drained. It is closely associated with the Davie sand and differs from that soil mainly in having a thin layer of peat or mucky material over the sand layers. The vegetation is similar to that described for Davie fine sand [i.e., mainly sawgrass, but invasion of myrtle, willow and grasses following drainage]." (Gallatin *et al.* 1958).

The Davie sands are a clear indication of drainage-induced changes in the Everglades. In the 1940s, Davie sands were the middle elements of an ordered sequence of four soils extending from the Everglades to the coastal ridge: Everglades peat over sand, Davie mucky fine sand, Davie fine sand, and Arzell sands. Prior to drainage, the areas mapped in 1940 as Davie sands would have been essentially indistinguishable from the Everglades peat over sand and both areas would have supported Everglades vegetation. In some parts of the Everglades, the areas mapped as Everglades Peats in 1940 would, in fact, probably have been classified as Loxahatchee Peats prior to drainage (compare Plate 11 and Plate 8). The cypress growing on the slightly higher Arzell sands (Evans and Allison 1942) bordered directly on the open Everglades vegetation, producing a distinct edge, exactly as described on the pre-drainage maps of Ives (1856) and Harshberger (1913) (Figure 2.6 and Figure 2.7), and on the retrospective vegetation map of Steinberg (1980), shown in Plate 36.

After drainage, the Davie sand areas became short hydroperiod wetlands that were no longer able to support peat accumulation. Davis (1943) mapped these areas according to the vegetation present there in the 1940s, i.e. as wet prairies, but recognized that prior to drainage these borders of the Everglades had a much different character:

> "The bordering wet prairies of low to tall grass vegetation of seasonally wet soils growing mainly on sand areas that form narrow zones [was Type 6 of the main Everglades vegetation types.] ... The eastern prairie zone extends along the pineland border of the glades from a few miles north of the North New River Canal to South Miami. ... Those [wet-prairie areas] along the east border were formerly much more marsh-like with thin peat or muck soils over sand, but now since some of this border zone has been drained and some of it cultivated the top peat or muck layer has largely disappeared so that these formerly marsh areas are now essentially grassy prairies on the sand soils that have been left after the disappearance of the covering layer of organic soils." (Davis 1943).

The same pattern of exposure of formerly peat-covered sands on the edges of the Everglades basin can also be seen on a smaller scale within the Peat Transverse Glades (for locations see Plate 13 and Plate 36). Prior to drainage, outflows from the main Everglades protected the peats in these glades from oxidation. After drainage, hydroperiods in the Peat Transverse Glades shortened and the peat began to disappear. Over time, strips of peat-free sand appeared along each edge of the Transverse Glades. As along the edges of the Everglades basin, these newly exposed sands were mapped in 1940 as Davie fine sands (Figure 3.20).

In most of the Everglades, the formation of exposed Davie sands occurred in a strip parallel to the border of the basin. An important exception to this pattern helps further clarify the origin of the Davie sands. In Township 50, Ranges 40 and 41, the Jones et al. (1948) soil map (Plate 11) shows a peculiar intrusion of Davie Mucky Fine Sand extending into the Everglades. This 3-

4 mile wide "tongue" of primarily sandy soil extending westward into the Everglades is conspicuously absent on all maps prior to 1939, including soil, vegetation and township maps (Bureau of Topographical Engineers 1846; Florida. Surveyor General's Office 1853; Bureau of Topographical Engineers 1856; Ives 1856a; Fries 1898-T50 R40; Fries 1898-T50 R41; Newman 1908-T50 R41; Ensey *et* a7. 1911; Matson *et al.* 1913; Harshberger 1913; Hassan 1915; Baldwin and Hawker 1915; Harper 1925; Marston *et al.* 1927; Board Comm. Ever. Drain. District 1935; Henderson 1939). The absence of this intrusion of sandy soil on early maps is consistent with pre-drainage reports of this area as part of the Ridge and Slough landscape. Numerous accounts describe boat travel from the headwaters of the New River out to Sam Jones Seven Islands and Pine Island (Cooley, 1856 in Knetsch 1979; Henshall, 1882 in Reiger 1971; **Appendix D and I**). By the 1940s, these islands, instead of being surrounded by water, were surrounded by the dry intrusion of Davie mucky fine sand. These islands can be recognized on **Plate 12** as narrow strips of Upland Sands in Ranges 40 and 41, respectively, of Township 50.

The intrusion first appears on the maps of Davis (1943), Jones *et al.* (1948b) and Jones *et al.* (1948c), and provides a stark example of the shrinking of the Everglades, both vertically and horizontally, that occurred between 1880 and the 1940s. As overall water levels were lowered, the edge of the Everglades and of the surface water were drawn to the center, and the peat was lost, exposing the underlying sand. The unusual extent of this particular intrusion likely reflects the early initiation of drainage in this area. One of the first pump stations in the Everglades was placed here in 1913 by the Davie District (Stephens 1951) and, as shown on a development plat (Newman 1908-T50 R41), many secondary canals were installed early. After its appearance in the 1940s, this intrusion of essentially bare sand soil remained recognizable on later soil and vegetation maps (Fla. Ag. Exp. Stn. and Soil Conserv. Serv. 1962; Davis 1967).

## VEGETATION CHANGES

With the onset of drainage, vegetation communities in the Everglades began to change in ways that were sufficiently regular and widespread that contemporary observers remarked upon them. Particularly the earliest observers of the first years of drainage had the benefit of either seeing or remembering the contrast with the original, pre-drainage vegetation. The rapid transformation of the Okeechobee Muck lands in the 1880’s from sawgrass to “dry land varieties" and "grasses which do not grow in water" was already noted in the section describing the Lake Okeechobee Phase.

Sixty years later, and a few years after completing his map of the vegetation of southern Florida, Davis (1946) described similar changes to sawgrass land, though apparently with a greater presence of shrubby species:

> "When saw-grass marshes are drained, as in the Everglades and a number of other large drainage districts, the saw-grass and other marsh plants decrease in number and size and usually weeds, shrubs, and some introduced cultivated plants invade the areas. A sparse growth of saw-grass with bushes, weeds, and in some places ferns usually indicates a drained marsh. The elderberry, *Sambucucs simpsonii* Rehder, sea myrtle or groundsel-bushes, *Baccharis* spp., primrose-willows, *Jussiaea* spp., and small willows, *Salix amphibea* Small, are some of the most abundant bushes. The careless weeds, *Acnida* [*Amaranthus australis* ], fennel, *Eupatorium capillifolium* (Lam.) Small, and some broom grasses, *Andropogon* spp., are also usually abundant." (Davis 1946, p.89).

The soil surveyors of the 1940's (Jones *et al.* 1948a), who were extensively in the field (Chapter 2), noticed changes similar to those described in more detail by Davis; invasion by "weedier" annual species, as well as by the shrub wax myrtle:

> "Since the land [the Sawgrass Plains and possibly Ridge and Slough landscapes] has been drained or burned over many plants have come in, such as marsh ferns, royal fern, smartweed, pigweed, goldenrod, and castor bean." (Jones *et al.* 1948a , p. 47).
>
> "Many clumps of wax myrtle have come in on the undeveloped sawgrass land since the canals were dug." (Jones *et al.* 1948a , p. 47).

The absence of references to either tree islands or sloughs in the above descriptions suggests that the observers were referring to areas that in pre-drainage accounts had been described as dense, impenetrable sawgrass (Chapter 4). This would include both the Okeechobee Muck lands to the west and the more central Sawgrass Plains. If so, the post-drainage progression in areas of sawgrass where the water table had been lowered to mostly or completely below ground appears to have been generally:

dense sawgrass ➔ thinning sawgrass ➔ invading herbs ➔ invading shrubs.

Variations in the post-drainage frequencies of vegetation fires would have affected the progression, particularly the shrub stage. Peat fires, which would have killed all of the vegetation types, would drastically affect the progression, likely eliminating sawgrass altogether and accelerating the invasion of herbs and shrubs.

Early observations that some of the same herbaceous and shrubby species rapidly colonized spoil banks of sawgrass peat thrown up along the canals suggest that one of the key factors driving the post-drainage changes in vegetation was simply the distance of the water table below the soil surface:

> "A notable feature of the trip along these [the North and South New River Canals] canals was the richness of the soil, which is a creamy black and ranging anywhere from three to five feet thick. Along the banks where the muck and rock have been thrown out great varieties of weeds are growing, some reaching the height of fifteen feet, with a diameter at the base of from three to six inches. This growth is most remarkable, especially when it is taken into consideration that much of it is less than a [sic.] six months old." (Anonymous 1907).

The drainage engineer Wright also noticed such a colonization, both in sawgrass land and along canal banks:

> "When the [sawgrass] land is once broken and this saw grass destroyed, it does not reproduce itself, but the ground is soon covered with a growth of coarse weeds, principally with what is called 'Careless Weed.' The writer has seen careless weeds along the canal banks, twenty inches in circumference at the ground and sixteen feet high--the growth of one season." (Wright 1912, p. 26)

In addition to the influence of water table distance below the surface, the breaking up and exposure of the peat soils played a role in promoting the change sequence presented above.

An observation was made only three years after the opening of the North New River Canal by soil scientists who in 1915 personally took samples in more than 100 square miles of the Sawgrass Plains and Ridge and Slough landscapes. In the (heavy) sawgrass areas they noted progressions similar to that diagrammed above: sawgrass to shrubs (willows), or sawgrass to a mix of herbs and shrubs (wax myrtle, maiden cane and fennel).

They also note a progression within the sloughs, areas that were originally wetter (deeper and longer hydroperiod) than the sawgrass. Aquatic areas of former water lilies were being invaded, as quickly as three years after canal opening, by sawgrass and another emergent species, *Sagittaria*:

> "The drainage of the Everglades has proceeded sufficiently to induce noticeable changes in the character of the vegetation in certain places. In the interior of the

> glades, along edges of the sloughs which once supported a luxuriant growth of water lilies the lowering of the water table is accompanied by the invasion of saw grass and Sagittaria on the lower ground. Two or three miles south of the lake willows are gradually encroaching upon ground which under former conditions of poorer drainage supported a heavy growth of saw grass. In the 'lower glades' saw grass is giving way to myrtle, maiden cane, and fennel." (Baldwin and Hawker 1915).

Loveless (1959), who studied the central Everglades forty five years later, noticed a similar progression, from aquatic sloughs to emergent “wet prairie species” (maiden cane, *Rhynchospora* spp. and *Eleocharis cellulosa*) to sawgrass

Observations by Loveless (1959), Andrews (1957) and Davis (1957); post-drainage vegetation studies by Gunderson (1989) and Olmsted et al (1984); as well as pollen analyses from soil cores (Willard ref) all suggest a post-drainage progression in wetter areas that were initially peat soil-based sloughs:

Aquatic sloughs ➔ wet prairie species ➔ thin or medium dense sawgrass

As in the case of the sawgrass areas, the progression appears to be primarily related to average water depths, in this case mostly above ground. This parallels the natural ordering of vegetation communities proposed by Gunderson (1994). Also as in the case of the sawgrass progression, the ordering was almost certainly not strict, and subject to variations due to fire and other causes.

The above sequences were derived primarily from observations made in the northern or central Everglades, north of Tamiami Trail. Although the Impoundment Phase increased water depths within the impounded Water Conservation Areas north of the Trail, in the unimpounded portions of the Everglades to the south, water depths do not appear to have risen, at least not during the earlier parts of the Impoundment Phase. The vegetation progressions there are additionally complicated by the differing substrates within the Ridge and Slough versus the Marl Marsh areas, but the general pattern of vegetation change appears to have been one reflecting continued low or declining water depths:

> “Local residents most familiar with the Everglades area [south of Tamiami Trail] agree that within the period of their observations (roughly 25 years) there has been a marked expansion of woody vegetation at the expense of the sawgrass area. It is also agreed that, in spite of fires which have destroyed many tree islands, this invasion has been sufficient to change the whole aspect of large areas particularly south of the Tamiami Trail. The species most involved in this thicket

> expansion is willow (Egler, 1952: 240; Poppenhager, Redding, Winte, pers. comm.). Some of the present willow areas mark sites of burned-out bayheads, but there seem to be many sites where willow scrub is independently invading sawgrass. It appears a reasonable hypothesis to attribute this development to the drying of the lower glades. It has, at least, occurred under conditions of lowered water levels, and cannot be interpreted as a fire effect because, as Egler points out (ibid), fire acts to limit this thicket extension." (Robertson 1953).

A remarkably similar description was made by the naturalist Charles Torrey Simpson 30 years earlier, shortly after the onset of canal drainage:

> "Although only the preliminary work of drainage has been done yet it has had a marked effect on the vegetation. Along the banks of the canals and on all slightly elevated spots a variety of trees and shrubs are springing up, so that where formerly the eye swept over a monotonous even expanse of saw grass, the view now presents patches of incipient forests. This new element in the flora is especially noticeable around the eastern border which is somewhat drier than the main body of the swamp. Here groves of young timber are claiming titles on every hand.
>
> One of the results of partial drainage is that along this same east border numerous low, timbered 'islands,' which were formerly quite wet, have now been changed to dry land. A considerable part of the foundation of these groves is peat and in dry times it is very liable to fire, and once begun it is well-nigh impossible to extinguish it. These groves, despoiled of their only defense against fire, are often wholly destroyed. So it happens that while the draining of the Everglades makes it possible for forests to spring up and flourish in some places it is the cause of their destruction in others." (Simpson 1920, p. 126-127).

The sawgrass land progression described above can also be recognized spatially in the patterns present in the Everglades vegetation of the 1940s. **Plate 4**, digitized from Davis (1943), presents a picture that we might expect as water levels progressively lowered within the basin: a pattern of drier vegetation types encroaching inward from the edges of the basin. The encroaching vegetation types tend to occur in sequential bands parallel to the edges.

Using the vegetation categories mapped by Davis (1943), such a sequence can be seen in **Plate 4** along the eastern border of the Everglades, between Ft. Lauderdale and Miami (T 50 to 54, R 40 and 41). The first band is the "Wet Prairies" bordering the Atlantic Coastal Ridge. Inward from these lies the second band of "Saw-grass (with wax-myrtle thickets)" which extends all the way north to the top of the Everglades in Township 41. As discussed in the previous section on peat to sand soil transformation, both the "Wet Prairies" band and the "Saw-grass (with wax-myrtle thickets)" band are displaced six or more miles inward in Township 50 by the exceptional and early drainage present in the vicinity of the North and South New River canals. Because the Ridge and Slough landscape between the Miami and North New River canal had already been transformed into sawgrass, which would have been the third band, "Saw-grass (with wax-myrtle thickets)" includes a large area that would have otherwise been separated into two bands (compare **Plate 11**, **Plate 12** and **Plate 13**).

We can also recognize similar banding along the western border of the Everglades (T 43 to 49), and in the northern Everglades between the Miami and North New River canals. Along the western border, the sequence passes from "Wet Prairies" to "Saw-grass (with wax-myrtle thickets)" and then to "Saw-grass Marshes (dense)." The dense sawgrass marshes most closely resemble the original pre-drainage landscape that completely covered the northern Everglades (approximately T 44 to 47, R 34 to 39).

In the northern Everglades, the areas of "Saw-grass (with wax-myrtle thickets)" and of "Saw-grass Marshes (medium dense to sparse)" mapped between the Miami and North New River canals also represent a form of this banding; prior to drainage they would both have been areas of dense sawgrass. The presence of the two drier sawgrass types between these two canals parallels the creation by soil subsidence of a locally higher, and presumably drier inter-canal region, which is visible on **Plate 10**.

**SUMMARY**

Many first-hand observations are available to understand the drainage history of the Everglades and the severe and widespread ecological effects that drainage had caused by the 1940s. The rapidity of change varied. Hydrologic and vegetational changes were already visible within the first years, whereas changes in soil type, topography and frequency of peat fires required 5-20 years to become obvious.  By 1940, these changes were recognizable throughout the system.

The drainage history can be divided into three phases, a Lake Okeechobee Phase (1882-1895), Muck Canal Phase (1905-1945) and Impoundment Phase (1950 to present). The first two phases greatly reduced water depths and form the principal content of this chapter. The Impoundment Phase, corresponding primarily to the “Central and South Florida Project for Flood Control and Other Purposes,” actually raised average water levels in the areas north of

Tamiami Trail ("Water Conservation Areas"), but largely blocked sheet flow and generally increased the annual and spatial variance in water level. South of Tamiami Trail, the Impoundment Phase generally did not increase water depths until special programs were introduced later. The ecological effects of the Impoundment Phase and the hydrologic history of the special programs were not addressed in this chapter.

The drastic changes that occurred during the 1940s underscore the fact that "snapshots" of soils and vegetation available from that period cannot be used as estimates of pre-drainage conditions. However, when combined with historical evidence, as presented in this chapter, they provide a strong basis for systematically estimating the extents and characteristics of the pre-drainage landscapes. This process of hindcasting forms the core of Chapter 4.

**CHAPTER 3 FIGURES**

Figure 3.1 View of the North New River Canal, January-March 1915. Note absence of levees and closeness of water level to land surface. (Baldwin and Hawker 1915).

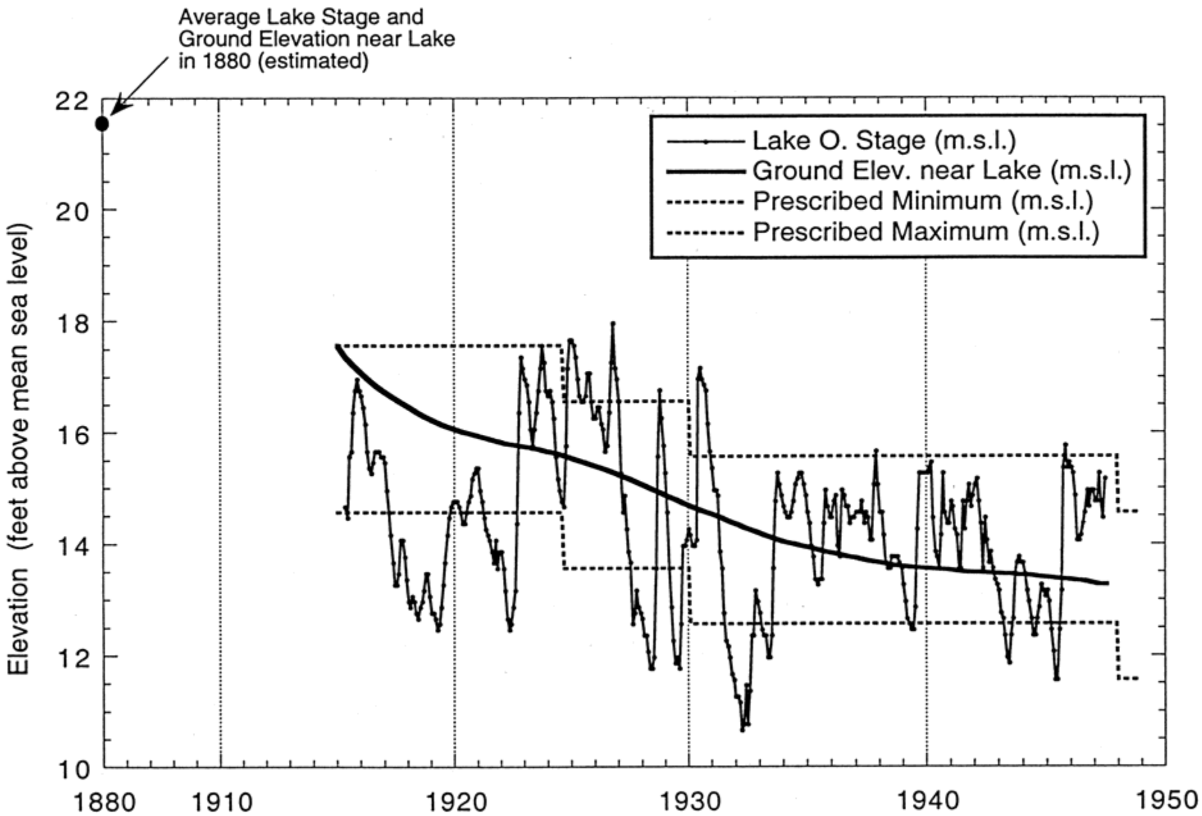
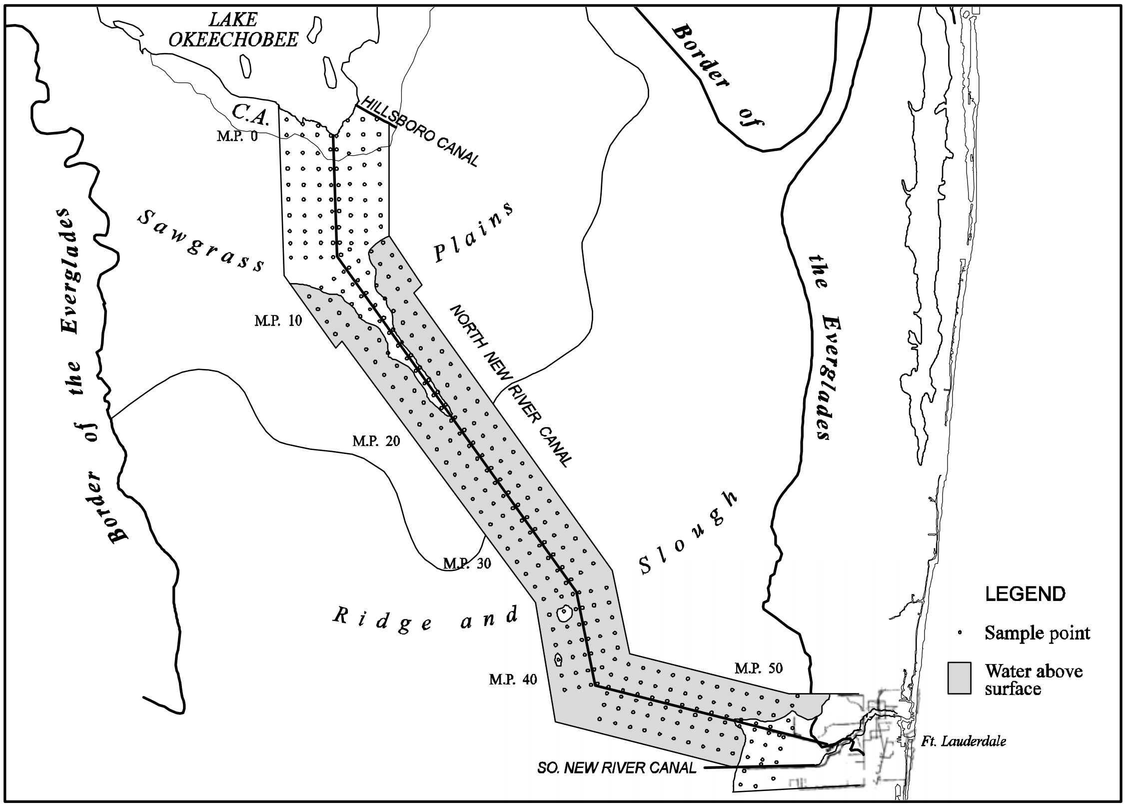



Figure 3.2 Partial history of (1) water levels in Lake Okeechobee and (2) ground elevations of the peat soil near the southern border of the lake. Note ground elevations of the peat soil near the southern border of the lake. Note especially the 4-5 foot drop in ground elevation and in average lake level between 1880 and 1915. After 1915 note that the decline in elevations of the prescribed (managed) lake minimum and maximum levels approximately paralleled the declining ground surface elevation. 1915 to 1947 data were derived from Johnson (1947).



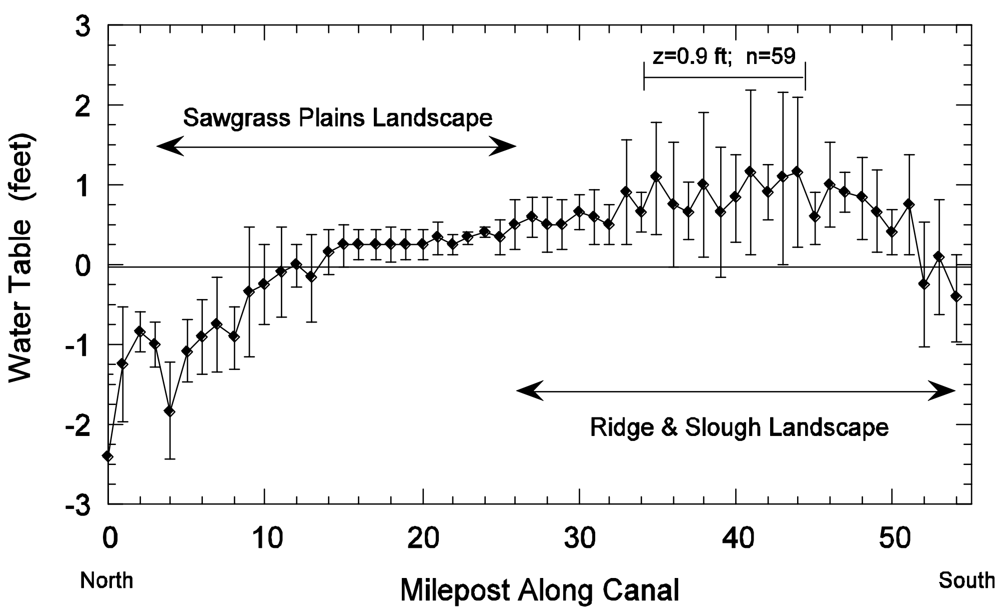




Figure 3.3 Surface water ponding depths along the North New River Canal, three years after canal opening. Measured in the dry season, 22 January to 16 March 1915. Top: area of ponding; bottom: measured depths and standard deviations. Note differences between landscapes (Map and data from Baldwin and Hawker 1915).

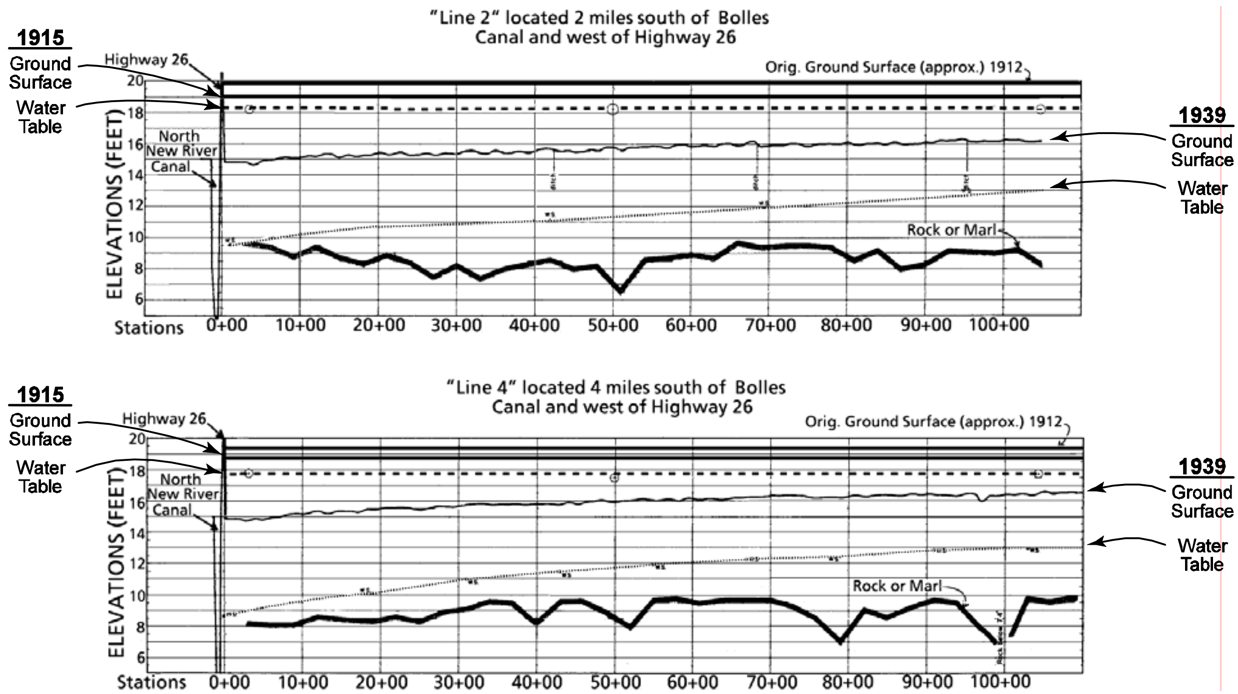



Figure 3.4　Water table and ground surface elevations along two transects in the Sawgrass Plains area during February-March of 1915 and 1939. Both were dry years. Locations are shown in **Figure 3.3** and **Figure 3.9** (modified from Clayton et al. (1942). Bedrock, 1912 ground surface and 1939 elevations were obtained from Clayton et al. (1942). 1915 ground surface levels were obtained from subsidence data (Clayton et al. 1942; Stephens and Johnson 1951). 1915 water tables from Baldwin and Hawker (1915; see also **Figure 3.3**).

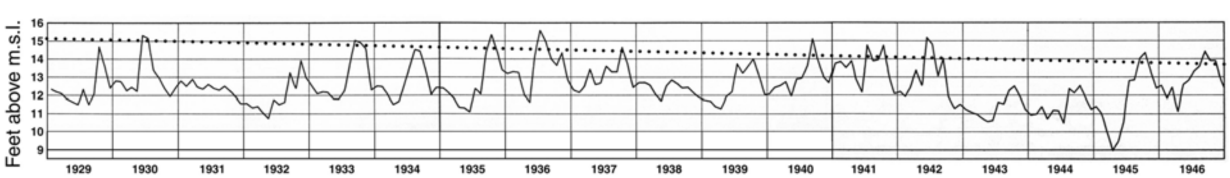



Figure 3.5　Monthly mean stage of the Hillsboro Canal at Shawano (Sect 13, T 45, R 38), 1929-1946. Parker et al. (1955) considered these stages to be representative of the surrounding Everglades (see text). Note that the water table was below ground surface (dotted line) during almost all of this period. Modified from Parker et al. (1955).

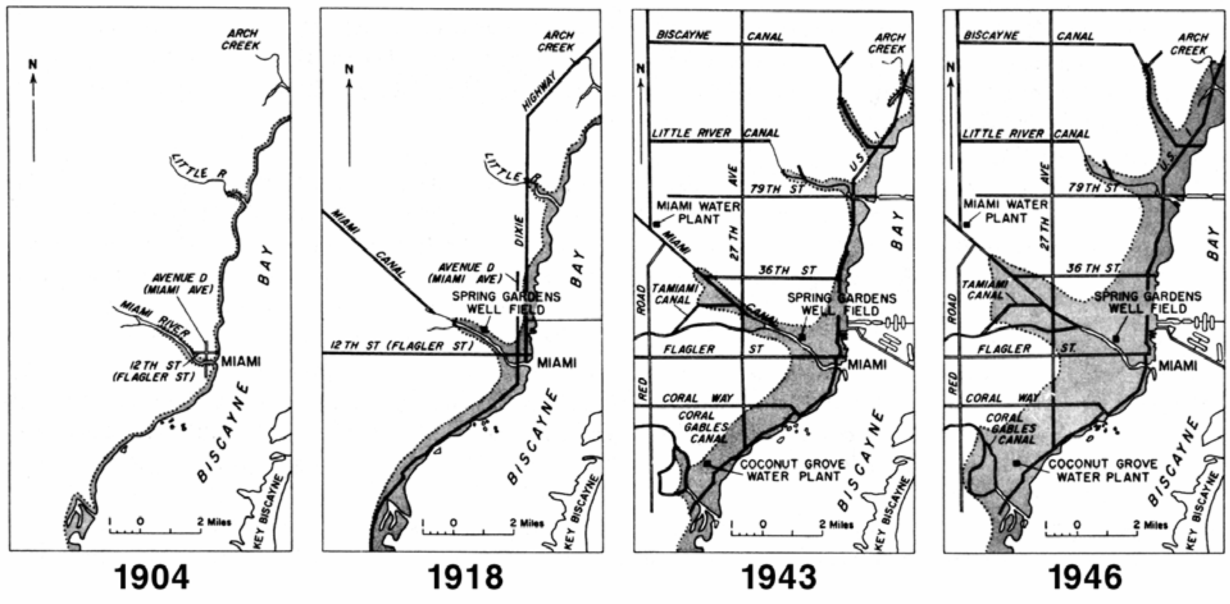



Figure 3.6 Intrusion of salt water into the Biscayne Aquifer, Miami area, as water levels in the Everglades were lowered by canal drainage from 1904 to 1946. (Modified from Parker et al. 1955).

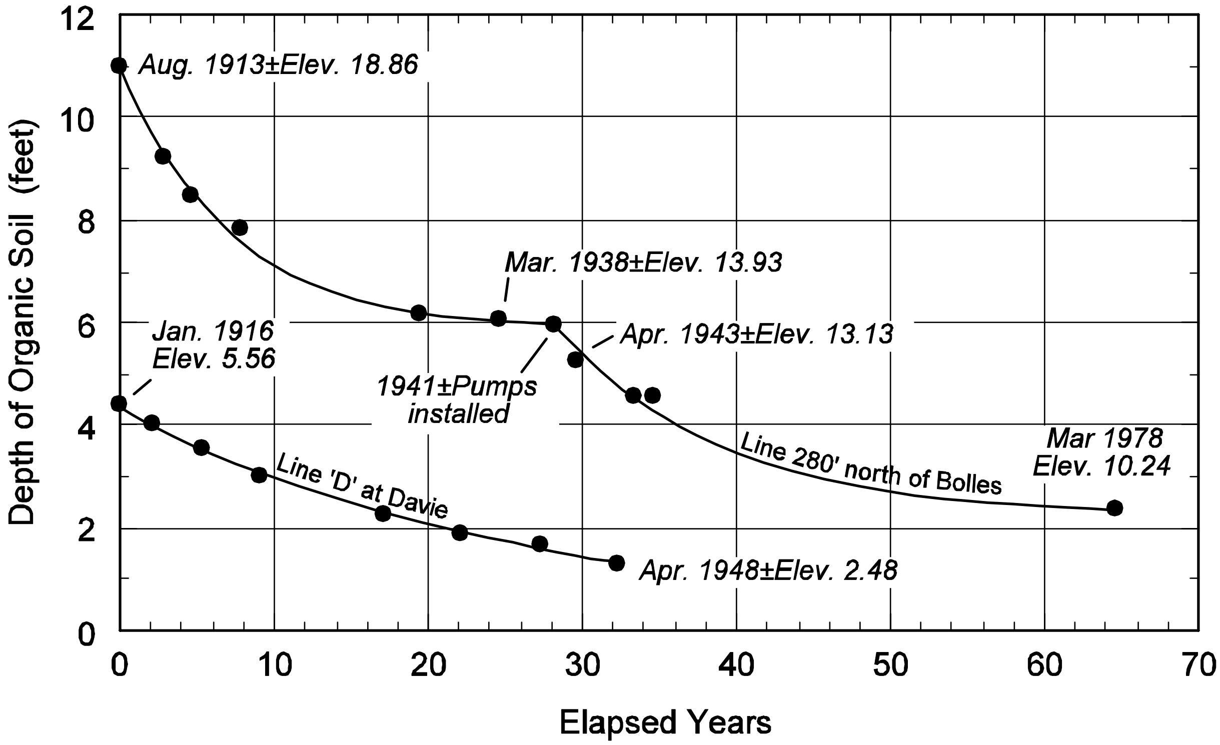



Figure 3.7 Subsidence of Everglades organic soils, 1913 to 1978. Survey lines established in 1913 and 1916 by the U.S. Dept. of Agriculture: "line 280' north of Bolles Canal at Okeelanta," and "line'D' at Davie. Locations are shown on **Figure 3-10**): Line 280' is located in T44 R 36 S 36; along transect C, north of Transect D; and Line 'D' is Transect E. (Data from Stephens and Johnson 1951; Shih et al. 1979).

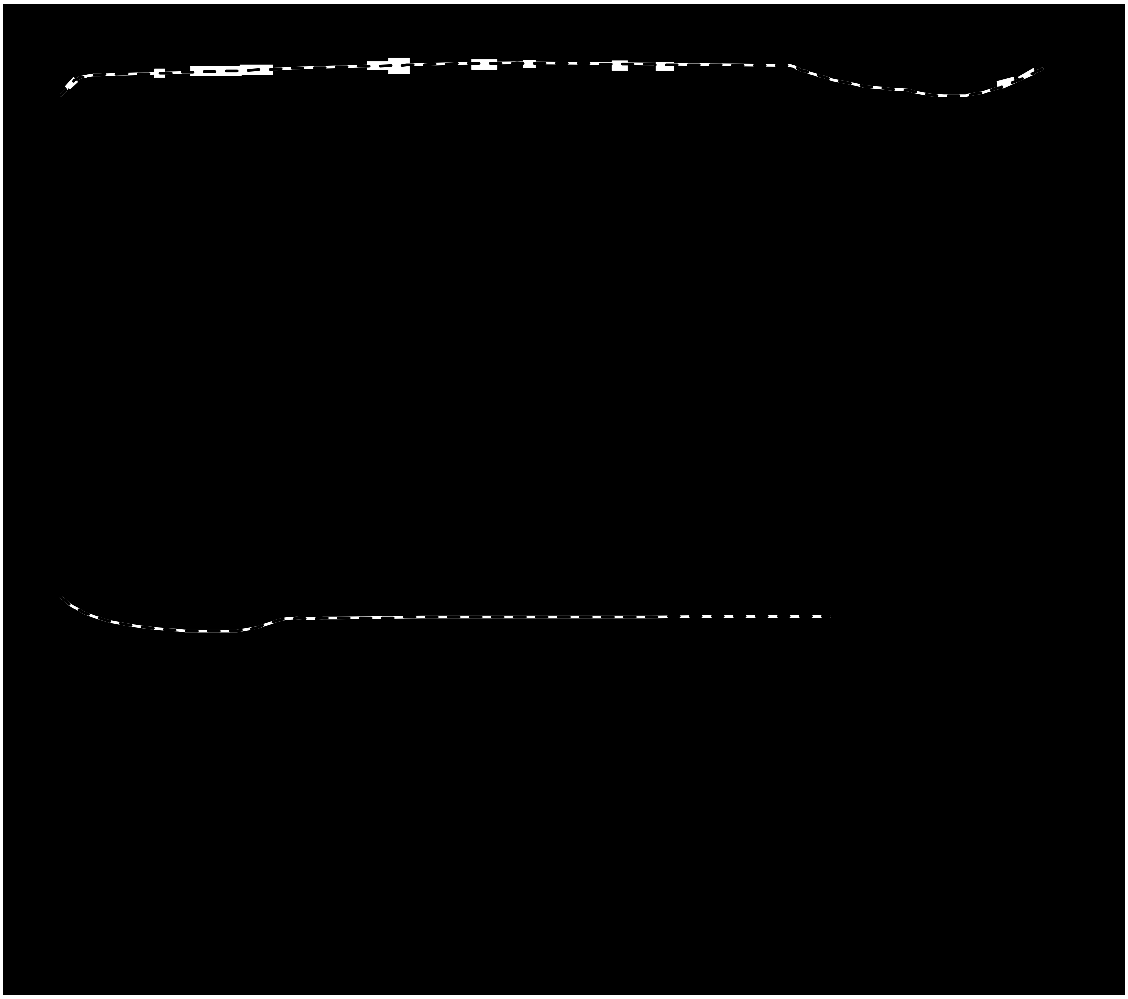


Figure 3.8 Subsidence of organic soils in the northern Everglades, 1912 to 1940. Location of transects A and B shown in **Figure 3.10**. 1912 elevations are likely similar to pre-drainage elevations. Note change from convex to concave surface and "subsidence valleys" along each canal. (modified from Stephens and Johnson 1951).

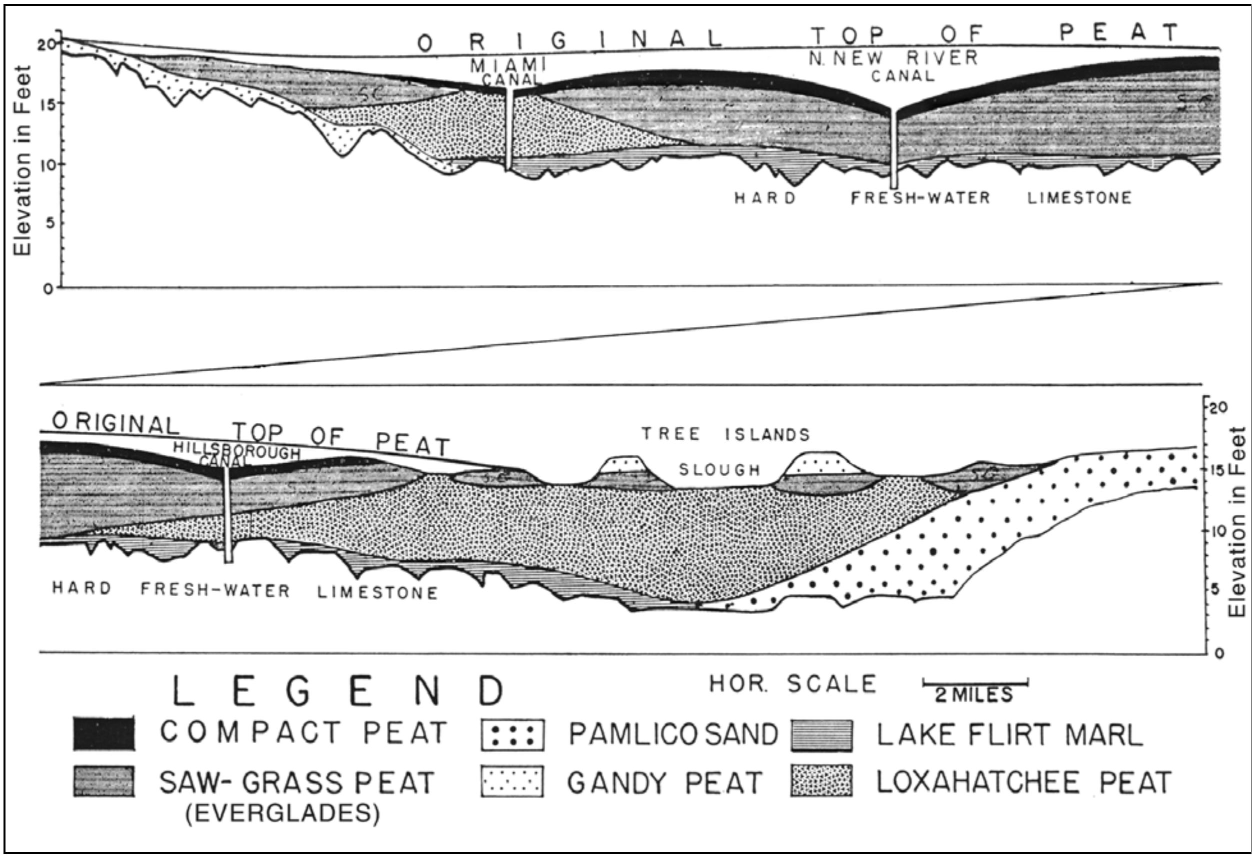



Figure 3.9 Subsidence of peat soil in the northern Everglades, 1912 to approximately 1940. Note the black surficial layer of post-drainage "Compact Peat" above the sawgrass (Everglades) Peat. Location shown in **Figure 3.10** as Transect C. (Modified from Davis 1946).

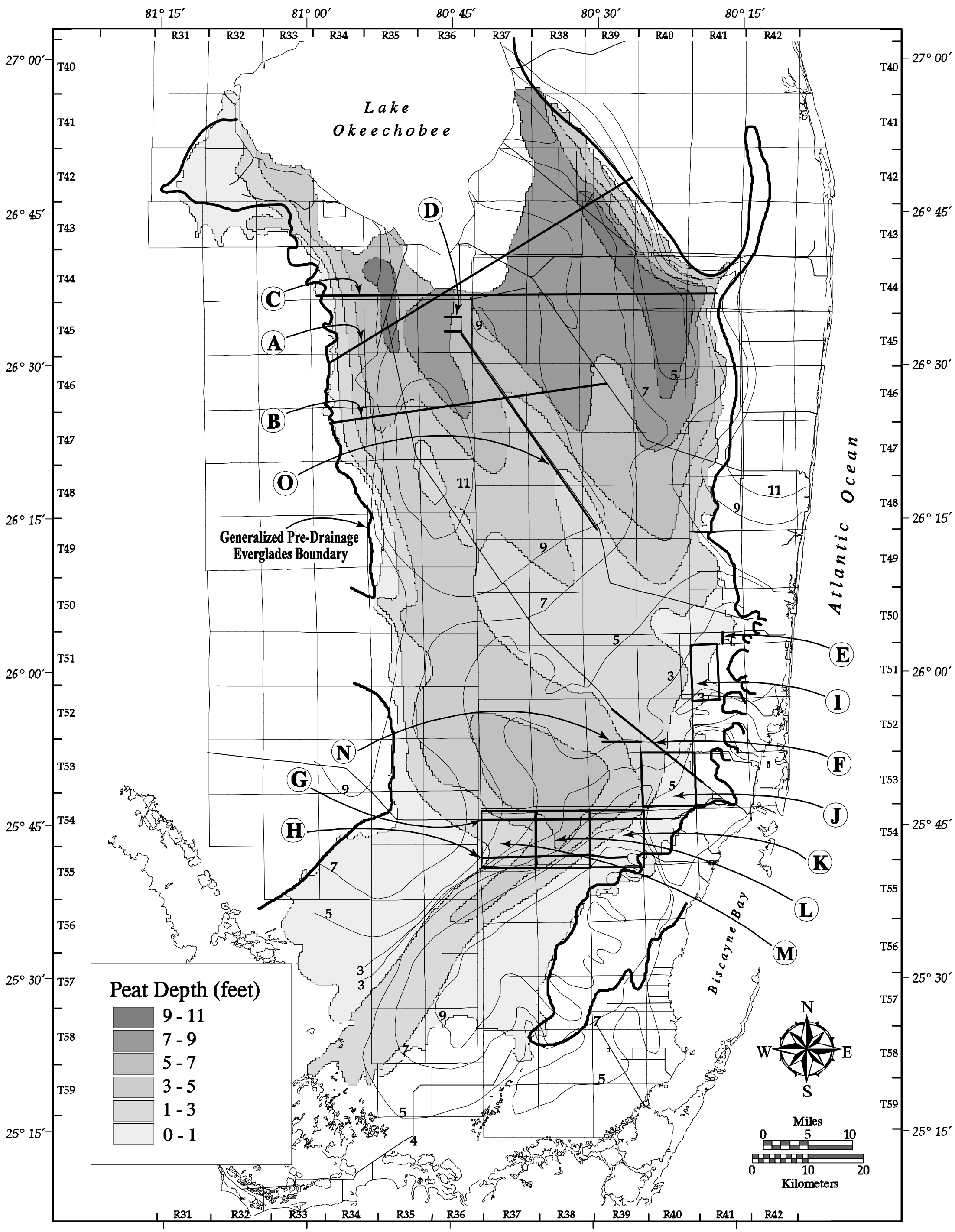



Figure 3.10 Map of approximate peat thickness, 1940-1945. From Davis (1946) and location map for transects used in other figures in this report. Alphabetic labels indicate locations of estimates of peat thickness prior to 1940. A,B are shown in **Figure 3.8**. C in **Figure 3.9**. D in **Figure 3.4**. E in **Figure 3.7**. F and N in **Figure 3.14**. G and H in **Figure 3.15**. I in **Figure 4.9**. K in **Figure 4.20**. L and M in **Figure 4.19** and O in **Figure 3.13**.

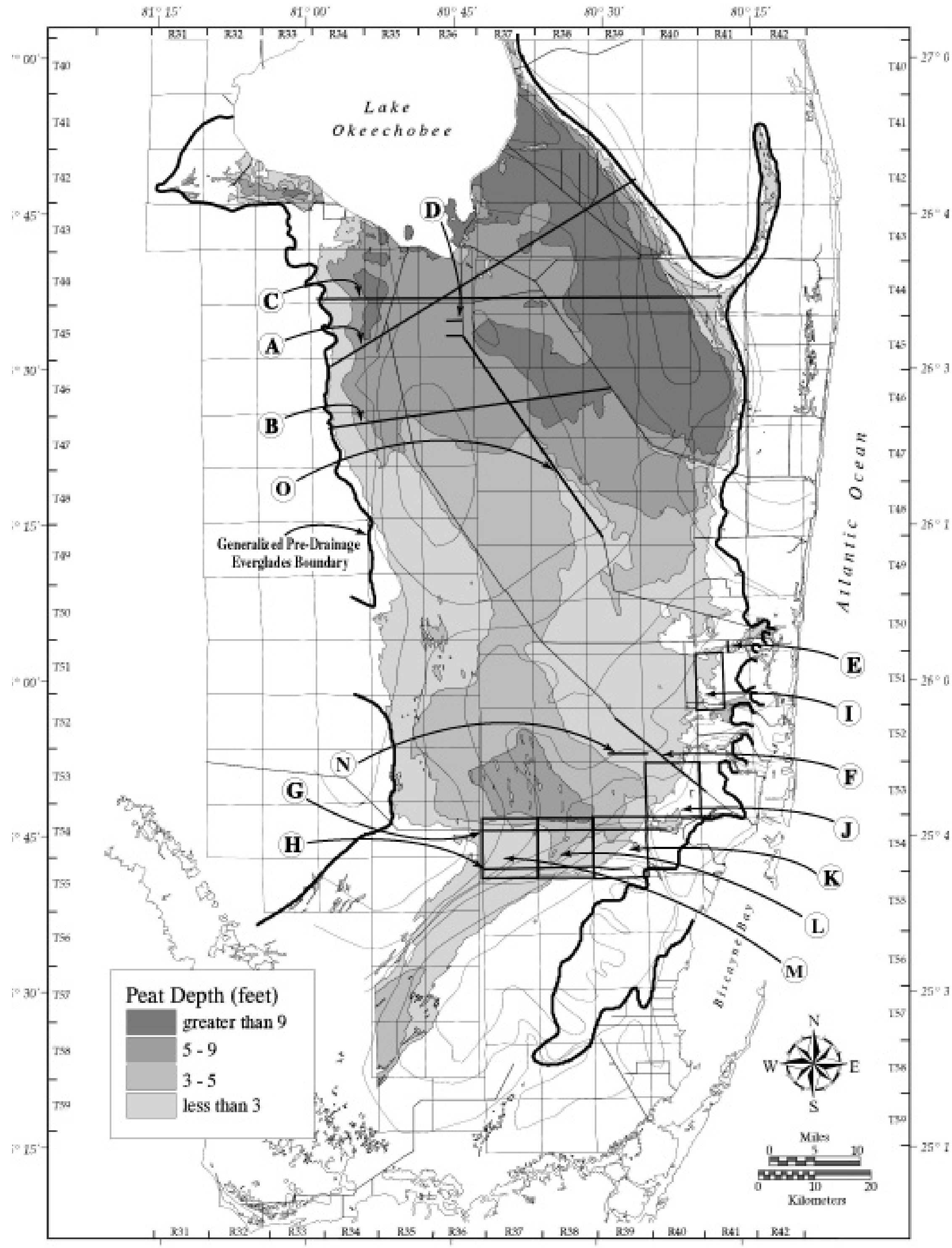



Figure 3.11 Map of surveyed peat thickness, 1939-1943. From Jones et al. (1948) soil map and locations transects used in other figures in this report. Alphabetic labels indicate locations of other, earlier estimates of peat thickness. A,B are shown in **Figure 3.8**. C in **Figure 3.9**. D in **Figure 3.4**. E in **Figure 3.7**. F and N in **Figure 3.14**. G and H in **Figure 3.15**. I in **Figure 4.9**. J in **Figure 4.8**, K in **Figure 4.20**, L and M in **Figure 4.19** and O in **Figure 3.13**.

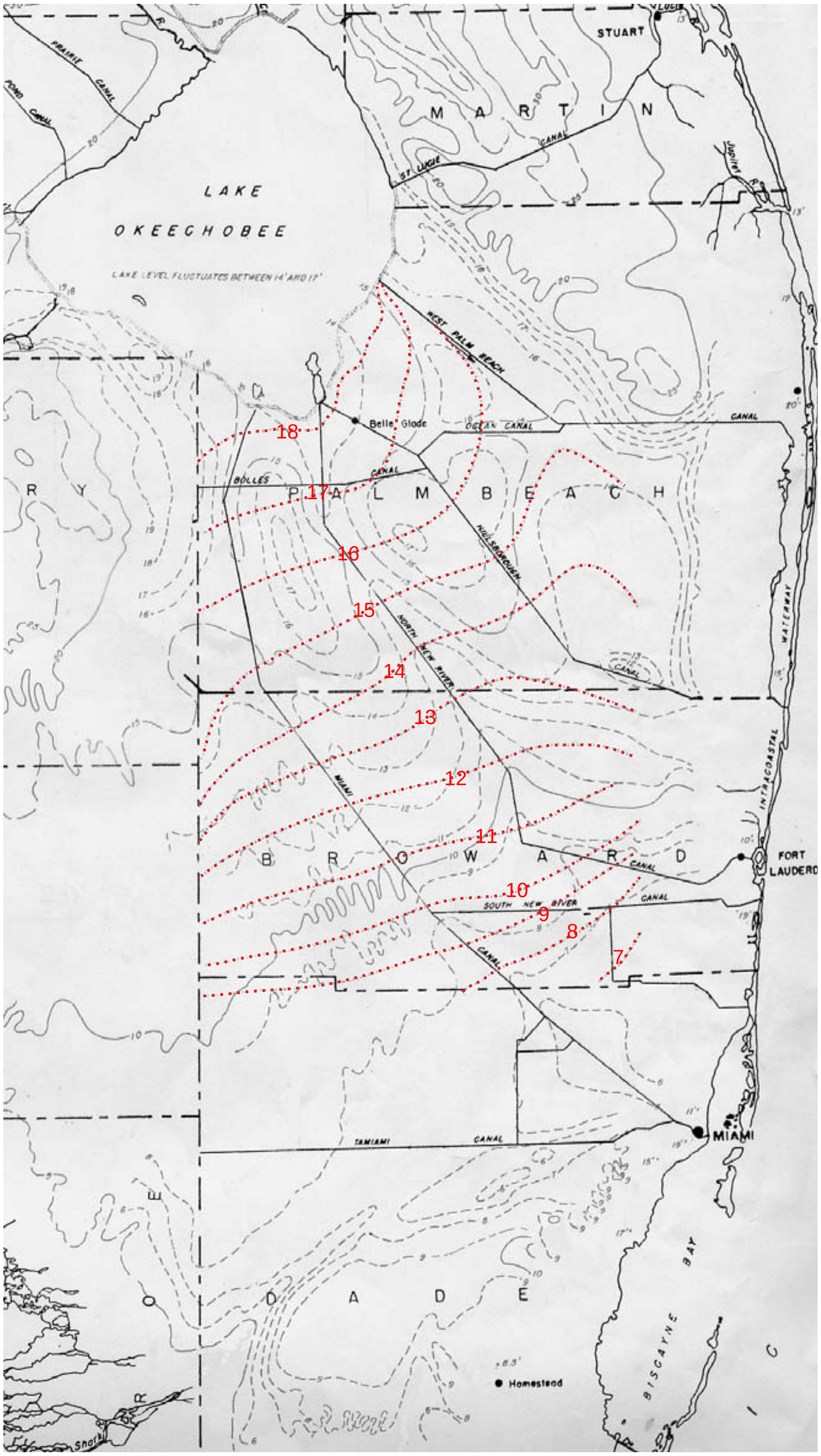



Figure 3.12 Section of contour map adapted from the Davis (1943) Topographic and Drainage Map of Southern Florida. Pre-drainage land surface elevation contours estimated by Davis (red lines) are compared to actual 1940's (dashed black lines) contours.

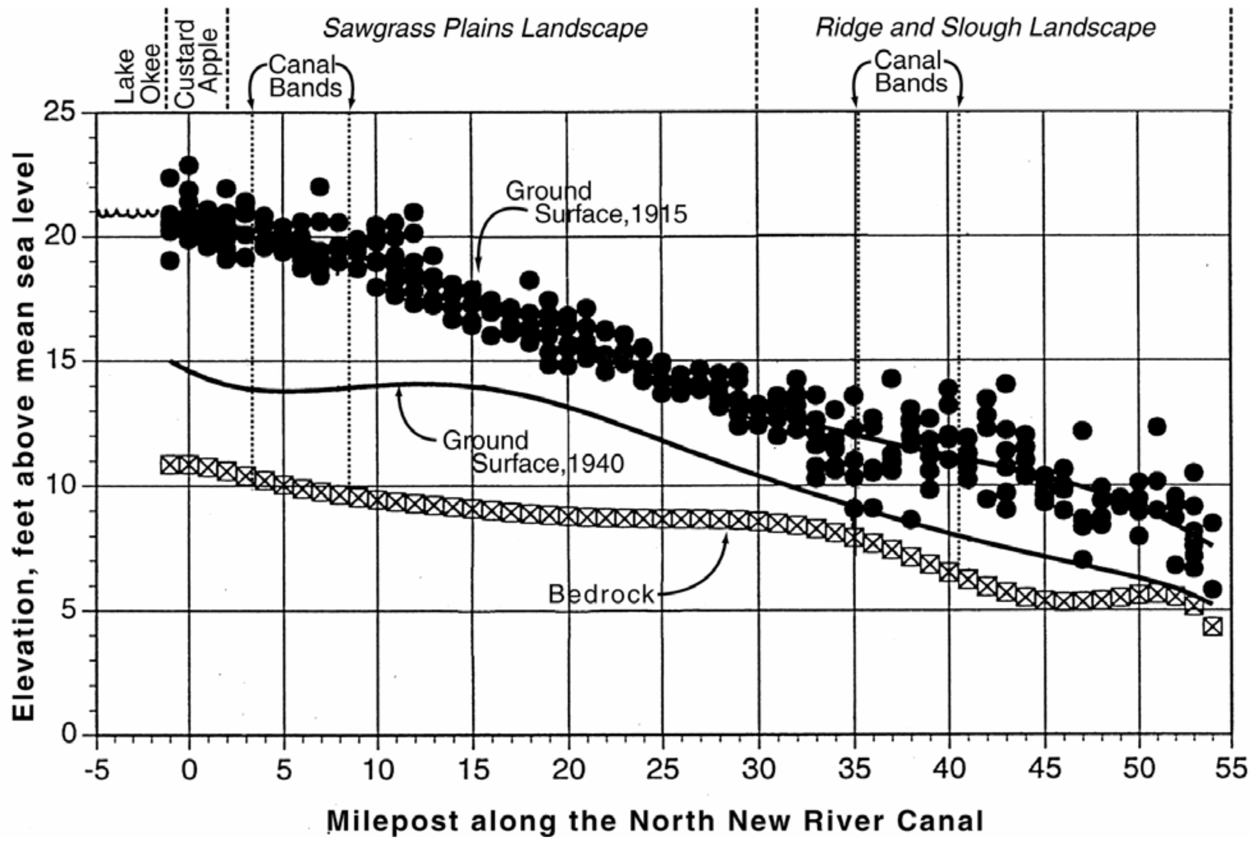



Figure 3.13 Ground surface elevations along the North New River Canal, 1915 and 1940. Based on measured surface elevations (1915, 1940) and measured peat thicknesses (1915; see text). See Plate 8 for milepost locations.

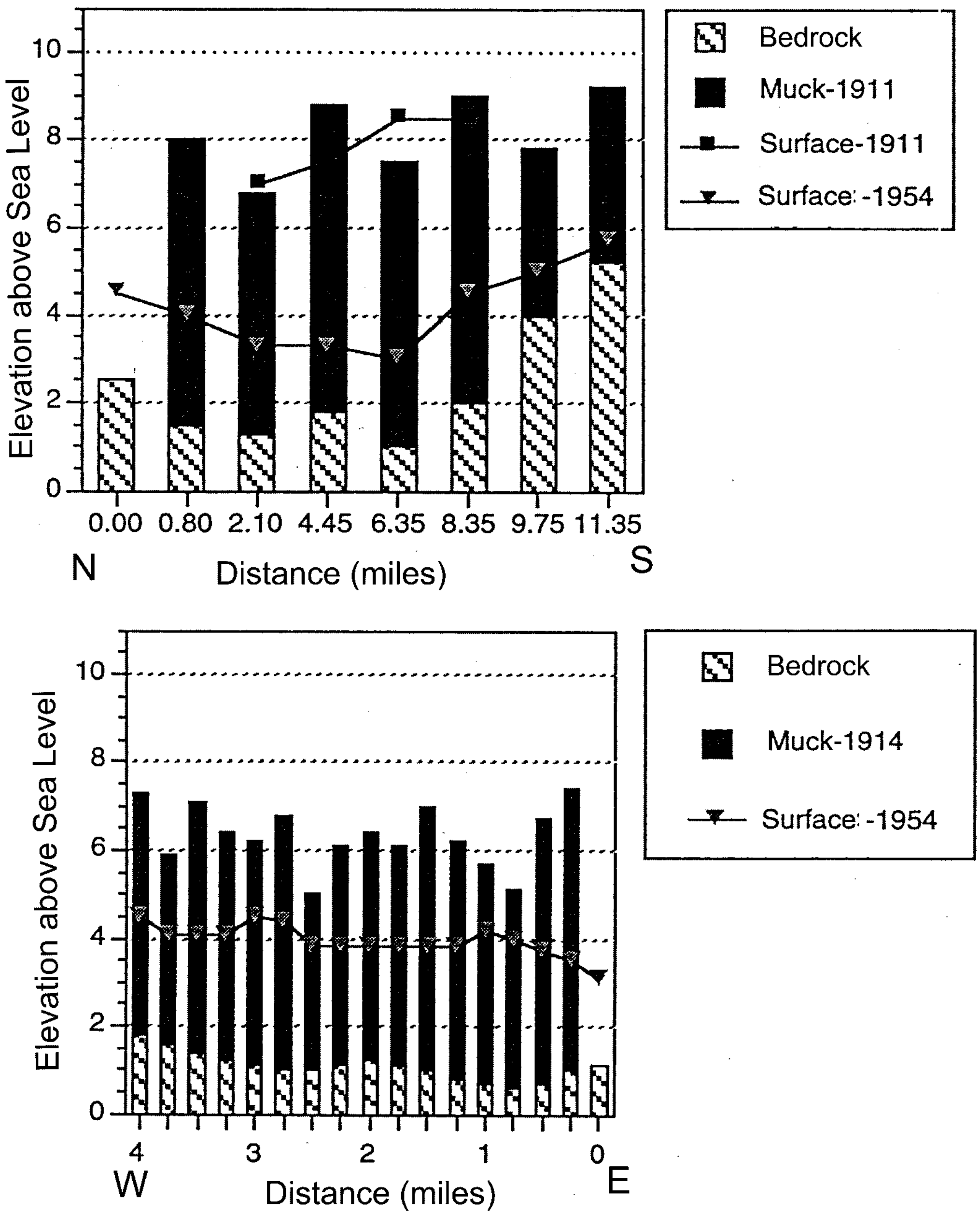



Figure 3.14 Peat thickness and ground surface elevations along (Top) and near (Bottom)) the Miami Canal, 1911 or 1914, and 1954. Locations of these transects are shown in **Figure 3.11**. 1911 and 1914 peat thicknesses are point measurements.

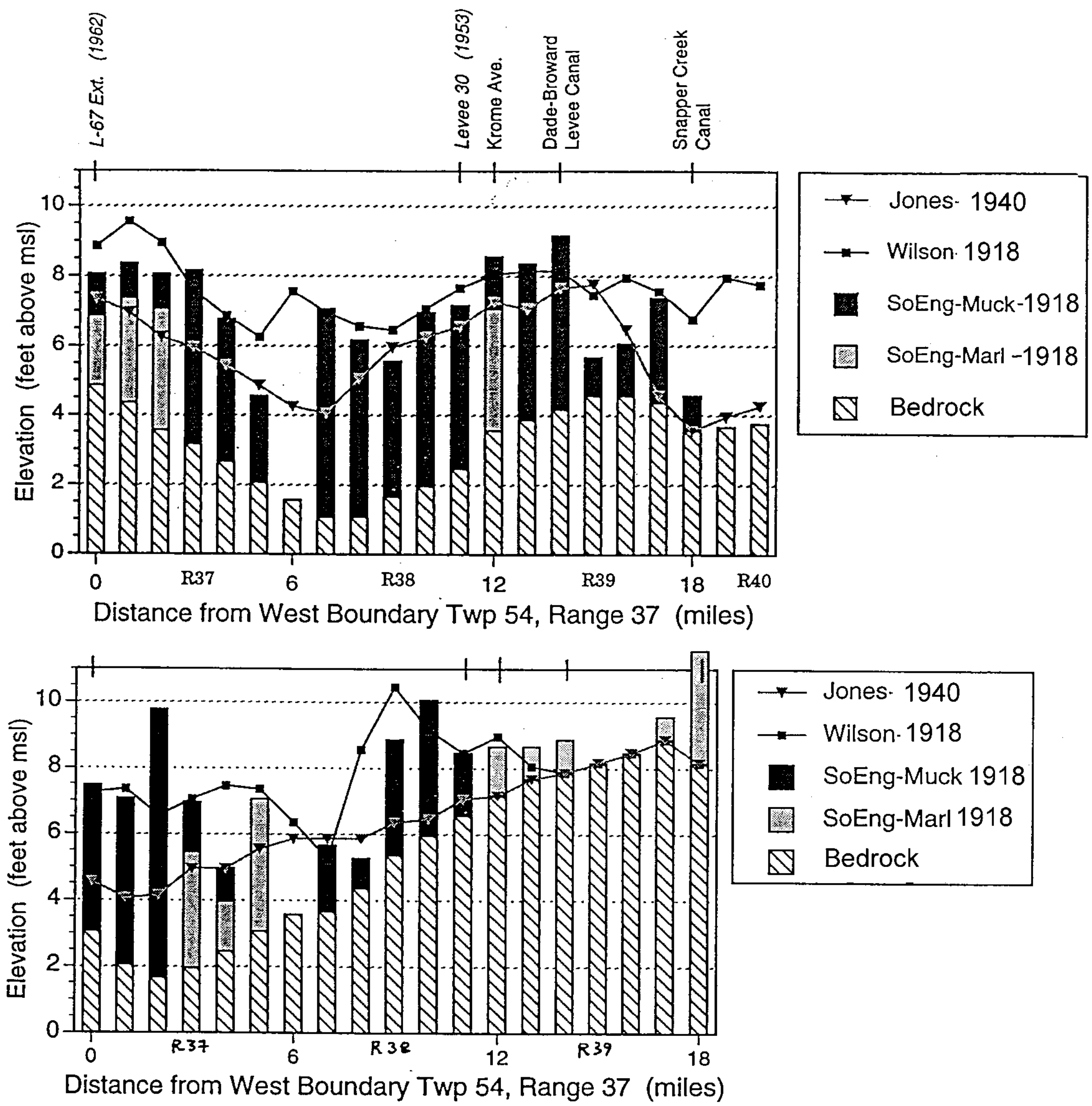



Figure 3.15 Peat thicknesses and ground surface elevations along the proposed Tamiami Canal (Top) and Snapper creek Extension Canal (Bottom). Locations of transects are shown in **Figure 3.11**. 1918 peat thicknesses are point measurements.

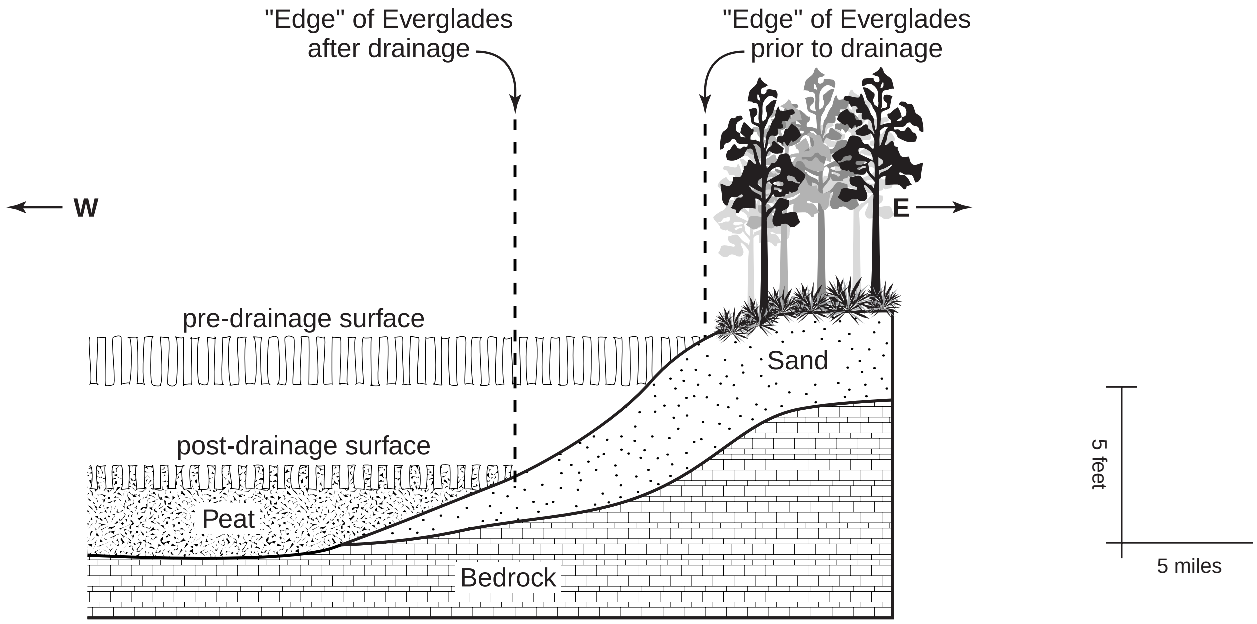



Figure 3.16 Anthropogenic formation of sandy areas along eastern edge of Everglades. With lowering of Everglades water levels, peat soils oxidized from the surface downward, exposing the underlying peripheral sand.

FLORIDA GEOLOGICAL SURVEY BULLETIN THIRTY—FRONTISPIECE

(Courtesy Miami Herald)

Fire in the Everglades burning peat, April 1944. Such fires occur frequently during the dry season and destroy some of the dry, surface peat. If the Everglades were more generously flooded such fires could be reduced and the peat saved.

Figure 3.17 An extensive peat fire, typical of the post-drainage Everglades during the 1920s to 1950s. Frontispiece of The Peat Deposits of Florida (Davis 1946).

Figure 3.18 "Annual fires have burned off muck to reveal solution pitted top of Miami oolite." Photo by Mrs. G.G. Parker, July 30, 1940. Location: Coral Way, ½ mile E. of S.W. 102 Ave, Miami (middle of the line between sections 8 and 17, T54 R40). Formerly Ridge and Slough landscape, near border with Rockland Marl Marsh (see **Plate 13**).

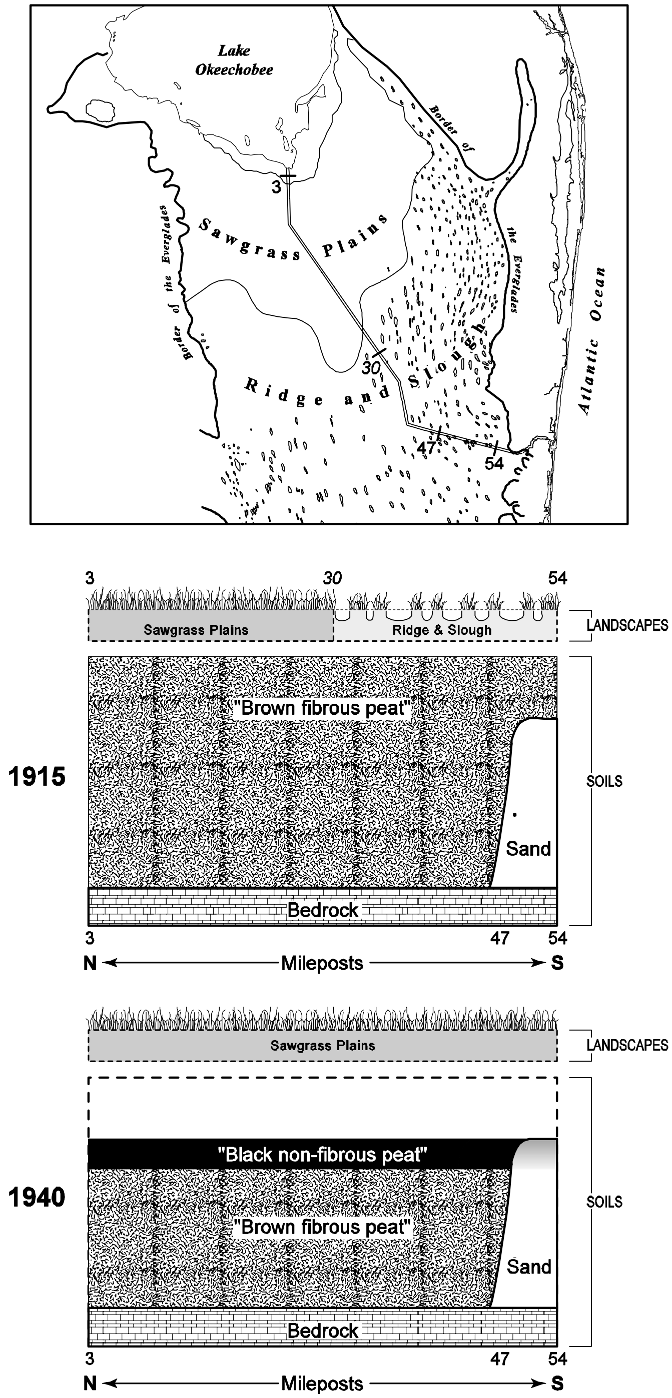



Figure 3.19 Landscape change in the upper Everglades during the first 25 years of drainage. Observations from the length of the North New River Canal, shown in relation to the pre-drainage landscapes (top). Vegetation and generalized soil profiles between mileposts 3 and 54 in 1915 (middle), and in 1940 (bottom). Note the disappearance of the Ridge and Slough landscape, subsidence of peat soils, and appearance of a surficial layer of decomposed, black, non-fibrous peat.

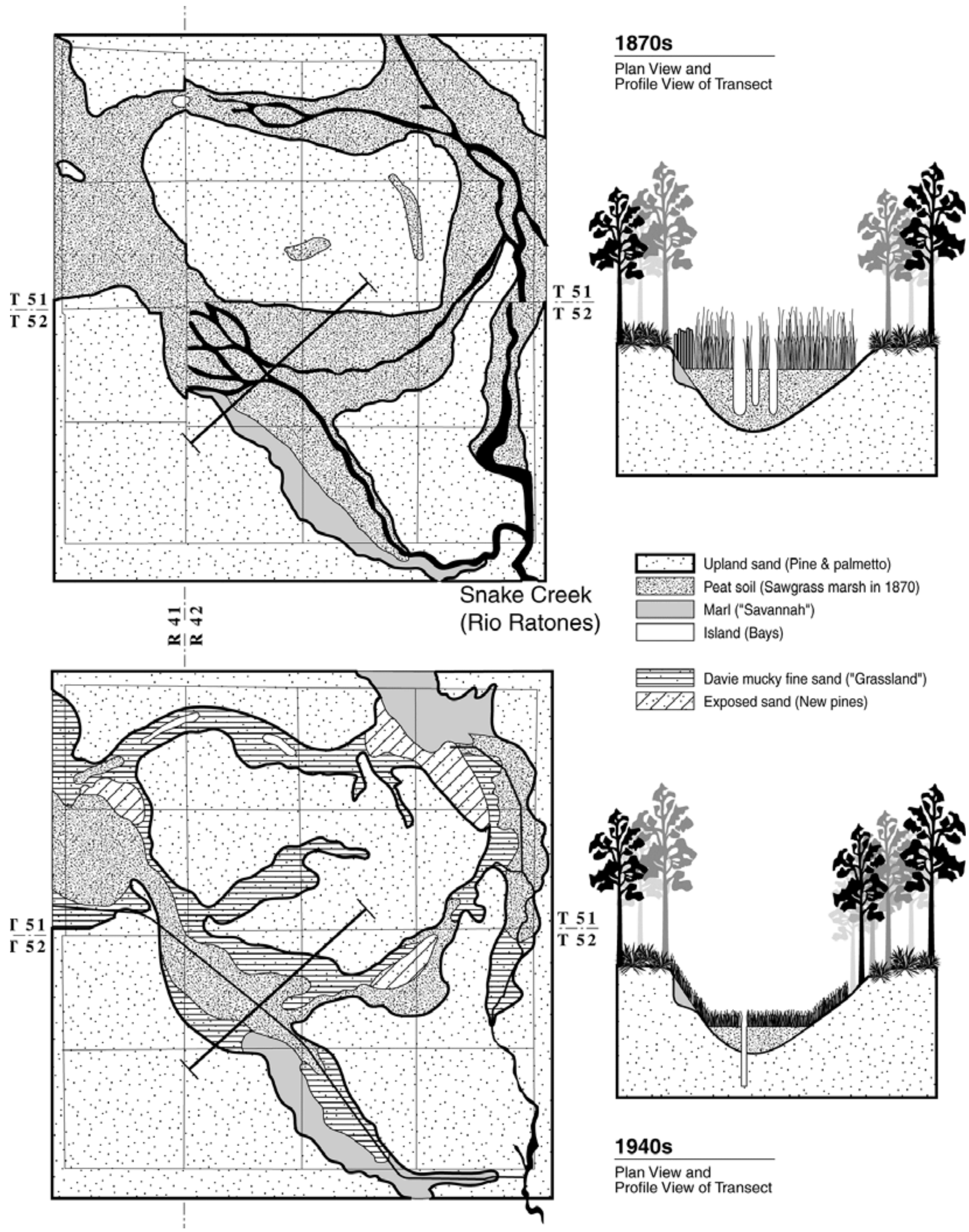



Figure 3.20 Peat subsidence in the Peat Transverse Glades, Snake Creek area. Lowering of water levels in the Everglades reduced surface outflows through the transverse glades, diminishing creeks, eliminating the canoe route. (c.f. **Plate 12**), and increasing oxidation of sawgrass peats. By 1940, peat remained only in the deeper centers of the transverse glades and shorter hydroperiod grasses had replaced the sawgrass. Pre-drainage plan view is a mosaic of four township surveys (Williams 1870 - T51 R42; Williams 1870 - T52 R41; Williams 1870-T52 R42; Newman 1908 - T51 R41); 1940s plan view was taken from the soil map by Jones et al. (1948).