

History and Development of
Water Delivery Schedules for
Everglades National Park through 1982

Report SFRC-87/

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INTRODUCTION

The classic view of "pre-drainage" Everglades basin hydrology bears little resemblance to that of the present intensively managed system. Parker et al. (1955) described the 3900 mi² historic Everglades marsh as the southern portion of a much larger (9000 mi²) basin stretching from the headwaters of the Kissimmee River to the Gulf of Mexico (Fig. 1). This description emphasized the hydrologic interconnections between the system's sub-basins, arguing that in very wet years Lake Okeechobee and its tributaries contributed large volumes of water to the northern Everglades. These waters supplemented rain falling directly upon the Everglades marsh as the system flowed southward to tide.

Over 100 years of south Florida water management has greatly altered this historic basin. Some 1500 miles of canals and levees (Fig. 2), known collectively as the "Central and South Florida Project," have been constructed to harness the region's water resources for the needs of man. Past management for flood control and water supply, however, has often been linked to degradation of south Florida's native vegetation and wildlife. In recent years the public's perception of the "needs of man" has expanded to include a link between the integrity of the Everglades and the quality of the human environment. Consequently, identifying and mitigating the effects of water management operations upon local and downstream systems has taken on increased importance in Project planning and in marsh restoration efforts.

The Shark River Slough's location at the southern terminus of the Kissimmee-Lake Okeechobee-Everglades basin (Fig. 2) has left it vulnerable to numerous upstream hydrologic perturbations. Though the absence of pre-drainage data prevents precise definition of early drainage impacts, there is no question that more recently constructed water control works immediately adjacent to the Shark Slough, Taylor Slough, and Eastern Panhandle areas of the park (Fig. 3) now allow water managers to completely regulate flow across park borders. Proper management of these facilities to meet regional flood control and water supply needs while still satisfying the park's water requirements has been debated since drainage began. Several water delivery schemes implemented from 1965-1982 to meet these goals failed to end the debate, and a new series of park water delivery experiments began in 1983 to further study this complex issue. The purpose of this report is to review the technical studies and political factors which shaped the water delivery schedules that were in effect through 1982. Subsequent reports in the series will compare the effects of more recent experimental delivery programs to hydrologic conditions under earlier management schemes.

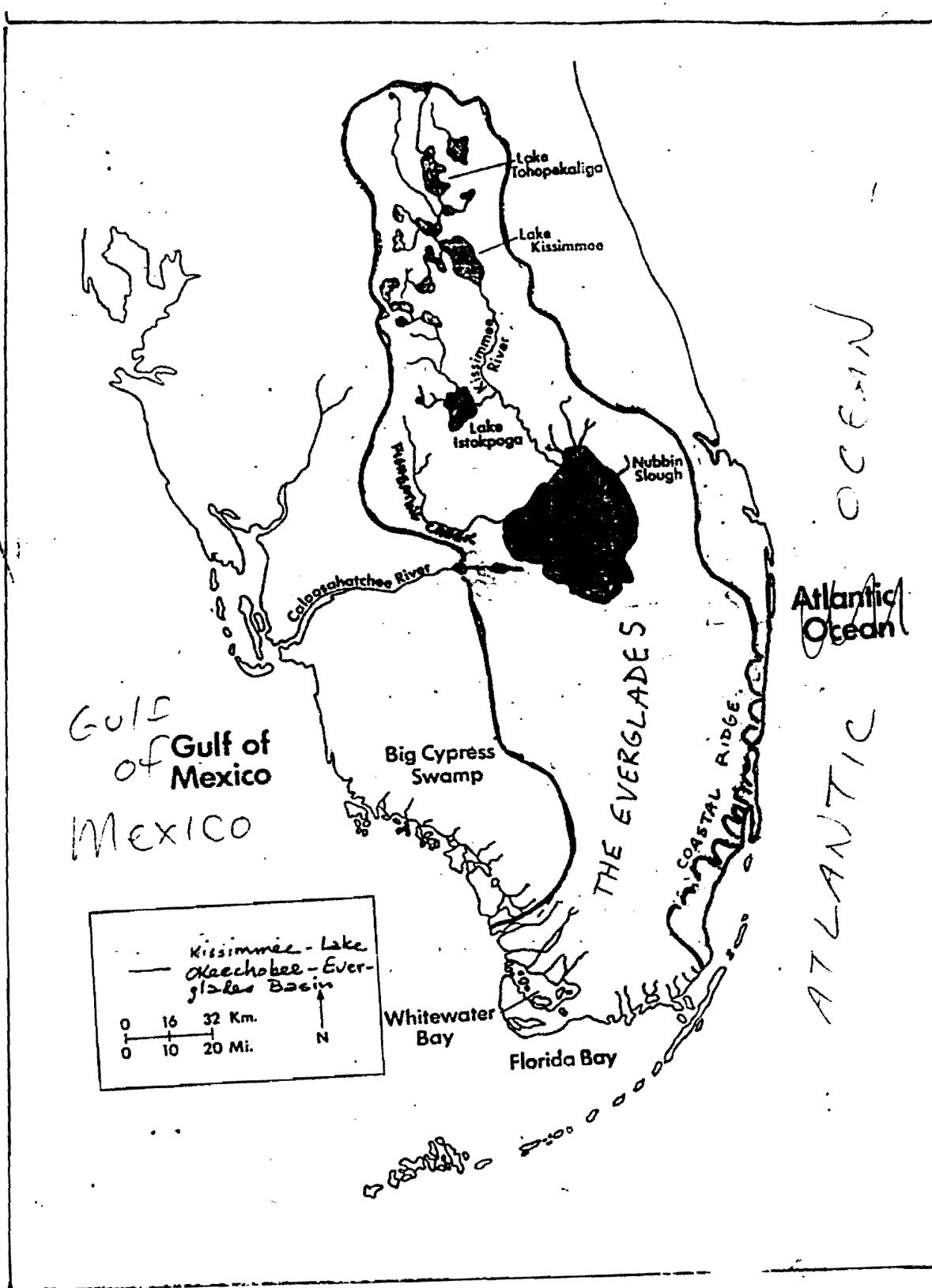


FIGURE 1. Pre-drainage Kissimmee-Lake Okeechobee-Everglades Basin (after J. Hartwell, unpublished map).

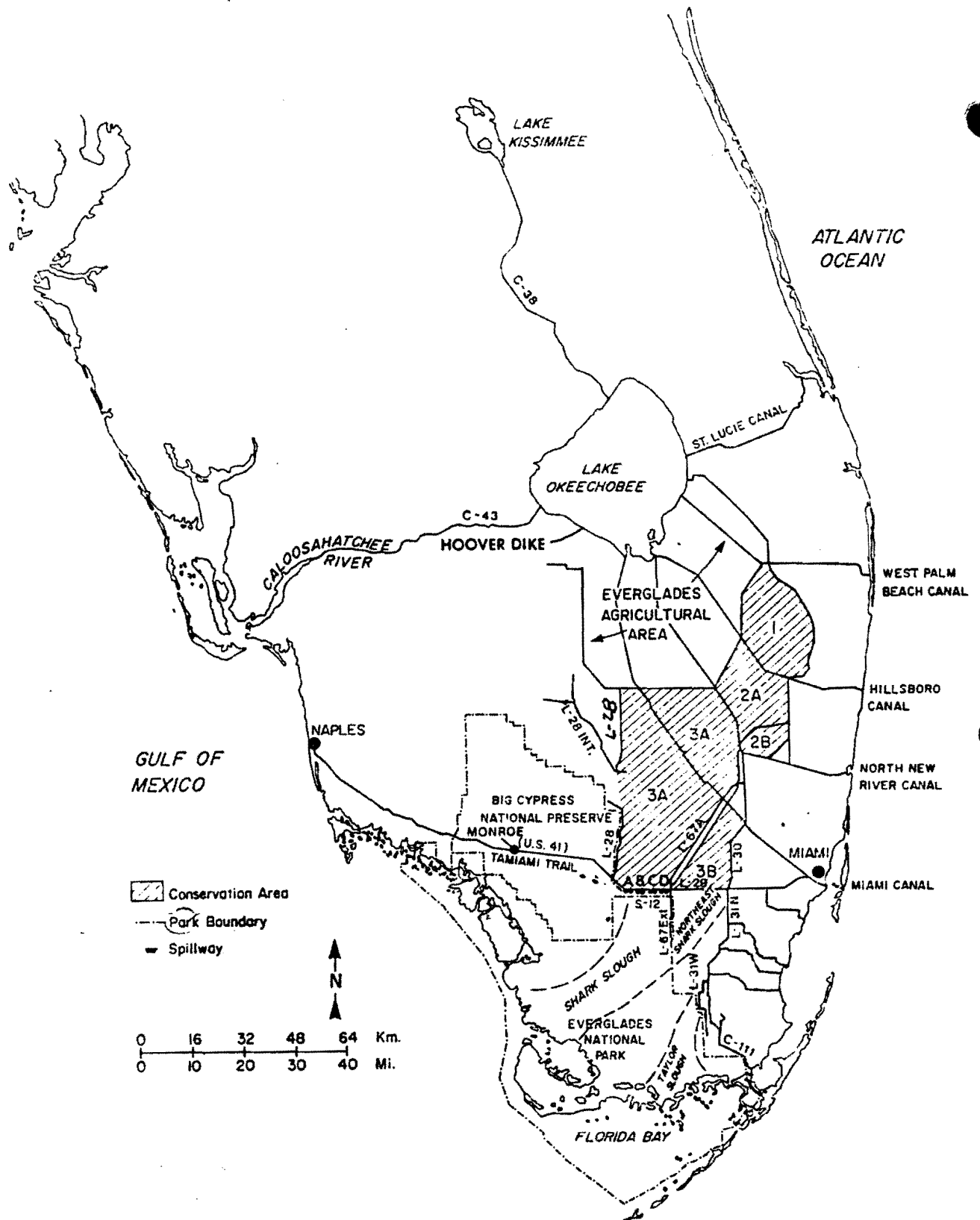


FIGURE 2. Some major features of the present-day Everglades water management system.

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FIGURE 3. Park Water Delivery System.

BRIEF HISTORY OF WATER CONTROL WORKS IN CENTRAL AND SOUTH
FLORIDA THROUGH COMPLETION OF STRUCTURE S-12

Completion of a shallow canal connecting Lake Okeechobee with the Caloosahatchee River in 1882 marked the beginning of significant alterations in the Everglades basin. Table 1 shows the year of completion of some major Project levees, canals, pump stations, and control structures which followed. In 1907, the Florida Legislature created the Everglades Drainage District to expedite development south of Lake Okeechobee and along the Atlantic Coast. The Miami, North New River, Hillsboro, and West Palm Beach canals (Fig. 2), all major drainage arteries designed specifically to drain the Everglades, were completed by 1915. Improvements in the Caloosahatchee canal and construction of the St. Lucie canal were completed by 1924, thus establishing the framework of south Florida's drainage system.

A low muck levee around the south and east sides of Lake Okeechobee was constructed in 1926 to provide flood protection for nearby urban and agricultural development. A hurricane in 1928, which swept water out of the lake and killed an estimated 2600 people, led to the upgrading of dikes around the lake's southern rim in the early 1930's (U.S. Army Corps of Engineers, 1968). By 1938, the improved dike system was extended to include the east and west sides of the lake. This effectively controlled the hydrologic link between Lake Okeechobee and the Everglades marsh to the south.

Mid population growth and agricultural development during the 1930's led to further improvements in drainage canals and other facilities south of the lake. However, resulting overdrainage became a significant problem along the southeast coast. By the end of the 1945 dry season, record low water levels allowed saltwater to follow landward gradients and contaminate Miami water supply well-fields (Klein et al. 1975). This apparent conflict between urban and agricultural interests strongly signalled the need for more unified water management in south Florida. Finally, extensive flooding in 1947 provided the impetus for public hearings sponsored by the U.S. Army Corps of Engineers to discuss formulation of a coordinated, regional water control plan.

By April 1948, the Corps of Engineers had prepared a report to Congress recommending a comprehensive flood control, drainage, and water storage plan for central and southern Florida. Department of Interior reaction to the report was generally favorable, but comments noted that Everglades National Park, established in 1947, was so new that the National Park Service had not yet been able to study the potential effects of the proposed "Central and South Florida Project" on the park. These comments, later published with the Corps of Engineers plan as House Document 643, 80th Congress, 2nd Session (1948), also stated that "... it is imperative that plans of operation should be the subject of negotiated agreements between the Corps of Engineers and the National Park Service prior to construction and so recognized in authorizing legislation for the Project." The Project, as approved by Congress in the Flood Control Act of 1948 (PL80-858), called for heavy state responsibility and

TABLE 1. Completion dates* of some major south Florida water management facilities.

Levee/Canal	Year of Completion
1. Miami Canal	1912
2. North New River Canal	1912
3. Hillsboro Canal	1915
4. West Palm Beach Canal	1915
5. St. Lucie Canal	1924
6. Caloosahatchee Canal (C-43)	1924
	(First connection from Lake Okeechobee in 1882)
7. Lake Okeechobee Dike:	
Low muck levee	1926
Hoover dike	1938
8. Tamiami Canal	1928
9. Levee 30 and borrow canal	1952
10. Everglades Agricultural Area Levees	1955-1959
11. Lake Okeechobee backpumping stations:	
S-2	1957
S-3	1958
S-4	1975
12. Conservation Area 1	1961**
Conservation Area 2	1961**
14. Conservation Area 3	1962**
(Including structure S-12 and levee 29)	
15. Levee 67A, L-67C, and borrow canals	1962
16. Levee 28 and borrow canal	
(Northern and southern sections and tieback)	1963
17. L-28 Interceptor and feeder canals	1967
18. C-38 Canal	1964
19. Levee 67 extension and borrow canal	1967
20. C-111 levee and canal	
(Including S-176, S-177, S-18C)	1967
21. Levee 31N and borrow canal	
(Including S-173)	1967
22. Structure S-197	1969
23. Levee 31W and borrow canal	
(Including S-174, S-175)	1970
24. Structures S-333, S-334	1978
25. Pump Station S-332	1980
26. Pump Station S-331	1983

*In some cases substantial modification occurred after the listed date.

**Surrounding levees largely completed and spillways functional.

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establishment of a single agency through which the federal government could deal with local concerns. In response to this need, the Florida Legislature created the Central and South Florida Flood Control District in 1949 to replace the Everglades Drainage District. The new agency would have such responsibilities as planning projects with the Corps of Engineers, acquisition of land for projects, and operation and maintenance of most pump stations, levees, canals and control structures of the Central and South Florida Project.

Project planners for the newly created Flood Control District concluded that large areas of the Everglades needed to be encircled with dikes to serve as freshwater reservoirs for supply during dry periods. Construction during the first phase of the Project included completion of an eastern levee system in 1952 (Fig. 2), which separated the Everglades from the lower east coast. Water which formerly flowed east past the present location of these levees was diverted further southward through the Everglades or drained through coastal canals. Once Conservation Areas 1 and 2 were completely enclosed in 1961, water impounded in these areas could be accessed for water supply purposes or could be routed southward to Conservation Area 3 as dictated by flood regulation schedules.

Completion of Conservation Area 3 (except for L-28) in 1962 significantly altered historic water flow in the southern Everglades. The L-67 levees (Fig. 2) were constructed to allow waters routed from the north to be stored in the less permeable western portion of the reservoir, thus, eliminating Area 3B from the Everglades flow-way. Levee 29, which bisects the Everglades from 40-Mile Bend to levee 30 and forms the southern wall of the reservoir (Figs. 2 & 3), was completed in December 1962. The new levee, however, was designed to allow total control of flow from Conservation Area 3A to Shark Slough. The S-12 structures were placed in the 10-mile stretch of levee 29 between L-67A and the western border of Shark Slough for regulatory discharge to the park. However, no outlets were provided at that time for water delivery to Northeast Shark Slough. Thus, the hydrologic system which once spread uncontrolled sheetflow across the 25-mile wide Shark River Slough now funneled excess waters from a heavily managed reservoir system through the 10-mile wide remnant of the slough now lying within Everglades National Park (Figs. 2 & 3).

DEVELOPMENT OF "WATER NEEDS" AND DELIVERY SCHEDULES TO EVERGLADES NATIONAL PARK

The Flood Control Act of 1948 (PL 80-858) stated that the Central and South Florida Project and Everglades National Park were "complimentary features of Federal activity necessary to restore and preserve the unique Everglades region." But despite that position and Corps of Engineers assurances that the park would be fully considered in Project planning, there were no guarantees of any particular allotment or frequency of surface water deliveries to the park from the Project.

To protect its resources, the National Park Service called for a cooperative agreement with the Flood Control District and the Corps of Engineers which would specify the magnitude, spatial distribution, and

timing of water deliveries to the park. (Letter* of July 18, 1961, from the Secretary of the Interior to the Secretary of the Army). However, the District and the Corps of Engineers declined to agree to a definite schedule. The Corps of Engineers argued that it did not have any legal basis for entering into a water allocation agreement, claiming that this was a matter to be settled between the Flood Control District and the National Park Service. The Secretary of the Army did, however, suggest that in lieu of an agreement, a "coordinating committee" should be formed with representation by all three agencies to determine the allocation of water resources on an annual basis. But, he also suggested that releases to the park should not "override the basic purposes of the Project or the higher priority needs of water supply based on the rapidly expanding population of Florida." (Letter from the Secretary of the Army to the Secretary of the Interior, March 13, 1962). The National Park Service agreed to the formation of a coordinating committee, but noted the apparent insufficient planning for park needs. Soon afterward, the National Park Service and the Corps of Engineers agreed that the Corps should initiate a study of the available South Florida water supply with consideration being given to park needs along with other beneficial water uses. (Letter of April 16, 1962, from the Secretary of the Interior to the Secretary of the Army).

Studies available at that time for determining park water needs are outlined below. Development of subsequent delivery schedules to meet these needs is then discussed.

Early Studies of Historic Flow and "Water Needs" of Everglades National Park.

1. Reference hydrologic data

Monthly stage and discharge hydrographs for Shark Slough are included here (Fig. 4) as references for following discussions of park water needs and development of supplemental delivery schedules. Mean monthly water level at central Shark Slough recorder P-33 is plotted in the upper portion of Figure 4. The period of record for this station began in October 1953 and is published by the U.S. Geological Survey (1953-1980) and Everglades National Park (1981-present). Discharge values shown in the lower portion of Figure 4 were summed for two Tamiami culvert flow sections "Levee 30 to Levee 67A" and "Levee 67A to 40-Mile Bend" measured by the U.S. Geological Survey (Miami) during the period 1939-1982.

Figure 5a summarizes Shark Slough discharge figures on an annual basis. Both monthly and annual data are listed in Appendix A. Figure 5b includes a summary of Everglades basin annual rainfall for the same period. Rainfall totals were computed by averaging monthly data from

*Note: Copies of correspondence or summaries of correspondence referenced in this report are on file at the South Florida Research Center, Everglades National Park.

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DISCHARGE, TAMIAHI CULVERT,
LEVEE TO 40-MILE BEND
(ACRES-FEET X 10³)

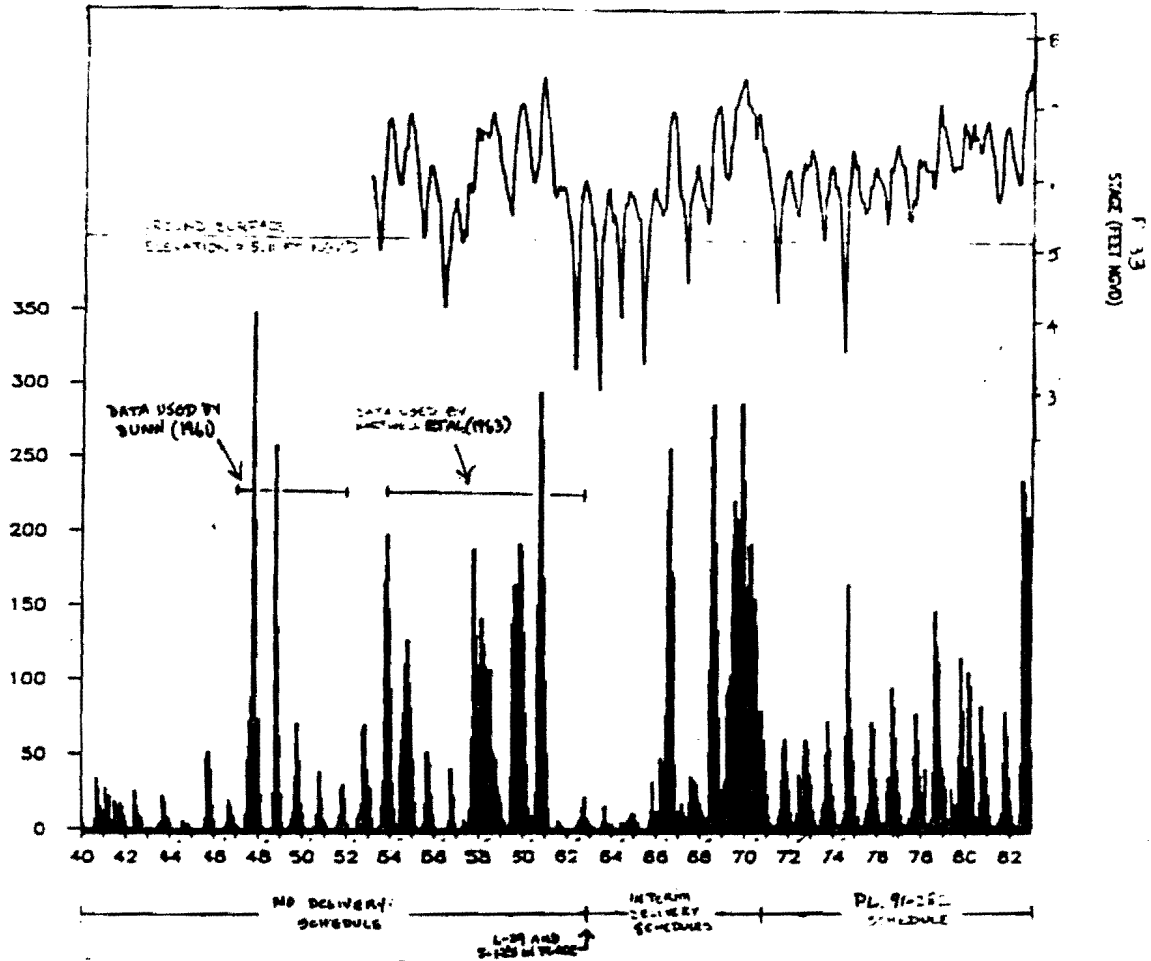
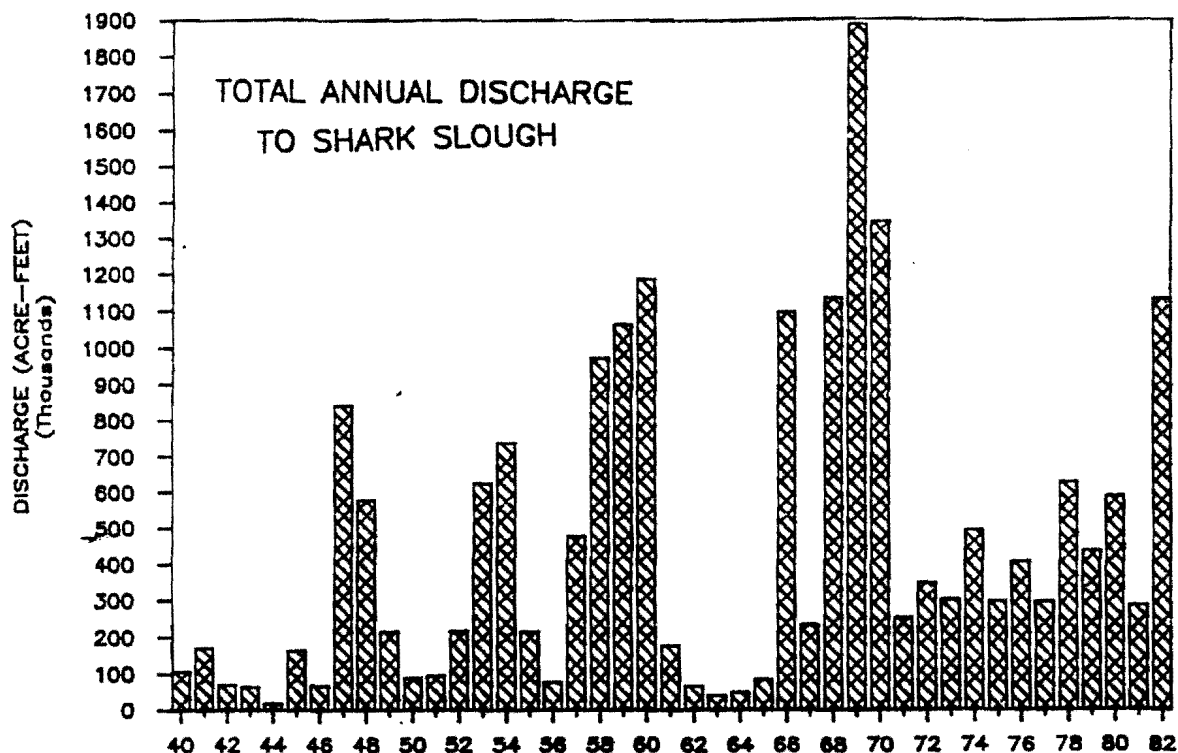


FIGURE 4. Mean monthly water level at central Shark Slough recorder P-33 and period of record (1939-1982) Shark Slough discharge, Levee 30 to 40-Mile Bend, FL. Data source: U.S. Geological Survey (Miami).

A)



B)

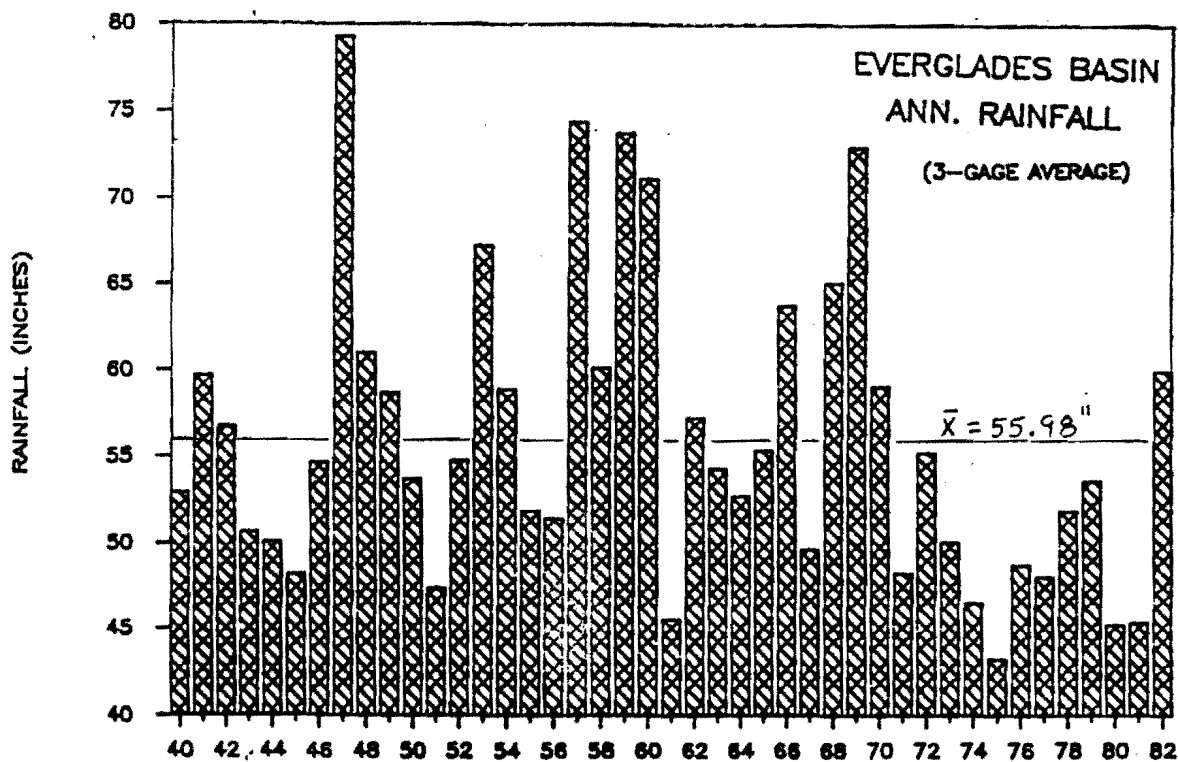


FIGURE 5. a. Total annual discharge to Shark Slough (L-30 to 40-Mile Bend), 1940-1982. (Data source: U.S. Geological Survey, Miami).
 b. Everglades basin annual rainfall, 1940-1982. (3-gauge average, NOAA stations Tamiami Trail at 40-Mile Bend, Belle Glade Experiment Station, Pennsuco 5 NW.)

National Oceanic and Atmospheric Administration (NOAA) gauges "Tamiami Trail at 40-Mile Bend", "Pennsuco 5NW", and "Belle Glade Experiment Station" (NOAA, 1940-1982). Monthly 3-gauge averages and total annual rainfalls are listed in Appendix B.

2. Estimates of pre-drainage flow to the Shark River Slough.

Two early studies were conducted to estimate pre-drainage runoff from the Everglades. The first was "A Report on Water Resources of Everglades National Park, Florida," in which the Central and Southern Florida Flood Control District (1950) used data from the 1940's to "...reconstruct and estimate primeval flood flow" to the Shark River Slough. The study evaluated rainfall and evapotranspiration over a 4000 mi² tributary area bounded on the north by the southern rim of Lake Okeechobee, on the south by Tamiami Trail, on the east by the Atlantic Ocean, and on the west by the Everglades-Big Cypress drainage divide. Additional pre-drainage inflow from outside these boundaries (primarily areas now drained by the St. Lucie and Caloosahatchee Canals) was considered "equal to the flood outflow through the natural channels to the Atlantic Ocean." Calculations of spillover from Lake Okeechobee during applicable years were also included as inflows. The study concluded that an annual average of 2,315,000 acre-feet of water flowed to Shark Slough.

A second study of Everglades basin runoff may be adapted to evaluate historic flow to Shark Slough. Langbein (in Parker et al., 1955) computed runoff from the "Everglades Area" south of Lake Okeechobee during 1941-1946 as part of a broader water budget study of central and south Florida sub-basins. In this study, net runoff was computed by calculating the amount of water diverted to the Atlantic Ocean from the "Everglades Area" via the major coastal canals (but excluding the Caloosahatchee River and St. Lucie Canals) and adding those results to measured flow to Shark Slough. The resulting average annual runoff estimate totalled 2,051,800 acre-feet.

The studies employed two methods commonly used in estimating water budgets for large basins. Results and applications of these studies must be viewed within the context of their assumptions. Perhaps the most significant assumptions in both studies occur in the treatment of natural runoff to the ocean from the Atlantic Coastal Ridge area. As noted previously, the Flood Control District study assumes this loss from the system via groundwater percolation and surface runoff to the coast via natural outlets to be equivalent to inflow from outside the study area. Langbein's figures for "Everglades Area" runoff do not account for percolation losses, however, this is somewhat balanced in that study by omitting contributions from the vast tributary basin to the north (Lake Okeechobee spillover). In view of the large water diversions through the St. Lucie Canal and the Caloosahatchee River during the 1940's (Hartwell, 1970), the latter were probably quite significant. Estimation of historic flow to Shark Slough in each study then depends upon the broad assumption that natural inflows from areas external to the study areas balance unmeasurable runoff to the ocean from the Atlantic Coastal Ridge. Thus, the results are only rough estimates.

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The Flood Control District (1950), Parker et al. (1955), and Hartwell (1970) all argue that, based on records available at the time, historic flow to Shark Slough was much greater than post-drainage flow. The two techniques referenced above lend support to these views in that different approaches were used to generate comparable estimates of average annual pre-drainage discharge to Shark Slough. However, neither of the studies was used in designing the supplemental water delivery schedules discussed below.

3. Studies of park "water needs".

In the atmosphere of steadily increasing competition for water in south Florida in the late 1950's, and in preparation for the Corps of Engineers study of available water supply in the early 1960's, the National Park Service initiated a study of park water needs. By this time significant drainage had already occurred in Shark Slough's headwaters, but no attempt was made to incorporate the historic flow estimates discussed above into the study. Rather, efforts centered on analysis of existing discharge records from the already modified system. In Taylor Slough and the "Eastern Panhandle" area of the park there was comparatively little drainage activity at this time and discharge in these basins was not measured. However, in anticipation of future extension of the Project into southern Dade County, the National Park Service study included estimates of water needs for these basins.

The initial attempt at determining park water needs was a 1960 preliminary study by Allyson van V. Dunn (Dunn, 1960) of the Water Resources Section, National Park Service. After review and input from the U.S. Geological Survey, this study was re-issued in a 1961 final report entitled, "Required Minimum Discharges to Everglades National Park from Central and Southern Flood Control District" (Dunn, 1961). Park water demands appearing in the final report (Table 2) were determined as follows. Although data for Tamiami Trail outlet flow was available for water years 1941-1958, Dunn concluded that only a portion of the record was applicable to determining park water needs. The 1941-1946 records were not considered in his calculations because of excessive upstream diversion to the Atlantic Ocean via coastal canals. Flow records after 1952 were not considered since "it seem(ed) logical to assume that the increasing discharge...from 1953 through 1958 (was) of transitory character during Project development" (Dunn, 1960). Thus, Dunn considered discharge records from the six-year period 1947-1952 to be most appropriate for his calculations, noting that average flow in this time period was approximately the same as in 1941-1958, and that these two time periods had comparable maximum and minimum annual flows. Maximums for items labeled "surface flow through Tamiami Trail outlets" in Table 2 are the maximum annual discharges during the six-year period. "Minimums" for this category are actually the average annual discharges for this same time period (Dunn, 1961). "Seepage under Tamiami Trail" values are estimates based upon underflow at "other locations in Dade County" with $\pm$ 50 percent accuracy (unpublished explanation provided by James Hartwell, U.S. Geological Survey to the National Park Service, September 18, 1961, on file at the South Florida Research Center).

TABLE 2. Annual water requirements of Everglades National Park from the Central and South Florida Flood Control District, in acre-feet*.

	Maximum	Minimum	Median
<u>To Park West of Levee 28:</u>			
Surface flow through Tamiami Trail outlets 22-96**	478,000	179,000	
Seepage under Tamiami Trail outlets 22-96	10,000	10,000	
Surface flow through Tamiami Trail outlets 95-77	<u>382,000</u>	<u>36,000</u>	
Total	870,000	225,000	157,500
<u>To Shark Slough:</u>			
Surface flow through Tamiami Trail outlets 23-39	423,000	156,400	
Seepage under Tamiami Trail outlets 23-39	5,000	5,000	
Surface flow through Tamiami Trail outlets 40-62	615,000	223,200	
Seepage under Tamiami Trail outlets 40-62	<u>5,000</u>	<u>5,000</u>	
Total	1,048,000	389,600	273,000
<u>To Taylor Slough Area:</u>			
Seepage and flow along east park boundary	71,500	32,300	
Residual flow from tributary area of southwest and south Dade areas	<u>61,500</u>	<u>22,300</u>	
Total	133,000	54,600	38,000
<u>Total Park Needs:</u>	2,051,000	669,200	468,500

*Adapted from Table II of Dunn (1961).

**Conduit locations are shown in Figure 6.

Requirements for the "Taylor Slough area" shown in Table 2 were calculated differently. "Residual flow from the tributary area of southwest and north Dade areas" values are estimates of runoff reaching northeastern Taylor Slough and the headwaters of the Eastern Panhandle region of the park. Comparisons between less than a year of discharge measurements available in 1961 at "Taylor Slough near Homestead, FL" (Fig. 3) and the discharge through Tamiami Trail outlets 40-62 showed that the Taylor Slough discharges were approximately 10 percent of the Tamiami Trail discharge. Thus, the "residual flow" figures for Taylor Slough in Table 2 were entered as 10 percent of the "surface flow through Tamiami Trail outlets 40-62" figures given in the "to Shark Slough" section. "Seepage and flow along the east park boundary" to the Taylor Slough area represents an estimate of the portion of flow through the Tamiami Trail outlets which reaches Taylor Slough. This was considered by Dunn to be equal to the residual flow figures as explained previously plus an estimated annual seepage of 10,000 acre-feet.

Upon reviewing Dunn's preliminary work, USGS hydrologists commented that median discharge would be more representative of minimum requirements of the park, and that 70 percent of the average discharge (minimums in Table 2) would provide a good estimate of the median flows (memorandum of March 9, 1962 from Dunn to the Superintendent, Everglades National Park). Dunn converted the average figures to medians and, thus, arrived at minimum requirements of 273,000 acre-feet for Shark Slough and 38,000 acre-feet for the Taylor Slough area as shown in Table 2 and Figure 6. By using monthly percentages of total flow provided by the USGS, Dunn also broke these figures down to monthly discharge requirements for Shark Slough and the Taylor Slough/Eastern Panhandle area (Table 3).

Less than a year after Dunn's final report was completed, the National Park Service determined that an independent study of Shark Slough water requirements would strengthen the park's negotiating position (pers. comm., James H. Hartwell, Miami, FL). Under an existing cooperative agreement, the National Park Service funded a re-study of park water needs by the Miami office of the U.S. Geological Survey. The resulting study by Hartwell, Klein, and Joyner (1963) employed an approach different from Dunn's to determine required releases from the Flood Control District to Shark Slough. In this study, monthly stage-duration curves were developed for continuous stage recorder P-33 in central Shark Slough for the period 1953-1962 (Fig. 7). Also, a relationship between stage at P-33 and discharge through Tamiami Trail outlets 34-59 (Fig. 8) was developed for the same period. Average monthly P-33 stages were approximated by taking the 50 percent frequency stage (median) from the monthly duration curves. These stage values were then applied to the stage-discharge relationship to estimate the runoff requirements shown in Table 4. The average annual discharge to the slough computed by this method is 243,580 acre-feet, compared to the 273,000 acre-feet median determined by Dunn (1961). These values are only 10% and 13%, respectively, of the estimates of average annual pre-drainage flows to Shark Slough discussed previously.

FIGURE 6. Minimum annual water requirements of Everglades National Park as determined by Dunn (1961).

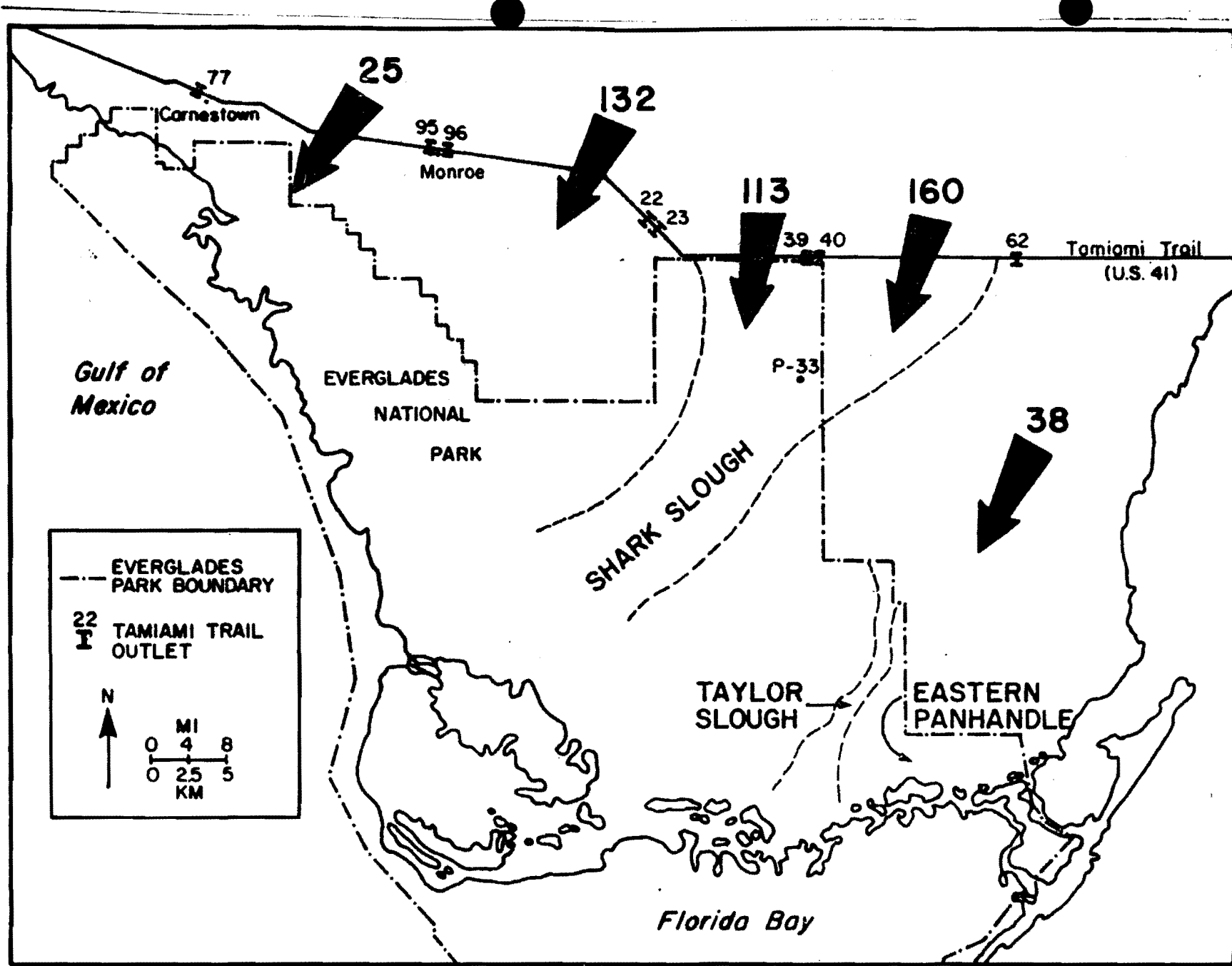


TABLE 3. Preliminary minimum monthly water requirements in acre-feet
(adapted from Table III, Dunn 1961).

Month	Monthly % of Annual Discharge	Shark Slough	Taylor Slough
January	6.0	16,380	2,291
February	4.0	10,920	1,530
March	2.5	6,830	955
April	1.8	4,910	688
May	1.8	4,910	688
June	4.0	10,920	1,530
July	6.0	16,380	2,291
August	7.1	19,380	2,715
September	14.1	38,470	5,385
October	27.8	75,900	10,640
November	16.1	44,000	6,150
December	8.8	<u>24,050</u>	<u>3,365</u>
TOTAL		273,000	38,000

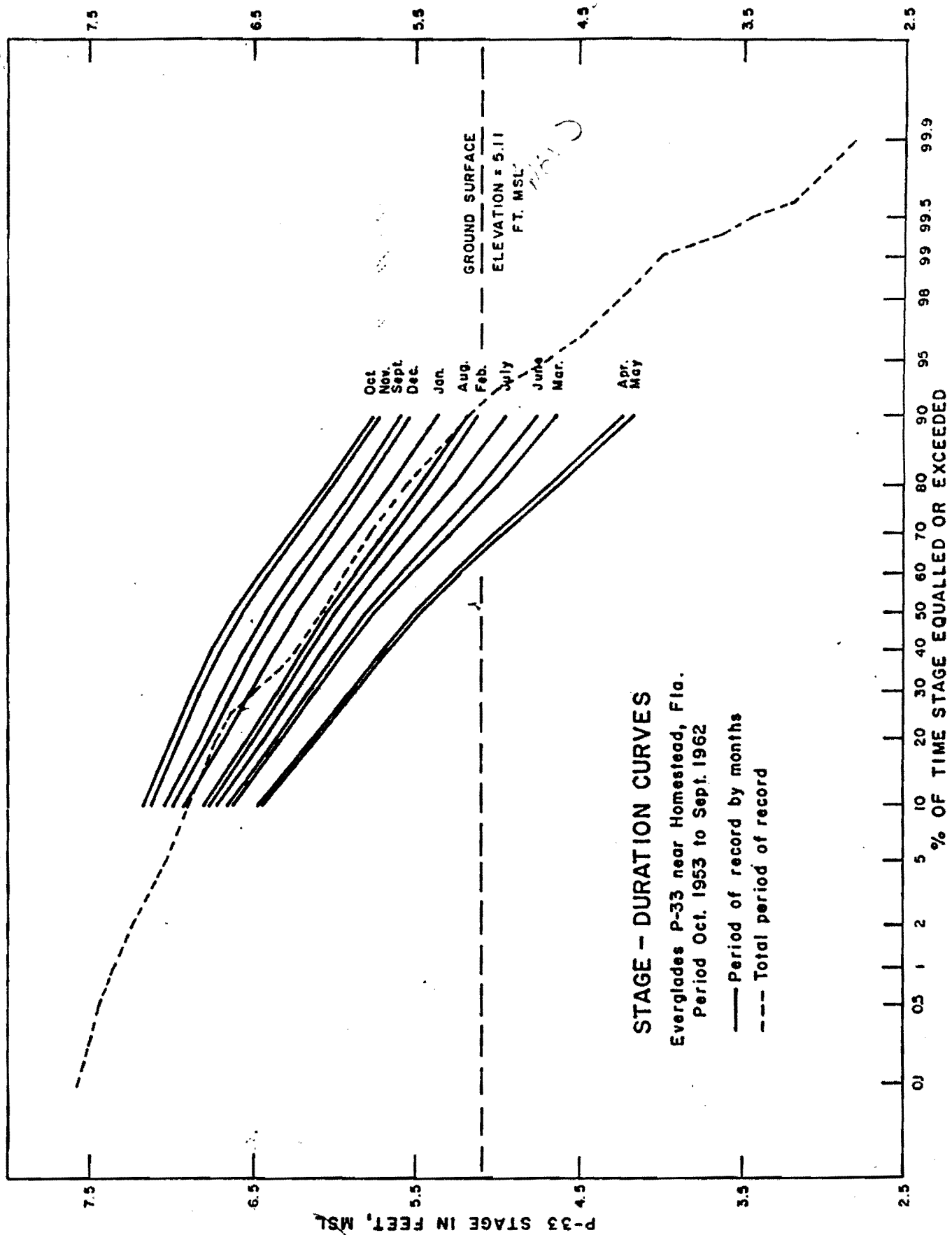


FIGURE 7. Stage duration curves for central Shark River Slough water level station P-33 (October 1953 to September 1962) from Hartwell, Klein, and Joyner (1963).

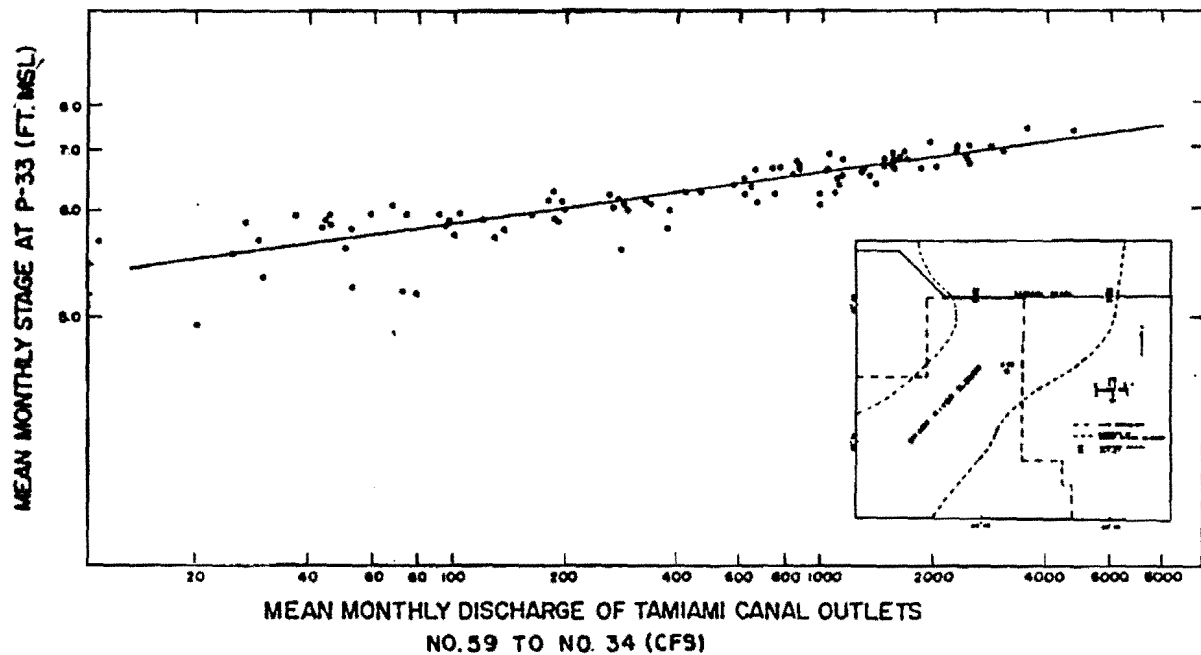


FIGURE 8. Stage-discharge relationship for stage at central station P-33 and discharge, Tamiami canal (U.S. 41) outlets 34 to 59, October 1953 to September 1962 from Hartwell, Klein, and Joyner (1963).

TABLE 4. Shark River Slough water needs as determined by Hartwell, Klein, and Joyner (1963).

Month	Average Runoff in Acre-Feet	Monthly % of Total Discharge
January	21,150	8.7
February	8,610	3.5
March	4,060	1.7
April	1,370	0.6
May	1,290	0.5
June	4,580	1.9
July	7,380	3.0
August	11,380	4.7
September	36,240	14.9
October	62,720	25.7
November	54,980	22.6
December	<u>29,820</u>	12.2
TOTAL	243,580	

Interim Schedules of Delivery to the Parkand Related Project Modifications.

Construction of levee 29 in 1962 forced Shark Slough into two distinct hydrologic regimes. The levee design included four sets of flood gates (structures S-12 A through D) for releases into western Shark Slough, but completely severed the sheetflow connection between northeast Shark Slough and its headwaters to the north. Upon completion of the levee in December, 1962, all 24 gates at the four S-12 structures were closed for the purpose of filling the newly created Conservation Area 3A. The gates were rarely opened during the following two years (Fig. 4), leaving seepage through levee 29 as the predominant source of inflow from the northern Everglades. As a result, flow to the slough during 1963-1965 averaged only 57,000 acre-feet annually, 16% of the 1940-1962 annual mean of 361,000 acre-feet.

In response to the severe drought conditions in Shark Slough during this period, the National Park Service provided the Corps of Engineers with a proposed interim water delivery schedule in September 1964 (Table 5). The schedule provided water requirements by 10-day periods based upon the work of Hartwell, Klein, and Joyner (1963). In a memorandum dated December 10, 1964, W. V. Storch of the Flood Control District responded by presenting an alternative operational procedure for interim surface water releases to the park. This schedule used a range of discharges related to Conservation Area 3A stage (Fig. 9). When the Conservation Area was above regulation stage (top line, Fig. 9), discharge to the park would be made such that stage in the reservoir was lowered and maintained below regulation. It was assumed that such flood releases would be in excess of discharges shown for the "normal range" (Zone A, Fig. 9). "Normal" discharges were the median monthly discharges determined by Hartwell, Klein, and Joyner (1963), and applied only when stage in Conservation Area 3A was within the "normal range." According to the plan, P-33 stage was an over-riding control for operation in the normal range. If stage at P-33 was at a point where the stage-discharge curve in Figure 8 called for larger deliveries than scheduled, then stage in Shark Slough would be considered too high and S-12 discharges would be reduced accordingly. When Conservation Area 3 stage fell below the normal range into Zone B, then a minimum range schedule would be in effect. This schedule was derived from average monthly discharges of the lowest 25 percent of the years during the period 1940-1964, with 10 cfs being a minimum even for months which called for zero discharge by this method. P-33 stage would not affect the schedule in this zone. Finally, if Conservation Area 3A stage fell below 8.5 feet N.G.V.D. (Zone C, Fig. 9), at which time storage falls off sharply, no discharges would be made regardless of conditions in the park or time of year.

As these interim plans were unfolding, the Department of the Interior was taking steps toward updating the park's negotiating position by preparing an official "position paper" on park minimum water requirements.

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TABLE 5. Proposed interim schedule of releases from Conservation Area 3A to Everglades National Park based upon the work of Hartwell, Klein, and Joyner (1963). (Proposed by the National Park Service in September 1964, but never implemented.)

Month	10-Day Period	Scheduled Releases (cfs)	Month	10-Day Period	Scheduled Releases (cfs)
Jan.	1-10	390	July	10-19	120
	11-20	350		20-29	130
	21-30	290		30-8/8	150
	31-2/9	210			
Feb.	10-19	160	Aug.	9-18	180
	20-3/1	110		19-28	220
				29-9/7	320
March	2-11	90	Sept.	8-17	540
	12-21	65		18-27	820
	22-31	45		28-10/7	1020
April	1-10	30	Oct.	8-17	1040
	11-20	25		18-27	1010
	21-30	15		28-11/6	1000
May	1-10	15	Nov.	7-16	980
	11-20	20		17-26	880
	21-30	25		27-12/5	750
	31-6/9	50			
June	10-19	75	Dec.	6-15	640
	20-29	90		16-25	440
	30-7/9	110		26-31	400

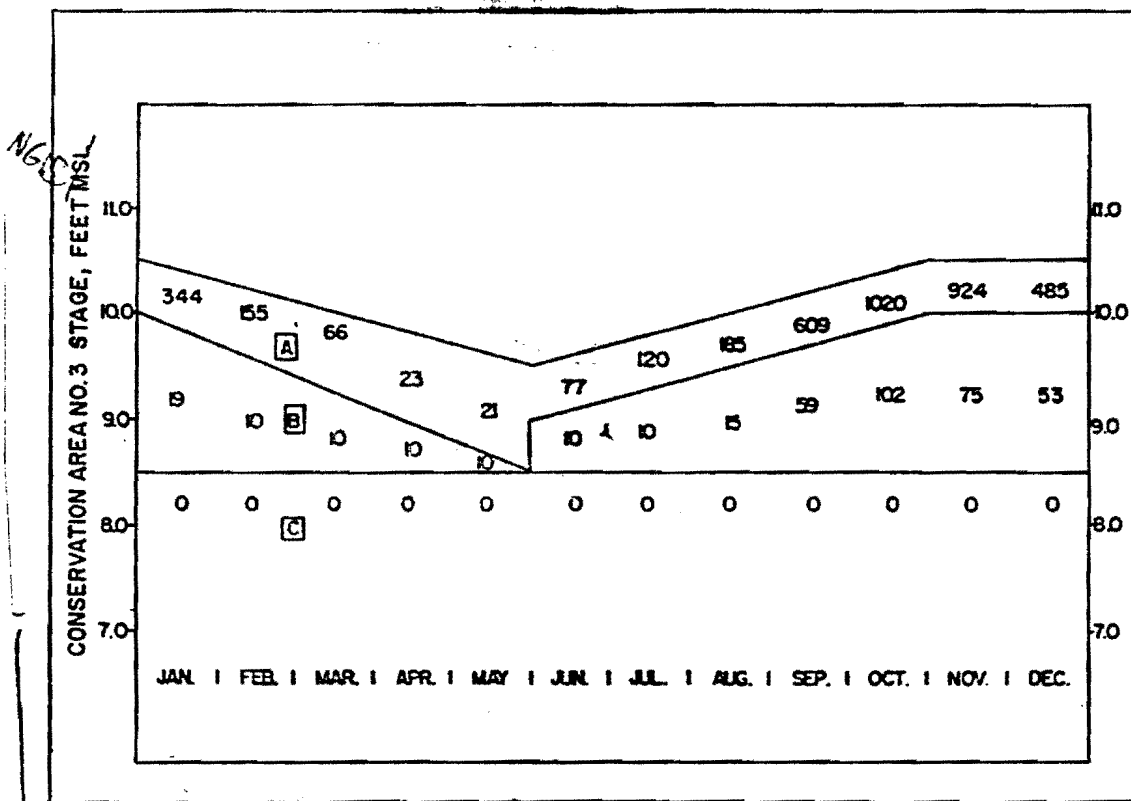


FIGURE 9. Interim water delivery schedule for Everglades National Park proposed by the Central and South Florida Flood Control District and in effect from March 1965 to March 1966 (discharge values are in cubic feet/sec.).

This document, approved by the Secretary of the Interior in November 1964, drew from the works of Dunn (1961) and Hartwell, Klein, and Joyner (1963), and determined that the annual minimum delivery needs were 260,000 acre-feet for the Shark Slough area, 38,000 acre-feet for Taylor Slough, and 157,000 acre-feet for the area west of L-28. The Shark Slough discharge requirement was derived by roughly averaging the 273,000 acre-feet computed as a minimum requirement by Dunn (1961) and the 243,000 acre-feet determined as an average flow to Shark Slough in the 1963 report by Hartwell, Klein, and Joyner (Hartwell 1972). Figures for Taylor Slough and the area west of L-28 were taken directly from Dunn's calculations (Table 2).

Correspondence between the Corps of Engineers, the Flood Control District, and the National Park Service, between December 1964 and March 1965, failed to resolve the differences in preference for interim schedules. Finally, in a letter of March 29, 1965, the National Park Service informed the Corps of Engineers that it would not object to the temporary use of the District's schedule (Fig. 9) rather than have no schedule at all. Summaries of this and subsequent delivery schedules, including dates in effect, are outlined in Table 6.

Despite institution of the Flood Control District's interim delivery schedule, only 13,000 acre-feet of water were released to the park from March through November 15, 1965. Finally in late November 1965, heavy rains of Hurricane Betsy brought Conservation Area 3A stages into the schedule's "normal" operating zone for the first time since 1962. Large, but temporary, releases to the park soon followed.

During 1965 and early 1966, discussions between the park, the Flood Control District, and the Corps of Engineers were convened to develop a Survey-Review plan for central and south Florida. Proposals for improving interim water delivery to the park centered on plans to move water from Lake Okeechobee southward through the Conservation Areas rather than wasting this water to the sea. On March 2, 1966, the Corps of Engineers presented a new interim delivery plan for the park. The plan raised the minimum control elevation of the lake from 13 to 13.5 feet N.V.G.D., delayed the usual spring drawdown for 30 days, and initiated the fall rise in the lake stage 30 days earlier to increase storage. The accompanying new schedule of releases to the park from Conservation Area 3A was as follows. When the lake was above regulation schedule, which varied from 13.5 feet N.G.V.D. at the beginning of the hurricane season to a peak of 15.5 feet N.G.V.D., the park would receive 1000 cfs through the S-12 structures. When the lake stage fell below the schedule, releases to the park would range from 500 to 140 cfs until the stage dropped to 12.5 feet N.G.V.D. Below the 12.5 foot stage, no water would be released to the park (U.S. Army Corps of Engineers, 1968).

The National Park Service agreed to this new plan on March 4, 1966, pending completion of the Corps of Engineers Survey-Review Report on the Central and South Florida Project. As a result of this plan (and increased rainfall in the Everglades basin), much larger water releases to the park soon began.

TABLE 6. Summary of water delivery schedules to Shark Slough, 1962-1982.

Schedule (Dates in Effect)	Summary
1. Conservation Area No. 3A Stage (12/62-3/65)	A. Park only to get excess water once Conservation Area filled.
2. Conservation Area No. 3A Stage (3/65-3/66)	A. All excess to park through S-12. B. 3 stage "zones" dictated 3 different monthly delivery schedules. C. P-33 as override.
3. Lake Okeechobee Stage (3/66-2/70)	A. 13.5-15.5 ft.* - 1000 cfs through S-12. B. 12.5-13.5 ft. - 140-150 cfs through S-12. C. Below 12.5 ft. - no delivery.
4. Lake Okeechobee Stage (2/70-9/70)	A. Above 12.5 ft. - 260,000 acre- feet schedule through S-12. B. Below 12.5 ft. - reduced % of schedule. C. P-33 as override.
5. Congressionally mandated (PL 91-282) minimum delivery schedule (1970-1982)	A. 260,000 acre-feet minimum schedule through S-12. B. Provisions for reduction to share adversity in drought.

*National Geodetic Vertical Datum (NGVD)

Through the period March 1966 to March 1968, some 125 letters and memoranda circulated amongst the agencies suggesting construction and management objectives to be included in the forthcoming Survey-Review Report. The National Park Service noted that the current interim schedule could provide adequate water supplies for the park during wet years, however, it was apparent after the dry year 1967 that the schedule was inadequate for periods of below normal rainfall. Furthermore, the schedule was based upon managed water levels in Lake Okeechobee rather than upon park conditions and requirements. Consequently, park deliveries were tied to excess waters after upstream management objectives were met rather than being a natural response to meteorological conditions.

To alleviate the weaknesses of previous interim agreements and to firmly establish park water requirements for inclusion in the Survey-Review Report, National Park Service Deputy Director Harthorn Bill presented an updated water policy position to the Corps of Engineers via a letter dated October 20, 1967. The letter outlined a park minimum requirement of 315,000 acre-feet per year including the first dry year, and 200,000 acre-feet in the second and succeeding dry years. A dry year was defined as the year ending the 12th consecutive month for which the cumulative water delivery to the park from Conservation Area 3A totals less than 315,000 acre-feet. Two-hundred and sixty-thousand acre-feet of the total was to be delivered to Shark Slough, 37,000 acre-feet to Taylor Slough, and 18,000 acre-feet to the Eastern Panhandle region of the park. Monthly distribution (Table 7) utilized roughly the same percentages of total flow computed by Hartwell, Klein, and Joyner (1963).

The 260,000 acre-feet figure appearing in the letter was once again derived by roughly averaging the results of Dunn (1961) and Hartwell, Klein, and Joyner (1963). The 37,000 acre-feet figure for Taylor Slough was also derived from Dunn (1961). The origin of the requirement for the Eastern Panhandle is apparently not documented. Most likely, this figure was derived by computing the difference between the average flow to the Taylor Slough area from Table 2 (55,000 acre-feet) and the 38,000 acre-feet median figure from the same table, leaving a remainder of 17,000 acre-feet. It is not clear why the slightly different 37,000 and 18,000 acre-feet values appeared in Deputy Director Bill's letter. The park's minimum requirements ultimately appearing in the Corps' Survey-Review Report agreed with Dunn's 38,000 acre-feet value for Taylor Slough, with the remaining 17,000 acre-feet for the Eastern Panhandle. This difference was apparently never resolved, as both sets of figures appear in subsequent correspondence, reports, and congressional documents.

Deputy Director Bill also noted that the National Park Service could support a Survey-Review Report which included assurances that meeting park water requirements was a primary Project purpose and that the conservation areas would be managed such that surplus water, including that wasted to the sea from other Project areas, would be discharged to the park to the maximum extent feasible. The letter of October 20, 1967, also called for statements in the Survey-Review that the Corps of Engineers would be responsible for delivery of water to the park, that additional research should be initiated on all water uses, and that the 1966 interim agreement providing water to Shark Slough would remain in effect until conveyance facilities necessary to meet the 315,000 acre-feet minimum schedule were completed.

TABLE 7. Minimum monthly water requirements for Everglades National Park as presented in a letter of October 20, 1967 from the National Park Service to the U.S. Army Corps of Engineers.

Month	Releases in Acre-Feet	Percent
January	27,000	8.6
February	11,000	3.5
March	5,000	1.6
April	2,000	0.6
May	2,000	0.6
June	6,000	1.9
July	9,000	2.9
August	15,000	4.8
September	47,000	14.9
October	81,000	25.7
November	71,000	22.5
December	<u>39,000</u>	12.4
Total	315,000	

In February 1968, the Corps of Engineers released the "Survey-Review Report on Water Resources of Central and South Florida." The proposed Project plan included raising the level of Lake Okeechobee by 4 feet and backpumping waters into the lake and the conservation areas which otherwise would have been diverted to the ocean. Water flow into and through the conservation areas and to Dade County and Everglades National Park were to be improved via a new system of canals, levees, pumping stations and control structures. These structural plans included extension of levee 28 to provide water for the park west of Shark Slough and an eastward continuation of levee 67 extension canal to join the South Dade canal system, thus conveying water to Taylor Slough and the Eastern Panhandle. Getaway channels below Tamiami Trail were also planned for better distribution of flow to the park.

National Park Service Deputy Director Harthorn Bill responded in detail to the Survey-Review Report in a letter of May 1, 1968. He noted that the plan failed to provide a written guarantee that the park requirement of 315,000 acre-feet, as set forth in the report, would be met and that such deliveries would not be diminished by future water users. The timing and distribution of releases to the park were also not addressed adequately, and consequently the weaknesses in the 1966 interim agreement were not alleviated. The letter also noted that there is no proven need for additional conveyance inside the park boundaries, including the proposed getaway canal paralleling L-29 and the extension of L-28 canal.

In a series of meetings and correspondence from May 1968 through early 1970, the agencies attempted to work out problems stemming from the proposed plan. Much of the plans for additional conveyance facilities within the park were dropped or altered, leaving guaranteed timing, distribution, and volume of deliveries as the main unresolved issues. A major stumbling block was the legal question of authority for regulatory water releases to the park. Legal counsel for the Department of the Army felt that the Corps of Engineers did not have the legal authority to promulgate regulations for water releases to the park, while the Solicitor of the Department of the Interior issued an opposing opinion. Direct negotiations between the two agencies failed to resolve the issue, and the question was presented to the Department of Justice for resolution. No ruling came from the Justice Department before the Attorney General left office in January 1969, and, in November of that year, the Senate Committee on Public Works returned the issue back to the two agencies for resolution (Senate Report No. 91-528).

Further inter-agency correspondence followed, and on February 16, 1970, an updated interim schedule developed by the Corps of Engineers was approved by representatives of the Department of the Interior, the Department of the Army, and the State of Florida. This schedule would be in force until completion of Project works allowing increases in Lake Okeechobee regulation stages and providing conveyance to Taylor Slough and the Eastern Panhandle area. Under the new plan, when the lake was equal to or above 12.5 feet N.G.V.D., the percentages shown in Table 7 would be applied to the 260,000 acre-feet figure to determine minimum monthly deliveries, as shown on the top row of numbers in the upper portion of

Figure 10. P-33 stage was to be monitored on the first day of each month, and if that stage was equal to or above the level shown in the lower portion of Figure 10, then the monthly minimums would be reduced to the asterisked numbers. This reduction would not be considered a deficit to be made up later. When the lake fell below the 12.5 foot level, reduced monthly volumes would be delivered as shown on the schedule, and deficits in monthly deliveries created by these reductions would be made up in later months, when possible.

Establishment of the 1970 Minimum Delivery Schedules

The new interim schedule still provided no water delivery guarantees to the park, and negotiations continued to determine whether or not the Corps of Engineers had the authority to make such guarantees. Finally, on April 8, 1970, the Senate Committee on Public Works heard testimony from the Corps of Engineers, the National Park Service, the State of Florida, several U.S. Senators, and other interested groups on the problem of supplying water to the park. By May 1970, the Committee produced Senate Report 91-895 (U.S. Senate, 1970) which recommended legislation guaranteeing minimum deliveries to the park and expediting construction of conveyance facilities necessary to meet these delivery requirements. The recommended amendment became law in June 1970 when it was incorporated into the "River Basin Monetary Authorization and Miscellaneous Civil Works Amendments Act of 1970" (P.L. 91-282). The amendment included a formula which provided to the park 315,000 acre-feet of water or 16.5 percent of the total deliveries of the Project in the previous 12 months, whichever was less.

Senate Report 91-895 detailed the origins of the delivery formula and provided rules for implementation. The formula was based on the 315,000 acre-feet minimum annual park water requirement being 16.5 percent of the 1,905,000 acre-feet figure given by the Corps of Engineers as the "normal capability" of the Project in 1970. In times of drought, if total deliveries from the Central and Southern Florida Project fell below the annual rate of 1,905,000 acre-feet, the park guarantee would be proportionately reduced. The Committee on Public Works noted in the report that present (i.e., 1970) capabilities existed to provide 260,000 acre-feet per year to Shark Slough, and that the remainder of the 315,000 acre-feet total should be delivered to Taylor Slough and the Eastern Panhandle area "as soon as practicable and in any event upon completion of the appropriate conveyance facilities" (U.S. Senate, 1970). The resulting minimum monthly schedules shown in Figures 11 and 12a and b were derived from the requirements outlined in the letter of October 20, 1967, from the National Park Service to the U.S. Army Corps of Engineers. Monthly minimums are tabulated in Table 8.

The Senate report also supports the National Park Service's request for delivery of "surplus" water from the Project to the park to the maximum extent feasible. No provision was included in the Act or in accompanying reports to put a ceiling on the amount of water which could be released, nor were specifications included for gate opening strategies. These issues were left open to negotiation between the National Park Service, the Corps of Engineers, and the Flood Control District.

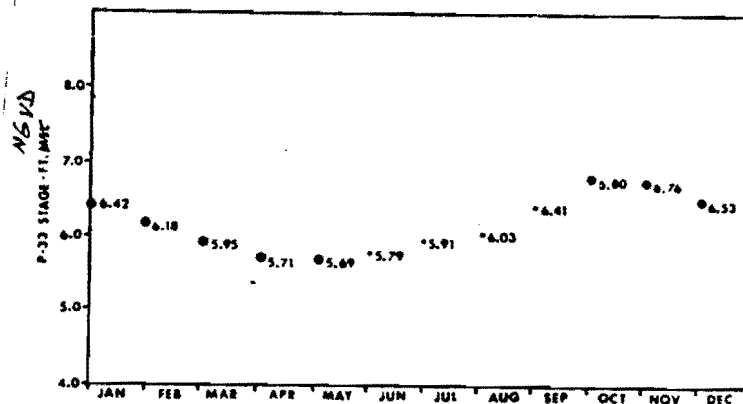
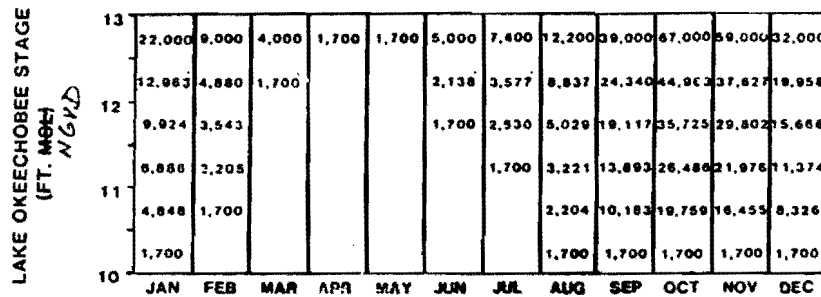


FIGURE 10. Interim water delivery schedule (with P-33 override criteria) for Shark Slough developed by the U.S. Army Corps of Engineers and in effect from February 1970 to September 1970.

SHARK SLOUGH MINIMUM DELIVERY SCHEDULE

(PL 91-282)

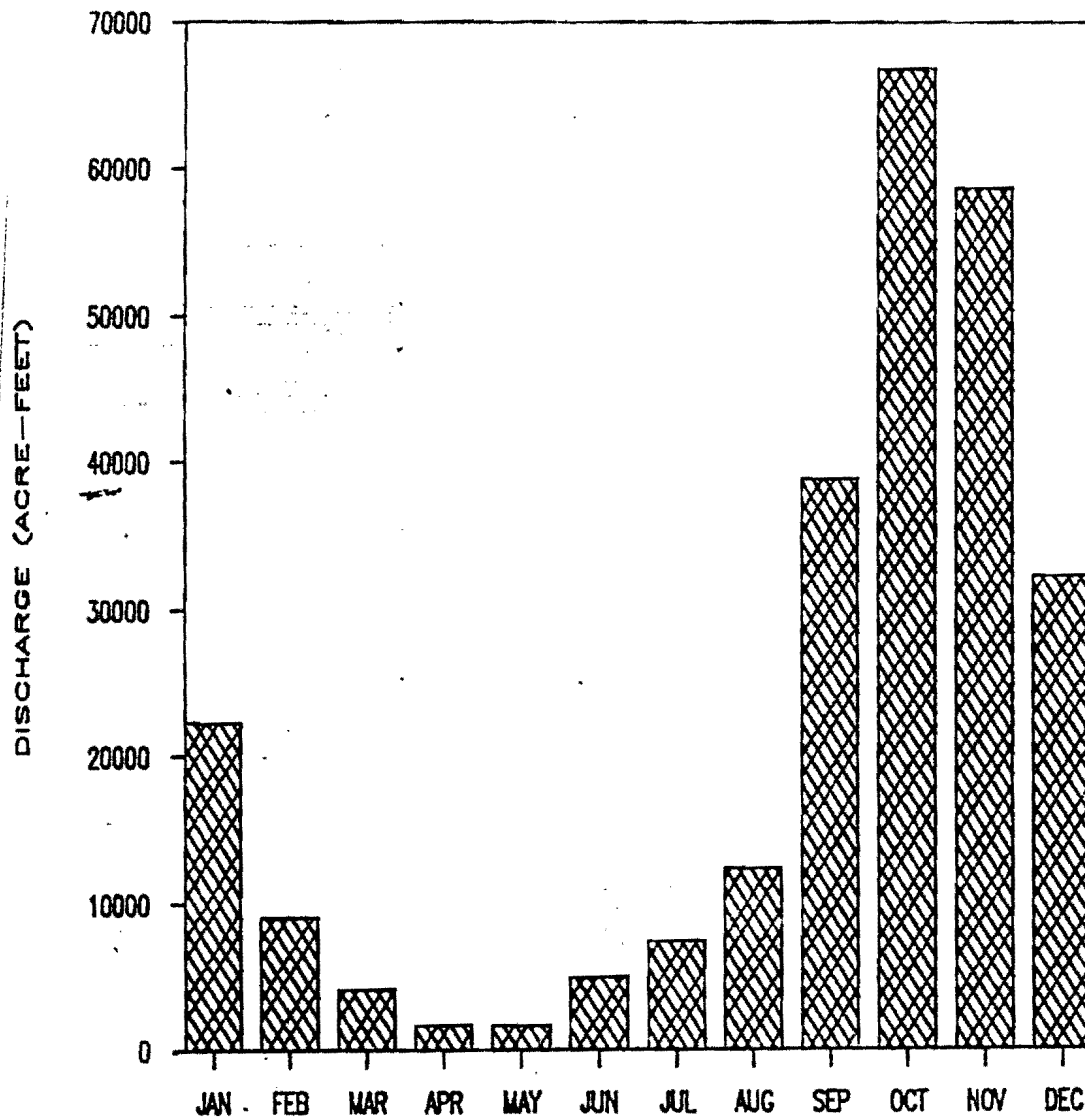


FIGURE 11. Minimum monthly water delivery schedule for Shark Slough as outlined in Public Law 91-282.

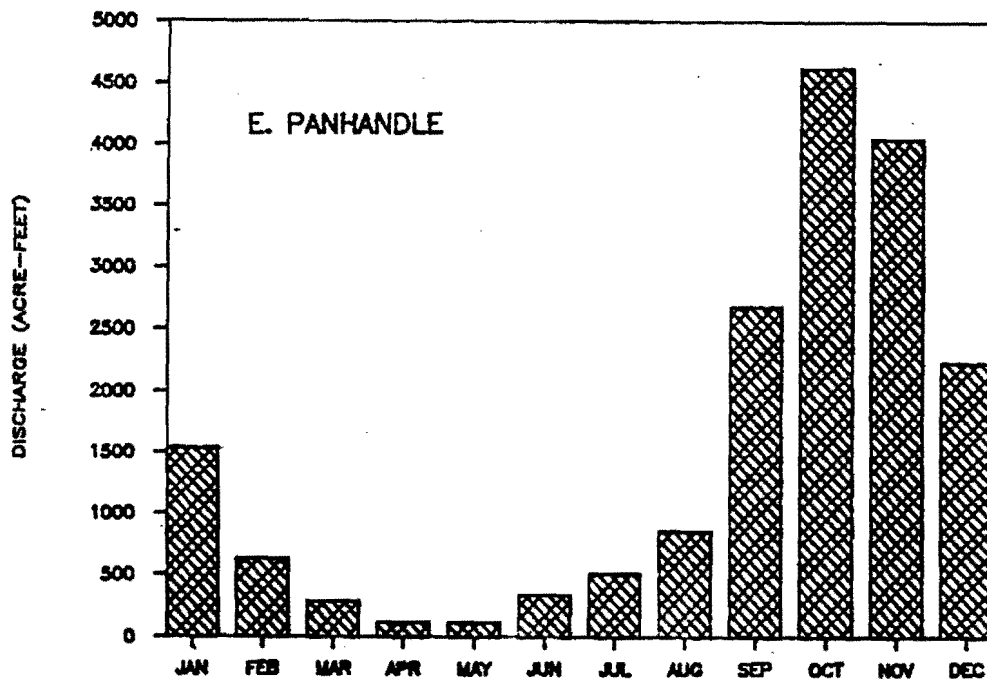
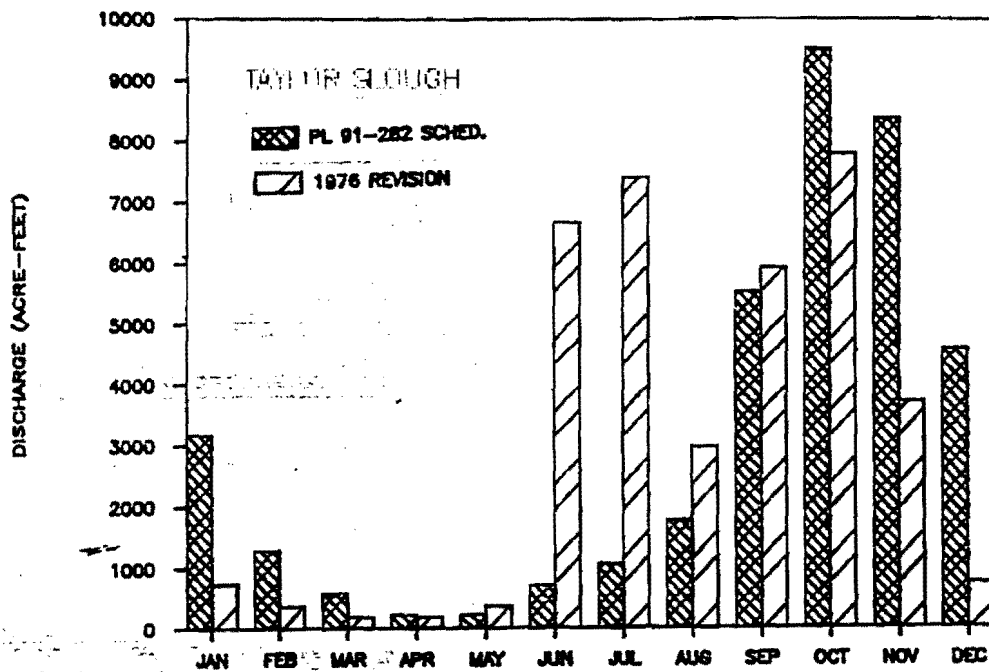


FIGURE 12. a. Taylor Slough minimum monthly delivery schedule as outlined in Public Law 91-282 and as revised in the 1976 Agreement and permit for operation of pump station S-332. b. Eastern Panhandle minimum monthly delivery schedule as outlined in Public Law 91-282.

TABLE 8. 1970 Minimum Monthly Water Delivery Schedule for Everglades National Park (PL91-282).

Month	Snark River Slough		Eastern Panhandle		Taylor Slough		Total	
	cfs	ac.ft.	cfs	ac.ft.	cfs	ac.ft.	cfs	ac.ft.
Jan.	362	22,290	25	1,540	52	3,170	439	27,000
Feb.	164	9,080	11	630	23	1,290	198	11,000
Mar.	67	4,130	5	290	9	580	81	5,000
Apr.	28	1,650	2	120	4	230	34	2,000
May	27	1,650	2	120	4	230	33	2,000
June	83	4,950	6	340	12	710	101	6,000
July	121	7,430	8	510	17	1,060	146	9,000
Aug.	201	12,380	14	860	29	1,760	244	15,000
Sept.	652	38,790	45	2,680	93	5,530	790	47,000
Oct.	1,087	66,860	75	4,630	155	9,510	1,317	81,000
Nov.	985	58,600	68	4,050	140	8,350	1,193	71,000
Dec.	523	32,190	36	2,230	75	4,580	634	39,000
Total		260,000		18,000		37,000		315,000
Avg. Annual	359		25		51		435	
% of Total		82.54		5.71		11.75		100

Quality of delivered water was also addressed in Senate Report 91-895. Congress directed the Corps of Engineers and the National Park Service "to reach an early agreement on measures to assure that water delivered to the Park is of sufficient purity to prevent ecological damage or deterioration of the park's environment" (U.S. Senate, 1970). In 1979, the agencies responded by signing a "Memorandum of Agreement Among the Army Corps of Engineers, the South Florida Water Management District and the National Park Service for the Purpose of Protecting the Quality of Water Entering Everglades National Park", which outlines water quality standards for park delivery waters. The agreement was updated in 1984 and will continue to be revised periodically as needed.

The water delivery formula did not attempt to establish priorities of use between present and future users, nor did it depend upon the reliability of Corps of Engineers projections of future demands and water supply. The Senate Report also noted a commitment by the Corps of Engineers to review the water resource needs in Central and South Florida by 1980, prior to the scheduled completion of the Project in 1984. This review would "determine whether further modifications of the Project are warranted, and give further assurances of maintaining the essential water supply to insure protection of the park's ecosystem" (U.S. Senate, 1969). Congress has the power to reevaluate the 315,000 acre-feet schedule or take appropriate steps to modify the Project should updated park water requirement studies become available.

1976 Adjustment of the Taylor Slough Minimum Delivery Schedule

Pump Station S-332 in the L-31W canal (Fig. 3) was designed to meet Taylor Slough's guaranteed minimum annual allocation. In "Exhibit B" of the 1976 "Agreement and Permit" for construction of the pump station (Appendix C), the Corps of Engineers, the South Florida Water Management District and the National Park Service agreed to maintain the 37,000 acre-feet minimum annual discharge figure outlined in Senate Report 91-895, but altered the schedule of monthly allotments (Fig. 12a, Appendix C). Analyses used for deriving the revised schedule are apparently not documented. It appears that these revisions resulted from consultation between the involved agencies, with decisions taking into account updated flow measurements by the U.S. Geological Survey at "Taylor Slough Bridge near Homestead, FL" and professional opinion regarding effects of S-332 pumpages on discharge downstream (pers. comm., Frank Nix, Naples, FL, and James Hartwell, Miami, FL).

The "Agreement and Permit" for S-332 also established new decision rules for discharges above the specified minimums. While Senate Report 91-895 had encouraged discharge to the Park to the maximum extent feasible, the permit stated that the monthly minimums established for S-332 were not to be exceeded without the mutual agreement of all parties. No limit, however, was established for releases to Taylor Slough via structure S-175.

Language was also included in the agreement requiring the parties to take all reasonable steps to deliver water of sufficient purity to prevent ecological damage or deterioration of the park environment. The agreement also established the right of the Director of the National Park Service to refuse water not meeting water quality standards developed in the U.S. Department of Interior Report "Appraisal of Water Quality Needs and Criteria for Everglades National Park" (U.S. National Park Service, 1971). The updated set of standards first appearing in the 1979 Memorandum of Agreement discussed above has replaced these earlier standards.

The minimum delivery schedules for both Taylor Slough and the Eastern Pannhandle went into effect once the South Dade Conveyance System was completed in 1983.

SOME OBSERVATIONS ON WATER DELIVERY TO SHARK SLOUGH
UNDER THE 1970 MINIMUM DELIVERY SCHEDULE (P.L. 91-282)

1. Compliance with the minimum delivery schedule

Figure 13 shows the record of compliance with the PL 91-282 minimum monthly delivery schedule for Shark Slough (Table 8) during October 1970 - December 1982. (Monthly variances are listed in Appendix D). Sufficient water was delivered through the S-12 structures in 74 percent of the months during that period to meet prescribed discharges to Shark Slough. Many cases of non-compliance were relatively small, probably the result of S-12 gate setting errors and underestimates of flows when setting the gates under low-flow conditions. These can be avoided by using revised structure rating curves and by allowing for a larger margin of error in gate-setting decisions.

The larger noncompliance cases tended to occur in the early portion of the record, with the greatest monthly deviation being - 15,010 acre-feet during the drought year 1971. However, a number of substantial shortfalls also occurred in the dry 1980-81 period. No documentation could be found to indicate that the criteria for shared adversity during drought conditions outlined in the 1970 law were used to justify reduced flows to Shark Slough. The required calculations were attempted and debated by the Corps of Engineers during the 1971 drought but no agreement could be reached as to how to properly determine the capacity of the Project as provided for in the minimum delivery legislation. No agreement was reached, and the discussions ended with resumption of adequate rainfall in the system later in the year. (Personal communication, Louis Hornum, U.S. Army Corps of Engineers).

2. Delivery system Operational Practices

Figure 14 summarizes water delivery operations at the S-12 structures during 1976, a relatively dry year for the Everglades basin/ but representative of conditions while the minimum delivery schedule was in effect. During January through April, Conservation Area 3A stage fell

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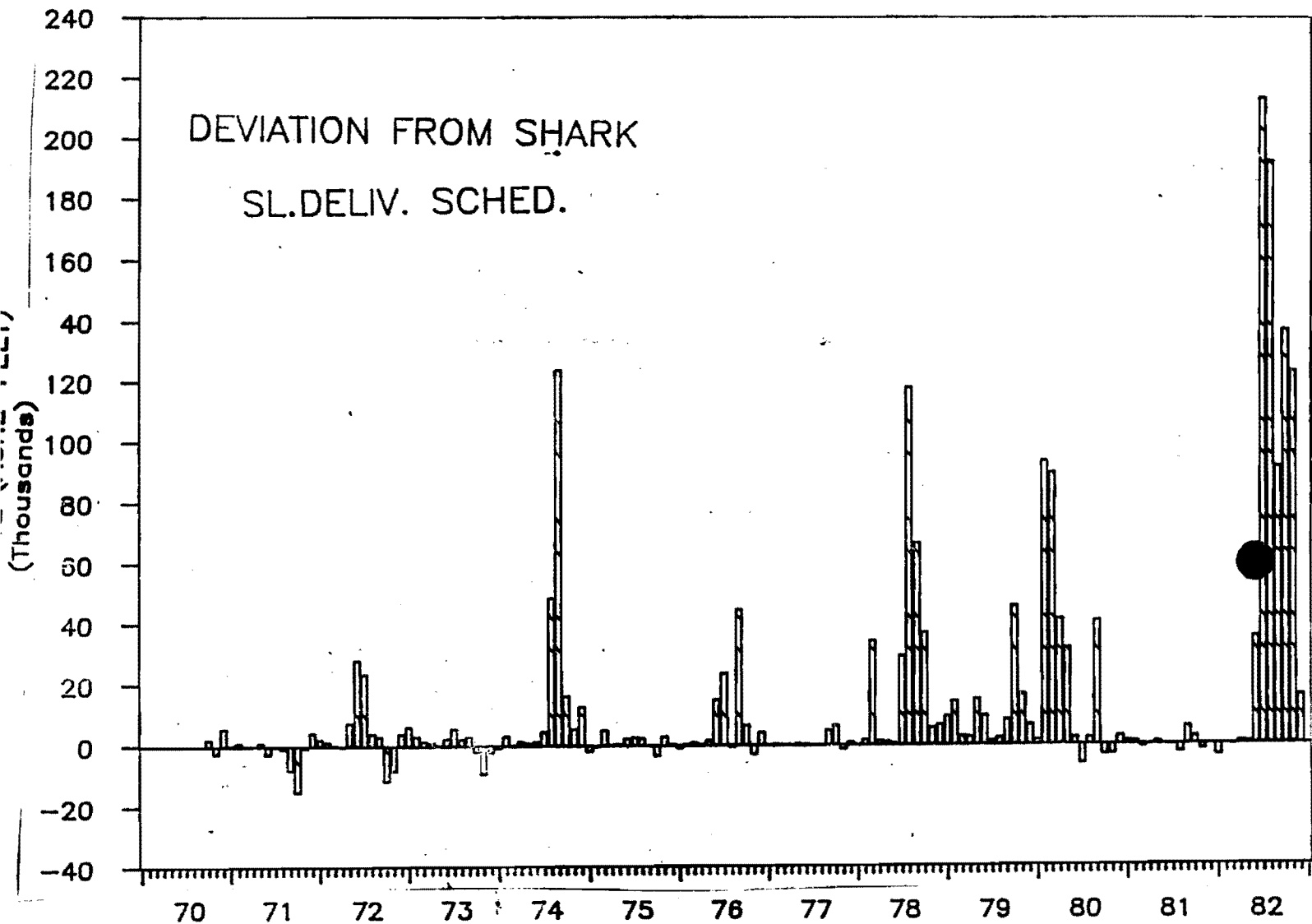


Figure 13. Deviation from the Shark Slough minimum monthly delivery schedule, October 1970 - December 1982. (Negative values indicate non-compliance).

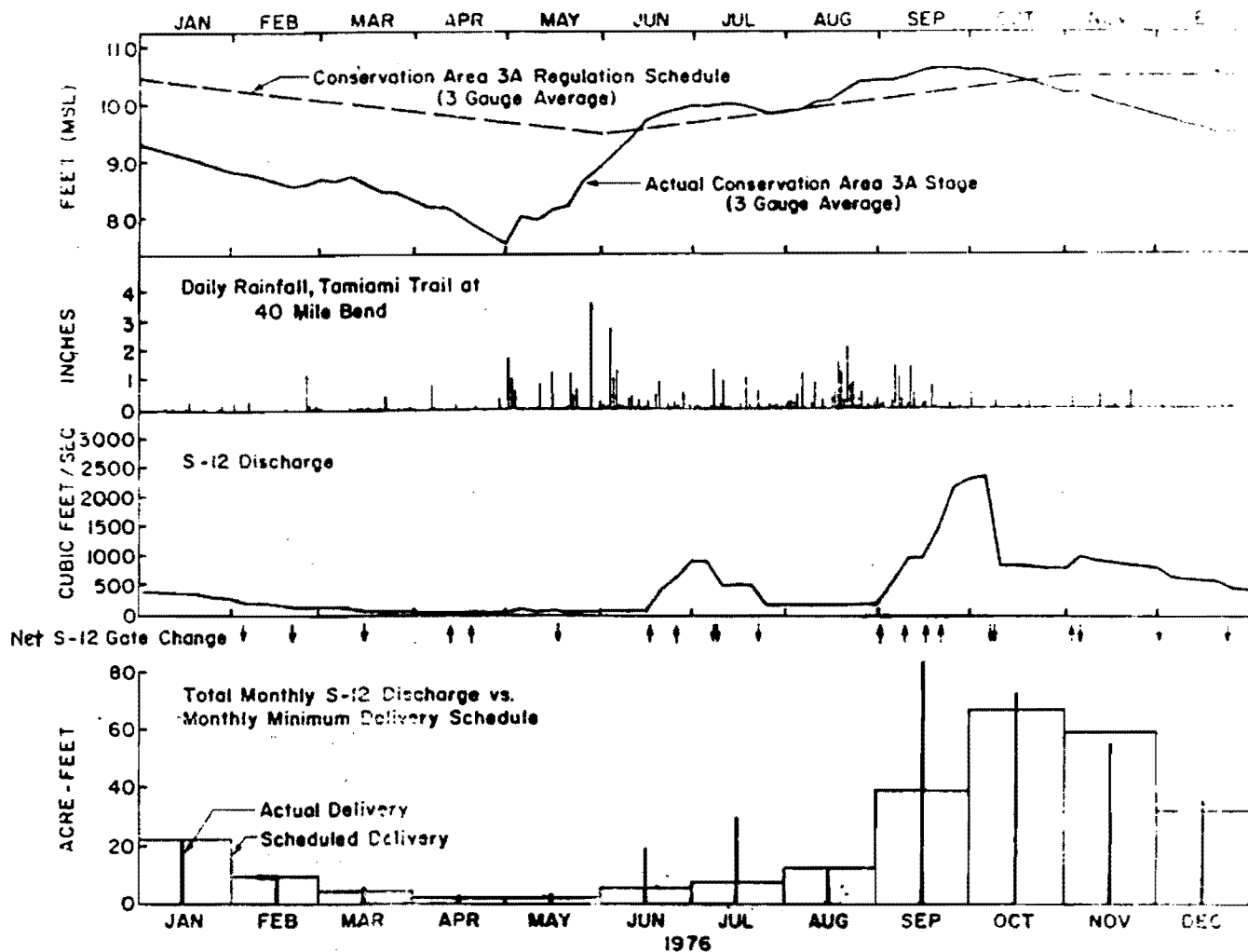


FIGURE 14. Summary of 1976 Shark Slough water delivery system operations.

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considerably below its regulation schedule and park deliveries were held at the minimum schedule. Rainfall increased in May, and Area 3A stages responded by rising more than 1.5 feet from May 1 to June 15. However, structure S-12 deliveries were not increased during this period. Rather, the water was held in the Conservation Areas for supply purposes. As the wet season continued through June, Area 3A stage rose above the regulation level and sudden delivery increases were initiated to reduce stages back below regulation. As a result, the spike in structure S-12 discharge shown in June and July began long after water levels in the Conservation Area rose in response to rainfall. Deliveries were once again cut back to minimum rates when Area 3A stage receded below regulation levels in late July. But then heavy August rainfall brought stages above schedule again and the cycle of delayed discharge was repeated. Clearly, the minimum delivery schedule and management of Conservation Area 3A for water supply and flood control purposes interacted to draw timing and magnitude of flow to Shark Slough substantially away from a natural response to rainfall in 1976, a pattern repeated in most other years after enactment of the 1970 schedule.

3. Spatial Distribution of Deliveries

As noted previously, construction of levee 29 and subsequently L-67 (Ext.) canal and levee divided Shark Slough into two distinct hydrologic regimes. The histogram of relative discharge through the two Shark Slough flow sections shown in Figure 15 illustrates a dramatic alteration of flow distribution to the Everglades south of Tamiami Trail. Prior to construction of levee 29, 34 percent of total flow to Shark Slough (1940-1962) was through the L-67A to 40-Mile Bend flow section with the balance (66 percent) entering the eastern half of the slough (L-30 to L-67A). But once delivery schedules were in effect a sustained reversal of spatial distribution began, with 92 percent of total flow delivered to the western half of the slough through the S-12 structures during the P.L. 91-282 period. (Data by flow section are tabulated in Appendices E and F.). Thus, flood releases linked to the operations of Project structures as outlined for 1976 were funnelled through less than half the historic Shark Slough flow-section.

4. Downstream effects of dry season deliveries

Figures 4, 5a, and 5b show that although the October 1970 through December 1982 period was unusually dry, discharge to Shark Slough was substantially greater than for previous periods of similarly low rainfall. This was possible largely due to the conveyance capability afforded by the L-67A and L-67 (Ext.) canals.

Central Shark Slough response to increased dry season deliveries is illustrated in the plot of period of record mean monthly water level at stage recorder P-33 (Fig. 4). While average monthly water levels at P-33 fell below the ground surface in 20 months during October 1953 and September 1970, dry season deliveries during October 1970-December 1982 held stages above the ground surface for all but two months at this station despite 11 consecutive years of below average basin rainfall (Fig. 5b). From these data, it is clear that increased dry season deliveries maintained higher stages in portions of Central Shark Slough even under very dry conditions. The areal extent of this effect, however, is unknown.

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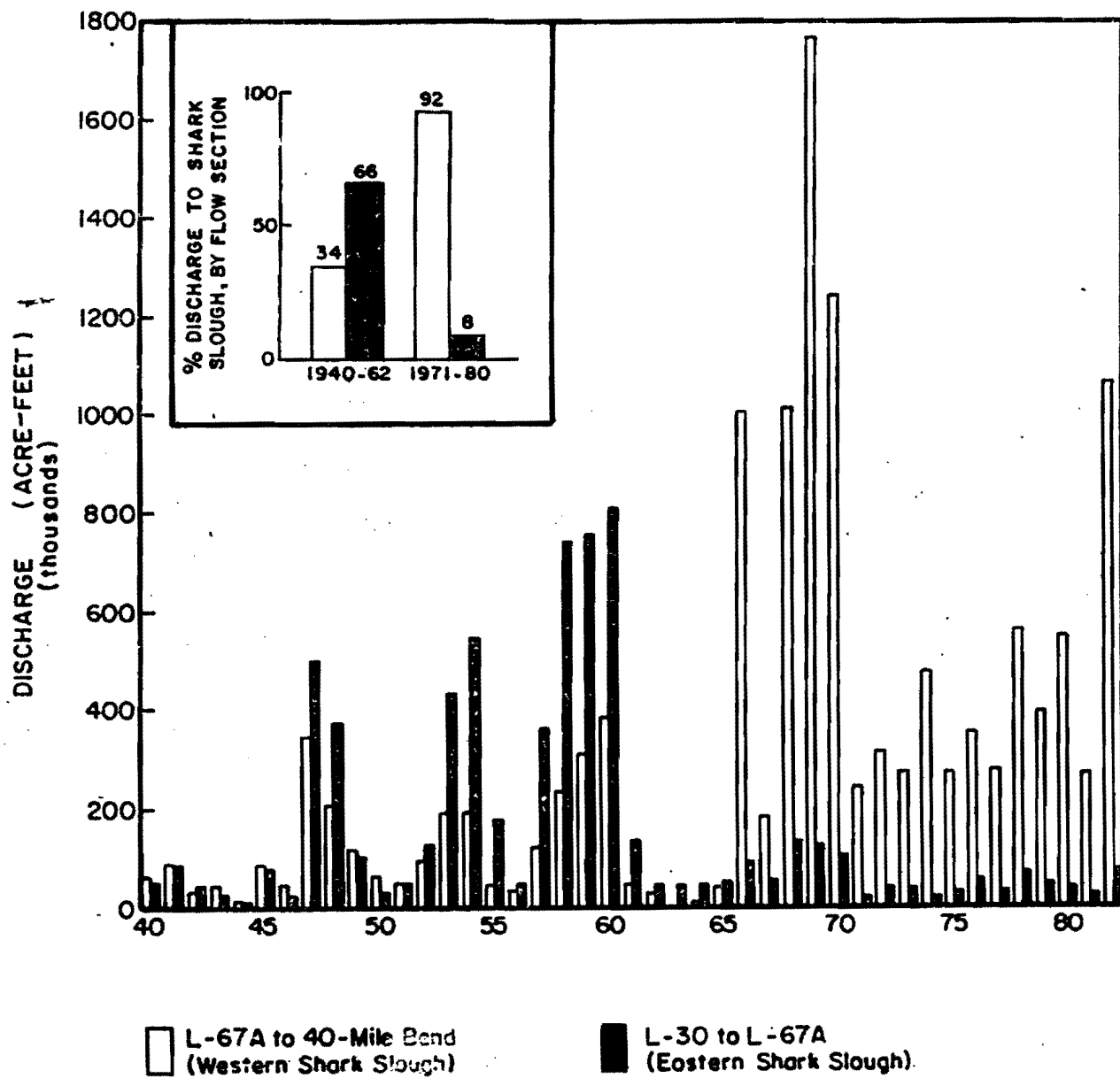


FIGURE 15. Annual discharge to Shark Slough by flow section (Tamiami outlets, L-30 to L-67A and L-67A to 40-Mile Bend, FL). Data source: U.S. Geological Survey (Miami).

SUMMARY AND CONCLUSIONS

The Everglades were not gauged sufficiently prior to major drainage operations to directly determine pre-Project flows to Shark Slough. However, rough water budget analyses by the Central and Southern Florida Flood Control District (1950) and by Langbein (in Parker et al., 1955) both concluded that average annual pre-drainage inflow to Shark Slough was over 2 million acre-feet. Neither study was used in development of water delivery schedules for Everglades National Park.

Two studies were used in developing interim Shark Slough water delivery schedules in the late 1960's and in developing the minimum monthly Shark Slough delivery schedule adopted by Congress in the Monetary Authorization Act of 1970 (P.L. 91-282). The first study by Dunn (1961) analyzed Shark Slough discharge records for a 6-year period (1947-1952). Median annual flows totalling 273,000 acre-feet for that period were recommended in the study as minimum annual delivery requirements for Shark Slough. Hartwell, Klein, and Joyner (1963) used stage-duration curves at central Shark Slough ^{stage} recorder P-33 for the period October 1953-September 1962 and a stage-discharge relationship between P-33 ^{stage} and flow to Shark Slough for that period to develop an annual discharge requirement of 243,580 acre-feet. The results of the two studies were (roughly) averaged by the National Park Service to arrive at the 260,000 acre-foot minimum water delivery requirement for Shark Slough that was eventually incorporated into Public Law 91-282.

The minimum delivery schedule for Taylor Slough appearing in P.L. 91-282 was based solely on the work of Dunn (1961). First, an estimate of locally derived flow was computed based upon comparison of less than a year of flow records at U.S. Geological Survey (Miami) flow section "Taylor Slough near Homestead, Florida" with flow to Shark Slough (U.S. Geological Survey (Miami) records for Tamiami culverts 40-62). Spillover from Shark Slough was estimated and added to this value to arrive at an average annual flow of 55,000 acre-feet. As with Dunn's Shark Slough analysis, the median discharge value (38,000 acre-feet) was recommended as the minimum requirement. For reasons that remain unclear, the minimum requirement was reduced to 37,000 acre-feet in the October 10, 1967, letter written by National Park Service Deputy Director Harthorn Bill to the U.S. Army Corps of Engineers. Ultimately, the lower figure appeared in P.L. 91-282 as the minimum annual requirement for Taylor Slough.

Monthly minimum deliveries for Taylor Slough set in P.L. 91-282 were amended in 1976 via the "Agreement and permit for construction and operation of Taylor Slough pump station S-332" (Appendix C). No record of the analyses leading to the amended schedule could be found, however, personal communication with parties to the negotiations indicated that the new schedule took into account updated U.S. Geological Survey records for the Taylor Slough Bridge flow section and professional opinion regarding probable effects of S-332 pumpages on downstream flow.

Derivation of the minimum delivery schedule for the park's Eastern Panhandle area appearing in P.L. 91-282 is apparently not documented. It most likely was derived for Deputy Director Harthorn Bill's letter of October 20, 1967, by computing the difference between the average annual flow to the eastern park border area (55,000 acre-feet) computed by Dunn (1961) and the median flow value (38,000 acre-feet) computed in that report.

Four operational modes governed water releases through the S-12 structures before P.L. 91-282 was adopted by Congress in 1970. The interim delivery schedules during this period varied in their origins and contents, but the P.L. 91-282 schedule was the first to both guarantee minimum monthly water rights for the park and provide a mechanism for sharing adversity in times of drought. The 260,000 acre-foot Shark Slough requirement guaranteed by the law is only 10-13 percent of the two early water budget estimates of pre-Project flow to Shark Slough. However, this value was intended only as a minimum guaranteed allocation, and instructions were included in Senate Report 91-895 for delivery of "surplus" water from the Project to the park to the maximum extent feasible. No provisions were included for placing a ceiling on water deliveries or for gate opening strategies. These were left for negotiation amongst the National Park Service, the Corps of Engineers, and the Flood Control District.

The Senate Report did commit the Corps of Engineers to review water resource needs in central and south Florida, including Everglades National Park, by 1980 in order to determine if "further modifications of the Project were warranted, and give further assurances of maintaining the essential water supply to insure protection of the park's ecosystem" (U.S. Senate, 1969).

Discharge records available for the period October 1970-December 1982 indicated the following:

--The record of compliance with the minimum monthly delivery schedule for Shark Slough shows that discharges fell short of the monthly allocations 26 percent of the time. The smaller shortfalls scattered throughout the record can be avoided by improving structure rating curves and allowing for a greater margin of error when setting S-12 gates. Larger shortfalls, however, generally occurred under low rainfall conditions. While P.L. 91-282 provides a mechanism for reducing flows to Shark Slough during droughts, no documentation was found which indicates that this mechanism was employed to determine the reduced flows. This mechanism for determining shared adversity in drought should be re-evaluated with a goal of providing a more workable definition of drought and a more workable means of determining flow reductions.

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-- S-12 structure operations, as shown in the analysis for 1976, showed a pattern of delivering only minimum monthly allocations as long as Conservation Area 3A was below regulation schedule. This allowed retention of upstream rainfall and runoff in the reservoir as the wet season progressed, with sudden, large releases to the park once the schedule was exceeded. This pattern drew timing and magnitude of deliveries away from a more natural response to Everglades basin rainfall.

-- The interim water delivery schedules of the late 1960's and P.L. 91-282 did nothing to relieve the dramatic alteration of water distribution to Shark Slough beginning after completion of Conservation Area 3. Prior to completion of levee 29 and the S-12 structures in 1962, 34 percent of total annual flow to Shark Slough was through the L-67A to 40-Mile Bend (western Shark Slough) flow sections, with 66 percent through the eastern half of the slough (L-30 to L-67A). But once the delivery schedules were in effect a sustained reversal of spatial distribution began, with 92 percent of annual flow delivered to the western half of Shark Slough during the P.L. 91-282 schedule period. By 1963, the hydrologic system which once spread uncontrolled sheetflow across the 25-mile-wide Shark River Slough could funnel unnaturally timed flood releases from a reservoir system into the 10-mile wide remnant of Shark Slough now lying within Everglades National Park.

-- Although the period 1971-1982 included 11 consecutive years of below average basin-wide rainfall, it appears that the water management system was capable of delivering substantially more water to Shark Slough than in comparably dry periods before the 1970 delivery schedule was adopted. This was reflected downstream at stage recorder P-33, where monthly average water levels fell below the ground surface only twice once scheduled deliveries began. The areal extent of this effect, however, is unknown. Research is needed to link local stage readings to marsh hydropatterns.

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Appendix A. Discharge, Tamiami Canal Outlets, L-30 to 40-Mile Bend, 1940-1982, in acre-feet.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
1940	8300	3560	184	179	184	60	615	7370	33920	27060	15230	10270	106932
1941	11740	27468	13040	22130	5900	2497	18450	15680	12680	17340	15050	8860	170835
1942	4670	888	676	536	984	25950	15680	7750	8870	4429	0	0	70433
1943	0	0	0	0	307	119	3074	4670	21900	17830	8800	7370	64070
1944	3620	403	0	0	246	0	984	5650	893	2889	3093	246	18024
1945	123	0	0	0	0	0	676	7504	47600	51780	39630	15980	163293
1946	6210	111	0	0	246	476	1353	4485	19520	16660	10060	8110	67231
1947	3140	1726	553	60	61	10000	46230	72190	87410	348400	207890	64190	841850
1948	73480	23410	1781	0	61	0	184	861	24520	257500	135080	61800	578677
1949	23360	3110	0	0	0	2140	6639	12300	35460	70220	45160	17040	215429
1950	10510	1000	307	0	0	0	1721	922	9940	38060	20110	6270	88840
1951	4119	1885	0	0	0	0	676	3441	9280	25950	29810	19800	94961
1952	4120	2540	0	0	0	238	8670	10450	16950	65850	69500	39790	218108
1953	28530	27220	7070	119	61	60	2397	15500	31950	167030	197580	147540	625057
1954	93830	30270	13530	1730	3570	43140	60200	77720	109430	126600	97290	80790	738100
1955	45930	17660	2090	0	0	1249	3690	16230	51470	43170	23980	9899	215368
1956	2090	288	0	0	0	0	0	676	5890	40340	22370	3623	75277
1957	184	56	123	0	6269	238	3260	13220	60690	188250	129430	76620	478340
1958	109330	141360	123710	108120	83560	103300	106490	51210	47600	46490	28800	23420	973390
1959	18140	6665	4794	1490	1414	34760	137670	164190	156210	160930	191820	186630	1064713
1960	131280	77480	42240	14520	4303	9340	8180	23860	150540	293900	262000	169180	1186823
1961	99240	50480	13709	595	0	357	1660	5650	3100	1353	0	0	176144
1962	0	0	0	0	0	2440	5660	6890	14930	21650	7850	5840	65260
1963	3570	1610	1350	0	0	0	1350	4920	15650	4540	3570	2490	39050
1964	3330	1250	373	10	650	5070	3370	3500	4650	6840	8070	10490	47603
1965	9940	5150	4480	1333	113	-22	-34	825	5520	12960	32090	12180	84535
1966	10600	12350	47940	44480	43810	76490	215880	255960	174370	169440	42770	4390	1098480
1967	12550	10520	17490	11139	6380	8492	18850	35370	32070	32520	29930	19310	234621
1968	17530	12470	8920	5569	8390	106730	264920	285600	193010	133420	74770	26650	1137979
1969	25290	32730	90610	95450	103360	188920	221460	209680	192760	206360	286110	234970	1887700

Appendix A. Discharge, Tamiami Canal Outlets, L-30 to 40-Mile Bend, 1940-1982, in acre-feet.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
1940	8300	3560	184	179	184	60	615	7370	33920	27060	15230	10270	106932
1941	11740	27468	13040	22130	5900	2497	18450	15680	12680	17340	15050	8860	170835
1942	4670	888	676	536	984	25950	15680	7750	8870	4429	0	0	70433
1943	0	0	0	0	307	119	3074	4670	21900	17830	8800	7370	64070
1944	3620	403	0	0	246	0	984	5650	893	2889	3093	246	18024
1945	123	0	0	0	0	0	676	7504	47600	51780	39630	15980	163293
1946	6210	111	0	0	246	476	1353	4485	19520	16660	10060	8110	67231
1947	3140	1726	553	60	61	10000	46230	72190	87410	348400	207890	64190	841850
1948	73480	23410	1781	0	61	0	184	861	24520	257500	135080	61800	578677
1949	23360	3110	0	0	0	2140	6639	12300	35460	70220	45160	17040	215429
1950	10510	1000	307	0	0	0	1721	922	9940	38060	20110	6270	88840
1951	4119	1885	0	0	0	0	676	3441	9280	25950	29810	19800	94961
1952	4120	2540	0	0	0	238	8670	10450	16950	65850	69500	39790	218108
1953	28530	27220	7070	119	61	60	2397	15500	31950	167030	197580	147540	625057
1954	93830	30270	13530	1730	3570	43140	60200	77720	109430	126600	97290	80790	738100
1955	45930	17660	2090	0	0	1249	3690	16230	51470	43170	23980	9899	215368
1956	2090	288	0	0	0	0	0	676	5890	40340	22370	3623	75277
1957	184	56	123	0	6269	238	3260	13220	60690	188250	129430	76620	478340
1958	109330	141360	123710	108120	83560	103300	106490	51210	47600	46490	28800	23420	973390
1959	18140	6665	4794	1490	1414	34760	137670	164190	156210	160930	191820	186630	1064713
1960	131280	77480	42240	14520	4303	9340	8180	23860	150540	293900	262000	169180	1186823
1961	99240	50480	13709	595	0	357	1660	5650	3100	1353	0	0	176144
1962	0	0	0	0	0	2440	5660	6890	14930	21650	7850	5840	65260
1963	3570	1610	1350	0	0	0	1350	4920	15650	4540	3570	2490	39050
1964	3330	1250	373	10	650	5070	3370	3500	4650	6840	8070	10490	47603
1965	9940	5150	4480	1333	113	-22	-34	825	5520	12960	32090	12180	84535
1966	10600	12350	47940	44480	43810	76490	215880	255960	174370	169440	42770	4390	1098480
1967	12550	10520	17490	11139	6380	8492	18850	35370	32070	32520	29930	19310	234621
1968	17530	12470	8920	5569	8390	106730	264920	285600	193010	133420	74770	26650	1137979
1969	25290	32730	90610	95450	103360	188920	221460	209680	192760	206360	286110	234970	1887700

Appendix A, continued.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
1970	139850	162790	190920	192740	70230	154920	136570	78730	36040	79810	60160	39580	1342340
1971	23291	10359	4173	1550	2670	2270	8700	13370	33290	54860	60780	38560	253873
1972	26630	11120	4440	2360	10740	37320	33760	20880	50190	60130	54050	37760	349380
1973	29930	12983	6010	2582	1710	7163	14970	18730	50960	72400	54250	31260	302948
1974	22425	12319	4010	2770	2360	6090	12331	63080	165540	87870	67110	47030	492935
1975	21970	9360	9148	1830	2498	7524	12890	17020	41290	72190	68020	34810	298550
1976	22472	10249	5779	2041	4540	25350	35380	21790	95170	82260	61940	39390	406361
1977	24590	10154	4348	1830	3600	7380	8092	13490	49330	77770	60430	36440	297454
1978	25190	13080	41140	3749	3409	7250	38740	147060	123550	112340	70200	42200	627908
1979	35730	28690	7181	4914	27470	17170	10550	17090	49840	115680	79180	42030	435525
1980	26960	105590	96400	49500	38580	9220	4450	18280	83040	65057	56572	34856	588505
1981	23459	10046	3227	1375	2366	4919	6988	11187	44837	78884	63171	35766	286225
1982	19899	9624	3775	2489	2416	43353	235273	227628	138391	210578	187062	53467	1133955

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Appendix B. Monthly and total annual Everglades basin (3-gauge average) rainfall; NOAA stations "Tamiami Trail at 40-Mile Bend," "Belle Glade Experiment Station," and "Pennsuco 5 NW."

Month	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Jan	2.77	3.55	1.75	1.15	0.93	1.68	0.71	1.06	2.57	0.12	0.15	0.46	1.02	3.22	0.45
Feb	2.55	4.96	2.20	0.46	0.03	0.30	0.81	1.95	0.69	0.55	0.72	1.50	3.26	2.65	2.01
Mar	3.40	3.96	3.34	0.63	1.54	0.75	3.64	5.89	0.80	0.30	2.04	0.56	1.70	1.68	2.97
Apr	1.59	5.38	5.20	4.54	2.22	1.68	0.24	3.32	4.82	2.94	3.71	4.06	2.04	4.13	5.39
May	3.89	1.82	4.39	7.43	6.71	2.11	6.86	5.74	3.30	3.72	3.99	1.93	4.70	2.42	8.44
Jun	9.09	7.63	18.51	5.93	4.15	7.05	7.57	13.30	3.57	10.06	4.89	4.92	7.03	7.43	12.00
Jul	4.88	11.24	4.16	8.70	9.62	10.53	11.02	11.59	7.57	11.29	7.48	11.16	7.67	12.23	5.63
Aug	7.78	3.87	5.92	6.42	11.33	7.53	9.49	6.65	8.93	8.24	9.61	8.29	6.39	9.00	5.62
Sep	9.43	7.24	7.57	9.12	4.65	10.02	7.71	11.84	19.29	10.53	6.69	4.49	7.79	12.49	9.09
Oct	2.34	5.74	0.72	3.26	8.38	3.89	1.30	13.46	7.87	5.40	10.61	8.63	11.71	9.06	3.72
Nov	0.49	3.46	0.95	2.66	0.28	1.62	3.25	3.58	0.77	1.21	2.06	1.09	0.29	1.34	2.66
Dec	<u>4.73</u>	<u>0.81</u>	<u>2.06</u>	<u>0.37</u>	<u>0.24</u>	<u>0.99</u>	<u>2.09</u>	<u>0.88</u>	<u>0.78</u>	<u>4.31</u>	<u>1.76</u>	<u>0.23</u>	<u>1.19</u>	<u>1.59</u>	<u>0.87</u>
Annual															
Total	52.94	59.66	56.77	50.67	50.08	48.15	54.69	79.26	60.96	58.67	53.71	47.32	54.79	67.24	58.85

Appendix B, continued.

Month	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Jan	1.17	1.81	2.58	7.43	2.08	0.23	3.09	1.45	0.78	1.34	0.85	4.23	1.90	0.88	2.87
Feb	1.51	1.10	5.33	0.98	0.51	2.58	0.81	0.69	3.87	1.84	3.47	2.34	2.00	2.34	1.79
Mar	1.16	0.75	2.55	6.48	6.09	1.85	0.97	3.56	0.87	1.71	2.09	1.25	1.75	1.59	3.98
Apr	2.16	3.26	7.67	2.27	1.90	6.42	1.64	2.57	0.75	4.36	1.04	3.42	0.08	0.76	4.94
May	4.77	2.79	7.98	10.21	8.97	3.91	8.32	3.75	6.21	4.00	1.68	7.08	1.60	11.64	6.22
Jun	13.75	7.31	5.68	5.78	14.23	8.64	6.92	14.53	8.87	8.47	9.07	16.83	13.23	14.19	15.17
Jul	6.83	6.91	8.21	4.73	8.56	10.10	6.26	8.14	5.20	4.14	7.60	7.78	6.69	7.72	7.75
Aug	5.80	11.15	10.31	7.76	5.97	9.06	9.88	6.78	8.14	9.16	7.49	7.03	4.20	6.18	7.79
Sep	7.25	8.48	10.10	5.67	9.37	20.10	3.85	10.97	10.60	5.87	11.48	6.73	5.91	8.09	9.39
Oct	4.80	7.17	6.97	4.22	7.90	5.26	2.82	2.80	2.42	7.80	8.10	5.61	8.38	9.79	9.51
Nov	0.76	0.38	2.24	1.19	7.54	2.50	0.83	1.54	2.37	1.13	1.68	0.56	1.94	1.69	2.24
Dec	<u>1.88</u>	<u>0.25</u>	<u>4.79</u>	<u>3.40</u>	<u>0.65</u>	<u>0.47</u>	<u>0.10</u>	<u>0.46</u>	<u>4.22</u>	<u>2.88</u>	<u>0.78</u>	<u>0.84</u>	<u>1.90</u>	<u>0.15</u>	<u>1.32</u>
Annual															
Total	51.84	51.36	74.41	60.12	73.77	71.12	45.49	57.24	54.30	52.70	55.33	63.70	49.58	65.02	72.97

Appendix B, continued.

Month	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Jan	2.90	0.85	1.32	2.43	0.88	0.34	0.51	2.92	2.30	3.37	4.02	0.77	0.55
Feb	2.16	1.70	2.37	1.26	0.09	2.32	2.88	1.07	2.46	0.39	0.94	3.14	1.82
Mar	12.06	0.50	2.85	2.70	0.27	0.58	0.69	0.19	2.63	0.52	1.71	1.67	4.84
Apr	0.16	0.13	5.43	0.93	0.95	1.10	0.91	1.69	1.76	6.25	5.59	0.20	3.92
May	7.56	4.66	9.13	2.19	3.03	6.61	9.90	7.36	3.36	5.33	4.98	3.09	8.06
Jun	9.20	9.52	7.64	9.18	10.44	5.57	8.37	7.07	10.83	5.79	2.90	4.80	13.99
Jul	7.76	6.07	7.82	13.14	11.28	9.16	4.58	3.68	10.67	7.38	6.55	5.06	5.15
Aug	5.74	6.22	5.90	7.88	7.32	4.54	8.88	7.02	2.56	4.55	5.21	15.53	5.49
Sep	5.40	8.50	4.28	6.13	6.12	9.05	7.09	10.31	5.26	10.85	5.12	7.25	8.16
Oct	5.78	5.93	3.45	2.33	1.36	2.81	1.17	0.50	4.48	2.97	2.56	1.30	4.07
Nov	0.08	2.56	3.24	0.55	2.80	0.67	1.94	3.33	2.75	3.28	2.62	2.12	2.84
Dec	<u>0.17</u>	<u>1.52</u>	<u>1.75</u>	<u>1.28</u>	<u>1.90</u>	<u>0.47</u>	<u>1.74</u>	<u>2.81</u>	<u>2.73</u>	<u>2.90</u>	<u>2.97</u>	<u>0.38</u>	<u>1.00</u>
Annual													
Total	59.03	48.16	55.18	50.00	46.44	43.22	48.66	47.95	51.79	53.58	45.17	45.31	59.89

Decision rules for missing data:

- (1) If Belle Glade Experiment Station or Tamiami Trail at 40-Mile Bend data missing, two remaining gauges were averaged.
- (2) If Pennsuco 5NW data missing, North New River Canal No. 2 (NOAA, 1940-82) was substituted and 3-gauge average was maintained. If both Pennsuco 5NW and North New River Canal No. 2 missing, two remaining gauges were averaged.
- (3) For 1940, mean of Belle Glade Experimental Station and Pennsuco No. 2 (Florida Board of Conservation, 1954) was used.

Appendix C. Exhibit B from the 1976 "Agreement and permit for construction and operation of Taylor Slough pump station S-332.

It is the understanding and agreement of the parties that the average monthly flows in cubic feet per second shown below are the minimum pumping rates governing the operation of Pumping Station 332 and are subject to the availability of water in the system. During flood periods such rates may be exceeded, up to the capacity of the pumping station, upon mutual agreement of all parties. Except as specified for flood flows, it is further understood that the rates below will not be exceeded without the agreement of all parties.

It is further understood that water not meeting the water quality standard guidelines established in the U.S. Department of Interior report, "Appraisal of Water Quality Needs and Criteria for Everglades National Park," dated June 1971, may be refused by the Director, National Park Service. It is further understood that all reasonable steps shall be taken by all parties to deliver water of sufficient purity to prevent ecological damage or deterioration of the Park environment as set forth in Public Law 91-282, and that subject to availability of funds the "CORPS" shall monitor the quality of water and report the results to the Director, National Park Service.

Pumping Station 332
Cyclical Flow Rate

Month	Percent of Annual Flow	Monthly Flow In Acre-Feet	Average Monthly Flows In Cubic Feet per Second
		Taylor Slough	Taylor Slough
Jan	2.0	740	12
Feb	1.0	370	6.7
Mar	.5	185	3.0
Apr	.5	185	3.1
May	1.0	370	6.0
Jun	18.0	6,660	112.0
Jul	20.0	7,400	120.0
Aug	8.0	2,960	48.0
Sep	16.0	5,920	100.0
Oct	21.0	7,770	126.0
Nov	10.0	3,700	62.0
Dec	2.0	740	12.0
Total	100.0	37,000	

(in acre-feet)

Appendix D. Deviation [^] from the Shark Slough minimum monthly delivery schedule, October 1970-December 1982. (Negative values indicate non-compliance)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
JAN		270	2070	6090	-710	-1850	-790	110	-80	9060	1260	1038	-3845
FEB		920	1090	3050	3170	-300	440	230	1610	13940	93320	901	8
MAR		30	0	1350	-120	4770	810	120	34100	2680	89510	-903	-399
APR		-100	-340	840	1120	180	390	180	1220	2310	41060	-275	770
MAY		1020	7400	60	710	410	1400	320	860	14730	31620	716	502
JUN		-2700	27960	2180	1140	2240	14820	220	440	9330	2090	-31	35168
JUL		110	23270	5480	4530	2690	23440	-90	29010	1030	-6360	-442	213155
AUG		-830	3840	2000	48470	2160	-550	-110	117820	2110	2000	-2675	192297
SEP		-7890	3010	2910	123610	-70	44630	4820	66410	8090	40580	5579	91189
OCT	2030	-15010	-11590	-2010	16050	-3410	6380	6230	36640	45540	-3475	2396	136746
NOV	-2590	-610	-8100	-9200	5270	2870	-2960	-1310	5330	16350	-3252	-1816	122930
DEC	5590	4220	3940	-2370	12540	320	3990	740	6270	6160	2666	-12	15769

Appendix E. Discharge, Tamiami Culverts, L-67A to 40-Mile Bend, in acre-feet (from U.S. Geological Survey, 1940-1982).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
1940	4610	1780	123	179	123	60	0	6330	22610	14700	5710	4240	60465
1941	4300	12140	5600	10290	3070	2140	12240	9350	6130	8240	8450	5230	87180
1942	2830	666	615	298	984	14820	6400	1350	1250	799	0	0	30012
1943	0	0	0	0	0	119	2890	3380	15350	11500	4400	3500	41139
1944	1780	403	0	0	0	0	615	3810	417	2090	2260	246	11621
1945	123	0	0	0	0	0	676	7320	24810	27920	17910	7500	86259
1946	3010	111	0	0	123	357	1230	3870	11130	12850	6310	6270	45261
1947	2090	1670	553	60	0	6190	32830	39480	41770	125600	64090	30560	344893
1948	16420	3970	61	0	0	0	0	861	15830	109100	43320	15500	205062
1949	11680	0	0	0	0	2080	6270	10640	21240	38370	18680	7690	116650
1950	5160	0	0	0	0	0	1660	861	8390	29640	10650	3870	60231
1951	3320	1330	0	0	0	0	676	3380	5830	12850	12910	6460	46756
1952	1480	1040	0	0	0	238	5600	8240	11360	31910	22550	11810	94228
1953	8420	6000	1110	0	0	0	2090	8610	30470	51530	50280	32340	190850
1954	17890	4610	1600	60	1230	20710	21890	21950	33320	31050	22490	14140	190940
1955	6700	1220	0	0	0	179	1600	4490	13630	8060	4220	799	40898
1956	0	0	0	0	0	0	0	246	4820	18320	7080	123	31089
1957	0	0	0	0	369	0	1720	5900	20940	47650	27730	14390	118699
1958	25580	32660	30130	19700	23980	29040	32340	14630	9760	9350	2800	2640	232610
1959	1910	555	184	0	799	15000	38610	40890	44210	49930	60520	55030	307638
1960	32040	18520	7440	3210	123	4460	2950	12670	70450	107400	84200	36280	379743
1961	25020	11050	799	0	0	0	922	3870	1670	861	0	0	44192
1962	0	0	0	0	0	1190	3260	2770	6720	9410	1070	0	24420
1963	0	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	56	811	2530	1570	0	0	0	0	0	4967
1965	2260	0	0	93	0	0	0	728	3460	5720	21700	2980	36941
1966	1320	5780	43490	41750	42360	67770	200300	242500	165600	159900	35690	0	1006460
1967	9130	7760	16310	10640	6380	7750	17720	33440	29520	18490	16380	7860	181380
1968	9350	7630	6240	4830	5430	91520	248000	269100	179700	113500	59330	16370	1011000
1969	15850	26620	85450	91850	97230	178400	214000	197400	182400	192500	264800	218200	1764700