Special Report

An Analysis of Water Supply Backpumping

for the

Lower East Coast Planning Area

February, 1982

(Revised)

Resource Planning Department

South Florida Water Management District

West Palm Beach, Florida

RECOMMENDATIONS

Based on the findings of this investigation, the following recommendations are made regarding Lower East Coast Water Supply Backpumping:

1. Approve the conceptual plans for water supply backpumping of the following basins:
   a. Western C-51 (West Palm Beach Canal)/L-8
   b. North New River Canal/C-13
   c. Western Snake Creek Canal (C-9)
   d. Western Tamiami Canal (C-4)
2. Authorize detailed design and construction of the necessary facilities for water supply backpumping of North New River Canal/C-13 Basin to WCA 3A. Completion of facilities construction should be targeted no later than mid-May 1982.
3. Authorize a request to the Corps of Engineers to initiate the necessary studies and reports for:
   a. Retroactive participation in the water supply backpumping facilities for the North New River Canal/C-13 Basin.
   b. Construction of water supply backpumping facilities for the Tamiami Canal and Snake Creek Canal Basins.
4. Operate the S-5A pump station and associated facilities to backpump water from the Western C-51/L-8 Basin to WCA 1.
5. Authorize proceeding with implementation of the land use and water quality control program.
6. Continue coordination of the analysis and evaluation results with local, state, and federal agencies.

Abbreviations Used in This Report

BCEQCB	Broward County Environmental Quality Control Board
C-2	Snapper Creek Canal
C-4	Tamiami Canal
C-9	Snake Creek Canal
C-51	West Palm Beach Canal
CFS or cfs	Cubic feet per second. 1 cfs = 7.48 gallons per second.
CMP	Corrugated metal pipe
CSFFCP	Central and Southern Florida Flood Control Project
FT MSL or ft msl	Feet above mean sea level
gpm	Gallons per minute
MPN	Most probable number
NNR or NNRC	North New River or North New River Canal
PBCAPB	Palm Beach County Area Planning Board
PBCHD	Palm Beach County Health Department
RCP	Reinforced concrete pipe
RO	Reverse osmosis
SDC	State Duration Curve
SFWMD	South Florida Water Management District
USCOE	United States Army Corps of Engineers
USGS	United States Geological Survey
WCA	Water Conservation Area

AN ANALYSIS OF WATER SUPPLY BACKPUMPING

FOR THE LOWER EAST COAST PLANNING AREA

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CHAPTER 1

INTRODUCTION

Basis for the Study

Weather conditions since June 1980 have been characterized by a deficiency of rainfall throughout much of the SFWMD region and have resulted in the lowest regional water storage levels recorded in south Florida. Due to these conditions the District has undertaken various programs to restrict water use and increase availability of fresh water to meet agricultural and urban demands. In spite of these efforts, severe restrictions of water use will be required during the upcoming months if hydrologic conditions do not improve.

In view of these circumstances, various methods for enhancing the efficiency and operation of the existing Central and South Florida Flood Control Project have been examined. These methods were evaluated on the basis of the following criteria:

a) be regional in nature and clearly lie within the District's legislated authority;

b) be of reasonable cost;

c) have a reasonable implementation time;

d) have minimal adverse environmental impacts; and

e) provide water to benefit all users of the system.

The concept of cloudseeding emerged from this review as having potential for enhancement of water supply during periods when appropriate weather conditions prevailed. This technique was applied with some benefit during the summer and fall of 1981. As the 1981-82 dry season began, however, water conditions in the District continued at record low levels. The Governing Board directed District staff to continue with the review and analysis of additional water supply enhancement methods. Prominent among these was the concept of water supply backpumping. The basic ideas of backpumping for water supply purposes were presented to the District's Governing Board in September 1980. Based on this presentation, the Board requested that District staff develop a more detailed analysis of backpumping with the goal of implementing remedial water supply measures as soon as possible. This report, in response to that directive, provides the Board with:

a) description of water supply backpumping options for four basins in terms of water yield, costs, and design parameters;
b) estimates of the impacts of backpumping on water supply capabilities, and hydrologic and environmental conditions in upstream and downstream areas; and
c) an examination of the time and procedures necessary for the District to implement these options and monitor their impacts.

Water Supply Backpumping - Defined

Water supply backpumping represents a structural approach to water conservation in which excess stormwater runoff is pumped back into regional storage areas. This water is stored so that, through seepage or releases to the existing canal system, it can be used to raise groundwater levels, recharge wellfields, and provide for salinity control in coastal areas. The major modifications that may be required to backpump coastal canal basins include the following:

a) new or modified pumping facilities located near the water conservation areas;
b) new or modified intermediate structures placed in canals to detain stormwater that normally flows to the east and to allow pumping of this water to the west;
c) modification of existing downstream control structures; and

d) canal improvements to allow additional water flow.

The concept of water supply backpumping must be clearly distinguished from flood control backpumping. The concept of backpumping, as set forth by the District in the 1977 Draft of the Water Use Plan, provided additional water to regional storage for water supply and also provided flood protection to inland basins by pumping water into regional storage during periods of excessive rainfall. Water supply backpumping differs from flood control backpumping both in terms of the size of pumping facilities necessary and in terms of the operating criteria used. Relatively small capacity pumps can remove excess runoff and provide extra water in storage. Large capacity pumps are required to provide adequate flood protection. Backpumping for water supply also means that water is not pumped when regional storage facilities are filled to regulation schedule. Backpumping for flood protection requires the pumps to operate whenever water levels in the basin are above flood stage. Reduction of pump sizes and operational criteria significantly reduces costs and environmental impacts of backpumping.

The primary drawbacks with the original backpumping proposals for flood protection and water supply centered around the expense of large capacity pumping facilities and adverse environmental impacts from periodically discharging large volumes of flood waters to the water conservation areas. In response to these environmental concerns, the District is conducting a number of on-going studies to evaluate the impacts of water discharges on marshlands.

Evaluation Procedure

The major steps in the evaluation of the water supply backpumping alternatives are outlined in Figure 1-1. The three major steps identified in this figure form the content of the three subsequent chapters of this report. The first major step in the evaluation (discussed in Chapter 2) was the selection

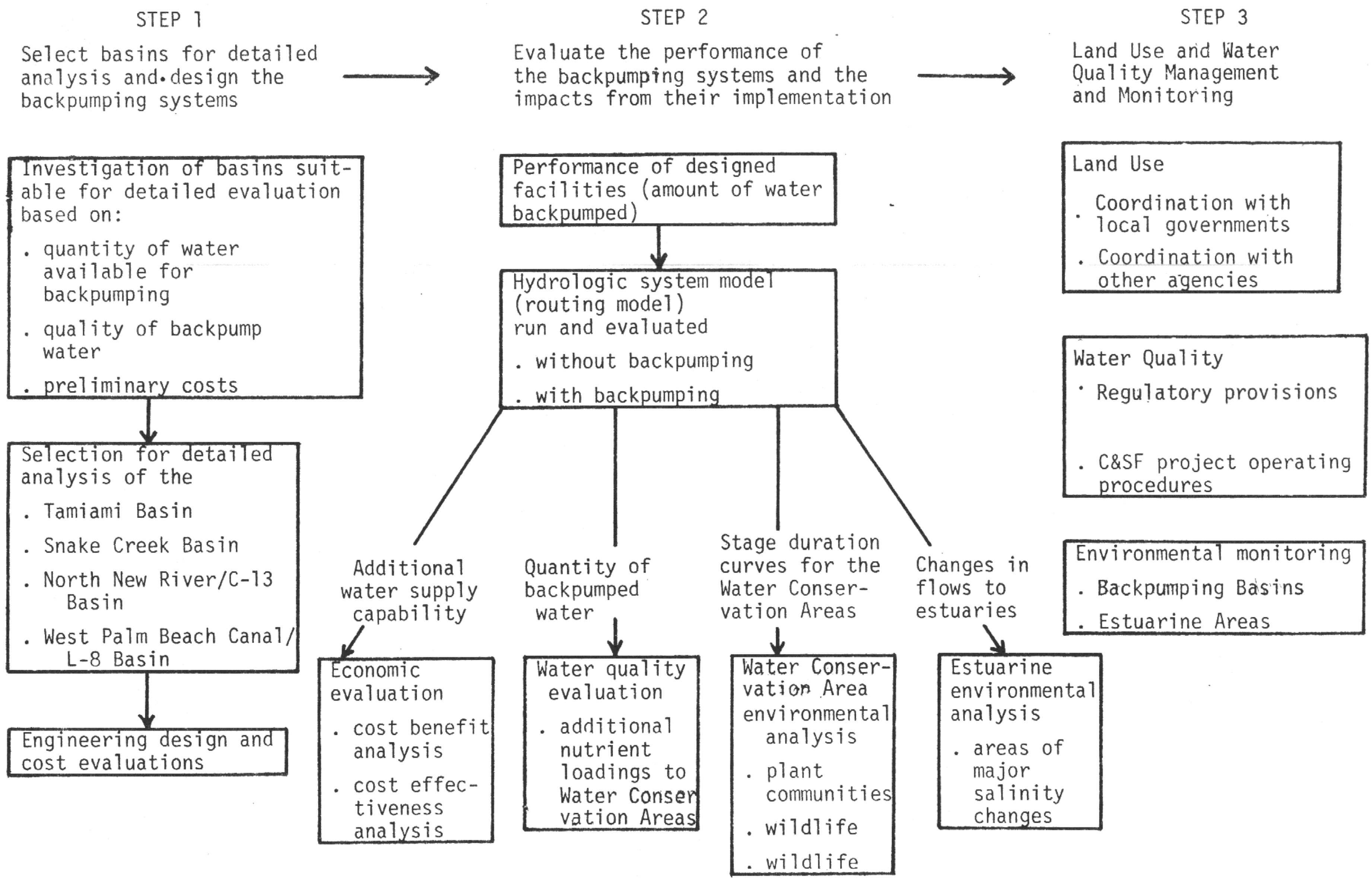


FIGURE 1-1 MAJOR STEPS IN THE EVALUATION OF THE WATER SUPPLY BACKPUMPING ALTERNATIVES

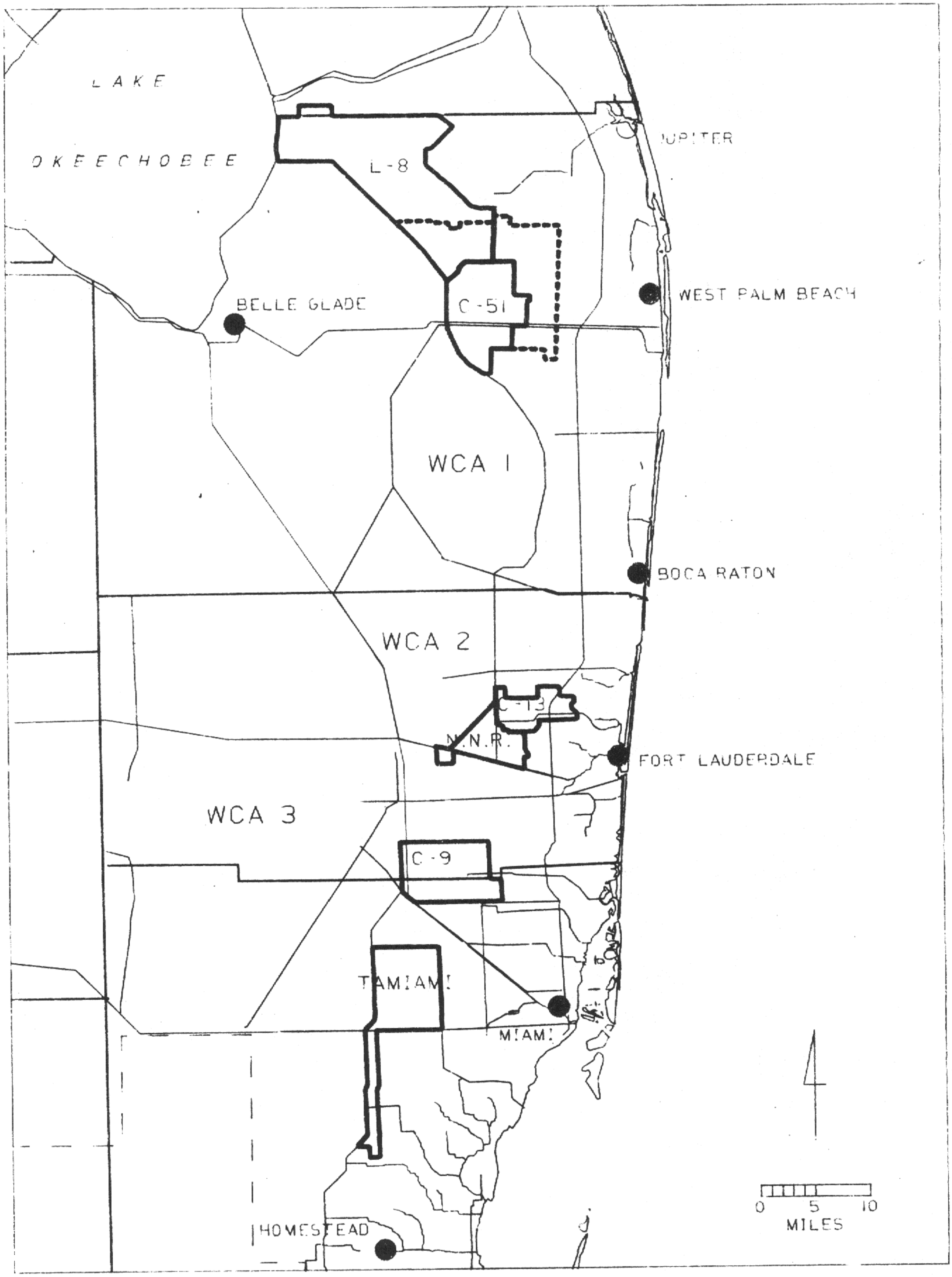


Figure 1-2 Backpumping Basins in the Lower East Coast Planning Area

of the basins and the design of the backpumping systems for those basins. Four basins: the West Palm Beach Canal/L-8 Basin, the North New River/C-13 Basin, the Snake Creek Canal Basin, and the Tamiami Canal Basin (Figure 1-2) were selected for evaluation based on the quantity of water available for backpumping, the quality of that water, and preliminary cost estimates for the required facilities. Engineering design and cost evaluations were then completed for water supply backpumping systems for these four basins.

The second step was to evaluate the performance of the backpumping systems and to assess the impacts that implementation would have on the following areas:

a) hydrologic conditions;

b) economics;

c) water quality; and

d) environmental conditions in the water conservation areas and estuaries.

These results are discussed in Chapter 3.

The performance of the backpumping facilities was evaluated based on the design of the systems and calculated for a range of meteorologic conditions. The primary tool in this analysis is a mathematical routing model that simulates water movement and conditions in Lake Okeechobee, the water conservation areas, the canals, and the coastal service areas. Runs of the routing model, made with and without with backpumping facilities, were compared to determine system differences in storage, quantities of water backpumped, changes in flow into the water conservation areas, changes in the stage duration curves in the water conservation areas, and changes in the amounts and timing of water released to estuaries. These data are themselves the major inputs to the other evaluations.

In the economic evaluation, additional water supply capabilities are adjusted by value and frequency of need considerations to estimate benefits from the backpumping. These benefits are compared to the costs of backpumping to form a benefit/cost analysis of the backpumping alternatives. When the costs of backpumping are compared to the costs of other alternatives for providing the same benefits, they provide a cost-effectiveness.

In the water quality evaluation, water quality in the backpumping basins is evaluated and compared to other sources of input to the Water Conservation Areas and to state standards. The quantities of water backpumped are combined with data on nutrient concentrations in the canals to estimate additional loadings into the Water Conservation Areas. These loadings are then compared with the quantities of nutrients that enter on an annual basis from other sources. In addition, a qualitative estimate is provided of the areal extent of the water quality changes in the marshes due to backpumping.

In the environmental evaluation of the Water Conservation Areas, the stage duration curves were used to estimate the effects that the backpumping would have on plant and wildlife communities. The estuarine environmental analyses used the changes in water flows and previous studies of salinity conditions in the estuaries to determine locations where salinity conditions might be significantly affected by backpumping.

The third major step in the evaluation was the analysis of implementation procedures and considerations regarding land use and water quality in the backpumping basins, as presented in Chapter 4. This step covers the means by which the District can initiate land use and water quality controls and monitoring in the backpumping system if the Governing Board decides to implement this alternative. Major considerations in this step include coordination with local governments, regulatory and operational provisions to control water quality, and development of appropriate monitoring programs.

CHAPTER 2

BASIN SELECTION AND BACKPUMPING SYSTEM DESIGN

The first major step in investigating the application of the concept of water supply backpumping to the coastal basins of southeast Florida was the selection of a limited number of basins for detailed evaluation. The next step was an analysis of basin features and the design of backpumping systems to service those basins. The first section of this chapter discusses the procedures that were used to select the four basins that are given detailed consideration. The remaining four subsections cover each of these four basins in turn. Each subsection first presents a description of the basin in terms of location and land use, hydrologic characteristcs, and water quality. The water supply backpumping system designed to service the basin is then described in terms of the divide structures (if any), the pump configuration and facilities, and the capital and operating costs.

Selection of Basins for Detailed Evaluation

Surface waters from at least ten basins along Florida's east coast have been considered for backpumping at one time or another based on analyses conducted by the U. S. Army Corps of Engineers (USCOE), the South Florida Water Management District (SFWMD), and various other special studies. Because such a number would be excessive for the scope and time available, it was decided to select a few high priority basins for detailed analysis. The major criteria in this selection process were:

a) the quantity of water available for backpumping in the basin;

b) the quality of the water available for backpumping; and

c) preliminary costs of the backpumping facilities required.

As a result of these evaluations, four basins were selected for detailed analyses, as indicated in Chapter 1 and Figure 1-2.

Some of the basins and basin designs that were originally considered were later excluded based on the foregoing criteria. The Hillsboro Canal/C-14 Basin was considered by the USCOE and in the 1977 Water Use Plan. This basin has subsequently been assigned lower priority due to poor water quality conditions in C-14. The USCOE proposed that the North New River Canal could be connected to C-11 and that both basins could then be backpumped at S-9. That design was found to be far less cost effective than direct pumping from the North New River Canal Basin near S-34. A portion of the Miami Canal was considered as a backpumping basin. Subsequent study showed that this basin provided relatively low quantities of water for backpumping. A further analysis was made based on connecting the Miami Canal and the Snake Creek Canal and backpumping both basins together. This alternative was not considered practical at this time due to stage maintenance requirements of the Miami Canal.

C-51/L-8 Basin

Analysis of the C-51/L-8 Basin is discussed in more detail than the other basins. Methods for determining pump size, cost of operation, and facility design that were used in all subsequent basin analyses are presented in this section.

Basin Description

Location and Land Use: The western portion of the West Palm Beach Canal (C-51) Basin occupies about 53 square miles in Central Palm Beach County and extends about four miles south and six miles north of C-51, from Loxahatchee on the east to Water Conservation Area (WCA) 1 and the L-8 Basin on the west. The L-8 watershed covers about 125 square miles and extends from the C-51 Basin generally north and west to Lake Okeechobee (Figure 2-1).

Existing development in the C-51 Basin consists of agriculture and estate land uses with houses on 5 or 10 acre tracts, and low density housing with

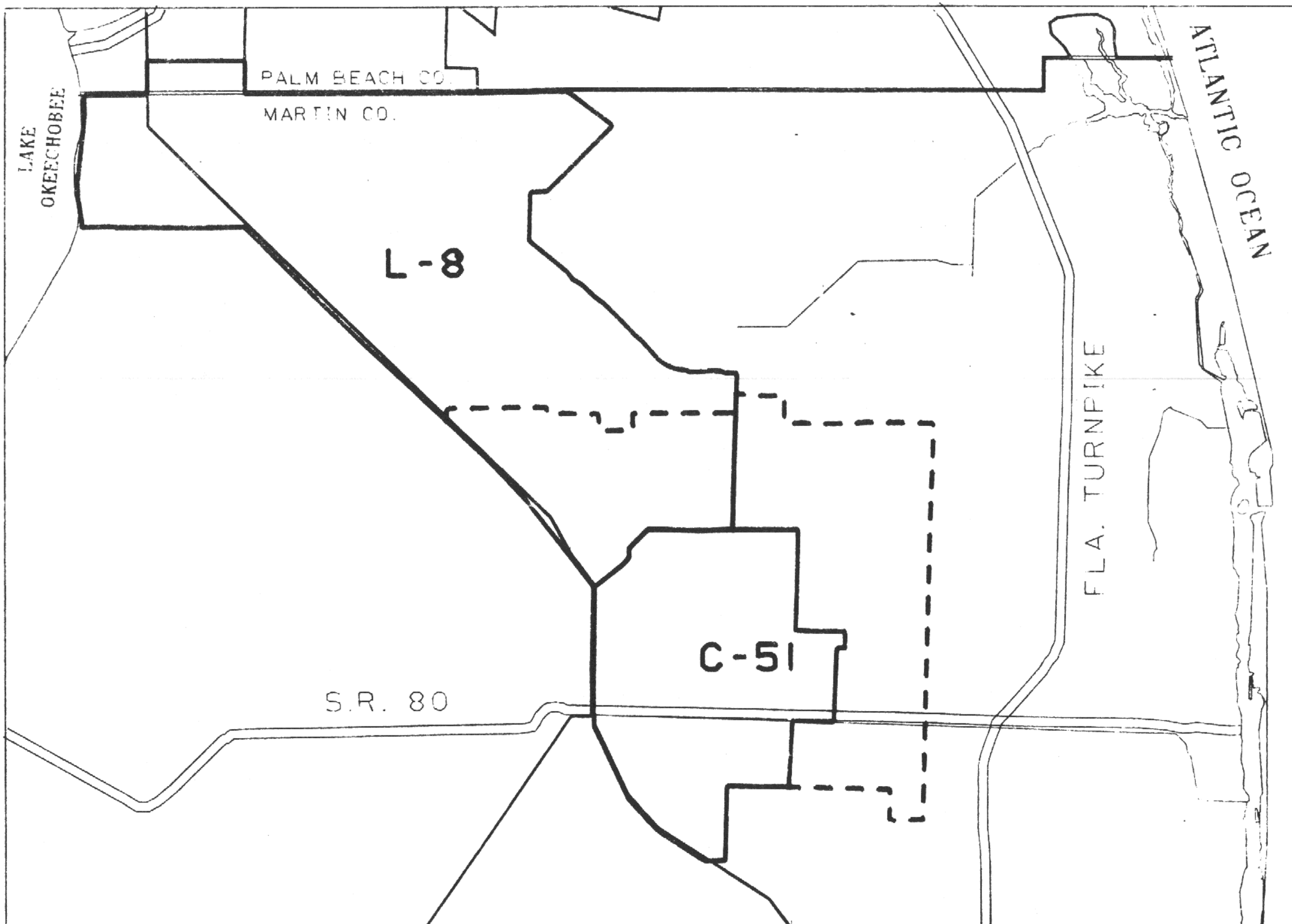


Figure 2-1. C-51/L-8 Basin (see page 16 of text for explanation).

LOWER EAST COAST

BACKPUMPING BASINS

5 MILES

less than one unit per acre. The Palm Beach County Land Use Plan projects future land use in this basin to be low density housing and agriculture. The L-8 Basin has some agricultural land use in the southern portion of the basin, but the majority of the area is managed as wildlife habitat. Little change in land use in this basin is projected in the future.

Hydrologic Characteristics: Ground elevations in these basins range from 13 to 22 ft msl (feet above mean sea level) and generally slope from north to south. There are no significant natural drainageways serving these basins. Major secondary drainage systems are present in Royal Palm Beach, Loxahatchee, and Wellington. A minor drainage network exists in the J. W. Corbett Wildlife Management Area in the L-8 Basin. Runoff from the L-8 Basin can be manipulated at the S-5A complex to discharge to tidewater through S-5A(E), to WCA-1 by gravity flow through S-5A(S), or by pumping to WCA-1 by way of S-5A(W). Runoff from the C-51 Basin is currently discharged to tidewater.

Rainfall in these basins averages 60 inches per year and ranges from 36 to 97 inches per year. Discharges to tidewater are measured at the Palm Beach Locks at the eastern end of C-51. Discharges from the L-8 Basin are measured near S-5A(E). The relationship between accumulated rainfall and runoff for this basin (Figure 2-2) indicates that average annual runoff is about 40% of rainfall. Seepage from WCA-1 into C-51 is minimal. Theoretical calculations based on a flow-net analysis indicate that this seepage contributes about 3 CFS to base flow. For the C-51/L-8 Basin, an estimated 154,000 acre feet of runoff would be available for backpumping. Net flow to tidewater after backpumping would be 213,000 acre feet, or 59% of historic discharge (Tables 2-1, 2-2, and 2-3).

Water Quality: Water quality data for the western C-51 Basin were obtained from the SFWMD, Palm Beach County Health Department (PBCHD), and the Palm Beach County Area Planning Board (PBCAPB). Results of the SFWMD study

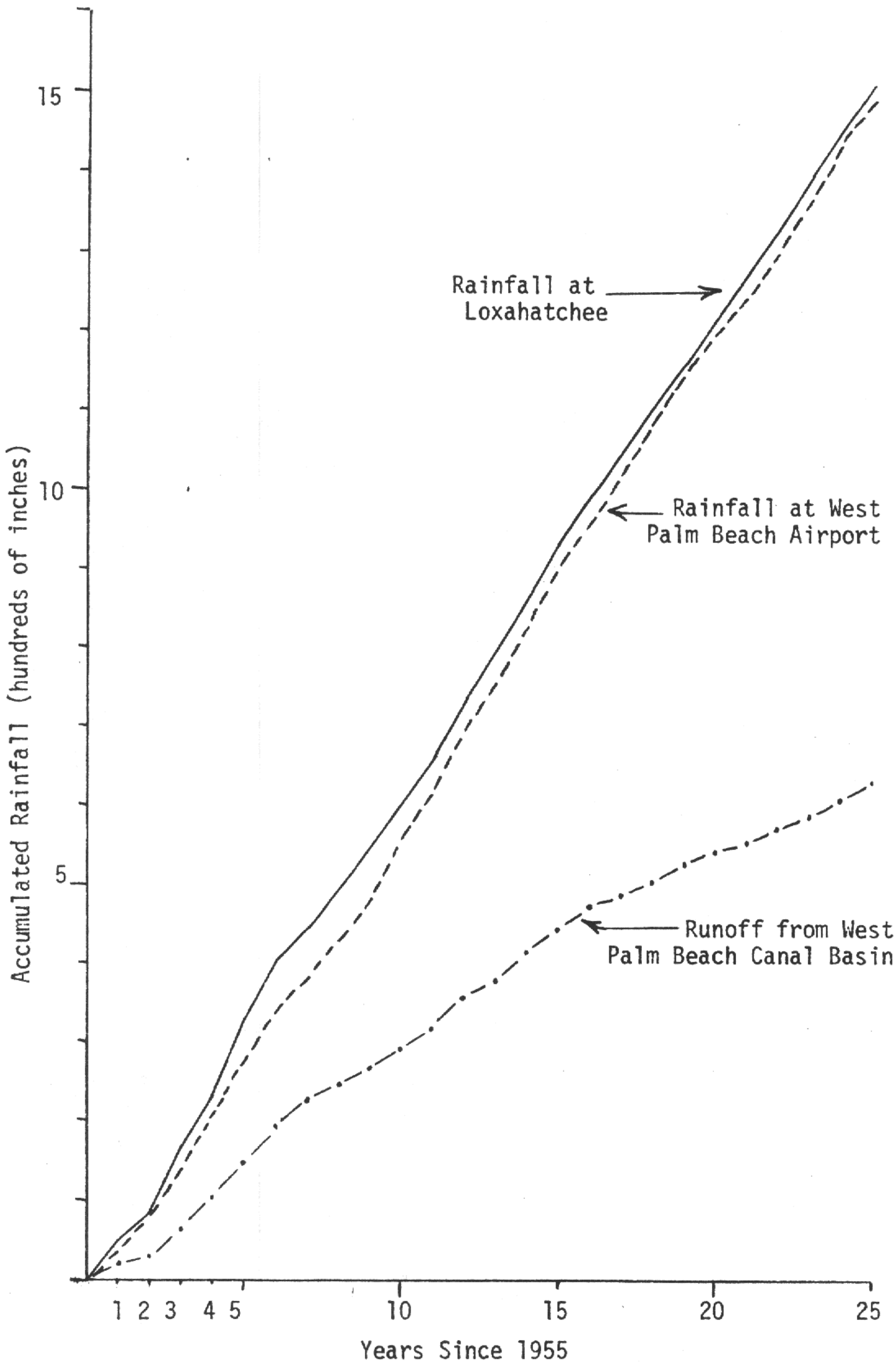


Figure 2-2 Accumulated Rainfall and Runoff in the West Palm Beach Canal Basin, 1955 through 1980.

TABLE 2-1 HISTORICAL FRESH WATER FLOW TO TIDEWATER FROM C-51 BASIN

Unit:cfs

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Sum.
1965	13624	9630	6122	9865	8426	10256	25667	21128	15202	49276	42403	15370	
1966	21103	23396	18649	12428	15377	38468	47990	45380	31098	31300	17984	17382	
1967	19379	16481	11599	4541	310	12614	19479	18572	17409	31695	13641	9915	
1968	3552	3137	3722	329	16265	70399	52382	28757	20484	44435	20133	5118	
1969	6502	2927	17538	9616	18227	28849	20335	24220	27080	43468	35251	23162	
1970	16919	21497	44376	25632	9136	29923	25893	23243	20219	19149	6160	440	
1971	717	489	310	300	2943	9015	12533	9188	15218	7370	24502	7882	
1972	7057	5204	3094	9094	32779	44111	17210	14954	9957	5163	8105	4594	
1973	3243	2255	2004	1897	3728	12979	31796	22962	32282	23152	7264	7094	
1974	21324	4150	1699	300	310	894	19373	27040	17902	21457	9376	10181	
1975	3391	3127	2371	373	3734	14717	24779	7537	20966	26466	13749	1568	
1976	438	459	8963	300	9043	6762	19306	33115	34981	13285	2108	1197	
1977	3830	1031	752	442	11838	9837	5820	3475	43341	6390	2862	14658	
1978	17884	4252	4767	715	3840	17346	24397	17788	17920	25393	24533	12446	
1979	22976	3214	8325	9163	18817	5880	6012	8337	53875	29200	12473	8247	
1980	5416	8191	8561	8835	7852	9930	17588	14617	28120				
Sum	167355	109440	142852	93830	162625	329980	370560	320313	406504	377299	240544	139254	
Avg.	10460	6840	8928	5864	10164	20624	23160	20020	25378	25153	16036	9284	181911
Acre feet	20753	13571	17713	11634	20165	40918	45959	39720	50350	49904	31815	18419	360911

TABLE 2-2 AVAILABLE WATER FOR BACKPUMPING FROM WESTERN C-51 BASIN (PUMP = 550cfs) UNIT: cfs

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Sum
1964	11361	8852	4885	3868	5020	8374	7155	10008	14013	12832	14810	13590	114768
1965	9822	6993	6249	2066	1075	6201	9886	10638	7204	14509	15013	9324	98980
1966	13156	12094	12393	4933	7434	16293	16828	17048	16500	15402	4053	4743	140877
1967	5266	3009	2962	164	153	5425	9929	8818	6876	13618	3708	1453	61381
1968	401	1375	1672	17	5750	16070	15907	12275	9817	13498	8839	2705	88326
1969	2223	1234	9434	3465	6257	12416	5508	10301	9793	15578	14478	13235	103922
1970	9782	11604	13983	13269	9136	16260	13752	14843	16421	12141	899	702	132792
1971	585	64	2218	865	782	2814	4110	2903	9145	2681	7077	2853	36097
1972	2201	1700	767	2594	11707	14499	8288	4914	3415	1726	2502	1432	55745
1973	1008	686	572	310	957	4130	13367	10590	12446	9394	2238	2298	57996
1974	5676	1459	511	12	6	3511	10974	12075	6096	7660	3468	3152	54600
1975	1398	4205	5366	853	5488	13118	11446	4008	6987	9080	4513	596	67058
1976	40	52	2905	110	4812	4552	8538	11183	12991	4015	636	356	50190
1977	2697	1687	224	45	5752	2968	2140	1043	14022	2663	875	6262	39978
1978	6393	1319	2631	149	3056	7371	11385	12074	8971	11926	8380	4414	78069
1979	11928	1006	1550	4079	6936	3753	4323	4880	15886	12234	6339	3026	75940
1980	2998	2606	1782	2224	4728	4338	7552	5560	12459				
Sum	86935	59945	70104	39023	79049	142093	161088	153161	183042	158557	97828	70141	
Avg	5114	3526	4124	2295	4650	8358	9476	9009	10767	9910	6114	4384	77727
Acre feet	10146	6996	8182	4453	9226	16582	18800	17874	21362	19661	12130	8698	154210

TABLE 2-3 ESTIMATED FRESH WATER FLOW TO TIDEWATER UNDER BACKPUMPING PLAN FROM C-51 BASIN
(Pump Size = 550cfs)

UNIT: cfs

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Sum
1964	13690	4797	2051	3434	9655	12778	7180	8833	14723	15808	10412	6017	109378
1965	3802	2637	0	7799	7351	4055	15781	10490	7998	34767	27390	6046	128116
1966	7947	11302	6256	7495	7943	22175	31162	28332	14598	15898	13931	12639	179678
1967	14113	13472	8637	4377	157	7189	9550	9754	10533	18077	9933	8462	114254
1968	3151	1762	2050	312	10515	54329	36575	16482	10667	30937	11294	2413	180387
1969	4279	1693	8104	6151	11970	16433	14827	13919	17287	27890	20673	9927	153153
1970	7137	9893	30393	12363	0	13663	12141	8400	3798	7008	5261	0	110057
1971	132	425	0	0	2161	6201	8423	6285	6073	4689	17425	5029	56843
1972	4856	3504	2327	6500	21072	29612	8922	10040	6542	3437	5603	3162	105577
1973	2235	1569	1432	1587	2771	8849	18429	12372	19836	13758	5026	4796	92660
1974	15648	2691	1188	288	304	5383	8399	14965	11806	13797	5908	7029	87406
1975	1993	0	0	0	0	1599	13333	3529	13979	17386	9236	972	62027
1976	398	407	6058	190	4231	2210	10768	21932	21990	9270	1472	841	79767
1977	1133	0	528	397	6086	6869	3680	2432	29319	4127	1987	8396	64954
1978	11491	2933	2136	566	784	9975	13012	5714	8949	13567	16153	8032	93312
1979	11048	2208	6775	5084	11881	2127	1689	3457	37989	16966	6134	5221	110579
1980	2418	5585	6779	6611	3124	5592	10036	9057	15661				
Sum	105471	64878	84714	63154	100005	209038	223807	185993	251748	247382	167838	188982	
Avg	6204	3816	4983	3715	5883	12296	13165	10941	14809	15461	10490	5561	107324[a]
W/o BP Avg	10460	6840	8928	5864	10164	20624	23160	20020	25378	25153	16036	9284	181911[b]
Percent	59.31	55.78	55.81	63.35	57.88	59.62	56.84	54.65	58.35	61.47	65.42	59.90	59.00

[a] 212,930 acre feet

[b] 360,911 acre feet

indicated that average dissolved oxygen levels in C-51 ranged from 0.5 to 8.3 mg/L, with a three year average of 4.1 mg/L for all stations. Average total phosphorus values were relatively high and ranged from 0.73 mg/L to 0.202 mg/L with an average of 0.113 mg/L. Average nitrogen values ranged from 1.55 mg/L to 3.56 mg/L with an overall average of 2.67 mg/L.

Coliform counts from samples collected by the PBCAPB averaged 438 MPN (most probable number). Ten percent of the values for total coliforms were in excess of state standards of 2400 MPN. Fecal coliforms averaged 84 MPN and did not exceed state standards of 800 MPN.

Water quality data from L-8 were obtained from the USGS. Dissolved oxygen values were generally low, varying from 1.3 to 7.3 mg/L with a mean of 4.0 mg/L. Total phosphorus values were moderate and averaged 0.066 mg/L. Total nitrogen values were also moderate and averaged 2.30 mg/L. In general, water in L-8 is of good quality and contains lower levels of nitrogen and phosphorus than water in C-51. Better water quality in L-8 may be related to less intensive land use practices.

System Design

Selection of Options: The original USCOE plan for backpumping in the C-51 portion of the West Palm Beach Canal/L-8 Basin called for installation of a new control structure, S-155A, at SR 7. This structure would create a basin of approximately 104 square miles and provide 50% more water for backpumping than is currently available in the western C-51 sub-basin (see dotted line east of C-51 sub-basin on Figure 2-1). This option was not considered at this time, however, due to costs, implementation time, and possible conflicts with the authorized USCOE project. Backpumping in the C-51 sub-basin will use an existing water control structure on C-51 west of Loxahatchee Road as a basin divide structure. Choice of this option now does not preclude construction of S-155A at some later time.

The current analysis considers that the entire L-8 sub-basin would be available for backpumping. Due to low stages in Lake Okeechobee, an additional temporary water control structure has been placed in L-8 to raise canal stages and allow water to drain to the lake from the L-8 sub-basin. The presence of this structure reduces the size of the L-8 sub-basin and the amount of water that would be available for backpumping (see dotted line in L-8 sub-basin on Figure 2-1). This structure may be removed or replaced by a larger structure in the future (Supplement A-1).

Divide Structure: The existing divide structure in the C-51 sub-basin consists of a concrete-capped earthen plug with gated culverts at a control elevation of 15.0 ft. msl. This structure has a design capacity of about 1100 CFS for release of water at flood stages.

Pump Configuration: The C-51/L-8 Basin would yield an estimated 154,000 ac/ft per year of runoff available for backpumping. Historic rainfall and runoff data were analyzed to produce a graph of the relationships between volume of runoff and the percentage of time that discharges of this volume or greater occurred (Figure 2-3). Based on this curve, a pump capacity was selected that would be exceeded 10 to 20% of the time. This curve indicated that a pumping capacity of 550 CFS would be exceeded less than 20% of the time during discharge periods. Estimated costs for purchase and installation of these pumps were $450,000.

Operating Costs: Basin runoff was further analyzed to determine the number of days that the volume of discharge from the basin would occur, at 27 CFS intervals, up to the maximum capacity of each of the pumps (Figure 2-3). For example, when discharges were 0-27, 27-55, 55-82, and 82-110 CFS, one 110 CFS pump would be in operation; when discharges were 110-220 CFS, two 110 CFS pumps would be in operation, etc. These criteria were then used to determine operation costs based on total number of pumping days per year.

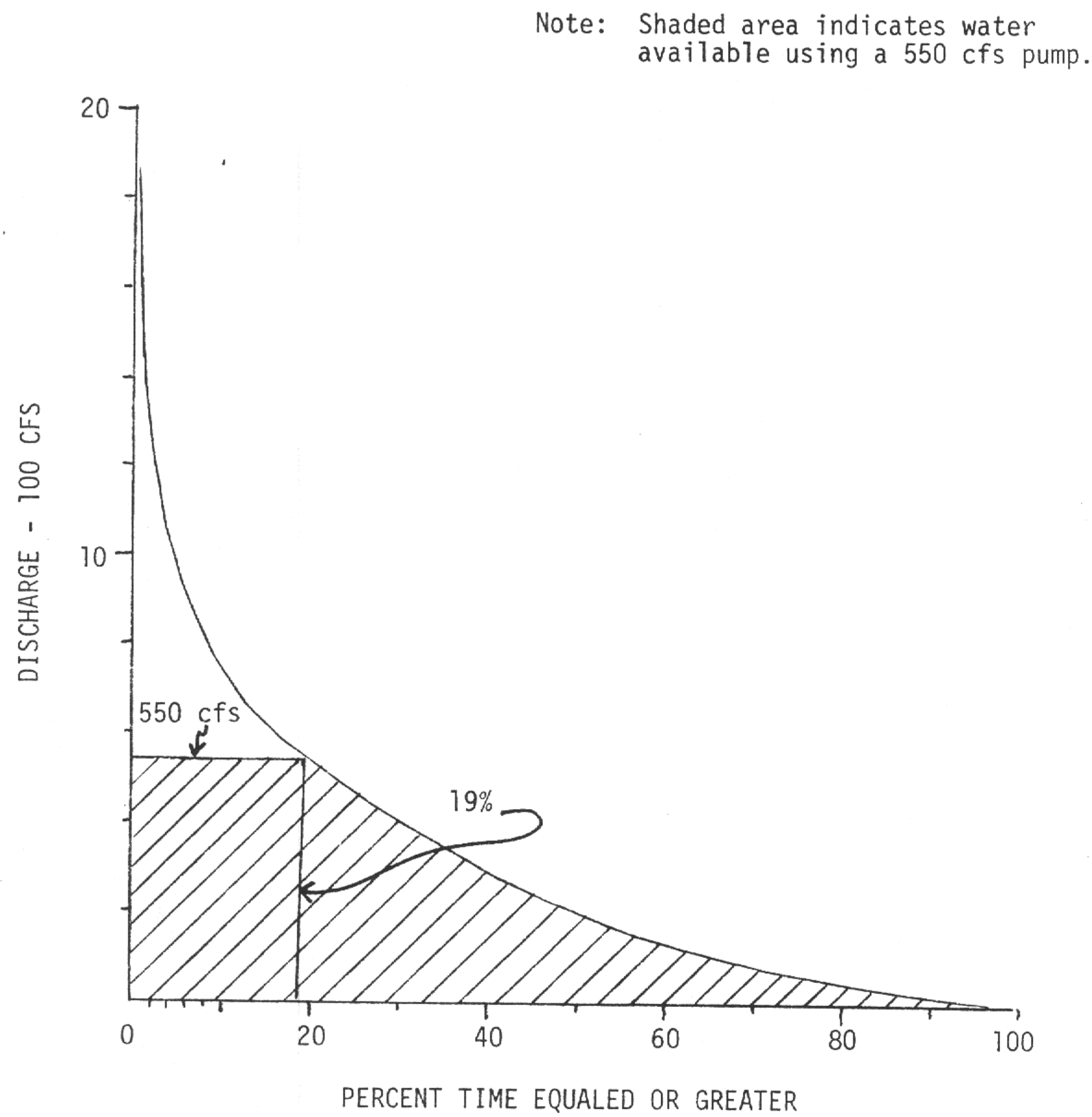


Figure 2-3 Water Available for Backpumping from West C-51 Basin

Costs were analyzed, based on the historic data, for years in which the least amount of backpumping would occur (minimum backpumping, Figure 2-4) and years when the greatest amount of backpumping would occur (maximum backpumping, Figure 2-5). These calculations led to an estimated minimum cost for C-51 pumps of $61,000 per year, a maximum cost of $212,000 per year, and an average cost of $140,000. Calculations were as follows for 5 units, 110 cfs capacity, 200 hp electric motor driven pumps:

200 hp pump X .746 kwh/hp = 149 kwh

149 kwh X 24 hr = 3580.8 kwh/day

Cost = 0.05/kwh X 3580.8 = $179.04/day

minimum backpumping = 341 pump days = $61,039

maximum backpumping = 1184 pump days = $211,936

Therefore, the average cost for operation of these pumps would be $136,488 per year for 762 pump days of operation. If operation schedules of the pumps were rotated on a regular basis, so that pumps received approximately equal use, then each pump would operate about 152 days per year.

Pumping Facilities: The C-51 facility would consist of 5 pump units located south and east of the existing S-5A complex (see Figure 2-6). An access canal would be constructed to transfer water from C-51 to the pump site. Water would be discharged through 150 ft. long pipes through the L-40 levee to the L-40 borrow canal and WCA-1 (see Figure 2-7). One acre of additional right-of-way should be purchased on the east side of L-40 at an estimated cost of $5,000. The pumps would be installed on steel frame or steel sheet pile structures - depending on field conditions. An access canal off C-51 would be constructed from C-51 east of S-5A(E) and continue south 400 ft. to the base of the pumps. This canal should have a bottom width of 20 ft., 1:2 side slopes, and be excavated from ground surface at 14 ft. msl to -1.5 ft. msl. Total excavation would involve approximately 12,000 cubic yards of material and cost about $30,000.

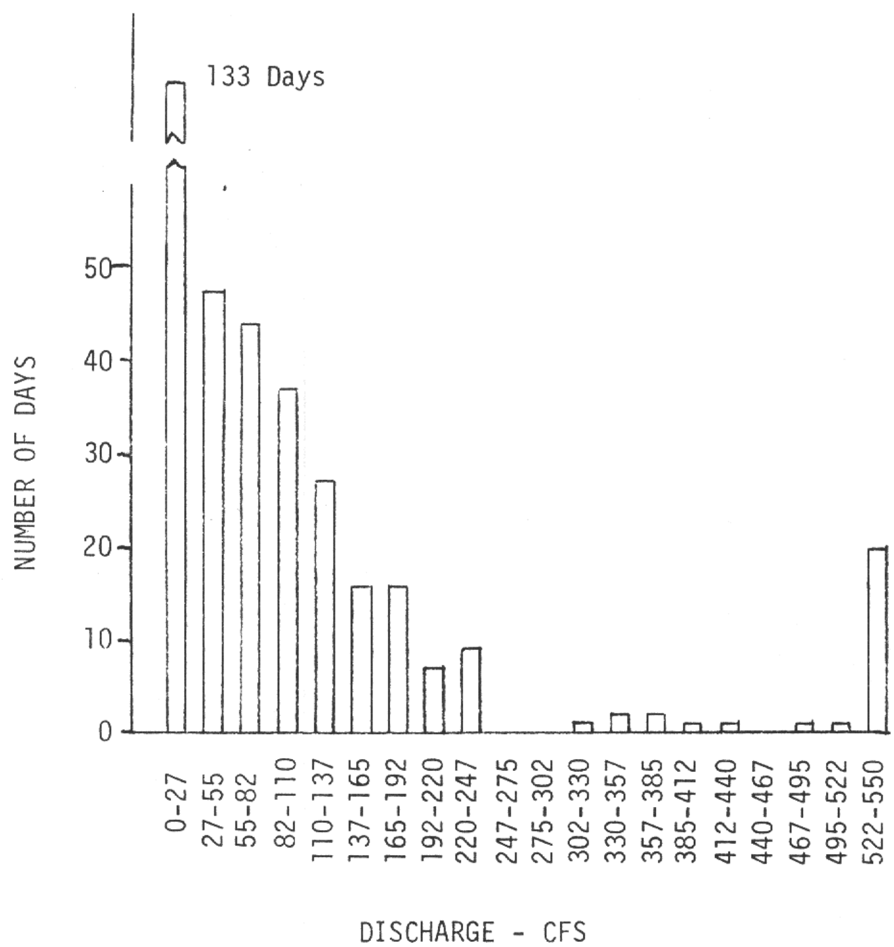


FIGURE 2-4 Projected Daily Pumpages in CFS Under Minimum Annual Backpumping, C-51/L-8 Basins

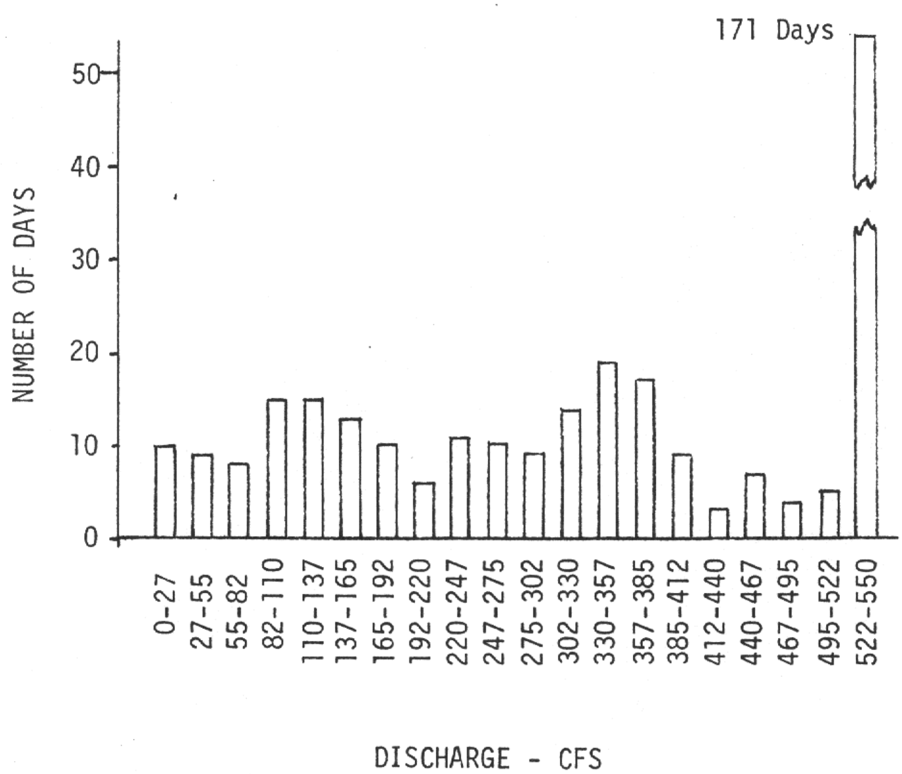


Figure 2-5 Projected Daily Pumpages in CFS Under Maximum Annual Backpumping, C-51/L-8 Basins

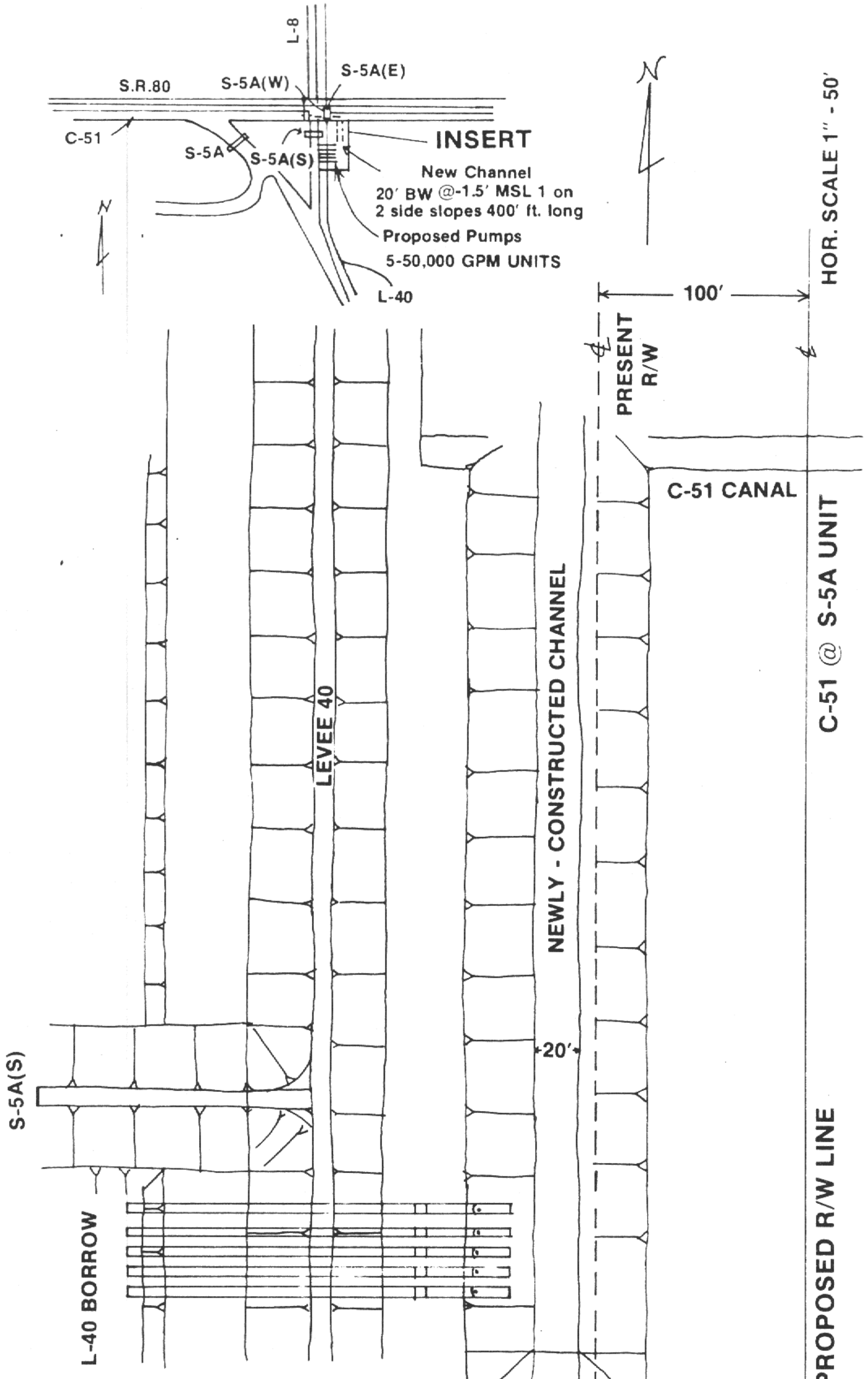


Figure 2-6. Proposed Pump Installtion at the S-5A Complex in the C-51/L-8 Basin

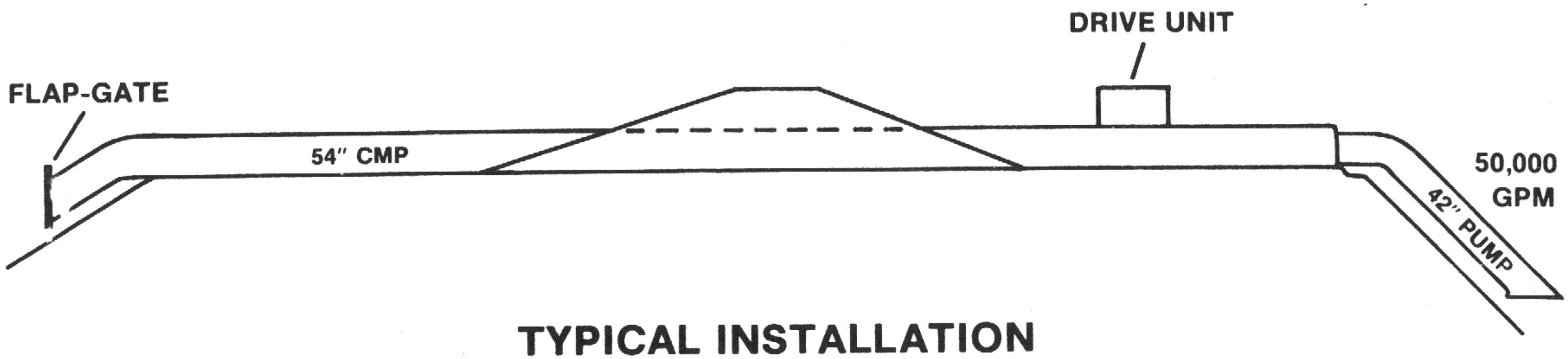


Figure 2-7. Typical Unit Pump Installation for Backpumping Facility

Design of the pump intake facilities was based on an average stage in WCA 1 of 15.8 ft. msl, an optimal canal stage of 9.5 ft. msl, a minimum canal stage of 7.5 ft. msl, and an existing canal bottom at -1.0 ft. msl. The pumps would thus operate against a static head of 6.3 to 8.3 ft. The pump intake would be submerged 7.5 ft to 9.5 ft below the surface of the canal to suppress formation of a vortex and cavitation. The suction bell of the intake would require a clearance of 3.0 ft. above the bottom to prevent undue intake of sediment. To meet these criteria, the forebay should have a length of 50 ft, a bottom width of 40 ft, and be excavated to a depth of -3.0 ft. msl with 1:2.5 side slopes.

C-13/North New River Basin

Basin Description

Location and Land Use: The C-13 sub-basin in central Broward County lies northwest of Fort Lauderdale, east of Water Conservation Area 2B (WCA 2B) in Broward County (Figure 2-8), and has an area of 22 square miles. The major portion of the North New River (NNR) sub-basin lies north of the North New River Canal, east of WCA 2B, and southwest of the C-13 sub-basin. Bonaventure Estates, south of the North New River Canal, is included as part of the North New River sub-basin. The total area is about 24.5 square miles.

Most of the land in the C-13 sub-basin is currently developed as medium density housing projects, mobile home parks, and planned communities based on recreational areas such as golf courses. The North New River sub-basin consists of low to medium density housing, planned recreational communities, and agricultural land uses. Agricultural use in the area east of C-42 is generally for groves, crops, and nurseries. Further west, the major agricultural use is pasture. The C-13/North New River Basin is under significant pressure for development, and will likely have increasing urban development in the near future when I-75 is completed.

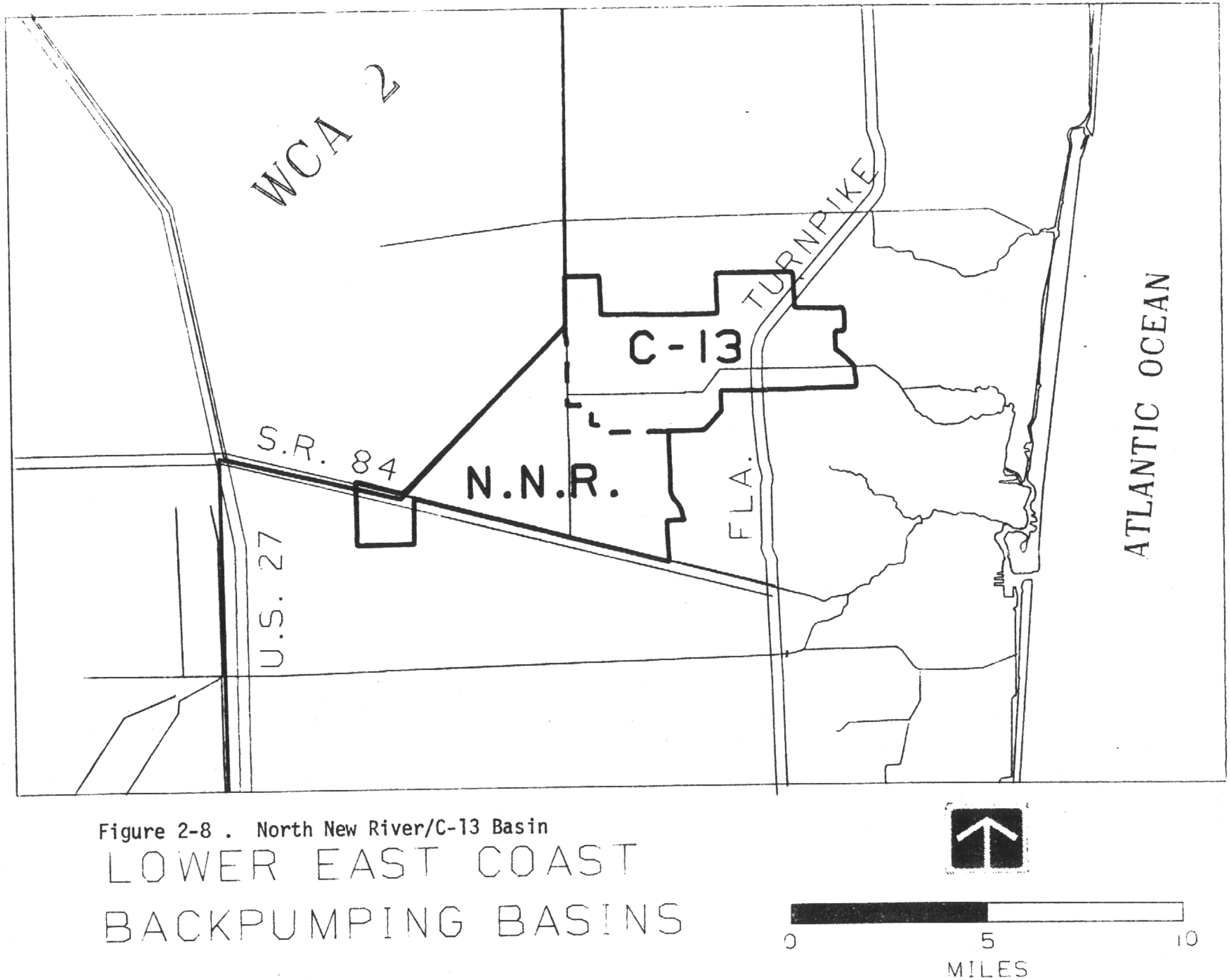


Figure 2-8 . North New River/C-13 Basin
LOWER EAST COAST
BACKPUMPING BASINS

Hydrologic Characteristics: The natural ground elevations vary from about 5 ft. msl to 9 ft. msl and slope from north to south. C-13 is about 12.7 miles long and discharges to tidewater at S-36. The North New River Canal receives flow from S-34 which is an outlet for WCA 2A, flow from C-42 which intercepts seepage from WCA 2A, local runoff from tributaries at Bonaventure Estates to the south, and from the major basin to the north.

Average annual rainfall in this area ranges from 60 inches near the turnpike to 54 inches at points inland. The relationship between accumulated rainfall and runoff (Figure 2-9) indicates that annual runoff is only slightly less than annual rainfall. Hence, under current conditions, the equivalent of almost all basin rainfall is discharged to tidewater. Discharges from the basin are measured at structures S-36 and Sewell Lock. Net basin discharge for the North New River sub-basin was estimated by considering releases from the water conservation area at S-34. Historically, the basin discharged an average of 184,200 acre feet per year to tidewater, of which 85% of the flow was discharged from the NNR Canal and 15% was discharged from C-13. An average annual volume of 125,000 acre feet is available for backpumping, so that flow to tidewater from the NNR/C-13 Basin would be reduced to 59,200 acre feet per year, or about 32.1% of historic flow. Seepage flow from the water conservation area was calculated as 110 CFS in the North New River Canal and it is included in this estimation. Seepage also contributes significant amounts of water to the C-13 sub-basin flow in dry seasons.

Water Quality: No water quality data were available for the westernmost 5.5 miles of the North New River Canal. Water quality samples within the remaining 8.5 miles of the North New River Canal were

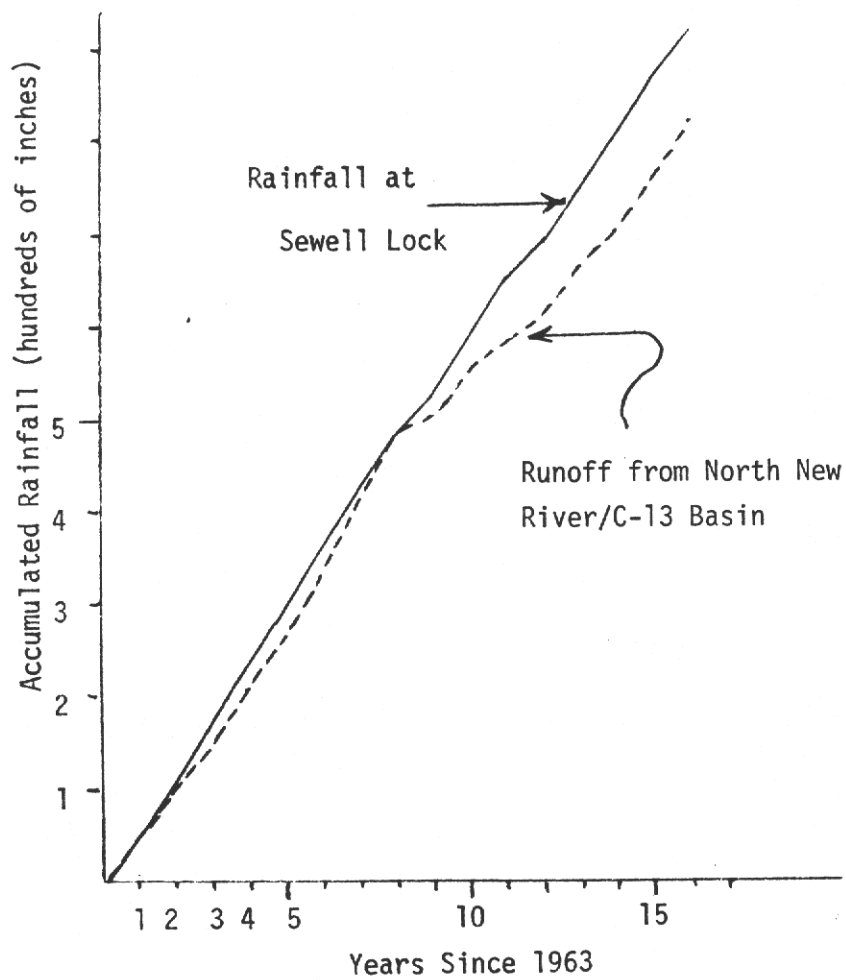


Figure 2-9. Accumulated Rainfall and Runoff in the North New River/C-13 Basin, Broward County, Florida.

collected monthly at seven stations by the Broward County Environmental Quality Control Board (BCEQCB) from 1975-1980.

Average dissolved oxygen values for all seven stations over the six year period were low, ranging from 1.6 mg/L to 3.8 mg/L. In general, the oxygen values decreased from east to west.

Total nitrogen and total phosphorus concentrations were relatively low. Average phosphorus values varied only slightly among the seven stations, from 0.03 mg/L to 0.06 mg/L, during the six years. The average total nitrogen values for the period of study also showed little variation from 1.12 mg/L to 1.37 mg/L.

The BCEQCB also collected fecal and total coliform data during this period. All seven stations had total coliform counts in excess of state standards (2,400 MPN) during one or more months of the study. Total coliform levels at two stations exceeded state standards in 8% of the samples that were collected during the six year period. Three of the seven NNR stations exceeded the state standards for fecal coliforms (800 MPN) in 3% of the samples taken during the study. Coliform concentrations showed no consistent trends from east to west within the canal basin.

System Design

Selection of Options: The C-13 and NNR sub-basins are hydrologically connected. Backpumping would involve routing of additional water from C-13 to the NNR Canal. Water from the western C-13 sub-basin would flow west to C-42, north to the L-25A borrow canal, and south through S-124 to the NNR Canal. Water from both sub-basins would be pumped at a new pump station to be constructed adjacent to S-34.

A second option was proposed for this basin by the USCOE in their 1968 Water Supply Study. This option would involve construction of a canal to connect the NNR Canal with C-11 and pumping both basins through the S-9 pump station. The S-9 pump station has sufficient capacity to handle the additional runoff and no construction of additional pump facilities would be required. The project would involve excavation of about 382,000 yd^3 of fill for canal improvements, placement of four 84 inch X 360 ft RCP gated culverts under SR 84, and construction of a 60 ft long, 2-lane bridge at Orange Avenue. The costs were estimated as follows:

382,000 yd^3 @ $1.75	=	$ 670,000
four culverts	=	720,000
2-lane, 60 ft bridge	=	150,000
		$1,540,000

The preferred option of installing pumps adjacent to S-34 would require no major structural changes in the basin and has an estimated cost of $370,000.

Pump Size: Pump size was selected based on NNR/C-13 Basin runoff data as described for the C-51 pump station. A graph of discharge vs time indicated that pumps of 440 cfs capacity would intercept basin flow 85% of the time. With this pump capacity, estimated water backpumped would be about 125,000 acre feet per year.

Operation Costs: The estimated pump operation curve for the NNR/C-13 pumps indicated that in years of minimum basin backpumping, costs would be $74,000 for 423 pump days of operation. Maximum backpumping would require $127,000 for 559 pump days. The average operation cost would be approximately $100,000 for 363 pump days of operation. If operation times for pumps were equally distributed, each of the four pumps would be in operation approximately 140 days of the year.

Pumping Facilities: Pumps would be installed on the east side of the S-34 pump station (Figure 2-10). Flow from these pumps would be directed through a short getaway channel into the North New River Canal, and then flow by gravity to WCA 3A via S-142, which consists of two 72-inch CMP

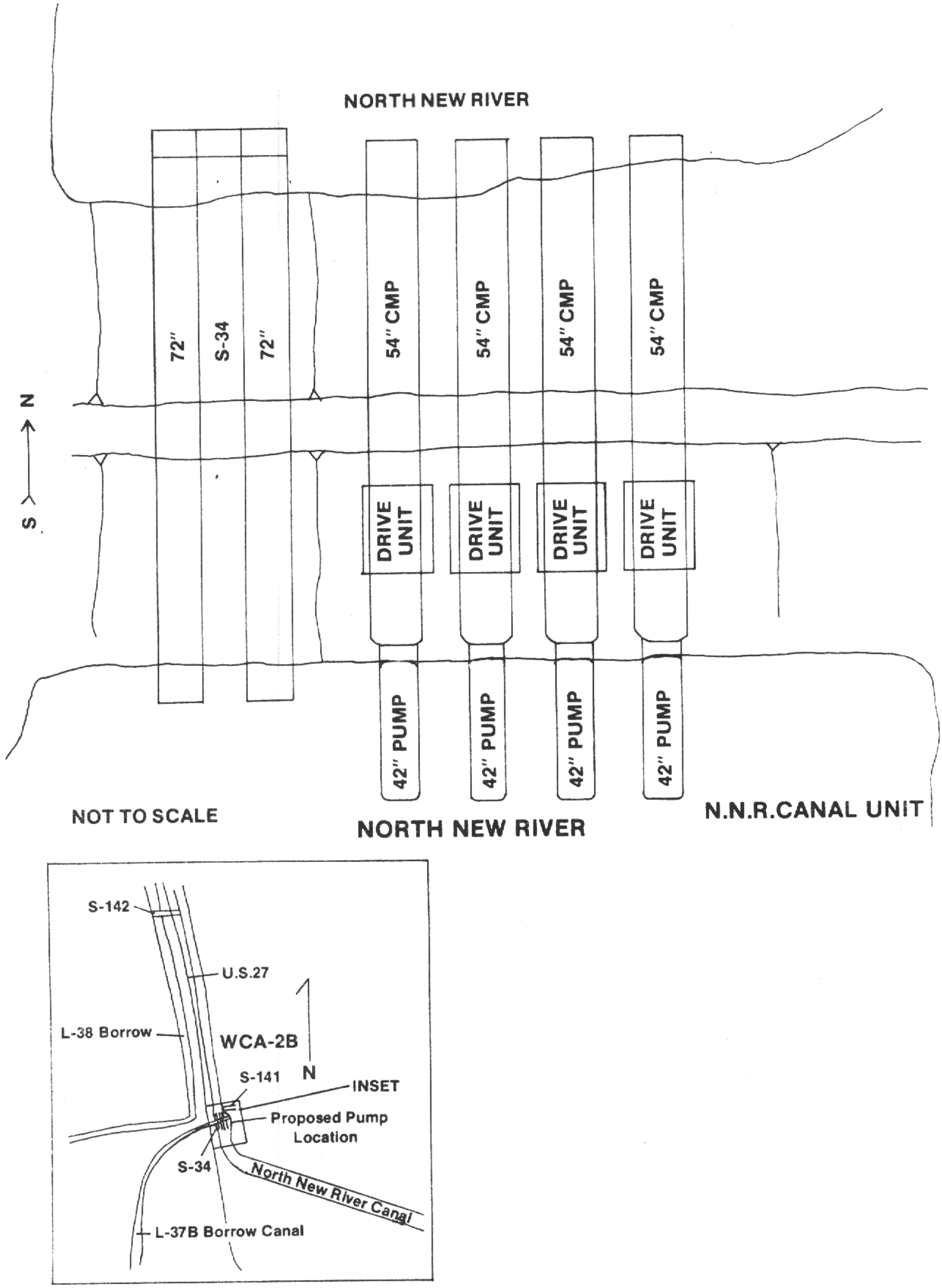


Figure 2-10. Proposed Backpumping Installation on the North New River Canal

culverts, with flow capacity of 500 CFS. The total estimated cost for installation of the pumps would be $370,000, which includes $20,000 for excavation of a get-away channel.

The average stage in WCA 3A is 9.5 ft. msl. The optimum canal stage is 4.0-4.5 ft. msl, and minimum stage at the forebay of the pump site is 2.5 ft. msl. Static head is 5 to 7 ft. The existing canal bottom is at -7 ft. msl. The forebay dimensions necessary to provide vortex suppression and pipe clearance are 50 ft. length, 40 ft. bottom width with 1:2 side slopes, and bottom elevation of -7.5 ft. msl.

Snake Creek Canal Basin
(Western C-9)

Basin Description

Location and Land Use: The Snake Creek Canal Basin (western C-9) is located in south Broward and north Dade Counties (Figure 2-11). The basin includes 45.7 square miles and extends west from SW 57th Avenue to L-33, and from Golden Glades Road on the south to Hollywood Boulevard on the north.

The western C-9 Basin is largely undeveloped. Land uses consist primarily of unimproved pasture, improved pasture, rangeland, and natural wetlands. Small areas in the north portion of the basin have been developed with medium to low density residential housing.

Hydrologic Characteristics: Ground elevations are very low with an average elevation of about 4 ft msl, and ranging from 3 ft msl to 6 ft msl. C-9 was originally constructed to provide conveyance for flood waters from the basin east of Red Road. This channel was later extended from Red Road westward to L-33 and S-30 on the east side of US Highway 27. S-29 is the outlet of this basin to tidewater.

There is apparently a large quantity of seepage from the Water Conservation Area into this basin. The L-33 borrow canal, the Miami Canal, and

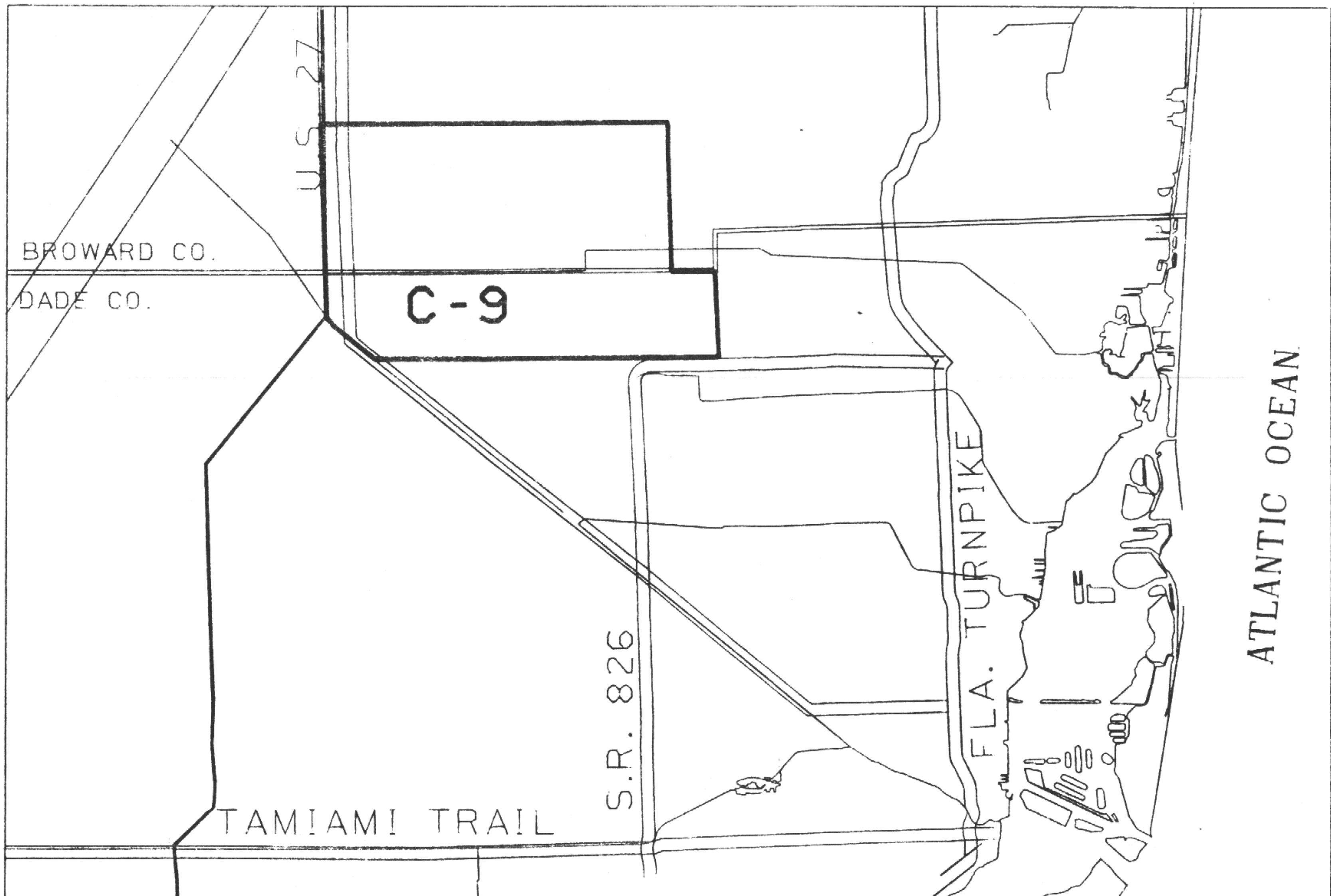


Figure 2-11. Snake Creek (C-9) Backpumping Basin

LOWER EAST COAST
BACKPUMPING BASINS

C-9 intercept portions of this seepage and hence these canals have a substantial base flow during most of the year. Calculations of seepage rates out of the Water Conservation Areas indicate that this seepage accounts for 225 cfs of the base flow in C-9 during the rainy season.

Average annual rainfall ranges from 60 inches near the coast to 52 inches at L-33. A plot of the relationship between accumulated rainfall and runoff for this basin is shown in Figure 2-12. The average annual volume of runoff from the C-9 Basin to tidewater is about 287,000 acre feet which corresponds to 82.56 inches. The runoff yield from this basin is almost 22 inches more than its average annual rainfall due to substantial seepage from WCA-3 and inflow from other basins through interconnecting underground channels. Under the backpumping plan, a pump capacity of 440 cfs would be able to backpump about 180,000 acre feet from this basin. Historical discharges to tidewater from the C-9 Basin were about 287,000 acre feet per year. With backpumping, these discharges will be reduced on the average by 63% to 107,000 acre feet.

Water Quality: Water quality studies have been conducted in the western reach of the Snake Creek Canal (C-9) from Red Road west to L-33 by the USGS and by Dade County. Dissolved oxygen levels showed a wide range from 0.6 mg/L to 6.6 mg/L and averaged 3.1 mg/L, compared to a state standard of 5.0 mg/L for surface waters. Total nitrogen and phosphorus concentrations were very consistent between stations. Average annual nitrogen levels were 1.30, 1.59, and 1.44 mg/L for three stations in C-9. Total phosphorus was even less variable with annual averages of 0.012, 0.010, and 0.012 mg/L for these same stations.

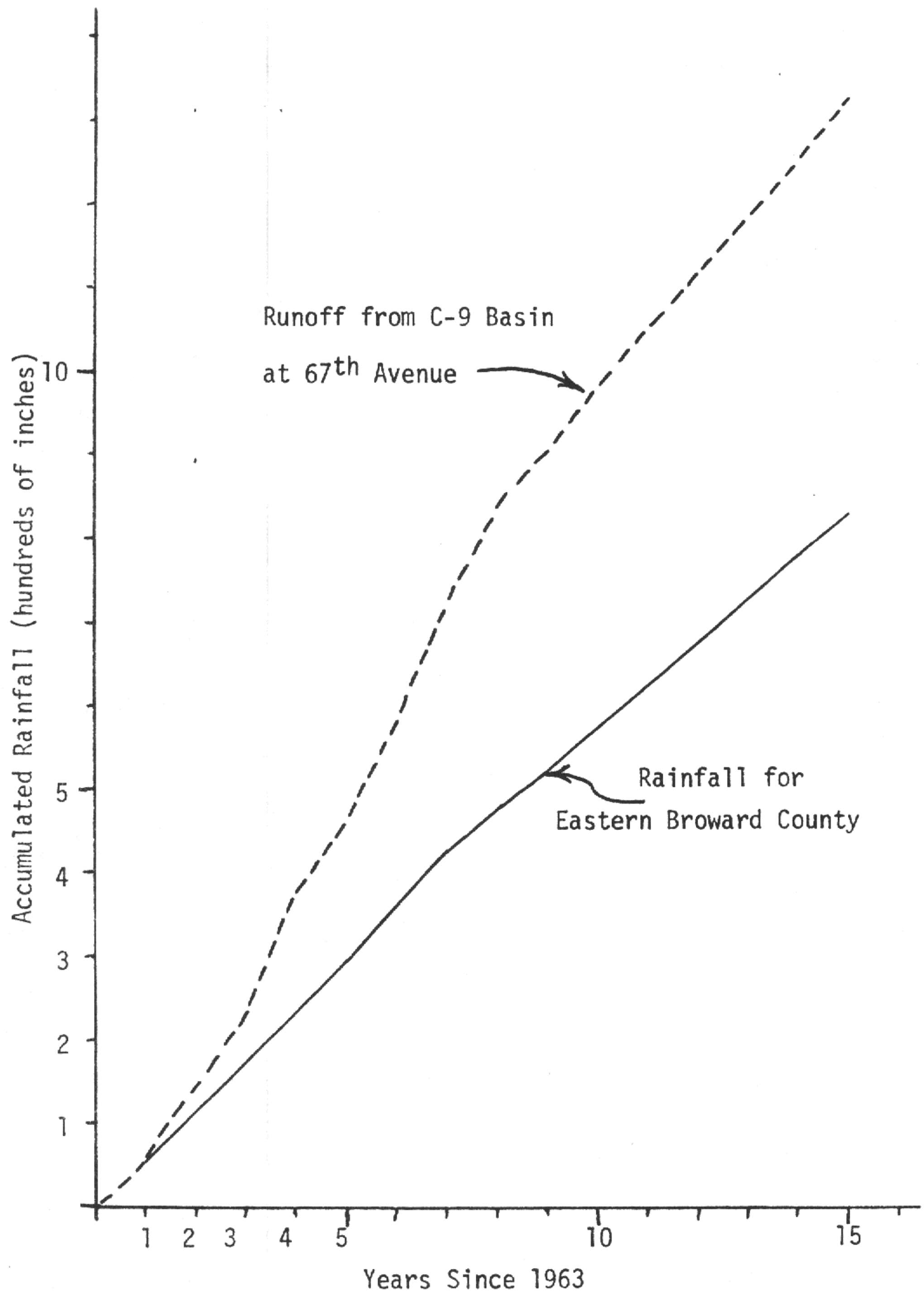


Figure 2-12 . Accumulated Rainfall and Runoff in the C-9 Basin, Broward, and Dade Counties, Florida

Coliform levels exceeded state standards occasionally . Total coliforms averaged 491 MPN, and three of the 24 values (13%) exceed the state standard of 2400 MPN. Monthly fecal coliform counts exceeded the state standard of 800 MPN only once (4%) during the study. The average fecal coliform level was 108 MPN for the two stations that were sampled.

System Design

Selection of Options: Backpumping of the C-9 Basin originally considered the possibility of providing hydraulic connection between the C-9 Basin and the Miami Canal Basin, and pumping the combined runoff into WCA-3. Results of initial studies, however, indicated that the western Miami Canal Basin was not suitable for backpumping in this manner, and pumping of this basin is not recommended at this time. The Miami Canal Basin would provide a relatively small amount of water available for backpumping (22,000 acre feet and could not effectively be held at a stage of 3.5 ft msl without having adverse impacts on flood conditions.

The recommended plan for backpumping the C-9 Basin would require installation of a divide structure at the eastern end of the basin and installation of four pump units (440 CFS total capacity) upstream of S-32 to discharge into WCA 3B.

Divide Structure: The basin divide structure would consist of a standard 16 ft wide gated water control structure designed to maintain an upstream water elevation of 3.5 ft msl and to pass 1500 CFS with approximately one foot of flood stage. This structure would be located on C-9 near SW 56th Avenue and would cost an estimated $500,000.

Pump Size: Size of the pump facility was determined by analysis of runoff characteristics of the basin as described previously for the C-51 and C-13 Basins. The discharge graph indicated that a pump capacity of 440 CFS would return runoff from the basin to the Water Conservation Area approximately 87% of the period of discharge. Approximately 180,150 acre feet per year of runoff would be available for backpumping from the C-9 Basin.

Pump Operating Costs: Operation costs for the C-9 pump stations were estimated as indicated for the C-13 and C-51 Basins. These costs are as follows:

Minimum cost.........659 pump days.....$118,000....165 days/pump/yr

Maximum cost.......1,019 pump days.....$184,000....257 days/pump/yr

Average cost.........838 pump days.....$150,000....209 days/pump/yr

Pumping Facilities: Facilities required for pumping from the C-9 Basin would be installed upstream of the existing S-32 control structure (Figure 2-13). Water from the C-9 extension would pass into the L-33 borrow canal to reach the pump site. Four 110 CFS pumps would discharge into C-304 through a small getaway channel across the marsh, just upstream of S-31 in WCA-3B. Cost of the pumps would be $345,000, which includes installation costs and construction of the getaway channel.

The average stage in WCA-3B is 7.1 ft msl. The optimum canal stage is 3.0 ft. msl and the minimum stage at the pumps is 1.5 ft msl. The static head is, therefore, 4.1 to 5.6 ft. The existing canal bottom is at -11.0 ft msl. Design for the forebay includes a length of 50 ft, a bottom width of 40 ft, and 1:2 side slopes. The bottom of the bay would have to be excavated to -14 ft. msl.

Tamiami Canal Basin

Basin Description

Location and Land Use: The Tamiami Canal Basin is located in central Dade County, west and south of Miami (Figure 2-14). The total area of the Tamiami Canal Basin is about 54.1 square miles. The land is rather flat

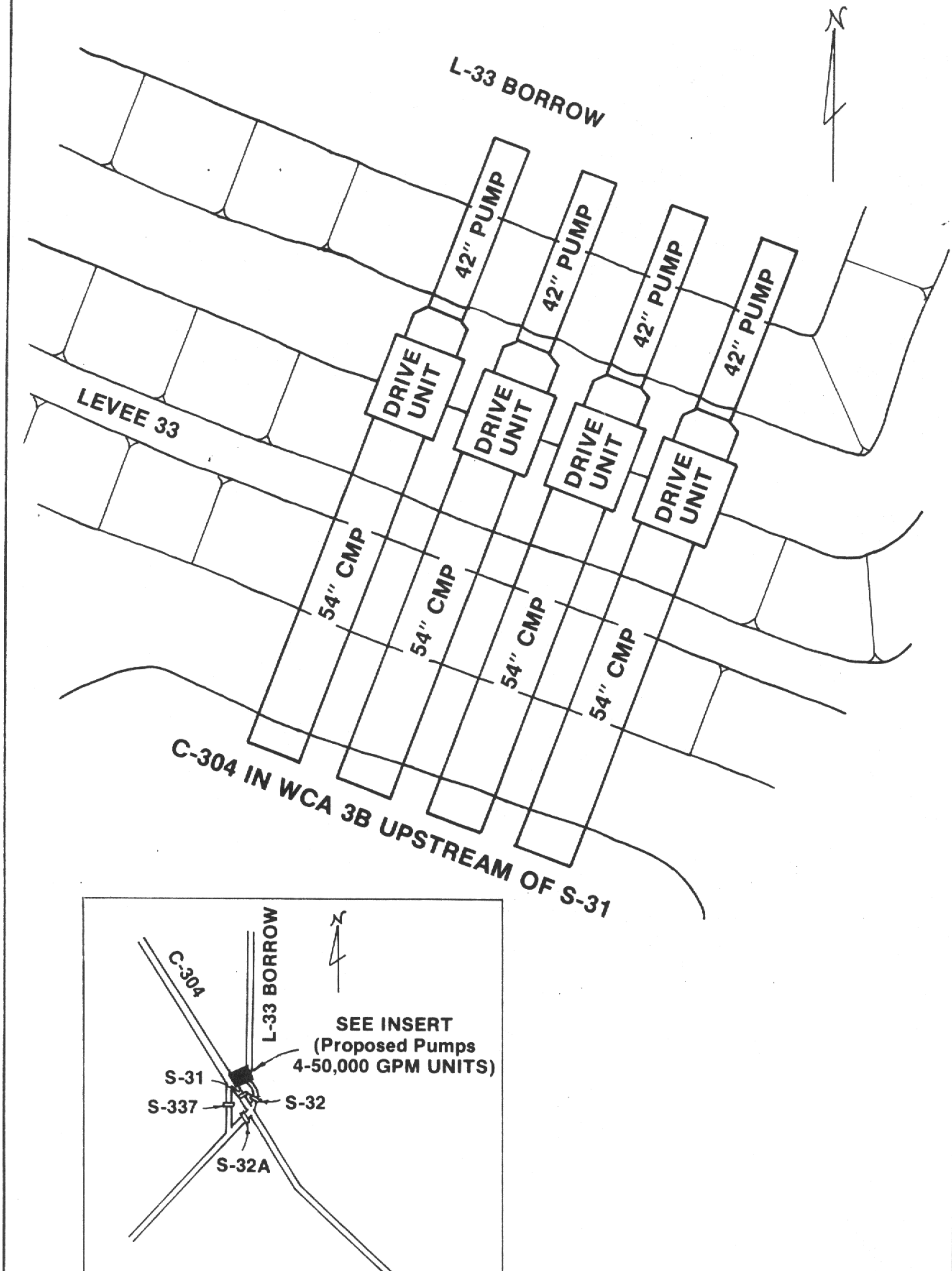


Figure 2-13. Proposed Backpumping Facility for the C-9 Basin

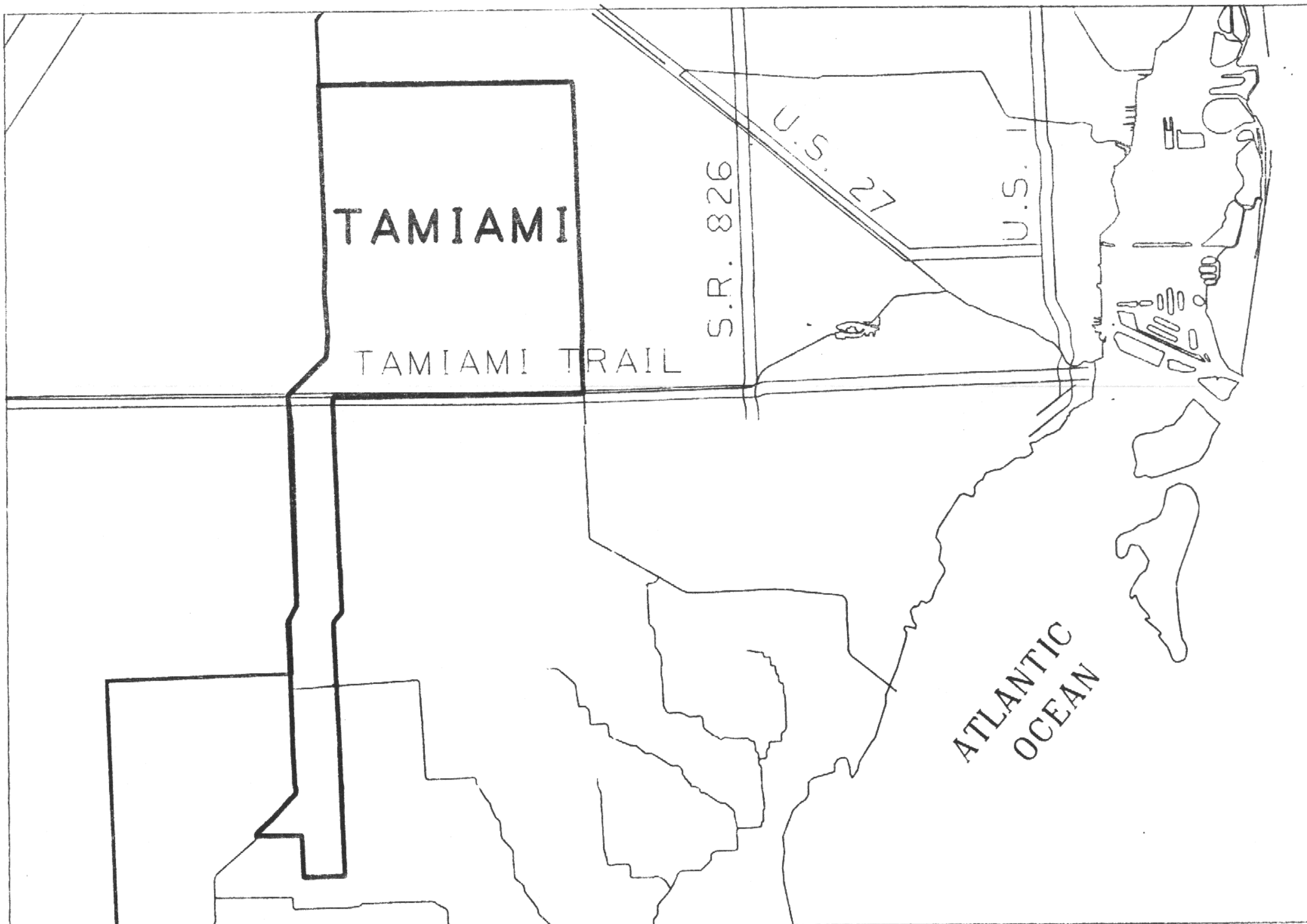


Figure 2-14. Tamiami Basin

LOWER EAST COAST
BACKPUMPING BASINS

and low with an average elevation of 5.5 to 6 ft msl. Drainage in this basin is very poor and the land is nearly all swamp. The northern and western portions of the basin are largely undeveloped vacant land. The eastern areas have some rock mining, open water rockpits, and industrial uses as well as low to medium density housing tracts. The southwest portion of the basin is used for improved agriculture.

Hydrologic Characteristics: This basin receives an average of 56 inches of rainfall per year. The Tamiami Canal Basin drains into C-4 on the north side of the Tamiami Trail between S-24 and the intersection with C-2 (Snapper Creek Canal) at the turnpike extension. Drainage from this basin flows east along C-4 to the Miami River at S-25B, or south through Snapper Creek Canal to S-22 at Biscayne Bay. This basin overlies the highly permeable Biscayne aquifer and hence receives substantial input of fresh water as seepage from the water conservation areas.

Analysis of the last 17 years of runoff-rainfall data indicated that about 25 inches per year, or about 44.6% of the average annual rainfall (Figure 2-15), is discharged as runoff. A substantial amount of seepage from WCA 3 is included. This seepage was estimated at 96 CFS and constitutes much of the base flow in the Tamiami Canal.

Analysis of historical discharges from this basin indicated that an average of 78,900 acre feet of runoff would be available for backpumping. Backpumping in this basin is constrained by the need to maintain a stage of 5.5 to 6.0 ft msl in the L-30 borrow canal. Historically, 232,600 acre feet were discharged from the Snapper Creek and C-4 Basins to tidewater. Discharge to tidewater after backpumping would be 153,700 acre feet, or 66% of historic discharge.

The amount of runoff available for backpumping may underestimate the total amount of water that would be available due to problems with assessing exact patterns of water flow from the basin, poor existing drainage

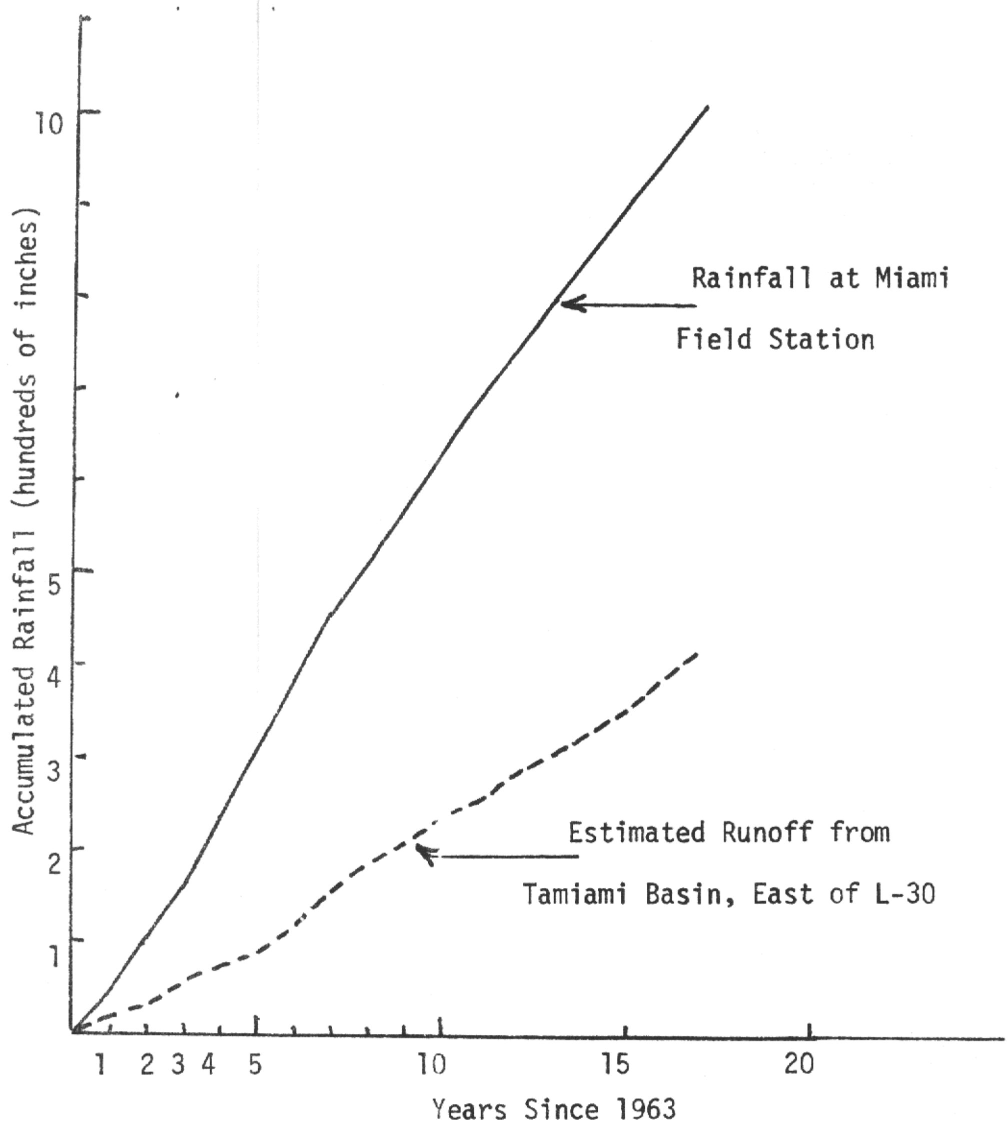


Figure 2-15 Accumulated Rainfall and Runoff in the Tamiami Canal Basin, Dade County, Florida.

conditions, and the nearly natural state of swampy wetlands in the basin.

Water Quality: The portion of the Tamiami Canal under consideration extends from the turnpike extension back toward the southeast corner of WCA-3B at L-30. Water quality in the canal is influenced by direct runoff from the drainage basin itself and by seepage through L-30. Water chemistry data were collected at two stations in this area by Dade County, under cooperation with the USGS, and by the SFWMD. This portion of the Tamiami Canal had the lowest dissolved oxygen values of any of the four backpumping basins and rarely met the state standard of 5.0 mg/L. Dissolved oxygen values ranged from 1.9 mg/L at the eastern end of the canal to 2.3 mg/L at the western end.

Total phosphorus concentrations in the Tamiami Canal were 0.033 mg/L at the eastern station and 0.011 mg/L at the western station for an average of 0.022 mg/L. Nitrogen values were also relatively low. Total nitrogen averaged 1.55 mg/L and ranged from 1.50 to 1.59 mg/L.

Analysis of total and fecal coliform data for both stations in the western Tamiami Canal Basin indicate that 10% of the total coliform values were in excess of state standards. The eastern station had a much higher average (4419 MPN) compared to the western station (759 MPN) as a result of extreme high counts in August of 1975. Fecal coliform counts did not exceed state standards at the western station nearest the proposed Tamiami backpump.

System Design

Selection of Options: Backpumping of the Tamiami Canal Basin would involve construction of a divide structure, canal improvements, and a discharge channel in WCA-3 in addition to construction of the pump station.

Divide Structure: A divide structure would be constructed in the Tamiami Canal, west of Snapper Creek, to maintain appropriate stages in the western portion of the canal. This [illegible]cture should consist of three 84-inch diameter CMP culverts with a design capacity at flood stage of approximately 600 CFS, and a control elevation of 5.5 ft msl. Cost of this structure would be $3[illegible],000. Construction of this divide structure would also require plugging the north end of a secondary drainage canal along SW 132nd Avenue and placement of a 36-inch diameter CMP culvert at an estimated cost of $20,000. Two existing 72-inch culverts at the entrance to the rifle range would be replaced with a 2-lane bridge across the canal at an additional cost of $150,000.

Pump Size: Calculation of required pump size for the Tamiami Canal Basin backpumping facility indicated that 330 CFS capacity pumps would collect basin runoff during 95% of the runoff period. An estimated 78,900 acre feet can be backpumped from this basin with a 330 cfs pump facility.

Pump Operation Costs: Operation costs for the Tamiami Basin pumping facility were estimated by the methods described previously. These costs are as follows:

Minimum cost........223 pump days......$40,000......74 days/pump/year

Maximum cost........475 pump days......$85,000.....158 days/pump/year

Average cost........363 pump days......$65,000.....121 days/pump/year

Pumping Facilities: Facilities required for pumping the Tamiami Canal Basin would include construction of 600 ft of new channel to connect the C-4 borrow canal and bypass the S-336 water control structure (Figure 2-16). Construction of this channel would involve excavation of approximately 5500 cubic yards of fill and cost about $35,000. This channel would convey water from C-4 to the new pumping station on the L-30 borrow canal. Three 110 CFS pumps would pump water across L-30 and discharge to a floodway in the WCA 3 marsh. The floodway would be 150 ft wide by 600 ft long and excavated about two feet below ground level of rock. Cost of installation

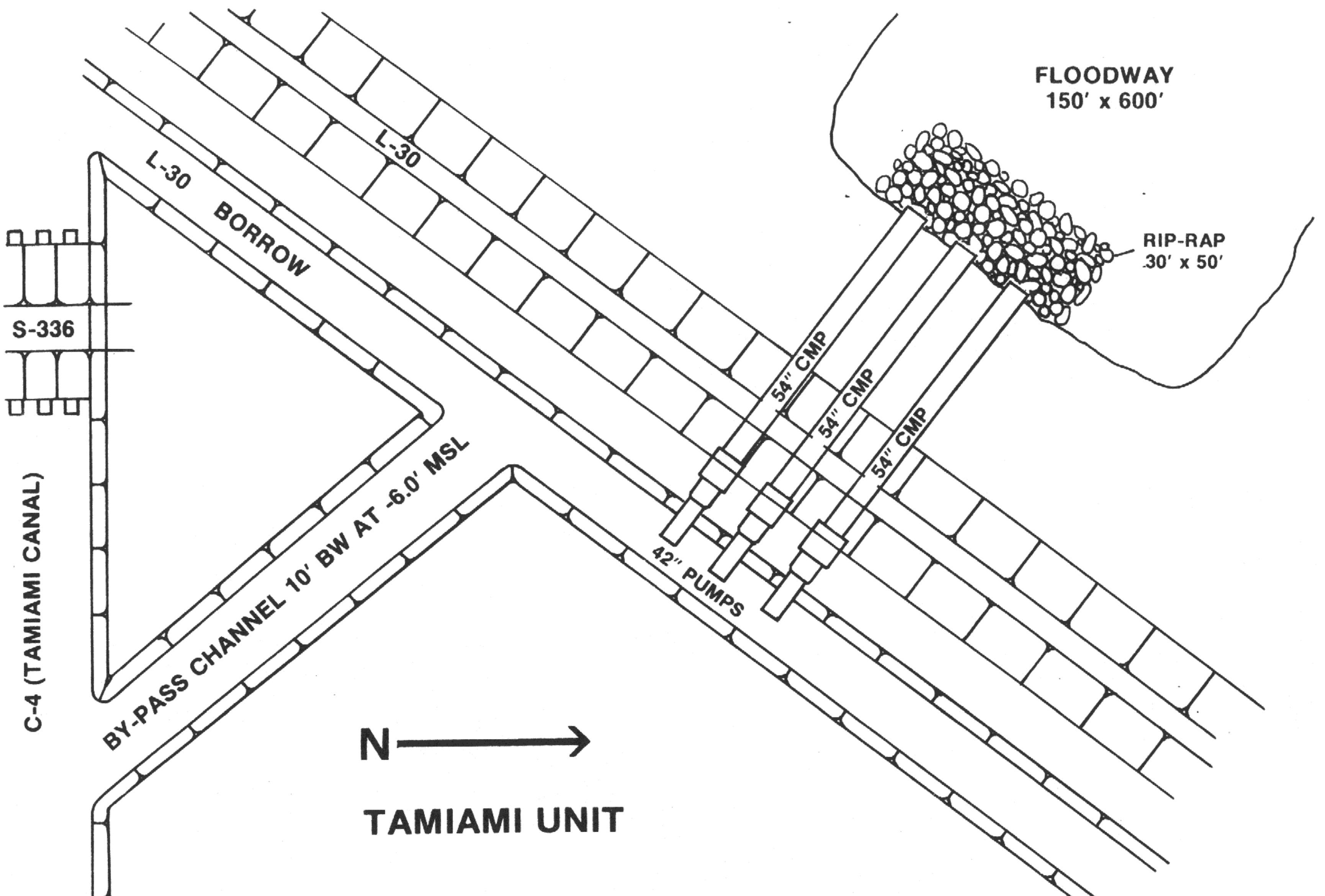


Figure 2-16. Proposed Backpumping Installation for the Tamiami Basin

of the pump would be $270,000. An additional $10,000 would be required for the floodway. The area of immediate discharge would require 1500 square feet of rip-rap to reduce erosion.

The average stage in WCA-3B is 7.1 ft msl. Optimum stage in the L-30 borrow canal is 5.5 ft msl and the minimum stage at the forebay of the pumps is 4.0 ft msl. The static head would therefore be 1.6 to 3.1 ft. The existing canal bottom is -5.0 ft msl. The forebay dimensions would be 50 ft long with a 16 ft bottom width and 1:2 side slopes, and excavated to a bottom elevation of -7.5 ft msl.

CHAPTER

EVALUATION OF IMPACTS OF BACKPUMPING

This chapter contains the evaluations of the hydrologic, economic, water quality, and environmental impacts of the water supply backpumping alternatives. Each of these topics is covered in a sub-section of this chapter.

Hydrologic Evaluation of Water Supply Backpumping Alternatives

The hydrologic evaluation of the water supply backpumping alternatives was carried out largely through the use of a mathematical mocel that simulates water conditions and water movements in Lake Okeechobee, the Water Conservation Areas, and the coastal surficial aquifers. The model simulates, on a monthly basis, the impacts on the system of inflows (rainfall and inflows to Lake Okeechobee) and outflows (urban and agricultural demands, natural systems evapotranspiration, use of water for prevention of salinity intrusion, Everglades National Park releases, and other releases to tidewater). These simulations take place using hydrologic principles and system capabilities (stage-storage relationships, discharge capacities, etc.) in order to meet operating criteria including regulation schedules, requirements for flood protection, minimum stages needed to prevent saltwater intrusion, desire to meet urban and agricultural demands, and Everglades National Park minimum required releases. The result of the simulation for each month is a set of stages in the lake, the Water Conservation Areas, and the coastal aquifers from which the next month's simulation can begin.

To assist in the evaluation of the water supply backpumping alternatives, six runs of the model were made. These covered each of the proposed backpumping basins separately, all four basins together, and a base run of no backpumping. Each run covered the period from June 1965 to May 1981, usi weather conditions for that period, but using demands which reflect current population and agricultural land use. These runs also reflected present regulation schedules and, following the water supply backpumping philosophy, do not permit backpumping when the Water Conservation Areas are above regulation schedule.

Since the system was operated under different regulation schedules in the late sixties and early seventies, and since demands have significantly increased, it is not relevant to make comparisons with historical conditions. However, a case with the present regulation schedules in Lake Okeechobee and the Water Conservation Areas, present demands, and no backpumping was simulated with the historical rainfall conditions. This no backpumping case was used as a baseline to compare the effectiveness of the different backpumping options.

Important hydrologic outputs from the model and from other calculations which are used in the further evaluations from the economic, water quality, and environmental standpoints include system storage, inflows to the Water Conservation Areas, outflows to the estuaries, and the stage duration relationships all presented with and without backpumping so that the differences due to these systems can be determined. Each of these major outputs is discussed in the sections where they are used.

Economic Evaluation of the Water Supply Backpumping Alternatives

Two important questions which need to be answered from an economic standpoint regarding the efficacy of the water supply backpumping alternatives are:

(1) Will the economic benefits exceed the costs?, and

(2) Is this supply alternative more cost effective than all other alternatives?

This investigation starts with the measurement of project benefits.

Measurement of Economic Benefits

The chief economic benefit of water supply backpumping is the reduction of drought damages during periods when present supplies are inadequate to meet all demands. The measurement of drought damage reduction benefits can itself be divided into two issues:

(1) the frequency with which all demands cannot be met, and

(2) the severity of the shortages when all demands are not met.

The frequency with which demands are not met provides a factor by which to adjust damage estimates. This is necessary because economic benefits cannot be attributed in situations wherein the present supply system can provide for all demands. Runs of the model covering the hydrologic/meteorologic record for the period from 1965 to 1981 indicate that in none of these years except 1981 was the ability of the present supply systems to meet all demands in serious question. Even previously stringent years like 1970-1971 and 1973-1974 showed large available storage amounts at the end of the dry season. This was apparently due to the supply capabilities generated through the higher regulation schedules on Lake Okeechobee. The minimum dry season storages for each of the years this model was run are shown in Table 3-1. This projected minimum storage probably understates the actual amounts available at that time since it does not include storage in the surficial aquifers of the interior and coastal areas. Also, the model used a relatively conservate minimum floor for Lake Okeechobee of 9.8 ft msl.

The magnitude of these storage values is such that project growth over the next decade will not alter the basic conclusion of generally adequate supply capability. Since little overall growth in agricultural demands is expected over the next decade across the whole of the Lake Okeechobee/Lower East Coast Service Areas, the major change will be in urban growth. Urban growth over the next two decades would increase dry season demands (November to May) by about 186,000 acre feet, which is only a small portion of the excess available storage in years other than 1981.

While the 17 years for which the model was run covers some of the variation in hydrologic/meteorologic conditions that can be expected in south Florida, there are years which will fall outside that range and have even greater shortages. It appears that 1981-1982 was one of those years due to the low storage levels left by the conditions of 1980-1981.

The overall experience of the last 18 years indicates, however, that the need for the backpumping supply alternative will be a fairly rare occurence. For the purposes of this study, it is assumed that this frequency of need will take place on a one in fifteen year basis. The impacts that the low water conditions of the present time have on this evaluation will be discussed later in this section.

TABLE 3-1. MINIMUM AVAILABLE WATER IN SYSTEM STORAGE WITHOUT BACKPUMPING DURING THE DRY SEASON (IN RANK ORDER[a])

Year	Minimum Storage (acre feet)	Month of Minimum Storage
1970	3,257,652	May
1969	3,072,159	May
1980	2,906,682	June
1978	2,829,718	May
1966	2,455,826	May
1979	2,327,861	June
1972	1,834,492	April
1977	1,663,843	April
1975	1,584,797	April
1976	1.539,997	April
1973	1,392,954	May
1967	1,334,878	May
1968	1,200,087	April
1974	927,792	May
1971	722,607	May
1981	98,233	July

[a] These acre feet represent the totals available for release from Lake Okeechobee and the three Water Conservation Areas. Water in storage in the coastal basins and the interior agricultural areas has not been included in the estimates. The amounts available for release are those above stage levels of 9.8 feet msl for Lake Okeechobee and 10.0, 7.0 and 6.0 feet msl for the three Water Conservation Areas.

The severity of the water demand cutbacks is the next question that must be investigated. This issue is important because the higher the amount of shortage the greater the value per acre foot that must be attributed to the water that the backpumping alternatives can supply. However, since the model did not show any inability to meet demands during the period simulated, there is no available basis on which to select the shortage levels.

For purposes of illustration, a schema has been derived which indicates the general categories of impacts and associated drought damages which are expected under alternative levels of water use cutbacks. This schema is summarized in Table 3-2. The wide range of the potential drought damage values indicates the importance of the severity question.

The values presented in Table 3-2 generally represent the market value of production lost because of reduced water availability and use. The value of the lost sales in agriculture include reduced returns to the farmer, and lost income to farm laborers and farm product processors. The value of the inconvenience to residential water users was imputed from the marginal costs of water and sewer service use typical of south Florida.

It is important to note that these loss estimates were formulated to apply to a short-term unexpected water shortage that has a low probability of occurrence and that the loss estimates on an acre foot basis greatly exceed those that would apply for a long-term water shortage that was known with certainty. The major difference is that for this short-term unexpected shortage analysis it has been assumed that the value of the input services thrown into unemployment because of the drought will be lost to society. For a long-term certain shortage, it would be assumed that resources unemployed in one industry would find employment in other industries or leave the region. Thus, in the case of

TABLE 3-2. DROUGHT DAMAGE LEVELS AND EXPECTED IMPACTS

Level Designation	Dollar Range of Expected Impacts (Dollars per Acre Foot)	Illustrative Types of Impacts
Mild	\$100 - \$300 (\$.30 - \$.92 per thousand gallons)	Retardation of growth of sugar cane and pasture; lawn watering at inconvenient hours; changing inside water consumption habits
Moderate	\$300 - \$1,000 (\$.92 - \$3.07 per thousand gallons)	Loss of pasture; loss of sugar cane; loss of citrus fruit
Severe	\$1,000 + [a] (\$3.07 per thousand gallons and up)	Loss of vegetable crop; loss of citrus trees; loss of lawns, landscaping,and golf course turf; loss of business in car washing establishments

[a] Most of the illustrative impacts involve losses in the \$2,000 to \$10,000 per acre foot range. (\$6.00 to \$30.00 per thousand gallons)

vegetable farming the drought losses that were measured were the lost market value of the vegetables. In case of drought damage, it is unlikely that vegetables would be harvested and the farmer would not have to pay harvest labor. Nonetheless, since it is unlikely that those laborers would find employment elsewhere, the lost value of their labor has been included in the drought losses.

Another reason why the agricultural damages are high is that a water shortage for a short period of time can wipe out assets created in times of water abundance. A clear example of this is the case of a short but severe water shortage which kills citrus trees. Any trees planted to take the place of those lost would not begin producing for about four years and would not reach the production level of mature trees for many years after that.

Assuming that the relevant shortage levels will be mild and properly managed, a value per acre foot of $250 has been selected for use in the subsequent evaluation to represent the expected benefits per acre foot of water supplied by backpumping in years when such water is needed.

The last remaining component needed to estimate the benefits from the backpumping structures is the amount of additional supplies which would be available as a result of backpumping. In measuring this amount, it is important to make the estimation at the time when the additonal demands would most likely be needed.

Estimates of the amounts of additional water in storage as a result of the backpumping stations were obtained from the runs of the model for sixteen years of hydrologic/meteorologic conditions. The months for which the differences were calculated correspond to the months of minimum storage presented in Table 3-1. Because the amounts of additional water varied significantly from year to year, the average of the amounts from the eight years with the lowest minimum storage was used to estimate the amounts available when they will be needed. These data are presented in Table 3-3. For purposes of benefit estimation it has been assumed that all of the additional storage will be made available for agricultural or urban uses.

With the development of these data, estimates of the benefits from water supply backpumping can now be formulated. These estimates are contained in Table 3-4. They represent the present value of benefits over a twenty year period. The twenty year period was chosen to correspond to the life of the major capital component of the backpumping stations, the pumps. The benefits were calculated as the product of the additional acre feet of water available (Table 3-3). the value per acre foot ($250), and the probability of needing the extra water (.067). Future benefits and costs were discounted using an assumed real interest rate of 10% per annum, accumulated over the 20 year period. As was noted above, the benefits were estimated under two alternative assumptions; the first of which does not consider the present water supply situation and assumes an equal likelihood of needing the additional supplies in all years, and the second of which considers the present water supply situation and pessimistically assumes that there is a 30% chance of needing the additional supplies in the next year.

In order to investigate the likelihood that water backpumped during the 1982-1983 hydrologic year would be needed to meet demands during the latter part of that year, special runs of the model were made. The initial condition for these runs were set, assuming that the rainfall received between now and the end of the dry season will be 50% of normal. This pessimistic assumption would leave Lake Okeechobee at a level of 9.16 feet by June 1. The model was then run for the hydrologic conditions of 1965-1981 with this low initial condition. These runs showed that storage

TABLE 3-3. AVERAGE ADDITIONAL STORAGE AVAILABLE AS A RESULT OF BACKPUMPING ALTERNATIVES[a]

Backpumping Alternative	Additional Available Storage (acre feet)
West Palm Beach Canal	33,800
North New River Canal	53,700
Snake Creek Canal	57,700
Tamiami Canal	23,400
All Stations	147,600

[a] The average is for the eight of sixteen years with the lowest minimum storage levels without backpumping. Additional available storage is measured at the time of minimum storage without backpumping.

TABLE 3-4. ESTIMATED BENEFITS OF WATER SUPPLY BACKPUMPING ALTERNATIVES

Backpumping Alternative	Twenty Year Present Value of Benefits (Thousands of Dollars) Assumption 1[a]	Assumption 2[b]
West Palm Beach Canal	$4,820	$6,592
North New River Canal	$7,658	$10,474
Snake Creek Canal	$8,229	$11,254
Tamiami Canal	$3,337	$4,564
All Stations	$21,049	$28,787

[a] An equal likelihood of needing the backpumped water of .067 is assumed for all years.

[b] Reflecting the current water supply situation, a likelihood of .3 of needing the backpumped water next year is assumed. The likelihood of .067 is assumed for all other years.

would fall below the targeted minimums in five of the sixteen years, or about 30% of the time.

Estimation of Costs

The capital and operating costs for the backpumping facilities were developed in Chapter 2 as part of the design of each of the systems. The purpose of this section is to calculate the present net value of the costs for the different alternatives. In this way, alternatives which have capital investments with different lives, and alternatives which have different ratios of capital costs to operating costs, can be compared.

The major assumption used in adjusting the costs from Chapter 2 is the use of a discount rate of 10% per annum. The 10% represents an estimated return on investment in the private sector with the effects of inflation taken out. The investment by the private sector is considered to be the alternative to the investment by this government agency. Because the costs presented are 1982 costs and they are used for future periods as well, and because the discount rate has the effects of inflation taken out, the present value of the costs are presented in 1982 dollars.

The cost evaluations of the four alternatives are presented in Tables 3-5 through 3-8.

Benefit/Cost Analysis

Taking the benefits and the costs from the previous sections, the benefit/cost ratios can now be formulated. They are presented in Table 3-9.

All benefit/cost ratios far exceed the value of one, which indicates that the backpumping alternatives should return more to south Florida in terms of

TABLE 3-5. COST EVALUATION FOR THE WEST PALM BEACH CANAL/L-8 BASIN PUMP STATION

20 Year Capital Cost

	Purchase Price	Life	20 Year Present Value of Cost
5 Pump Units (50,000 gpm each)	$450,000	20 yr.	$450,000
1 Acre Right of Way	5,000	-	4,000
Excavation of Canal	30,000	-	26,000
Total Capital Cost			$480,000

20 Year Operating Cost

	Annual Cost	20 Year Present Value of Cost
Electricity	$140,000	$1,192,000
Labor	2,500	21,000
Other		
Total Operating Cost		$1,213,000

20 Year Total Cost

	20 Year Present Value of Cost
Capital	$ 480,000
Operating	1,213,000
Grand Total	$1,693,000

TABLE 3-6. COST EVALUATION FOR THE NORTH NEW RIVER CANAL/C-13 BASIN PUMP STATION

20 Year Capital Cost

	Purchase Price	Life	20 Year Present Value of Cost
4 Pump Units (50,000 gpm each)	$370,000	20 yr.	$370,000
Total Capital Cost			$370,000

20 Year Operating Cost

	Annual Cost	20 Year Present Value of Cost
Electricity	$100,000	$851,000
Labor	4,000	34,000
Total Operating Cost		$885,000

20 Year Total Cost

	20 Year Present Value of Cost
Capital	$370,000
Operating	$885,000
Grand Total	$1,255,00

TABLE 3-7. COST EVALUATION FOR THE C-9 BASIN PUMP STATION

20 Year Capital Cost

	Purchase Price	Life	20 Year Present Value of Cost
4 Pump Units (50,000 gpm each)	$350,000	20 yr.	$350,000
Divide Structure (near 56th Ave)	500,000	30 yr.	452,000
Total Capital Cost			$802,000

20 Year Operating Cost

	Annual Cost	20 Year Present Value of Cost
Electricity	$150,000	$1,277.000
Labor	5,200	44,000
Total Operating Cost		$1,321,000

20 Year Total Cost

	20 Year Present Value of Cost
Capital	$802,000
Operating	$1,321,000
Grand Total	$2,123,000

TABLE 3-8. COST EVALUATION FOR THE TAMIAMI CANAL BASIN PUMP STATION

20 Year Capital Cost

	Purchase Price	Life	20 Year Present Value of Cost
3 Pump Units (50,000 gpm each)	$270,000	20 yr.	$270,000
Channel to By-Pass S-336	35,000	30 yr.	32,000
2 Lane Bridge at Rifle Range	150,000	20 yr.	150,000
Culvert Structure West of Snapper Creek	300,000	30 yr.	271,000
Plug with Culvert in North End of Dade County Canal along SW 132nd Ave	20,000	30 yr.	18,000
Total Capital Cost			$741,000

20 Year Operating Cost

	Annual Cost	20 Year Present Value of Cost
Electricity	$65,000	$553,000
Labor	4,200	36,000
Total Operating Cost		$589,000

20 Year Total Cost

	20 Year Present Value of Cost
Capital	$741,000
Operating	589,000
Grand Total	$1,330,000

TABLE 3-9. BENEFIT COST ANALYSIS

Backpumping Alternative	Benefit/Cost Ratio[a]	
	Assumption 1[b]	Assumption 2[c]
West Palm Beach/L-8 Basin	2.85	3.89
North New River/C-13 Basin	6.10	8.35
Snake Creek Canal Basin	3.88	5.30
Tamiami Canal Basin	2.51	3.43
All Basins	3.29	4.50

[a] This is the ratio of the 20 year present value of benefits (Table 3-4) to the 20 year present value of costs (Tables 3-5, 3-6, 3-7, and 3-8).

[b] An equal likelihood of needing the backpumped water of .067 is assumed for all years.

[c] Reflecting the current water supply situation, a likelihood of .3 of needing the backpumped water next year is assumed. The likelihood of .067 is assumed for all other years.

drought damages avoided than they will require in terms of commitment from the taxpayers to finance the projects. These data also indicate that among the alternatives, the North New River/C-13 Basin had by far the highest benefit cost ratio.

Under the pessimistic assumption that the backpumping will be needed with a 30 percent probability, the benefit cost ratios are far higher, thus indicating the importance that assumptions about our near term future conditions will have on evaluations of the efficacy of water supply backpumping alternatives.

Cost-Effectiveness Analysis

While the cost-benefit analysis has helped to show the degree to which the water supply backpumping stations are economically worthwhile, the cost-effectiveness analysis will show whether this water supply alternative is less, as, or more worthwhile than other alternatives. Because of the limited scope and time available, the cost estimates of other water supply alternatives were very rough. It is felt that these estimates provide information only as to which alternatives are or are not in the same order of magnitude as the water supply backpumping alternatives in terms of cost-effectiveness.

The cost effectiveness is measured in terms of dollars per acre foot of annual dry season supplemental water supply capacity. The dollars are the 20 year present value of all costs, the same concept that was used for the cost-benefit analysis. The annual dry season supplemental water supply capacity is used because, while the analyses indicate the supplemental capacity will not be needed in all years, the historical fluctuation in water conditions indicate that systems would have to be prepared to operate in all years. This is illustrated by the large changes in year to year rankings in Table 3-1. The lowest year (1981) was preceded by the third highest (1980) and the second lowest year (1971) was preceded by the highest year (1970). Thus, the terminal conditions of one water year cannot be used to determine whether extra water supply capacity will be needed in the next year.

Table 3-10 provides the basic cost-effectiveness comparison among several water supply alternatives. Each of these alternatives is designed to provide extra supply capabilities to meet demands generated by present users. The focus is on solving present water supply problems rather than providing extra capacity to meet additional demands. No data were available to assess the cost-effectiveness of major structural modifications to the Central and Southern Florida Flood Control Project (C&SFFCP), so alternatives like flood control backpumping, new conservation areas, and changing the dikes and the regulation stages on Lake Okeechobee were not included. The supply options, besides water supply backpumping, which are considered include, reverse osmosis, deepwell injection, moving present wellfields inland, weather modification, and retrofit of water conservation devices. Each of these alternatives to water supply backpumping is discussed in terms of the results presented in Table 3-10.

Retrofit of Water Conservation Devices: This program would involve the installation of water conservation devices such as displacement bottles (for toilets), shower inserts, and faucet devices into existing residences and tourist accommodations. By restricting flows with each water use, total water use will be reduced as will be the need for water and sewer treatment capacity.

In designing a conservation program to compare with the water supply backpumping alternative, care was taken to assure the installation and retention of

TABLE 3-10 COST EFFECTIVENESS COMPARISON OF SELECTED WATER SUPPLY ALTERNATIVES FOR MEETING PRESENT DEMANDS

Supply Option	Order of Magnitude Estimate of 20 Year Present Value of Costs Per Acre Foot of Annual Dry Season Support	Major Assumptions and Caveats
Water Supply Backpumping	$ 43	
Retrofit of Water Conservation Devices	$ -85	The proposed plan could save about 35,000 acre feet during the dry season. It could be implemented by next dry season. The negative figure represents a net cost savings in that water and sewer utility cost reductions would exceed the costs of the program.
Weather Modification	NA	The limited experience during the 2WM project showed costs comparable to water supply back-pumping in order of magnitude. More experience would be needed before this can be considered a proven reliable alternative.
Wellfield Relocation	$ 350	This covers only the capital cost of the new well-fields, the transmission lines and the pump stations. For this method to work the chief problem must be in the location of the wellfields and not the amount of water in the aquifer.
Deepwell Injection	$1,500	
Reverse Osmosis	$1,500	This covers only the capital costs of RO facilities.

NA = Not available because present data cannot provide a reliable estimate.

the devices and to avoid operating problems by excessive reduction of water use by any device. Thus, costs for professional installation were included to assure that devices would be used. Displacement bottles, rather than toilet dams, were used since the former, although they save less water per flush, would not present the potential operating problems that dams might cause.

The initial capital cost of this program would be about $480 per acre foot of water saved during the dry season, but as a result of this program, there would be sufficient savings in water and sewer treatment costs that would accrue and must be taken into account.

While reduced demands for utility services may create some temporary revenue problems, the long-run impact will be significantly reduced utility costs. Such savings can be passed on to the customers. The largest part of these savings will come when utility facility expansions, which otherwise would have been necessary, can be delayed because of the reduced system demands. Using $1.00 per thousand gallons as the amortized capital and operating expense of a new water plus sewer treatment facility, the total utility cost savings in one year would exceed the cost of the retrofit program. If all these savings could be implemented immediately, the 20 year present value of the savings would be about $168,000,000. If the savings did not being for several years, the cost savings would be less. If they occurred only during the last 10 years of the 20 year program, they would still amount to $47,000,000. For presentation in Table 3-10, the second, more conservative estimate has been used and the resulting savings is $85 per acre foot of dry season supply.

<u>Weather Modification:</u> This option would involve an annual program of cloud-seeding, over selected areas of the District, designed to increase rainfall and storage in the District's system. The District's very limited experience with

the 2WM (Cloudseeding) project last summer indicated very positive results. As was presented to the Governing Board, the preliminary estimates were that the program's costs were $2.00 per acre foot of augmented rainfall and $12.00 per acre foot which reached District storage areas. These estimates would make weather modification comparable to the water supply backpumping alternative; however, what is lacking is the experience to assure that a performance level such as this can be produced on a reliable basis. A final report and presentation to the Board on the 2WM project will be made at the March 1982 meeting.

Relocation of Present Wellfields: If the principal problem restricting the use of coastal aquifers during drought periods proves to be the location of certain wellfields in areas susceptible to saltwater intrusion, rather than the total amount of water in the aquifer, then some of the water shortage problems could be alleviated by shifting the demands to inland locations. This would involve the construction of new wellfields and a pipeline system to feed the water to the present treatment plants.

Estimates of wellfield development costs for the lower east coast from the 1977 Water Use and Supply Development Plan[1] indicate that the capital costs of relocating present wellfields 8 miles inland, and pumping the water to present treatment plants, would be on the order of $150,000 per MGD of capacity when fairly large (30 MGD) installations were made. Translating these costs from 1976 to 1982 prices, and putting them on the basis of acre feet of dry season capacity, this estimates becomes $350.

Deepwell Injection: Surplus water could be pumped into the Floridan aquifer for storage rather than backpumping it. A portion of this water could then be recovered in time of need. The cost-effectiveness for deepwell injection systems were last studied by the District for the Upper East Coast

[1] South Florida Water Management District, Water Use and Supply Development Plan, Volume IIIA, Technical Exhibit A, especially pp 1-83 to 1-91.

Planning Area[1]. In that study capital costs of $1,968,000 and annual operating costs of $40,500 were estimated for a system which would inject 5846 acre feet and recover 1842 acre feet. The total 20 year present value of these costs per acre foot of annual capacity is $1,256. This cost probably overstates the costs for a system designed for water supply during droughts since the repeated injection cycle and rare use of the water should increase the overall recovery efficiency above the 32% assumed in the foregoing example. Costs in the example are in 1980 dollars. Adjusted to 1982 dollars the 20 year present value of the cost of an acre foot of annual capacity would be $1,500.

Reverse Osmosis (RO): The RO desalination alternative would involve the substitution of this treatment method for the conventional treatment processes. This could be accomplished by installing the RO capacity at those wellfield treatment plant complexes most severely threatened by saltwater intrusion. The RO plants would then be operated, in combination with the conventional treatment plants, in a way that would maintain quality of delivered water while minimizing the operational cost of water treatment.

Costs of RO facilities were last studied by the District for the Upper East Coast Planning Area[1]. In that study, capital costs of a 25 MGD brackish water RO plant were presented. This cost adjusted to twenty year present value per acre foot of dry season capacity yields an estimate of $1,150 in 1979 dollars. Adjusted to 1982 dollars the estimate is $1,500. Since the RO plant costs more to operate per thousand gallons of water produced than conventional plants, it is clear that these expenses would also rise. How much could not be determined since the frequency the RO plant would be needed is not known.

[1] South Florida Water Management District, Advanced Water Supply Alternatives for the Upper East Coast Planning Area, Technical Publication #80-6, August, 1980, especially pp 47-4[illegible], 66-73.

Water Quality Impacts of Backpumping

Comparisons of Canal Water Quality with Other Inflows

Table 3-11 provides a comparison of water quality in each backpumping basin at the station nearest the proposed pump site. Total nitrogen, total phosphorus, dissolved oxygen, fecal and total coliform counts (where available) from January 1975 to the present are listed for the canals, other points of inflow, water in the Water Conservation Areas, and rainfall.

Average nitrogen concentrations in the canals proposed for backpumping are low in relation to nitrogen concentrations in other existing inflows and in the Water Conservation Area marshes. Total nitrogen levels range from 1.12 mg/L in the North New River Canal to 2.62 mg/L in the West Palm Beach Canal.

Average total phosphorus concentrations increase ten-fold from 0.01 mg/L in C-9 to 0.101 mg/L in C-51. With the exception of C-51, phosphorus levels in the canals are below phosphorus levels in some of the existing inflows, below existing levels in the Water Conservation Areas, and even below phosphorus levels in rainfall.

Dissolved oxygen concentrations in all four basins were low throughout the period of study, 1975 through 1981. Dissolved oxygen levels were highest during the dry season, January through May, due to reduced levels of water runoff, biochemical oxygen demand, and temperature. In general, dissolved oxygen levels decreased from north to south among the canals.

Comparisons with State Standards

Table 3-12 shows how levels of dissolved oxygen and coliform bacteria as well as nitrate, turbidity, and conductance at stations in the backpumping basins nearest the pump site compare with state standards for these parameters.

TABLE 3-11. WATER QUALITY COMPARISONS IN WCA's AND INFLOWS

	Source	Total Nitrogen[1]	Total Phosphorus[1]	Dissolved Oxygen[1]	Coliform[2]	Fecal Coliform[2]
PROPOSED[4] INFLOWS	L8	2.30	0.066	4.0	-	35
	C-51	2.62	0.101	4.7	533	32
	NNR	1.12	0.03	3.8	369	47
	C-9	1.59	0.01	3.1	1641	59
	Tamiami	1.59	0.011	2.3	759	43
EXISTING[4] INFLOWS	West Palm Beach Canal at S5A	5.74	0.165	4.1	N/A	N/A
	Hillsboro at S6	4.47	0.078	3.4	"	"
	NNR at S7	3.32	0.063	4.3	"	"
	Miami at S8	3.33	0.049	5.5	"	"
	Hendry County L3	2.04	0.077	6.0	"	"
	Hendry County S190	1.51	0.036	6.9	"	"
	SNR at S9	2.29	0.012	1.6	"	"
EXISTING INTERIOR QUALITY	Interior WCA1	3.19	0.033	4.5[3]	"	"
	Interior WCA2A	2.93	0.031	4.5[3]	"	"
	Interior WCA3A	2.13	0.017	4.5[3]	"	"
ATMOS-PHERIC	Rainfall	1.08	0.050	-	"	"

[1]All nutrient and D.O. data reported in mg/L

[2]Coliform counts reported as most probable number - MPN

[3]Typical diurnal ranges from 1.0 - 8.0 mg/L

[4]Average data from stations nearest the proposed backpumping site

TABLE 3-12.

SEVERAL WATER QUALITY PARAMETERS AS THEY COMPARE TO STATE STANDARDS CHAPTER 17.3, FAC, FOR STATIONS IN EACH CANAL NEAREST THE PROPOSED BACKPUMPING SITE

Parameter	State Criteria	L8/C-51	NNR	Snake Creek	Tamiami
NO_3	not to exceed 10 mg/L	none	none	none	none
Turbidity	not to exceed 50 JTU	none	none	none	none
Dissolved Oxygen	not less than 5.0 mg/L	frequent	frequent	frequent	frequent
Specific Conductance	not to cause over 50% increase to receiving water	unknown[1]/ 55%[2]	unknown[1]/ 59%[3]	unknown[4]	unknown[4]
Fecal Coliform	not to exceed 800 MPN	none	none	none	none
Total Coliform	not to exceed 2400 MPN	few (8%)	few (3%)	few (11%)	few (10%)

[1] The ability of this inflow to cause a change in the conductivity of the receiving body cannot be assessed at this time.

[2] Percent of inflows which exceed 150% of WCA 1 background conductance (464 μmhos/cm)

[3] Percent of inflows which exceed 150% of WCA 3A background conductance (516 μmhos/cm)

[4] No analysis of WCA 3B interior water quality available

Concentrations of dissolved oxygen in the backpumping basins rarely rose above state standards of 5.0 mg/L. However, average dissolved oxygen concentrations in the Water Conservation Areas themselves were also frequently below 5.0 mg/L. Since the canals to be backpumped have low BOD values, discharge of these waters into the Water Conservation Areas will probably not depress the dissolved oxygen levels in the Water Conservation Areas below their naturally low levels.

Fecal coliform counts in all four of the drainage basins were low and did not exceed state standards. Total coliforms, however, did exceed state standards in 8%, 3%, 11%, and 10% of the samples taken in the C-51/L-8, North New River, C-9, and Tamiami Canals, respectively. Comparisons with other inflow points and with coliform levels in the Water Conservation Areas are not possible due to lack of data in these areas.

Nitrate and turbidity levels for inflows never exceeded state standards of 10 mg/L and 50 JTU, respectively. Average nitrate values ranged from 0.531 mg/L in the West Palm Beach Canal to 0.050 mg/L in the Snake Creek Canal. Turbidity levels were all low. The highest turbidity value (9.2 JTR) occurred in the L-8 borrow canal.

State standards for specific conductance require that an inflow to a body of water may not cause the conductivity of the receiving body to rise more than 50% above background. It is unlikely that small inflows of water from backpumping could significantly raise conductivity throughout the Water Conservation Areas. The long-term effects of such inflows are unknown. Conductivity values for the C-51/L-8 and North New River/C-13 Basins exceeded 150% of the background conductance for WCA-1 and WCA-3 more than 50% of the time.

Nutrient Loadings

The impact of backpumping on the Water Conservation Areas was assessed by comparing the effects of backpumping under average rainfall conditions with the effects of backpumping during a drought. Effects of backpumping during both periods were evaluated based on the percent increases in water, nitrogen, and phosphorus discharged to the Water Conservation Areas.

Table 3-13 represents inputs to WCA-1 for "average" conditions from January 1978 through December 1980 and for a drought period from June 1980 through May 1981. The top portion of the table shows actual inputs to WCA-1 based on USCOE monthly hydrological budget sheets. The bottom portion of the table is an estimate of the increases in nitrogen, phosphorus, and water that would result from backpumping the C-51/L-8 Basin, based on results of the model. During "average" conditions, flow to WCA-1 would increase by approximately 140,000 acre feet (15%), which would result in increases of 13% and 9% in phosphorus and nitrogen inputs, respectively. During the drought period, only 95,000 acre feet would be available. However, due to generally dry conditions, this still represents an increase of 15% relative to no backpumping. Phosphorus and nitrogen loadings, as a result of this additional flow, would increase 15% and 11%, respectively.

During "average" discharge conditions, a portion of this additional water would flow through the WCA-1 marsh and out through the S-10 structures into WCA-2. Backpumping the C-51/L-8 Basin would result in an estimated increase of 116,974 acre feet of water (12% increase) through the S-10 structures. This water would transport 13% additional phosphorus and 15% additional nitrogen into WCA-2A. The percent increases of water, phosphorus, and nitrogen that flow to WCA-2A during a drought period would be 15%, 6%, and 21% respectively.

Nutrient and water budgets for WCA-3A were modified to reflect increases in input due to backpumping of the North New River Canal and the increased flow through the S-11 structures as the result of additional water in WCA-1 (Table 3-14). Water, nitrogen, and phosphorus were increased 7%, 8%

TABLE 3-13. NUTRIENT AND WATER BUDGET FOR WATER CONSERVATION AREA 1 AS INFLUENCED BY PROPOSED BACKPUMPING FROM THE C-51/L-8 BASIN

Budget for Average Conditions, 1978-80

	Source	Total P (tonnes)	Total N (tonnes)	Flow (AF)
Background Levels (Without Backpumping)	S-5A	58.5	2820	291,555
	S-6	18.82	1082	148,658
	Rainfall	31.74	687	518,187
	Total	109.40	4589	958,400
With Backpumping	C-51/L-8	14.50	418	139,913
	Total	123.90	5007	1,098,313
	% Increase	13	9	15

Budget for Drought Conditions, June, 1980 thru May, 1981

	Source	Total P (tonnes)	Total N (tonnes)	Flow (AF)
Background Levels (Without Backpumping)	S-5A	29.54	1488	171,542
	S-6	10.17	559	82,671
	Rainfall	24.59	531	399,803
	Total	64.30	2578	654,016
With Backpumping	C-51/L-8	9.41	285	95,367
	Total	73.71	2863	749,383
	% Increase	15	11	15

Budget for Average Conditions, 1978-80

	Source	Total P (tonnes)	Total N (tonnes)	Flow (AF)
Background Levels (Without Backpumping)	S-8	23.16	1415	279,157
	S-9	2.26	302	113,617
	S-140	13.78	254	106,250
	S-150	5.08	331	67,910
	L-281	4.08	90	48,710
	L-3	16.31	276	100,241
	S-11A	1.36	281	103,756
	S-11B	2.58	524	129,334
	S-11C	5.82	607	162,870
	Rainfall	100.94	2185	1,643,897
	Total	175.37	6265	2,755,742
With Backpumping	(1) S-11's	2.09	312	89,323
	NNRC	6.31	258	164,865
	Total	183.77	6835	3,009,930
	% Increase	5	9	9

Budget for Drought Conditions, June 1980 - May 1981

	Source	Total P (tonnes)	Total N (tonnes)	Flow (AF)
Background Levels (Without Backpumping)	S-8	10.53	620	135,492
	S-9	0.56	149	38,789
	S-140	1.94	58	25,232
	S-150	3.84	261	48,847
	L-281	0.44	22	9,617
	L-3	1.33	43	16,699
	S-11A	0.22	43	23,430
	S-11B	2.27	391	121,952
	S-11C	5.56	529	114,793
	Rainfall	91.68	1985	1,492,352
	Total	118.37	4101	2,027,203
With Backpumping	(1) S-11's	0.28	34	10,700
	NNRC	5.36	307	144,864
	Total	124.01	4342	2,182,767
	% Increase	5	6	8

(1) Additional flow due to C-51 backpumping

and 3%, respectively during the average period and were increased 9%, 7%, and 6%, respectively during the drought period.

Changes in the water and nutrient budget of WCA 3B due to backpumping of the Snake Creek and Tamiami Canals were not calculated due to a lack of background data for WCA 3B.

The accuracy of these estimates must be tempered by the assumptions on which the model is based. The model assumed current regulation schedules and water use demands which differed from conditions that existed historically. However, the increases in water and nutrients due to backpumping, as shown in the analysis, indicate the general magnitude of changes that can be expected. These additional nutrient loads are not significantly above levels that might occur during natural cycles from year to year. Sustained increase of this nature may lead to an increase in system stress, especially in the immediate area of discharge.

Local Impacts

Impacts to the Water Conservation Areas in the immediate vicinity of the pump discharges depend upon the quality of the receiving water and pump effluent, and the physical conveyance system downstream of the discharge. For the C-51/L-8 pump site, impacts will probably be confined to the L-40 borrow canal and the fringe of marsh adjacent to this canal. In addition, the effects of the much greater volumes of water discharged from S-5A pump station will predominate over impacts from the water supply pumps.

Impacts from the proposed NNR pump station and the C-9 pump station will also be primarily confined to the canals. Discharge from the NNR/C-13 Basin will be pumped into the L-68 borrow canal and C-9 Basin discharge will flow into C-304. Some of this water will flow into the marshes adjacent to these canals. However, as in the case of the S-9 pumps, these discharges are not expected to adversely impact large areas of the marsh

The discharge from the pump station at the Tamiami Canal, however, will be dispersed directly into the WCA-3B marsh. The impact of these discharges is unknown and depends upon the existing water quality, area over which this water will spread, and the rate of seepage to groundwater.

Effects of discharges on marshes have been examined by the District in WCA 2A below the S10 structures. These studies indicate that the following types of impacts may occur to the receiving marshes:

1. Elevated nutrient concentrations
2. Depressed levels of dissolved oxygen
3. Accumulation of unconsolidated organic material
4. Shift in periphyton from filamentous green to filamentous blue-green algae
5. Reduction in species diversity and dominance of cattail
6. Buildup of heavy metals and other potentially toxic materials in the sediments

These changes have occurred in the area downstream of the S10 structures that has received large volumes of discharge (400,000 AF annually) for over 15 years. The area of greatest degradation is estimated to be some four to five square miles and is possibly increasing in size with continued discharges.

There are no methods to determine whether these conditions will develop in areas that receive backpumping discharges. However, if such impacts depend upon volume of discharge, then as much as one square mile of WCA 3B could be impacted by the 80,000 acre feet average annual discharge from the Tamiami Basin. On the other hand, if the area of impact depends upon phosphorus loading, for example, then less than 100 acres of WCA-3B would be affected since the estimated phosphorus loads from the Tamiami Canal are only 2.5% of the loads from S-10.

Impacts to Everglades National Park

Backpumping water into the Water Conservation Areas when water levels are below regulation stage increases the probability that the stage will subsequently exceed regulation stage and that regulatory releases will be required. The combined impacts of this effect from WCA-1 and WCA-2, as well as the direct pumping into WCA-3A, will result in increased regulatory discharges into Everglades National Park via the S-12 structures (see Table 3-15). Results from the routing model indicate that the effect will range from no net increase in S-12 discharge during relatively dry years to over 400,000 acre feet of additional discharge during some wet years. The average increase in S-12 discharges for the 16 year period of record was 166,500 acre feet. This is approximately a 38% increase over the average annual discharge of 441,500 acre feet as estimated by the model without water supply backpumping. At this time it is expected that the quality of these additional discharges will be similar to the current quality at the S-12C or S-12D structures which pass the majority of the water into the park. Thus, the nutrient loadings to the park would increase by approximately the same percentage (38%) as the discharge.

TABLE 3-15. S-12 DISCHARGES (acre feet)

Year	Historical	Model: No Backpumping	Model: Backpumping	Difference B.P. - No B.P.
1965	84,580	260,000	260,000	0
1966	1,098,620	573,503	997,361	423,858
1967	191,340	260,000	260,000	0
1968	1,012,780	799,995	1,140,116	340,121
1969	1,766,320	1,206,819	1,485,564	278,745
1970	1,323,320	860,655	1,037,028	176,373
1971	240,830	260,000	260,000	0
1972	309,170	260,000	444,603	184,603
1973	268,430	260,000	260,000	0
1974	475,800	383,903	646,147	262,244
1975	270,000	260,000	351,465	91,465
1976	352,000	346,689	434,576	87,887
1977	271,460	367,230	528,723	161,493
1978	554,440	394,850	544,699	149,849
1979	391,593	283,698	383,799	100,101
1980	554,159	286,268	693,822	407,554
Average	572,803	441,475	607,993	166,518

Environmental Impacts - Water Conservation Areas

Methods

Evaluations of the impacts of backpumping on vegetation communities of the Water Conservation Areas were based on data generated by the model. Stage Duration Curves (SDC) and stage hydrographs for various indicator locations within the Water Conservation Areas were calculated for conditions with water supply backpumping and without backpumping. Two five-year time periods were selected from the historical record to represent a recent "wet" period and a recent "dry" period. The 1965-1969 time period was considered as "wet" and averaged 67.7 inches of rainfall over the four basins. The 1970-1974 period was considered as "dry" and had an average rainfall of 52.0 inches. These dates were selected because much is known and was observed about the response of Everglades vegetation and wildlife during these wet and dry conditions that prevailed in real life. The stage duration curves and hydrographs for the non-backpumping conditions that prevailed historically were used, in conjunction with known ecological and vegetative changes that occurred in these periods, to predict changes that would occur when stages were increased by backpumping.

Effects of Too Much or Too Little Water

Addition of extra quantities of water to the Water Conservation Area system can cause ecological problems in various ways. Too much water, either by way of water depth or duration of flooding, can cause changes in marsh vegetation. This generally becomes manifest by large increases in truly aquatic plants such as water lily and bladderwort, and by decreases in vegetation species that require a drying period to perpetuate their life history. This has already occurred in Water Conservation Area 2A, and in the southern portion of WCA 1. The upper limits of water levels in the Water Conservation Areas is determined by regulation schedules that are based primarily on maintaining adequate levels of water to meet water supply and flood control requirements. These schedules can be modified to allow for periodic drying of marshes, if necessary.

Conversely, when the Water Conservation Areas receive insufficient water, either in depth or duration of flooding, adverse changes can also occur. The shortened hydroperiods can allow serious wildfires which may consume tree islands or the actual peat soils, both of which are irreplaceable natural resources. There are two ways to extend hydroperiods to prevent fires of this severity from occurring. One way is to increase water depth in the marsh to such an extent that all of the water cannot be used up by evapotranspiration and the various agricultural and urban consumers. The second way to extend the hydroperiod is to have a continuous input of water to the marsh so as to constantly replace water lost to the various human and natural demands.

Backpumping, at times, can satisfy either or both of these requirements for additional water. Regulation schedules can be used to reduce the effects of excessive water depth or constant inundation that change marsh ecology to pond ecology. Pumping water into the Water Conservation Areas as it becomes available during the normal dry months, as opposed to the rainy months, can aid in extension of marsh hydroperiods.

Great care must be taken that the drying process is not removed from the Everglades cycle. These cycles are programmed in by nature and, with proper management, can be simulated by man.

The Stage Duration Curve (SDC)

Effects of backpumping were analyzed based on stage duration curves (SDC). These curves include the probability that the water level, or stage, in the Water Conservation Areas will be less than a given value. For example, Figure 3-1 shows two stage duration curves for Water Conservation Area 1 during the wet period, 1965 through 1969. The top curve (*) represents stage duration with backpumping and the bottom curve (o) represents stage duration without backpumping. The vertical scale indicates stage in ft msl. The horizontal scale is a measure of the probability (from 0.0 to 1.0) that the stage in WCA-1 will be less than a given stage. During the five year period WCA-1, according to this graph, maintained a stage that was always less than 17.0 (probability = 1.0) and never less than 10.0 (probability = 0). Fifty percent of the time the stage was less than 15.5 ft msl. The rapid decline in stages that occurs at 15.2 ft msl indicates the stage at which water levels begin to retreat from the marsh into the canals. Below a stage of 14 ft msl, water in most of the pool is confined to the canals. Changes in stage below 14 ft msl can occur quite rapidly as water is added or withdrawn, but these changes have little influence on the marsh.

As water retreats from the marshes into the canals, large quantities of water are stranded or "ponded" in the marshlands, well above the stages in the canals. For this reason, stage records from gages at interior marsh sites can be dramatically different from record gages in or near the canals. This ponded water is gradually lost to seepage and evaporation over an extended period, but several weeks may be required for the interior marshes to dry out after the canal stages have dropped. For this reason, low stages must be maintained for some period of time to provide an appropriate dry season hydroperiod throughout the marshes.

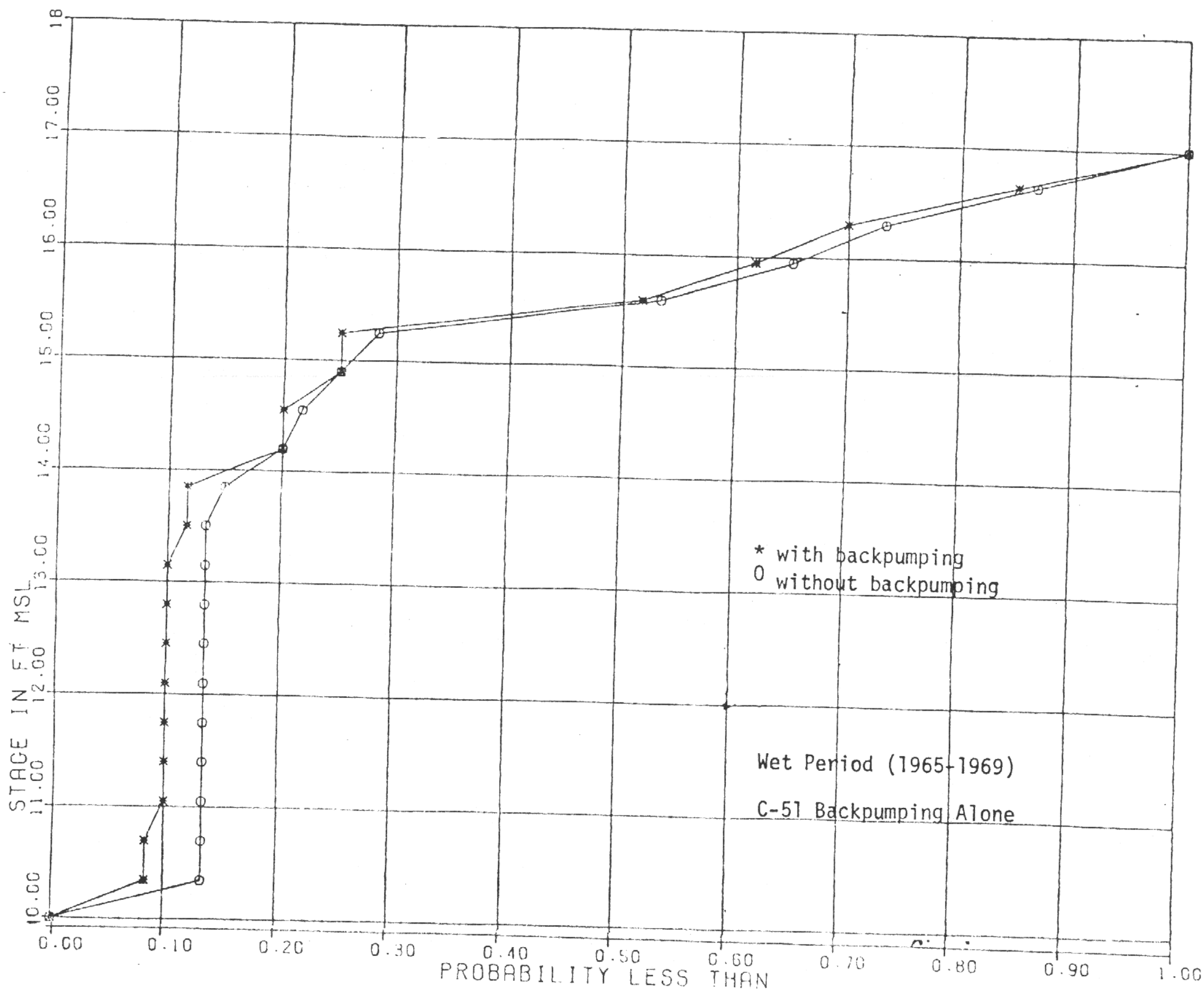


Figure 3-1 Stage Duration Curve for WCA-1

Effects of Backpumping C-51 Alone

Backpumping the C-51 area will place additional water into WCA-1 and lead to subsequent transfer of this water to WCA-2 and WCA-3 as regulation schedules are reached.

The SDC for the wet period in WCA-1 (Figure 3-1) indicates that only minor changes in hydroperiod occur as the result of backpumping. Stages below 14.0 ft msl tend to stay higher for significantly longer periods of time, but these fluctuations are primarily confined to the canals and should allow the same degree of marsh drying as previously occurred. During the dry period (Figure 3-2) backpumping would result in only minor changes in stage duration relative to the wet period. Drying events still occur, although the drying periods are of slightly shorter duration. Backpumping considerably shortens the time that low canal stages occur (from 15% to 8%) as opposed to not backpumping, but has relatively little impact on the marshes (above 14.5 ft msl). At 15.2 ft msl, for example, the probability has changed from 42% without backpumping to 35% with backpumping. The WCA-1 hydrograph (not shown) indicates that stages as low as 10.0 ft msl in the canals are still reached despite backpumping during dry time periods.

The stage duration curves for both the wet and dry periods for C-51 alone indicate that Water Conservation Area 2 would maintain higher stages for longer periods of time with backpumping than would be maintained without backpumping. Duration of a given stage is increased at all points along the curve. Drying of the marshes is all but eliminated during the series of wet years and effective marsh drying is eliminated in dry periods (Figures 3-3, 3-4).

Examination of the stage hydrograph for this analysis (not shown) indicates that stages in WCA 2 reach excessively high peaks at times and maintain

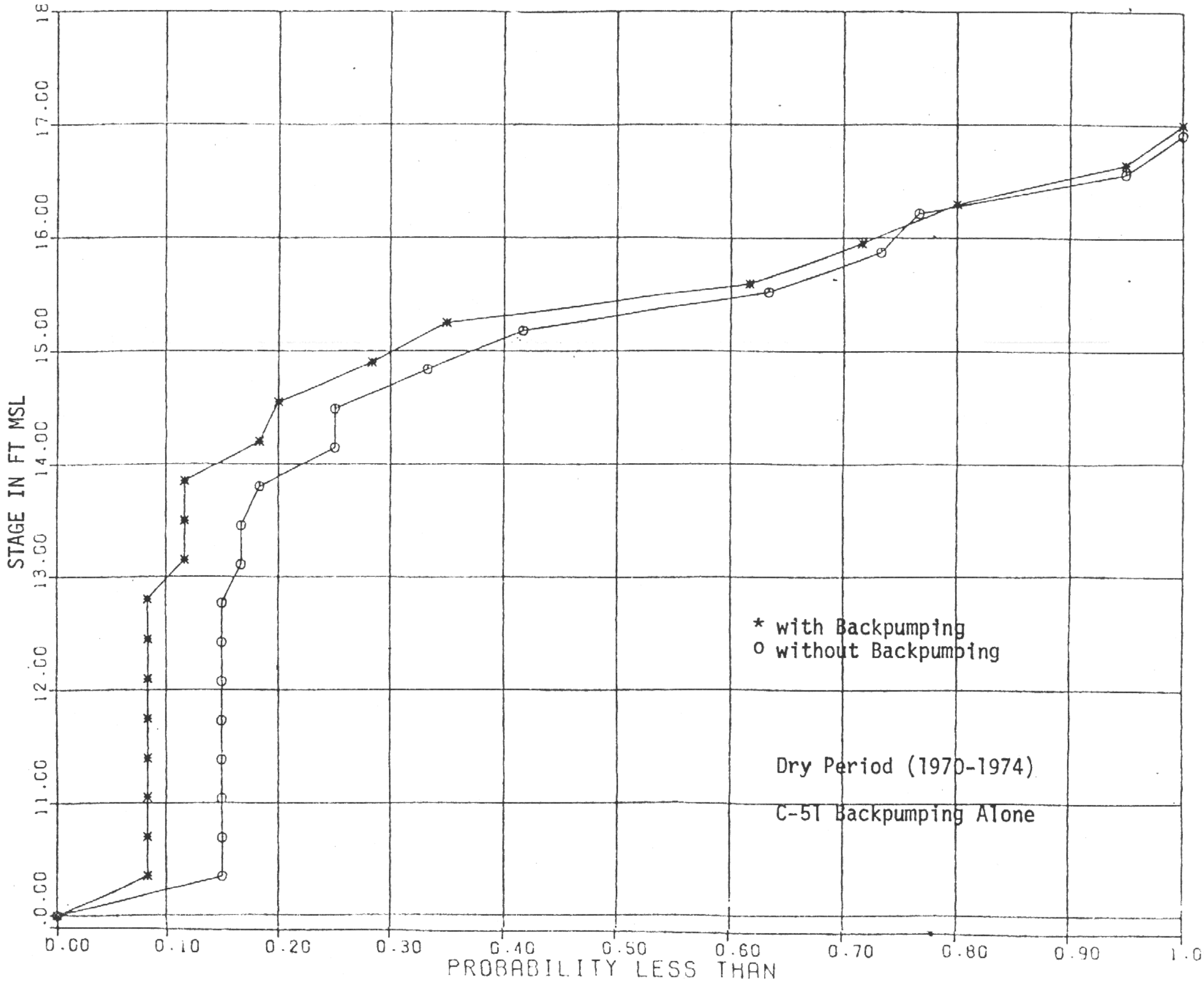


Figure 3-2 Stage Duration Curve for WCA- 1

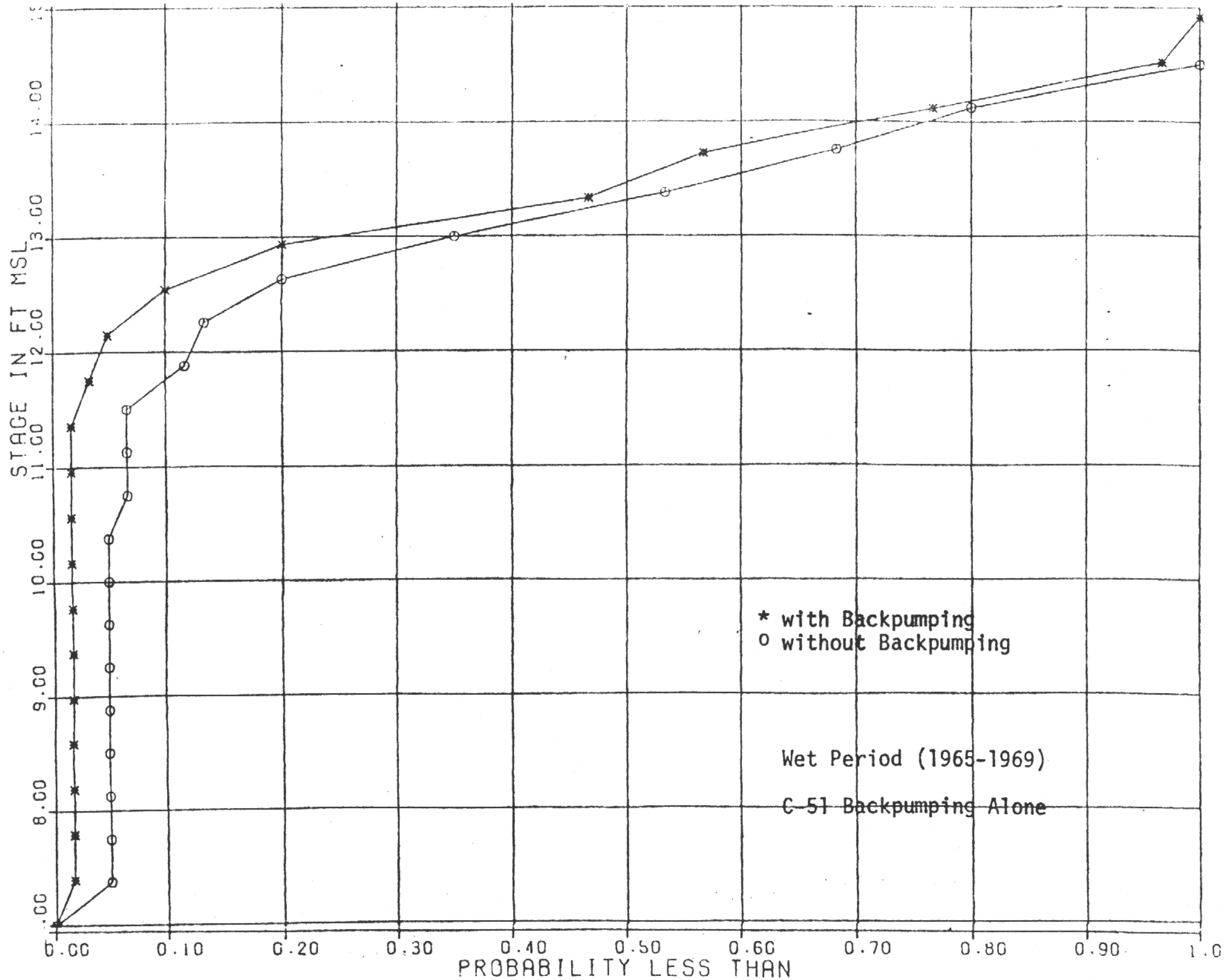


Figure 3-3 Stage Duration Curve for WCA-2A

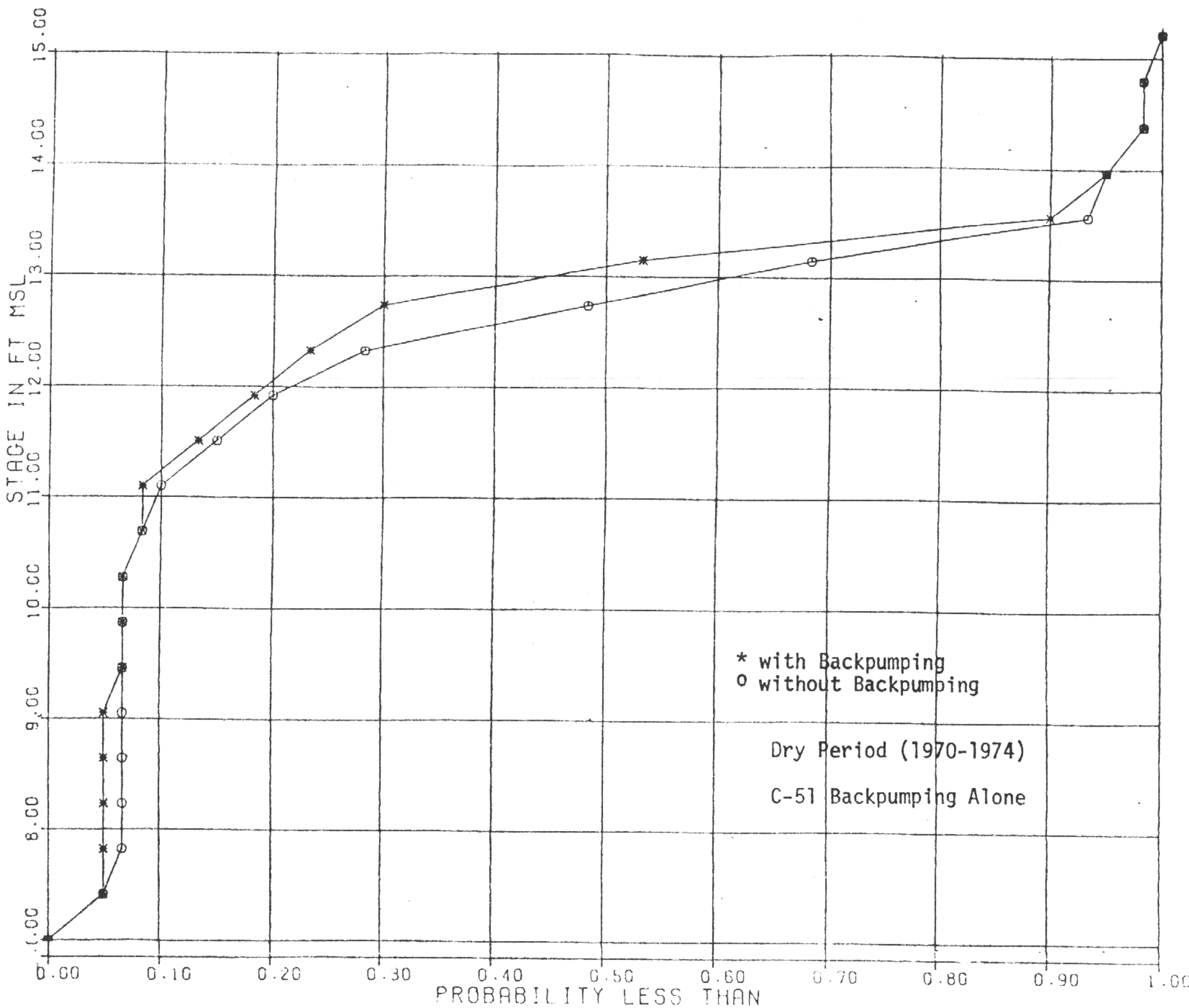


Figure 3-4 Stage Duration Curve for WCA-2A

consistently higher stages for extended periods of time. Since WCA-2 has suffered adverse impacts from higher water stages and extended hydroperiods in the past, increases in stage and increased duration of high water levels will further aggravate the already existing problems of the area.

The District is aware of the problems associated with excess water in WCA-2A, and has recently undertaken an area wide drawdown in an attempt to improve environmental conditions in WCA-2A. When results of this initial study are completed, recommendations for WCA-2 management will address the problems associated with excess water in the marsh.

Water Conservation Area 3 maintains higher water stages for longer periods of time during the wet period throughout the range of the stage duration curve (Figure 3-5). Stages above 10.0 ft msl will have adverse impacts on the deer herd in WCA-3, although Everglades ecology in general will not be adversely impacted. The curves indicate that the stage of 10.0 ft msl is exceeded 30% of the time with the backpumping and 22% of the time without backpumping during the wet period.

The stage duration curve for the dry period showed little change in stage or duration during the five year period that was analyzed (Figure 3-6). Much of the area would go dry with or without backpumping. Water will be held in the deeper portions of the marsh along L-67A and northward from the Tamiami Canal. The prolonged inundation from water available from C-51 backpumping will be beneficial to the southern reaches of WCA-3A.

Backpumping C-51, North New River, C-9, and Tamiami Canal Basins

The analyses for Water Conservation Areas 1 and 2 are identical to the analysis for C-51 alone. C-51 is the only backpumping plan proposed that will affect WCA-1 or WCA-2.

WCA 3: Examination of the impact of backpumping all four basins on WCA-3 indicates that considerable changes would occur in the stage duration curves.

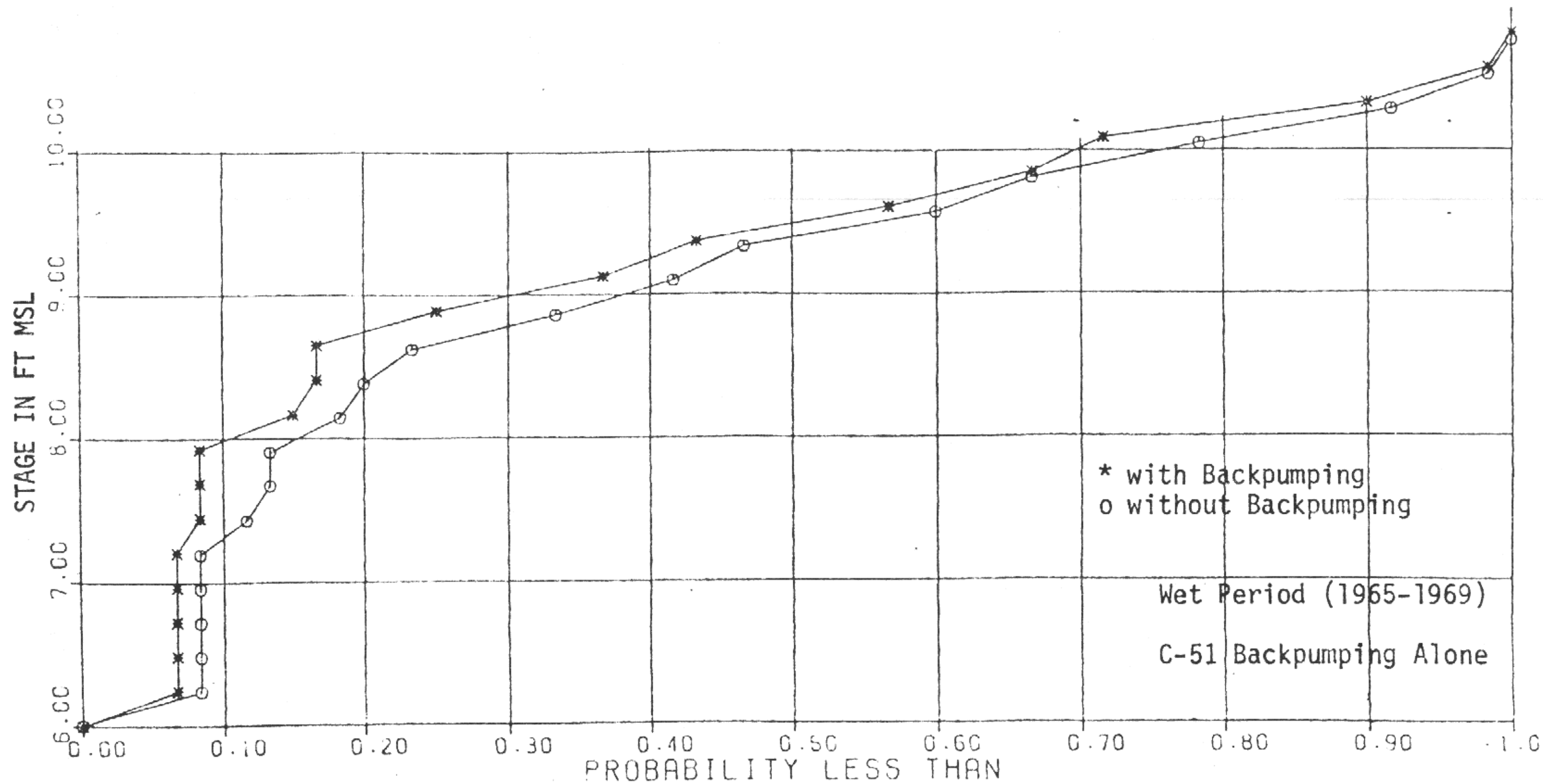


Figure 3-5 Stage Duration Curve for WCA-3A

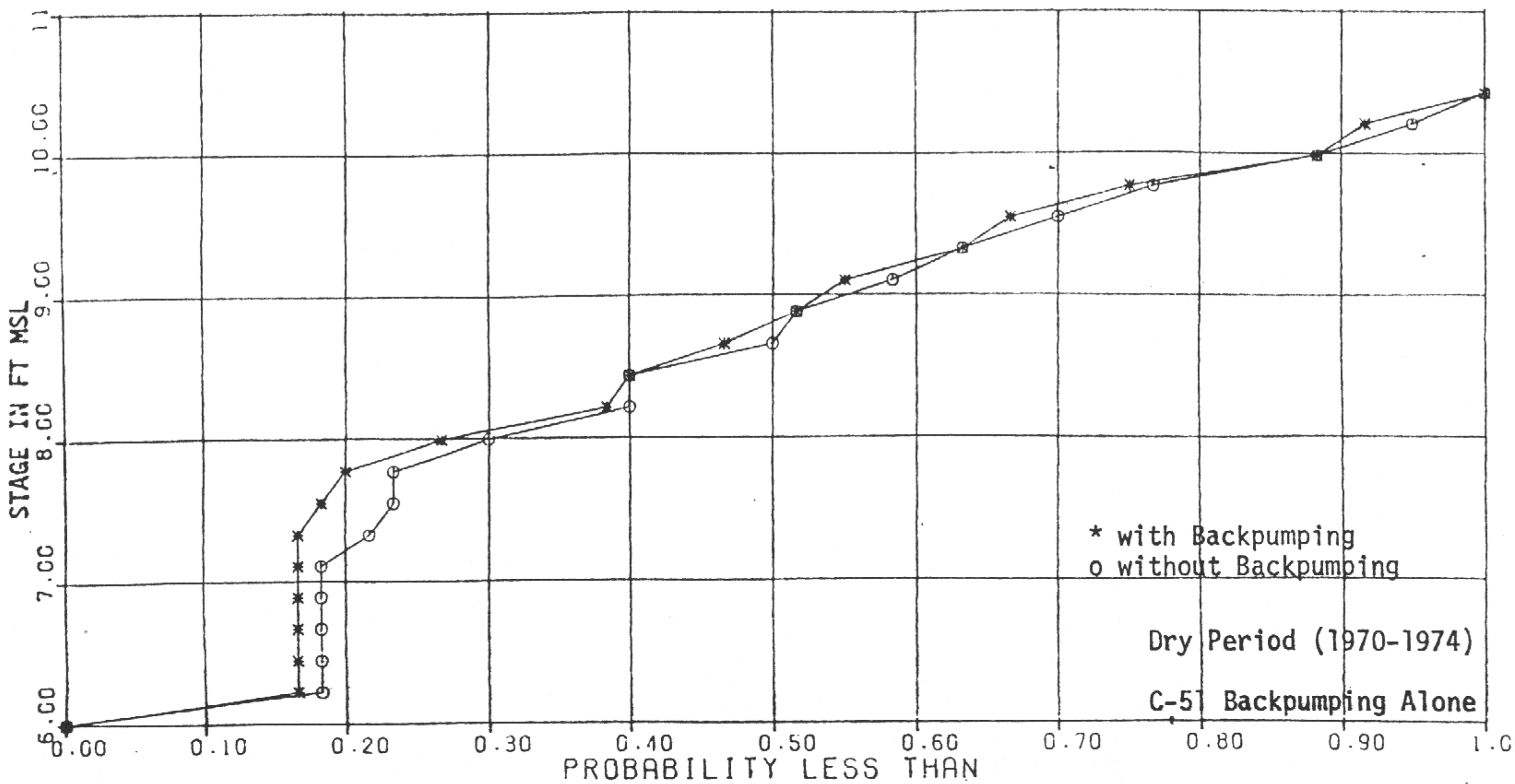


Figure 3-6 Stage Duration Curve for WCA-3A

Significantly higher stages are held for longer periods of time and occur more frequently when all four basins are backpumped than without backpumping, both during the wet and dry cycles. Adverse impacts are clearly indicated on the WCA 3 deer herd during the wetter periods (Figure 3-7). Increased and prolonged stages during the drier years (Figure 3-8) would, conversely, be enormously beneficial. The stage duration curve for backpumping of all four basins during the dry period closely resembles the stage duration curve without backpumping during the wetter period. The total marsh will still be allowed to dry out about 12% of the time during the drier time periods.

With backpumping, the entire pool would have experienced a period of drying during four years. Without backpumping, the pool would have experienced complete drying during eight years.

These results are presented in summary form in the table below.

Generalized Environmental Impact Matrix for Water Conservation Areas, Wet Period 1965-1969, Dry Period 1970-1974, for Various Backpumping Schemes.

	WCA 1 Impact[1]		WCA 2 Impact		WCA 3 Impact	
	Wet	Dry	Wet	Dry	Wet	Dry
C-51	0	+	-	-	+	+
North New River	0	0	0	0	+	+
Tamiami Canal	0	0	0	0	0	0
Snake Creek	0	0	0	0	+	+
All Basins	0	+	-	-	+	+

[1] Impacts were rated as Beneficial (+), Adverse (-), or None (0).

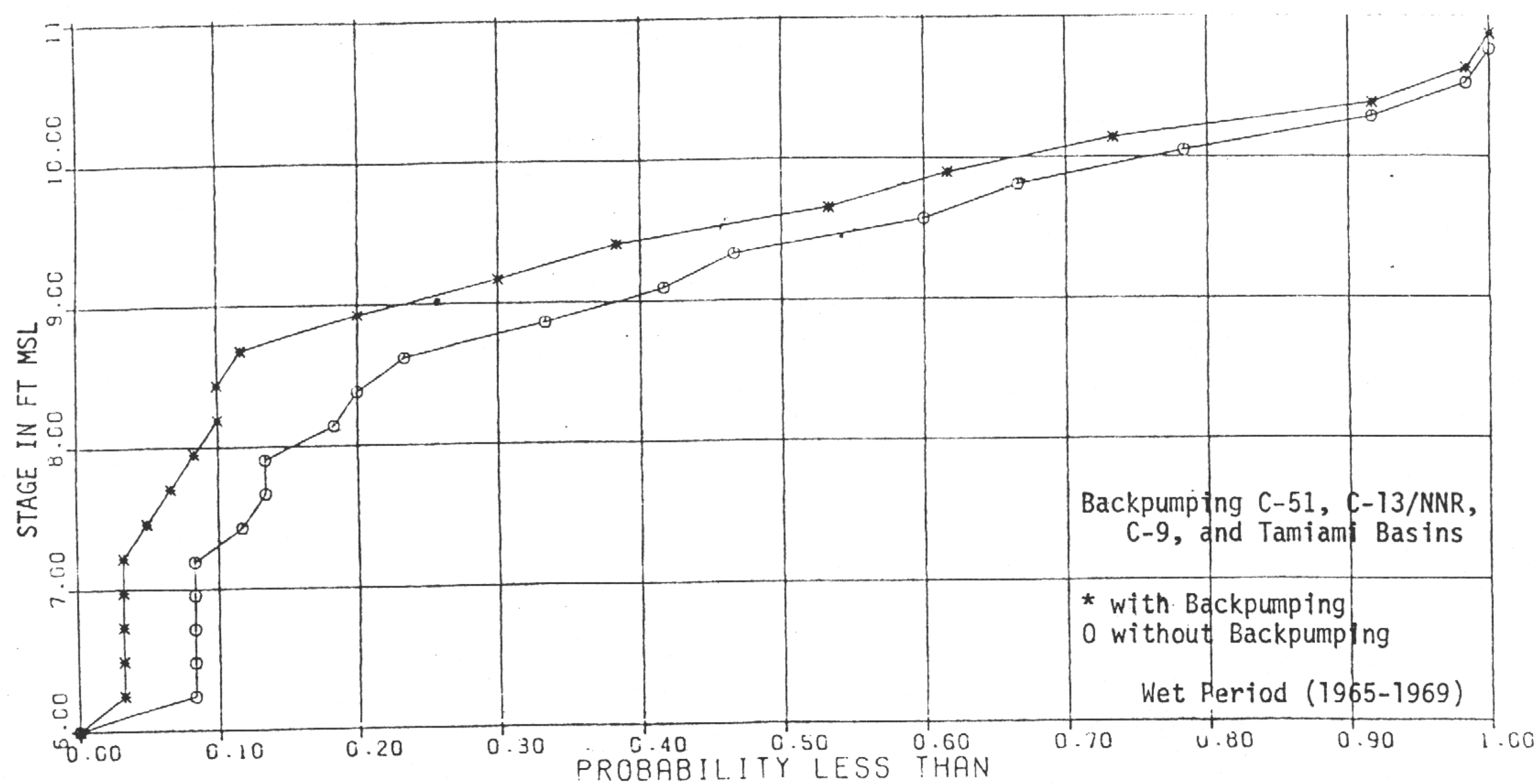


Figure 3-7 Stage Duration Curve for WCA-3A

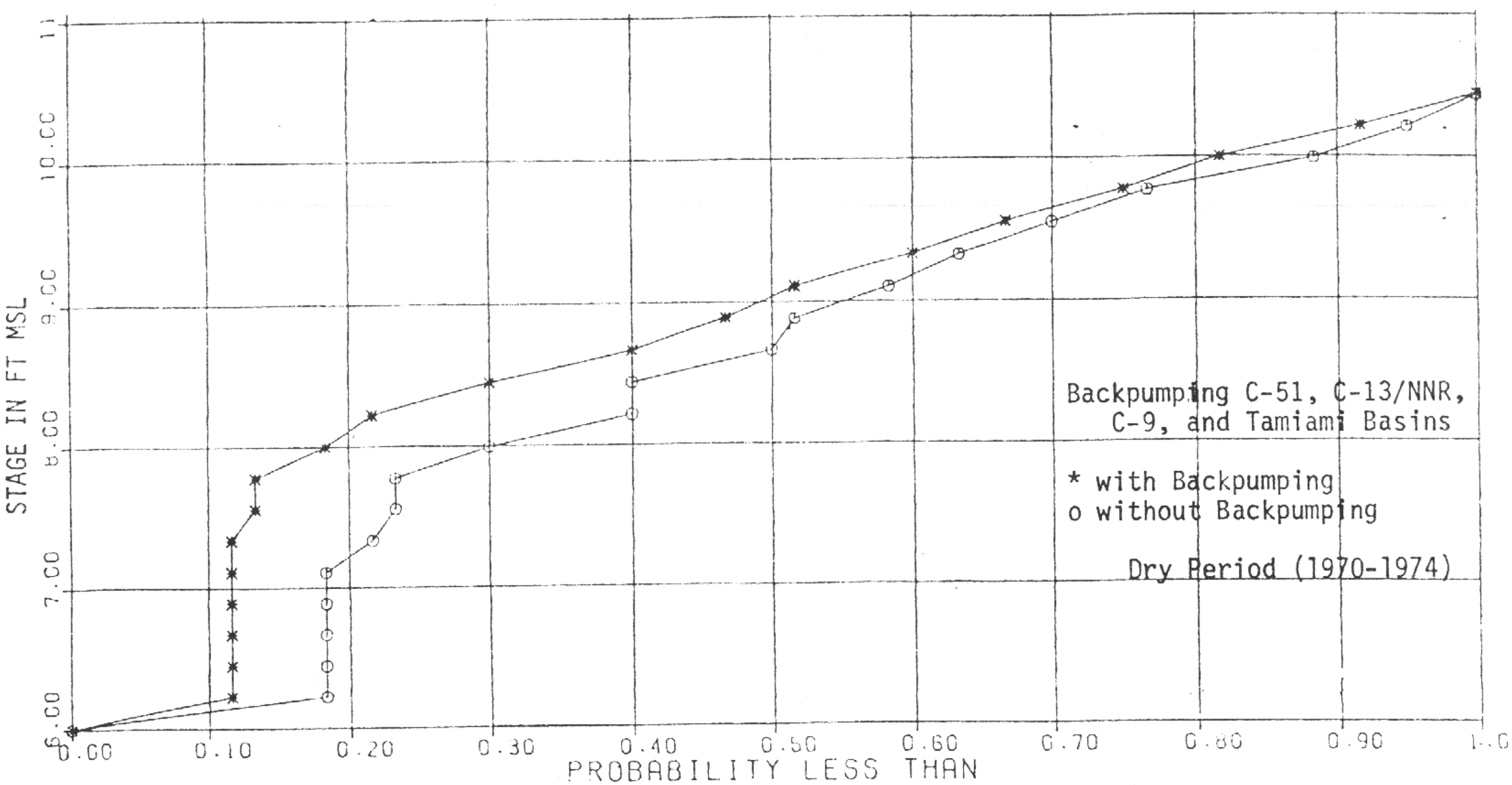


Figure 3-8 Stage Duration Curve for WCA-3A

On the southeast coast of Florida the District maintains and monitors many canals and structures that discharge fresh water to tidewater. These discharges from different drainage basins differ in quantity and quality of water and affect the receiving estuaries or coastal lagoons in varying ways. Man-induced freshwater inflow alterations usually simulate permanently the more adverse and severe natural excursions. The proposed backpumping operation will reduce the quantity of fresh water introduced to various environments and therefore, in most cases, will reduce the stresses that are usually associated with excessive freshwater discharges.

Four areas on the southeast coast would be affected by the reduced volume of water introduced to the systems: (1) the West Palm Beach Canal/L-8 discharges to Lake Worth at S-155, (2) North New River Canal/C-13 discharges at S-36 and Sewell Lock in Ft. Lauderdale, (3) Snake Creek Basin discharges at S-29, and (4) the Tamiami Basin discharges at S-25B and S-22 in Miami.

Lake Worth

Lake Worth evolved from a fresh water lake to a salt water lagoon. Man-made modifications have changed the lake to an estuarine lagoon that receives fresh water primarily as direct surface runoff from the land or as runoff and groundwater conveyed by C-51. Surface runoff may be of poor quality and may contain large amounts of nutrients, suspended solids, and biodegradable materials that lead to adverse water quality and increased sedimentation in the lake.

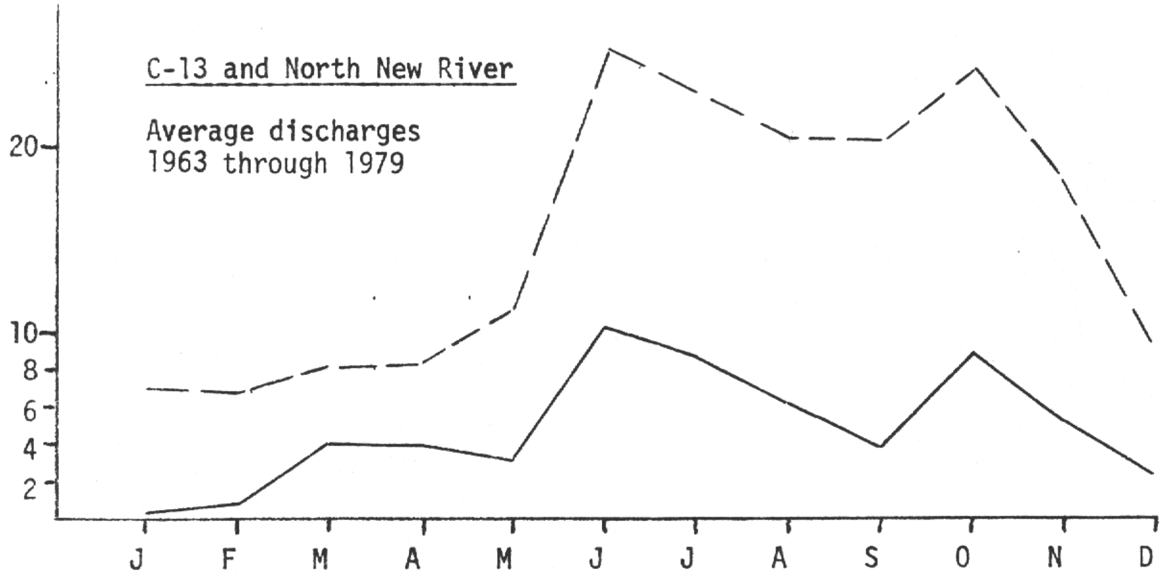
It is not feasible to return Lake Worth to a freshwater lake, but it is desirable to maintain the lake as a a productive lagoon or estuary. This may be accomplished to some degree by reducing freshwater discharges into the lake from C-51. Backpumping alternatives examined by the District in 1976 reduced the annual average discharge from C-51 by 75%. The present proposed backpumping plan reduces flow from C-51 by 41%. As before, a portion of the excess water from the western C-51 drainage basin would be pumped into the Water Conservation Areas.

The average water flow per year from C-51 without backpumping was about 360,911 acre feet. If backpumping had been used during this period, the yearly average flow from C-51 would have been 212,930 acre feet, or a 41% reduction in discharge to Lake Worth. Figure 3-9 shows the monthly average differences that would have occurred with backpumping. Note that the greatest average difference occurs during the wet season, while minimum discharges still occur during the dry season.

The former 1976 analysis of potential effects of backpumping on salinity, sediments, water quality, and biota of the lake provided the following conclusions which are still valid for the present proposed backpumping.

1. The primary effect of backpumping on Lake Worth will be an increase in the yearly average salinity and a decrease in the range of salinity fluctuations. During periods of no discharge, salinities in Lake Worth did not exceed about 37.0 ppt. During discharge from C-51, bottom salinities generally remain above 12 ppt.

2. Reduced discharge from C-51 will lead to significant reductions in nitrogen, turbidity, BOD, and carbon loadings to the lake and an increase in chloride and dissolved oxygen concentrations.



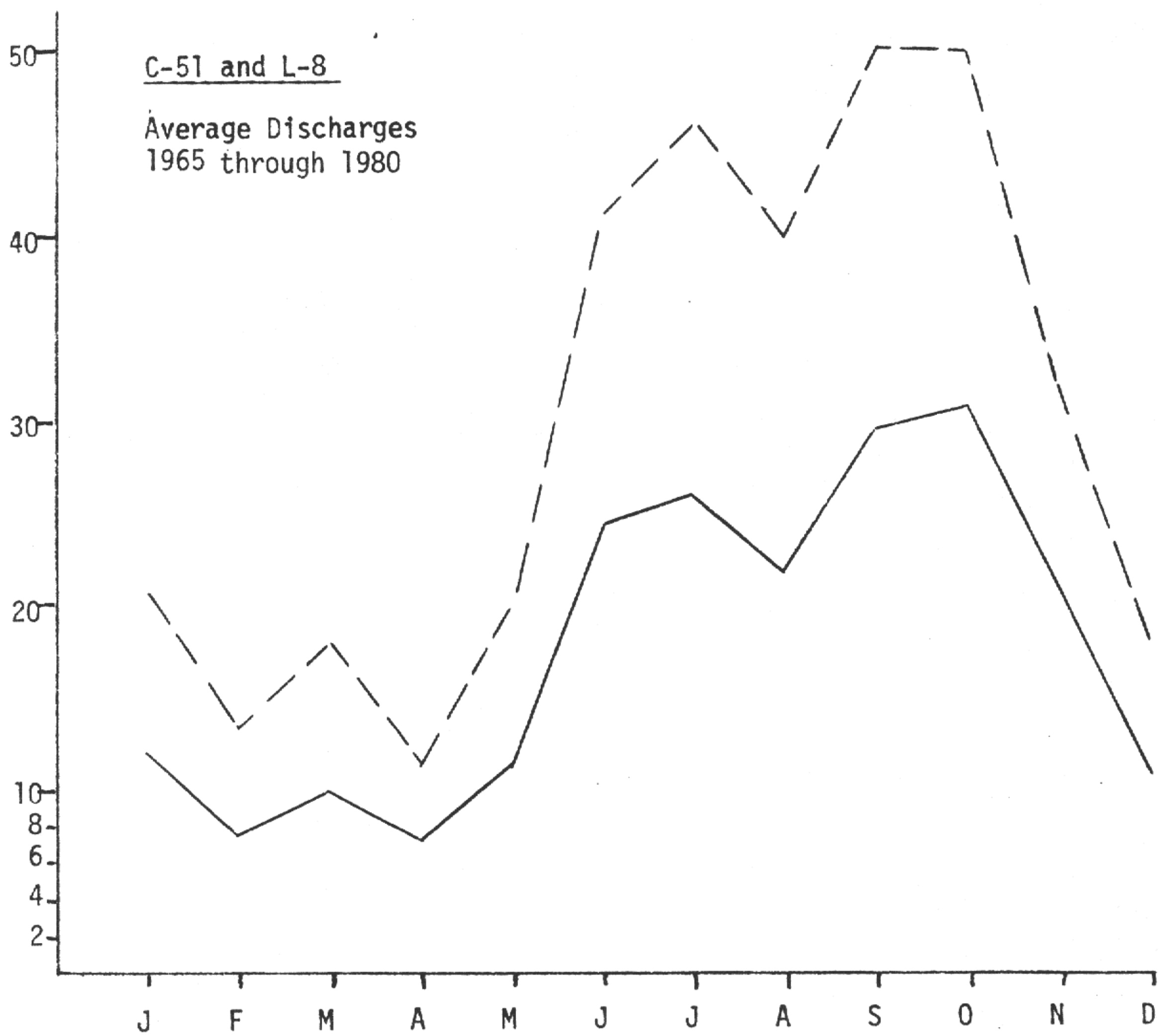


Figure 3-9. Monthly Average Discharge from the C-13 and North New River Canals and the C-51 and L-8 Canals without Backpumping (— —) and if Backpumping were in Use (———).

3. Polychaetes, crustaceans, and mollusks are the dominant benthic invertebrates in Lake Worth. Species diversity values for the benthic fauna are comparable to diversity values in other moderately-polluted estuaries. The benthic organisms in Lake Worth are mostly those that prefer higher salinities so that increased salinities due to reduced discharge from C-51 should have little impact on benthic communities.

4. At least 79 species of fish have been documented from Lake Worth. Most of these fish can live in full strength seawater but prefer conditions of reduced salinity that are found in estuaries. Reduced discharge from C-51 may result in seasonal changes in abundance of some species but should also result in a larger and more stable resident fish population.

5. Reduced discharge from C-51 should increase the macroalgae communities in Lake Worth due to reduced input of suspended solids, silt, and turbidity and overall increase in light penetration and salinity.

6. Decapod crustaceans can be expected to increase in abundance as the result of increased salinity and additional habitat provided by the macroalgae and seagrass communities.

Recommendation:

Since a possible negative effect of backpumping may be hypersaline conditions, it is recommended that the salinity be monitored near S-155 every week. If salinity exceeds 35.0 ppt the District should consider low volume, controlled discharges to keep salinity below 38.0 ppt.

North New River/C-13 Basin

Both of the discharge structures (S-36 and Sewell Lock) are located in Ft. Lauderdale. Downstream of these structures the shoreline is highly urbanized. The waters are of poor quality and low biological significance. An average of 184,200 acre feet per year were discharged from these two structures.

Historically, approximately 15% of the total volume released from both structures came from S-36. Backpumping would have caused a substantial reduction of about 68% of the annual historical flow. Figure 3-9 shows the average monthly decreases in flow. Past discharges have aided in flushing out the downstream waters which helped to maintain low salinity and a higher water quality than would have existed without this flow. Historical analyses show that very low or zero releases may occur under the backpumping plan which could cause stagnate water conditions and water quality problems.

Snake Creek Canal Basin (C-9)

The Snake Creek Canal Basin discharges at S-29 into tidewater at North Miami. North Biscayne Bay receives the majority of the runoff, where mixing with seawater at Bakers Haulover Cut takes place. The area is highly urbanized with many dead end finger canals. Biological and salinity information is very limited for this area.

Backpumping would reduce the amount of flow by approximately 63%. Figure 3-10 shows the average monthly difference in flow as a result of backpumping.

Recommendation:

Since salinity values are indicative of the amount of fresh water introduced to the system, salinity should be monitored at the structures every week throughout the year. These data could then be used to determine whether groundwater and rainfall are sufficient to flush out the system. If salinity becomes high and downstream water quality becomes a local problem, the District should consider low volume, controlled releases to help correct the situation.

Tamiami Canal Basin

The Tamiami Canal (C-4) drains the Tamiami Basin and discharges into the Miami River at S-25B, which leads to northern Biscayne Bay. Snapper Creek (C-2) discharges into the north-central part of the bay at S-22. In contrast to Lake Worth, Biscayne Bay has evolved as an estuarine lagoon. Man's activities during the last century have restricted and channelized freshwater flow into the lagoon. These activities have had a major influence on the seasonal salinity regime found in the bay. Hypersaline conditions presently exist during the dry season along the western shore of central Biscayne Bay. When canal discharges are reduced, these hypersaline conditions will persist for longer periods of time. However, it is not anticipated that hypersaline conditions will occur in the northern bay adjacent to the Miami River. Studies of water exchange indicate that the northern bay near the Miami River is rapidly exchanging with offshore waters via the inlets. In contrast, the residence time of water discharged from Snapper Creek is of the order of

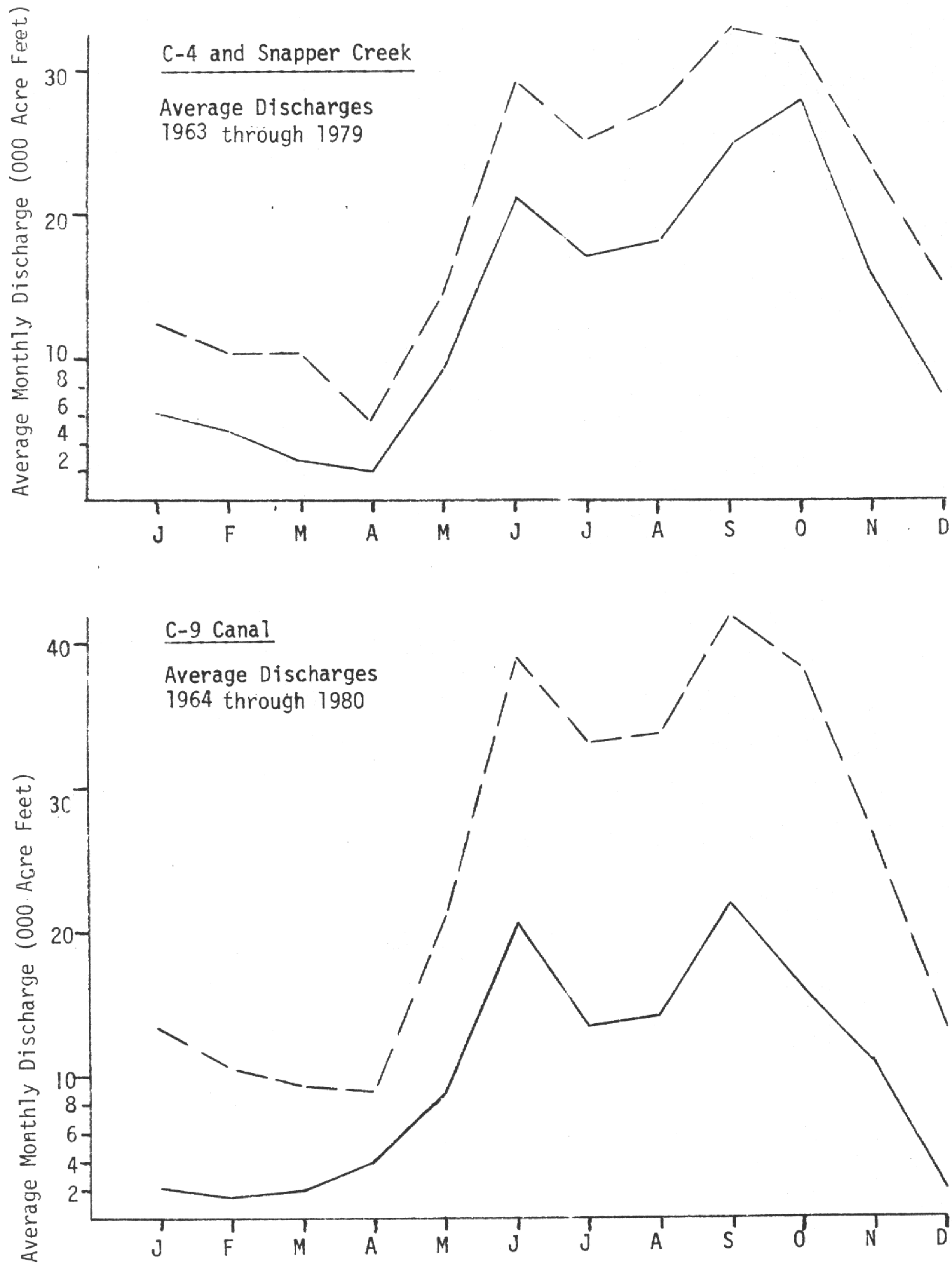


Figure 3-10. Monthly Average Discharges from the C-4 and Snapper Creek Canals and from the C-9 Canal without Backpumping (— —) and if Backpumping were in Use (———).

1 to 3 months. Therefore, the water from Snapper Creek has a much greater influence on helping to prevent hypersaline conditions in the bay.

On an average, backpumping would reduce freshwater flows by about 34% per year. Figure 3-10 shows the monthly average differences that are expected.

The 1976 analysis of backpumping made some biological conclusions which are still valid for the present proposed backpumping.

1. Benthic communities of northern Biscayne Bay have undergone extensive changes due to pollution and siltation. Reduced canal discharge may reduce loading of pollution and suspended materials and lead to a slight improvement in benthic communities in the northern bay.
2. Reduced freshwater discharges from the Miami River and the Snapper Creek Canal may cause a further decline in the number of species and number of individuals of estuarine fishes in the northern portion of Biscayne Bay and may lead to an increase in the number of species and number of individuals of marine and reef fishes. Reduction in turbidity and improved water quality and clarity may lead to a regrowth of benthic plant communities and an increase in the habitat available for larval and juvenile fish.

Recommendation:

If possible, the remaining freshwater runoff from the Tamiami Canal Basin should be discharged through S-22 rather than through S-25B to help mitigate hypersaline conditions in central Biscayne Bay. Weekly salinity measurements should be taken at both structures. If salinity becomes too high the District should consider low volume, controlled discharges to bring salinities down.

CHAPTER 4
LAND USE AND WATER QUALITY PROGRAM

Degradation of water quality in basins which may be backpumped for water supply purposes must be minimized. All of the basins considered in this investigation have lands which can and will undoubtedly be used more intensively in the future. A primary concern is that water quality within the backpumped canals will decline as a result of either stormwater runoff or wastewater.

Any effective strategy for water quality management must address the following principle elements:

a) Land Use

b) Water Quality Control Measures

c) Water Quality Monitoring

Intergovernmental Coordination of Land Use

Future land uses in backpumping basins will affect the quality of shallow groundwater and runoff which is pumped into the Water Conservation Areas. There are limits on improving the quality of runoff from existing developed areas, but additional agency review and evaluation for new developments is necessary to insure consideration of water quality and quantity impacts prior to, or as part of, local land use decisions. The District has three primary objectives with regard to land use in backpumping basins.

1. To insure that development within the basins incorporates water quantity and water quality control measures to protect the public investment and minimize harm to the water resources.
2. To insure that land uses with a high potential for generating water quality problems are strictly controlled and restricted.
3. To insure that the land use decisions of local governments are consistent with the above objectives.

The District has primary regulatory responsibilities for issuance of water use and surface water management permits. In addition, the District has implemented several programs to work with other governmental agencies regarding all phases of water management.

Cooperative arrangements with local and county agencies concerning land and water use practices in the backpumping basins have evolved based on the District's regulatory authority under Chapter 373 F.S. and the Local Government Comprehensive Planning Act (Chapter 163), advisory inputs into local land use planning and decision-making procedures, and providing staff advice and assistance to other agencies.

1. Agreement for District Input into Land Use Decisions.

   The WMD and key local governments enter into agreements that provide for advisory recommendations and review by the District regarding land development processes and decisions to insure that plans of local governments do not conflict with District goals. If and when it is determined that there is a conflict between water management goals of the District and current and/or future land management plans of a local government, efforts will be undertaken by our staff in cooperation with the appropriate local entity, towards resolution of same.

2. Project Review and Coordination.

   In addition to review of land use and comprehensive plans, reviews of water resource problems of various projects are evaluated by the District. As the regional Water Management District, by contract with the Regional Planning Councils, the District participates in formal reviews of Developments of Regional Impact, Environmental Impact Statements, and Federally funded A-95 projects.

3. Advisory, Task Force, and Development Review Committees.

   District representatives frequently serve on a variety of Technical

Advisory, Development Review, Task Force, and Supervisory Committees at the state, regional, county, and local levels. Presence on these committees is at the request of the Governor, the Regional Planning Council, or local government. These committees have either been formed by representatives of various agencies to address special problems or highly sensitive areas of the District, or are continuing and on-going land development review committees.

4. Planning Assistance to Local Governments.

   District staff often work with local government agencies to resolve special problems on a site-specific basis. Evaluations are performed on projects that have significant water related impacts. Mitigating measures are analyzed and recommendations made to the agency that has land use decision-making authority. Analysis and review of local government zoning, site planning, and subdivision codes are also part of this program. The District reviews these growth management tools to determine whether problems or areas of conflict exist that need to be resolved. The goal of this program is to assure that District criteria and policies are incorporated into the land development review procedure. In addition, District staff services are available to local governments on an "as needed" basis to help in the review, evaluation, or implementation of water resource related activities.

Water Quality Control Measures

Regulatory Provision

The District currently requires the incorporation of "Best Management Practices" into the design and operation of water management systems.

Best Management Practices for design and operation of surface water management systems provide for preventing significant lowering of groundwater levels below normal seasonal levels, provide for approximate equal pre- and post-development discharges, and maximum on-site detention consistent with maintenance of minimum flows.

To provide maximum assurance of water quality protection in water supply backpumping watersheds, District rules have been modified to provide that in these areas any project proposed to be constructed which is considering more than 40% impervious coverage must utilize a retention system for water quality enhancement.

Further, priority surveillance and review of operations reports for secondary systems within the backpumping watersheds have been undertaken.

Operations Provision

Aquatic weed control is a necessity in many canals to maintain the ability of the canals to transport water.

Water supply backpumping will be suspended during any periods of aquatic weed control activity in the backpumped canals. Pumping activities will not resume for five days following the end of chemical weed control treatments unless specific water chemistry analyses demonstrate that the levels of herbicides in the canals have reached safe limits in less than five days.

Water Quality Monitoring

Pump Stations

Water samples will be collected at all four proposed pumping stations as part of the Water Chemistry Division Water Quality Monitoring Program. Frequency of collection will be based on amount of pumping activity. Samples will be analyzed for routine water chemistries (nutrients and major ions) and other pertinent water quality parameters (turbidity, alkalinity, BOD, and color). Water temperatures, pH, dissolved oxygen, and specific conductance will be measured in situ at the time of sample collection. Twice annually during prolonged pumping events, composite samples should be collected and analyzed for trace metal concentrations. One of these two samples should also be analyzed for pesticides and herbicides that are commonly used in the backpumped drainage basins. Canal sediment samples should be collected annually near the proposed pump stations and analyzed for trace metal, pesticide, and herbicide content.

Receiving Waters

No additional water quality monitoring program is recommended for the receiving waters for the C-51/L-8 backpumping, since any impacts in the north end of WCA 1 will be greatly overshadowed by impacts from the existing S-5A pump station which is currently monitored. At the other three locations, the following research program is recommended.

Water samples for general chemistry analysis (nutrients, major ions, BOD, color, turbidity, alkalinity, pH, dissolved oxygen, and specific conductance) should be collected at the same frequency as the routine pump station samples. One sample should be collected within the discharge plume of each pump and a second sample at a close-by location not physically influenced by the pump discharge. Water and sediment samples for trace metal and pesticide analyses should be collected at these stations annually during or following prolonged pumping events. Diel dissolved oxygen measurements should be made quarterly at these same sample locations. Dye or other tracing technique studies should be made under varying hydrologic conditions to determine the area directly influenced by each pump. Once these areas are established, periodic sampling along transects running from the pump station out through the area of influence should be conducted to determine the nature of water chemistry gradients within these areas of influence.

The following ancillary data and/or monitoring programs will be required to support the above water chemistry program.

1. Daily volume of discharge for each pump.
2. Detailed land use and drainage system maps for each drainage basin. These maps should be as current as possible and periodically updated to reflect new development within each basin.

3. Any water quality monitoring in a backpumped canal, especially bacteriological sampling, should be continued and the resulting data forwarded to the District on an annual basis.

Evaluation of Monitoring Data

The results of all monitoring data will be evaluated relative to the Class III Water Quality Standard as contained in Chapter 17-3, FAC. Any substantial increases in the concentration of trace metals or pesticides in either the backpumped water, receiving water, or sediments in the discharge plume should be thoroughly investigated as to its source and potential impacts.

Water supply backpumping should be terminated during these investigations if the pollutants of concern are toxic in nature. Other criteria to interpret the significance of these data may be developed as the results of this program, other District research in the WCA, or research by others in similar wetland systems.

Estimated Costs of Water Monitoring Program

A basic water quality monitoring program would include annual operating costs for manpower, data analysis, travel from District headquarters, and appropriate capital outlay costs for automatic sampling equipment.

	North New River only	NNRC, C-9, and Tamiami
Manpower	$ 7,748	$ 15,496
Analysis	6,400	19,200
Travel	700	2,000
Equipment (Automatic Samplers)	2,000	6,000
Total	$ 16,848	$ 42,696

First Flush

Water supply backpumping should be suspended during the early portion of high volume storm water runoff periods in oder to minimize any potential adverse impacts due to the first flush of pollutants out of the primary and secondary canal systems. Specific first flush criteria will be developed for each basin based upon the local meteorological, geographic, and hydrological parameters for each canal.

Toxic Chemical Spills

Water supply backpumping will be suspended in the event any accidental spillage or clandestine dumping of hazardous and toxic materials into the backpumped canals or into the major secondary drainage systems tributary to any backpumped canal is detected. Pumping should remain suspended until specific chemical tests have positively demonstrated that the levels of the chemical introduced into the water have returned to what are generally considered safe levels.

Arrangements should be made with local environmental or water quality monitoring agencies to perform a once-weekly salinity check at high tide, immediately downstream from water control structures at S-22 and S-25B in Dad County, Sewell Lock and S-29 in Broward County, and the Palm Beach Locks in Palm Beach County. When conditions in these estuaries become hypersaline beyond historically demonstrated levels (38 ppt in Palm Beach and Broward Counties and the Miami River and 45 ppt in Biscayne Bay), intensity of monitoring should be increased to once daily. The possibilities for release of fresh water to the estuaries for flushing or for salinity control should be considered at these times.

SUPPLEMENT

Recent completion of the temporary divide structure on the L-8 borrow canal has the result of enlarging the portion of the L-8 Basin that is tributary to Lake Okeechobee to about 107 square miles. With the divide structure in place, the C-51/L-8 backpumping basin is reduced to an area of about 82.4 square miles.

The next hydrologic effect of the L-8 divide structure on Lake Okeechobee will be to increase the average annual flow to Lake Okeechobee by 71,000 acre feet. Concommitantly, the average annual water available for backpumping from the reduced C-51/L-8 Basin will be about 115,000 acre feet, compared to 154,000 acre feet under the original plan previously evaluated. The hydrologic data are presented in Tables 1 and 2.

From an operational viewpoint, the reduced L-8 Basin flow to the south has the significant additional result of permitting the use of pump station S-5A to backpump the western C-51 Basin under moderate L-8 inflow conditions. This would be done by operating S-5A(W) and S-5A(E) in the proper sequence and timing to maintain acceptable stage conditions at the various structures.

Operational experience is required to determine the actual performance of this system. Additional information on the amount and frequency of inflows and on actual stage conditions will allow a better estimate of the quantity of water that could actually be backpumped. Current estimates of the amount which could be backpumped from C-51/L-8 are about 70,000 acre feet, or about 61% of the available quantity and about 50% of the quantity which could be handled by the 550 cfs installation.

TABLE 1. WATER AVAILABLE FOR BACKPUMPING FROM C-51 AND REDUCED L-8 BASIN (100%) Pumped by S-5A

unit - cfs

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sum
1964	6275	4840	2285	2013	3239	6141	4210	6051	8910	9452	8347	6303	68066
1965	3926	3145	2249	895	548	3982	9317	6648	4420	12298	11112	4019	70806
1966	7640	8523	6319	2386	4115	13759	14352	14453	11425	10230	2379	2119	97700
1967	2417	2075	1443	151	155	4388	7098	4583	4631	11737	3102	1405	43185
1968	401	1121	1309	17	5467	17531	14145	7829	7443	12519	5201	1243	74266
1969	1899	938	6459	1886	4547	10192	5080	7074	7625	17069	12497	6968	82234
1970	5147	6420	12054	8726	4593	11811	8461	8523	8714	6893	618	321	82281
1971	325	65	978	549	795	2727	3807	2856	6734	2401	8630	2566	32433
1972	2182	1619	691	3046	11278	15355	6398	4614	3087	1628	2501	1411	53810
1973	992	686	572	310	957	4047	11420	8283	11159	8057	2238	2222	50943
1974	6981	1334	480	12	6	2991	7405	8462	5552	6852	3010	3143	46228
1975	1036	1524	1929	727	2726	7371	9075	2866	6692	8611	4329	545	47431
1976	36	52	2736	59	3679	2840	6721	9613	10171	3984	636	356	40883
1977	1772	756	224	45	4360	2957	1903	1043	13066	2061	875	5112	34124
1978	5830	1308	1845	149	1811	6329	9140	8067	5827	8709	7893	3865	60773
1979	6734	944	1415	3675	5767	2251	2471	3213	14886	9454	4607	2563	57980
1980	2304	2518	1694	1742	3081	3251	5725	4112	10058				34685
Sum	55847	37868	44682	26388	57124	117923	126928	108290	140400	131955	77975	44161	
Avg.	3285	2228	2628	1552	3360	6937	7466	6370	8259	8247	4873	2760	57965
Acre Feet	6517	4420	5214	3079	6666	13763	14813	12638	16386	16362	9668	5476	115003