

**Ecological Aspects of Test Iteration 7:
Experimental Program of Water Deliveries to
Everglades National Park**

First Annual Report

DRAFT

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Ecological Aspects of Test Iteration 7:
Experimental Program of Water Deliveries to Everglades National Park

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1.0. Introduction

This is the first annual report on the ecological monitoring component for Test Iteration 7: Experimental Program of Water Deliveries to Everglades National Park. Specific projects included under this program were designed by an interagency committee and are listed in Table 1. Under the first year of this program only projects which were specifically designated under the memorandum of understanding (MOU) signed by the National Park Service (NPS), the Army Corps of Engineers (ACOE), the U.S. Fish and Wildlife Service (USFWS) and the South Florida Water Management District (SFWMD) will be included in this first year monitoring report. These projects were chosen as indicators expected to provide close links to water management changes. Some of these projects were already in process as part of other programs and some projects were initiated under this program. This program will be re-evaluated each year after results are available and the annual report for the program is complete. As other programs and projects are reviewed and new data becomes available from projects funded under other forums, information will be included in this report as appropriate.

This current document contains abstracted summaries of the existing programs funded under the Test Iteration 7 MOU. Methods and results are abstracted from the projects as listed. Recommendations will be provided as the projects progress. Projects abstracted and discussed in this report are listed in Table 2.

2.0 History of Experimental Water Deliveries to ENP

2.1. Biologic Impacts to the Study Area

Biologic problems in the Everglades ecosystem and the decline of the ecologic resources of Everglades National Park have been described since the first major components of drainage were in place in the larger south Florida system. The first reports documenting problems in the natural system related to drainage were written in the early part of this century (Small, 1929; Harper, 1927; Beard, 1938; and Davis, 1943). In his report describing the resources of the newly designated Everglades National Park, Beard (1938) documented many problems facing the park due to drainage including decreased habitat and increased fire frequency. In this report he asserted that gator holes were "one of the principal keys to restoring wildlife in the park" and that "the ecological communities known as gator holes have been largely destroyed by lowered water levels in dry seasons." He also described the effects of unnatural, intentionally set dry season fires, which occurred too frequently and during the dry season rather than during the wet season when natural lightning fires would occur. Subsequent data analysis and sampling during the existence of the Park have followed the worsening of these problems and clarified portions of the nature and extent of the impacts on ecologic integrity associated with drainage and altered water deliveries to the Park.

Further sampling clarified and quantified the impacts associated with drainage including loss

of habitat, increased fire frequency, decreased habitat productivity, spatial and temporal shifts in wildlife populations, and a decline in population numbers. One of the major ecologic components showing early decline has been wading birds. Since the 1940's wading bird populations are believed to have declined to between 5-10% of their original size (Frederick *et al.*, 1996; Ogden, 1994). Wood stork nesting has shifted both temporally and spatially, moving into the spring season and out of the estuarine areas of ENP to the water conservation areas (WCA's) (Frederick and Collopy, 1988; Frederick *et al.*, 1996; Ogden, 1994). The largest wading bird colonies were originally found within the ENP mangrove zone (Frederick *et al.*, 1996). During the period between the 1950's and the 1970's these colonies shifted away from the coastal zone of ENP into the interior marshes of the Everglades, central Florida and other locations as far north as South Carolina.

During the 1970's it became apparent that the biologic resources of ENP were continuing to decline. Research at the South Florida Research Center and by independent researchers showed significant declines in various biologic components of the ecosystem. Principal among these components were the lower trophic levels; fish and macro-invertebrates as well as other portions of the system dependant upon these trophic components such as wading birds and alligators (NPS, 1990). Other components of the Everglades ecosystem dependant on natural hydrologic conditions were also in decline such as the downstream estuarine system, natural vegetative communities, and various components of the system which depend upon these portions of the ecosystem. In 1983 a seven point plan was proposed to offset and reverse the biological impact due to water management and water deliveries to the Park (Table 3). These measures were proposed in direct response to the biological and ecological degradation documented within the Park boundaries. The seven point plan also proposed formal measures to address the removal of key portions of the natural system such as Northeast Shark River Slough (NESRS) by the construction of L-67E and the compartmentalization of the system due to L-29 and L-28.

Problems more recently outlined in a National Park Service (NPS) report (1990) on the proposed alternatives for the U.S. Army Corps of Engineers' General Design Memorandum for Modified Water Deliveries to Everglades National Park included declines in nesting wading birds, a decrease in abundance of higher trophic-level consumer populations, reduced hydroperiods, loss of marsh productivity, increased alligator nest flooding, loss of wetland habitat, reduction of flows to the downstream estuary and abandonment of former foraging habitats. These problems are in part due to reducing the hydroperiod of some slough areas and other marshes to shorter hydroperiods. This has resulted in reducing rich slough habitat to degraded marshes with low standing stocks of fishes and invertebrates thereby reducing utilization by upper level consumers such as wading birds and alligators (ACOE, 1987). Loftus *et al.* (1986) have documented adverse impacts of shortened hydroperiods on the aquatic food chain.

2.2. Hydrologic Impacts to the System

The Experimental Water Delivery Program and current schedule of water deliveries to ENP

was initiated in 1983 in response to the seven point plan (Table 3). As a response to this request, the Corps of Engineers initiated a series of tests. The resulting Experimental Program of Water Deliveries to Everglades National Park is a series of iterative tests intended to build upon the results of previous tests as a means to restore more natural water deliveries to address the biological declines previously outlined. Experimental water deliveries to ENP were divided between schedule changes to both Shark River Slough and to Taylor Slough. The first five iterative tests were conducted in the Shark River Slough drainage. Test 6 incorporated Taylor Slough into the experimental program for the period beginning June 1993 through October 1995. Test 6, therefore involved changing operating practices for the existing structural features of the C& SF system that affect water deliveries and hydrological conditions in both Shark River Slough and Taylor Slough. This program is intended to provide a practical means of testing ecosystem responses to water deliveries with the goal of ecologic restoration for the natural systems of ENP.

3.0 Background Description of Test 7

3.1. Test 7 Objectives and Features

The C-111 General Reevaluation Report (GRR) recommends that an operational plan be developed for both Shark Slough and Taylor Slough as part of the Experimental Program. Test 7 was designed as a means of examining the impacts of refinements recommended from Test 6. Test 7 is the implementation and examination of the effects of changes recommended at the conclusion of Test 6.

3.2. Ecologic Monitoring

An ecological monitoring program was agreed to by the National Park Service (NPS), the US Fish and Wildlife Service (FWS), the Army Corps of Engineers (ACOE) and the South Florida Water Management District (SFWMD). The ecological monitoring elements for this program were based on four criteria. These criteria were developed by an interagency group convened to design the ecological monitoring elements of the sampling program for the Experimental Program of Water Deliveries to Everglades National Park (ENP). The first criteria was the potential sensitivity to hydrological change. The second criteria was the result of the Endangered Species Act (ESA) Section 7 consultation for Test 7 with respect to reasonable and prudent alternatives for the Cape Sable Seaside Sparrow, the American Crocodile and the Wood Stork. The third criteria was that monitoring measures would be chosen based on their importance as baseline for ecological changes. The fourth criteria was the relevance of the monitoring data to ongoing modeling efforts in the Across Trophic Level System Simulation (ATLSS) or Everglades Landscape Model (ELM) programs.

Items examined for inclusion into the ecological criteria were classified into essential and moderate in priority. Essential efforts were those considered as minimum tasks necessary to evaluate the ecological responses to Test 7. Moderate tasks were those which would provide useful information but were not critical as minimum tasks to understanding the system on the spatial and

temporal scale of Test 7. Components of the system recommended for monitoring as essential were: plant communities; algal communities; fish and macro-invertebrates; wading bird nesting surveys; wood storks; Cape Sable seaside sparrow (CSSS); alligators; and the American crocodile (Table 1). Recommendations from the ecological assessment for Test 6 were that further monitoring should be based on a spatial scale and extent which is comparable to that expected from the hydrologic changes (Ogden *et al.*, 1995). Because of this consideration and the evaluation of data under Test 6, some programs were not found to be on a scale appropriate to evaluate the responses of the ecosystem to water delivery changes. Much of the information derived from the Systematic Reconnaissance Surveys (SRF) program with respect to wading birds was considered to be in this category (Ogden *et al.*, 1995).

4.0 Data Collection and Methodology

4.1. Introduction

Geographic coordinates for all sampling programs are found in Appendix 1. Detailed reports on the sampling programs are found in Appendix 2. Methodology is listed in general here as a means to give context to results and resulting recommendations. For more detailed information refer to complete reports in Appendix 2.

4.2. Vegetation

4.2.1. *Macrophytes* (Jones and Armentano, 1997)

Macrophyte vegetation sampling was initiated in Taylor Slough as a means to give consistent quantitative baseline information on vegetation changes as a result of Test 7. Because of its design and the location of this sampling program, it is also possible to reference it to past sampling in Taylor Slough. Data from historical vegetation sampling in Taylor Slough is limited as baseline information. The majority of previous sampling information such as that generated by Tabb *et al.* (1967), Alexander and Crook (1975), Werner (1975), and Hofstetter and Hilsenbeck (1980), is of historical importance but is incomplete and limited as a quantitative baseline data set for comparing changes in Taylor Slough. The survey and analysis by Olmsted *et al.* (1980), provides a more reliable baseline for assessing rapid changes in vegetation patterns in the northern part of the slough. The current vegetation study builds upon the system of transects and sampling plots established by Olmsted *et al.* (1980) and is focused on the herbaceous wetland communities of Taylor Slough with the addition of several transects both north and south of the original study area. This approach is designed to provide a comprehensive analysis of vegetation responses to hydrological alterations along the entire length of Taylor Slough, from its headwaters in the Park south to Florida Bay. This work covers the vegetation monitoring component of the test for the first year ending in early 1997.

Linear transects (with sampling plots) were established across study area gradients based on previous hydrological and ecological studies and anticipated effects of the test. A total of seven permanent transects, with sampling plots, were established, or are planned, across Taylor Slough (Fig. 1 and 2). Vegetation sampling estimates live vegetation cover by species within permanent plots consisting of a linear array of five contiguous 1 m² quadrats. Open (bare) ground and

periphyton-covered ground surfaces were visually estimated. Water and soil depths were measured in each quadrat and averaged to produce mean plot soil and water depths. One survey of all transects will be finished by December 1997 and all transects will be re-sampled in alternate years. Elevation surveys of plots along transects and within plots were made and were used to calculate water levels at each plot using hydrologic data from station TSB at Taylor Slough Bridge.

4.2.2. *Algal Communities*

(Rudnick *et al.*, 1997; Appendix 2)

Objectives of the Test 7 periphyton project were to determine baseline ecological characteristics of areas in the southern Everglades (in Everglades National Park) affected by the hydrologic changes of Test 7, to quantify ecological impacts from these changes, on periphyton and associated plant communities to document water quality changes and associated ecological impacts due to these changes. Periphyton was sampled in Everglades National Park along six transects crossing Taylor Slough in an east-west direction that coincides with vegetation sampling of macrophytes by Park personnel (Figure 3).

Water quality was sampled each time phytoplankton samples were taken and analyzed for total nitrogen as total kjeldahl nitrogen, total phosphorus, and soluble reactive phosphorus (SRP), nitrate, nitrite, ammonium, dissolved organic carbon, calcium, and iron were sample once during the wet season and once during the dry season. Periphyton was sampled using two methods, periphytometers, which measure growth on artificial substrates (glass slides) and the measure of natural communities. Periphytometers were deployed quarterly and were measured for taxonomic composition and chlorophyll-a after seven weeks of growth. Periphyton was sampled semi-annually from natural substrates and analyzed for biomass, nutrient content, and taxonomic composition. This was done using three randomly selected 0.25m² quadrats at each station to quantify epiphytes and periphyton in both floating and benthic mats. Floating mats were sampled as all floating material, all material attached to macrophyte substrates, and all suspended material. Benthic mats were sampled by coring surface sediments.

4.3. **Fish and Macroinvertebrates**

4.3.1. *Freshwater Sampling* (Trexler, 1997)

This project was intended to provide background sampling for fish and macroinvertebrates in both Shark River Slough and Taylor Slough. This project involves continued sampling in Shark River Slough and initiating complementary sampling in Taylor Slough. This project established study sites along three transects in Taylor Slough for fish, macroinvertebrates, and associated vegetation using throw traps. Transects were located upstream, midstream and downstream in each slough system. Thirteen study plots were established in Taylor Slough and nine in Shark Slough. Freshwater fish sampling locations are shown in Figure 4. Field samples in Taylor Slough and Shark Slough were collected for April, July, October, December, and February of 1996-1997. Study plots in Taylor Slough were set up to include short and long hydroperiod sites. Shark River Slough sites were relatively long hydroperiod sites.

4.3.2. Saltwater Sampling (Lorenz *et al.*, 1997)

Saltwater fish were examined in the Taylor Slough/C-111 drainage by researchers from the National Audubon Society (NAS) as part of an ongoing ecological assessment of the mangrove fringe area of Northeast Florida Bay. This study examined the relationship between salinity, hydrology, vegetation and mangrove fish communities. The mangrove fish community was examined by looking at community composition, biomass, density, and structure as well as relationships to physical and hydrologic parameters. Fish were sampled in the upper dwarf mangrove zone of Florida Bay and Biscayne Bay from 1990-1996 at 4 to 6 week intervals (Figure 5). Because of its relevance to upstream water management, this study was included under the Test 7 program when Test 7 sampling was designed.

The mangrove fish community was examined by looking at community composition, biomass, fish density, habitat, and relationships to physical and hydrological parameters. Data were analyzed and weighted based on the amount of wetted area sampled. Weighing was used to account for fish concentration due to the aerial extent of wet area available to be occupied. To avoid violating statistical assumptions and sampling error, density and biomass of fish were calculated using a stratified mean for each sample. Density and biomass were generated by using a stratified mean estimate per site, which was divided by the total square meters of wet area per site.

Four areas were sampled: Taylor River, Joe Bay, Highway Creek and Barns Sound. Three net samples were taken at each site sampled using 9 m² drop nets. Hydrology was measured continuously at each site and salinity was recorded at the time of sampling. Submerged and emergent vegetation was sampled at each fish collecting site as well. Species composition and abundance were quantified at each sampling site for submerged and emergent vegetation. Abundance was determined using point intercept method. Vegetation sampling began in April 1996. Sites were also sampled on a salinity gradient from the fish sampling station, downstream to Florida Bay in May and November 1996.

4.4. Birds

4.4.1. Wading Birds (Bass and Oberhofer, 1997; Frederick *et al.*, 1996)

4.4.1.1 Water Conservation Areas

Wading birds were sampled in WCA's 2 and 3 for wading bird nesting, food intake and nesting energetics and environmental variables that may affect wading bird foraging success. Nesting effort was evaluated for Everglades National Park, Loxahatchee National Wildlife Refuge (WCA 1), and Big Cypress National Preserve. Aerial survey protocol was designed specifically to detect breeding wading bird colonies. Surveys were conducted and positions recorded using a global positioning system (GPS) during the middle of each month from February 1996 through June 1996. Survey methodology was developed by Frederick and Collopy (1988). Dark plumaged bird colonies were located and verified using systematic airboat surveys. Regurgitated food was collected from young herons, identified, and quantified when possible. Energetics of nestlings was sampled using techniques to evaluate food intake and body mass increase over time.

Environmental and hydrological factors affecting wading birds were evaluated using sites co-located with fish and macroinvertebrate sampling sites in Shark River Slough and Water Conservation Area 3 (Figure 6). Foraging behavior and success were quantified by making observations of individual birds foraging and by measuring environmental variables. Target species observed were great egrets, snowy egrets, white ibises, and wood storks representing foraging techniques of tactile, active visual, and sit and wait. Environmental variables measured were; number of captures, approximate prey size, prey type and bird behaviors; vegetation and physical features within 150 meters; dominant vegetation type at each foraging site and percentage of periphyton coverage; depth of water to flocculent layer, average depth of water, water and air temperature and type of substrate; estimated weather variables; size and species composition of the foraging flock and closest bird to measured bird.

4.4.1.2 Everglades National Park

NPS biologists flew a total of 7, fixed wing aircraft colony checks during the 1996 wading bird nesting season. These flights were designed to census traditional colony sites and investigate additional colonized discovered during SRF surveys. Surveys were conducted on 24 January, 20 March, 22 April, 13 May, 6 June, 2 July, and 2 August 1996.

4.4.2. *Cape Sable Seaside Sparrows* (Pimm *et al.*, 1996)

4.4.2.1. Helicopter Survey Methods

CSSS were sampled using observers who were flown from site to site by helicopter where sparrows were known to exist, existed in the past, or could be expected to exist due to habitat suitability. Methods are thoroughly documented in Appendix 3. Observers listened for singing males after the methods of Kushlan and Bass (1983) in a 1 km² grid. This methodology was modified in 1995 to a stratified random sampling structure. Sparrows were sampled in 1981 and then from 1992-present. Sparrow study areas within the region of the Modified Water Delivery project are divided into six regions (Figure 7).

4.4.2.2. Life History (Pimm *et al.*, 1996; Lockwood *et al.*, in press)

Breeding/nesting success, foraging behavior, survivorship, and habitat suitability were also examined. Nesting success was evaluated by counting the number of known eggs resulting in fledged birds. Systematic nest surveys and behavioral observations were made from late March through mid-August in 1995 and from early March through the end of July in 1996. Nests were marked and monitored until fledging or failure, egg numbers, hatching, fledging dates, predation, and prey items were recorded. Surface water depth at nest sites was recorded once per week within study areas. Prey items were identified as adult birds returned to the nest and by using sweep net samples of the insect community in the study plots to determine prey preference. Birds were banded within the area of permanent plots. Birds were called in with recorded songs and mist netted. Vegetation was measured in two unoccupied sites and in six occupied areas. At each plot four 1 m² quadrats were surveyed with the addition that eight quadrats were sampled at Taylor Slough. In occupied sites study plots were randomly set in the vicinity of a territory holding male.

4.5. Crocodilians

4.5.1. Alligators (Bass, 1997)

A systematic experimental design, in combination with standard aerial survey transect counting techniques (Norton-Griffith 1978) was used to document annual nest abundance patterns of alligators within Taylor Slough. East-west transects are oriented across the topographical gradients of the sloughs and systematically spaced at 2 km intervals north to south; these transects are flown annually, approximately one week following an estimated mean egg laying date, calculated each year by an egg deposition-ambient air temperature regression relationship developed from previous research (Kushlan and Jacobsen 1990). Survey height (40m), strip width (250m), and ground speed (50 knots) are standardized for all study years.

Hatching success and the sources and extent of egg mortality are estimated from a representative subset of nests monitored each year at approximately two week intervals throughout the incubation and hatching periods. Flooding patterns of nests within the slough are examined from a systematic subset or sample of the nests located during each year's initial nest survey. Subsequent biweekly monitoring flights are conducted to sample each nest to record the number of original eggs lost by mortality throughout the incubation and hatching periods.

4.5.2. American Crocodile (Mazzotti, 1997)

The crocodile monitoring program for the American crocodile (*Crocodylus acutus*) was designed to evaluate the population parameters known to be most susceptible to hydrological conditions. The population parameters under evaluation are distribution, growth, survival, nesting effort and nesting success.

Objectives of this program were:

- 1) To monitor nesting effort (number of crocodiles that attempt to nest) and nesting success (number of hatching nests) within Everglades National Park.
- 2) To assess the patterns of growth and survival of crocodiles from nests from different locations and habitats.
- 3) To evaluate the effects of high-water levels during 1994-1995 on crocodiles.

Nesting effort and success were determined by searching potential habitat during April and May and recording nest location, adjacent salinity, and nest dimensions. Hatching success was determined by returning to nests and looking for eggshells or hatchling crocodiles and recording nest failure and causes whenever possible. Growth was assessed by mark and recapture studies. All possible hatchling crocodiles are captured, marked and measured for comparison against future growth records. Overall crocodile habitat suitability within Northeastern Florida Bay in the mangrove zone, coastal prairie fringe and, the offshore islands was based on salinity levels. The most suitable habitat for hatchlings was defined as being between 0-10 ppt, intermediate as 11-30 ppt and least suitable as being greater than 30 ppt. Seasonal isohalines were obtained from monthly summaries of water quality data provided by the SFWMD for December 1993, April 1994, July

1994 and December 1994.

5.0 Ecologic Responses in the System

5.1. Vegetation

5.1.1. *Macrophytes* (Jones and Armentano, 1997)

The vegetation data collected along Transects 1, 2, and 3 for the 1995-96 period are summarized in Table 4. Transect 3 is the wettest of the three transects and appears to differ from the other two transects by having the lowest mean number of species in plots (17 compared to 29 in transect 1 and 34 in transect 2) and the highest mean sawgrass (*Cladium jamaicense*) % cover (72% compared to 48.3% in transect 1 and 25.1% in transect 2). These vegetation patterns are reflective of long hydroperiod areas and would be expected at such a site. Transects 1 and 2 show relatively higher mean % cover estimates of *Muhlenbergia filipes* and both long hydroperiod and short hydroperiod prairie species than transect 3. With only baseline vegetation data available for the first year of the test, potential changes in vegetation patterns due to the test are not yet detectable.

5.1.2. *Algal Communities* (Rudnick *et al.*, 1997)

Nutrient sampling in conjunction with algal sampling showed low (<8ug/L) total phosphorus throughout the slough, which increased during the dry season. Analysis of total nitrogen as TKN showed the same pattern as total phosphorus. Currently the results of periphyton biomass, species composition, and other measures of algal productivity are incomplete.

5.2. Fish and Macroinvertebrates

5.2.1. *Freshwater* (Trexler, 1997)

Seasonal patterns of water fluctuations were roughly similar for Shark and Taylor Sloughs with the highest water depth in October and the lowest in April. Site characterizations show that the long hydroperiod areas in Shark River Slough were distinctly different from those in Taylor Slough. The downstream portion of Taylor Slough had less emergent vegetation and lower fish density than the downstream Shark Slough site. These sites were most different in fish and plant productivity.

5.2.2. *Saltwater* (Lorenz *et al.*, 1997)

5.2.2.1. Introduction and Site Characterization

The fish community in the mangrove ecotone is dominated by euryhaline species of the families *Cyprinodontiae*, *Poeciliidae*, and *Cichlidae*. Table 5 lists all species collected and their relative abundances. Study sites showed a range of hydrologic and salinity characteristics which are likely to affect the fish community composition and productivity. Sites can be characterized as long hydroperiod, relatively low salinity (Taylor River), long hydroperiod relatively stable marine salinities (Barnes Sound), highly variable water level and salinity (Highway Creek), and intermediate in all ways (Joe Bay). Highway Creek is primarily characterized by its close correlation of physical parameters with the operation of the C-111 canal. Barnes Sound is primarily affected by the US 1 roadbed which isolates it from natural overland surface water flow. Taylor River has the longest wet

season, highest water level and lowest salinity in January and February. Although there are times when Highway creek had extended periods of low salinity, salinity in this drainage is highly variable and alternates with periods of extremely high salinity (SERP, 1997). Highway Creek had the lowest water levels and the shortest hydroperiod, averaging four months annually of water levels below the flats.

5.2.2.2. Community Composition

The transitional mangrove fish community composition and its relationship to physical variables was examined using de-trended correspondence analysis (DCA). Based on scores, only the first two axes generated by DCA were determined to be important. These axes described various fish communities which were correlated with a variety of variables depending on the axis being examined. The primary factors describing fish community structure were salinity and hydroperiod-hydropattern. The community structure found along the first axis was defined by the number of low salinity days and the length of the longest low salinity period. The primary variable in determining community structure on this axis was the length of time a site experienced low salinity. The community structure on the second axis was correlated with variables which were estimators of depth. This factor was controlled by depth and duration (hydroperiod).

5.2.2.3. Density and Biomass

Taylor River and Barnes Sound had the highest biomass of fish, the highest water levels, and the longest hydroperiod. Highway Creek had the shortest hydroperiod, lowest water levels, and lowest density of fish. All sites except Taylor River, had the highest density of fish during the high water months of September-October, with a sharp decline in January-February. This pattern was shifted in Taylor River and extended, so that high densities of fish were available through January-February and declined in March-April. These data combined with the extended hydroperiod of Taylor River, support the critical relationship between hydroperiod and fish density.

Biomass at each site was related to average salinity. Taylor River had the lowest consistent salinity and the highest biomass. Barnes Sound had the highest salinity and lowest biomass. It appears that biomass may be closely related to prolonged periods of either low or high salinity rather than responding to short term fluctuations. This may be due in part to the locations of the sites, which were upstream sites and thus this habitat niche would be more naturally characterized by upstream freshwater fish. These areas would not be expected to be normally colonized by marine fish. The relationships between biomass and salinity at other sites did not hold for Highway Creek. The relationships at Highway Creek are likely due to wide fluctuations in water levels and salinity. Biomass and density were correlated differently with environmental changes. Biomass was correlated with longer-term environmental changes. Density was correlated with shorter term environmental changes.

Submerged macrophyte abundance varied seasonally at all three sites and was inversely correlated with salinity. Total macrophyte abundance appears to be related to high salinity. Salt-

intolerant vegetation decreased as salinities increased. Salinity tolerant vegetation, such as *Ruppia* increased as salinities increased. Submerged macrophyte abundance decreased at the end of the dry season in May and increased in the mid-wet season, with highest abundance at the end of the wet season. Highway Creek did not exhibit a strong a signal as the Taylor River or Joe Bay sites. This is likely due to its extreme variability in salinity.

5.3. Birds

5.3.1. Wading Birds

5.3.1.1 Water Conservation Areas

The number of nesting wading birds in the Everglades region is broken down by area and shown in Table 6. The geographic distribution for nesting in the 1996 season showed large colonies on the edge of deeper water areas that had immediate access to shorter hydroperiod marshes. This pattern was geographically similar to the high water years of 1993-1995. When the 1996 nesting season was compared to this period, numbers of nesting white ibises were down by 50%, great egrets, little blue herons and cattle egrets were up 150%, Wood storks were up by 150% and Roseate Spoonbills were found nesting in small numbers in the Ally North colony. The proportion of wading birds nesting in the mainland Everglades in the Water Conservation Areas remains high (83%) compared to the proposed restoration goal of moving nesting birds to the coasts to reinitiate the coastal nesting colonies inside Everglades National Park boundaries.

Timing of colonies was slightly earlier than nesting in the past ten years. Nesting was generally successful, with the only large scale abandonments occurring at the Wood Stork Crossover colony, partial abandonment of the Gator Bay Snowy Egret colony, and White Ibises in early April at North colony. The majority of white ibises, however, were believed to have re-nested. Only large scale abandonments (> 50%) were recorded in this work. Total nesting for the WCA's and mainland Everglades National Park is less than 40% of the high nesting years 1992 and 1975. Tricolored herons, Snowy Egrets, and Great Egrets diets were made up primarily of fish except for Snowy Egrets which had about 3% identifiable invertebrate components. Food intake positively influenced weight gain independently of colony location, age, and hatch order. Food intake data provides the basis for information on the levels of food necessary to maintain chicks of specific ages and may not necessarily be strongly related to geographic differences among colonies.

Birds were observed to determine their relationship to various environmental and hydrologic factors (Figure 6) in the WCA 3A and Everglades National Park. All four target birds (great egrets, snowy egrets, white ibises, and wood storks) were observed in the Everglades National Park Site 50 during the period March 26 until June 6 in flocks of between 2 to 377 birds. Two other sites in Everglades National Park contained flocks of Great Egrets and Wood Storks of up to 150 birds. Site 50 in ENP was located in a transition zone during the observation period that was completely dry by June 6. Prey captured at this site were estimated to be less than 2 cm. The other sites in ENP, ENP 6 and ENP 8 had longer hydroperiods and were found to have larger target species feeding there. Longer hydroperiod sites generally produce larger fish (Loftus and Eklund, 1994). The

environmental variables which have influences on wading bird foraging success in wet prairies are water depth, water temperature, wind speed, and vegetation.

5.3.1.1 Everglades National Park

During the 1996 late season surveys (May-August) a total of 2578 wading bird nests were counted in the mainland portion of the Park (Table 7). There were 896 great egret nest identified during the four late-season surveys. Most of these nests were located in the traditional colony sites at Rodger's River Bay, Tamiami West, Grossmans Ridge, and NE Grossman B. During this period 575 Wood Stork nests were identified. These were located in five colonies within the Park boundaries. The largest colonies were found at Paurotis Pon and Tamiami West and contained 1750180 nests each. Cattle Egret nests were counted at 1200 and were located in NE Grossman B, Crossman Ridge, Tamiami West and a new colony site at Madeira Ditches.

5.3.2. *Cape Sable Seaside Sparrows* (Pimm *et al.*, 1996; Curnutt *et al.*, in prep.; Nott *et al.*, in prep; Lockwood and Pimm, 1997; Lockwood *et al.*, in press; Balent *et al.*, in prep.)

5.3.2.1. Introduction

During the period 1992-1995 the total sparrow population decreased by 58%, precipitated by the near extinction of the western Shark River Slough population (Curnutt *et al.*, in prep). Population estimates for the Cape Sable Seaside Sparrow are found in Table 8. During 1996 and 1997 a slight population increase occurred over the 1992-1995 levels (Curnutt *et al.*, in prep). Hydrologic changes in this area may result in both short and long term impacts on sparrow populations (Nott *et al.*, in prep.). Short-term population changes are due to direct impacts of high water on breeding and nesting activity. Long-term population changes due to indirect effects can be a result of vegetation shifts from long hydroperiod *Muhlenbergia* dominated marl prairies to long hydroperiod sawgrass (*Cladium*) prairies. In the study area of Test 7 and Modified Water Deliveries, the sparrow populations have been impacted in the western part of Shark River Slough by direct high water impacts on breeding and nesting activity and in the eastern area by vegetation shifts and fire frequency (Nott *et al.*, in prep; Curnutt *et al.*, in prep).

5.3.2.2. Nesting and Life History (Lockwood *et al.*, in press)

High water can impact sparrow nesting and breeding primarily in two ways. High water can physically flood nests. Nests are generally located an Average of 14 cm above the ground and can therefore be physically impacted by water. Under natural conditions the consistent high water resulting from the onset of the wet season determines the end of the breeding season. Transient flooding events that are of short duration will not necessarily end breeding but were found to increase predation. Information from the vegetation survey was preliminary through 1996. Data collected on vegetation with respect to sparrow occurrence and use during 1997 is currently being analyzed. Birds were banded as a means to look at behavior, survivorship and life history. This information is still being examined, however it has indicated, to date, that sparrows remain in the prairies during the non-breeding season (inter-nesting period).

5.3.2.3. Population Distribution

The Cape Sable sparrow populations in the study area can be divided into six sub populations by region (Figure 7). Two of these sub populations are core populations consistently made up by the largest number of birds. These constantly occupied core areas are located both west and east of Shark River Slough as populations A and B respectively and are critical to the sparrows survival (Curnutt *et al.*, in prep.; Nott *et al.*, in prep.; Pimm *et al.*, 1996). The other four regions are currently considered peripheral and are either intermittently occupied or have been occupied in the past (Curnutt *et al.*, in prep.). Populations C and D have widely fluctuated in numbers but have not included large numbers of birds (Curnutt *et al.*, in prep.). Areas occupied by sub-populations F and E contain few or no birds (Curnutt *et al.*, in prep.). In 1981 Core population A was estimated to have held 2688 individuals while core population B was estimated to have been made up of 2320 individuals. At this time peripheral sub-population E held about 700 individuals, sub populations C and D held about 400 individuals each and sub-population F held about 112. Population estimates for all years are show in Table 6.

Sparrow habitat is adversely affected by unnatural fire frequency. Sparrow numbers were statistically lower at site with dry season fires (Curnutt *et al.*, in prep.). Numbers of individuals were highest in areas with one or two wet season fires over the previous ten year period. Sub-populations in peripheral areas F and C are almost extinct (Pimm *et al.*, 1996). These areas have a very high fire frequency (approximately 1 year) and therefore have a very reduced number of sparrows. The population use in Area C is divided into use above and below the pump station at S-332. The area above the pump station is severely impacted by fire and has had no use by sparrows. Sparrows can be considered to be extirpated due to the increased fire frequency of this area. The area south of the pump station has low use likely due to vegetation type.

The population in Area A has declined between 1992 and 1993 remaining low through the 1997 season (Table 8). This decline is related to high water levels between 1993 and 1995. The decline resulted from two factors; changes in vegetation and elevated water levels during nesting season (Nott *et al.*, in prep.). Shifts in vegetation change areas from mixed muhly-sawgrass prairie to primarily sawgrass in response to longer hydroperiods. Hydrology at NP205 is a good indicator of favorable conditions for sparrows in core area A of western Shark River Slough (Nott *et al.*, in prep.). Above-average water level conditions in the April-May portions of the breeding season are primarily determined by three factors: 1) initial height of the water, 2) rainfall, and 3) flow over the water control structures at Shark Slough, the S-12 structures (Nott *et al.*, in prep.). Statistically the flow over S-12A explains most of the variance in sparrow populations and is the primary factor explaining sparrow decline in the area (Nott *et al.*, in prep.). Given the sparrows breeding range, approximately 34-44 days for one complete nest cycle and 80 days for two complete nest cycles, it is reasonable that at the end of the dry season, the western population should have time to complete at least on successful cycle. Figure 8 show sparrow breeding cycle hydrologic requirements.

5.4. Crocodilians

5.4.1. *Alligators* (Bass, 1997)

In 1995, alligator nests were not evenly distributed over the study area, but instead were found mostly in the central portion of Shark River Slough. Subsequent ground checks were conducted on a representative sample (53%) of the surveyed nests. The overall nesting estimate for the study area was 473 nests with nest success estimated at 60 percent in 1995. Only 4 % of the total estimated number of nests were located in Taylor Slough (n=20), 4% were located in East Slough (n=20), and 3% were located in Northeast Shark Slough (n=13). Most alligator nesting still occurs in Shark River Slough--an area that retains higher surface water levels throughout the nesting season. Eighty-nine percent (n=420) of the nests were found within this region.

Nest flooding was the major source of egg mortality (24%). Other sources of mortality included crushing (8%), infertility (6%), and predation (2%). Although nest flooding substantially lowered possible hatchling recruitment, the estimated production of individual hatchlings was still quite high (n=7904).

5.4.2. *American Crocodile* (Mazzotti, 1997)

Results from crocodile surveys are not available for the current period of Test 7, however background data are available for the modified water delivery period of Test 6. This background data indicates, based on a salinity model developed by Mazzotti and Brandt (1995), several possibilities as follows:

- 1) Increased freshwater and resultant lower salinity in northeastern Florida Bay increases the amount and suitability of crocodile habitat;
- 2) Water flow directed through Taylor Slough can potentially provide increased habitat area and improved habitat quality;
- 3) Under current conditions most suitable crocodile habitat occurs closer to the C-111 drainage area than to Taylor Slough.

The factors affecting nesting success during these 2 years are difficult to determine. To begin to understand the nesting information, nesting effort must also be monitored. A summary of 1994-1995 nest success for the American crocodile in the Test 7 study area is found in Table 9.

6.0. Evaluation and Ecologic Responses: Summary and Conclusions

This section is based on the committee members and researchers' assessment that one year of sampling under Test 7 is too short a timeframe to be able to make conclusions and recommendations. Detailed summaries are included for research which has been ongoing for periods of time prior to the initiation of Test Iteration 7. Most projects were started for Test Iteration 7 and so have not been active long enough to have adequate data upon which to base an assessment and draw conclusions. It is also very important to assess all research results in the context of previous work and other background material when possible.

Where adequate data have been available summaries and conclusions have been drawn. When further information is necessary to make an assessment this is noted. Detailed descriptions and summaries are available from the referenced reports. All projects listed as essential under the December 15, 1995 Memorandum of Understanding (MOU), signed as part of the Concurrence with Test 7 Monitoring Plan, have been implemented.

6.1. Vegetation and Periphyton Communities

6.1.1 *Macrophytes*

Although vegetation changes are potentially great, linking them directly to the Test 7 manipulations will be difficult, considering the long history of water management actions in and around Taylor Slough. Standard statistical analyses will be carried out to provide a thorough characterization of this data and vegetation baseline conditions.

6.1.2 *Algal Communities*

Analysis of algal community samples collected under the first year of this program have not been completed. Conclusions recommendations and assumptions can only be made after sample analysis and data compilation are complete.

6.2 Fish and Macroinvertebrates

6.2.1 *Freshwater Communities*

Analysis of freshwater fish and aquatic macroinvertebrate samples collected under the first year of this program have not been completed. Conclusions recommendations and assumptions can only be made after sample analysis and data compilation are complete.

6.2.2 *Saltwater Communities*

Salinity and hydroperiod were primary and secondary forces, respectively, in structuring the mangrove fish community in the study area. Long term (180 days) salinity condition was inversely related to prey base fish biomass (i.e., high salinity over the long term was related to lower fish biomass). Since salinity was lower in the mangroves during the first year of Test 7, the above conclusions indicate that fish biomass was higher during the first year of Test 7 than in previous years of study. An analysis of the fish community also indicated a shift in species composition, with the mangrove community becoming more similar to freshwater Everglades fish communities during

the first year of Test 7. Although these changes may be, in part, attributable to Test 7 operational standards, the principal investigator primarily attributed the changes in mangrove salinity and fish community dynamics to the extreme natural conditions that coincided with the first year of Test 7. Record high rainfalls over southern Florida between November 1994 and November 1995 resulted in favorable dry season (December 1995-June 1996) conditions and extremely wet season conditions in the mangroves during the first year of Test 7, thus better explaining the above findings.

6.3 Birds

6.3.1 Wading Birds

6.3.1.1 Water Conservation Areas

This project was intended to monitor reproductive responses of wading birds with respect to nestling energetics and factors affecting food availability. Totals for the wading bird nesting in this sampling year are less than 40% of that of the high years 1992 and 1975 and were not exceptional in the context of the past ten years. This year was a high water year following two high water years. Most compartments showed stages well above normal for average nesting years. Early and late nesting season water recession rate were some of the fastest on record for WCA 3. Nesting response was unexceptional with increases in cattle egrets, great egrets, wood storks, and little blue herons and decreases in white ibises by comparison with the period 1986-1989.

The period 1993-1996 delivered considerably more water to the coastal regions of the estuarine everglades. When reviewed in context of the hypothesis that rewatering the coastal zone will restore nesting habitat there were little obvious changes. Although wood storks have increased slightly in the coastal regions of ENP there is no obvious increase in nesting and no evidence of a geographical shift of nesting from inland locations towards the coast. There is however considerable uncertainty as to timing of this with respect to rewatering coastal areas.

Results of nestling energetics on 39 snowy egret and little blue heron nestlings for 5-22d of age in three colonies showed a significant positive effect of food amount on chick mass. These results imply that food amount consumed has a strong residual effect upon chick mass even when the effects of species, hatch order colony and age have been controlled for. Analyses of environmental and biotic variables affecting wading bird foraging success are incomplete at the end of the 1996 sample year. Some preliminary analyses indicate species specific, significant negative relationships between foraging success and water depth, water temperature and vegetation density for most species. No significant relationships were detected between foraging success and sun angle, time of day, soil type, soil color, and air temperature.

6.3.1.2 Everglades National Park

There were no conclusions reached with respect to wading birds inside the Everglades National Park in response to Test 7.

6.3.2 Cape Sable Seaside Sparrow

Cape Sable seaside sparrows are habitat specialists; they depend on short-hydroperiod marl prairies to support their breeding activities. Under natural, undisturbed conditions they have a relatively high breeding potential. In an undisturbed system, short-hydroperiod marl prairies are inundated, on average, from 3 to 7 months per year. In South Florida, 25 percent of the marl prairies have been lost to agricultural and urban land uses and are no longer suitable for use by the sparrows. Remaining marl prairies occur in Everglades National Park, Big Cypress National Preserve, and the Everglades Wildlife Management Area; 25 percent of these marl prairies are unavailable to sparrows because of water management practices and changes in habitat as a result of water management practices.

Water management practices in South Florida have led to artificial conditions within the marl prairies of Everglades National Park and Big Cypress National Preserve that are either too wet or too dry to support Cape Sable seaside sparrows. Cape Sable seaside sparrows would benefit from water management operations that redistribute water flows across the full area of historic Shark River Slough. These operations would result in reduced hydroperiods on the west side of the slough and increased hydroperiods on the east side of the slough, and would create habitat conditions more like those of the unaltered system, benefiting all fish and wildlife that depend on marl prairies.

Sparrow populations are currently comprised of two primary core populations found in marl prairies on the periphery of Shark River Slough (in Areas A&B) and four remaining smaller populations throughout the rest of Everglades National Park (in Areas C,D,E,& F), which are temporally unstable (Figure 8). The two core populations, A and B, account for the majority of the total population and are critical to the species survival. These populations are vulnerable to a number of different factors; hydrology, fire, and catastrophic meteorological events. Population A is primarily vulnerable to the effects of water management with the number of high water days in breeding habitat negatively impacting breeding success. This population has experienced a severe decline since 1992, due to water management at the S-12 structures, and remains low. The population in Area B, which represents approximately 75% of the total remaining population, is especially vulnerable to fire. Currently this population appears healthy and stable.

April and May are the critical breeding season for the sparrow, and water levels during this time must be under specific control. Breeding season can normally last from March through June (Lockwood *et al.*, in press). Results of the research on the sparrow have linked high water levels in western Shark River Slough to the decline of subpopulation A; large quantities of rainfall, in combination with regulatory releases of flood waters into Everglades National Park in 1993, added over 20 cm depth of water to the area and resulted in a decline of subpopulation A by 83 percent between 1992 and 1993. Since 1993, and for several consecutive years, the managed distribution of water into ENP has flooded nearly half of the sparrow's range within Everglades National Park (ENP) and Big Cypress National Preserve during the breeding season. It is therefore critical that a maximum proportion of this area remain dry during the entire period of the breeding season. Strict control of water deliveries at the S-12 structures during the breeding season is critical to accomplish

this. The long term survival of the species is dependant on a healthy abundant population of sparrows west of Shark River Slough.

In summary, the presence of surface water limits breeding activity in sparrows. Under undisturbed natural conditions sparrows have a naturally high breeding potential, which is principally limited by the extent of the breeding habitat that is affected by the amplitude and variability in breeding season water levels (Nott *et al.*, in prep.). Preliminary results from the CSSS component of ATLSS (Across Trophic Level System Simulation) models suggest that population levels west of Shark River Slough are predictable given and specific hydrologic scenarios (Nott, personal communication). The CSSS component of ATLSS provides an important quantitative tool with which to evaluate proposed water management changes and help ensure effective hydrologic management for the survival of this species.

Actions benefitting this species include removing L-67e to move water to the east, into the East Everglades Park expansion area. Extended periods without inundation also adversely affect marl prairies and lead to conditions that are not suitable for use by sparrows. In Everglades National Park, northeast Shark River Slough has been overdrained and has resulted in the invasion of woody vegetation; Cape Sable seaside sparrows will not use prairies that support vegetation. The addition of water into the expansion area would reduce the possibility of flooding the western prairies during sparrow breeding season and benefit the peripheral populations by maintaining suitable breeding habitat and potentially decreasing fire frequency to the east. Healthy populations in this area also decrease the likelihood of a catastrophic event negatively affecting both populations simultaneously.

6.4 Crocodilians

6.4.1 Alligators

This program should continue to monitor nesting success. In addition to monitoring nesting success a more sensitive short term measure of the success of the program would be growth and survival of alligator hatchling cohorts.

6.4.2 American Crocodile

Monitoring should continue for nesting in the downstream area of the Test 7 program. Although monitoring nesting success is useful as a general indicator of the health of a crocodile population, a more sensitive short term measure of the success of the program would be growth and survival of crocodile hatchling cohorts. This would be a more sensitive measure of the movement of freshwater and decreased in salinity in the Test 7 area and would more quickly reflect changes prior to catastrophic events. Decreases of salinity in the area of the Test 7 program should not come at the expense of other areas.

7.0. Assessment and Recommendations**7.1. Assessment and Recommendations for Ecologic Monitoring under the Memorandum of Understanding****7.1.1 Research and Monitoring**

- 1) Summarize past and present work as a means to describe background ecological conditions. Include work from Metro Dade County Department of Environmental Resources Management (DERM), Florida Game and Fresh Water Fish Commission (FGFWFC), the South Florida Water Management District (SFWMD), Florida Department of Environmental Protection (FDEP), USGS, or university programs such as Florida International University - Southeast Environmental Research Program (FIU-SERP), University of Miami or Florida Atlantic University (FAU). Create a bibliography to serve as background material for a general ecological review. Information not specifically funded under the Test Iteration 7 program but generated in the area of interest should be included as part of the report review.
- 2) Review and evaluate the components of the system expected to be affected by hydrologic changes of the Modified Water Delivery Program, if these are different from the existing list develop a new list of projects and subject areas of interest.
- 3) Review sampling designs of existing ecologic projects and how these projects are interconnected. Evaluate sampling designs with respect to modeling and monitoring uses for this information.
- 4) Evaluate the hydrologic sampling and the resulting hydrologic report to make recommendations on how this work can be better integrated with the ecologic sampling and analysis.
- 5) Analyze data and other ecological information for periods prior to the test for comparison to data from the current Test Iteration 7 to begin to understand the changes when compared to historical data.

eg. Although the importance of wading bird SRF surveys as a monitoring element of Test 7 was considered to be moderate, the analysis and report completion of the existing 10 year data set for ENP was given the highest priority in this category. A progress report on this data should be included. The completion of this data analysis and report is crucial to understanding wading bird foraging dynamics in the Everglades system as a whole.
- 6) Determine and monitor the relationship between salinity and both primary and secondary productivity.

- 7) Restart the investigation of mangrove creek habitat utilization by upper trophic level fish species.
- 8) Monitoring should include growth and survival of hatchling cohorts for both alligators and American crocodiles.
- 9) Consider better integration of hydrological, ecological and water quality sampling efforts including:
 - a) co-location of sites;
 - b) coordinated sampling schedules; and
 - c) modifications of sampling techniques to include additional parameters that would benefit other groups.
- 10) The monitoring of wading bird colonies in Shark River Slough and Taylor Slough were considered to be essential elements. However, Table 6 reflects a lack of data for nesting of dark-plumaged species within ENP in comparison to the WCAs and Loxahatchee NOR. This indicates that aerial surveys alone in ENP are probably failing to detect the nesting of dark-plumaged herons. Ground surveys should be implemented within ENP in order to determine any effects that Test 7 may be having on these more cryptic components of the wading bird community.

7.2 Assessment and Recommendations beyond the existing Memorandum of Understanding

7.2.1 Research and Monitoring

- 1) Renew comprehensive monitoring of Roseate spoonbills as an indicator of Florida Bay and mangrove ecotone health.
 - a. Develop an ecological model of the interaction between Roseate spoonbills and the prey base fishes in mangrove the ecotone.
- 2) Physically survey the mangrove ecotone to provide a base of information for extending hydrology models into Florida Bay.
- 3) For Table 7, Cape Sable seaside sparrow population estimates by study area, subpopulation D is also regularly censused by FGFWFC personnel which should be included in this report as well. For instance, FGFWFC data for the year 1994 had an estimate of 32 sparrows, whereas the table indicates that no data was collected for that year. The area of coverage by ENP for this subpopulation (D) should be compared to the area surveyed by FGFWFC in the Southern Glades Wildlife and Environmental Area to determine the difference in area coverage, if any, that exists between the two efforts. Incorporate FGFWFC Cape Sable seaside sparrow (CSSS) sampling into the overall CSSS sampling strategy.

- 4) Initiate water quality sampling to document the effects of changes in marsh hydrology on marsh chemistry.
 - a) Initiate sampling designed to develop an understanding of nutrient budgets, including measurement of standing stocks of nutrients by structural compartment (plants, periphyton, and soils).
 - b) Initiate soil studies in the Taylor Slough area to document changes which may be due to altered inflows.
 - c) Review pesticide and anthropogenic chemical sampling in the downstream receiving areas for the inflow points with respect to the general screening for these compounds outside of the Park. Suggest additional water and sediment sampling if warranted and include possible organismal sampling
- 5) Re-initiate monitoring of hydroperiod changes in the vegetation of the C-111 basin as previously funded by the SFWMD to describe additional hydroperiod patterns and other seasonal patterns.

7.2.2 Structural and Operational

- 1) Restore the hydrologic integrity of Taylor Slough by raising canal stages in the South Dade Conveyance System (SDCS).
- 2) Redistribute and supplement flow through the C-111 gaps.
- 3) Establish fresh water flow to the "Triangle Lands" between U.S. Highway 1 and Card Sound Road.
- 4) Reconfigure the Modified Water Deliveries Project to reconstruct historical flow pathways routing flood flows from Water Conservation Area 3A to 3B and northeast Shark Slough.

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TABLE 1. Specific Projects Designed by The Inter-agency Committee.

Rating	Monitoring Element	Comments	Basins	Responsible Agency
Essential	Fish and macroinvertebrates	Sensitivity is high; Marginal applicability to the Section 7 consultation; Importance to baseline is high; Modeling needs relative to ATLSS.	Taylor FL Bay SRS	Corps NPS
Essential	Plant communities	Sensitivity is high; Some applicability to the Section 7 consultation on sparrow habitat; High value for establishing a baseline in Taylor Slough; Modeling needs high relative to ELM.	SRS Taylor	NPS
Essential	Periphyton	Sensitivity is high; No direct applicability to the Section 7 consultation; Would be establishing a baseline; Modeling applicability is high.	Taylor	SFWM
Moderate	SRF wading bird surveys	The applicability of these surveys to a monitoring program for Test 7 is uncertain; priority will be placed on the existing data set from 10 years of SRF surveys; new wading bird SRFs can not be recommended for monitoring Test 7.	SRS Taylor WCAs C-111	NBS-complete report from existing data set; NPS, FWS, and Corps will support analysis and write-up if NBS is unable to complete
Essential	Wading Bird Colonies	Ecological sensitivity is thought to be high; close connection to Section 7 consultation (see wood stork); continuation of the Everglades baseline is important; modeling needs marginal.	SRS Taylor	NPS Corps

TABLE 1. Specific Projects Designed by The Inter-agency Committee. (Continued)

Rating	Monitoring Elements	Comments	Basins	Responsible Agency
Essential	Alligator nesting surveys	Sensitivity of alligators to Test 7 monitoring is potentially high; it has no applicability to the Section 7 consultation; it is fairly important for future baselines and is the subject of ATLSS modeling.	Taylor	NPS
Essential	Cape Sable seaside sparrow	Sensitivity is moderate; it is central to the biological opinion; development of a baseline is important; data will be useful to ATLSS modeling but may require additional funding.	Taylor SRS C-111	Corps FWS NPS
Essential	Wood Stork	Sensitivity of wood storks to Test 7 may be high; important for Section 7; the importance of nesting data to the baseline for future management action is relatively high; data would be collected as part of a larger effort to evaluate wading bird colonies.	Taylor SRS	See wading bird colonies and SRFs
Essential	American crocodile	Ecological sensitivity may be high depending on salinity tolerance; high relevance to Section 7 consultation; low need to develop a baseline; does not directly benefit model development.	Taylor FL Bay	FWS, NPS, and Corps will investigate continuing surveys.
Moderate	Florida panther	Sensitivity low; Do not recommend including separate studies to assess the effects of Test 7; abundance too low for baseline; is subject of ATLSS model.	SRS Taylor	None
Moderate	Snail kite	Sensitivity moderate; studies to assess the effects of Test 7 not recommended.	SRS WCAs	None

Table 2. Projects Included Under Ecological Monitoring for Test Iteration 7: Experimental Program of Water Deliveries to Everglades National Park

- Balent*, K. L., J. L. Lockwood and K. H. Fenn. in prep. Wet-Season Distribution and Behavior of the Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*). *Dept. Biological Sciences, SUNY College at Brockport, 350 New Campus Drive. Brockport, N.Y. 14420.
- Curnutt, J. L., A. L. Mayer, T. M. Brooks, L. Manne, O. L. Bass, Jr, D. M. Flemming, and S. L. Pimm*. in prep. Population Dynamics of the Endangered Cape Sable Seaside Sparrow. *Department of Ecology and Evolutionary Biology, Univ. of Tenn., Knoxville, TN 37996-1610.
- Frederick, P.C., J. Salatas, and J. Surdick. 1996. Monitoring and Research on Wading Birds in the Water Conservation Areas of the Everglades: the 1996 Nesting Season. Dept. of Wildlife Ecology and Conservation P.O. Box 110430 University of Florida, Gainesville Florida 32611-0430 Final Annual Report for the U.S. Army Corps of Engineers, Jacksonville Florida November 30, 1996.
- Jones, D. and T. Armentano. 1997. Temporal and Spatial Patterns in Taylor Slough Marsh Vegetation in Relation to Test Iteration 7. First Year Report on the Experimental Evaluation of Test Iteration 7 of the Experimental Program of Water Deliveries to Everglades National Park. South Florida Natural Resource Center, Everglades National Park, 40001 S.R. 9336, Homestead Florida 33034.
- Lockwood, J. L., K. H. Fenn, J. L. Curnutt, D. Rosendthal, K. L. Balent, and A. L. Mayor. 1997. Life history of the endangered Cape Sable Seaside Sparrow. The Wilson Bulletin 109(4)
- Lorenz, J. J., C. Faunce, and D. M. Morrison. 1997. The Effects of Hydrology on Resident Fishes of the Everglades Mangrove Zone. Final Report to South Florida Natural Resources Center- Everglades National Park. Homestead Florida. by National Audubon Society, 115 Indian Mound Trail, Tavernier Fl. 110 pp.
- Mazzotti, F.J. 1997. A Report on the Monitoring Program for the Endangered Crocodile in Everglades National Park. A report to the South Florida Natural Resources Center- Everglades National Park by the Department of Wildlife Ecology and Conservation, University of Florida
- Nott, M. P., O. L. Bass, D. M. Flemming, and S. L. Pimm. in prep. Hydrologic regimes rapidly change the vegetational patterns for an endangered bird. Dept. Ecology and Evolutionary Biology, University of Tennessee, Knoxville, Tenn. 37996.
- Pimm, S. L., K. L. Balent, T. Brooks, J. Curnett, T. Fenn, N. Fraley, S. Killeffer, J. Lockwood, L. Manne, A. Mayer, M. P. Nott, G. Russell, and E. Stanton. 1996. Annual Report 1996. Population Ecology of the Cape Sable Sparrow (*Ammodramus maritima mirabilis*) to the South Florida Natural Resources Center, Everglades National Park.
- Rudnick, D., P. McCormick and M. O'Dell. 1997. Periphyton monitoring for ENP Experimental Water Deliveries Program Test 7: First Annual Report. April 25, 1997. ESRD-ERD, South Florida Water Management District P.O. Box 24680 West Palm Beach, Florida 33416.
- Trexler, J. 1997. Fish and Aquatic Macroinvertebrate Monitoring Studies in Taylor Slough. First Annual Report to the South Florida Natural Resources Center and Everglades National Park (ENP), for Cooperative Agreement CA05280-6-9011. between ENP and Florida International. Univ., Miami FL April 1, 1997.

Table 3: Statement by Gary Hendrix, Ph.D. Research Director South Florida Research Center Everglades National Park on Thursday March 10, 1983 before the Board of the South Florida Water Management District.

Seven Point Plan

1. Fill in L-28 canal and remove substantial segments of the levee. L-28 canal is over-draining the eastern Big Cypress during the dry season and the levee prevents high water from moving into Big Cypress as it traditionally did. Removal of the levee will provide some flood relief to Everglades National Park and restore high water flow through several historical drainages.
2. Fill in L-67 extended canal and completely remove its levee. Water deliveries to the Park through this canal at times cause abnormal flooding of the Park during the dry season and the levee prevents the historic hydrological connection with deeper water areas of Northeast Shark Slough.
3. Restore Water Conservation Area 3-B to the Everglades system. Species finally, divert as much flood waters as are environmentally acceptable into WCA-3B. [Sic]
4. Distribute water deliveries from Water Conservation Area 3A along the full length of the Tamiami Canal from L-28 to L-30. Northeast Shark Slough contains the center of the drainage to Everglades National Park and the prevention of flow through the upper reaches of this drainage has severely stressed the park.
5. Establish whatever rigorous water quality monitoring program necessary to provide an early alert to degradation of delivery waters to Everglades National Park.
6. Defer any implementation of new drainage districts, such as that proposed in the East Everglades, until the full impact of any potential flood discharges to Everglades National Park are thoroughly thought out and all possible mitigations to the Park are considered.
7. Starting as soon as possible, field test a new delivery schedule to Everglades National Park. The delivery schedule will be based upon a reference station in the Big Cypress that predicts what the Shark Slough should be receiving based upon current rainfall and normal runoff, not upon upstream water management. Any quantities above that predicted will be considered "flood discharges" and all efforts should be made to divert those excess waters. We feel this method of determining what to deliver to the Park is the best current solution. The present delivery schedule is not working and must be replaced immediately for the health of the park.

Table 4: Results of Freshwater Vegetation Survey (Jones and Armentano, 1997).

	Transect 1	Transect 2	Transect 3
Mean no. Species in plots	29.0	34.0	17.0
Of Total Species:			
Graminoid	10.0 (34.5%)	13.0 (38.0%)	6.5 (38.0%)
Herbaceous	19.0 (65.5%)	21.0 (62.0%)	10.5 (62.0%)
Mean total plant cover in plots	39.1%	48.0%	55.5%
Of total plant cover:			
Graminoid	84.8%	79.2%	90.2%
Herbaceous	15.2%	20.8%	9.8%
or			
<i>Cladium</i>	48.3%	25.1%	72.0%
<i>Muhlenbergia</i>	9.7%	12.8%	7.8%
<i>Eleocharis</i>	9.7%	18.6%	8.8%
Aquatics	.1%	7.6%	2.7%
Long Hydroperiod	21.0%	17.0%	2.6%
Short Hydroperiod	5.7%	16.7%	3.6%
Mean no. of species with 1% plant cover or more	7	8	3
Mean no. of species/m ²	5	8	5
Mean no. of species/5m ²	16		6

Table 5: Transitional Mangrove Fish Communities

Family	Genus species	Common Name	TR %	JB %	HC %	BS %	Tot %
Ictaluridae							
	<u>Ameiurus natalis</u> (Lesueur)	yellow bullhead		0.01			<0.01
Clariidae							
	<u>Clarius batrachus</u> (Linnaeus) (E)	walking catfish		0.01	0.03		0.02
Batrachoididae							
	<u>Opsanus beta</u> (Goode and Bean) (J)	gulf toadfish		0.03	0.02	0.41	0.08
Atherinidae							
	<u>Menidia peninsulae</u> (Goode and Bean)	tidewater silverside	0.93	2.93	0.94	8.58	2.90
Belontiidae							
	<u>Strongylura notata</u> (Poey)	redfin needlefish	0.06	0.08	0.05	0.13	0.07
Cyprinodontidae							
	<u>Adenia xenica</u> (Jordan and Gilbert)	diamond killifish		0.21	1.32	0.03	0.52
	<u>Cyprinodon variegatus</u> Lacépède	sheepshead minnow	3.76	20.61	35.27	11.21	20.70
	<u>Floridichthys carpio</u> (Gunther)	goldspotted killifish	2.14	3.14	13.01	22.25	8.88
	<u>Fundulus chrysotus</u> (Gunther)	golden topminnow		0.01			<0.01
	<u>E. confluentus</u> Goode and Bean	marsh killifish	0.12	2.48	4.93	0.03	2.43
	<u>E. grandis</u> Baird and Girard	gulf killifish	0.30	4.36	12.54	2.69	5.85
	<u>E. similis</u> (Baird and Girard)	longnose killifish	0.12	0.43	1.32	1.55	0.82
	<u>Jordanella floridae</u> Goode and Bean	Florida flagfish		0.01			<0.01
	<u>Lucania parva</u> (Baird and Girard)	rainwater killifish	32.36	28.98	12.49	13.74	22.28
Poeciliidae							
	<u>Belonesox belizanus</u> Kner (E)	pike killifish	0.18	0.35	0.07	0.03	0.19
	<u>Gambusia holbrooki</u> Girard	mosquitofish		1.72	0.39	0.60	0.87
	<u>Poecilia latipinna</u> (Lesueur)	sailfin molly	8.00	13.17	12.09	12.60	11.91
Syngnathidae							
	<u>Syngnathus louisianae</u> Gunther	chain pipefish				0.16	0.03
Gerreidae							
	<u>Eucinostomus</u> sp	mojarra	0.03	0.08	0.03	5.79	0.95
Gobiidae							
	<u>Lophogobius cyprinoides</u> (Pallas)	crested goby	4.27	0.01			0.71
	<u>Microgobius gulosus</u> (Girard)	clown goby	16.03	2.40	0.47	20.07	6.84
Centrarchidae							
	<u>Lepomis</u> spp. (J)	sunfish species	1.56	0.83	0.02		0.58
Cichlidae							
	<u>Cichlasoma bimaculatum</u> (Linnaeus) (E)	black acara		0.01			<0.01
	<u>C. urophthalmus</u> (Gunther) (E)	Mayan cichlid	29.83	17.99	4.84		13.24
	<u>Tilapia mariae</u> (Boulenger) (E)	spotted tilapia	0.30	0.14			0.11
Soleidae							
	<u>Trinectes maculatus</u> (Bloch and Schneider)	hogchoker		0.03		0.09	0.03
TOTAL NUMBER FISH COLLECTED			3325	7744	5965	3159	
20193							
NUMBER OF NETS SAMPLED			99	183	172	94	548
NUMBER OF DATES SAMPLED			13	25	25	11	74

Table 6: Nesting Pairs of Wading Birds in the Everglades Region During Spring and Early Summer 1996 (after Frederick *et al.*, 1996) (data included from 1996 late season nesting report by SFWMD, West Palm Beach, Fl)

	Loxahatchee NWR (WCA 1)	WCA's 2 & 3	Everglades National Park (mainland)	Florida Bay	Big Cypress National Preserve	Total Nesting Pairs
Great Egret	814	2,686	896	333	400	5,129
Snowy Egret	26	554	100			680
White Ibis	807	1013	5	315	1,250	3,390
Wood Stork	0	225	395			620
Great Blue Heron	117	253		573		943
Anhinga		989				989
Little Blue Heron	1,372	678				2,050
Tricolored Heron	197	749		102		1,048
Double Crested Cormorant	0	8				8
Black Crowned Night Heron	30	22				52
Glossy Ibis	0	19				19
Cattle Egret	2,253	100	1,200			3,553
Roseate Spoonbill	0	15		80		95
Totals*	3,363	6,214	1,396	1,403	1,650	14,026

Table 7 Late Season Active Wading Birds Nests 1996 in Everglades National Park

Colony Name	Location Latitude	Longitude	Species GE	WI	WS	SE	CE	BCNH	TCH	TOTAL
Lane River	251802	805318	0	0	0	0	0	0	0	0
Rodger's River	253340	810419	100	0	150	100	0	0	0	350
Cuthbert Lake	251256	804650	30	0	0	0	0	0	0	30
Madeira	251310	803964	0	0	0	0	0	0	0	0
East River	251614	805206	35	0	0	0	0	0	0	35
Paurotis Pond	251689	804818	60	0	175	0	0	0	0	235
Preserve Pond	254051	805587	40	0	0	0	0	0	0	40
East Slough	253632	805024	35	0	0	0	0	0	0	35
West of Obs. To	253948	804796	60	0	0	0	0	0	0	60
Colony 'A' Nort	253825	804338	8	0	0	0	0	0	0	8
Colony 'A' Sout	253825	804338	13	0	0	0	0	0	0	13
Pond Apple Hamm	254420	804410	35	0	0	0	0	0	0	35
N. of 10 Mile C	254067	804929	25	0	0	0	0	0	0	25
Colony 'B'	253747	803862	6	0	0	0	0	0	0	6
NE Grossman A	253881	803655	4	0	0	0	0	0	0	4
NE Grossman B	254110	803450	100	0	0	0	600	0	0	700
Grossman Ridge	253768	803874	100	0	0	0	300	0	0	400
Tamiami West	254547	803269	175	5	180	0	100	0	0	460
Tamiami East	254548	803047	70	0	0	0	0	0	0	70
NE Shark Slough	254067	803434	0	0	0	0	0	0	0	0
S. BICY Woodsto	254627	810973	0	0	70	0	0	0	0	70
Madeira Ditches	251939	803874	0	0	0	0	200	0	0	200
Species Total			896	5	575	100	1200	0	0	2776

Table 8: Cape Sable Seaside Sparrow Population Estimates by Study Area*

Site	Year					
	1981	1992	1993	1994	1995	1996
Area A	2688	2608	432	(80)**	224	416
Area B	2320	2992	2416	2176	2048	2048
Area C	432	48	0	ND	0	48
Area D	400	112	96	ND	0	80
Area E	672	592	320	112	352	192
Area F	112	NS	0	ND	0	16

* based on number of observed birds and correction factor of 16, after Mayor *et al.*, in prep.

NS = not surveyed

ND = no data

** = reflects only 25% of Area A surveyed in 1994 the same site held 80 sparrows in 1993

Table 9: Summary of 1994 and 1995 nesting seasons of American Crocodiles Test 7 Study Area

Year	Successful Nests	Failed Nests	Depredated Nests	Flooded Nests	Total Nests
1994	14 (70%)	2 (10%)	4 (20%)	0 (0%)	20
1995	10 (43%)	2 (10%)	7 (30%)	4 (17%)	23

Everglades National Park

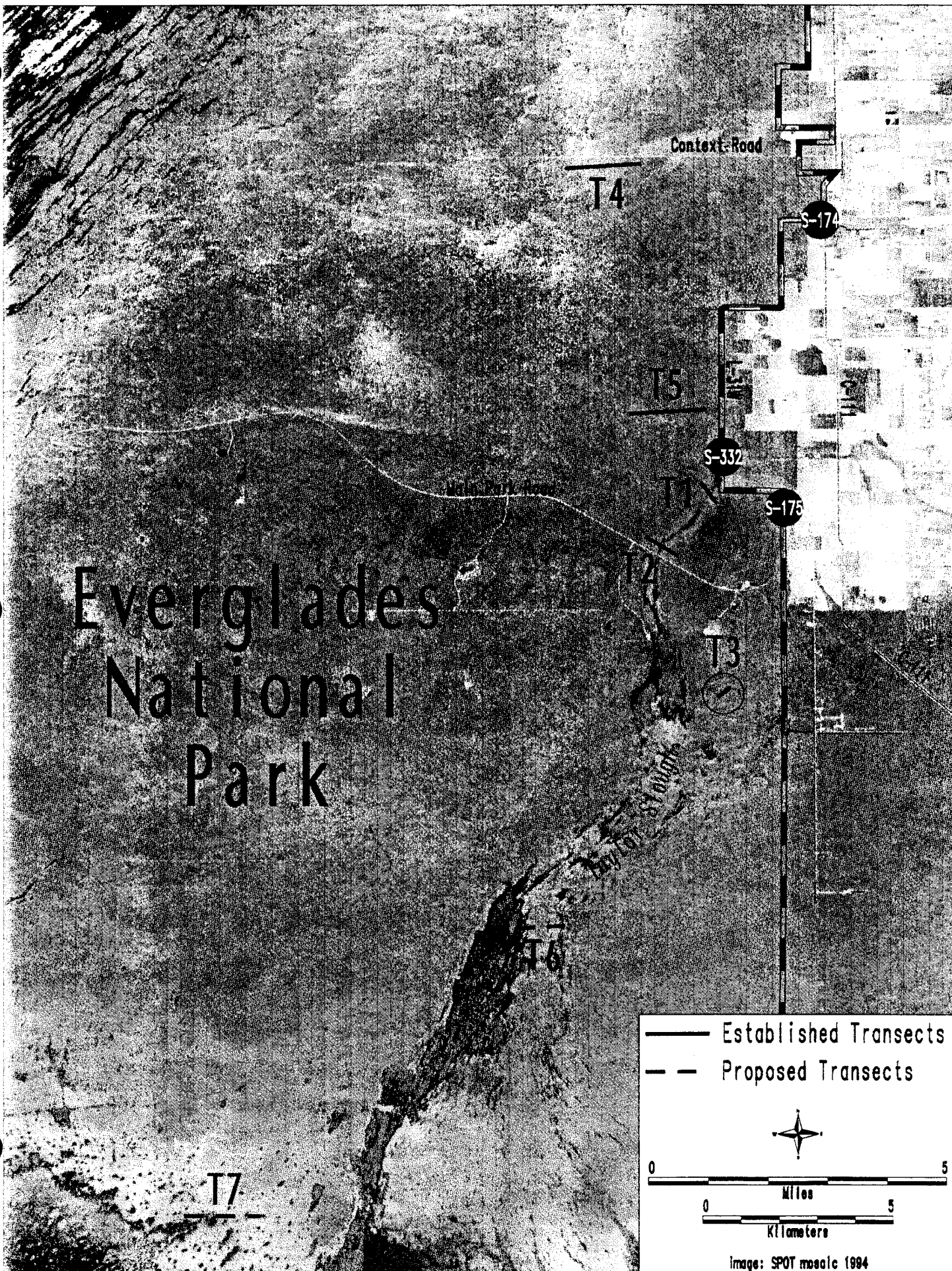


Figure 2. Taylor Slough Vegetation Sampling Plots

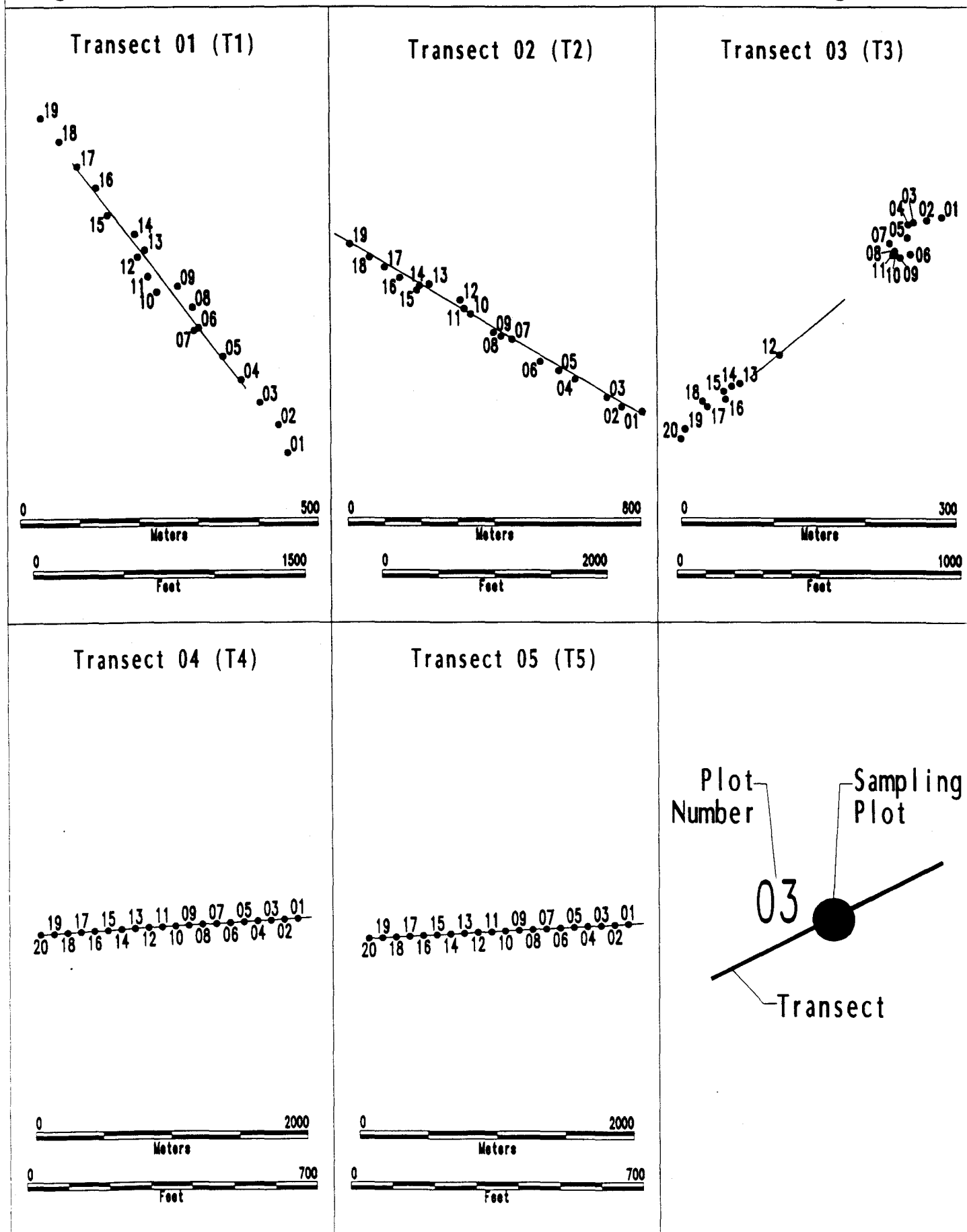


FIGURE 3. Location of Periphyton Sampling Plots across Taylor Slough.

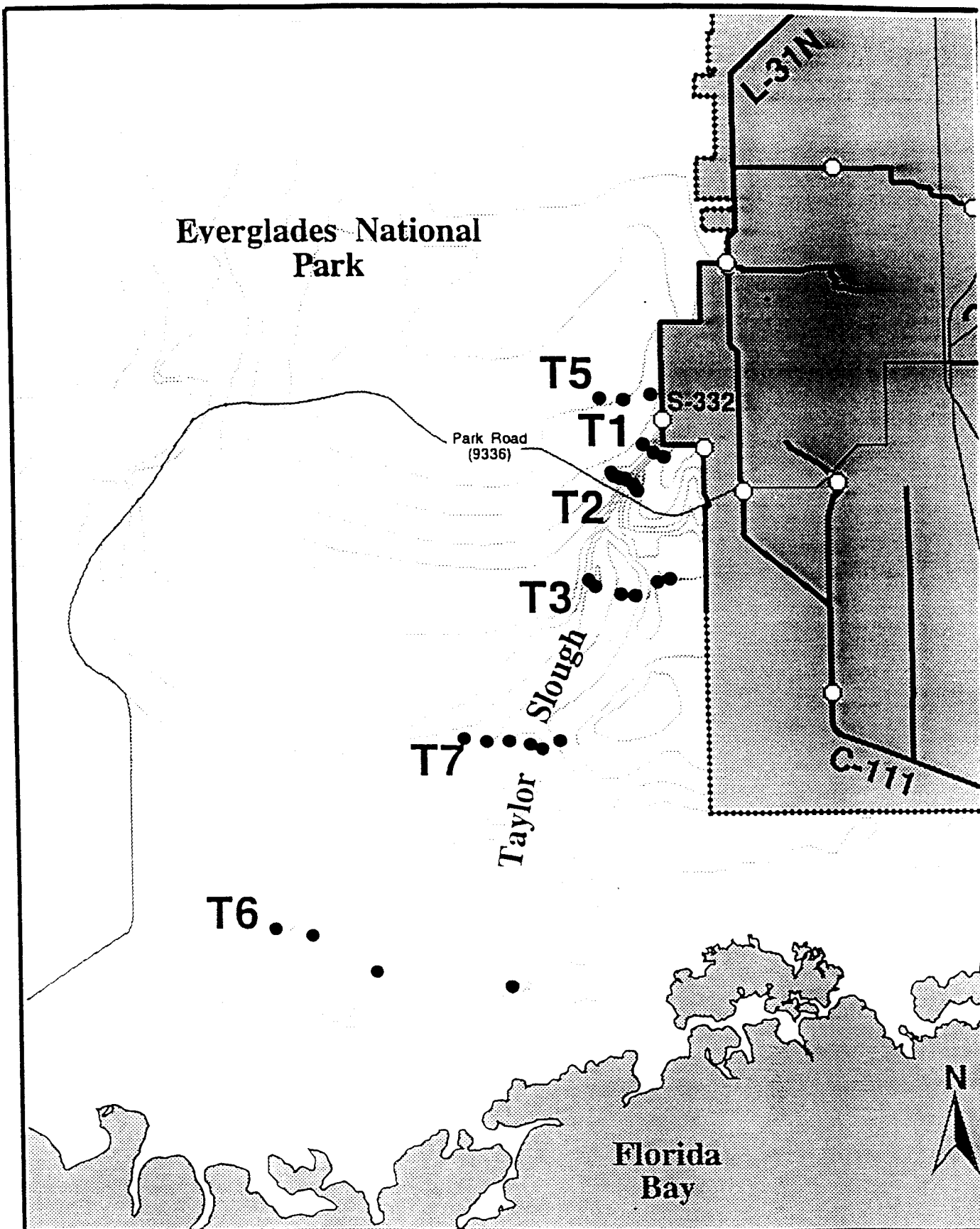


FIGURE 4. Map Showing Freshwater Fish Sampling Locations.

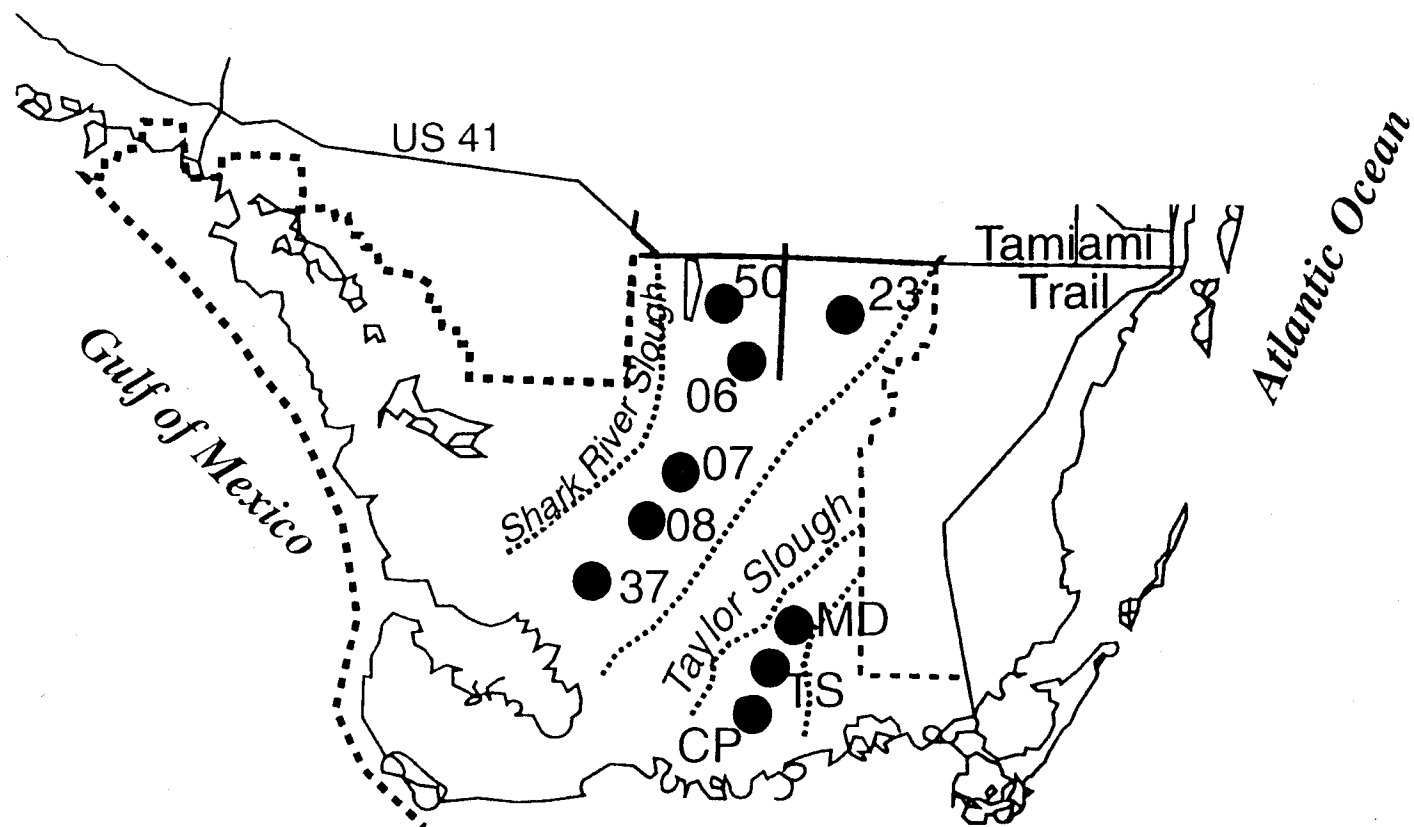


FIGURE 5. Map Showing Saltwater Fish Sampling Locations.

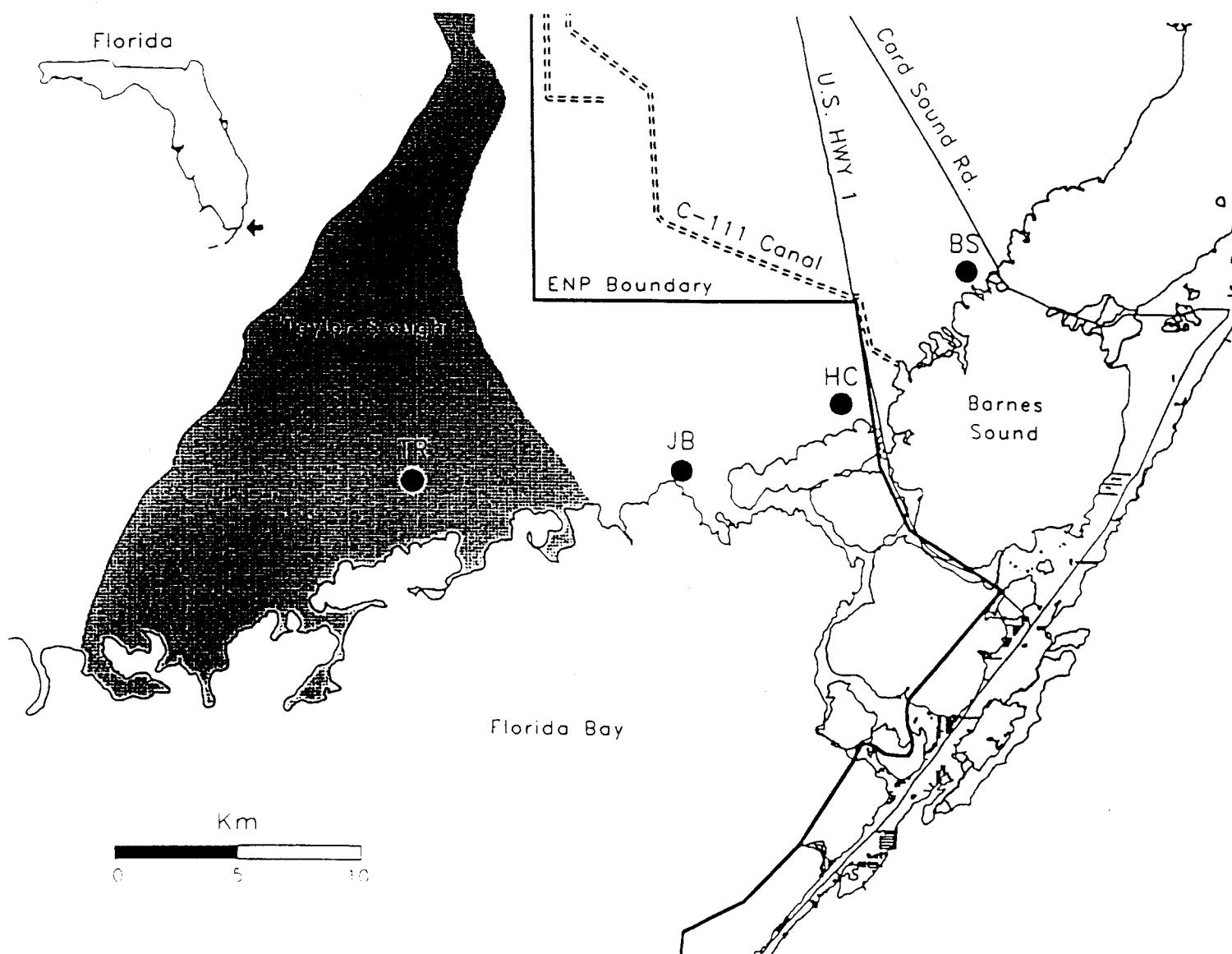


FIGURE 6. Environmental and Hydological Wading Bird Evaluation Sites.

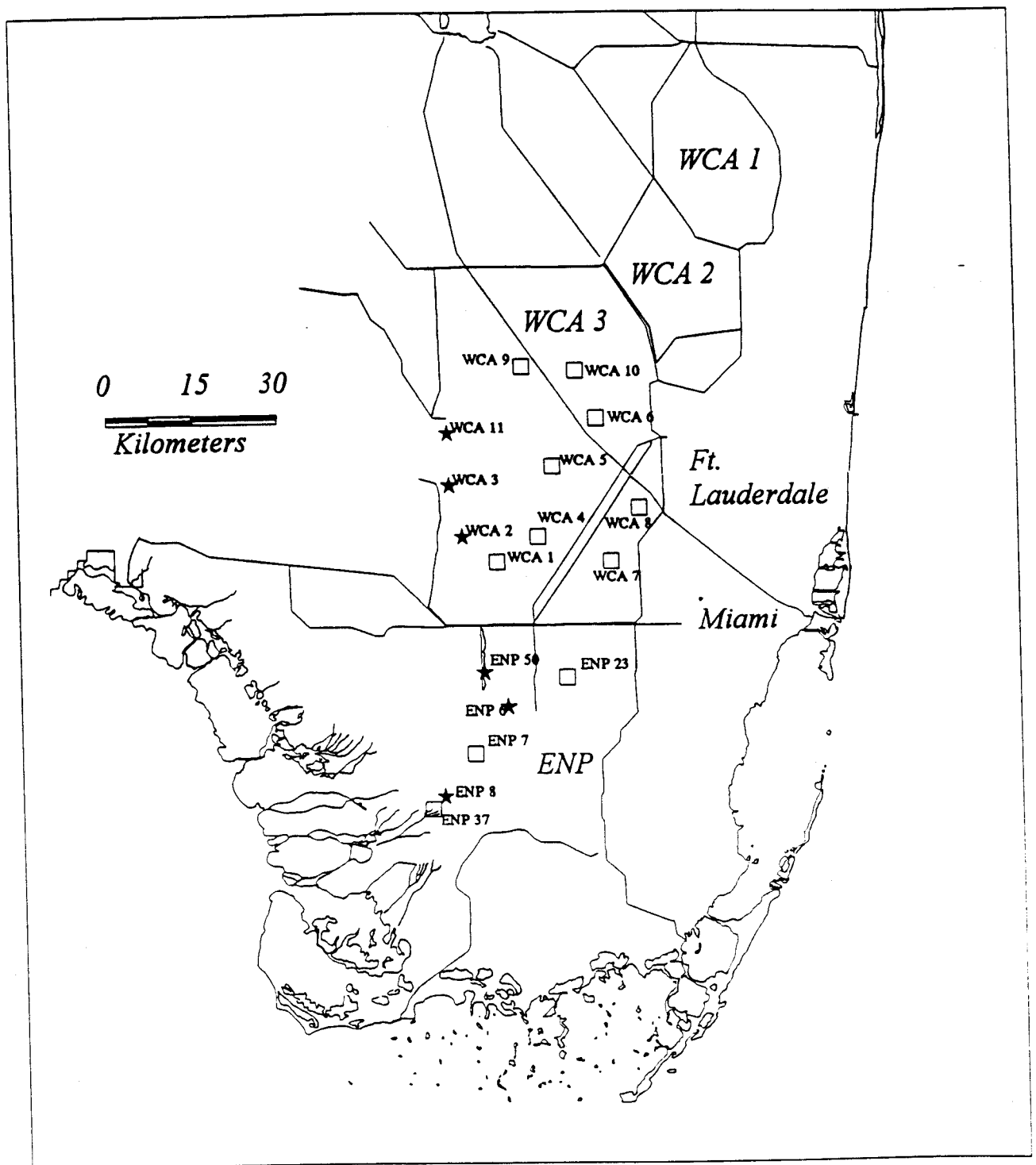
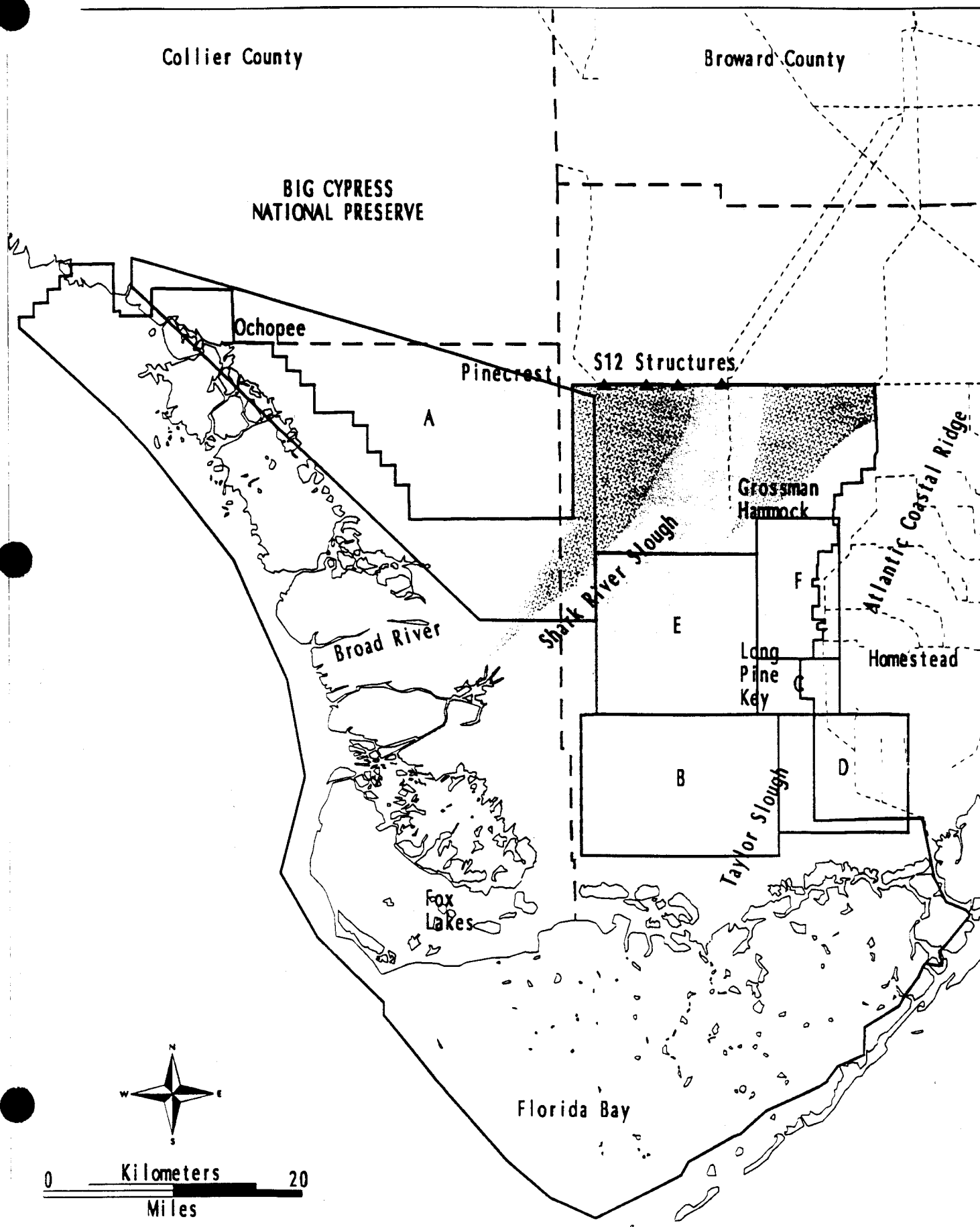
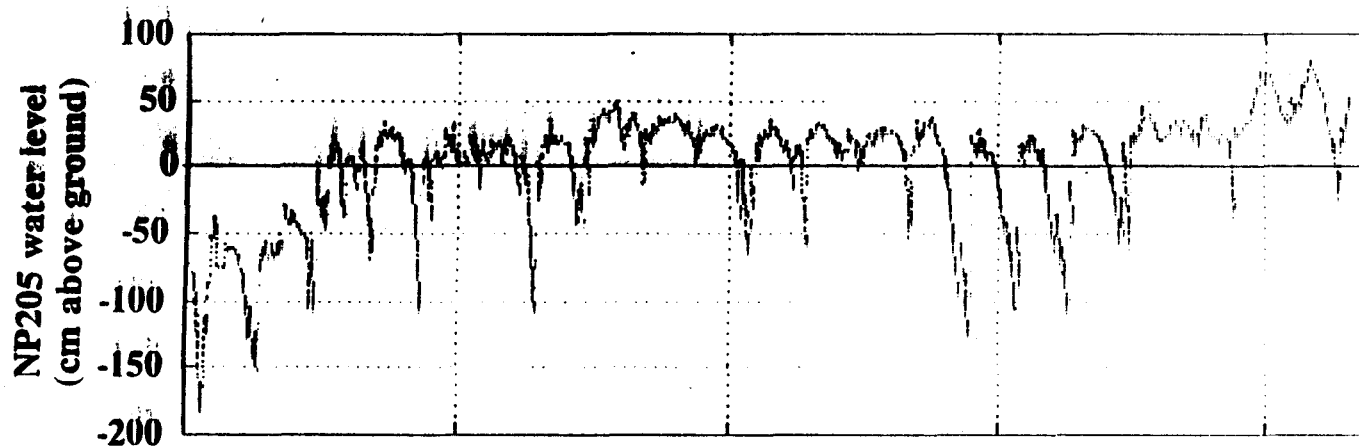


FIGURE 7. Cape Sable Seaside Sparrow Populations.



a)



b)

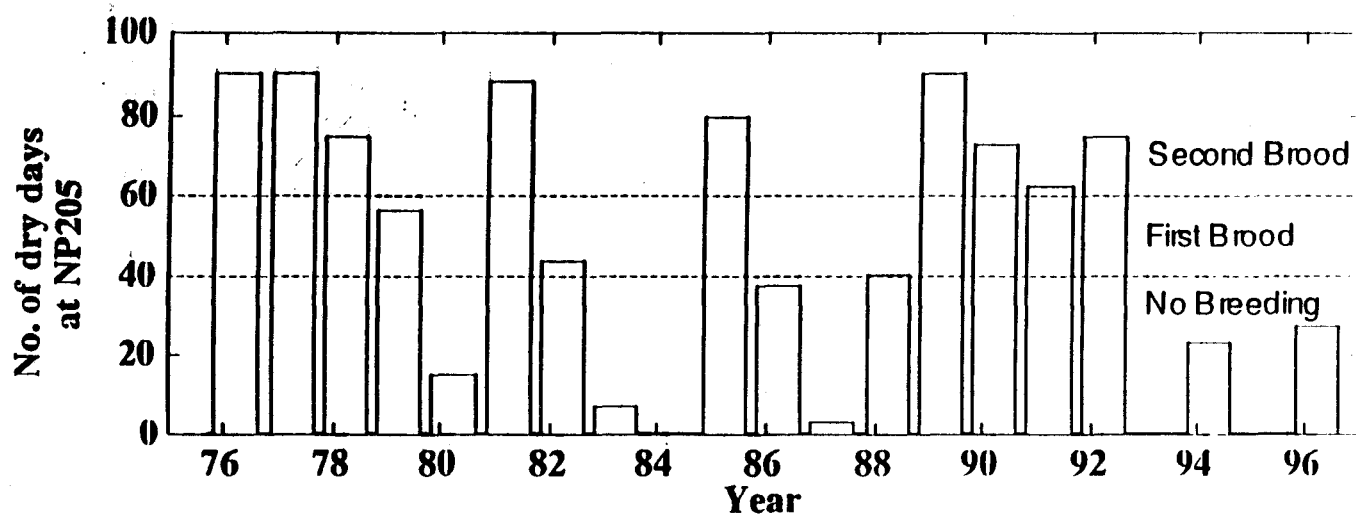


Figure 8: Cape Sable Seaside Sparrow Breeding Cycle Requirements

APPENDIX 1.1 UTM and Lat/Long Coordinates of Marsh Vegetation Plots for Taylor Slough Transects.

Plot*	Easting	Northing	Longitude	Latitude
0101	541043	2810805	80:35:30.8W	25:24:54.0N
0102	541027	2810852	80:35:31.4W	25:24:55.6N
0103	540996	2810890	80:35:32.5W	25:24:56.8N
0104	540965	2810928	80:35:33.6W	25:24:58.0N
0105	540935	2810968	80:35:34.7W	25:24:59.3N
0107	540887	2811012	80:35:36.4W	25:25:00.8N
0106	540895	2811016	80:35:36.1W	25:25:00.9N
0108	540885	2811050	80:35:36.5W	25:25:02.0N
0109	540860	2811085	80:35:37.4W	25:25:03.1N
0110	540825	2811076	80:35:38.6W	25:25:02.9N
0111	540810	2811101	80:35:39.1W	25:25:03.7N
0112	540793	2811134	80:35:39.7W	25:25:04.7N
0113	540804	2811145	80:35:39.4W	25:25:05.1N
0114	540788	2811173	80:35:39.9W	25:25:06.0N
0115	540742	2811205	80:35:41.6W	25:25:07.1N
0116	540723	2811252	80:35:42.2W	25:25:08.6N
0117	540692	2811288	80:35:43.3W	25:25:09.8N
0118	540661	2811330	80:35:44.4W	25:25:11.1N
0119	540631	2811368	80:35:45.5W	25:25:12.4N
0201	539999	2809409	80:36:08.4W	25:24:08.7N
0202	539943	2809423	80:36:10.4W	25:24:09.2N
0203	539902	2809450	80:36:11.8W	25:24:10.1N
0204	539815	2809500	80:36:14.9W	25:24:11.7N
0205	539771	2809523	80:36:16.5W	25:24:12.5N
0206	539721	2809549	80:36:18.3W	25:24:13.3N
0207	539646	2809609	80:36:21.0W	25:24:15.3N
0208	539616	2809618	80:36:22.0W	25:24:15.6N
0209	539595	2809628	80:36:22.8W	25:24:15.9N
0210	539533	2809678	80:36:25.0W	25:24:17.5N
0211	539516	2809693	80:36:25.6W	25:24:18.0N
0212	539506	2809716	80:36:26.0W	25:24:18.8N
0213	539421	2809759	80:36:29.0W	25:24:20.2N
0214	539395	2809755	80:36:29.9W	25:24:20.0N
0215	539387	2809743	80:36:30.2W	25:24:19.7N
0216	539340	2809777	80:36:31.9W	25:24:20.8N
0217	539299	2809806	80:36:33.4W	25:24:21.7N
0218	539258	2809833	80:36:34.8W	25:24:22.6N
0219	539205	2809869	80:36:36.7W	25:24:23.8N
0301	541389	2805887	80:35:19.0W	25:22:14.1N
0302	541372	2805884	80:35:19.6W	25:22:14.0N
0303	541357	2805881	80:35:20.1W	25:22:13.9N
0304	541352	2805879	80:35:20.3W	25:22:13.8N
0305	541351	2805864	80:35:20.4W	25:22:13.4N
0306	541354	2805846	80:35:20.2W	25:22:12.8N
0307	541331	2805858	80:35:21.1W	25:22:13.2N
0308	541337	2805850	80:35:20.9W	25:22:12.9N
0309	541343	2805842	80:35:20.6W	25:22:12.6N
0310	541337	2805846	80:35:20.9W	25:22:12.8N
0311	541335	2805845	80:35:20.9W	25:22:12.7N

* First 2 digits refer to transect, second 2 digits to plot, e.g., 0101= transect 01, plot 01.

APPENDIX 1.1 cont.,

Plot*	Easting	Northing	Longitude	Latitude
0312	541210	2805737	80:35:25.4W	25:22:09.2N
0313	541166	2805706	80:35:27.0W	25:22:08.2N
0314	541158	2805703	80:35:27.3W	25:22:08.1N
0315	541149	2805697	80:35:27.6W	25:22:07.9N
0316	541151	2805689	80:35:27.5W	25:22:07.7N
0317	541131	2805680	80:35:28.2W	25:22:07.4N
0318	541126	2805686	80:35:28.4W	25:22:07.6N
0319	541107	2805656	80:35:29.1W	25:22:06.6N
0320	541102	2805645	80:35:29.3W	25:22:06.3N
0401	538934	2819833	80:36:45.4W	25:29:47.7N
0402	538834	2819827	80:36:49.0W	25:29:47.5N
0403	538734	2819821	80:36:52.6W	25:29:47.4N
0404	538634	2819815	80:36:56.1W	25:29:47.2N
0405	538535	2819809	80:36:59.7W	25:29:47.0N
0406	538435	2819804	80:37:03.3W	25:29:46.8N
0407	538335	2819798	80:37:06.8W	25:29:46.7N
0408	538235	2819792	80:37:10.4W	25:29:46.5N
0409	538135	2819786	80:37:14.0W	25:29:46.3N
0410	538035	2819780	80:37:17.6W	25:29:46.1N
0411	537936	2819774	80:37:21.1W	25:29:45.9N
0412	537836	2819768	80:37:24.7W	25:29:45.7N
0413	537736	2819763	80:37:28.3W	25:29:45.6N
0414	537636	2819757	80:37:31.9W	25:29:45.4N
0415	537537	2819751	80:37:35.4W	25:29:45.2N
0416	537437	2819745	80:37:39.0W	25:29:45.0N
0417	537337	2819739	80:37:42.6W	25:29:44.8N
0418	537237	2819733	80:37:46.2W	25:29:44.6N
0419	537137	2819727	80:37:49.8W	25:29:44.5N
0420	537038	2819722	80:37:53.3W	25:29:44.3N
0501	540635	2813285	80:35:45.2W	25:26:14.7N
0502	540535	2813280	80:35:48.7W	25:26:14.5N
0503	540435	2813274	80:35:52.3W	25:26:14.4N
0504	540335	2813268	80:35:55.9W	25:26:14.2N
0505	540235	2813263	80:35:59.5W	25:26:14.0N
0506	540136	2813257	80:36:03.0W	25:26:13.8N
0507	540036	2813251	80:36:06.6W	25:26:13.6N
0508	539936	2813246	80:36:10.2W	25:26:13.5N
0509	539836	2813240	80:36:13.8W	25:26:13.3N
0510	539736	2813234	80:36:17.4W	25:26:13.1N
0511	539636	2813229	80:36:20.9W	25:26:13.0N
0512	539536	2813223	80:36:24.5W	25:26:12.8N
0513	539437	2813217	80:36:28.1W	25:26:12.6N
0514	539337	2813212	80:36:31.6W	25:26:12.4N
0515	539237	2813206	80:36:35.2W	25:26:12.3N
0516	539137	2813200	80:36:38.8W	25:26:12.1N
0517	539037	2813195	80:36:42.4W	25:26:11.9N
0518	538937	2813189	80:36:46.0W	25:26:11.7N
0519	538838	2813183	80:36:49.5W	25:26:11.5N
0520	538738	2813178	80:36:53.1W	25:26:11.4N

* First 2 digits refer to transect, second 2 digits to plot, e.g., 0101= transect 01, plot 01.

APPENDIX 1.2 ENP Periphyton Monitoring Site Coordinates for Transects
across Taylor Slough.

SITE	latitude	longitude
T5-1	25 26.174	80 35.677
T5-2	25 26.054	80 36.317
T5-3	25 26.087	80 36.870
T1-1	25 24.832	80 35.407
T1-2	25 24.924	80 35.628
T1-3	25 24.894	80 35.782
T2-1	25 24.131	80 36.040
T2-2	25 24.243	80 36.114
T2-3	25 24.371	80 36.306
T2-4	25 24.403	80 36.455
T2-5	25 24.431	80 36.574
T2-6	25 24.497	80 36.614
T3-1	25 22.242	80 35.294
T3-2	25 22.182	80 35.583
T3-3	25 21.882	80 36.117
T3-4	25 21.923	80 36.439
T3-5	25 22.084	80 37.026
T3-6	25 22.221	80 37.190
T7-1	25 18.787	80 37.918
T7-2	25 18.604	80 38.331
T7-3	25 18.694	80 38.595
T7-4	25 18.772	80 39.094
T7-5	25 18.771	80 39.622
T7-6	25 18.834	80 40.144
T6-1	25 13.518	80 39.130
T6-2	25 13.854	80 42.270
T6-3	25 14.626	80 43.755
T6-4	25 14.746	80 44.594

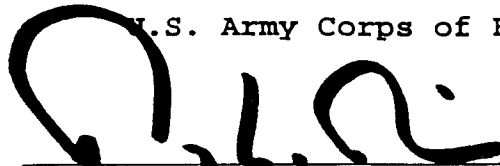
**APPENDIX 1.3 Lat/Long Coordinates for Fish and Aquatic
Macroinvertebrate Study Sites in Taylor Slough.**

Site Name	Latitude	Longitude
Madeira Ditches (MD)		
MD-A	N25 19.326	W80 38.656
MD-B	N25 19.379	W80 38.450
MD-C	N25 19.529	W80 38.542
MD-D	N25 19.063	W80 38.116
MD-E	N25 20.017	W80 38.374
Central Taylor Slough (TS)		
TS-A	N25 16.188	W80 40.880
TS-B	N25 15.919	W80 40.359
TS-C	N25 16.220	W80 40.976
TS-D	N25 15.737	W80 39.938
TS-E	N25 16.515	W80 41.225
Craighead Pond (CP)		
CP-A	N25 13.777	W80 42.239
CP-B	N25 14.137	W80 42.225
CP-C	N25 14.206	W80 43.065

Appendix 3:Memorandum of Understanding Concurrence with the Test 7 Monitoing Plan

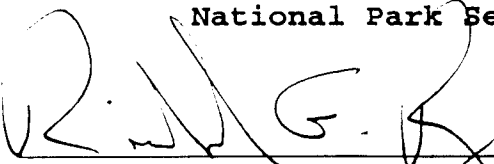
CONCURRENCE WITH THE TEST 7 MONITORING PLAN

U.S. Army Corps of Engineers

 15 DEC 95

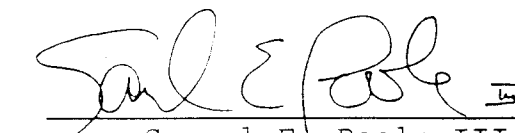
Terry L. Rice Date
Colonel, U.S. Army
District Engineer

National Park Service

 12-15-95

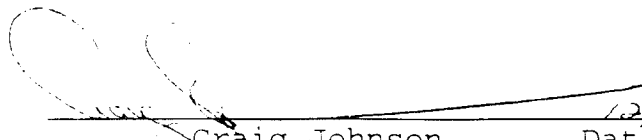
Richard G. Ring Date
Superintendent, Everglades National Park

South Florida Water Management District

 12/15/95

Samuel E. Poole III Date
Executive Director

U.S. Fish and Wildlife Service

 12/15/95

Craig Johnson Date
Supervisor, South Florida
Ecosystems Office

MONITORING PROGRAM EXPERIMENTAL PROGRAM OF WATER DELIVERIES TO ENP

The National Park Service agreed to take the lead in developing the monitoring plan for Test 7 of the Experimental Program of Water Deliveries to Everglades National Park (Experimental Program), as specified in item 4 of the October 5, 1995 Concurrency Agreement. Representatives of the National Park Service (NPS), the Corps of Engineers (Corps), the South Florida Water Management District (SFWMD), and the Fish and Wildlife Service (FWS) jointly formulated this ecological monitoring plan for Test 7. The agencies were represented by Tom Armentano, Dave Busch, Bob Johnson, and Dave Sikkema (NPS), John Moulding, Steve Sutterfield, Jim Vearil, and Susan Bullock (Corps), John Ogden, Dave Rudnick, Jocelyn Branscome, and Susan Olson (SFWMD), and Craig Johnson (FWS).

I Ecological Monitoring Plan Element

The plan outlined here was developed to assess ecological responses during the period of Test 7, and to establish ecological baselines for future iterations of the Experimental Program. The geographical area of coverage for this monitoring program is all portions of the southern Everglades region predicted to be affected by the Experimental Program. The monitoring elements were derived from (1) results of the interagency effort to recommend ecological monitoring measures for the Experimental Program of Water Deliveries to Everglades National Park (Experimental Program), (2) monitoring commitments appearing in Table 2 of the Test 7 Preliminary EA, and (3) the Biological Opinion for this project under the Endangered Species Act (ESA) Section 7 consultation.

The agency representatives decided to rate potential monitoring elements on four criteria (Table 1). The first of these was their potential sensitivity to hydrological change. As used in this discussion, this is an estimation of the responsiveness of the monitoring elements to the kinds of changes we are trying to effect through Test 7. There was strong support for the proposition that temporal and spatial scale is critical to the selection of appropriate factors for monitoring of the Experimental Program. The greatest probability for detecting ecological effects that are likely to be induced by the relatively small amount of hydrological change planned for Test 7 lies in focusing investigations upon lower trophic level organisms. Comments on Test 7 monitoring sensitivity (Table 1) reflect this proposition and not other criteria, such as priorities arising from Test 7 ESA consultation or value as overall indicators of ecosystem restoration.

The second major criterion for ranking of potential monitoring measures was the ESA Section 7 consultation for Test 7. Reasonable and prudent alternatives for the Cape Sable seaside sparrow, as well as conservation recommendations for the American crocodile and wood stork, were used as guidelines in determining rankings and agency responsibilities for conducting monitoring projects. High relevance on either of the first two criteria was grounds for including monitoring measures on the list of those recommended for support.

Also of importance in rating the various potential monitoring measures was their relative value as environmental baselines. Higher priority was assigned where current baseline data are in need of continuation, are incomplete, or are nonexistent. Finally, the relevance of monitoring data to ongoing modeling efforts (ATLSS or ELM) was considered, although not given equivalent weight to the first two criteria.

There was not complete agreement between those measures recommended as sensitive monitoring indicators and those studies that may be needed to fulfill institutional requirements (e.g., the Endangered Species Act). However, a higher rating resulted where monitoring would provide information in both realms, or benefit a related area (e.g., development of a baseline for future modifications or empirical information for modeling).

The components of the ecological monitoring program identified as "Essential" (Table 1) are considered to be the minimum tasks necessary to evaluate the ecological responses to Test 7. Those components identified as "Moderate" would provide additional information for interpreting Test 7, but were not considered to be as high a priority as the "Essential" measures. Those elements rated Moderate would not be a part of the Test 7 monitoring program although agencies may wish to support these measures based on their importance to other programs.

The production of ecological monitoring assessments will require information on the hydrological effects of Test 7, expressed in formats and on schedules that are most useful for ecological interpretation. The additional monitoring stations recommended by NPS hydrologists should permit more complete analyses of Park hydrological conditions throughout Test 7. These are summarized in the attachment to this Plan entitled "Hydrological Monitoring and Report Preparation." Stage hydrographs, stage-duration curves, water depth difference plots, and water depth contour maps produced from the interagency hydrological network will be used to produce ecological analyses of the Test's effects. At a minimum, hydrological inputs to these analyses must cover annual wet and dry season variation, as well as major local precipitation events, or regulatory water releases based on regional precipitation. Critical information needs are peak wet season stages, minimum dry season water levels, and periods of

inundation. Although the emphasis is on hydrological change as a forcing variable, ecological studies should also incorporate information on key "secondary" factors from ongoing monitoring efforts dealing with water quality (especially nutrient loading and salinity) and disturbance (e.g., fire or storms), where appropriate and practical.

Agency representatives for the ecological sciences will reconvene semiannually to assess progress throughout the course of the Test 7 ecological monitoring program. NPS will continue to facilitate interagency review of the monitoring program. Table 2 presents the schedule that was agreed upon for the Test 7 monitoring process.

To the greatest extent possible, timetables for agency cooperators or contractors in the Test 7 monitoring process should be set to meet this schedule. It is impractical for any monitoring efforts not currently ongoing to be put in place by November 1, 1995. However, each agency will expedite the process of initiating the elements of this plan for which it is responsible. Annual and final reports will be compilations of individual investigator reports. The agency representatives for Test 7 monitoring will produce an integrated summary of the various hydrological and ecological reports as part of each annual and final report.

The recommended Test 7 monitoring plan is outlined in the narrative that follows as well as in Table 1. The costs presented are the estimates of the interagency team and are provided to reflect a recommended level of effort rather than rigid commitments. All monetary recommendations are subject to management approval and annual budget appropriations over the course of Test 7.

Freshwater Fish and Macroinvertebrates

NPS has developed a long-term data base on fish and aquatic macroinvertebrates inhabiting Shark River Slough. However, aquatic biota from Taylor Slough and the C-111 Basin are likely to be more heavily affected by Test 7 hydrological manipulations. Information on aquatic biota is needed for ATLSS modeling and to more fully understand wading bird foraging ecology. While NPS can restructure its program to some degree to evaluate project influences, the recent completion of two cooperative research efforts signals a reduction in overall field effort for fish and macroinvertebrates. Additional support is required to cover freshwater and transitional areas of the Taylor Slough and C-111 drainages.

To fill the gap in existing fish and invertebrate sampling programs for Test 7, effort must be shifted to Taylor Slough and the short hydroperiod wetlands in the eastern Everglades. The

sensitivity of organisms to hydrologic change in these regions is high, and would be particularly valuable if the surveys are modified to determine how the Experimental Program affects larger size classes of fish. This is important because wading birds, particularly wood storks, feed preferentially on larger prey size classes. The need to establish a baseline on freshwater fish and macroinvertebrates is great in Taylor Slough and the eastern Everglades. Continued studies in Shark River Slough contribute to the baseline which has been developed over 20 years. Surveys for fish and macroinvertebrates (as well as most other elements) should be conducted along cross-drainage gradients.

Recommendations:

- a. Support for the type of survey currently underway in lower Taylor Slough/Florida Bay (Lorenz) will be provided by the Corps.
- b. Freshwater fish and macroinvertebrate surveys in Taylor Slough will be initiated by the Corps by either extending the lower Taylor Slough work up the drainage or by arranging for another investigator.
- c. Continuing the fish and macroinvertebrate monitoring in Shark River Slough will be given a high priority by the NPS. The present level of effort will be maintained.

Plant Communities

Investigators have reported rapid vascular plant community response to the recent high water conditions in ENP. However, past monitoring projects have not been specifically designed to evaluate vegetation change resulting from the Experimental Program. A relatively small amount of additional support is required to supplement ongoing efforts to evaluate plant community responses and the mechanisms of plant response to hydrological variation.

New transects will be placed in northern Taylor Slough to establish a baseline there. Data will be collected along vegetation transects elsewhere in the ENP to monitor the effects of the Experimental Program. To the degree possible, study areas will be co-located with the focal areas used by the University of Georgia mapping effort.

Recommendation: NPS will continue vegetation surveys along existing transects in Taylor Slough and will conduct supplemental analyses devised to evaluate how shrub invasion and fire affect marsh habitat.

Algal Communities

Periphyton research will be rescaled from the more-focused experimental approach currently employed by FIU scientists working in Shark River Slough up to landscape-level monitoring. Test 7 monitoring suitability is high, and these studies are essential. Floating vegetative complexes (including *Utricularia*) are very responsive to changes in hydroperiod, water quality, and nutrient loading. In scoping a periphyton study, emphasis will be placed on the ecological effects of the Experimental Program, not basic research.

Recommendation: Because SFWMD has some expertise in this area and because this measure can be linked to Emergency Interim Plan responsibilities associated with Test 7, SFWMD will take lead responsibility for implementing a periphyton monitoring project by 1st qtr. CY1996.

SRF Wading Bird Surveys

SRF surveys for wading birds provide information on wading bird distribution, abundance, and foraging patterns in relation to hydropattern. The 10 years of SRF data already available cover a range of wading bird responses to environmental variation throughout the Everglades. This data base is thought to be sufficient for ongoing modeling efforts and to serve as an adequate baseline for future measurements. Information from SRF surveys is better applied to evaluating larger regional scale ecosystem change rather than the type of change anticipated during Test 7.

There is more than a decade of SRF survey data for the ENP, but these data have not been analyzed. Until analyses and reports are produced, agency resources should be focused on other aspects of the monitoring plan.

Recommendation: The National Biological Service (NBS) is responsible for analyses and reports from the unanalyzed portions of the SRF data base. NPS, FWS, and the Corps will fund completion of reports by an independent scientist if NBS is unable to produce a complete set of reports on wading bird distribution and abundance by June 1996. As currently envisioned, new SRF data will not be needed for Test 7 ecological analyses.

Wading Bird Nesting Surveys

Aerial surveys and colony visits are used to evaluate wading bird nesting success. As with SRFs, variation in wading bird productivity may be more easily attributable to factors operating over broad spatial and temporal scales, rather than small scale

hydrological modifications. However, the colony patterns are considered to be strong indicators of ecological conditions in the Everglades region.

There are three options proposed for these surveys: (1) aerial surveys of all wading bird colonies, including wood stork colonies with a fixed wing aircraft, (2) aerial surveys of only wood stork colonies, and (3) supplement the fixed-wing surveys with helicopter checks of the wood stork sites to gain more detailed data on chick growth and survival.

Recommendation:

a. NPS will continue to fly wading bird surveys and will add the helicopter checks of the wood stork sites. A standardized colony survey protocol consistent with that used in other regions of the Everglades will be used.

b. FWS will provide additional funds or staff support as needed.

c. The Corps will support wading bird breeding ecology surveys in the WCAs. Colony surveys will be conducted by the standard protocol.

Wood Storks

Wood storks have been monitored along with other wading birds as part of the program described above. The above recommendations for wading bird colonies and distribution and abundance surveys will satisfy the Conservation Recommendation in the ESA Section 7 Biological Opinion.

Cape Sable Seaside Sparrow (CSSS)

NBS has had the lead on CSSS studies through the work of Dr. Stuart Pimm (Univ. of Tennessee) and is the appropriate source for the required studies of sparrow biology.

Reasonable and Prudent Alternative No. 3 in the ESA Section 7 Biological Opinion can be fulfilled by funding the efforts of Pimm to monitor the CSSS. NPS, FWS, and the Corps will support aspects of Pimm's proposal that are related to monitoring, but this may not fully address portions of the CSSS investigation that are related to model development.

Recommendations:

a. The Corps, NPS, and FWS will jointly support the CSSS monitoring project. FWS may use in-kind services for some of this support and GFC will be requested to provide additional

in-kind survey support.

b. NBS will seek alternate funding sources for aspects of the Pimm proposal related to model development or for studies of winter ecology of the CSSS.

Alligator Nesting Surveys

These surveys are carried out using a combination of SRF surveys to locate nests and nest visits to document productivity. Surveys were recently expanded to cover Taylor Slough in an attempt to better document the effects of the Experimental Program. Alligators are a keystone species in the Everglades and are sensitive to hydrological change, while also causing substantial physical alteration to the ecosystem.

Recommendation: NPS will continue surveys of nesting alligators, making sure that the Taylor Slough Basin is covered.

American Crocodile

Ongoing support of the effort to monitor crocodile nesting patterns in Florida Bay would satisfy the conservation recommendation made for this species in the Biological Opinion. Test 7's effects may be substantial in its habitat.

Recommendation: FWS, NPS, and the Corps will ensure continued crocodile monitoring.

Florida Panther

NPS conducts aerial surveys of telemetered panthers within ENP and has plans to continue this effort. Test 7 ecological monitoring sensitivity is low, so this species will not be considered as a Test 7 monitoring element.

Snail Kite

Recent snail kite research in the vicinity of ENP has been conducted by NBS via Rob Bennett. Expansion of survey efforts within the Test 7 project area would require additional resources. Test 7 monitoring priority for this species is low. Therefore, the snail kite will not be part of the monitoring program for Test 7.

Table 1: Major elements of the ecological monitoring program for Test 7

Rating	Monitoring Element	Comments	Basins	Responsible Agency
Essential	Fish and macroinvertebrates	Sensitivity is high; Marginal applicability to the Section 7 consultation; Importance to baseline is high; Modeling needs relative to ATLSS.	Taylor FL Bay SRS	Corps NPS
Essential	Plant communities	Sensitivity is high; Some applicability to the Section 7 consultation on sparrow habitat; High value for establishing a baseline in Taylor Slough; Modeling needs high relative to ELM.	SRS Taylor	NPS
Essential	Periphyton	Sensitivity is high; No direct applicability to the Section 7 consultation; Would be establishing a baseline; Modeling applicability is high.	Taylor	SFWMD
Moderate	SRF wading bird surveys	The applicability of these surveys to a monitoring program for Test 7 is uncertain; priority will be placed on the existing data set from 10 years of SRF surveys; new wading bird SRFs can not be recommended for monitoring Test 7.	SRS Taylor WCAs C-111	NBS-complete report from existing data set; NPS, FWS, and Corps will support analysis and write-up if NBS is unable to complete
Essential	Wading Bird Colonies	Ecological sensitivity is thought to be high; close connection to Section 7 consultation (see wood stork); continuation of the Everglades baseline is important; modeling needs marginal.	SRS Taylor	NPS Corps

Table 1: Major elements of the ecological monitoring program for Test 7 (Continued)

Rating	Monitoring Elements	Comments	Basins	Responsible Agency
Essential	Alligator nesting surveys	Sensitivity of alligators to Test 7 monitoring is potentially high; it has no applicability to the Section 7 consultation; it is fairly important for future baselines and is the subject of ATLSS modeling.	Taylor	NPS
Essential	Cape Sable seaside sparrow	Sensitivity is moderate; it is central to the biological opinion; development of a baseline is important; data will be useful to ATLSS modeling but may require additional funding.	Taylor SRS C-111	Corps FWS NPS
Essential	Wood Stork	Sensitivity of wood storks to Test 7 may be high; important for Section 7; the importance of nesting data to the baseline for future management action is relatively high; data would be collected as part of a larger effort to evaluate wading bird colonies.	Taylor SRS	See wading bird colonies and SRFs
Essential	American crocodile	Ecological sensitivity may be high depending on salinity tolerance; high relevance to Section 7 consultation; low need to develop a baseline; does not directly benefit model development.	Taylor FL Bay	FWS, NPS, and Corps will investigate continuing surveys.
Moderate	Florida panther	Sensitivity low; Do not recommend including separate studies to assess the effects of Test 7; abundance too low for baseline; is subject of ATLSS model.	SRS Taylor	None
Moderate	Snail kite	Sensitivity moderate; studies to assess the effects of Test 7 not recommended.	SRS WCAs	None

II Hydrologic Monitoring Plan Element

Test Iteration 7 proposes to evaluate methods to restore a more natural hydroperiod to ecosystems within Everglades National Park. The hydrologic monitoring plan for test iteration 7 will continue the monitoring efforts that have been in place during the previous test iterations and will include new monitoring sites within Everglades National Park and along L-31N, L-31W and C-111. A hydrological monitoring group will be established from the NPS, SFWMD, USGS and the Corps, for data acquisition and hydrologic analysis for the Experimental Program.

Introduction

There is a well established long-term hydrological monitoring program in place throughout much of the freshwater and marine ecosystems of South Florida. Although this monitoring system is adequate for characterizing the overall water level and rainfall conditions within the system, recent analyses have shown that coverage of the short hydroperiod marl prairies is sparse. For this reason, additional hydrologic monitoring stations have been proposed for installation during Test 7. These sites are located throughout the Rocky Glades and the central and lower portions of Taylor Slough, and one new site is located in the western Shark River Slough marl prairies. For modeling purposes several new groundwater sites are being installed along the L-31N Canal, the C-111 Basin, and in the developed areas east of L-31N. The expanded network covers much of the area that will be most directly impacted by the operational changes implemented under Test 7 and will also provide needed baseline information for hydrological and ecological evaluations related to the Modified Water Deliveries and C-111 GRR projects.

Monitoring Areas

Test Iteration 7 will focus on the following areas:

1. **Northeast Shark River Slough (NESRS).** An experimental water delivery plan for Northeast Shark River Slough was implemented in July 1985, and has continued to the present. In conjunction with this program, an extensive monitoring network was initiated through the cooperative efforts of the USGS, NPS, Corps, and SFWMD. Monitoring of selected existing sites is an ongoing effort to determine how the surface and groundwater gradients are influenced by the raising of the L-31N Canal stage. Refer to figures 1A and 1B for all locations of monitoring stations within the Experimental Program. Sites in the vicinity of known Cape Sable seaside sparrow nesting areas will be monitored.

2. **Taylor Slough.** Several new monitoring sites will be added in the Taylor Slough Basin, and existing gages will be upgraded. Pre- and post-conditions will be compared to determine basin changes in surface and groundwater.

3. **Rocky Glades Area.** The area of higher ground elevations between Shark River Slough and Taylor Slough is referred to as the Rocky Glades area. Additional groundwater sites will be added for monitoring during this test.

4. **8.5 Square Mile Area.** The residential area known as the 8.5 square mile area is bounded on the east by L-31N and on the north and west by the Everglades National Park boundary. Unusually severe weather during 1993 and 1994 resulted in high water levels in this area. Two additional groundwater monitoring sites will be constructed for this test and pre- and post-project conditions will be compared to determine basin changes in surface and groundwater.

5. **Lower C-111 Basin.** Beginning in 1984, the SFWMD and USGS established a network of surface and groundwater monitoring sites within the freshwater marshes adjacent to C-111. This network consists of five surface water recording gauges (EVER1, EVER2A, EVER2B, EVER3, and EVER4) and two groundwater water stations G-3354 and G-1251. Hydrologic monitoring of these existing stations will continue throughout the duration of the test. An additional groundwater monitoring site is proposed along C-110, and existing stations will be upgraded.

Water supply to the ENP Eastern Panhandle flows through a series of gaps spaced along the south levee of C-111 between S-18C and S-197. Natural ground elevations at these gap openings range from 0.6 to 1.6 ft., NGVD. Baseline hydrology for these gages has been established and hydrologic monitoring will continue throughout the duration of the test. Pre and post conditions will be compared to determine basin changes in surface and groundwater.

6. **Florida Bay.** Various studies are currently being conducted by SFWMD, NPS, Dade County Environmental Resource Management (DERM), and other agencies. These ongoing-studies will provide baseline data relating salinity and ecological conditions with hydrologic change. Variations in salinity, conductivity, dissolved oxygen, ph, and temperature will continue to be monitored.

7. **East of the L-31N Canal.** Groundwater wells east of the L-31N Canal will be monitored to measure impacts on private lands east of the canal.

Annual Reporting

A key part of the ecological assessments for Test 7 involves the analysis of spatial water levels, water depth, hydroperiod, and seasonal rainfall data. The collection and dissemination of this data will be provided to the ecological monitoring group by the hydrological monitoring group in accordance with the schedule shown in Table 2. In addition, the hydrological monitoring group will perform an annual operational evaluation of Test 7 and prepare a joint annual monitoring report.

Funding

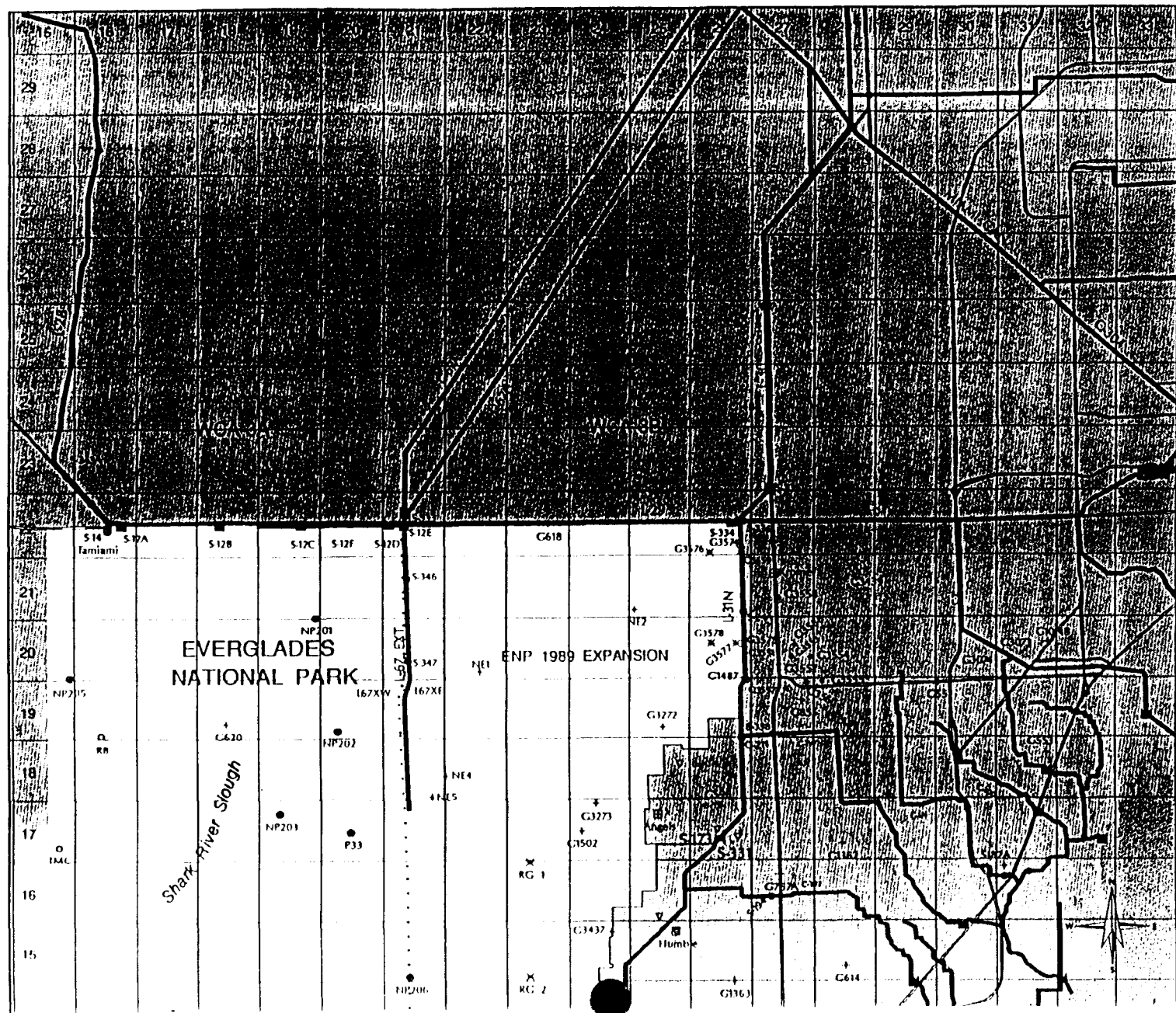
Funding for the monitoring plan will depend upon agency appropriations and recommendations of the hydrologic and ecological monitoring groups.

Data Exchange

The exchange of hydrologic data will be in accordance with the format agreed upon by the IDCT working group. This group consists of members from the Everglades National Park (NPS-ENP), the SFWMD Operation Division and Data Management Division, the U. S. Geological Survey in Miami (USGS), and the U.S. Army Corps of Engineers Water Management and Meteorology Section (Corps). A generalized Data Exchange Format was developed from a modified .E format of Standard Hydrologic Exchange Format (SHEF).

Table 2. Monitoring Schedule

DATE	ACTION
November 1, 1995	Initiate monitoring (where possible)
January 31, 1996	Finalize ecological needs for hydrology data
October 31, 1996	Complete 1st year of data collection
January 31, 1997	Hydrological data outputs due
March 31, 1997	Annual hydrological and ecological assessments/reports due
October 31, 1997	Complete 2nd year of data collection
January 31, 1998	Hydrological data outputs due
March 31, 1998	Annual hydrological and ecological assessments/reports due
October 31, 1998	Complete 3rd year of data collection
January 31, 1999	Hydrological data outputs due
March 31, 1999	Annual hydrological and ecological assessments/reports due
October 31, 1999	Complete data collection
January 31, 2000	Final hydrological data outputs due
March 31, 2000	Final ecological and hydrological assessments/reports due
May 1, 2000	Decision on changes to program



WATER MONITORING STATIONS (North Section)

Station Symbols

- NPS Active
- NPS Proposed
- NPS Active (missing data)
- SEWMD Active
- SEWMD Proposed
- SEWMD Active (missing data)
- ▲ NBS Proposed
- HA Associates Active
- Big Cypress Preserve
- ▽ COI Proposed
- DERMUSGS Existing
- × NPS Proposed (new)
- † USGS Active
- USGS Active (missing data)

Boundary and hydrology data provided by South Florida Water Management District.

Roads were extracted from USGS and TIGER digital line files.

Projection: Universal Transverse Mercator Zone 17, North American Datum of 1927.

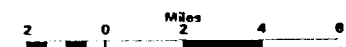


Figure 1A. Location Map

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2 Introduction

This section of the Test 7 hydrologic evaluation details the impacts of the Test 7 operating criteria on the resources of Everglades National Park. It represents a compilation and evaluation of the available hydrologic information gathered by numerous federal and state agencies, and local organizations during the current iteration of Experimental Water Deliveries Program , Test 7 Iteration. Additionally, period of record and selected intervals prior to the start of the testing program in 1983 is included, to indicate the longer-term trends observed under the Experimental Water Delivery program. The purpose of this section is to evaluate and report the associated hydrologic responses due to the water management operations during the current Test 7 iteration. Inherent in this objective is to provide information that can be utilized by the Army Corps of Engineers for the development of temporary and permanent solutions necessary for achieving the larger ecosystem restoration objectives. The study area and associated features are shown in Figure 1.

Documentation and evaluation of earlier iterations is available through several technical reports. The ENP technical report Van Lent *et al.* [1993] provides analyses of earlier iterations through 1990 with conclusions that ENP drainage has been exacerbated by reductions in the water level operating criteria at structures throughout the L-31N, L-31W, and C-111 canals. In addition,

a brief summary of the hydrologic impacts of the current Rainfall Plan for the Shark Slough basin, and the Park's recommendations are presented in Johnson [1994]. A technical report evaluating Test 6 is presented in Everglades National Park [1995a] with conclusions that the minimal operational increments undertaken in Test 7 are insufficient to achieve the stated objectives of the Experimental Program of Water Deliveries to Everglades National Park.

A summary of the concerns raised related to Experimental Program of Water Deliveries to Everglades National Park in these documents are as follows.

- The current rainfall based water delivery plan for Shark Slough, with the fixed regulation schedule in WCA-3A is not adequate often resulting in large regulatory releases to ENP.
- The re-establishment of persistent surface water inflows into Northeast Shark Slough (NESS) is not been possible due to constraints imposed by water level ceilings in the L-29 canal and inappropriate trigger well criteria at G-3273.
- Large seepage losses from NESS to northern L-31N further erodes discharges to NESS contributing to failure in reestablish the hydrologic regimes necessary to sustain the viability of its peripheral wetlands.
- Attempts to provide flood mitigation to developed areas of the East Everglades results in less than optimal hydropattern and hydroperiods of the northern Rocky Glades.
- The ability to establish desired hydroperiod and hydropatterns in the northern Taylor Slough is hampered by the a combination of lowered L-31N canal water levels, wet season flood operations and lack of storage.
- Historically there has been a reduction in the quantities of freshwater flow from Taylor Slough into Florida Bay as a result of water management operations and there effect on Everglades hydrologic regimes.

Although many of these problems were identified in the Test 6 hydrologic analyses, only minor modifications were made to the operating criteria for Phase I evaluations under Test 7.

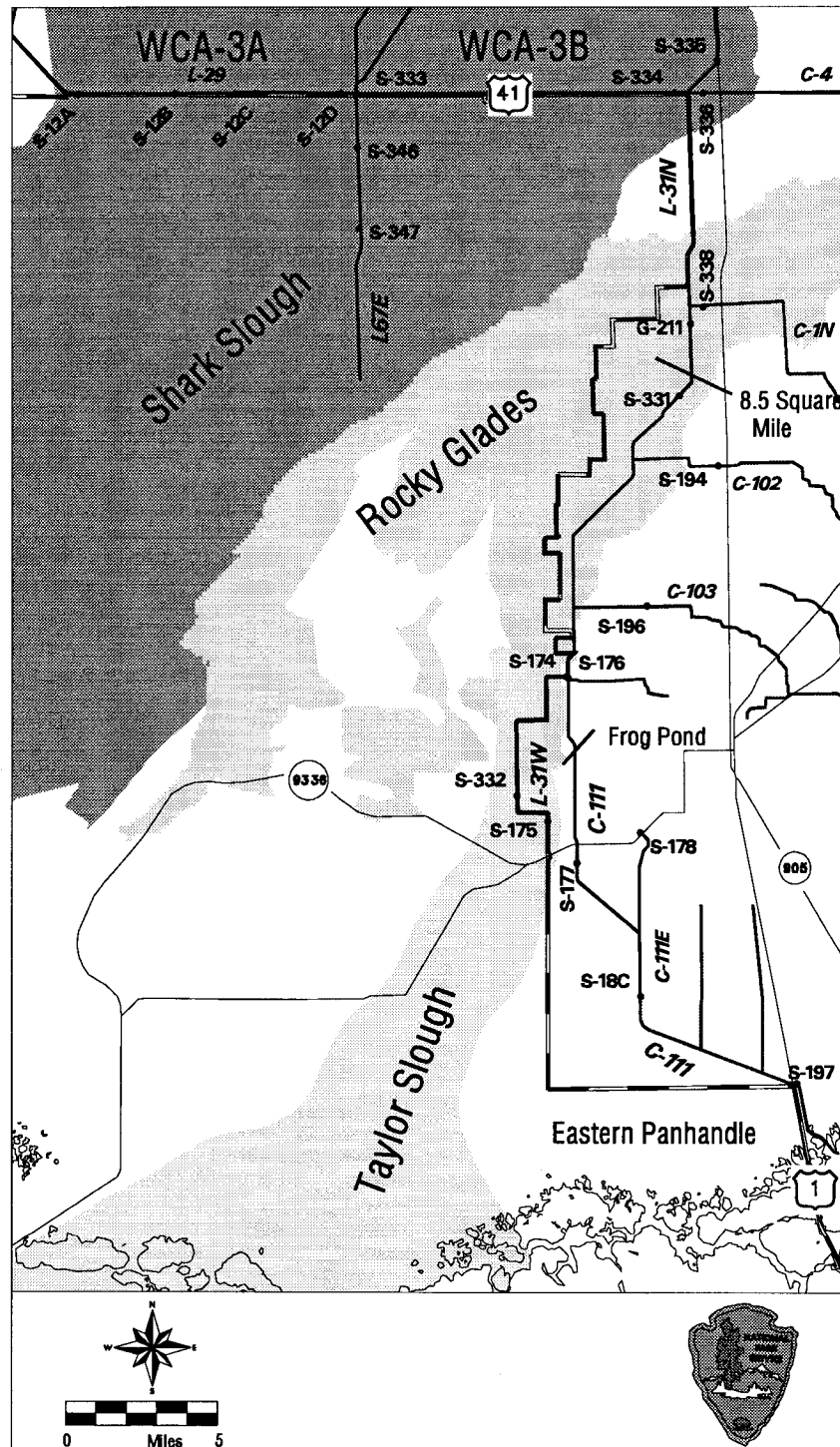


Figure 1: General Location Map.

2.1 The Test 7 Iteration

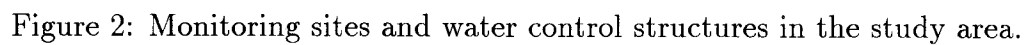
The current iteration (Test 7) of the Experimental Water Deliveries Program began in November 1995 and was authorized to continue through May 1, 2000. The objectives of Test 7 is the evaluation of methods to restore a more natural hydropattern and hydroperiod of wetlands within ENP including NESS and Taylor Slough, as well as, reduce large, freshwater discharges through S-197 into Manatee Bay and Barnes Sound. An additional element was added during Test 6 iteration to increase freshwater inflows to Florida Bay. The latter objective was to be accomplished by increased pumping of up to 500 cfs at S-332 resulting in flows through Taylor Slough, thereby rehydrating the adjacent wetlands.

ENP's focus continues to be maintaining authorized water levels in the L-31N, L-31W, and C-111 canals. Through increasing operational stages in these canals ENP losses through seepage can be reduced, allowing for more of the wet season rainfall to be stored in the upstream wetlands and underlying aquifer. This approach would reduce excessive groundwater seepage losses, attenuate the rapid flow pulses associated with flood control operations, and delay the release of wet season runoff, producing more persistent flows into the dry season. Once authorized water levels have been reestablished investigations can be directed to ways to increase water levels while mitigating their effects.

The specific areas previously identified and included in this monitoring and evaluation report on the hydrological impacts of the Test 7 include: (1) Western and Northeast Shark Slough and the adjacent developed East Everglades, (2) the Rocky Glades, (3) Taylor Slough, and the adjacent Frog Pond, (4) the developed areas in the C-1, C-102, and C-103 basins and (5) the ENP Eastern Panhandle. Daily rainfall, water level and discharge for the stations and structures shown in Fig. 2 were obtained from the USGS, Army Corps of Engineers, and the SFWMD and were added to ENP's database for inclusion in this evaluation.

3 General Hydrologic Conditions

The pre-drainage Everglades landscape was dominated by sustained surface and groundwater flows responding naturally to the sequential patterns of seasonal rainfall. The characteristic flooding and drying patterns that resulted



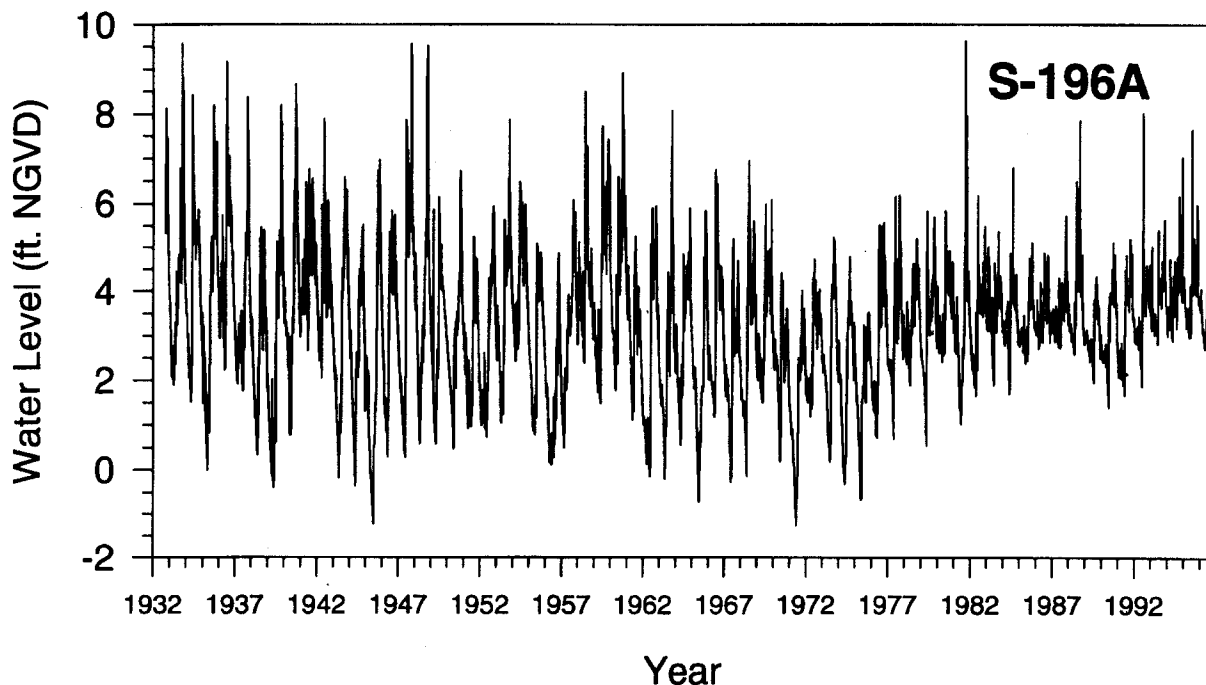


Figure 3: Monthly average water levels at S-196A for the period of record.

were sufficient to sustain the Everglades ecological processes.

Flood control operations are designed to rapidly remove excess runoff. Due to effective flood control and water supply operations, a regional lowering of wet season surface and peak ground water levels and a raising of dry season ground and surface water levels has occurred. This truncating of peaks and raising of minimums is graphically evident in Figure 3. This plot shows period of record average monthly water levels at S-196A, located just east of Everglades National Park (see Fig. 2). This station has one of the longest water level records in southern Dade County. This hydrograph graphically depicts the combined effects of both water supply and flood control water management practices on the water level regimes in the areas in and adjacent to Everglades National Park. During the early portions of the record there were numerous years when water levels fluctuated widely in response to variations in rainfall. More recently, the hydrograph depicts a more narrow range of water level fluctuations due to the effective removal of the extreme water level events. As seen in this figure, both the maximum and minimum water levels characteristic of the early record have been eliminated through effective water management. The alteration of water levels as shown in Fig. 3 has resulted in a regional loss

of storage that previously sustained Everglades flows. The Everglades system now responds to short- and long-term events surrounding the management of water levels necessary to sustain man's activities.

3.1 Rainfall Conditions

Monthly, seasonal, and annual (hydrologic year) rainfall for selected stations throughout the study area are presented in Table 1. This time period, from November 1994 through October 1996 includes hydrologic year 1995 of Test 6 (HY95) and year 1 of Test 7 (HY96). Station period of record monthly, seasonal and annual averages are included for comparison purposes. Monthly rainfall totals during this period resulted from the range of meteorological conditions typical of South Florida including convective thunder storms, cold fronts, warm fronts, tropical storms and hurricanes. For additional information about events of note during this period refer to the November 1994 through October 1996 Surface Water Conditions Detail Reports (SWCDR) [South Florida Water Management District, 1994 1996].

Monthly rainfall totals shown in Table 1 highlight the spatial and temporal characteristics of rainfall that predominate South Florida rainfall. Consideration of these characteristics is important to note given the spatial extent of the study area (see Fig. 1). Because of this temporal and spatial variability it may be necessary to examine rainfall at additional stations and times scales other than presented in Table 1 in subsequent sections. These summaries will be useful when examining water levels, open-water budgets, and hydropatterns as well as understanding water management including flood control operations and water supply in subsequent sections.

Rainfall frequency analysis is useful because it provides not only qualitative but also quantitative information in terminology consistent with the original design of the C&SF project. Frequency analysis provides the probability of occurrence or the chance of occurrence (return period) associated with rainfall totalled over some interval. A frequency analysis using monthly rainfall for three stations in study area with sufficient period of record was performed, with results shown in Table 2. The period of record was sufficient in length that missing data was not estimated for this analysis. Return periods for hydrologic year, dry and wet season rainfall for all the stations shown in Table 1 and Table 2 can be estimated from frequency isohyets of rainfall maximums for Central and South Florida generated by MacVicar [MacVicar, May 1981].

The Dry Season is from November through May.									
The Wet Season is from June through October.									
The Year represents the sum of the wet and dry seasons.									
	Forty Mile Bend			S-12D			S-336		
MTH	POR	HY95	HY96	POR	HY95	HY96	POR	HY95	HY96
NOV	1.77	7.72	0.16	1.73	4.56	1.45	2.56	8.68	1.92
DEC	1.29	4.75	0.91	1.12	1.15	0.81	1.32	3.57	0.81
JAN	1.67	3.38	0.95	1.66	3.38	1.41	1.60	3.41	1.72
FEB	1.64	0.59	0.67	1.37	1.82	0.72	1.40	1.70	0.15
MAR	2.01	1.57	2.72	2.17	1.25	2.47	2.58	-M-	1.36
APR	2.34	1.85	2.38	1.81	2.10	2.58	2.15	1.41	2.97
MAY	5.54	6.89	9.11	4.80	3.60	5.00	4.32	3.68	8.93
JUN	9.77	17.39	8.48	10.80	18.65	11.50	8.32	19.23	6.91
JUL	7.62	7.53	3.05	6.50	7.11	2.32	5.32	5.60	2.81
AUG	7.22	8.55	7.12	7.86	9.60	11.56	7.03	14.35	7.22
SEP	7.62	8.53	6.54	6.29	6.54	3.56	7.44	9.71	4.07
OCT	4.90	12.03	7.62	5.29	11.36	7.79	4.17	10.85	10.40
DRY	16.16	26.75	16.90	14.05	17.86	14.44	15.22	22.45	17.86
WET	36.79	54.03	32.81	38.10	53.26	36.73	31.12	59.74	31.41
HY	52.95	80.78	49.71	52.15	71.12	51.17	46.34	82.19	49.27
Forty Mile Bend period of record (POR) 01/49—10/96									
S-12D period of record (POR) 01/62—10/96									
The S-336 period of record (POR) 5/79—10/96.									
	Royal Palm			S-18C			Hom.Fld.		
MTH	POR	HY95	HY96	POR	HY95	HY96	POR	HY95	HY96
NOV	2.51	9.91	0.96	1.87	6.31	0.36	2.51	6.80	0.71
DEC	1.33	3.74	1.00	1.14	3.23	0.58	2.01	5.10	1.63
JAN	1.72	2.65	1.98	1.11	1.13	0.66	1.19	2.42	1.65
FEB	1.82	-M-	-M-	1.25	0.03	0.04	1.85	0.46	2.13
MAR	1.82	-M-	1.66	1.41	1.48	1.24	1.98	1.82	1.65
APR	2.78	2.68	2.90	2.09	3.38	1.45	2.32	1.57	2.49
MAY	6.17	6.26	7.89	5.16	4.40	2.59	6.37	7.17	5.15
JUN	9.43	15.21	-M-	7.87	12.60	7.98	10.06	12.71	11.65
JUL	7.01	6.52	3.29	4.48	3.74	0.82	7.26	12.08	3.33
AUG	7.84	11.83	7.96	6.90	10.64	5.75	8.23	9.98	7.49
SEP	8.28	4.96	6.16	6.37	9.41	4.07	9.13	11.00	10.03
OCT	5.77	-M-	9.39	4.41	10.90	10.92	4.03	11.56	5.14
DRY	17.76	25.24	16.39	13.61	19.96	6.92	20.43	25.34	15.41
WET	38.18	-M-	-M-	30.50	47.29	29.54	40.35	57.33	37.64
HY	55.94	-M-	-M-	44.11	67.25	36.46	60.78	82.67	53.05
The Royal Palm period of record (POR) 5/49—10/96.									
S-18C period of record (POR) 3/67—10/96									
The Homestead Field Station period of record (POR) 1/68—10/96.									

Table 1: Rainfall totals for selected gages in the study area (in inches).

	Forty Mile Bend		IFS Experimental		Royal Palm	
1995 Wet Season						
	Rain (in)	Return Period(yrs)	Rain(in)	Return Period(yrs)	Rain(in)	T(yrs)
JUN-95	17.39	15.96	-M-	-M-	15.21	7.10
JUL-95	7.53	2.27	-M-	-M-	6.52	1.99
AUG-95	8.55	3.90	-M-	-M-	11.83	9.24
SEP-95	8.53	3.00	-M-	-M-	4.96	1.16
OCT-95	12.03	31.51	10.97	4.89	-M-	-M-
1996 Dry Season						
NOV-95	0.16	1.16	1.05	1.43	0.96	1.36
DEC-95	0.91	1.73	0.83	1.58	1.00	1.83
JAN-96	0.95	1.52	1.57	2.14	1.98	2.65
FEB-96	0.67	1.33	1.16	1.58	-M-	-M-
MAR-96	2.72	3.59	1.58	1.78	1.66	2.10
APR-96	2.38	2.37	2.38	1.78	2.90	2.43
MAY-96	9.11	7.02	8.08	3.37	7.89	3.54
1996 Wet Season						
JUN-96	8.48	1.80	12.96	4.80	-M-	-M-
JUL-96	3.05	1.04	2.26	1.00	3.29	1.06
AUG-96	7.12	2.25	8.18	2.27	7.96	2.41
SEP-96	6.54	1.77	9.49	2.27	6.16	1.39
OCT-96	7.62	5.81	6.67	1.93	9.39	8.28
Forty Mile Bend period of record (POR) 01/49—10/96.						
IFS Experimental Station period of record (POR) 01/14—10/96						
Royal Palm period of record (POR) 05/49—10/96.						

Table 2: Return periods (years) for monthly rainfall totals (inches) for selected gages in the study area.

The annual (hydrologic year), dry and wet season frequency isohyets for 2, 5, 10 and 25 year return periods with approximate station locations plotted are shown in Figures 4, 5 and 6. Although the length of the dry and wet seasons are different than those used to compute the seasonal totals in Table 1 the variability associated with May and October rainfall permits their use in this analysis for a reasonable estimate of seasonal and annual year rainfall return periods.

To assist in determining the areal extent of seasonal rainfall throughout the study area contours for the 1995 wet season, 1996 dry and wet seasons were generated. These rainfall contours were produced using the kriging method. This method is widely accepted as an appropriate method for contouring rainfall at a seasonal time scale. These seasonal rainfall contours will be useful in subsequent sections.

Many of the study area stations recorded near or POR maximum wet season rainfall totals during hydrologic year 1995. Wet season 1995 totals for the stations shown in Table 1 indicate that the majority of the 1995 wet season months were above average. Dade County wet season rainfall estimated from the meteorological summary October 1995 [South Florida Water Management

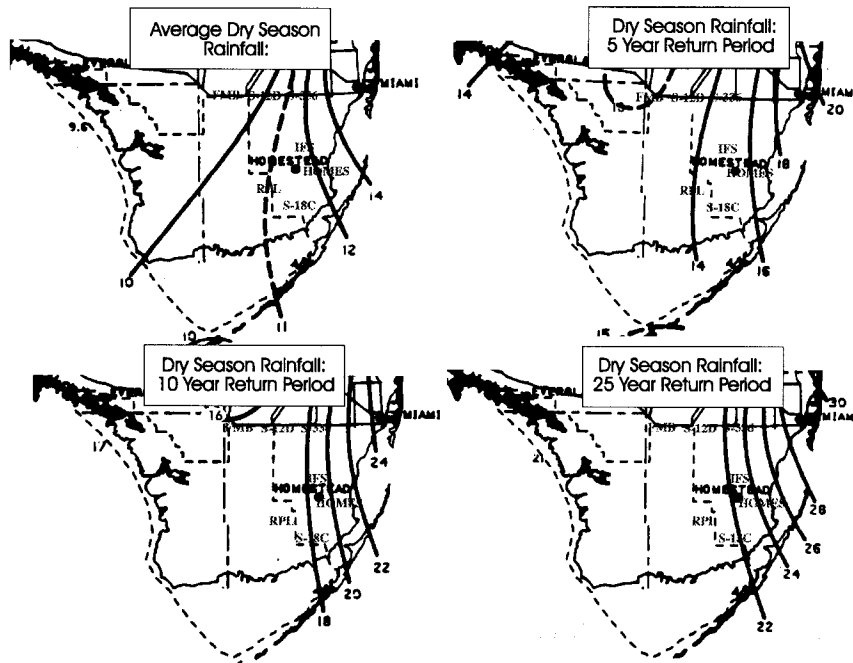


Figure 4: Dry season rainfall frequency isohyetal maps[MacVicar, May 1981].

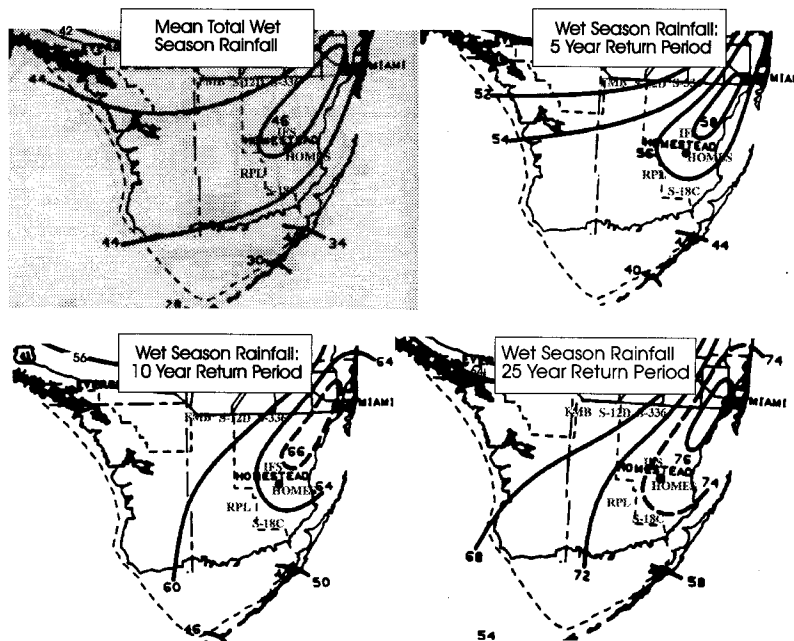


Figure 5: Wet season rainfall frequency isohyetal maps[MacVicar, May 1981].

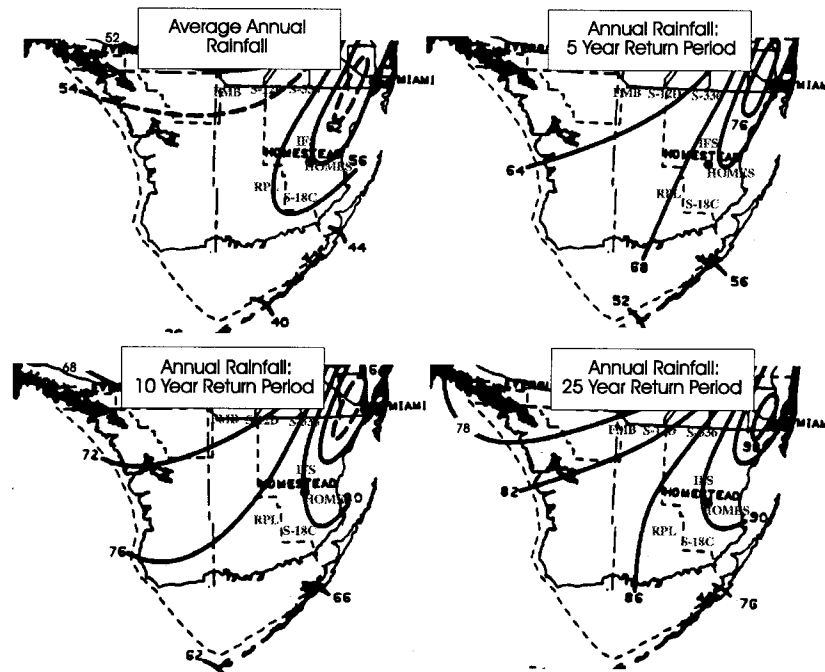


Figure 6: Annual rainfall frequency isohyetal maps [MacVicar, May 1981].

District, 1995] was approximately 58 inches or 150% of normal, consistent with the seasonal totals reported in Table 1. Monthly return periods for the stations in Table 2 during this period ranged from less than 2 to more than 30 years. Return periods for the wet season rainfall estimated from Fig. 5 for the stations used in Table 1 ranged from 5 to 10 years. The omission of May rainfall could extend this range to include the 1 in 25 year return period. Figure 7 shows the spatial extent of wet season rainfall in inches. It is evident that the areal extent of rainfall over the study area varied by approximately 20%. The variability occurred along a northwest-southeast diagonal between the northeast-southwest quadrants of the study area. Along this diagonal and in the northeast-southwest quadrants variability was less than 10%. Differences between the actual measured values in Table 1 and contours in Fig. 7 exist and result from the elimination of noise attributed to sources external to the rainfall data.

Hydrologic year 1996 began with below average early dry season rainfall. These less than average rainfall conditions persisted into the later months of the dry season. Late dry season rainfall compensated for these drier conditions resulting in a dry season total only 19% below average for Dade County

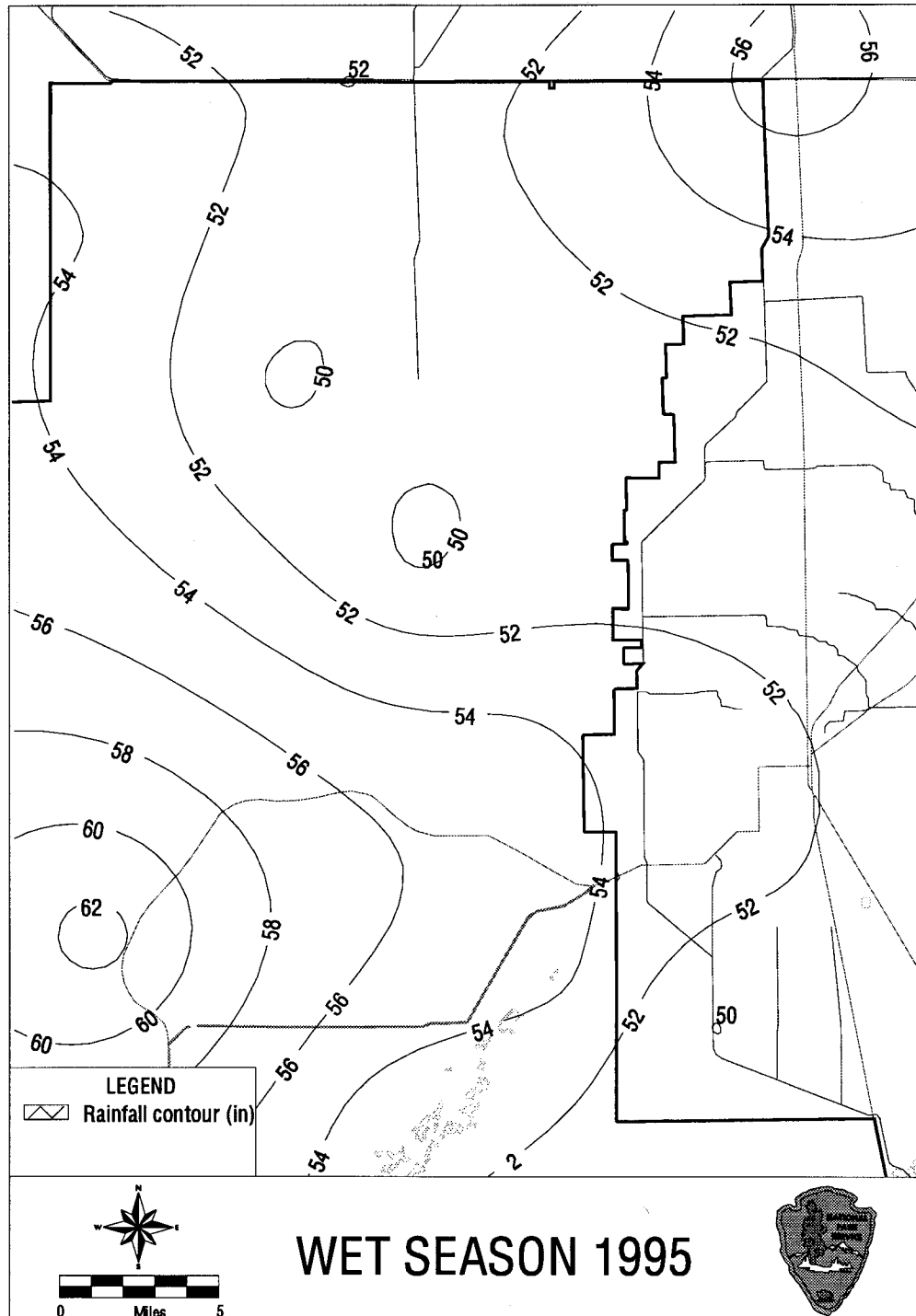


Figure 7: Rainfall contours in inches for wet season hydrologic year 1995.

estimated from the June 1996 SWCDR [South Florida Water Management District, 1996]. Dry season totals for the stations shown in Table 1 ranged from very dry to normal suggesting that the 1996 dry season could best be described as drier than normal. Monthly rainfall return periods for the stations in Table 2 during this period ranged from less than 2 to 7 years. Return periods for the dry season rainfall estimated from Fig. 4 for the stations used in Table 1 ranged from 2 to 10 years. Omitting May rainfall would lower the 1 in 10 year return period to approximately 1 in 5 years. The areal extent of 1996 dry season rainfall is shown Figure 8. Figure 8 indicates that less rainfall, approximately 30%, occurred in the interior of Shark Slough than in the Taylor Slough portions of the study area over the dry season. Dry season rainfall was also less in the Eastern Panhandle.

The 1996 wet season total reported in the October 1996 SWCDR [South Florida Water Management District, 1996] indicates average wet season rainfall occurred through Dade County. This Dade County rainfall is consistent with the wet season totals shown in Table 1. Monthly rainfall return periods for the stations in Table 2 during this period ranged from less than 2 to approximately 8 years. The return period for the wet season rainfall estimated from Fig. 5 for the stations used in Table 1 was 2 years or less. Inclusion of May rainfall would extend these return periods upwards to approximately a 1 in 5 year return period. Wet season 1996 rainfall contours shown in Figure 9 indicate a 25% increase in wet season rainfall from the northern study area to the more southern portions. This trend is not clearly evident by the 1996 wet season totals shown in Table 1.

3.1.1 General Observations

Rainfall during the wet season of hydrologic year 1995 was capable of producing very wet hydrologic conditions throughout the study area. Return periods determined for monthly rainfall during June and October 1995 at Forty Mile Bend (FMB) were 16 and 32 years, and corresponded to monthly totals of 17.39 and 12.03 inches, respectively. Other stations in Table 1 had June monthly totals ranging from 12.60 to 19.23 inches, with the upper values of this range being recorded at stations in the northern portion of the study area. October 1995 rainfall at other stations shown in Table 1 ranged from 10.85 to 12.03 inches. June and October rainfall for these stations contributed approximately 50% to the wet season total. Wet season contours indicate that the highest rainfall occurred in lower central Shark Slough. Return periods estimated for

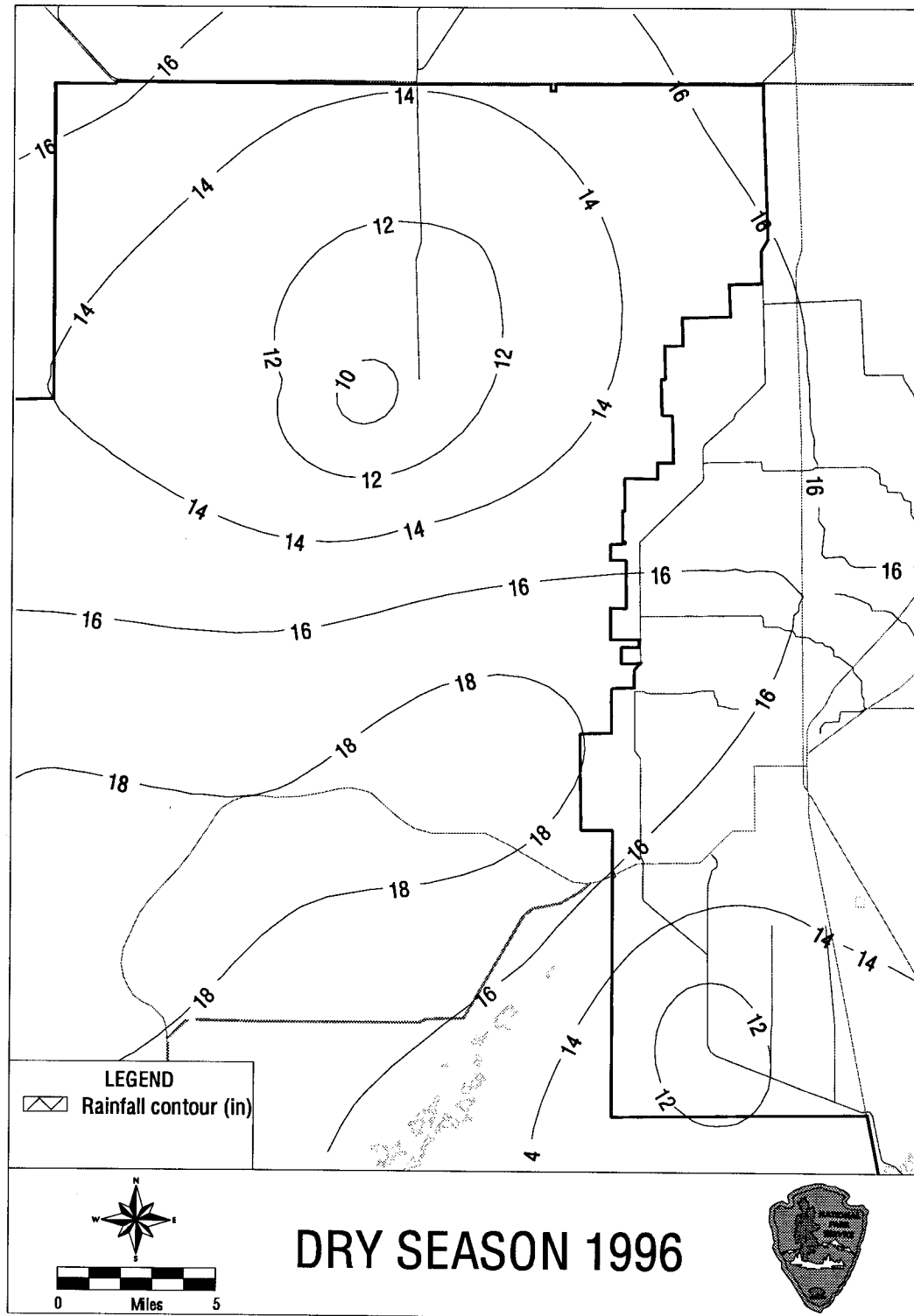


Figure 8: Rainfall contours in inches for dry Season hydrologic year 1996.

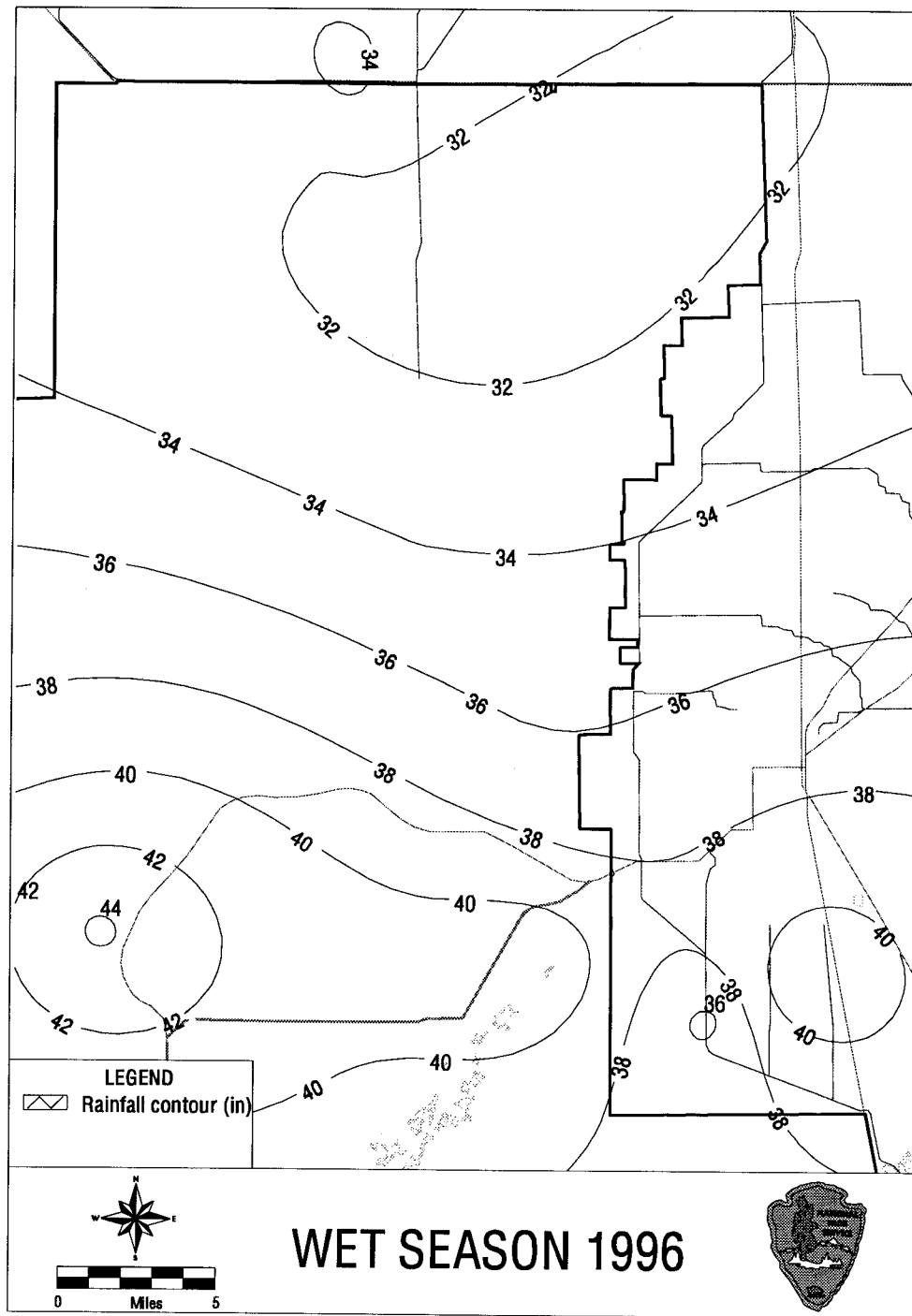


Figure 9: Rainfall contours in inches for wet season hydrologic year 1996.

wet season rainfall at these stations ranged from 10 to 25 years. Hydrologic year 1995 rainfall totals for stations shown in Table 1 were well above average. Return periods for this hydrologic year rainfall as estimated from Fig. 6 ranged from 5 to 50 years. The higher return period would have resulted if May 1995 had been included in the wet season totals.

The 1996 dry season rainfall varied spatially with respect to location within the study area. Lower than average rainfall occurred in the Eastern Panhandle and central Shark Slough regions of the study area. Return periods for monthly rainfall determined for stations shown in Table 2 indicate that on average, dry season monthly rainfall was less than 1 in 2 years. The lone exception was May rainfall having return periods ranging from approximately 3 to 7 years. The 1 in 7 year May rainfall was recorded at FMB and corresponds to 9.11 inches of rainfall. The return period for 1996 dry season rainfall for the stations shown in Table 1 were estimated to be approximately 1 in 2 year when May rainfall was excluded from the dry season totals.

Test 7 year 1 wet season rainfall began with average to below average rainfall in June, followed by similar variable monthly rainfall through the September. Return periods during this period were generally 1 in 2 years for the stations shown in Table 2. October monthly rainfall of 9.39 inches recorded at Royal Palm corresponded to a return period of 8.28 years. IFS reported October rainfall having a return period less than 1 in 2 years, while totals for the same month at FMB resulted in a return period of 1 in 6 years. The 1996 wet season rainfall could be described as average with an estimated return period of less than 1 in 2 years for the station totals shown in Table 1. The first year of Test 7, hydrologic year 1996 concluded with less than average annual rainfall in the south and average annual rainfall in the north of the study area, both with estimated return periods of less than 1 in 2 years.

3.2 Shark Slough Watershed

Water deliveries into the Shark Slough watershed are made according to the Rainfall Plan described in Appendix A.1 by Neidrauer and Cooper [1989] of the South Florida Water Management District (SFWMD). The quantity of the water deliveries derived from this plan is determined weekly and consists of two components: a rainfall base component and a supplemental component. The rainfall component is derived from the rainfall over Water Conservation Area 3A. The supplemental component is based on the current average weekly

stage in Conservation Area 3A reservoir. The regulation levels attempt to incorporate flood operations and adjustments for seasonal variations in water levels in the area.

Water deliveries into Shark Slough originate directly from upstream WCA-3A. This reservoir receives water from local rainfall as well as the other conservation area's, Lake Okeechobee, Mullet Slough, and the Everglades Agricultural Area (EAA). During high rainfall periods, inflows from these areas contribute significant quantities of water to WCA-3A. The subsequent increase in water levels in the conservation area may result in increased quantities of the supplemental component when compared to the rainfall component of the total Rainfall Plan water releases to ENP.

During the minimum delivery schedule period (1970 through 1983), the water deliveries to Shark Slough averaged approximately 430,000 acre-feet annually. During this period, all surface water was delivered to western Shark Slough through the four S-12 structures along Tamiami Trail (see Fig. 1). Under the operations prescribed by the Rainfall Plan (1985 through 1995), Shark Slough averaged approximately 804,200 acre-feet. Average annual rainfall recorded at Tamiami Rangers station for the earlier period was 52.1 inches. The later period average annual was 57.4 inches. Although a major focus of the Experimental Water Deliveries Program has been to re-establish flow to NESS, less than 35 percent of the flow during this period passed into the Northeast Shark Slough portion of the basin. The period of record surface water deliveries to Shark Slough and distribution of flow is shown in Figure 10. Clearly, there is a large, disproportionate distribution of flow between Western and Northeast Shark Slough. This trend began in the mid 1960's and has continued through both Test 6 and Test 7.

During the 1993 through 1995 period associated with Test 6, high rainfall and inputs resulted in record high water levels in WCA-3A. These levels subsequently resulted in record high discharges to Shark Slough. Total surface water flow to Shark Slough for hydrologic years 1993 through 1995 was 4,990,000 acre-feet with less than 18% entering the historic conduit of Northeast Shark Slough. These discharge conditions were very evident during hydrologic year 1995 of Test 6 when a total of 2,558,000 acre-feet was delivered to Shark Slough and only 3% of this total was delivered to Northeast Shark Slough. Surface water flows during Test 7 totaled 1,329,700 acre-feet to Shark Slough with a nominal 14% entering NESS.

Prior to Test 6, regulatory inflows into western Shark Slough were confined

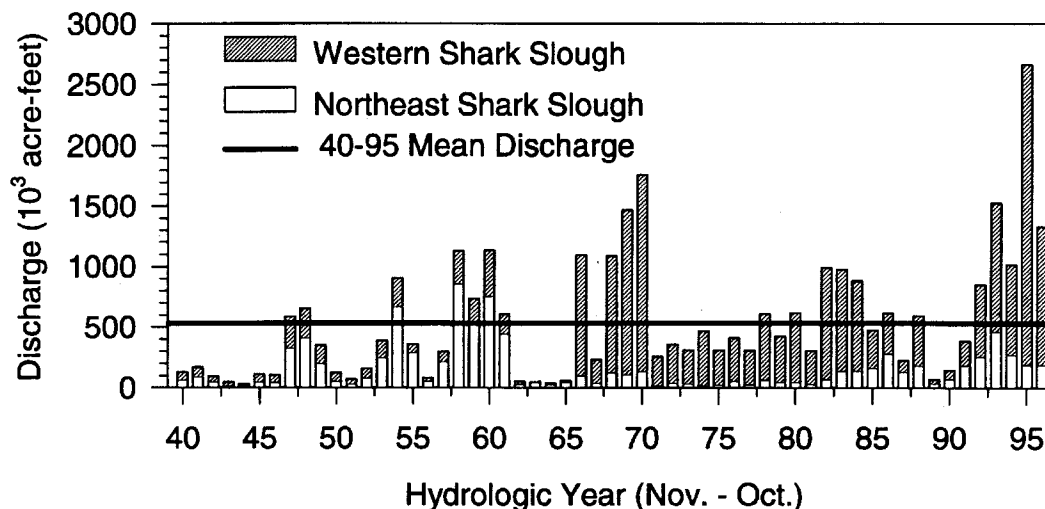


Figure 10: Period of record annual surface water deliveries to Shark Slough.

to periods of approximately three to four months during the peak of the wet season. During hydrologic year 1995 of Test 6, high WCA-3A stage resulted in large supplemental flood releases throughout the dry season. The regulation schedule and flows to Shark Slough for hydrologic year 1995 of Test 6 and for Test 7 are shown in Figure 11. The top plot shows WCA-3A average stage for hydrologic year 1995 with the WCA-3A regulation schedule. Supplemental flows to ENP occur whenever the WCA-3A average stage exceeds the bottom zone or zone E (lower dashed line). Supplemental inflows increase at a rate of 2,500 cfs for each foot that the WCA-3A average stage exceeds the zone E water level. Under this plot is the weekly discharges into Shark Slough for Test 6 during the same period. The discharges are divided into the rainfall formula and supplemental flow components to illustrate how the supplemental component dominated the overall total discharges during this time period.

During Test 7 (hydrologic year 1996) large supplemental flood releases to Shark Slough continued. The Test 7 discharge hydrographs are shown in Fig. 11 in the lower two plots. These two plots show WCA-3A average stage and the weekly discharges into Shark Slough during Test 7. During this period, water levels in WCA-3A exceeded regulation levels for approximately eight months resulting supplemental flows of 873,980 acre-feet to Western Shark Slough accounted for more than 70 percent of the total Shark Slough surface water deliveries. Northeast Shark Slough flows were less than 40% of those specified by the rainfall formula.

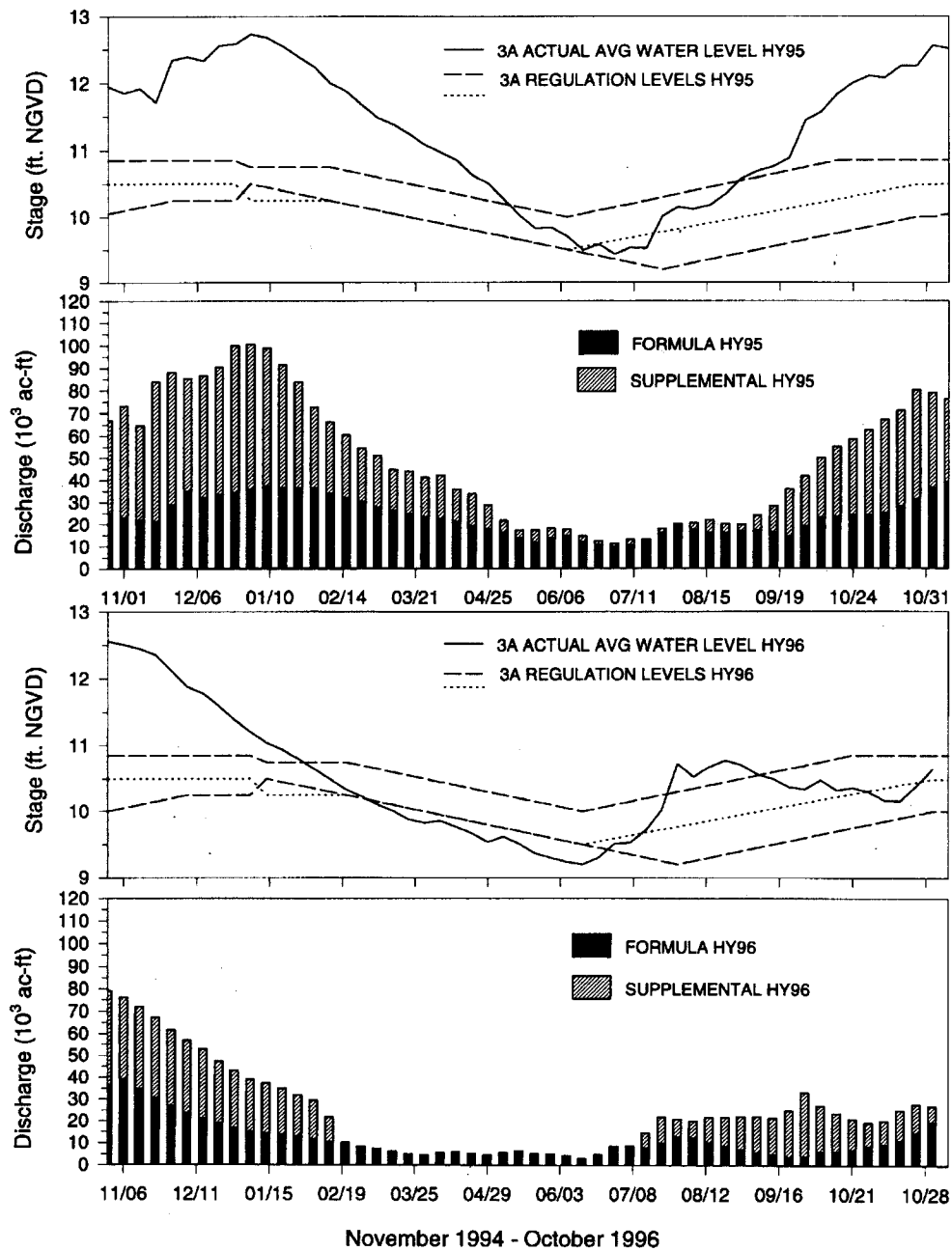


Figure 11: WCA-3A regulation schedule and Shark Slough flows.

Figure 12 shows the distribution of weekly surface water inflows delivered to the Western and Northeast Shark Slough flow sections during the hydrologic years 1995 (Test 6) and 1996 (Test 7-year 1). The actual weekly flow to each flow section is represented by bars while the curved lines represents the target flows specified by the Rainfall Plan. These quantities correspond to the historical distribution of flow within the basin and as specified in the Rainfall Plan are targeted at 55% into Northeast Shark Slough and 45% into Western Shark Slough. The existing discharge capacity of S-333 (1350 cfs) coupled with the operational constraints that are in effect to protect the developed areas of the East Everglades make it impossible to meet the current Rainfall Plan targets under conditions such as Test 6 and Test 7.

Inflows into the Northeast Shark Slough basin are controlled by the operational criteria put into place to protect the 8.5 Square Mile Area (8.5 SQMA). Fig. 13 show weekly NESS inflows via S-333 for hydrologic year 1995 Test 6 and Test 7. The two limiting operational criteria for inflows are also shown in Fig. 13. S-333 inflows into Northeast Shark Slough are halted when the S-333 tailwater exceeds 7.5 feet, and/or groundwater levels at the G-3273 trigger well exceed 6.8 feet. During hydrologic year 1995 of Test 6 S-333 inflows were limited by a combination of both S-333 tailwater and G-3273 water level conditions for approximately 10 months. G-3273 water levels exceeded 6.8 feet in late August 1994, and did not drop below criteria until March 1995. Weekly inflows remained at or above 5,800 acre-feet, for a brief 13 week period during the 1995 dry season before the discontinuation of S-333 operations until late January 1996. S-333 flows resumed in January 1996 following a 32 week absence, due to a combination of water levels in L-29 and at G-3273.

Weekly S-333 inflows during the 1996 dry season were approximately 5,000 acre-feet with wet season flows averaging approximately 3,200 acre-feet. Closure of S-333 occurred in mid-September 1996 due again to a combination of water levels in L-29 and at G-3273 responding to basin wide rainfall.

3.2.1 Water Levels in Western Shark Slough

A combination of above average rainfall and large supplemental releases through the S-12 contributed to the persistence of high water levels in the marshes of western Shark Slough. As a result of these releases, water levels in western Shark Slough remained high during hydrologic year 1995 of Test 6 and throughout the first year of Test 7. Hydrologic year 1995 of Test 6 and

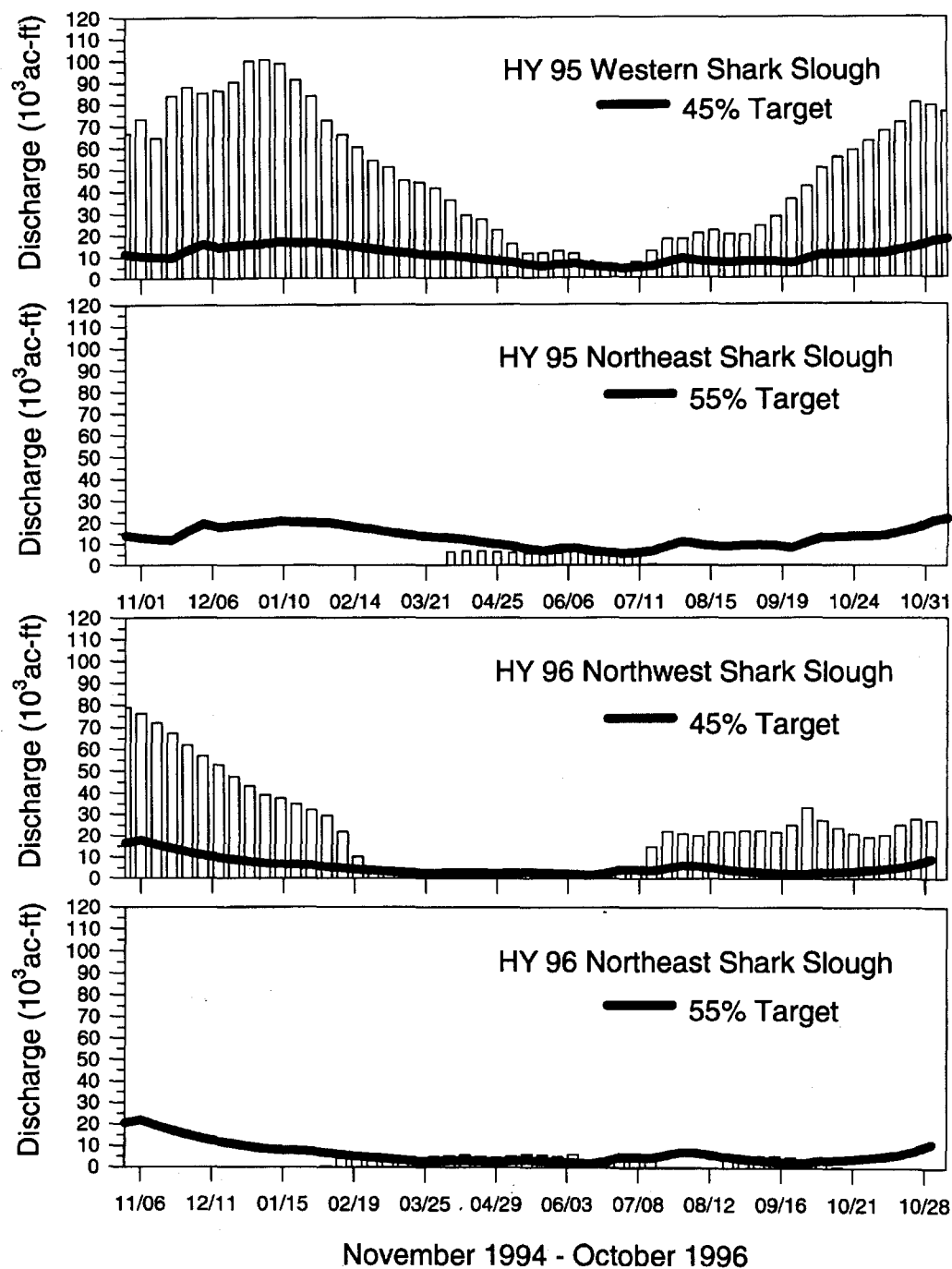


Figure 12: Flow distribution between western and Northeast Shark Slough.

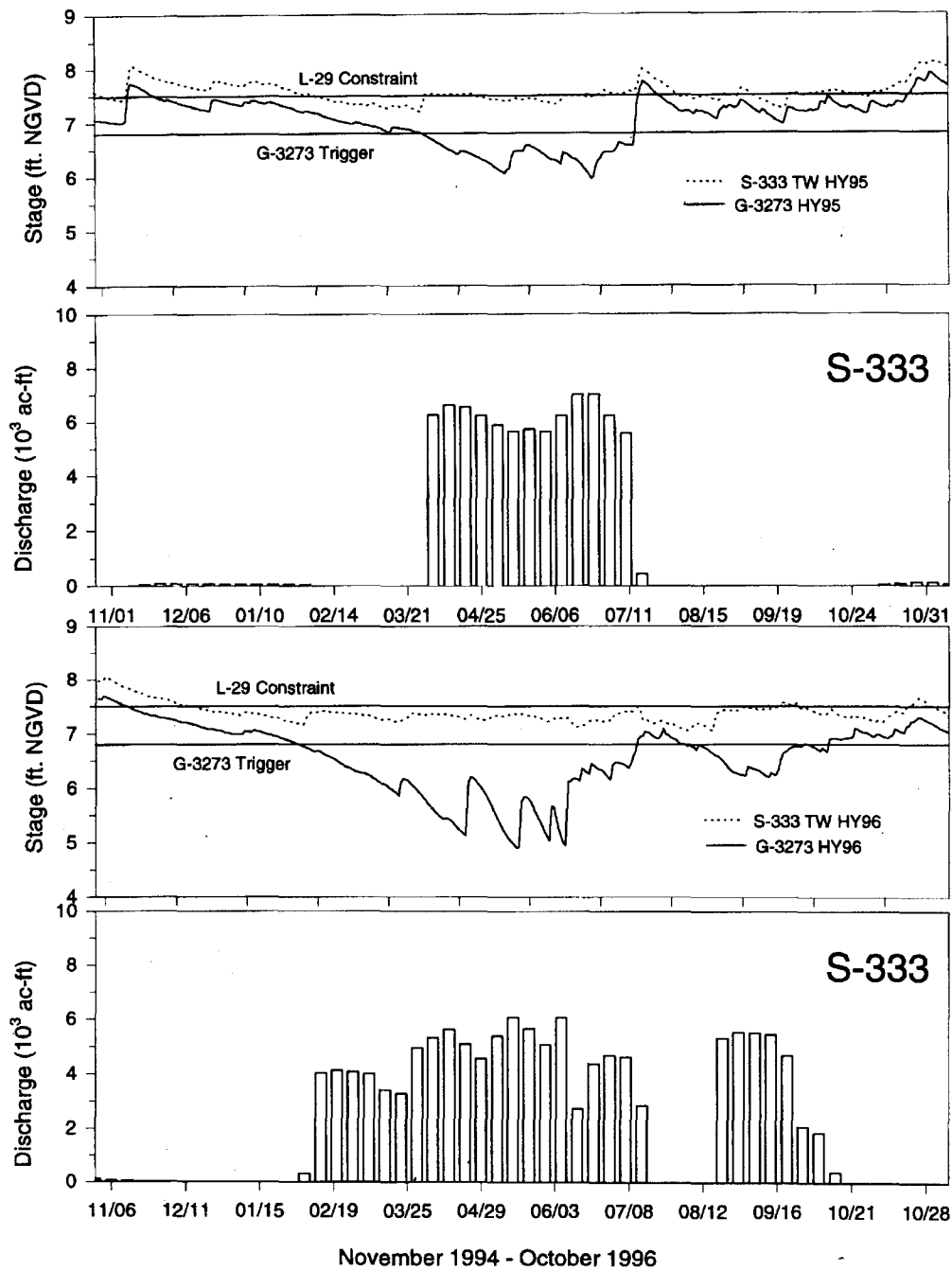


Figure 13: Hydrologic year Test 6 and Test 7 Northeast Shark Slough inflows with water levels S-333TW and G-3273.

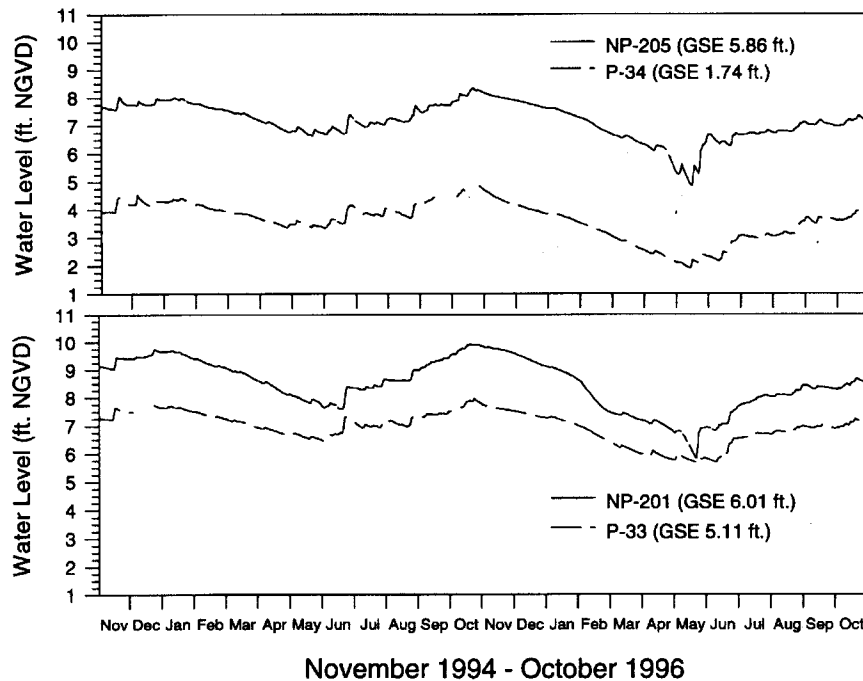


Figure 14: Water levels at NP-205, P-34, NP-201 and P-33.

Test 7 water levels for western Shark Slough stations NP-205 and P-34 are shown in the top two plots of Fig. 14. Water level plots for the same period for central Shark Slough stations NP-201 and P-33 are shown in the bottom plots of Fig. 14. The plots show water levels at these stations was sufficient for them to remain inundated through both periods. Large surface water discharges through the S-12 structures, in conjunction with above average rainfall in the western Shark Slough basin, resulted in similar surface water inundation patterns within these peripheral wetland areas of the slough. These conditions have persisted since the onset of the high water conditions beginning in 1992.

Hydroperiods for hydrologic year 1995 of Test 6 and Test 7 were determined using the average monthly stage for these stations. Each of these stations were determined to have an approximate 12 month hydroperiod in both hydrologic year 1995 and Test 7 (year 1). The average hydroperiods for sites P-33 and P-34 for the period 1954 through 1996 were 11 and 7 months, respectively. The higher hydroperiods during the Test 7 period highlights the concerns associated

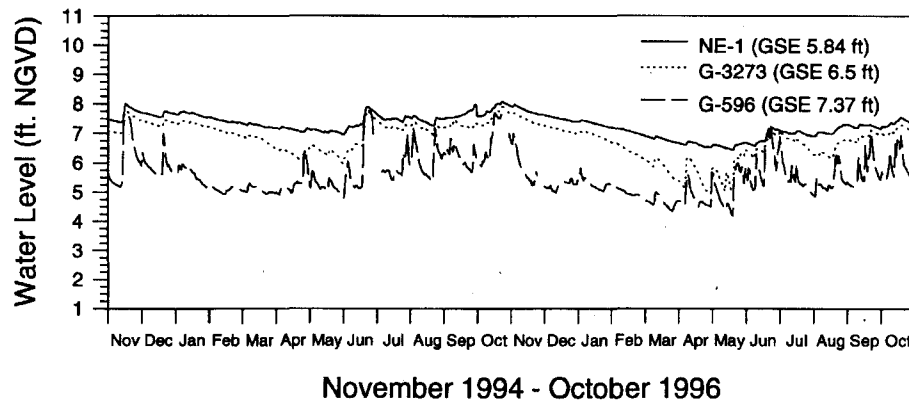


Figure 15: Water levels at NE-1, G-3273, and G-596 during hydrologic year 1995 and 1996.

with the large supplemental water releases during high rainfall periods on the peripheral western Shark Slough wetlands inhabited by the endangered Cape Sable Sparrow. Although attempts were made to curtail the quantities of surface water being delivered to this area during Test 7, these efforts occurred too late to appreciably effect the lowering of water levels within the area.

3.2.2 Water Levels in Northeast Shark Slough

Northeast Shark Slough is the area of the lowest ground surface elevations; therefore, this area historically had the deepest water depths and the longest hydroperiods of any region within the slough. A combination of factors influence the surface water conditions in NESS including local rainfall, seepage from WCA-3B into L-29 and under the Tamiami Trail, seepage from NESS eastward into L-31N, flows around and beneath the L-67 extension canal, flows through culverts in L-67 extension as well as inflows from Conservation Area 3A via S-333. Water levels in the northern and more eastern portions of NESS are influenced by the criteria associated with operations of the L-31N and L-29 canals. Fluctuations in water levels in Northeast Shark Slough and Rocky Glades due to local rainfall and the operation of these canals can be characterized by water levels recorded at stations NE-1, G-3273 and G-596 (see Figure 2).

It is evident during the 1995 and 1996 hydrologic years that NE-1 water

levels responded to local rainfall but further increases in water levels at this site were attenuated during the high water episodes of these years by the 7.5 ft-msl water levels in the L-29 canal. Water levels at G-3273 and G-596 both show similar characteristic responses to local rainfall, and being closer to L-31N are influenced by the maintenance of L-31N canal water levels between S-331 and G-211. The influences of L-31N operations on water levels at G-596 are more noticeable during the dry then wet season. During the periods when NESS water levels are relatively high, substantial water level gradients between these marshes and the L-31N canal are created. These gradients result in large groundwater seepage into L-31N canal.

The maintenance of 7.5 ft-msl canal stages in the reach between S-333 and S-334 also affected the hydroperiods at sites within the Northeast Shark Slough. Hydroperiods determined using average monthly data for NE-1 and G-3273 were 12 months and 10 months, respectively for hydrologic year 1995 of Test 6. During Test 7, the hydroperiods at these same sites were 12 months and 7 months, respectively. The reductions in hydroperiod at G-3273 during Test 7 could partially be attributed to a combination of lower rainfall and discharges to the area coupled with seepage losses from the area associated with the management of water levels in the L-31N canal.

A direct graphical comparison of the water conditions in the West Shark Slough and the Northeast Shark Slough during hydrologic years 1995 and 1996 is depicted in Figure 16. The data plotted in this figure represent the water levels attained at similar points along the north-south alignment of the slough. The sites in Western Shark Slough (S-12B TW, NP-201, and NP-203) exhibited overall higher water levels with relatively steep water level gradients between the sites when compared to the sites in Northeast Shark Slough. The latter sites had similar overall levels attained and corresponding shallow water level gradients. It is again evident from these data that the high discharges into Western Shark Slough, and the coincident lower water releases into Northeast Shark Slough in conjunction with the high seepage losses from the area, resulted in very different water level regimes for the two areas.

3.3 L-31N Watershed

The losses from NESS through seepage into and eastward beneath L-31N are controlled through the operation of S-338 and G-211. In 1991, the SFWMD completed construction of the G-211 structure in the L-31N canal just up-

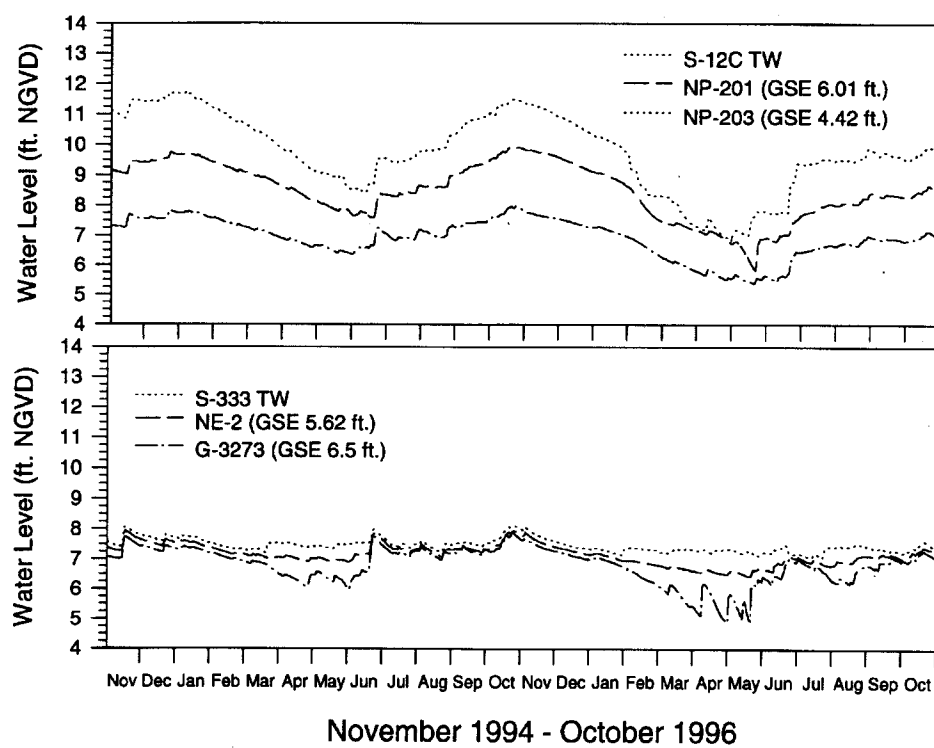


Figure 16: Water levels in Western Shark Slough represented by S-12B tailwater, NP-201, and NP-203 and in Northeast Shark Slough by S-333 tailwater, NE-2 and G-3273 during hydrologic year 1995 and 1996.

stream of the northern edge of the 8.5 SQMA, as part of the C-111 Interim Plan. This structure was designed to be kept closed as much as possible during periods of S-331 pumping to limit the drainage impacts in Northeast Shark Slough. To accomplish this objective, the operational levels upstream of G-211 were to be held as high as 6.0 feet in an attempt to limit the water losses from the adjacent wetlands. Figure 17 (top) depicts the L-31N levels attained between November 1994 and October 1996 at the headwater of structures S-338 and G-211. The middle and lower graphs represent the weekly discharge totals for these same structures. As seen in this figure, flows from structure G-211 during most of the late Test 6 and much of the Test 7 periods were minimal.

At the onset of the dry season of 1995 (November 1994-May 1995), weekly discharges through both structures, S-338 and G-211, were made in an attempt to control the high water levels in the L-31N canal upstream of Structure G-211. Weekly volumes through S-338 remained between 2,500 and 4,500 acre-feet throughout much of the period between November 1994 through October 1996. These operations were conducted to maintain the water levels within this reach of the L-31N canal at or below the 6.0 ft-ngvd upper operating limit. The only extended period of time when S-338 was not releasing water during this period was during the months of February through May 1996 when water levels in the canal reach were considerably below the lower limit of the operating criteria of 5.5 ft-ngvd. However, during this period of time considerable water was released through G-211 to meet downstream water supply requirements.

The operation of these two structures for control of water levels in the L-31N canal has an impact on the hydrologic conditions within the expansion area of Everglades National Park. The continued operation of S-338 to discharge water from the upper reach of the L-31N canal allowed for the removal of approximately 40,000 acre-feet of water from the marshes of Northeast Shark Slough during the months of November-February 1996. When S-338 releases were stopped in March 1996, G-211 releases were initiated which resulted in an additional 30,700 acre-feet of water being removed from the wetlands of Northeast Shark Slough. These volumes are detailed in subsequent portions of this section of the report. Operations of the two structures in tandem for the dual purposes of water supply and flood control exemplify the effectiveness of these structures can be in controlling adjacent water level conditions in Northeast Shark Slough.

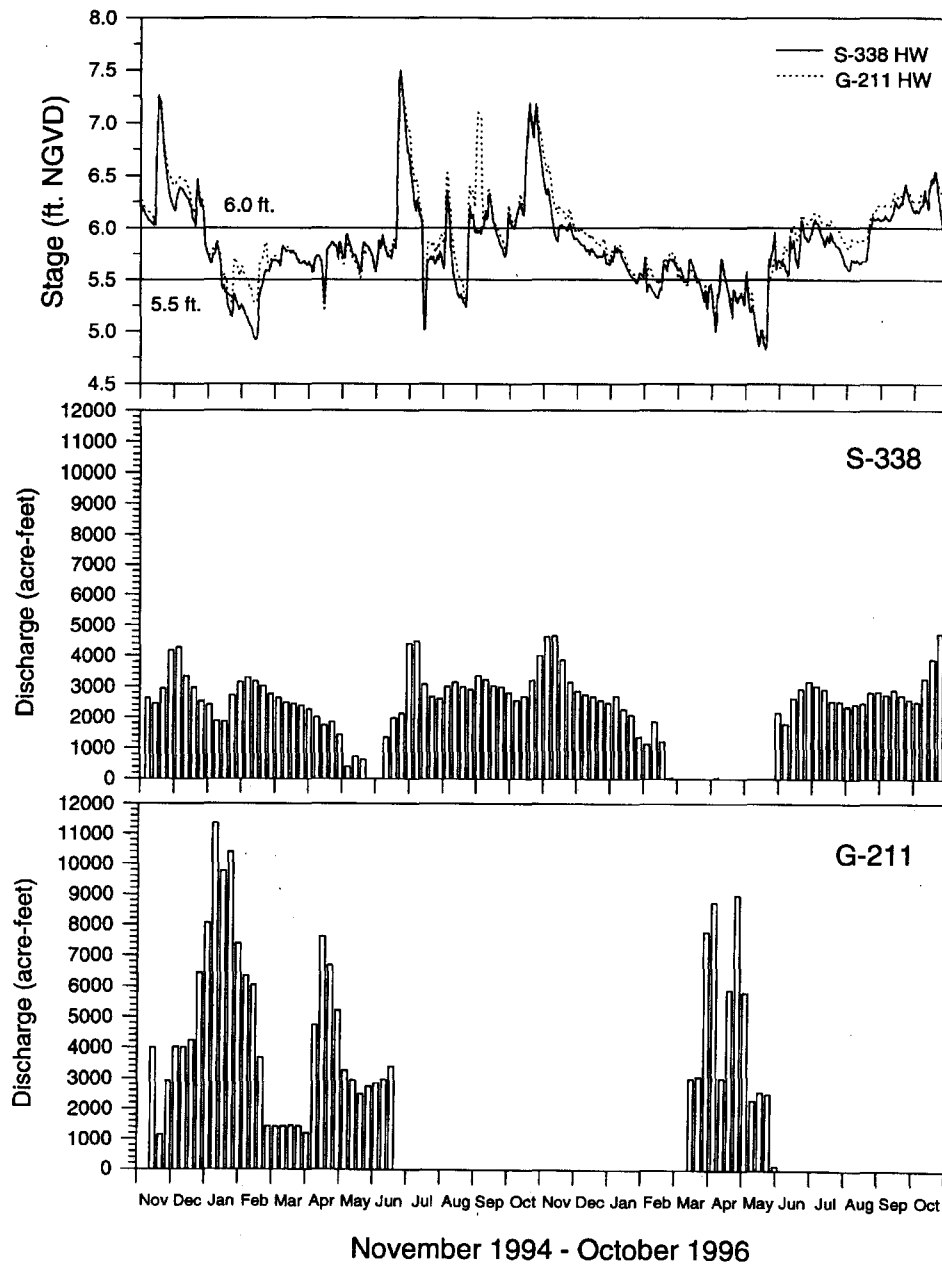


Figure 17: Operations and water levels at G-211 and S-338.

3.3.1 Water Levels in the East Everglades

Water levels in the developed portions of the East Everglades, including the 8.5 SQMA, respond to local rainfall, water management operations in adjacent L-31N canal, and to a lesser extent, antecedent hydrologic conditions in Northeast Shark Slough resulting from the introduction of surface water flows via S-333. Fig. 18 shows water levels at the two East Everglades trigger wells (G3273 and Angels wells) with L-31N stage above S-331, rainfall at S-336 and weekly S-333 flows. A close examination of water levels at the trigger wells during these two years shows little evidence of direct responses to S-333 releases. During the periods of continuous and uniform S-333 inflows, March through May 1996, water levels at G-3273 and Angels well responded more closely to variations in rainfall as opposed to S-333 inflows. During several periods of continuous and uniform S-333 inflows from March through May in both hydrologic year 1995 and 1996, water levels at the trigger wells were receding during periods of S-333 inflows, apparently in response to the lack of local rainfall inputs and L-31N operations. Similar rainfall responses were noted during early November 1994 and June 1995, when water levels at these sites fluctuated in response to rainfall events associated with tropical storms.

3.3.2 Water Levels in the Rocky Glades

To the southeast of Northeast Shark Slough, on the higher elevation Rocky Glades water levels are influenced by local rainfall, water levels of Shark Slough and L-31N operations. The wetlands and aquifer adjacent to the reach of L-31N from S-331 to S-176 has resulted in long term modifications to the water levels at well S-196A shown earlier (Figure 3). Operations of this section of the canal reach has effectively eliminated the extremes of the hydrograph to conform to levels more conducive to agricultural and urban development. Other representative gages within this area of L-31N are G-3437 and G-1363. The former station is located on the edge of the eastern ENP boundary in the vicinity of agricultural activities while G-1363 is located east of L-31N between C-102 and C-103. These two sites are also distinguished by G-3437 being located in an area not afforded the same level of flood protection as G-1363 site. The latter site is located east of the protective canal and levee system while the former is west of the protective levee. Stage hydrographs for these two stations are shown Fig. 19 and are indicative of the regional easterly groundwater gradient established between ENP and the developed areas east

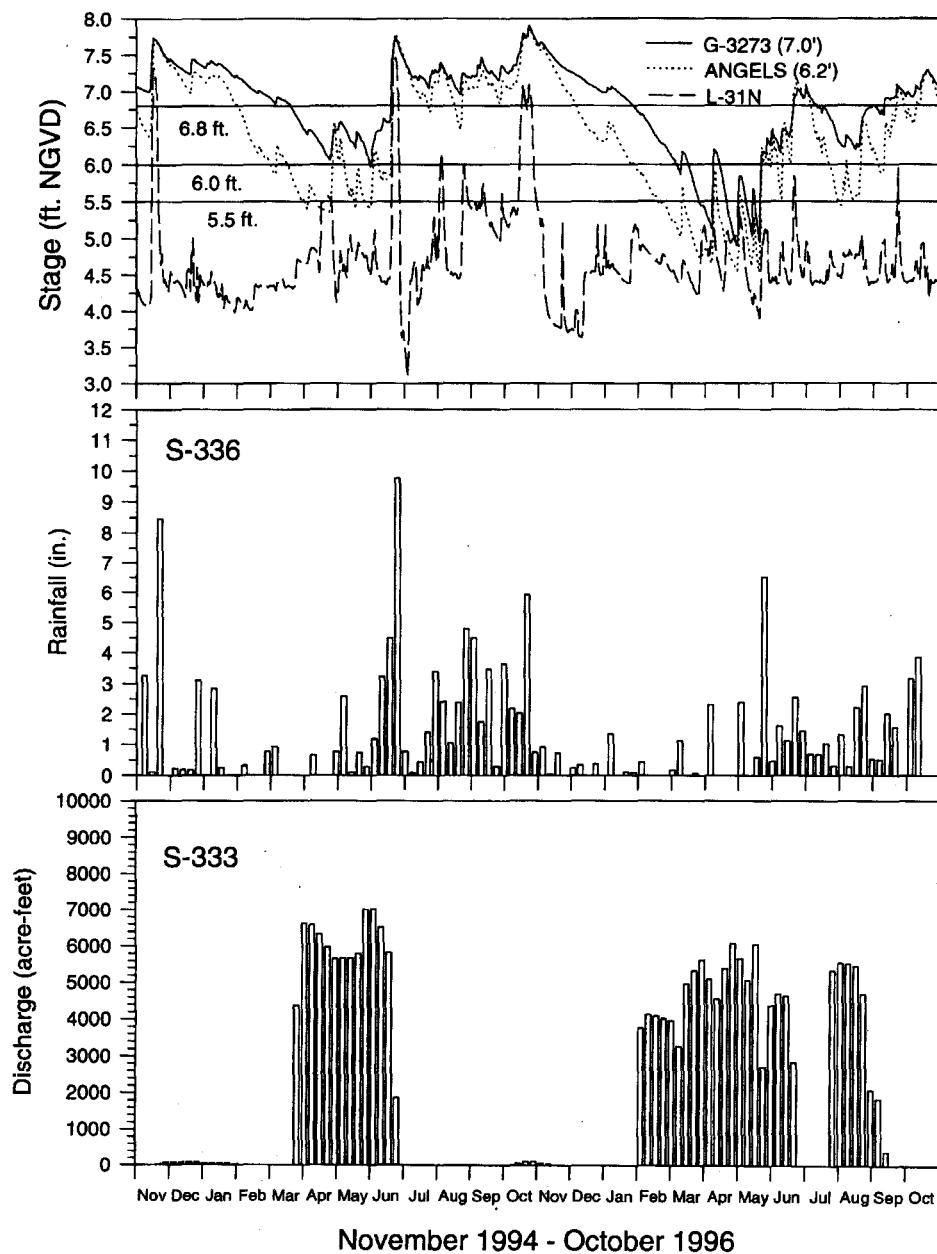


Figure 18: G-3273, Angels and L-31N water levels, average rainfall and S-333 flows during hydrologic years 1995 and 1996.

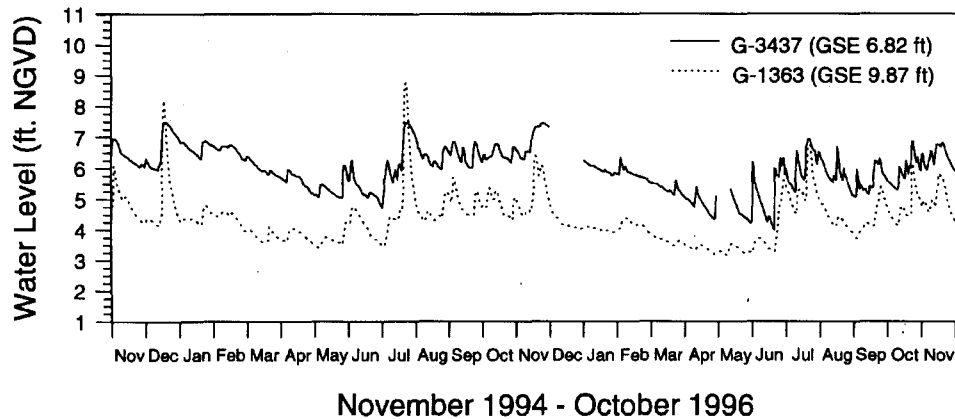


Figure 19: Water levels at G-3437 and G-1363.

of the canal system. This easterly groundwater gradient results in a sustained loss of water from ENP.

The large easterly groundwater flows are a result of the maintenance of low water levels upstream of structures, S-165 and S-167, in the C-102 and C-103 canals, respectively [Everglades National Park, 1995a]. The lowering of regional groundwater levels, caused by low L-31N canal levels, has eliminated surface water in the peripheral wetlands west of the Eastern Protective Levee System. The shortening of hydroperiods to below those of a functioning Everglades wetland, is evident in the stage hydrograph of G-3437 shown in Fig. 19. It is only during periods with above average rainfall occurring in successive years, coincident with large quantity short duration rain events, that surface water conditions are established at G-3437. However, these surface water conditions and the resultant water storage prevail for only very short durations. It is this removal from storage through lowered operational stages in the L-31N canal system that has resulted in the loss of sustained flows within the western wetlands and the subsequent alterations in hydroperiod and hydropatterns within these portions of the remnant Everglades.

3.4 Taylor Slough and L-31W

The overdrainage of Taylor Slough and its peripheral wetland areas due to past water management operations of the L-31W canal has resulted in significant alteration to both hydroperiod and hydropatterns of northern Taylor Slough.

The L-31W canal was built originally for water supply for Taylor Slough, flood protection for areas east of L-31N above S-174 and protection of areas east of C-111 from surface waters. More recently the L-31W has been utilized for flood operations to sustain agricultural activities in the Frog Pond, located immediately east of Everglades National Park. These water management operations of L-31W have negatively impacted Taylor Slough wetlands [Wagner *et al.*, 1985], [Johnson *et al.*, 1988], [Johnson and Fennema, 1989] and [Everglades National Park, 1995b]. Due to the ecological declines observed in both Taylor Slough and downstream Florida Bay, corrective measures were initiated during Test 6 in an attempt to reverse these observed trends. The Test 6 criteria allowed for the implementation of a rainfall plan for Taylor Slough. This plan utilized local rainfall within the basin to determine the target stage in the L-31W canal. During Test 6 water levels in the L-31W canal were allowed to fluctuate between a dry season optimum of 3.5 ft-ngvd to a wet season upper limit of 4.7 ft-ngvd. With the acquisition of the Frog Pond in 1995, the dry season S-175 criteria were removed, replaced with a single year-round criteria. During Test 7 L-31W water levels during fluctuated according to the rainfall plan between 3.0 and 4.7 ft-ngvd. The lower limit was established to compensate for the truncation of target levels above 4.7 ft-ngvd. The combination of the these operational criteria produced water levels in the L-31W canal which more closely followed the management criteria rather than being indicative of water levels allowed to fluctuate according to climatologic variability within the basin.

3.4.1 Rainfall Formula

The L-31W rainfall formula is a statistical model relating rainfall to water levels within the basin. Prior to the actual development of the statistical model, a rainfall period and location at which the stage was to be predicted needed to be identified. The current model utilizes rainfall at the SFWMD Homestead Field Station to calculate a stage response for the headwater at S-175 using a 1970-1982 rainfall data set to determine the model coefficients. An evaluation, Van Lent on rainfall patterns during this time period indicates that the rainfall for this period may represent a lower than historical rainfall total [Van Lent, 1995]. This report recommended the time period 1933 to 1947, determined to be a more representative of historical rainfall.

The upper plot of Figure 20 illustrates the differences between predicted S-175 headwater stages during hydrologic year 1995 of Test 6 and Test 7 us-

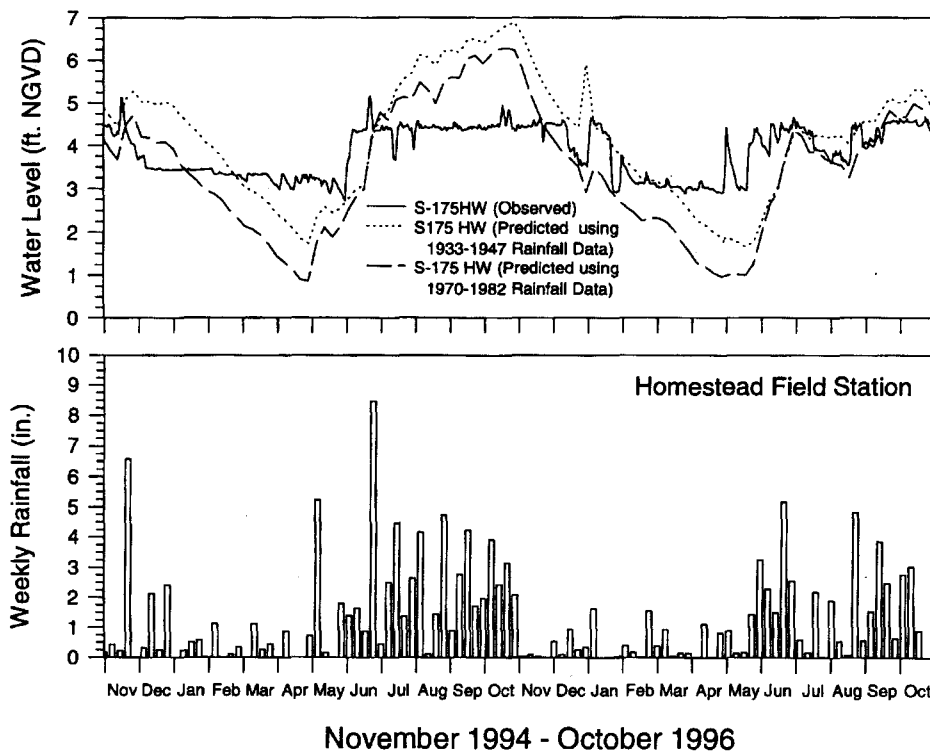


Figure 20: Predicted S-175 headwater (ft.) from the Taylor Slough Rainfall models, actual S-175 headwater (ft.) and weekly rainfall at Homestead Field Station (inches).

ing both models for the two rainfall periods, 1933-1947 and 1970-1982. Also shown in the Fig. 20 is the actual S-175 headwater stage during the Test periods along with the actual rainfall at the Homestead Field Station used as input for the target L-31W stage values. Examination of Figure 20 shows that for the majority of the 1995 wet season of Test 6 and 1996 dry season of Test 7 both models predicted a target L-31W stage above the 4.7 ft-ngvd operational limit and also values below the 3.0 ft-ngvd lower operational constraint. Additionally, the figure also indicates that the model utilizing the 1933-1947 rainfall data consistently predicts S-175 headwater stages approximately 0.5 ft higher than the model utilizing the 1970-1982 rainfall data. The higher water levels attained as a result of the use of the 1933-1947 rainfall period model allows for the extension of approximately one month before the imposition of the 3.0 ft-ngvd lower operating limit on L-31W stage. Also present in both models is a lag of several weeks from the onset of wet season rainfall and the peak response in stage. This lag in the stage response to rainfall is not evident

when water levels are below ground surface.

The above average rainfall during the 1995 wet season of Test 6 is very prominent in both the model outputs. The 4.7 ft-ngvd L-31W operational stages required to maintain flood protection was approximately 2 feet lower than the L-31W targets predicted by either of the models. The 1970-1982 model period stage targets exceeded the upper L-31W operational constraint approximately 29% of the time for the period covering hydrologic year 1995 and Test 7. During this same period predicted stages were less than the lower bound, 3 ft-ngvd, approximately 17% of the time. In marked contrast, the model developed using the 1933-1947 rainfall period resulted in stage targets which would have exceeded the upper L-31W constraints more than 48% of the time and the lower limit by only approximately 8% of the time for the same period.

3.4.2 Water Levels in Northern Taylor Slough

Water levels in northern Taylor Slough should be a result of natural climatologic variability within the basin. If the rainfall formula for Taylor Slough were implemented without the operating constraints associated with the L-31W canal, the hydrograph should resemble the model output as presented in Figure 20. Previous investigations ([Everglades National Park, 1995b]) have focused on water levels close to L-31W such as NTS-1 and more distant sites including R-3110 to explain the water level conditions within the northern Taylor Slough portion of the basin. With the additional pump capacity at S-332 added during Test 6, difficulties arose in the use of water levels at station NTS-1 because of its proximity to S-332. NTS-1 is located only approximately 1000 feet west of L-31W and approximately 0.5 mile north of S-332. This places the site within the area influenced by the S-332 discharges. Prior to the increases to the capacity of the S-332 pump station, NTS-1 was very useful in showing the effect of L-31W operations on wetland water levels immediately adjacent to L-31W.

The increased capacity has allowed for improved hydrologic conditions within the immediate vicinity of the pump station but the overriding effects of the canal operational constraints are still evident at the more distal sites. R-3110 located approximately 12,000 ft west of the L-31W canal and 2.5 miles northwest of S-332 remains outside the direct influence of the pump station. Prior to the current test iteration, increases in R-3110 water levels in response

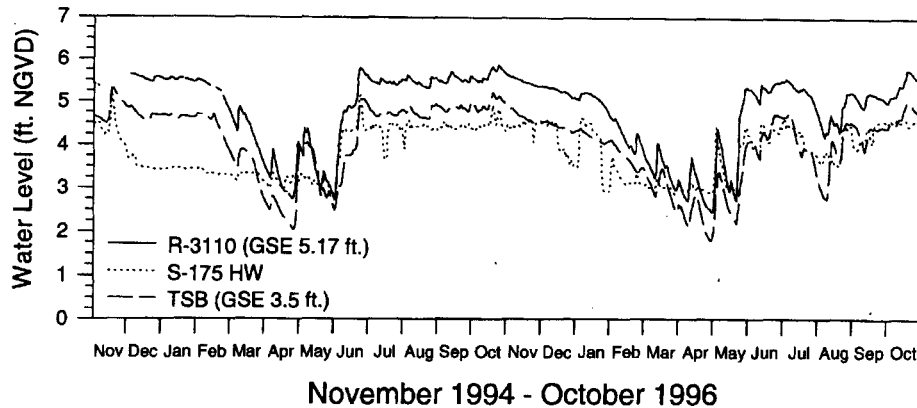


Figure 21: Water levels at R3110, TSB, and S-175 headwater.

to rainfall were quickly damped due to large eastward flows created by water level gradients established between R-3110 and the lower water levels in the L-31W canal. Additionally, the artificial dry season drawdowns in L-31W to 3.5 feet caused any surface water at R-3110 to be lost early in the dry season. Inadequate local or regional surface and ground water storage and large seepage losses prevented these wetlands from attaining functional hydroperiods and hydropatterns [Everglades National Park, 1995a].

The high rainfall of hydrologic year 1995 make it difficult to distinguish between the effects of this rainfall event and the implementation of the Taylor Slough rainfall plan. Stage hydrographs for R-3110, TSB and S-175 headwater are shown in Fig. 21. The characteristic hydrograph shape predicted by the rainfall plan evident in Fig. 20, is not evident in the stage hydrographs of either R-3110 or TSB during the 1995 wet season. During this period Taylor Slough stage appear limited by the 4.7 ft-msl upper limit on L-31W stage. The resulting hydrograph at each of these sites is more indicative of the L-31W operating criteria rather than resulting from the implementation a plan based on natural climatological variability. The figure also illustrates the close link of the S-175 headwater stage, including the lower and upper operating constraints, has on water levels at TSB and R-3110.

3.4.3 Water Levels in Southern Taylor Slough

Water levels in southern Taylor Slough can be characterized through the evaluation of water level fluctuations at stations R127 and P37. Water levels

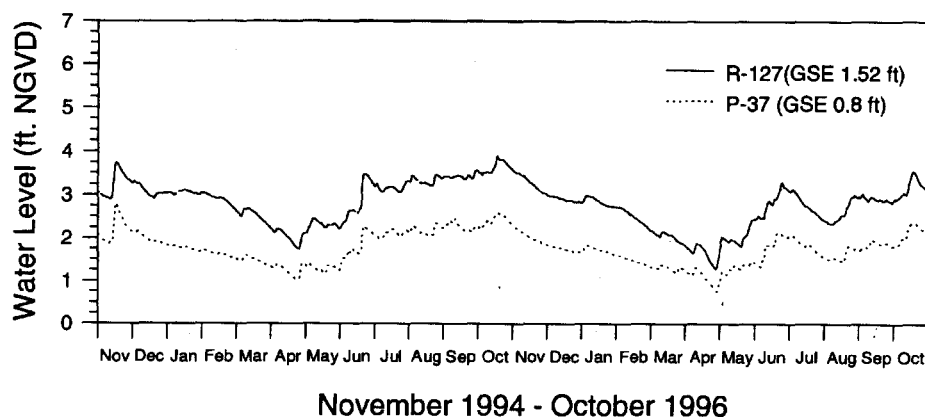


Figure 22: Water levels at R-127 and P-37.

recorded at these stations are plotted in Fig. 22. Both of these southern Taylor Slough stations exhibited little to no perceptible fluctuations directly attributable to the management of water levels in the L-31W or C-111 canals. However, since regional water levels are determined by levels in these canals there is certainly some large-scale effect. The constraints on water levels associated with the 4.7 ft-msl upper limit within the L-31W canal may have resulted in lower water levels at these sites. In general, both sites remained inundated throughout the dry season of 1996 and the Test 7 period.

3.5 Lower C-111 Basin

A principal objective of the Test 7 Iteration of the Experimental Water Deliveries Program (EWD) is the reduction or elimination of S-197 discharges. Large S-197 discharges into Manatee Bay have been documented as a contributing factor in the ecological decline of this estuary. Additionally, the Minimum Monthly Deliveries Schedule for the Eastern Panhandle as dictated by PL 91-282 remains in effect with the specified monthly volumes continue to be delivered through structure S-18C each month. This portion of the ENP section of the report focuses on the actual operation of C-111 structures and the effectiveness of these modifications to operational criteria in achieving this objective. The structures and canals of lower C-111 relevant to this section are shown in Fig. 1.

Test 7 operational criteria for S-197 and the other lower C-111 structures

Operational Settings			
Structure	Open HW (ft. NGVD)	Close HW (ft. NGVD)	
S-176	5.0	4.75	flood ops close - 4.60 ft. - 3 culverts open when S-177 open full and either S-177 HW greater than 4.10 or S-18C HW greater than 2.80 - 7 culverts open when S-177 HW greater than 4.20 for 24 hours or S-18C HW greater than 3.10 - 13 culverts open when S-177 HW greater than 4.30 or S-18C HW greater than 3.30
S-177	4.2	3.6	
S-18C	2.6	2.3	
S-197			

Table 3: Operational Settings for Structures in lower C-111 [U.S. Army Corps of Engineers, 1995]

are show in Table 3 [U.S. Army Corps of Engineers, 1995]. Once structure S-197 has been opened the criteria for closure of the structure depends on three conditions:

1. Headwater at S-176 has declined below 5.2 ft-ngvd and headwater at S-177 has declined below 4.2 ft-ngvd. Stage levels above these water levels will trigger mandatory flood releases at S-197.
2. The position of the storm causing the use of S-197 has moved away from the basin. This condition is assumed met when there is a declining trend in stage below the the specified criteria stated in Condition 1.
3. When conditions 1 and 2 are met but some number of S-197 culverts remain open to match the residual discharge being passed through S-176. All culverts would be closed once the S-177 headwater stage has decreased below 4.1 feet.

There are two differences between the criteria shown in Table 3 and the Test 6 criteria. The first difference is a change in the S-176 operating criteria. During Test 6, structure S-176 had both wet and dry season operational criteria. The wet and dry season opening criteria was 5.0 ft. The closure criteria for the dry season season was 4.75 ft. and the wet season closure criteria was 4.6 ft. During Test 7 a single year round operational criteria was applied, opening at 5.0 ft. and closure at 4.75 ft. with the exception that during flood operations the closure criteria would be lowered to 4.6 ft. The second difference between

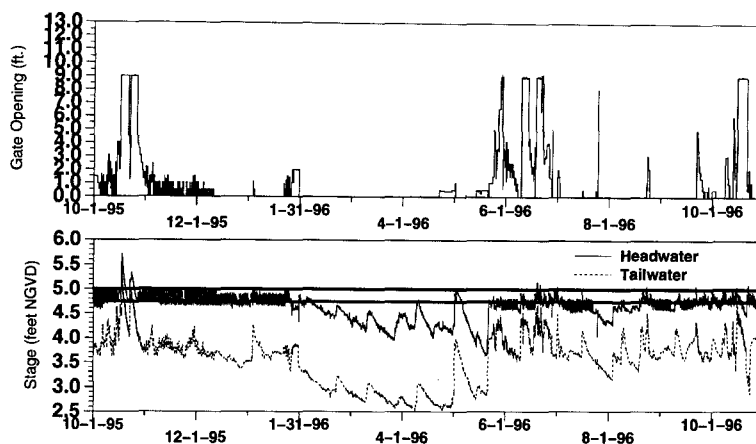


Figure 23: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-176

Test 6 and test 7 operating criteria is an increase in the S-18C closure criteria from 2.0 to 2.3 ft-ngvd. and the removal of wet and dry season operational criteria to a single year round criteria shown in Table 3.

A review of the South Florida Water Management operations break point data shows that Test 7 iteration included 3 instances requiring the opening of S-197. These three instances occurred at the beginning, middle and end of Test 7, during the months of October-November 1995, June 1996, and October 1996. Operations data were plotted to determine if actual operations remained consistent with the rules specified in Table 3. Test 7 headwater and gate operations for each of the structures listed in Table 3 are shown in Figures 23 through 26. October 1995 is included in each of the plots because the November 1995 S-197 opening was a continuation of an event beginning on the 10th of October continuing into November. Structure operation criteria shown in Table 3 are represented by the bold horizontal lines in each plots. S-197 opening criteria are included in stage plots of S-18C as the uppermost two horizontal lines.

Flood protection is only one aspect of the C&SF Project objectives. Another of the project purposes is water supply. Water supply has two components, water supply to Everglades National Park (ENP) and the maintenance of regional water levels for wellfield withdrawal and prevention of salt water intrusion. ENP water supply for the C-111 Eastern Panhandle basin is authorized under the Minimum Schedule of Water Deliveries PL 91-282. Figure 27 is a plot of S-18C total monthly discharge and the Eastern Panhandle min-

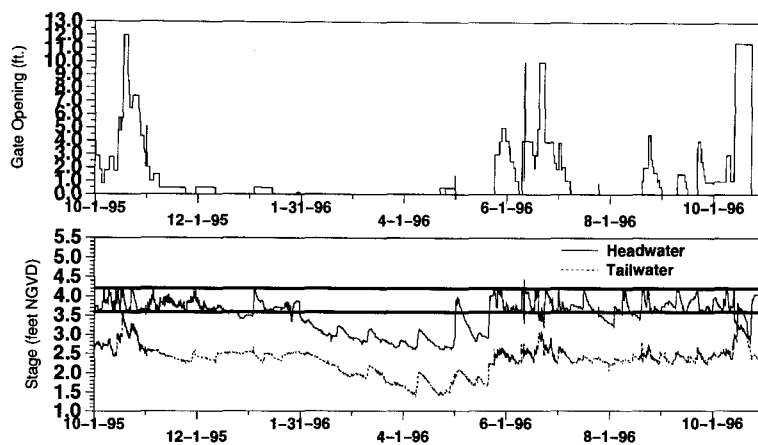


Figure 24: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-177.

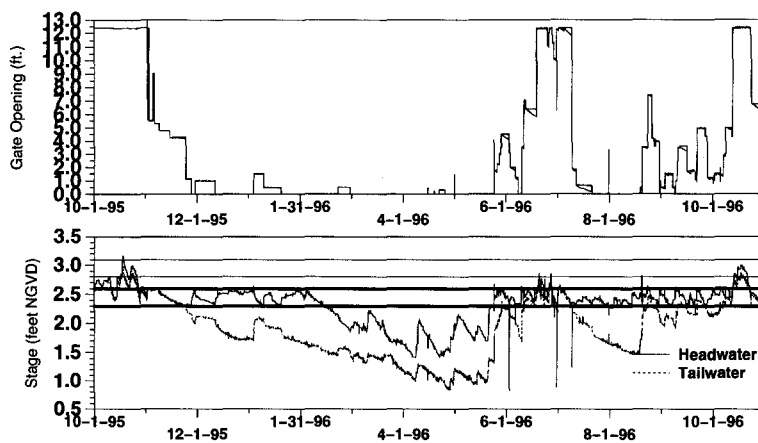


Figure 25: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-18C

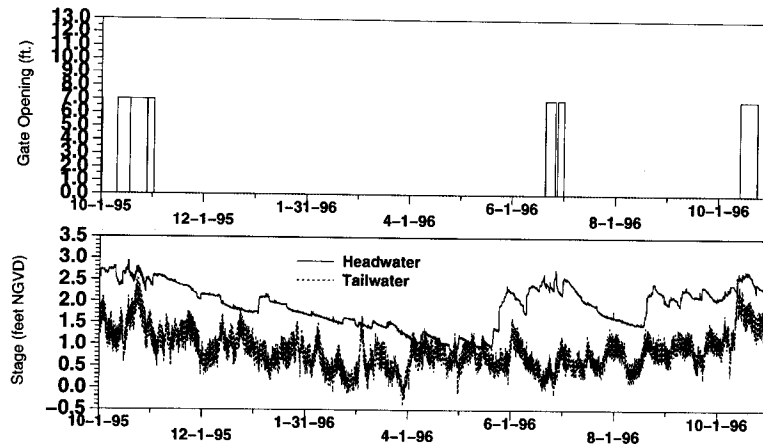


Figure 26: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-197.

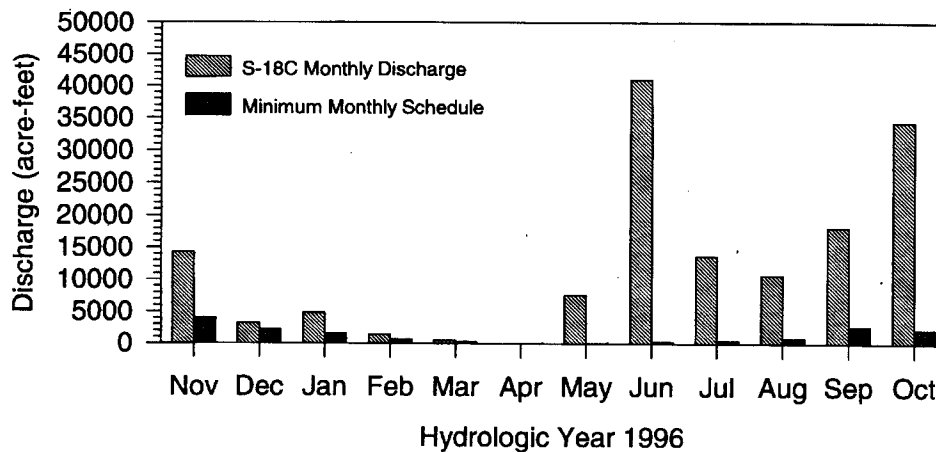


Figure 27: S-18C total monthly discharge (acre-feet) and the Eastern Panhandle minimum monthly scheduled discharge (acre-feet).

imum monthly schedule. Monthly discharge greatly exceeded the minimum schedule every month of Test 7 except from February through April. During these months because of the very small volumes to be delivered difficulties arise in ascertaining that the schedules were delivered. These difficulties are compounded by errors within the database and the multiple sources of flow data available for S-18C. More importantly during two of these months, February and March inspection of the gate opening shown in Figures 23 through 25 indicates the minimum schedule delivery was made at the expense of the upstream aquifer and marshes. The monthly delivery at S-18C during both of these months occurred with both S-176 and S-177 closed. There is concern whether such operation remains consistent with the original intent of the Minimum Deliveries Schedule Program.

3.5.1 October-November 1995 S-197 Event

The examination of operations surrounding S-197 events must include determinations that its opening and continued operation through closure must be consistent with the criteria shown in Table 3 and the Items 1—3. The 1995 wet season ended as it began with the opening of S-197 for an extended period (22 days total) from October 10 to November 1 1995, with culverts 1—3 open for the entire period. The maximum number of culverts open during this event was 7 open October 18th to the 28th. As noted in Section 3.1, antecedent rainfall at S-18C for the previous two months, August and September was 10.64 and 9.4 inches. S-18C October rainfall was 10.9 inches. The S-18C wet season total was 47.3 inches, 156% above average. The S-18C 1995 hydrologic year total was 67.25 inches or 148% average.

Monthly total rainfall at several stations with shorter period of records located within the study area are shown in Table 4. Note that this table contains the monthly totals from August 1995 to October 1996 to account for all events previously identified for examining C-111 operations. The 22 day event recorded several large 1- and 5-day rainfall events at each of the stations. The 1-day rainfall events ranged from 0.41 to 4.25 inches and the 5-day events ranged from 0.62 to 8.1 inches. The largest of each of these 1- and 5- day events prior to the initial opening of 3 and the additional 4 culverts were determined to have return frequencies of less than 1 in 3 years. Return frequencies are useful in that they provide a tool to relate the probability of a specific rainfall event with a coincident operational change. The return frequencies were determined from frequency isohyets of rainfall maximums for Central and South Florida

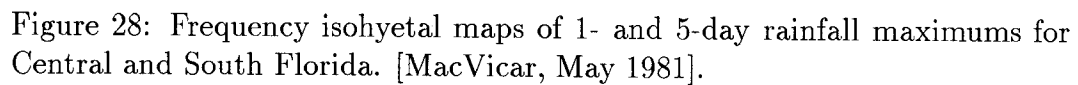
YY-MM	ROBBLEE	R-3110	NTS-10	R-127	EVER-8	EPR
95-08	11.33	9.08	6.16	12.14	12.23	14.42
95-09	8.14	10.94	11.37	8.62	9.43	8.28
95-10	17.01	11.71	10.32	14.09	12.51	9.61
95-11	0.50	0.92	0.89	0.38	0.35	0.41
95-12	1.49	1.07	0.81	1.16	1.15	1.22
96-01	2.48	1.70	1.20	2.11	1.54	1.90
96-02	1.11	1.22	1.70	0.52	0.72	0.60
96-03	2.03	2.63	2.26	2.08	2.05	1.93
96-04	3.42	2.37	1.51	2.72	2.69	2.63
96-05	-NA-	13.29	9.43	7.31	6.32	5.16
96-06	10.62	10.86	10.33	14.35	20.75	10.45
96-07	4.03	3.73	2.90	2.80	2.00	4.42
96-08	9.39	7.21	6.75	10.38	5.88	5.20
96-09	4.90	4.16	3.96	8.23	8.27	10.83
96-10	13.26	10.10	-NA-	9.89	10.19	15.81

Table 4: Monthly total rainfall (inches) at stations located within the Taylor Slough and C-111 basins.

generated by MacVicar [MacVicar, May 1981]. Frequency isohyets for 1, 2, 5, and 10 year 1- and 5-day events with approximate station locations are shown in Figure 28.

These events and antecedent wet season rainfall contributed to peak end of the wet season water levels at many area marsh and groundwater stations, either meeting or exceeding hydrologic year maximum water levels. To assist in the review October - November 1995 lower C-111 operations stage and gate height break point data for C-111 structures is shown in Figures 29 through 31. Water level hydrographs at the Frog Pond and ROBBLEE monitoring stations will be utilized to indicate receding water levels and the storms movement away from the basin.

The stage hydrographs shown in Figure 31 indicate that S-18C headwater reached 2.8 ft. on the 10th of October at 0930 hours resulting in 3 S-197 culverts to be opened by 1310 hours on this day. During this time period S-177 headwater was at or exceeded 4.2 ft but the gate heights shown in Figure 30 indicate only partial opening of S-177. Heavy rainfall on the 17th resulted in full opening of S-177 between 1100 and 1900 hours. At 2000 hours on the 17th S-177 headwater was 4.21 ft and 4.09 ft. by 0400 hours early on the 18th. At 2100 hours on the 18th S-18C headwater was 3.16 ft. These criteria prompted an additional 3 culverts at S-197 to be opened on the morning of the 18th at approximately 0800 hours. Rainfall events from the 22nd through the 24th allowed these 7 culverts to remain open through the 28th of October. The closure of culverts 4—7 on the 28th resulted because each of the Items 1—3 specified for closure had been met. Although operational stages were below



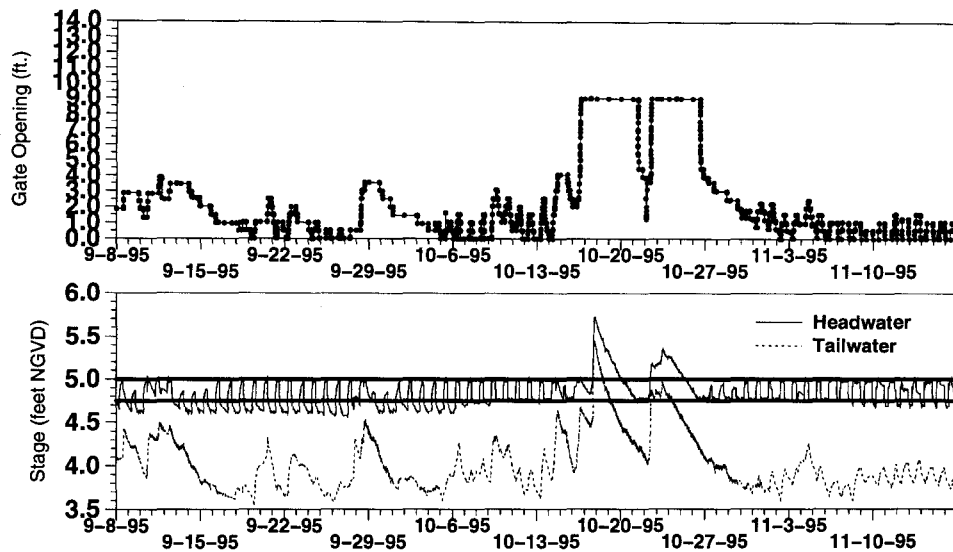


Figure 29: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-176

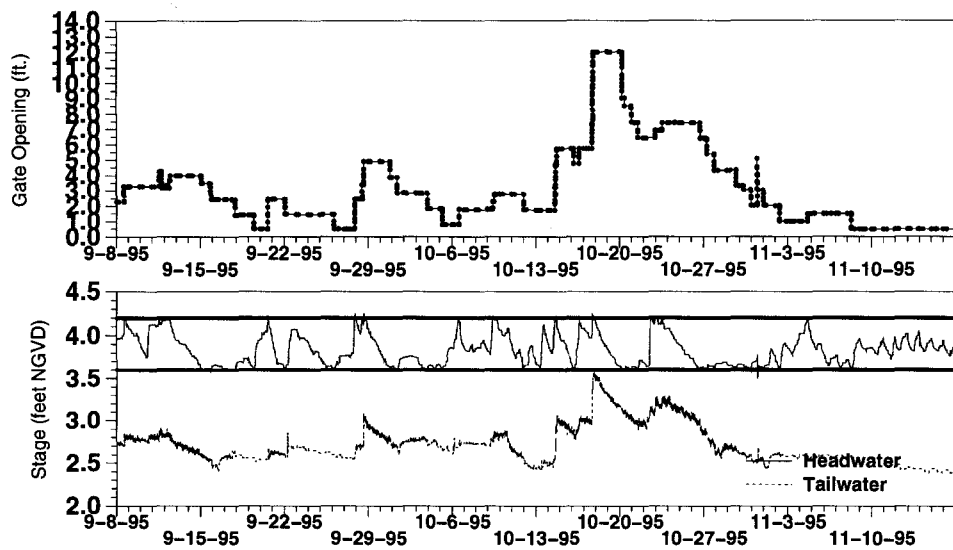


Figure 30: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-177.

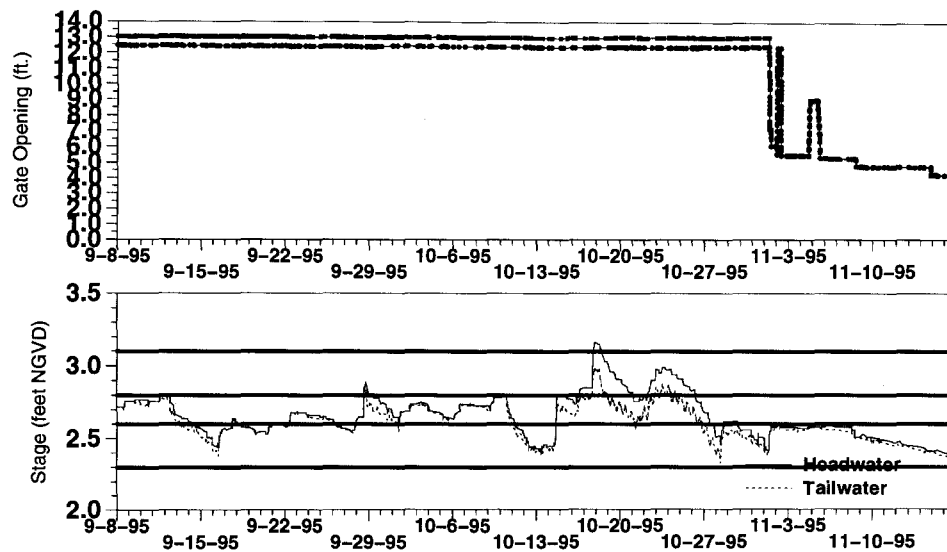


Figure 31: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-18C

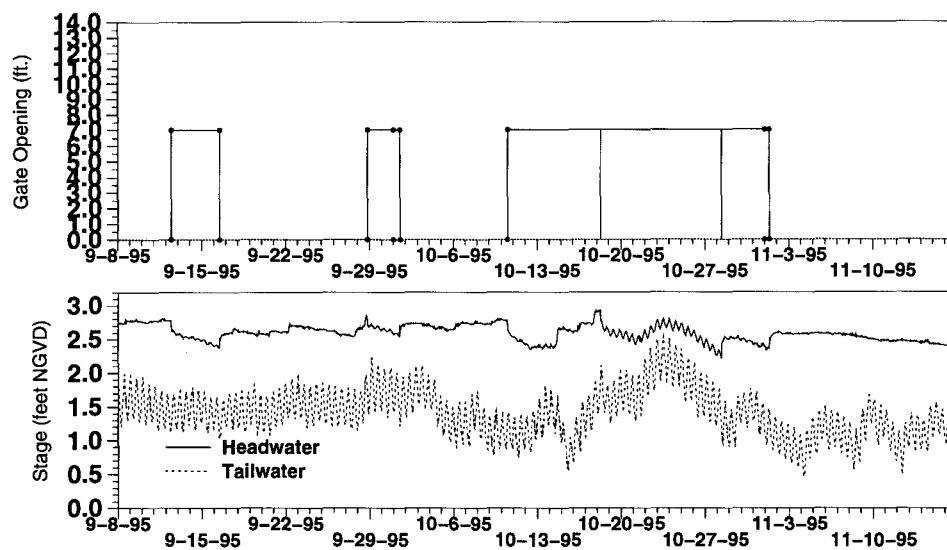


Figure 32: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-197.

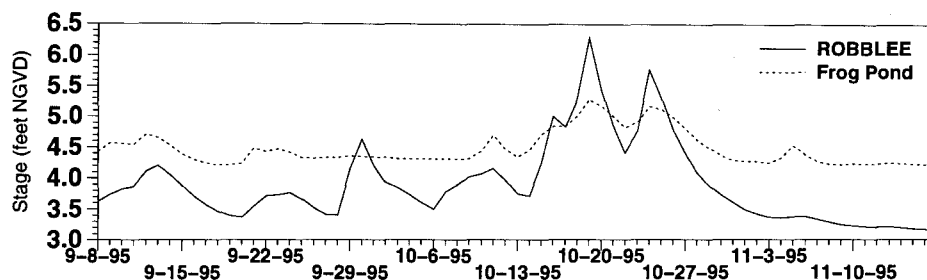


Figure 33: Frog Pond and ROBBLEE stage (ft. NGVD).

pre-event levels on this date complete closure of the remaining S-197 culverts did not take place until November 1st.

Figure 33 provides an additional tool useful in determining whether S-197 was extended beyond what was necessary for maintenance of project "flood control" objectives. The stage hydrographs show that at both Frog Pond and ROBBLEE groundwater levels returned to pre-storm levels of October 11th by the 28th. Both these stations are at points distant to C-111 (see Fig. 2) and can be considered to some degree representative of the groundwater levels adjacent to C-111. Although they are not representative of regional groundwater levels or currently used as criteria for the closure of S-197, they do provide a good indication of when hydrologic conditions are sufficient to initiate closure of the structure. These stage hydrographs also highlight the effectiveness of water management operations at S-197 on water levels in the areas west and east of the C-111. The operational criteria shown in Table 3 and these stage hydrographs indicate that closure was possible prior to November 1st. Furthermore, November and the beginning of the dry season, with the drier conditions that often prevail would provide a margin of safety. An earlier closure on the 28th could have resulted in a 5% reduction in Test 6 1996 S-197 discharges and approximately a 2% reduction in S-197 discharges for Test 7.

3.5.2 June 1996 S-197 Event

Rainfall activity was slow to begin in June with dry conditions predominating during the first week. Heavy rainfall, associated with the start of the wet season, across the lower C-111 basin began and continued through the end of June. The May and June monthly totals for S-18C reported in the Section 3.1 was 2.59 and 7.98 inches. These rainfall totals were 63% and 100% of the period of record average for May and June, respectively. Other stations in the lower C-111 basin shown in Table 4 indicate monthly variability of more than 200% between the lowest and highest totals recorded for each month. The dry season rainfall at S-18C was 6.92 inches or 45% of the period of record average dry season total.

Several large 1- and 5-day rainfall events were recorded at stations within the basin both preceding and during the June 1996 operation of S-197. These events ranged from 1.5 to 3.73 inches for the 1-day rainfall and from 2.45 to 7.91 inches for the 5-day rainfall events. The majority of the largest of these events prior to the initial opening of 3 culverts and through the conclusion of the event were determined to be 1 in 2 year from from frequency isohyets of rainfall maximums for Central and South Florida generated by MacVicar [MacVicar, May 1981]. The exception was a 5-day 7.91 inch EVER-8 total that occurred between June 20th and July 1st that resulted in approximately a 1 in 5 year return period. This rainfall was sufficient to rapidly increase water levels from near hydrologic year dry season season minimums to wet season stages sufficient to warrant C-111 flood operations.

Stage and gate height break point data for this time period for structures are shown in Figures 34 through 36. On June 19th at 2120 hours S-177 headwater was 4.22 ft. with a partially opened gate (5.18 ft.). The S-177 headwater was 3.77 ft. at 2130 hours with S-177 full open (9.64 ft.). On June 20th at 1315 hours S-18C headwater was 2.86 ft. At 1300 hours on 20th S-197 culverts 1—3 were opened and remained open until June 26th when the criteria identified in Items 1—3 were present warranting the closure of S-197. Rainfall events on 26th and 27th ranging from 0.01 to 1.66 inches was recorded at monitoring locations in the study area. On the 27th an increase in headwater at S-18C from 2.68 to 2.85 between the 0935 and 1150 hours prompted the reopening of 3 culverts at S-197 at 1600 hours. Although rainfall recorded at the stations in the area was insufficient to account for the total increase in stage no other factors, such as rapid gate closures were evident. It is interesting to note that in the hours preceding the rise in headwater at S-18C a 0.5 ft. increase

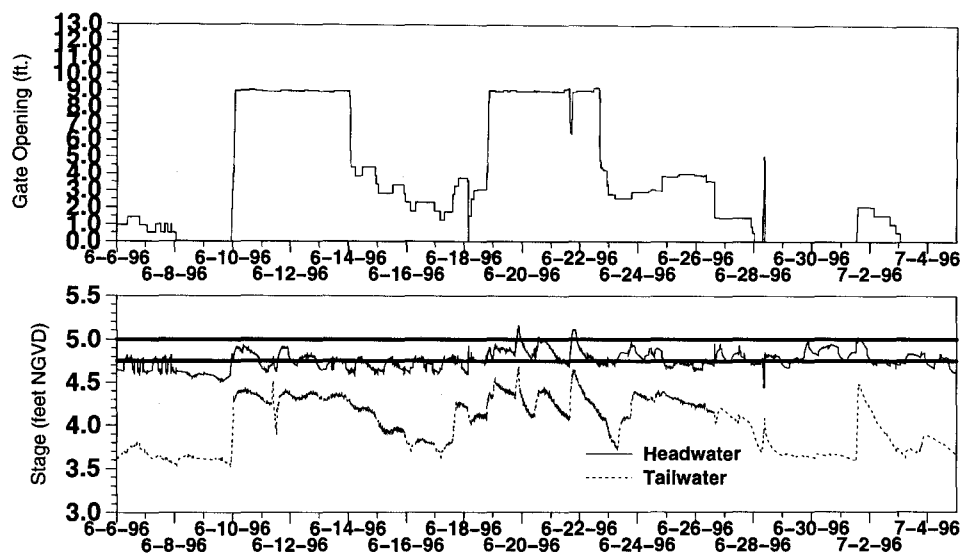


Figure 34: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-176

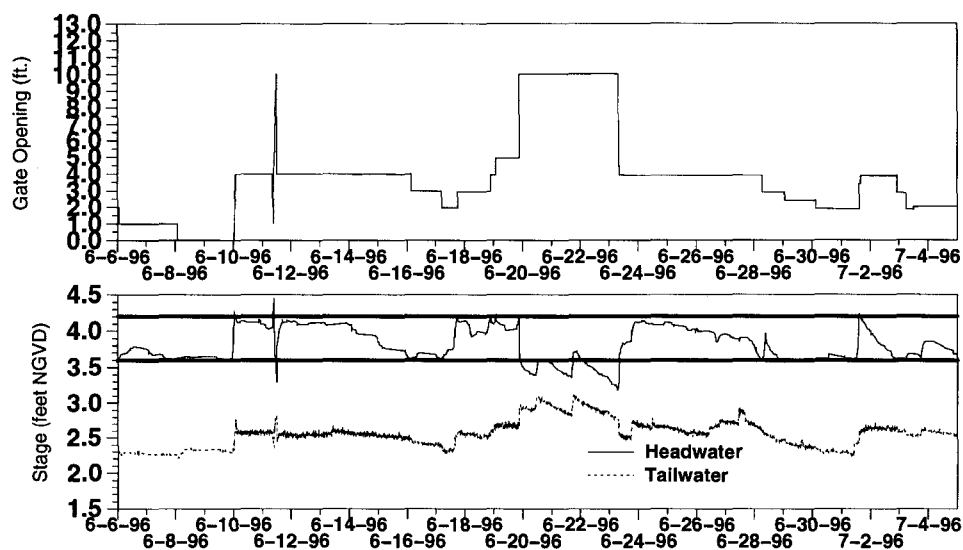


Figure 35: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-177.

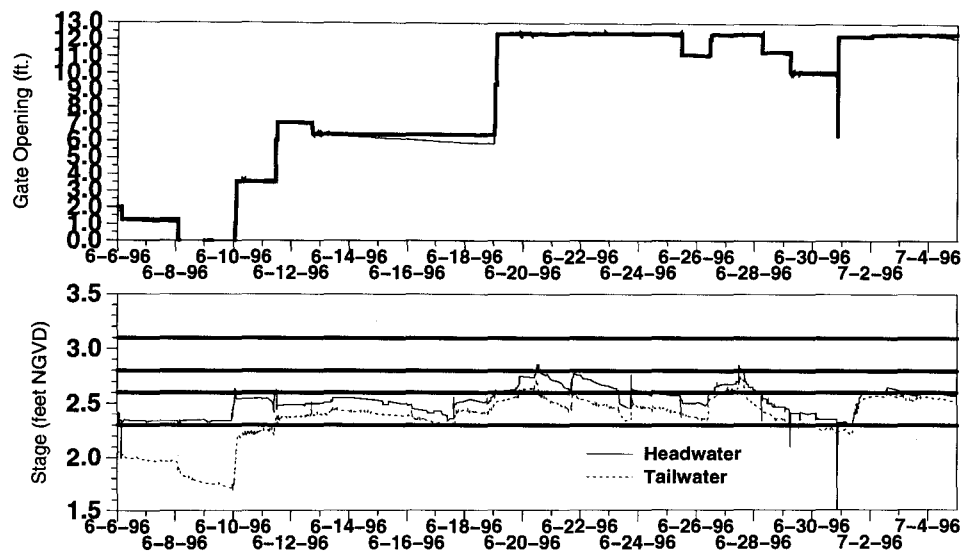


Figure 36: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-18C

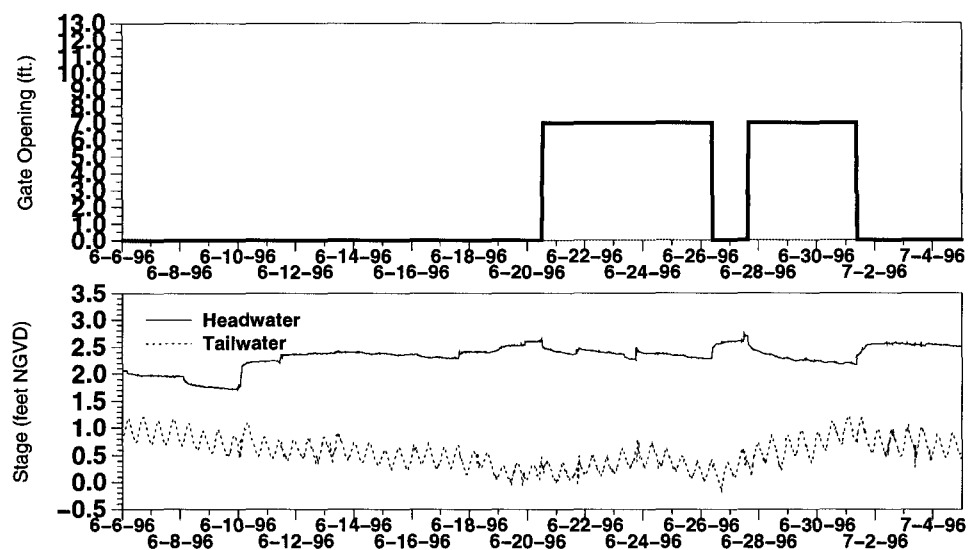


Figure 37: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-197.

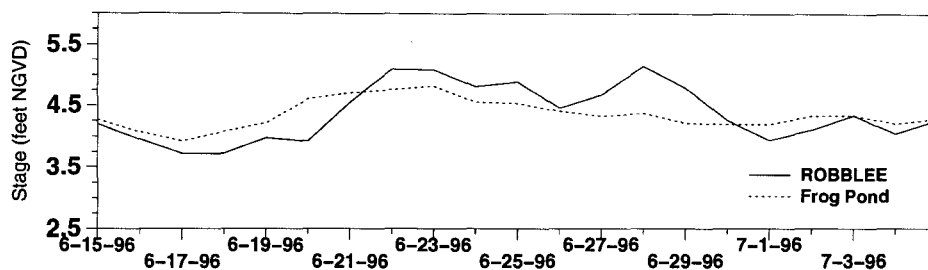


Figure 38: Frog Pond and ROBBLEE stage (ft. NGVD).

was recorded at S-197 tailwater. The 3 culverts remained open until the 1st of July.

Canal budgets computed from SFWMD DBHYDRO flow data show that from the 20th to the 23rd approximately 30% more outflow from the reach between S-176 and S-177 resulted than the S-177 to S-18C reach. During the period of the partial opening of S-177, drainage from below S-177 to S-18C reversed increasing to 30% more than the S-176 to S-177 reach. Stage hydrographs at the Frog Pond and ROBBLEE monitoring stations, shown in Figure 38 indicate by the 29th, water levels at these stations had returned to the levels that existed when S-197 was closed on the 26th. Operational stages on this date were at or below the those that prompted the closing on the 26th. Using the earlier stages as criteria for this event, the data indicates that S-197 closure on the 29th could have been sustained. Closure on the 29th would have resulted in an approximate 16% reduction in S-197 discharge for this event and approximately 9% reduction in S-197 discharge for Test 7.

3.5.3 October 1996 S-197 Event

The October 1996 S-197 event was preceded by August and September rainfall totalling 5.75 and 4.07 inches, respectively was recorded at S-18C. Both

these months were below the period of record averages for S-18C presented in Section 3.1. October rainfall recorded at S-18C was 10.92 inches, a period of record maximum for this month. October rainfall was sufficient to raise the S-18C 1996 wet season total to 29.54 inches or 98% of the S-18C period of record wet season average total. The 1996 hydrologic year total recorded at S-18C was 36.5 inches or 20% below average.

The highest consecutive 1- and 5- day rainfall totals for stations listed in Table 4 were determined to have return frequencies of less than 1 in 2 years. The exception was ROBBLEE a 5-day rainfall resulting in a 1 in 5 year return period. The 1-day rainfall events ranged from 0.90 to 3.73 inches and the 5-day events ranged from 0.90 to 8.35 inches. The return frequencies were determined from frequency isohyets of rainfall maximums for Central and South Florida generated by MacVicar [MacVicar, May 1981]. These rain events resulted in peak end of the wet season water levels at many area marsh and groundwater stations that either met or exceeded hydrologic year 1996 maximum water levels.

The stage hydrographs for this time period, shown in Figures 39, 40 and 41 indicate that headwaters reached levels indicated in Table 3 early on the 13th of October triggering the opening of 3 S-197 culverts. Specifically, it was S-18C headwater levels of 2.85 ft. at 1150 hours on the 13th that triggered the opening of S-197 by 1410 hours. A S-18C maximum headwater recorded for the event occurred on the 19th 2.97 ft. By mid-day on the 21st S-18C headwater was 2.80 ft. At the time of S-197 closure at 1550 hours on the 23rd S-18C headwater was approximately 2.5 ft.

On October 16, 1996 operational changes to S-176 with concurrence by USACE, SFWMD and ENP were enacted. The changes included the following modifications to S-176 operational criteria;

OPTION 1: S-176 would be opened full and set to close at 4.0 ft. in order to move water to the east through C-111. S-177 would remain open full open.

OPTION 2: In addition to OPTION 1, temporarily change the Test 7 operating criteria in L-31W by setting S-174 to open at 4.8 ft. and to close at 4.0 ft., continue pumping at S-332, and set the S-175 gates open full to allow water to move through L-31W. Due to tailwater conditions at S-175 it is unlikely that the tailwater would go below 4.0 ft.

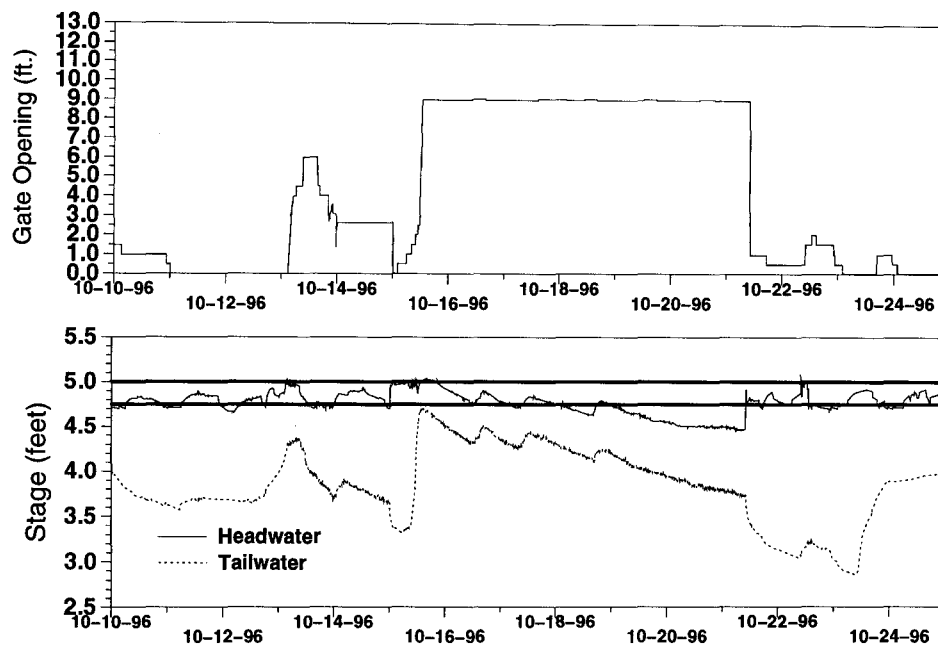


Figure 39: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-176

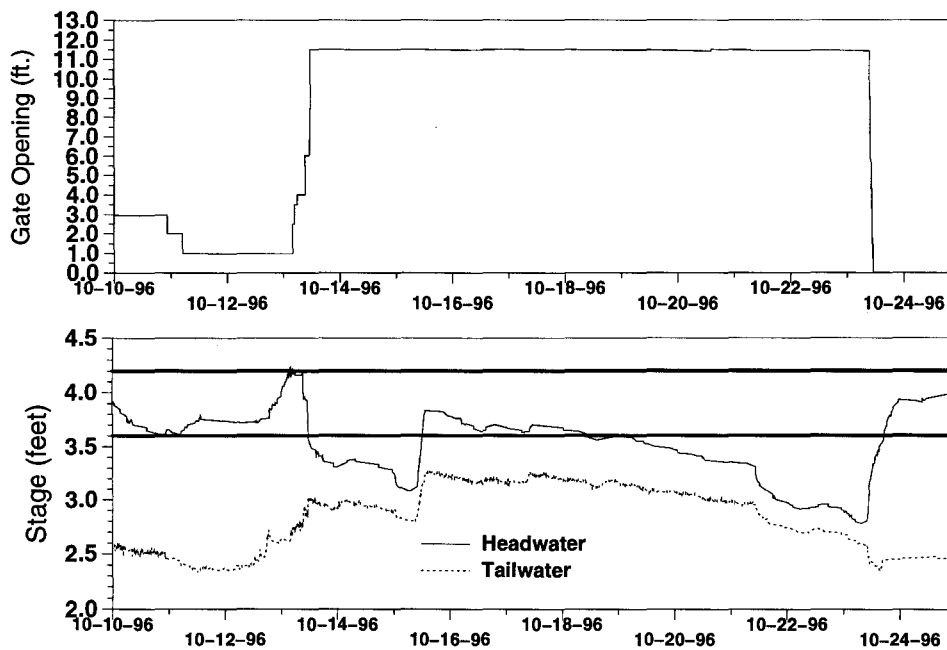


Figure 40: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-177.

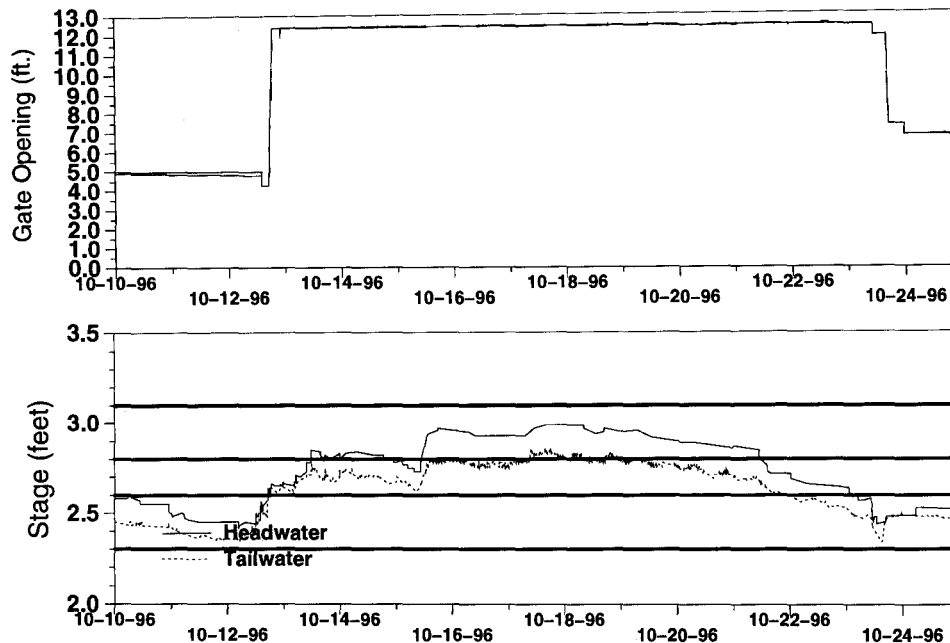


Figure 41: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-18C

These changes were requested by the SFWMD because of concern over the coincidence of peak wet season water levels coupled with the additional rainfall inputs from approaching Hurricane Lili. This hurricane was predicted by SFWMD meteorologist to be a wet Category I storm capable of 24 hour rainfall total exceeding 15 inches. A south Florida landfall with these totals were considered to jeopardize the "authorized levels of flood protection" in southern Dade County. These operational changes would provide "increased storage in the L-31N in anticipation of heavy rainfall in the basin". Furthermore, "these changes would remain in effect until the threat of flooding from the forecasted weather systems have passed" [U.S. Army Corps of Engineers, 1996]. Option 1 was implemented on the 16th, with OPTION 2 to be implemented as warranted by developing weather conditions. "These operations were to remain in effect until water levels call for closing S-197 consistent with criteria in Test 7 for S-197 operations".

To identify whether the conditions for lifting of S-176 emergency changes and S-197 closure were met prior to the actual closure date one needs to first examine Figures 39 and 40. From these graphs it is easy to identify immediately that the headwater stages never exceeded the stages indicated in

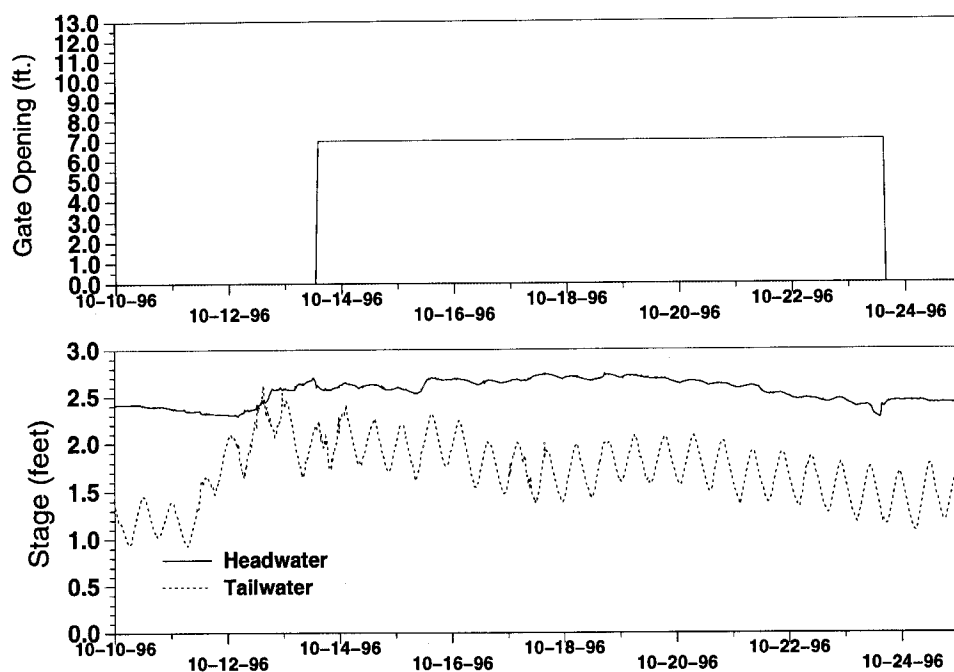


Figure 42: Gate height (ft.), headwater and tailwater stage (ft. NGVD) for S-197.

Item 1 after the 14th of October. Additionally, from these graphs it is obvious that declining trends in water levels (headwater stages) are concernable by October 17th. The conditions under Item 2 are excerpted from the October 1996 SWCDR [South Florida Water Management District, 1996] . "Lili's exit eastward through the Bahamas accelerated a cold front through the District by the morning of the 19th. This effectively ended the wet season as high pressure with virtual dry conditions dominated through the end of the month." Additionally, it was reported as early as the evening the 18th by local media that threats from Lili were minimal. Therefore conditions for the immediate lifting of the emergency operational changes were present early on the 19th of October but no such action was taken on until the 21st. The basis of the

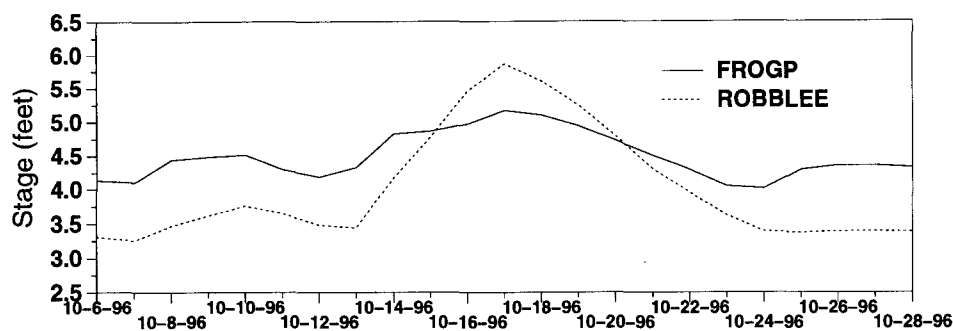


Figure 43: Frog Pond and ROBBLEE stage (ft. NGVD).

Figure 43 shows water levels at the Frog Pond and ROBBLEE monitoring stations. The stage hydrographs show quite clearly the return of groundwater levels to pre-storm levels at points distant from the C&SF project. It is apparent from the plot that water levels peaked on the 17th, began tapering off from this date forward. The hydrographs highlight the effect of water management operations on water levels in the areas west and east of C-111. Using the SFWMD meteorologist report and the groundwater recession rate at the FROGP and ROBBLEE an approximate closure date for S-197 could be placed sometime between the 19th and 20th of October. Using the 20th as a date for the closure of S-197 would have resulted in approximately 3510 acre-feet available for dry season storage. A 32% reduction in S-197 discharges for hydrologic year 1996, year 1 of Test 7 could have been realized through a sustained S-197 closure on the 20th of October.

3.6 Water Levels in Lower C-111

The previous Section 3.5 provided some indication as to the effects of C-111 operations on water levels at nearby stations FROGP and ROBBLEE. Another way measure to the effectiveness of these operations is to examine the frequency of occurrence of some maximum or minimum hydrologic parameter. The frequency of occurrence of 1-, 5- day and monthly rainfall was presented in the previous section to provide possible relationships between rainfall and the operation of S-197. Frequency analysis of maximum and minimum hydrologic year water levels are also useful in evaluating the effectiveness C-111 operations. Frequency analysis is only appropriate when the data is available for a sufficient period of record, usually 25 or more years. While several groundwater stations with a period of this length are available in the developed areas

of south Dade County, none exist in natural marsh environments preventing similar analysis.

Figure 44 shows the results of the frequency analysis for maximum and minimum hydrologic year water levels at two longer period of record stations in the C-111 basin. Hydrologic years 1994, 1995 and 1996 are noted on the plots to provide a perspective of Test 7 maximums and minimums in addition to the Test 6. It must be noted that when interpreting Fig. 44 there is no differentiation of when in the hydrologic year the maximums or minimums water levels occur. This means that the maximum for the hydrologic year could occur in November due to high water conditions prevailing from the previous wet season rainfall, and conversely a minimum could but rarely occur in September. Figure 44 shows that maximum water levels at both G-789 and G-613 (see Figure 2), for Test 7 fall approximate to 70 percent exceedance. The return periods associated with a 70% exceedance is approximately 1—1.4 years. Based on this information it is evident that the flood operations during Test 7 were more than sufficient to fulfill C&SF Project 1 in 10 year flood protection objectives. The hydrologic year minimums illustrate that project water supply objectives were also well maintained during Test 7.

As already stated it is more difficult to assess the hydrologic effects of operations in the adjacent wetlands of lower C-111. Figure 45 shows water levels at four stations (see Fig. 2) located in the lower C-111 wetland area. Distinguishing between changes due to operations of C-111 and local rainfall at these stations is difficult. Maximum water depths in 1996 were only marginally less than during hydrologic 1995 across the Eastern Panhandle, but it is evident for Figure 45 that deep water did not persist for the entire 1996 hydrologic year. Maximum water levels in the marshes occurred on or about the 18th of October from rainfall associated with Hurricane Lili. It should be noted that at some of the monitoring stations adjacent to lower C-111 maximum hydrologic year stages were recorded the previous November from antecedent 1995 hydrologic conditions. Minimum water levels at most stations in the Eastern Panhandle occurred in the last week of April similar to the previous year.

Hydroperiods based on average monthly stage were computed. Data for EVER-3 was not sufficient to calculate the hydroperiod but could be expected to be similar to the EVER-4 hydroperiod of approximately 9 months. During hydrologic year 1995 EVER-4 hydroperiod was approximately 11 months. The average hydroperiod for EVER-4 for 1986-1996, (1992 and 1993 missing) is approximately 8 months. The EP-9R hydroperiod for Test 7 hydro-

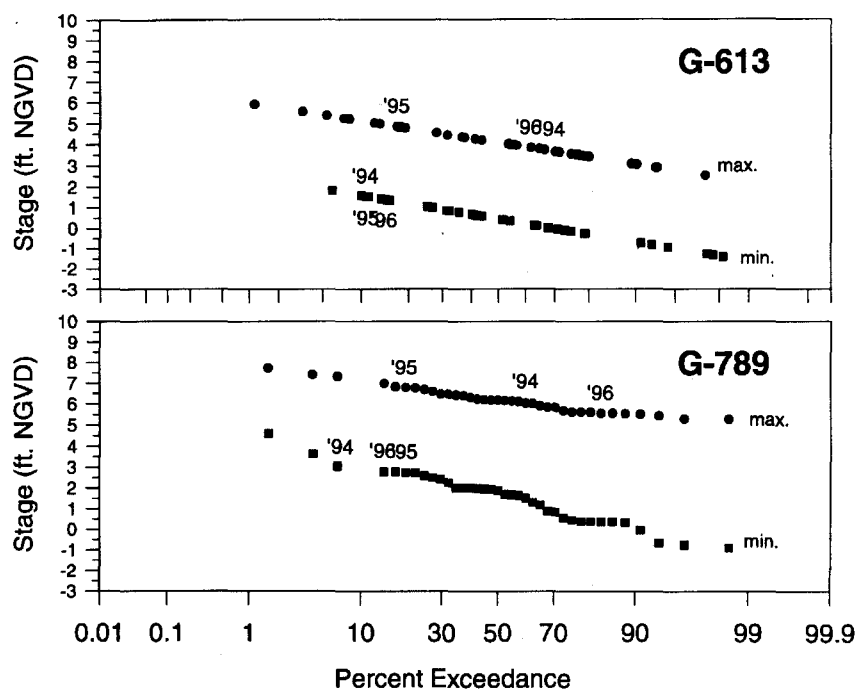


Figure 44: Hydrologic year maximum and minimum stage exceedance at G-789 and G-613 (ft. NGVD).

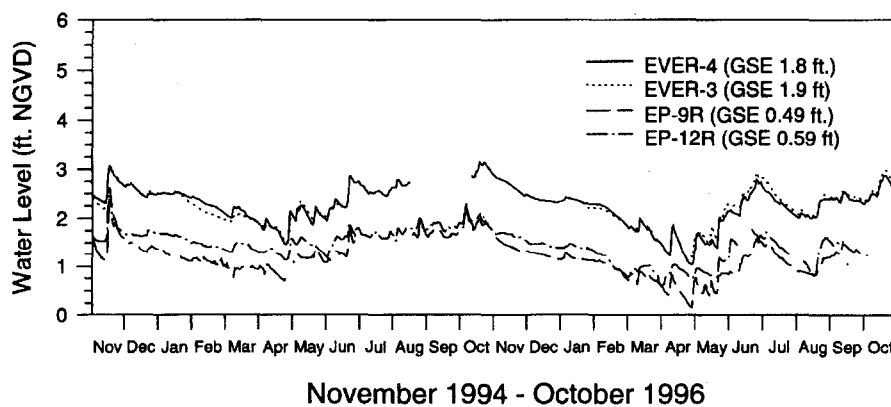


Figure 45: Stage hydrographs for hydrologic year 1995 and 1996 at EVER-3, EVER-4, EP-9R and EP-12R (ft. NGVD).

logic year 1996 was approximately 10 months, down from 12 months the previous hydrologic year, 1995. The average hydroperiod at EP-9R for 1990-1996 is approximately 10.5 months. The hydroperiod at EP-12R during hydrologic year 1996 was approximately 10.5 months.

4 Regional Analyses of Water Management Operations

Daily average discharge data from the South Florida Water Management District's DBHYDRO database were used to compute monthly, seasonal, and annual flows for the structures along Tamiami Trail and the L-31N, L-31W, and C-111 canals. These flows define the amount of water delivered from the regional system into the Shark Slough, Taylor Slough, and Eastern Panhandle basins of ENP. The volumes computed do not differentiate between water deliveries as part of the Experimental Water Deliveries program, flows originating from flood control and/or water supply operations to developed areas of western Dade County. This summarization of flow data allows a better understanding of the hydrologic conditions during the study period in response to water management operations.

The regional perspective of how operations route water through the C&SF Project is accomplished through monthly, seasonal and hydrologic year basin summaries. These summaries presented include both hydrologic year 1995 of Test 6 and Test 7. It is important to emphasize that during hydrologic year 1995 period of record maximum monthly water levels were attained during every month of the year for the majority of the stations within ENP. During the 1995 hydrologic year record discharges for many of the structures were also recorded. This antecedent, above average rainfall to Test 7 sustained high water levels well into the average 1996 dry season. The 1996 wet season as noted in Section 3.1 was in general characterized as average. The extremes in hydrologic conditions during these periods make an evaluation of the minor operational changes during Test 6 and Test 7 difficult to distinguish. These basin summaries will attempt to differentiate between periods of flows originating from flood control and attributed to water supply operations for developed areas of western Dade County.

Seasonal open water budgets calculated for selected reaches of the L-31N, L-31W, and C-111 canal systems are presented from a regional perspective

to define the major sources of water and their subsequent routing through the major canals of the Central and Southern Florida (C&SF) Project. The open water budgets computed for Northeast Shark Slough and the L-31N, L-31W, and C-111 canals for wet season 1995, dry and wet 1996 use the following conventions. The blue arrows with associated flow numbers indicate the conveyance of flows within the canal systems. Green arrows and their associated flow numbers indicate discharges from the canals into the adjacent marsh, or aquifer recharge. Red arrows indicate groundwater and wetland seepage losses into the adjacent canals. These open water budgets do not attempt to differentiate between flood operations and water supply.

4.1 Water Budgets

4.1.1 L-31N S-335 to S-331/S-173

Table 5 presents the structure total monthly discharge and open water budgets for the upper reaches of the L-31N canal between S-335 and S-331. Inflows to this reach are through S-334 and S-335 are from the upstream regional system. Outflows are east through S-338 and south through side by side S-331 and S-173. Between S-331 and S-338 is G-211 an internal conveyance structure used to reduce seepage losses from the wetlands and aquifer adjacent to L-31N (see Fig. 1). G-211 divide the upper L-31N canal system into two segments. Outflows from the upper most L-31N system can be through southward through G-211 or eastward through canal C-1 via S-338.

During the 1995 wet season approximately 70,900 acre-feet was removed from the northern most reach of L-31N, S-335 to G-211. This is approximately volume of flows into NESS (see Table 6). The total volume removed from this same reach for hydrologic year 1995, Test 6 was approximately 260,000 acre-feet or approximately 140% of flows to NESS through the combination of S-333 inflows and WCA-3B seepage. Seepage from L-31N during Test 6 were similar to the volumes prior to the construction of G-211 in 1990. L-31N seepage for the period 1983-1990 averaged 200,000 acre-feet annually [Everglades National Park, 1995a]. It was large seepage losses such as these, that prompted construction of G-211 in addition to the recent increases in the operational criteria upstream of G-211. During the dry season 1996 Test 7, approximately 66,500 acre-feet or approximately 58% of the flows into NESS were removed from this reach of L-31N. Total dry season losses from this reach of L-31N was more than double the volume introduced through S-335 during water supply operations.

Mon/YR	S-334	S-335	S-336	S-338	G-211	S-331	Stor1	Stor2
1995 DRY SEASON WATER BUDGET								
Nov-94	0	0	0	14124	13196	23428	-27321	-10232
Dec-94	0	0	0	12660	25247	33753	-37907	-8506
Jan-95	0	0	0	10717	40224	42818	-50941	-2594
Feb-95	0	0	0	11946	15327	16183	-27272	-857
Mar-95	0	0	0	10664	6177	12640	-16841	-6463
Apr-95	0	0	0	7311	24924	20071	-32235	4854
May-95	0	0	0	1694	12565	17281	-14259	-4716
Dry 95	0	0	0	137859	69115	166174	-190121	-80577
1995 WET SEASON WATER BUDGET								
Jun-95	0	0	0	9132	6782	17222	-15914	-10441
Jul-95	0	1439	0	14267	0	30823	-12829	-30823
Aug-95	0	34	0	13543	0	25108	-13509	-25108
Sep-95	0	0	0	12943	0	22967	-12943	-22967
Oct-95	0	0	0	14321	0	18879	-14321	-18879
Wet 95	0	1473	0	64205	6782	114999	-69514	-108217
HY95	0	18326	0	202064	75897	281173	-259635	-188794
1996 DRY SEASON WATER BUDGET								
Nov-95	0	0	0	16308	0	27383	-16308	-27383
Dec-95	0	0	0	11483	0	21431	-11483	-21431
Jan-96	0	0	0	8014	0	17797	-8014	-17797
Feb-96	0	0	0	4204	NA	11685	NA	NA
Mar-96	0	4611	0	0	15241	15409	-10631	-168
Apr-96	0	20148	0	19	29143	21909	-9015	7235
May-96	1263	986	0	1251	12076	8404	-11079	3672
Dry 96	1263	25745	0	41280	56461	124018	-70733	-55872
1996 WET SEASON WATER BUDGET								
Jun-96	0	0	0	10894	0	13970	-10894	-13970
Jul-96	0	1	0	12023	0	12464	-12022	-12464
Aug-96	0	14	0	11402	NA	11187	NA	NA
Sep-96	0	1	0	11667	NA	12420	NA	NA
Oct-96	0	0	0	16255	0	14691	-16255	-14691
Wet 96	0	16	0	62241	0	64732	-62225	-41125
HY96	1263	25761	0	103521	56461	188750	-132957	-96996
Storage1 is sum of all inflows (S334, S335) for the reach upstream of G211 minus the sum of all outflows (S336, S338, and G211).								
Storage2 is the sum of all inflows (G211) for the reach upstream of S331 minus the sum of all outflows (S173, S331 pumping, S331 siphoning).								

Table 5: Monthly, seasonal, and annual discharges for the upper L-31N canal system between S-335 and S-331 (acre-feet).

1995 WET SEASON FLOWS									
MON/YR	S12A	S12B	S12C	S12D	L67FMB	L30L67	SStot	WSS %	NESS %
1995 DRY SEASON FLOWS									
Nov-94	74997	60735	86062	112158	333953	8311	342264	97.57	2.43
Dec-94	82096	75731	107717	144025	409569	16459	426028	96.14	3.86
Jan-95	82731	71303	103116	127626	384775	12275	397050	96.91	3.09
Feb-95	47146	37786	65189	78447	228569	8120	236689	96.57	3.43
Mar-95	34936	26055	48498	65838	175327	15227	190554	92.01	7.99
Apr-95	17268	10337	24883	34534	87022	26447	113469	76.69	23.31
May-95	7159	6427	13720	18864	46170	27907	74077	62.33	37.67
Dry 95	346333	288373	449185	581492	1665384	114746	1780131	93.6	6.4
1995 WET SEASON FLOWS									
Jun-95	3314	7791	14686	12640	38431	32704	71134	54.0	46.0
Jul-95	16618	10926	25946	35145	88634	5749	94383	93.9	6.1
Aug-95	20286	17621	40759	46462	125127	13538	138665	90.2	9.8
Sep-95	42950	35972	67589	86102	232612	9035	241646	96.3	3.7
Oct-95	70825	57172	85130	113289	326416	14559	340975	95.7	4.3
Wet 95	153992	129482	234109	293637	811220	75584	886804	91.5	8.5
HY95	500325	417856	683294	875130	2476604	190330	2666935	92.9	7.1
1996 DRY SEASON FLOWS									
Nov-95	66482	47997	76464	99824	290767	15023	305791	95.1	4.9
Dec-95	45056	33596	56605	74085	209341	5868	215209	97.3	2.7
Jan-96	31853	20907	43832	52536	149128	5640	154767	96.4	3.6
Feb-96	3038	5870	8965	12473	30346	21143	51489	58.9	41.1
Mar-96	0	486	1509	2358	4353	20732	25085	17.4	82.6
Apr-96	0	0	0	0	0	22533	22533	0.0	100.0
May-96	0	0	0	0	0	22156	22156	0.0	100.0
Dry 96	146429	108855	187376	241276	683935	113094	797029	85.8	14.2
1996 WET SEASON FLOWS									
Jun-96	3117	3780	9643	24036	40576	20512	61088	66.4	33.6
Jul-96	12923	11127	31996	37584	93629	9522	103152	90.8	9.2
Aug-96	17982	14450	32791	43660	108883	27695	136577	79.7	20.3
Sep-96	16465	12745	30631	40213	100054	8606	108660	92.1	7.9
Oct-96	20516	15277	33620	42426	111839	11355	123194	90.8	9.2
Wet 96	71003	57378	138681	187919	454982	77690	532671	85.4	14.6
HY96	217431	166233	326057	429195	1138916	190784	1329700	85.7	14.3
L67FMB is the published flow for the Levee 67 to Forty Mile Bend flow section (S12A through S12D). L30L67 is the published flow for the Levee 30 to Levee 67 flow section (includes S333 plus seepage). WSS% and NESS% are the percentages of the total Shark Slough flow (SSTOT) passing through the western (L67FMB) and eastern (L30L67) flow sections, respectively.									

Table 6: Monthly, seasonal, and annual discharges into the Shark Slough watershed (acre-feet).

The majority of this seepage volume originates from NESS wetlands and the aquifer adjacent to L-31N as a result of S-338 flood operations. March through May water supply operations accounted for approximately 40% of the total dry season drainage of 66,500 acre-feet along this L-31N reach. During the 1996 wet season, S-338 flood operations resulted in approximately 62,225 acre-feet being removed from NESS wetlands and the aquifer adjacent to L-31N. This volume represents approximately 80% of the flows into NESS during this same period. A total of 128,774 acre-feet, 67% of the flows into NESS, were removed from NESS wetlands and aquifer adjacent to northern reach of L-31N due to management operations during hydrologic year 1996, the first year of Test 7.

During the 1995 wet season flood control operations associated with the East Everglades developed areas resulted the removal of 108,200 acre-feet from storage in the reach of L-31N between G-211 and S-331 (see Table 5). During this period the use of G-211 was limited because of the high water levels in the downstream developed areas. Hydrologic year 1995 Test 6 ended with 188,800 acre-feet removed from this reach of L-31N in response to flood operations. The 1996 dry season included both flood control and water supply operations. The earlier portion of the dry season began with a continuation of flood operations due to antecedent high stages, with water supply occurring late in the dry season. Flood control operations at S-331 during the early dry season, with G-211 closed accounted for 63% of the total dry season 124,000 acre-feet discharged through S-331/S-173. During the March through May water supply, G-211 flows were approximately double S-335 inflows resulting in the removal of approximately 30,716 acre-feet from storage from NESS wetlands. G-211 inflows exceeded S-331/S-173 outflows by approximately 10,700 acre-feet which accounted for 42% of the regional water supply. Consistent flood operations at S-331 resulted in a monthly removal from storage of approximately 13,000 acre-feet. Hydrologic year 1996 water management operations at S-331 resulted in 64,700 acre-feet moved to the downstream basin.

4.1.2 L-31N S-331/S-173 to S-174/S-176

Monthly total discharge and open water budgets for structures in lower L-31N between S-331 and S-176 are shown in Table 7. Inflows to this reach of L-31N originate from S-331 pumping, S-331 siphoning and S-173 flows. Outflows occur to the east through C-102 and C-103 canals with operational control provided by S-194 and S-196, respectively. Outflows from this section of L-31N canal are made into either C-111 through S-176 or the L-31W canal

MON/YR	S-331	S-194	S-196	S-174	S-176	Outflows	Stor
1995 DRY SEASON WATER BUDGET							
Nov-94	23428	4174	5314	14876	18522	42885	-19457
Dec-94	33753	7563	4572	7117	21849	41101	-7347
Jan-95	42818	8161	4560	9685	23038	45444	-2625
Feb-95	16183	7837	6002	4324	681	18843	-2660
Mar-95	12640	6060	6643	527	191	13422	-782
Apr-95	20071	6977	6682	2867	5780	22306	-2235
May-95	17281	694	2822	2865	3015	9396	7885
Dry 95	124018	41465	36596	42260	73075	193397	-27222
1995 WET SEASON WATER BUDGET							
Jun-95	17222	-563	1474	9094	24235	34239	-17016
Jul-95	30823	5003	4046	13962	16198	39209	-8386
Aug-95	25108	3206	3807	14009	16895	37918	-12810
Sep-95	22967	6277	7493	12016	11747	37533	-14565
Oct-95	18879	5198	5643	13000	20563	44404	-25524
Wet 95	114999	19121	22464	62080	89638	193302	-78303
HY95	281173	60586	59060	104340	162713	386698	-105525
1996 DRY SEASON WATER BUDGET							
Nov-95	27383	NA	5413	13783	4716	23912	3471
Dec-95	21431	5949	4460	8872	892	20173	1258
Jan-96	17797	3161	2701	5990	3163	15016	2782
Feb-96	11685	0	0	183	0	183	11502
Mar-96	15409	0	0	123	0	123	15286
Apr-96	21909	0	0	1840	1235	3075	18834
May-96	8404	209	0	689	8803	9702	-1298
Dry 96	124018	9320	12574	31481	18809	72183	51835
1996 WET SEASON WATER BUDGET							
Jun-96	13970	-828	2280	6214	20233	27899	-13929
Jul-96	12464	2447	6001	4379	639	13465	-1001
Aug-96	11187	0	0	7445	798	8242	2945
Sep-96	12420	NA	0	11973	2729	14701	-2281
Oct-96	14691	718	425	13313	13308	27765	-13074
Wet 96	64732	2336	8706	43324	37707	92073	-27341
HY96	188750	11656	21280	74804	56515	164255	24494
Outflows is the sum of all of the outflow structures.							
Storage is the total inflows minus the total outflows.							

Table 7: Monthly, seasonal, and annual discharges for the L-31N canal between S-331 and S-176 (acre-feet).

through S-174. During the 1995 wet season outflows were more than two times inflows. This significant increase in seepage from earlier Test 6 wet seasons possibly resulted from a combination of factors including but not limited to above average rainfall resulting regionally high water levels and extended periods of flood control operations. During Test 7 dry season, flood operations at S-331 continued through the early dry season. November through January S-331 flood operations resulted in the removal of approximately 66,600 acre-feet from above S-331, with only 88% of this volume accounted for at the outflow structures. Water supply during the late dry season resulted in recharge to the aquifer to L-31N above S-176. During this period approximately 78% of the flows entering the reach or 44,534 acre-feet were dissipated as groundwater recharge. During the previous Test 6 dry seasons this reach acted in both a discharge and recharge capacity. During the 1994 dry season because of large S-331/S-173 inflows and limited use of S-194 and S-196, dry season operations resulted in recharge to adjacent aquifers. However, during the 1995 dry season under the same operational criteria but different antecedent hydrologic conditions, operations in this reach resulted of drainage of wetlands to the west and aquifer to the east.

The 1996 wet season of Test 7 highlights the problems associated with the operational criteria in L-31N between S-331 and the S-174 S-176 complex. Frequent S-331 flood operations during this period resulted in drainage of the Rocky Glades, indicated by wet season outflows exceeding inflows by approximately 125%. Approximately 60% of the total wet season flow out of this reach occurred through S-174 and S-176 during June and October flood operations. Drainage during this period prevents water levels in the Rocky Glades wetlands from reaching wet season water levels of sufficient duration to be a functional wetland as shown in Section 3.3.2.

The distribution of flow from L-31N canal westward to L-31W through S-174 quantified as a percentage of S-176 continues to vary with season and antecedent hydrologic conditions. The use of a S-174 S-176 flow ratio is used to identify variations in the division of flow westward to Taylor Slough and south to the Eastern Panhandle. The ratio for Test 6 and Test 7 dry seasons ranged from 57 to 167% during hydrologic year 1995 of Test 6 and Test 7. Smaller values represent less flow towards Taylor Slough, more downstream towards the Eastern Panhandle. During the wet season for the same period the ratio of S-174 to S-176 flows ranged from 69% in hydrologic year 1995 to 150% during hydrologic year of 1994, both in Test 6. The ratio during Test 7 wet season was 115%. Examination of Table 7 shows how the monthly variability is weighted

with regard to specific objectives. For instance in June of 1996 concerns over endangered species resulted a shift flood operations more to C-111 indicated by a 30% ratio. From July through early September with less than average rainfall the S-174 S-176 ratio averaged less than 700%, indicating that the majority of available flood waters were moved westward during these month. This is the result of implementing the rainfall formula and consistent with the higher operational stage at S-176. Over the month of October during which above average rainfall occurred, upstream flood waters were evenly distributed between S-174 and S-176. For year 1 of Test 7 these operations resulted in a 132% ratio or a 57% 43% split between S-174 and S-176, respectively of L-31N flows.

4.1.3 L-31W

Table 8 contains monthly total discharge and open water budgets for the structures of the L-31W canal between S-174 and S-175. Structure inflows to the L-31W canal occur through S-174 with outflows through S-332 and S-175. During the wet season 1995 more than twice as much water was discharged from the L-31W canal then entered as inflows. Outflows exceeded inflows during every month of hydrologic year 1995. The 298,825 acre-feet discharged from L-31W during the 1995 hydrologic year was more than double the average annual outflows for the 1983 through 1993 experimental water delivery period. This large difference between inflow and outflows indicate local drainage from northern Taylor Slough wetlands and seepage from the aquifer adjacent to L-31W.

During the 1996 dry season antecedent hydrologic conditions resulting in high stages were waning. Throughout this period outflows exceeding inflows persisted, as necessary to maintain the rainfall plan weekly L-31W targets. During the 1996 dry season, the operational strategy of pumping at S-332 with S-174 closed while minimizing the use of S-175 was utilized to maintain stage in L-31W prescribed by the rainfall plan. This mode of operation resulted outflows approximately $2\frac{1}{2}$ times greater than inflows, about the same during the previous 1995 dry season. The operations associated with the drawdown experiment during January accounted for 19% and 18% of dry season inflows and outflows, respectively. The composition of outflows during the 1996 dry season is similar to those identified early, seepage inflows from the wetlands west of L-31W and recirculation of S-332 pumping.

MTH/YR	S-174	S-332	TSB	S-175	Sum Outflows	Storage
1995 DRY SEASON WATER BUDGET						
Nov-94	14876	25474	12630	13919	39392	-24516
Dec-94	7117	27288	8721	6088	33376	-26259
Jan-95	9685	28716	7430	8014	36730	-27046
Feb-95	4324	16532	5184	1916	18448	-14124
Mar-95	527	5514	1342	964	6479	-5952
Apr-95	2867	3336	276	443	3779	-912
May-95	2865	6837	2447	469	7306	-4441
Dry 95	42260	113698	38030	31812	145510	-103250
1995 WET SEASON WATER BUDGET						
Jun-95	9094	9128	7656	12981	22109	-13016
Jul-95	13962	19830	12582	11691	31521	-17559
Aug-95	14009	19076	11119	15140	34216	-20207
Sep-95	12016	18426	10571	13890	32316	-20301
Oct-95	13000	16764	12209	16389	33153	-20154
Wet 95	62080	83225	54138	70091	153316	-91236
HY95	104341	196922	92168	101903	298825	-194484
1996 DRY SEASON WATER BUDGET						
Nov-95	13783	16340	6804	10751	27091	-13308
Dec-95	8872	18218	5344	537	18755	-9883
Jan-96	5990	12862	3222	1969	14831	-8841
Feb-96	183	9302	1255	0	9302	-9120
Mar-96	123	5550	393	58	5608	-5484
Apr-96	1840	2263	52	0	2263	-424
May-96	689	5329	1503	0	5329	-4640
Dry 96	31481	69864	18573	13315	83179	-51698
1996 WET SEASON WATER BUDGET						
Jun-96	6214	12316	6837	4074	4074	-10176
Jul-96	4379	6114	5604	996	6114	-2731
Aug-96	7445	12798	6306	1872	14670	-7226
Sep-96	11973	17341	8091	1032	18373	-6400
Oct-96	13313	25119	15214	6110	25119	-17915
Wet 96	43324	73688	42052	14084	68350	-44448
HY96	74804	143552	60624	27399	151528	-96146
Total column is the sum of all of the L-31W outflow structures (S332 and S175).						
TSB designates flows through the Taylor Slough Bridge flow section.						
Storage is the sum of all L-31W inflows (S174)						
minus the sum of all outflows (S1 75 and S332).						

Table 8: Monthly, seasonal, and annual discharges for the L-31W canal (acre-feet).

The available data summarizing the 1996 wet season operations of structures with L-31W indicates that operation of outflow structures to maintain the rainfall target continued in a mode similar to the dry season. The major difference flood operations resulting in significantly larger outflows. Outflows during the 1996 wet season exceeded inflows by more than $1\frac{1}{2}$ times. During 1996 hydrologic year, Test 7 nearly 2 times the amount of water that entered L-31W was removed through operation of S-332 and S-175. This indicates that although modifications of the operational stage in L-31W has occurred they have not significantly reduced localized inflows in the form of seepage from northern Taylor Slough wetlands and aquifer adjacent to L-31W.

4.1.4 C-111

The monthly summaries and open water budgets for the three segments of the C-111 canal are presented in Table 9. The upper reach is between S-176 and S-177, the middle between S-177 and S-18C (including the C-111E to S-178, see Fig. 1) and the lower between S-18C and S-197. Data from S-178 was not included in Table 9 because of the uncertainty in the quality of the data. Approximately 6 years of missing data and almost a year of questionable or estimated data accounts for 46% of the 16 year period of record. The infrequent operation of S-178 results in additional uncertainty given the very limited number of data not equal to zero that remain after removal of questionable and estimated data.

The northern reach provides drainage to the agricultural areas east of C-111 and in the past to the Frog Pond. During the wet season of 1995 more than $1\frac{1}{2}$ times more water left this reach than entered through S-176. Drainage of wetlands above S-18C is indicated by S-177 flows accounting for only 71% of S-18C flows during the same period. The average volume removed from storage monthly during this period was approximately 10,500 acre-feet (above S-177) and 11,400 acre-feet (above S-18C). These upstream flood operations resulted period of record maximum S-18C wet season flows of approximately 199,000 acre-feet, of which S-197 discharged of 94,328 acre-feet. This S-197 volume was almost 6 times the period of record wet season average. Approximately 44% of these S-197 discharges resulted from the drainage of wetlands and aquifer adjacent to C-111 below S-177. Hydrologic year 1995 of Test 6 S-197 discharges to tide totalled 114,133 acre-feet leaving the remaining 238,000 acre-feet remaining to be dispersed throughout the marshes of the Eastern Panhandle. Approximately 32% of the S-197 hydrologic year total was from

drainage due to flood operations below S-177.

The 1996 dry season included very brief S-197 operations early, operations necessary to meet the minimum monthly water deliveries and operations associated with the drawdown experiment in January. These operations combined resulted in only marginal drainage of the reach of C-111 between S-176 and S-177. During this period below S-177, S-18C outflows exceeded inflows by more than $1\frac{1}{2}$ times. Approximately 13,300 acre-feet was removed from storage between S-177 and S-18C as seepage from the wetlands and aquifer adjacent to C-111 during flood operations from November to January. February and March water supply resulted in the drainage of an additional 1,950 acre-feet from these wetlands. Water supply from the regional system to meet the minimum monthly delivery schedule for the Eastern Panhandle occurred for the first time during Test 7 in April and again in May.

During the 1996 wet season flood operations resulted in the removal of approximately 39,700 acre-feet from the aquifer between S-176 and S-177. Flood operations removed an additional 40,400 acre-feet from period was from aquifer between S-177 and S-18C. Surface water deliveries of from upstream flood operations delivered approximately 91,000 acre-feet or 77% of S-18C discharges to the Eastern Panhandle. Flood operations of S-197 removed approximately 27,000 acre-feet from storage or approximately 33% of the total volume of water removed from aquifer and wetland between S-176 and S-18C. Approximately 41% of this volume was removed at the onset of the 1997 dry season. Over the entire hydrologic year, 1996 more than $2\frac{1}{2}$ times as much water as entered through S-176 was diverted to the Eastern Panhandle. During this period no operational strategies were implemented for L-31W and C-111 flood operations allowing higher Frog Pond stages, between the higher western and lower eastern water levels. The implementation of operations could lead to new practices to reduce seepage losses from northern Taylor Slough wetlands, seepage losses from the wetlands adjacent to C-111 between S-177 and S-18C while maintaining the authorized levels of flood protection to the east.

4.2 1995 Wet Season of Test 6

In Western Shark Slough, large supplementary flows of approximately 811,000 acre-feet were delivered from the upstream Water Conservation Areas, during the 1995 wet season. Of the total Shark Slough flows Northeast Shark Slough received approximately 9%, or 75,584 acre-feet. The large disparity between

MTH/YR	S-176	S-177	S-18C	S-197	Storage1	Storage2
1995 DRY SEASON WATER BUDGET						
Nov-94	18522	25250	40255	19805	-6728	-15005
Dec-94	21849	22043	31772	0	-194	-9729
Jan-95	23038	21813	29878	0	1225	-8065
Feb-95	681	5131	14676	0	-4451	-9545
Mar-95	191	5136	10916	0	-4945	-5780
Apr-95	5780	8389	10288	0	-2609	-1899
May-95	3015	10250	16135	0	-7235	-5886
Dry 95	73075	98012	153920	19805	-24936	-55908
1995 WET SEASON WATER BUDGET						
Jun-95	24235	34415	39192	20331	-10180	-4777
Jul-95	16198	23239	31415	7707	-7041	-8176
Aug-95	16895	26734	41032	16558	-9839	-14298
Sep-95	11747	21841	31889	7314	-10094	-10048
Oct-95	20563	35976	55453	42419	-15413	-19477
Wet 95	89638	142204	198980	94328	-52566	-56776
HY95	162714	240215	352260	114133	-77501	-112045
1996 DRY SEASON WATER BUDGET						
Nov-95	4716	5666	14312	492	-950	-8646
Dec-95	892	1635	3237	0	-743	-1602
Jan-96	3163	1738	4816	0	1425	-3078
Feb-96	0	0	1444	0	0	-1444
Mar-96	0	0	512	0	0	-512
Apr-96	1235	1175	-157	0	60	1332
May-96	8803	8988	7652	0	-185	1337
Dry 96	18809	19202	31815	492	-393	-12614
1996 WET SEASON WATER BUDGET						
Jun-96	20233	31972	40971	15294	-11739	-8999
Jul-96	639	4384	13727	506	-3745	-9343
Aug-96	798	7050	10741	0	-6253	-3691
Sep-96	2729	7915	18168	0	-5186	-10254
Oct-96	13308	26147	34294	10970	-12839	-8147
Wet 96	37707	77468	117901	26770	-39762	-40433
HY96	56515	96670	149717	27262	-40155	-53047
Storage1 and Storage2 refer to the storage changes in the C-111 canal upstream of S-177 and S-18C, respectively.						

Table 9: Monthly, seasonal, and annual discharges for the C-111 canal (acre-feet).

the surface water delivered to Western and Northeastern Shark Slough during this period is very evident in Figure 46. This disparity as noted in Section 3.2 resulted from the suspension of S-333 flows due to downstream L-29 canal constraints and exceedance of G-3273 trigger well criteria during this period of regionally high water levels. During this period the operation of G-211 and S-338 resulted in as much water, 91% being removed from Northeast Shark Slough wetlands adjacent to L-31N as entered. The majority of these flows were discharged through S-338. During the 1995 wet season operation of S-338 produced flows that were 6 times and double, 1993 and 1994 wet season flows, respectively. Concern over high water levels in the East Everglades developed areas and further downstream resulted in the use of G-211 as a divide structure as originally designed. G-211 flows during this period were approximately 20 times less than during either of the two previous wet seasons.

High water levels in NESS sustained by above average wet season rainfall required operations throughout the wet season at S-173/S-331. flows. The limited use of G-211 resulted in only 6% of the 115,000 acre-feet discharged through S-331/S-173 during this period to originate from NESS wetlands adjacent to L-31N. This large disparity between inflows and outflows is the result in attempting to provide relief to the East Everglades developed areas from regionally occurring high water levels. This exemplifies concerns noted in Test 6 analysis [Everglades National Park, 1995a] of using a large regional water supply pump station such as S-331 to provide local drainage. The removal of 100,000 acre-feet from storage from the East Everglades developed areas is suggestive of seepage losses of similar magnitude from NESS. Total losses from NESS wetlands during this period possibly approached 177,000 acre-feet during the 1995 wet season. This quantity represents more than 2 times the volume of water that entered NESS through the L-67 to L-30 NESS flow section and S-335.

During the 1995 wet season outflows from L-31N below S-331 exceeded inflows by approximately 80,000 acre-feet, up from earlier Test 6 wet seasons in 1993 and 1994. Thirty-six percent of S-331 flows passed eastward through S-194 and S-196. The west to east hydraulic gradient in this area during the 1995 wet season suggest that a large percentage of this total can be attributed to seepage from the Rocky Glades. The removal from storage of water from the Rocky Glades contributes to the dysfunction of these wetlands.

The Test 6 objective of delivering more water to Taylor Slough is achieved partly at the expense of the drainage of the Rocky Glades and northern Taylor Slough wetlands and aquifer adjacent to L-31W. During the 1995 wet season

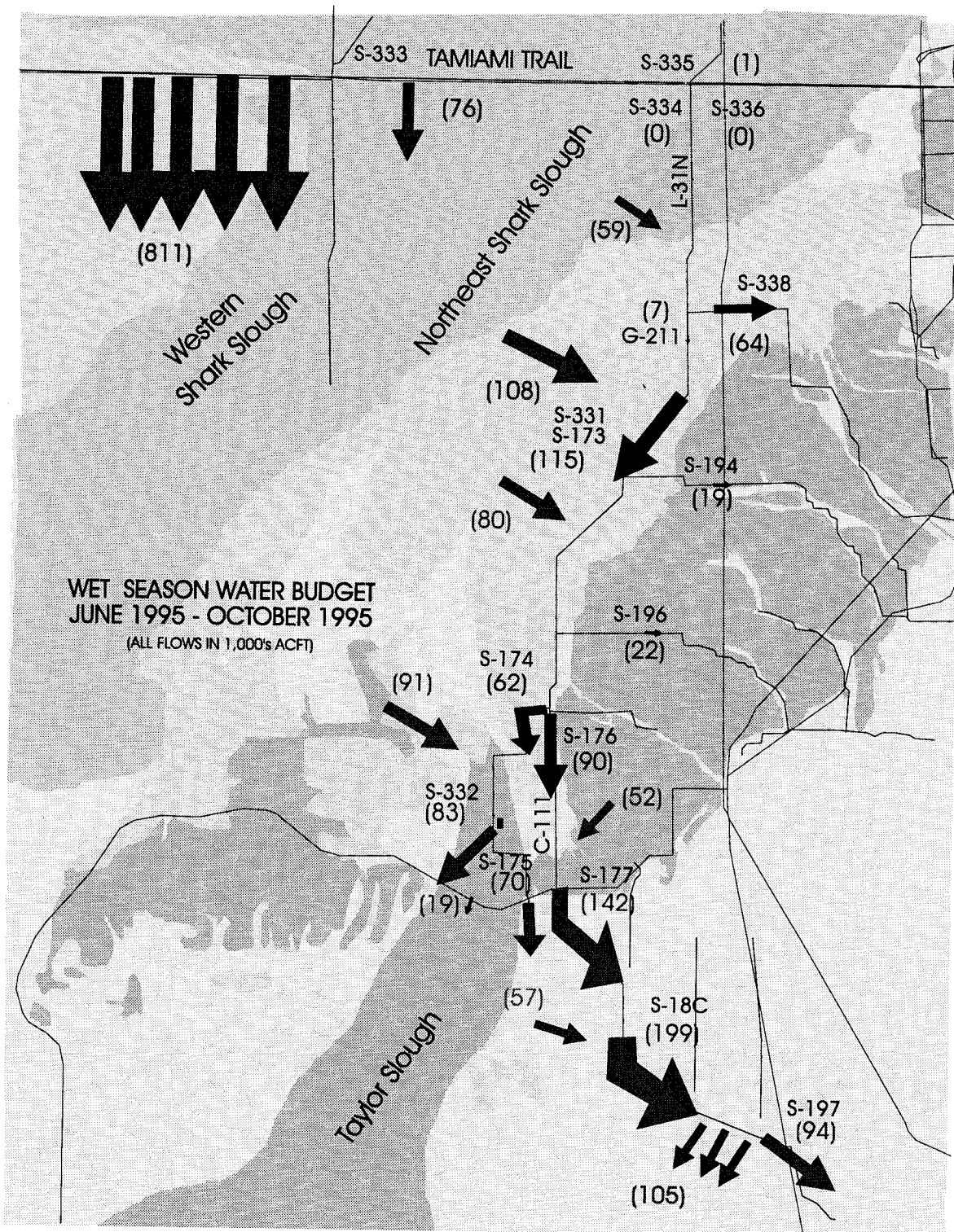


Figure 46: Wet season water budget for the period from June 1995 through October 1995.

L-31W outflows exceeded inflows a little less than $2\frac{1}{2}$ times or approximately 89,000 acre-feet. It can be expected that a large majority of this difference can be accounted for by seepage from ENP wetlands north of S-332, although some contribution due to recirculation of S-332 pumping is expected. Of the total 83,000 acre-feet pumped at S-332 only 23% was recorded at the downstream Taylor Slough flow section, indicating that the possibility of seepage back into L-31W below S-332 as the source of S-175 flows during the same period.

Water management operations of C-111 resulted in large diversions of surface water delivered to the Eastern Panhandle (EP). Eastern Panhandle surface waters originate from the aquifer upstream and below S-176. During the 1995 wet season approximately 45% or 90,000 acre-feet of EP surface waters come from above S-176. Another 52,000 acre-feet was removed from storage between S-176 and S-177. Wetlands and the aquifer adjacent to C-111 below S-177 accounted for for only 29% of the S-18C flows. Seepage below S-177 has been suggested to be the result of low operational stages maintained upstream of S-18C[Everglades National Park, 1995a]. Although EP wetlands were able to convey 105,000 acre-feet in excess of local rainfall during the 1995 wet season, the total 199,000 acre-feet of S-18C flow required the operation of S-197 during every month of the 1995 wet season. Hydrologic year 1995 of Test 6 total S-197 discharges to tide were the maximum for the published period of record.

4.3 Test 7

4.3.1 1996 Dry Season

Surface water flows delivered from WCA-3A to Shark Slough during the dry season 1996 totalled approximately 796,000 acre-feet. A large percentage of the volume delivered was above the quantity specified by the rainfall formula. The distribution of flow during this period was 86% delivered into Western Shark Slough or approximately 683,000 acre-feet with remaining 113,000 acre-feet entering Northeast Shark Slough. NESS received 5 times less than if the total Shark Slough delivery were apportioned as specified by the rainfall formula flow distribution, 45% into western Shark Slough and 55% into Northeastern Shark Slough.

One of the objectives of Test 7 is the reduction of seepage from NESS wetlands and aquifer adjacent to L-31N between G-211 and S-335. During

the 1996 dry season a reduction in seepage from this northern most reach of L-31N was realized over the previous 2 dry seasons, 1994 and 1995. Although seepage appears to have been reduced it is important to note that flows into NESS were the lowest for these same periods. Notwithstanding this reduction in seepage L-31N operations in this reach continues to capture large volumes of groundwater from adjacent wetlands and aquifer. During the 1996 dry season G-211 and S-338 total flows exceeded inflows into the reach by approximately 71,000 acre-feet. This volume accounted for approximately 63% of the flows into NESS. It is difficult to assess the contribution of raising the operational stage at G-211 by 0.5 ft. to this reduction in seepage from the previous periods due to differences in rainfall and L-31N operations.

During the 1996 dry season large quantities of groundwater were removed from storage from the 8.5 SQMA as a result of S-331 operations. The change in storage between S-331 and G-211 amounted to a net gain in this reach of approximately 68,000 acre-feet. G-211 flows account for only 45% of S-331/S-173 flows during this period. The 1996 dry season open water budget presented in Fig. 47 indicates that S-331 operations resulted in approximately 52,000 acre-feet made available recharge of the lower aquifer adjacent to L-31N between S-331 and S-176.

Dry season S-174 flows to L-31W increased in comparison to previous iterations. During iterations 1 through 5 dry season S-174 flows into the L-31W canal averaged less than 22,000 acre-feet, or approximately 30 percent of the S-176 inflows [Everglades National Park, 1995a]. During the previous two dry seasons of Test 6 1994 and 1995, S-174 flows represented 85% and 58% of S-176 flows. During Test 7 S-174 flows increased to greater than 160% of S-176 flows. The increase in the ratio of S-174 to S-176 flow as noted previously [Everglades National Park, 1995a] is the result of maintaining higher operational stages at S-176. These S-174 flows into L-31W accounted for only 37% of the total flows through S-332 and S-175. The implementation of a rainfall formula during Test 6 prescribed a target stage for L-31W. During the dry season the target stage predicted was often less than the actual L-31W stage requiring operations to lower L-31W stage. The operational strategy employed was to maintain S-332 pumping while limiting S-174 flows, thereby drawing down L-31W. Fig. 47 indicates that this this operation contributed to the removal of groundwater from northern Taylor Slough which is contradictory to the objective of the implementation of the rainfall formula. A percentage of the disparity between L-31W inflows and outflows can be attributed to recirculation of water through S-332 pumping. Reducing dry season drainage from

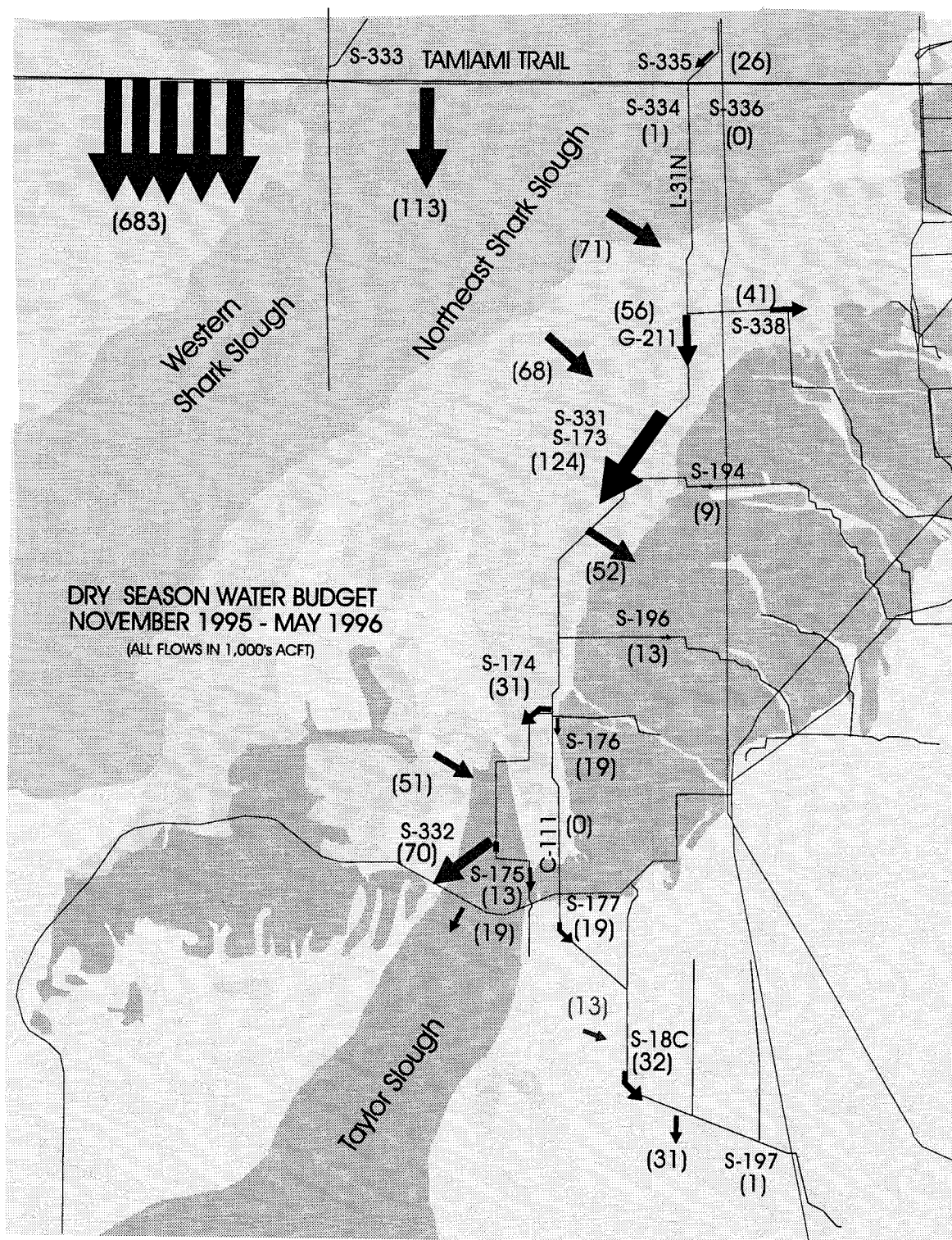


Figure 47: Dry season water budget for the period from November 1995 through May 1996.

northern Taylor Slough wetlands adjacent to L-31W can be accomplished by allowing L-31W to fluctuate in response to prevailing conditions as opposed to S-332 pumping to reach down to target stages. With below average dry season rainfall recorded at S-18C during Test 7 year 1 it is difficult to assess the significance of the increase in the S-18C operational criteria during Test 7. Each of these factors contributed to the approximate 23% reduction in seepage below S-177 from the previous dry season of Test 6, but determining the percentage of each requires further analysis. Whether a reduction in seepage was actually realized is further suspect considering the 1996 dry season, Test 7 year 1 seepage accounted for 40% of S-18C flows in contrast to 58% and 31% for the 1994 and 1995 dry seasons, respectively. During both of these earlier periods S-18C dry season rainfall was more than double that recorded during Test 7.

4.3.2 1996 Wet Season

During the wet season of 1996, approximately 531,000 acre-feet of surface water was delivered to Shark Slough from the Water Conservation areas. Figure 48 shows that target distribution of flow between Western 45% and Northeastern Shark Slough 55% were not achieved during this period. The total volume delivered to Northeast Shark Slough was only 14% of the total wet season flow delivered to Shark Slough. Large groundwater and surface water losses from NESS wetlands and aquifer adjacent to L-31N due to water management operations at S-338 occurred during this period. Approximately 80% of the flows into NESS can be accounted for by S-338 discharges. Utilization of G-211 as a divide structure as designed during this period and operations at S-331/S-173 resulted in the removal from storage of approximately 65,000 acre-feet from the reach of L-31N between G-211 and S-331.

Seepage from the Rocky Glades and aquifer adjacent to L-31N between S-331 and S-176 during previous Test 6 wet seasons varied from 6% to 52% of the combined flow through S-176 and S-174. The low value occurred in the wet season of 1993 and the high during the 1995 period of regionally high water levels resulted from very wet rainfall. The operation of structures in this reach during the 1996 wet season with average rainfall resulted in seepage approximately 33% of the combined flow through S-174 and S-176. This volume, approximately 27,000 acre-feet, during average wet season rainfall indicates that the nominal increase in the S-176 operating criteria is insufficient to provide any meaningful reduction in seepage in lower L-31N.

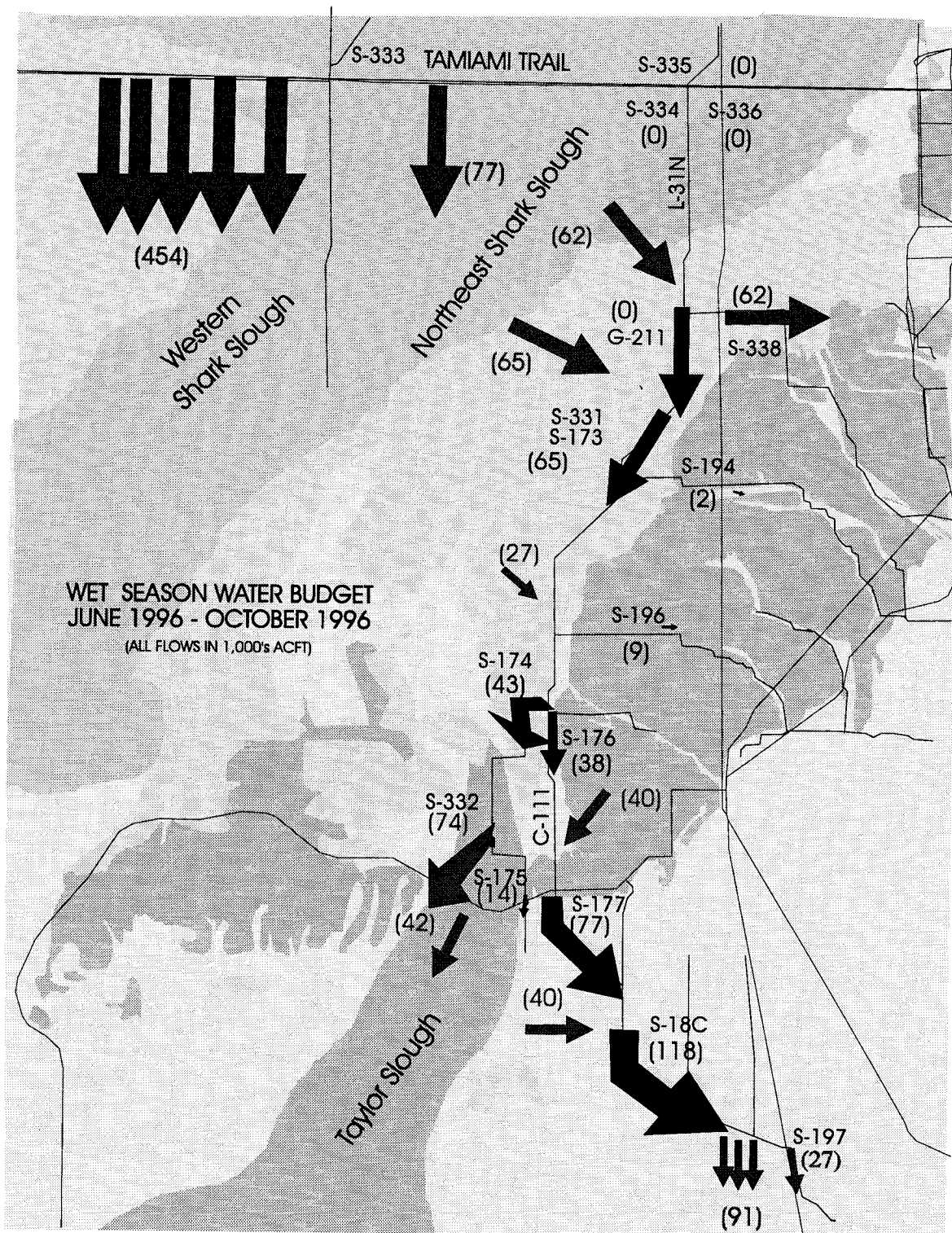


Figure 48: Wet season water budget for the period from June through October 1996.

During Test 7 the 1996 wet season L-31W outflows through S-332 and S-175 were approximately twice S-174 inflows. Flows through S-174 were 113% of S-176 flows. The range in the ratio of S-174 to S-176 during previous Test 6 wet seasons was from 71 to 140%, the 1995 and 1994, respectively. The origins of the difference between inflows and outflows can be attributed to drainage from northern Taylor Slough wetlands and recirculation of water due to S-332 pumping. During Test 7 minimizing the use of S-175 was integrated into the operation of L-31W, to minimize seepage from ENP into L-31W below S-332. During the 1996 wet season Taylor Slough flows were marginally higher, despite average wet season rainfall, than during any of the Test 6 wet seasons. Taylor Slough flows were approximately 57% of the total S-332 flow. The combination of higher operational L-31W stages and the limited use of S-175 may have contributed to this increase of Taylor Slough flows.

C-111 operation of S-176 and S-177 during this period resulted drainage of the Frog Pond. Below S-177 drainage of the wetlands and aquifer adjacent to C-111 was similar to the previous wet season. During the 1996 wet season S-18C flows were approximately 150% more than S-177, the 1995 wet season ratio was approximately 140%. Eastern Panhandle wetlands were able to remove approximately 91,000 acre-feet of drainage from upstream but capacity of these marshes were exceeded requiring the operation S-197 to remove an additional 27,000 acre-feet.

5 Hydropatterns in ENP

Water level data from the available gages in the Everglades National Park and the Lower East Coast were used to generate stage contour plots of the study area. These contour plots were then subtracted from an elevation contour plot to generate surface water depth and depth to groundwater plots. The dates were selected to provide a general indication of ENP hydropatterns throughout hydrologic year 1996. These dates were arbitrarily decided on prior to the initiation of Test 7 and did not account for specific water management operations that occurred during the study period. The dates chosen were the 15 of November 1995 and the 15 of January, March, May, July, and September 1996. A description of March hydropatterns was omitted since these dates did not correspond to specific climatological or operational events within the Test study period. Discussion of the hydropattern characteristics of the test will also include a general description of the hydrologic and operational conditions

preceding each of the map dates.

The general patterns of the water depths are illustrated very well in the surface subtraction maps. Shark Slough becomes well defined and the drainage associated with operation of C&SF Project canals along the eastern boundary is evident through examination of the stage contour maps; as indicated by the orientation of the stage contours lines parallel to the canal system alignment. The large supplemental releases from WCA-3A into western Shark Slough and the effects on water levels in Western Shark Slough become very evident south of the S-12 structures. Except for wet conditions following the wet season of 1995, much of the Rocky Glades had little or no surface water most of the year. The historical surface water connection between Northeast Shark Slough and Taylor Slough was not evident for any appreciable period of time during Test 7. Attempts to compensate for the effects of drainage in the Rocky Glades and Northern Taylor Slough by increased pump capacity at S-332 show up in the water level contours as small increases confined to an area just north of State Road 9336.

5.1 Transition Period Hydrologic Conditions- November 1995

The antecedent 1995 wet season hydrologic conditions were sufficient to sustain surface water conditions throughout much of ENP. Water levels throughout ENP were at or near their maximum for hydrologic year 1996, similar to those that existed during November 1994 after Tropical Storm Gordon. The wet season rainfall events decreased soon after October 26. Rainfall recorded at stations throughout the study area several days prior to November 15 were less than 0.10 inch. The exception was a 0.75 inch rainfall in the northeastern quadrant of the study area. The S-12 total discharge during this same time period was approximately 5,000 cfs per day with the majority of these releases confined to structures S-12C and S-12D. No S-333 flows to NESS or to L-31N through S-335 and S-334 occurred. Flood operations at S-338 were steady at approximately 500 cfs and G-211 was closed. S-331 was pumping consistently at approximately 500 cfs for several days prior to and during November 15. S-194 was closed and S-196 averaged approximately 89 cfs. Less than half (240 cfs) of S-331 discharges were diverted into L-31W through S-174. Total combined flows out of L-31W through S-332 and S-175 are more than double inflows through S-174. In C-111 S-176 discharges were approximately the same as downstream S-177 flows (75 cfs per day). Below S-177, S-18C flows indicate

that approximately 180 cfs is unaccounted for as S-177 inflows to this reach. No S-197 discharges have occurred since November 1st.

The stages in northern Western Shark Slough shown in Figure 49 resulted from a combination of high stages in WCA-3A and supplemental releases from the area through the S-12 structures. These conditions created deep water not only in central portions of the basin but extended into the far western wetlands as shown in Figure 50. Antecedent rainfall and water levels in both WCA-3B and L-29 contributed to relatively uniform surface water conditions existing over much of Northeastern Shark Slough. The effect of the comparatively lower ground water levels east of L-31N and water management operations of the canal are evident in Figure 49. The factors, combined with the distribution of Shark Slough flows, prevented the restoration of the surface water connection between the NESS, the Rocky Glades, and northern Taylor Slough.

5.2 Early Dry Season Hydrologic Conditions-January 1996

The lack of rainfall, in combination with the C&SF flood operations, have contributed to a lowering of water levels in eastern ENP. Deeper waters still persist in western ENP. Rainfall recorded at stations throughout the study area during the 5 days prior to January 15 were less than 0.05 inches. The Shark Slough flow distribution was 100% to Western Shark Slough and 0% Northeastern Shark Slough as S-333 flows. The combined discharge through the S-12 structures was approximately 2,500 cfs with zero flow at S-333. No flows to L-31N through either S-334 or S-335 occurred during this period and operations at S-338 resulted in daily discharges of approximately 150 cfs. Structure G-211 was closed. S-331 average daily discharge during this period was approximately 275 cfs. Daily discharges at downstream structures over this period have been averaged the follow quantities: 70 cfs at S-194, 60 cfs at S-196, 135 cfs at S-174 and S-176 was closed. L-31W operations included S-332 discharges of 175 cfs and S-175 was closed. In C-111, flow at S-177 averaged approximately 60 cfs while discharges at S-18C were approximately 90 cfs. S-197 structure was closed.

Under these general hydrologic conditions January 15th water levels in Western Shark Slough shown in Figure 51 have receded by approximately 1 foot from November stages. Water depths for this date shown in Figure 52 highlight the combined effects of the relatively larger S-12 flows and the in-

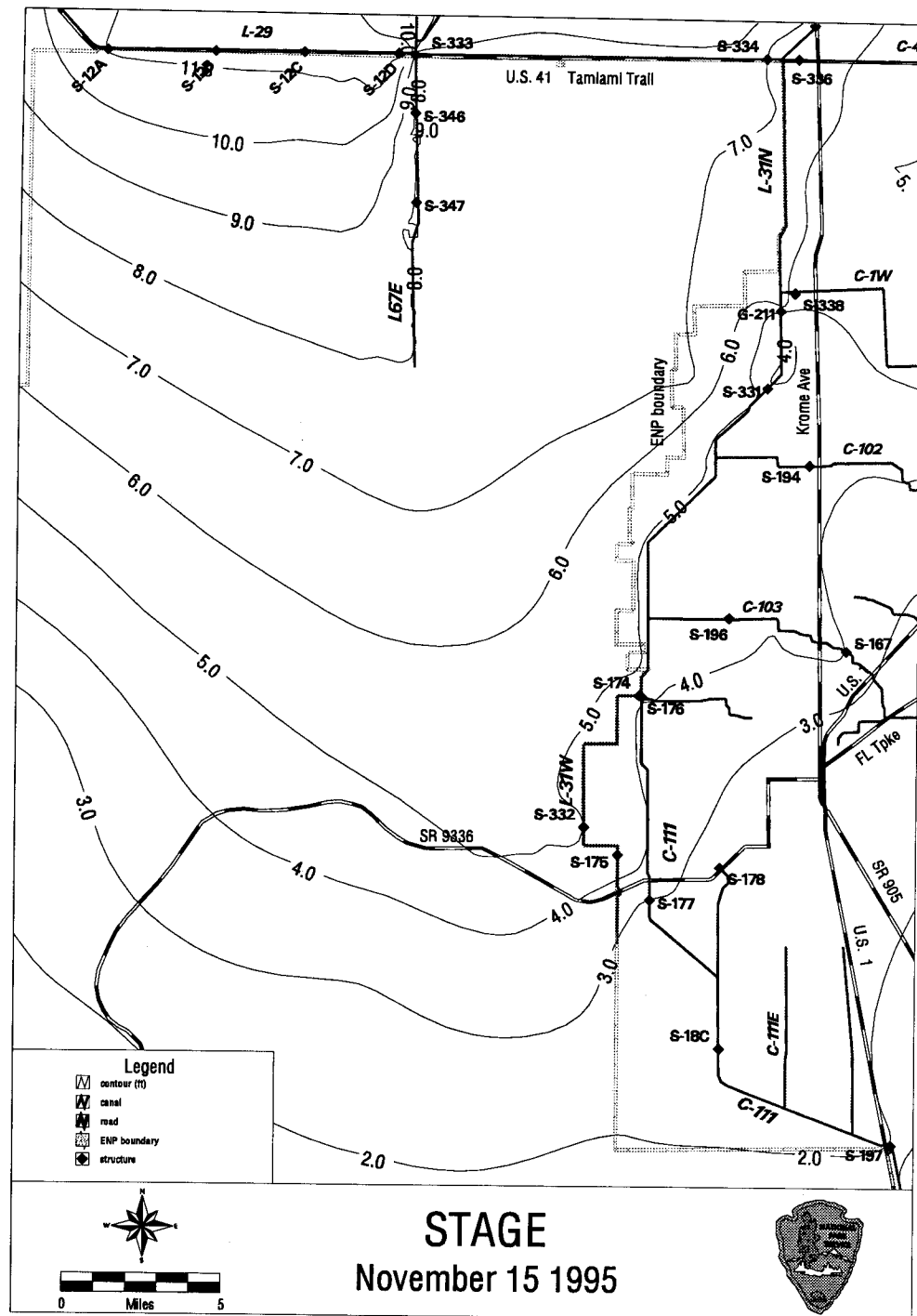


Figure 49: Water level contours for November, 15 1995.

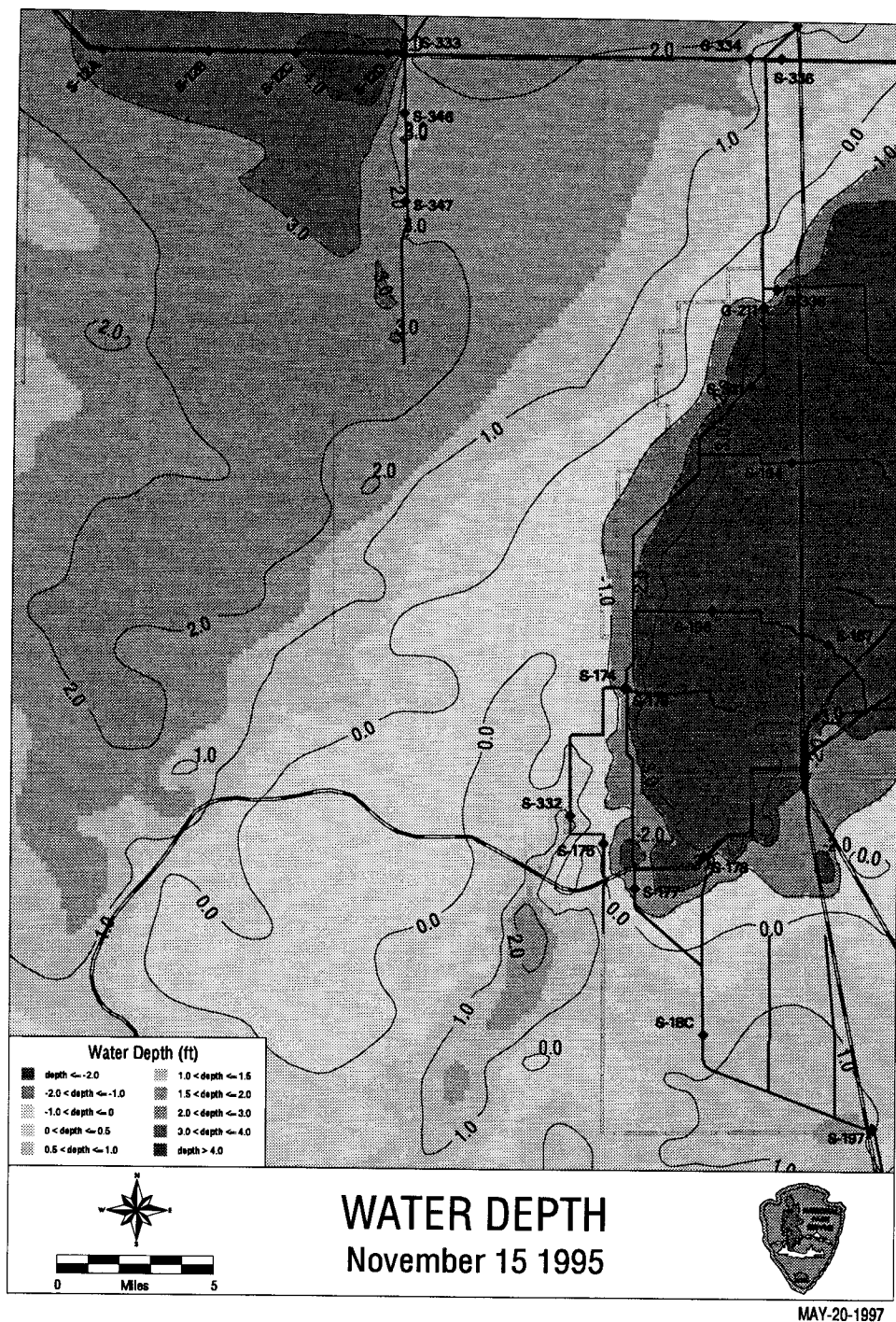


Figure 50: Water depths for November, 15 1995.

terception of these flows by the L-67 Extension levee. These two features resulted in the persistently higher water levels in Western Shark Slough in comparison to Northeast Shark Slough. Surface water conditions in the peripheral wetlands NESS have receded to the deeper central portions of the slough.

5.3 Late Dry Season Hydrologic Conditions-May 1996

The small quantities of late dry season rainfall in eastern ENP resulted in the lowest 1996 dry season water levels recorded at stations in the study area during the last week of April. Minimum dry season water levels did not occur in western ENP until later in May. Therefore, the resulting hydropatterns on May 15 represented the end of the 1996 dry season. Rainfall during the previous 5 days prior to May 15 was generally light and highly variable. Rainfall within the area recorded on the May 14 ranged from 0 at S-336 to 3.0 inches at FMB. On May 15, 3.69 inches was recorded at S-331 with other stations throughout the study area recording zero rainfall. No discharges through the S-12 structures into Western Shark Slough had occurred since March. Inflows to NESS through S-333 averaged 400 cfs. Inflows to L-31N through S-335 were not made although approximately 186 cfs was discharged to the reach through S-334 during May 13 through 14. Average daily discharges at G-211 during this period were approximately 175 cfs. Siphoning at S-331 averaged approximately 47 cfs with gravity flow at S-173 providing an additional 57 cfs for a total discharge outflow from the L-31N reach of 104 cfs. Operation of structures downstream of S-331 were initiated on the May 14. On this date, average S-174 discharge was approximately 20 cfs while S-176 averaged approximately 55 cfs. L-31W operations included average daily S-332 discharges of approximately 24 cfs with S-175 closed. S-177, S-18C and S-197 had not been operated in the previous 5 days. At this time in hydrologic year 1996, water levels as shown in Figure 54 receded to well below the ground surface throughout much of the area within and adjacent to ENP. Throughout ENP water levels receded almost two feet lower than the January stages presented Figure 51. Figure 54 shows that in northern ENP surface water is now present only in the deeper portions of central NESS and below the S-12 structures. Water depths on the peripheral areas of both Western and Northeast Shark Slough are now both very proximate to or below the ground surface. Stages are well below ground surfaces throughout the Rocky Glades and Northern Taylor Slough. Southern central Taylor Slough and Eastern Panhandle stage

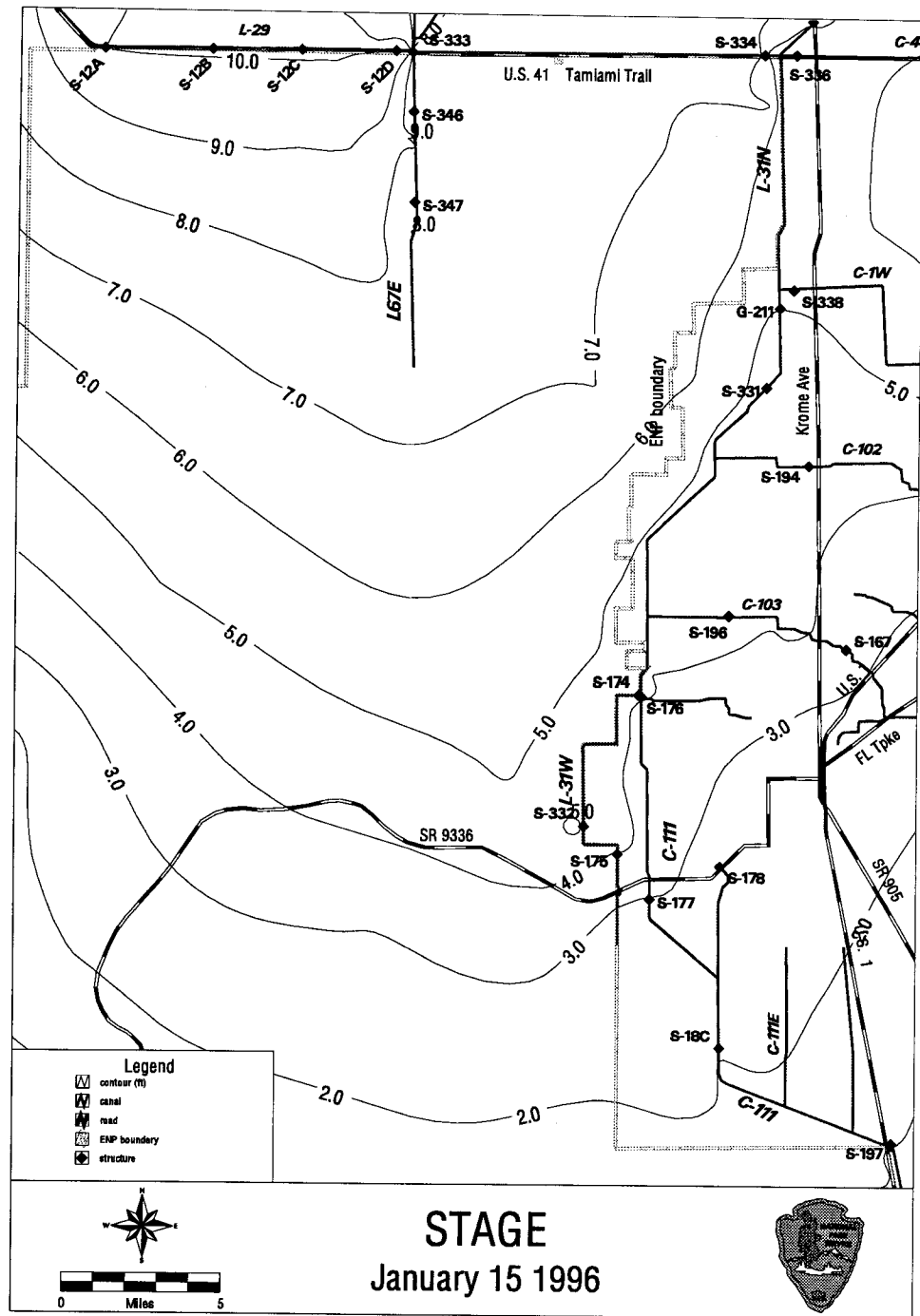


Figure 51: Water level contours for January 15, 1996.

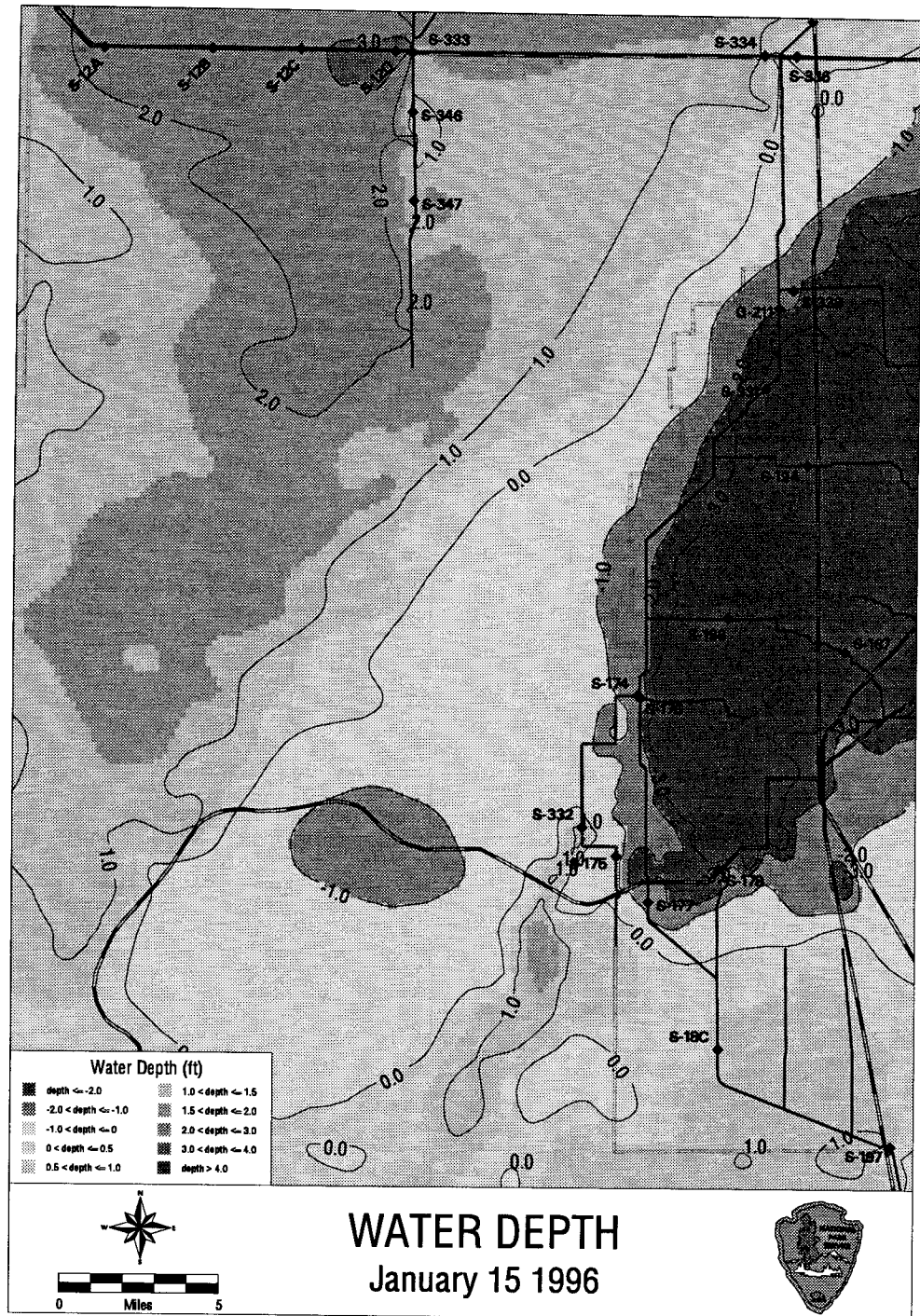


Figure 52: Water depths for January 15, 1996.

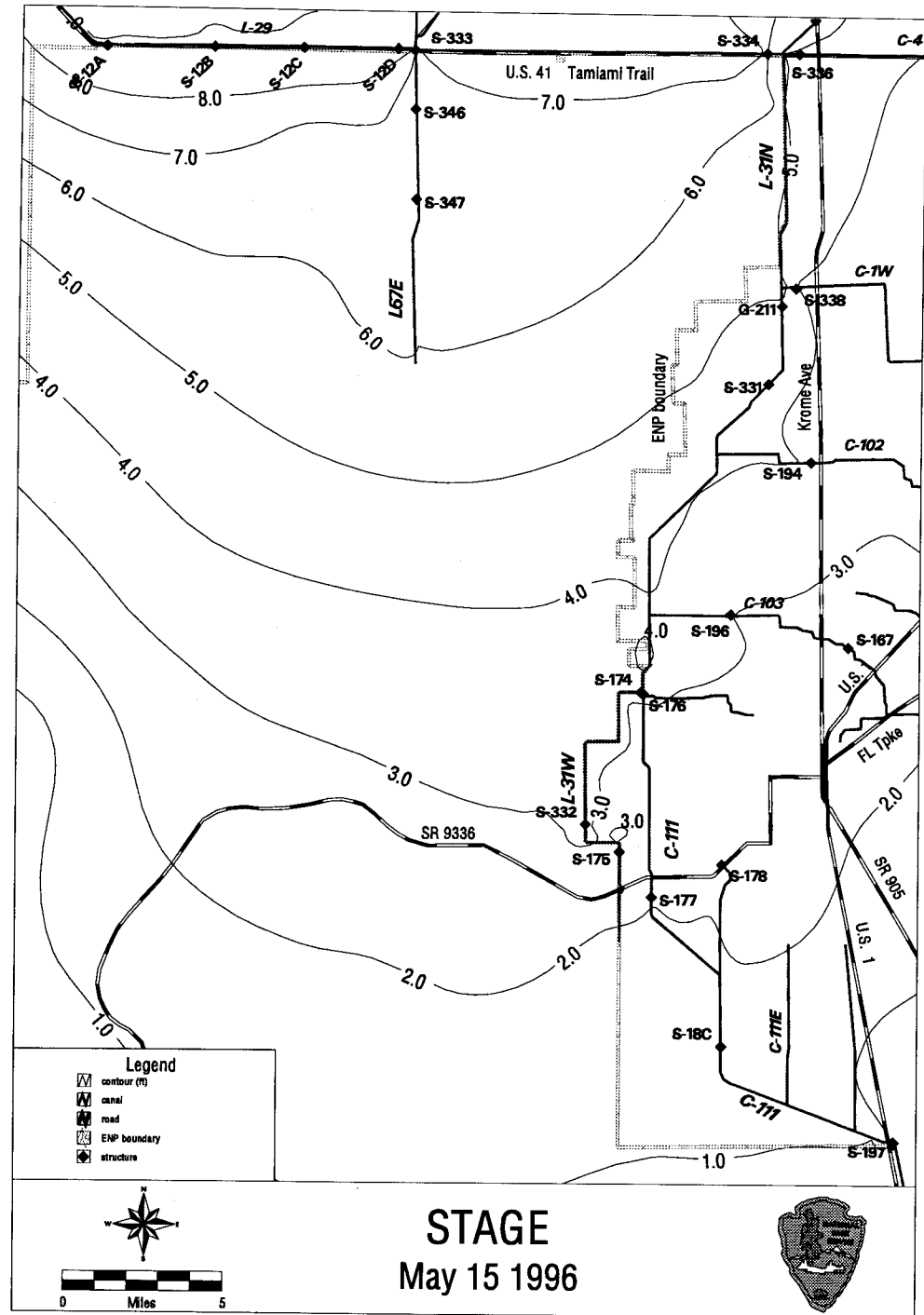


Figure 53: Water level contours for May, 15 1996.

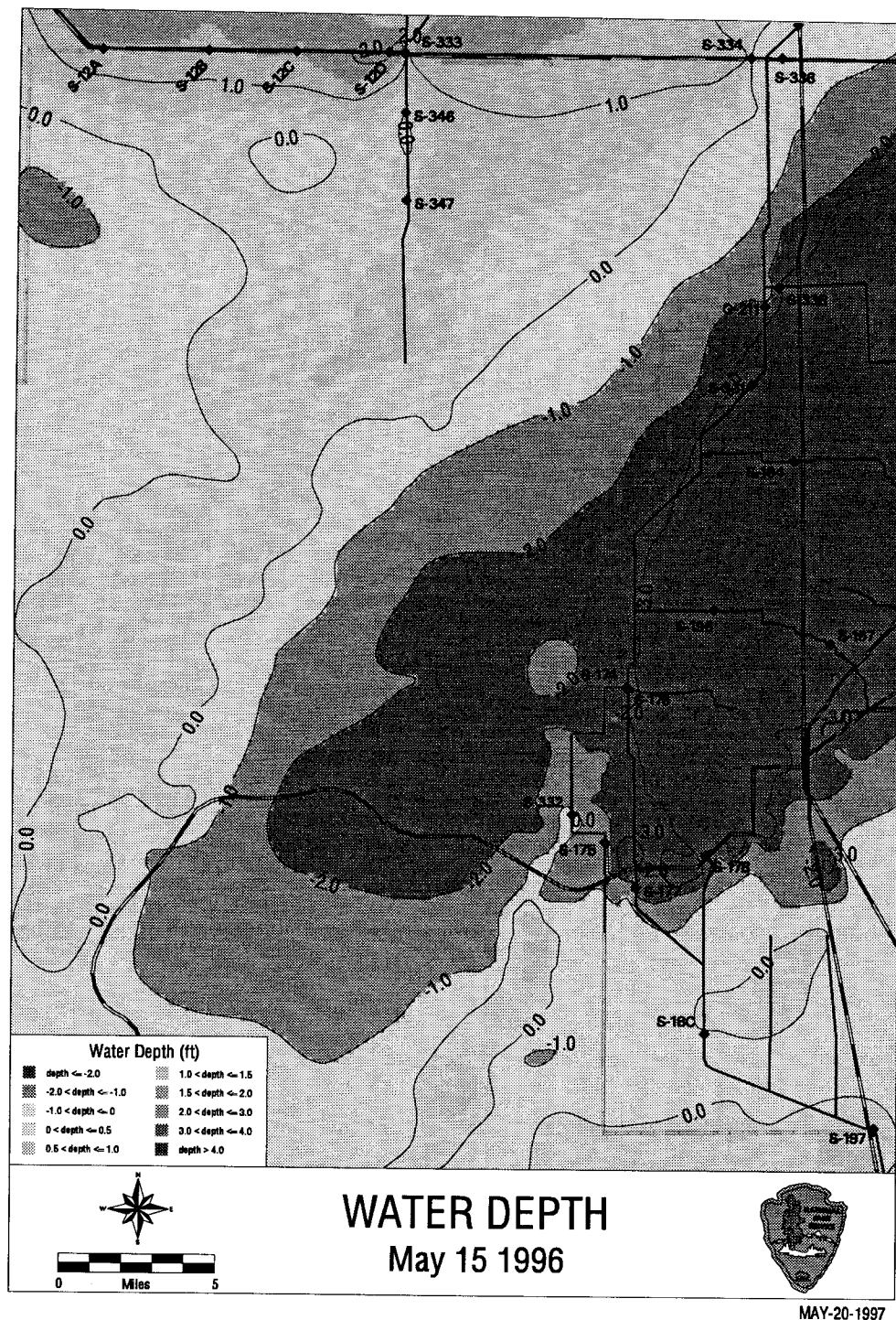


Figure 54: Water depths for May, 15 1996.

were sufficient to retain some surface water near to or at the ground surface.

5.4 Mid Wet Season Hydrologic Conditions-July 1996

Prior to the hydropattern characteristics found on July 15, 1996, major climatological and operational changes occurred. During June, large rainfall totals resulted in operational changes at many of the South Dade structures. For instance, the June rainfall totals resulted in the operation of S-197 for an extended period of time. This June rainfall event and subsequent flood operations were followed by a period of limited wet season rainfall.

Rainfall just prior to July 15 was variable over the study period, ranging from a nominal 0.01 to 0.93 inches with the larger quantities occurring over an area extending from R-127, through R-3110 and continuing north to S-336. Average daily total discharge at the S-12 structures was approximately 1,425 cfs. No inflows to NESS through S-333 were made. Flood operations in northern L-31N resulted in average daily discharges of approximately 211 cfs at S-338 and G-211 was closed. Structure S-331 pumping averaged approximately 185 cfs, with operation of S-194 and S-196 discharging the majority of the S-331 total into both the C-102 and C-103 canals. During this period S-174 was being operated to discharge only approximately 10 cfs. No discharges were made through S-176 into the C-111 canal. Pump Station S-332 average daily discharges from the L-31W canal were approximately 20 cfs and structure S-175 was closed. S-177 was closed but downstream flood operations required S-18C average daily discharges of 250 cfs. S-197 remained closed.

The stage contours shown in Figure 55 indicate that water levels throughout ENP had increased by approximately 1 foot since May 15. Figure 56 shows that surface water is present in central NESS but not its peripheral wetlands. In Western Shark Slough, water management operations at the S-12 structures created deeper pools behind L-67 extension and southward into central Shark Slough. Throughout the Rocky Glades and northern Taylor Slough water levels are near or just below ground surface elevations. It is in these areas that hydropatterns are most affected by flood operations. This problem becomes more acute when average early wet season rainfall events are removed through flood operations before being allowed to contribute to storage and subsequent surface water conditions. If these operations are followed by periods of less than average wet season rainfall similar to the 1996 wet season, water levels in eastern ENP never fully recover. The loss of this upstream storage due

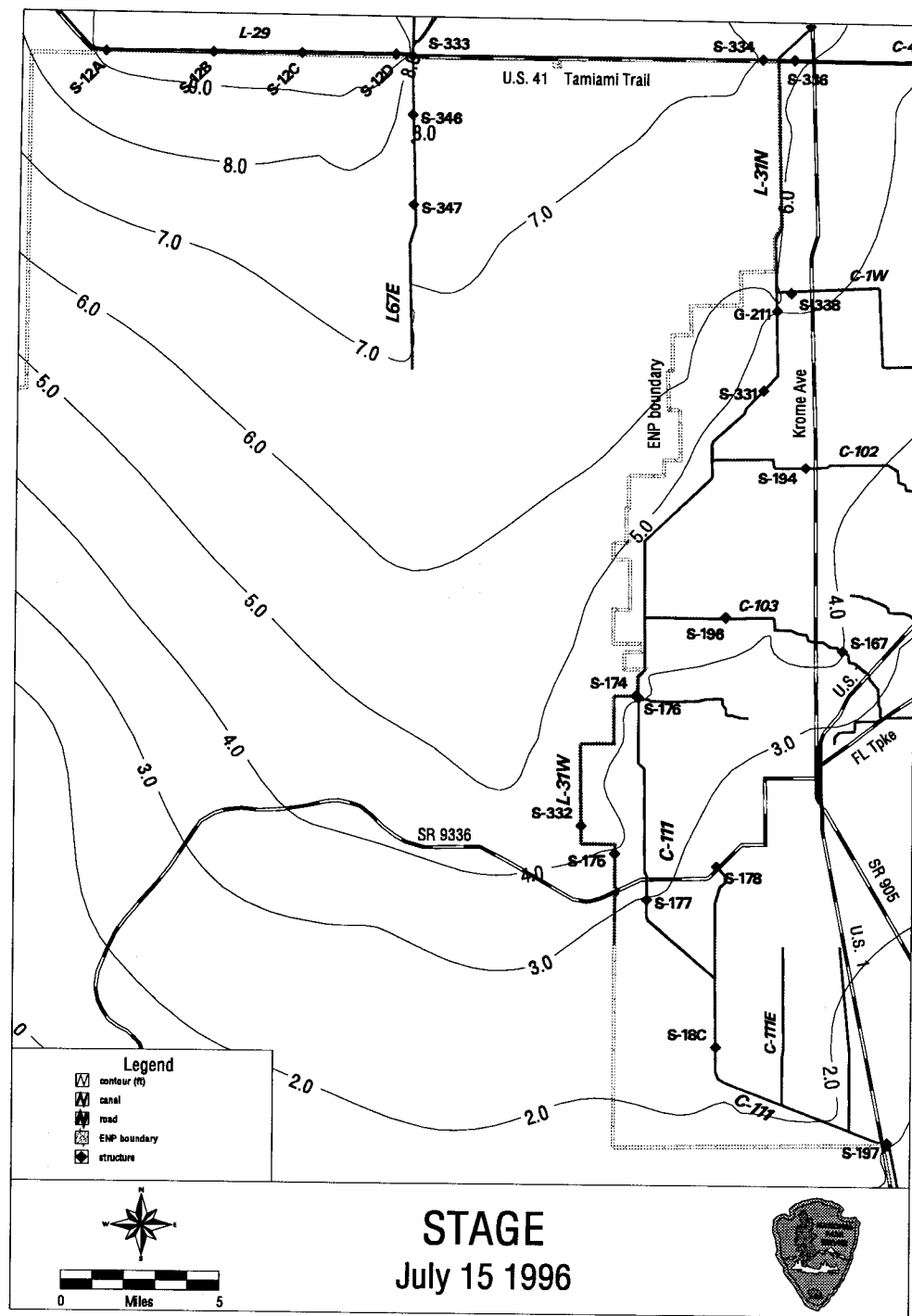


Figure 55: Water level contours for July, 15 1996.

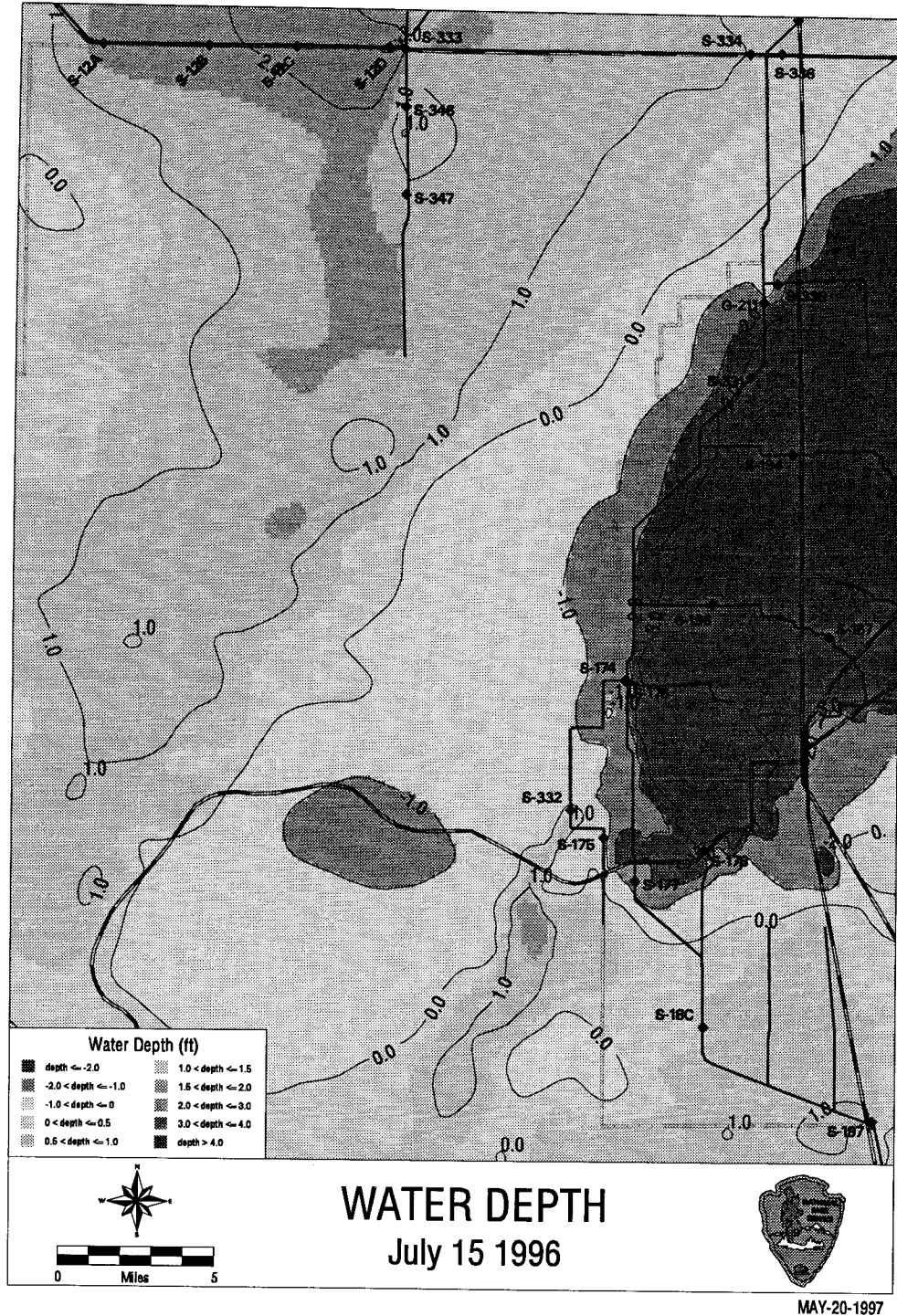


Figure 56: Water depths for July, 15 1996.

to water management is reflected in downstream Taylor Slough surface water conditions being confined to the central and southern slough. The Eastern Panhandle with lower elevations shows uniform surface water conditions.

5.5 Late Wet Season Hydrologic Conditions-September 1996

The September stage contour and water depth map provides information on hydropatterns within ENP for the antecedent rainfall and water management operations. The monthly rainfall totals presented in Section 3.1 suggest that July rainfall was less than average and August rainfall varied from average to above average. During the first 15 days of the month, approximately 47 to 78% of the September total had accumulated indicative of below average rainfall for the month. Rainfall during the 5 days prior to September 15 included events of 1.5 inches in the vicinity of S-331 and S-336 on the 11th and 1.25 inches at Flamingo on 14th. Typically, during this period for the stations examined no rainfall under 0.5 inches was recorded.

Water management operations in the 5 days prior to September 15 were as follows: S-12 total daily discharge averaged approximately 1,700 cfs with 25 to 30% of this total surface water delivery made through S-12A and S-12B. Surface water deliveries to NESS were halted on the September 11. Prior to this date, September average discharges through S-333 were 134 cfs. No inflows to L-31N occurred and flood operations at S-338 averaged approximately 207 cfs with G-211 closed. Average daily discharges due to pumping at S-331 were approximately 225 cfs. Data was missing for S-194 for this period and S-196 was closed. Water originating from L-31N below S-331 were diverted to Taylor Slough via S-174 and averaged approximately 257 cfs. During the first 15 days of September S-176 was not operated. In L-31W S-332 discharges ranged from 115 to 530 cfs. S-175 average daily discharges during this period were approximately 75 cfs. Flood operations in C-111 included average daily discharges of 179 and 376 cfs at S-177 and S-18C, respectively. S-197 had not be utilized in flood operations since July.

September stage contours shown in Figure 57 are similar to the July stage contours in the southern portion of the study area. In the northern study area stages increased by approximately a 0.5 foot from the levels attained in July. Surface water conditions exit below the S-12 structures and in central NESS Figure 58. However, surface water conditions in the peripheral NESS

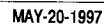
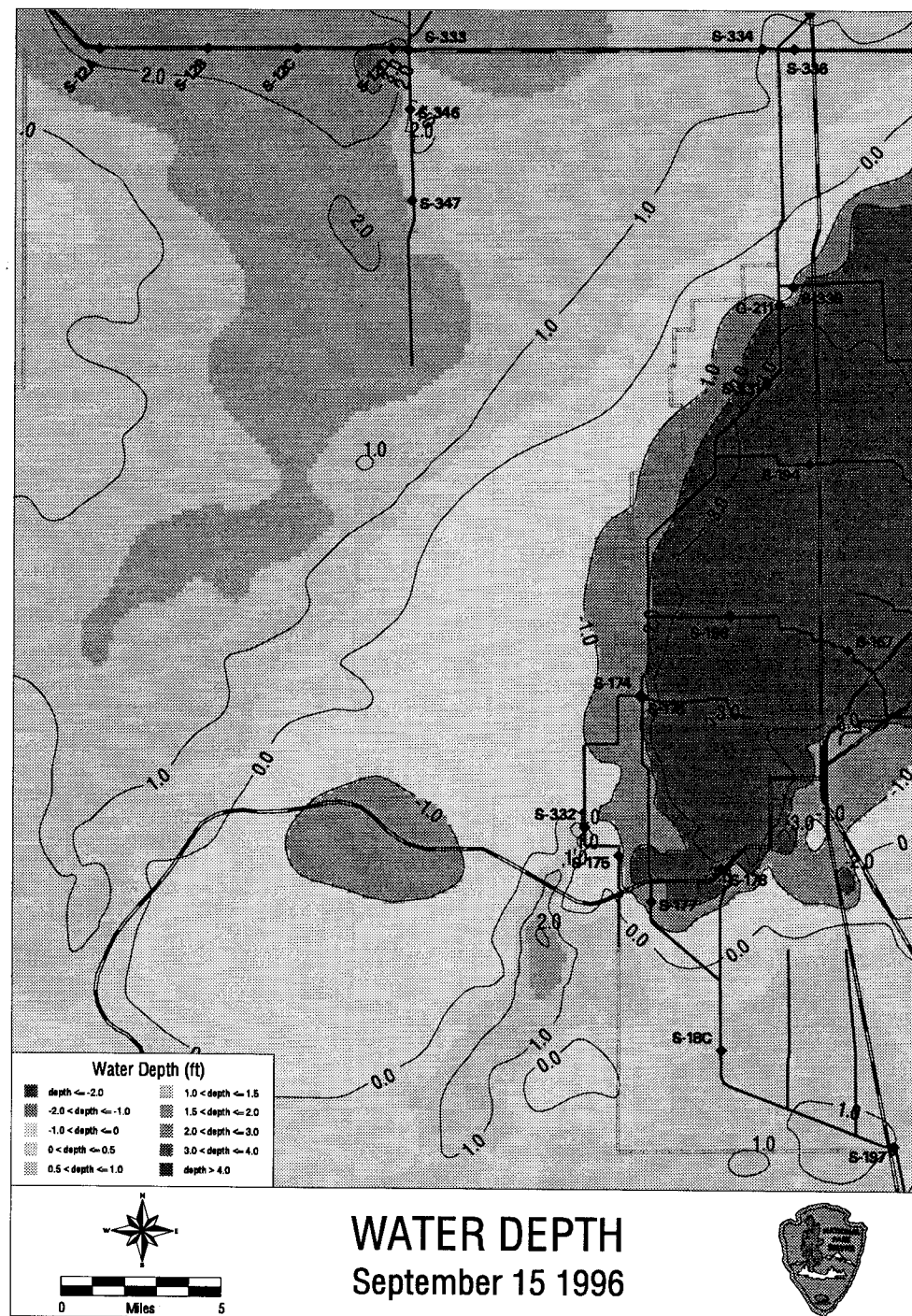


Figure 57: Water level contours for September, 15 1996.



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Figure 58: Water depths for September, 15 1996.

wetlands and the Rocky Glades would be intermittent and limited to only lower elevations such as solution holes. Water levels in Northern Taylor Slough wetlands were similar to July by being near or below ground surface. Figure 58 shows the localized effects associated with S-332 pumping. All surface water resulting from these discharges are quickly dissipated due to lower water levels that prevail in the canals adjacent to Taylor Slough. Local rainfall, lower ground elevations, and distance from water management operations allowed surface water to persist in southern Taylor Slough through the drier periods of the 1996 wet season. Throughout much of the Eastern Panhandle surface water conditions were present.

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