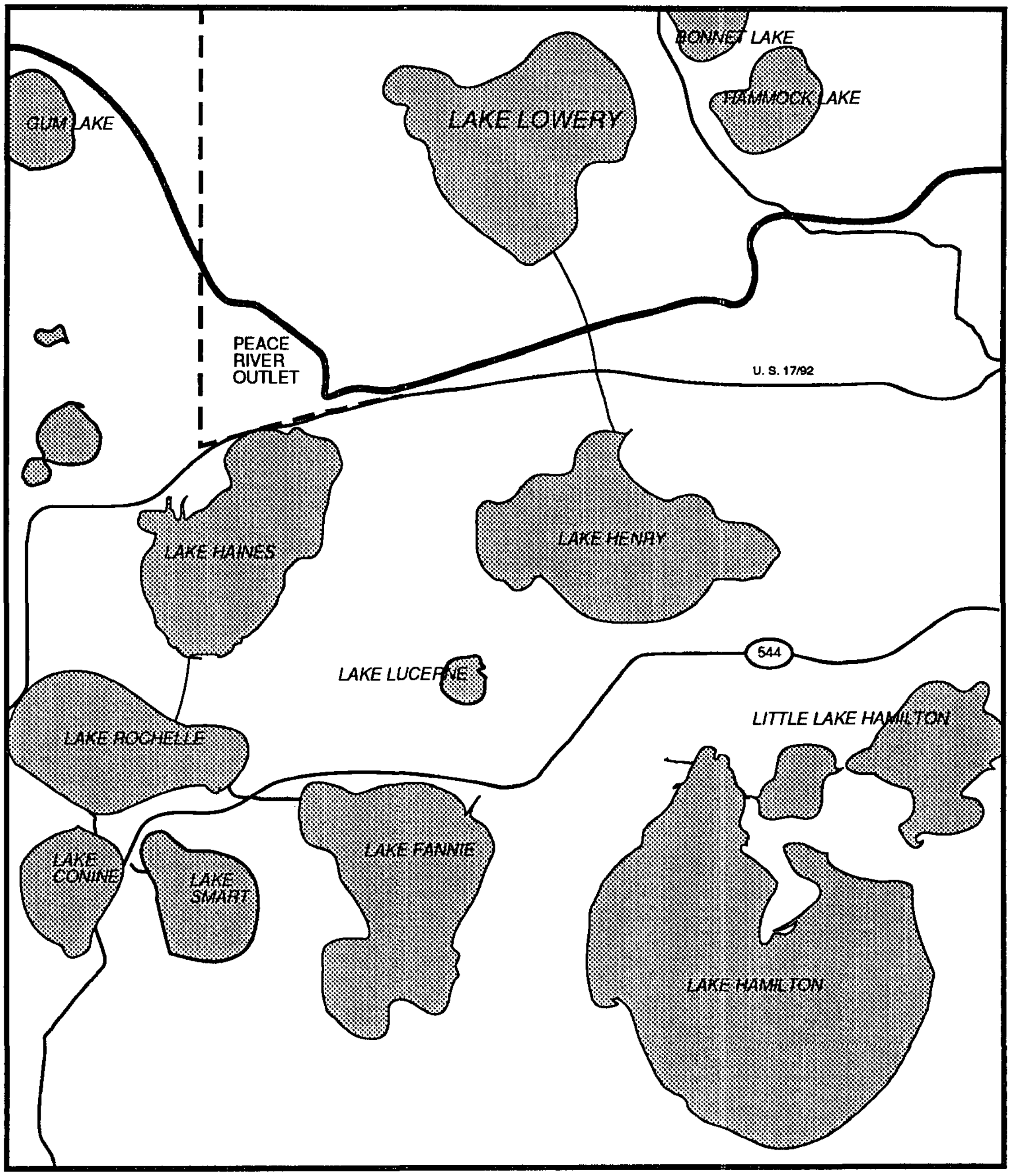
Technical Publication SJ 90-6

Lake Lowery Basin Surface Water Management Study: Additional Evaluation of South Diversion of Lake Lowery Floodwaters



St. Johns River Water Management District

Technical Publication SJ 90-6

LAKE LOWERY BASIN SURFACE WATER MANAGEMENT STUDY

ADDITIONAL EVALUATION OF SOUTHWARD DIVERSION OF LAKE LOWERY FLOODWATERS

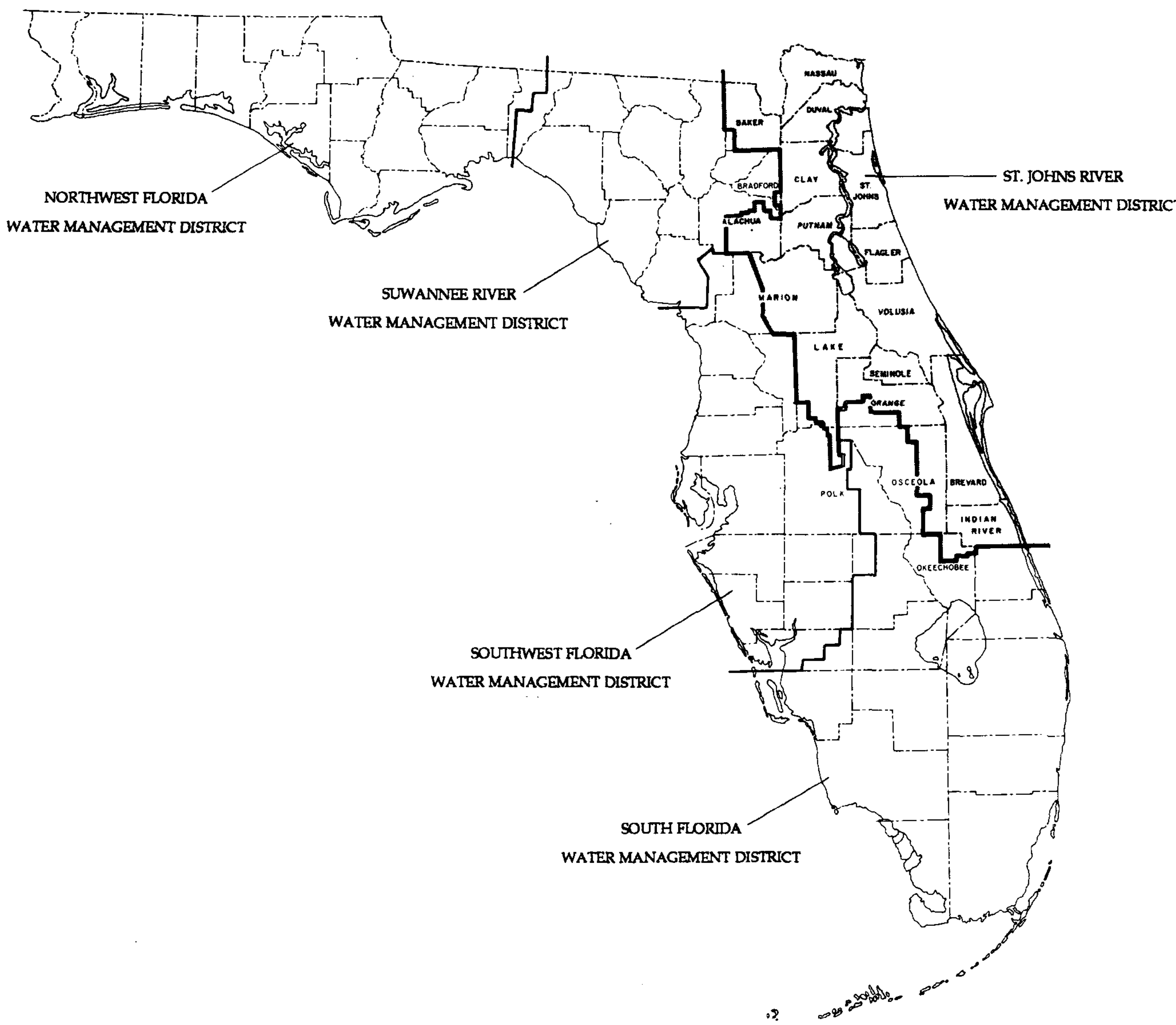
by

Gary Bethune

Donthamsetti V. Rao

St. Johns River Water Management District
Palatka, Florida

1990



THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

The St. Johns River Water Management District (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or parts of nineteen counties in northeast Florida. The mission of SJRWMD is to manage water resources to insure their continued availability while maximizing environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management. Technical reports are published to disseminate information collected by SJRWMD in pursuit of its mission.

EXECUTIVE SUMMARY

A residential area located on the north shore of Lake Lowery, in north-central Polk County, experienced localized flooding (primarily septic system failures) during high stages in the lake. A water management study completed by the SJRWMD in 1987 identified diversion of floodwaters from the lake into the Upper Peace River Basin, located in the Southwest Florida Water Management District (SWFWMD), as the most cost effective of several flood control alternatives. This alternative assumes diversion of floodwaters up to a maximum rate of 125 cubic feet per second (cfs) whenever the elevation of Lake Lowery exceeds 130.00 ft NGVD. The downstream impacts of such diversion were not evaluated by the 1987 study.

To limit the downstream impacts of the proposed diversion, SWFWMD provided allowable discharge criteria. According to these criteria, a maximum diversion of 30 cfs is allowed whenever Lake Lowery exceeds 130.00 ft NGVD and at least one of the two receiving water bodies (i.e., Lake Henry or Lake Hamilton) is below its regulation schedule elevation. This report presents the results of a re-evaluation of the diversion alternative under these discharge criteria.

Peak stages for Lake Lowery with diversion governed by the allowable discharge criteria were evaluated using two methods. The first method (Method A) modifies the previously generated long-term (56 years) simulated peak stage data to reflect diversion under the allowable discharge criteria. Correction factors for modifying the simulated stages were established based on observed data for 1965-1984. The second method (Method B) applies a 'worst case' approximation to estimate maximum elevations for different return periods. The two methods give the average annual damages as $13,640 and $47,200, respectively. The annual damages for the existing conditions were calculated as $64,700 and for the diversion alternative of the previous (1987) study as $8,510.

The annual cost of the diversion project using an existing culvert under U.S. Highway 17/92 was calculated as $12,300. This leads to a project benefit/cost ratio of 4.2 for the results

obtained with Method A and 1.4 for Method B. The actual ratio may fall between these extremes.

The existing culvert under U.S. Highway 17/92, however, has a discharge capacity of about 20 cfs. To achieve the design discharge capacity of 30 cfs, it would be necessary to expand this culvert, which would increase the project's annual cost by approximately $3,400. This would reduce the benefit/cost ratio from 1.4 to 1.1 for the results under Method B. The need for expanding the existing culvert, however, would be determined at a later date based on flooding experience.

CONTENTS

FIGURES

TABLES

INTRODUCTION

BACKGROUND

Located near Haines City in north-central Polk County, Lake Lowery is situated within the Palatlakaha River basin (Subbasin 1, Fig. 1), one of the two watersheds forming the headwaters of the Oklawaha River basin. During the latter half of 1982, elevations in Lake Lowery rose to relatively high levels and remained high until 1984. A residential area located on the north shore experienced localized flooding, primarily septic system failures.

In response to concerns expressed by residents of the flooded area and a request made by the Polk County Board of County Commissioners, a water management study was conducted by the St. Johns River Water Management District (SJRWMD). Technical Publication SJ 87-5, Lake Lowery Basin Surface Water Management Study (Bethune and Tai 1987), was the result of that study. The study concluded that a diversion of floodwaters from Lake Lowery into the upper Peace River basin (UPRB), up to a maximum rate of 125 cubic feet per second (cfs) whenever elevation of Lake Lowery exceeded 130.00 ft NGVD, was the most cost effective of eleven flood control alternatives evaluated. The diversion would be accomplished through a drop-inlet spillway at Lake Lowery, connected to a closed conduit discharging into Lake Henry. This alternative is described by Bethune and Tai (1987) as "Southward Diversion Alternative No. 3."

Impacts of the diversion on UPRB were not quantified in the original SJRWMD report. In order to limit downstream impacts of the proposed diversion, the Southwest Florida Water Management District (SWFWMD) staff provided allowable discharge criteria. According to these criteria, a maximum diversion of 30 cfs from Lake Lowery to UPRB will be allowed whenever Lake Lowery exceeds 130.00 ft NGVD and at least one of the two receiving lakes (Lake Henry or Lake Hamilton) is below its regulation schedule elevation.

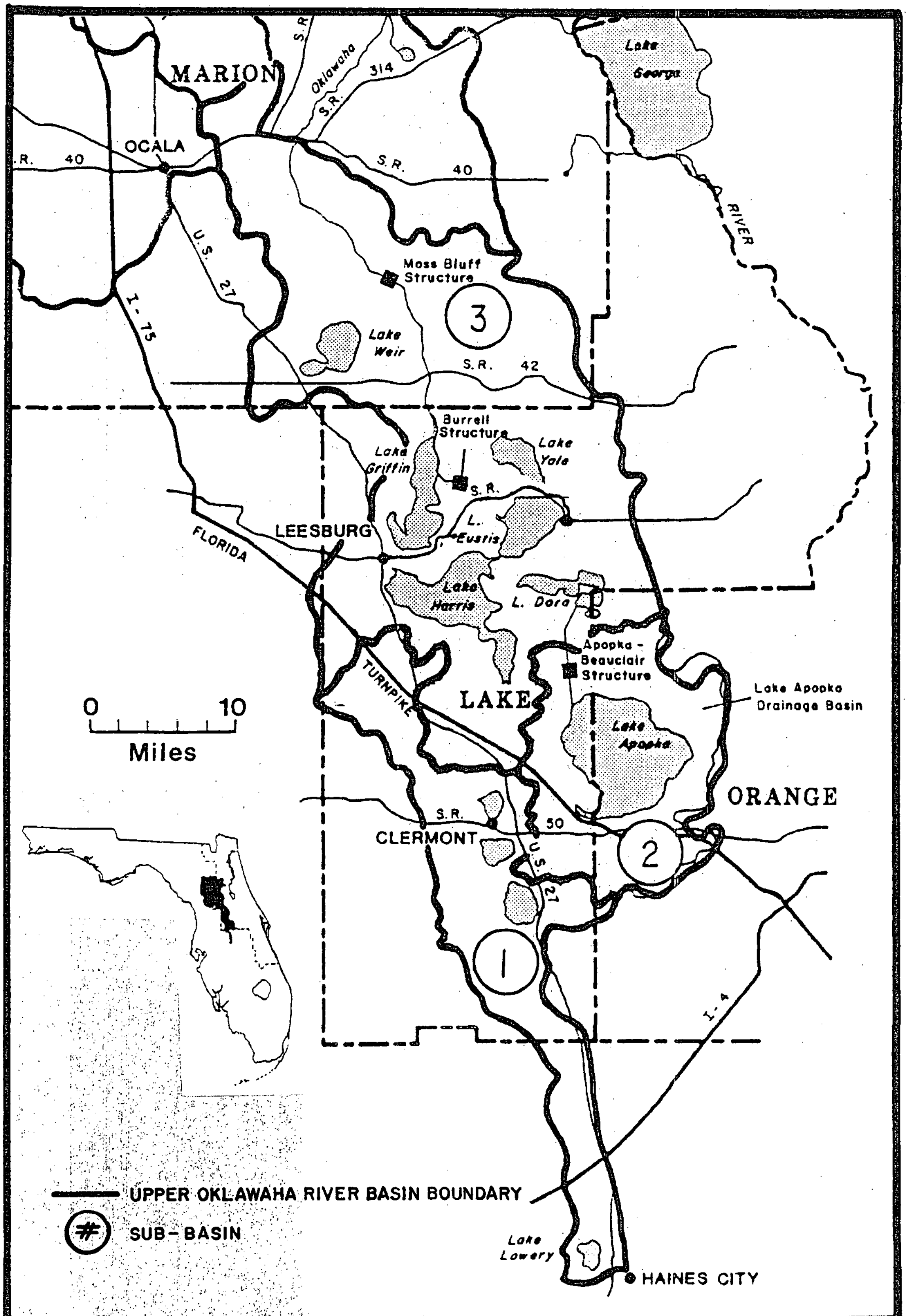


Figure 1. Oklawaha River basin

PURPOSE

The purpose of this additional study is to examine the economic and hydrologic feasibility of the diversion to UPRB under the allowable discharge criteria established by the SWFWMD staff.

HYDROLOGIC ANALYSIS

LAKE LOWERY SURFACE WATER SYSTEM

Lake Lowery is located at the headwaters of the Palatlakaha River basin. Although the hydraulic gradient is slight and the flow regime is not clearly defined, the current direction of drainage is generally to the north. Lake Henry and Lake Hamilton are located south of Lake Lowery at the headwaters of the Peace River basin (Fig. 2). Before the construction of the existing Seaboard Coast Line railroad tracks and U.S. Highway 17/92, floodwaters from Lake Lowery probably entered Lake Henry. Discharge from Lake Lowery into Lake Henry crosses the boundary between SJRWMD and SWFWMD.

To reduce the maximum elevations and durations of extended high water periods in Lake Lowery, SJRWMD concluded (Bethune and Tai 1987) that floodwaters be diverted from Lake Lowery into Lake Henry when Lake Lowery is at or above an elevation of 130.00 ft NGVD. However, to prevent downstream damages (in UPRB), the proposed diversion has been modified so that diversion from Lake Lowery is regulated by allowable discharge criteria. The criteria allow no discharge into UPRB when Lake Henry and Lake Hamilton are simultaneously at or above their design regulation schedules.

METHODS FOR CALCULATING ANNUAL PEAK STAGES

Two methods were used to estimate Lake Lowery's maximum elevations under the allowable diversion criteria. The first method (Method A) modifies the previously generated long-term (56 years) simulated peak stage data to reflect diversion. Correction factors for modifying the simulated stages are established based on observed data for 1965-1984 (20 years). The second method (Method B) applies a "worst case" approximation to estimate maximum elevations for different return periods.

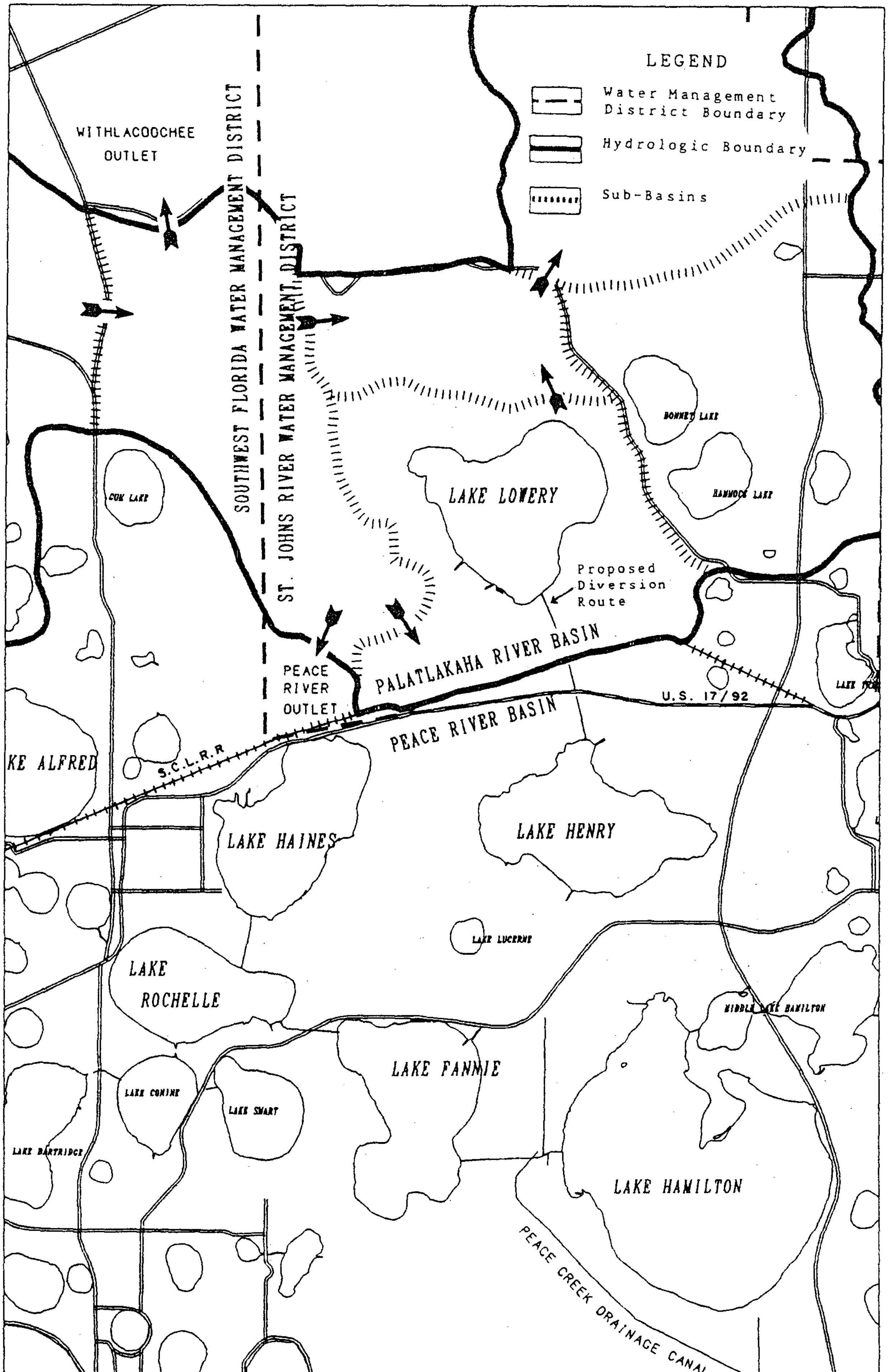


Figure 2. Lake Lowery surface water system

Method A

Daily stages for Lake Lowery, Lake Henry, and Lake Hamilton are collected by the United States Geological Survey (USGS) and SWFWMD. These stages for the period October 1965 through May 1984 are shown in Figure 3. Stage records for Lake Henry, which has the shorter period of record, began in October 1965. Although Lake Henry and Lake Hamilton are regulated, all three lakes exhibit similar trends (Fig. 3). During the three extended high water periods in Lake Lowery (i.e., 1969-71, 1980-81, and 1983-84), elevations in Lakes Henry and Hamilton only periodically exceeded their respective regulation schedules (Figs. 4 and 5), thereby indicating that there is opportunity for diversion of waters from Lake Lowery (Fig. 6).

Diversion Hydrograph. The diversion potential for a given day for Lake Lowery can be determined using the observed stages of Lake Henry and Lake Hamilton. Diversion potential exists if the observed elevation of Lake Henry or Lake Hamilton is below its regulation elevation.

The observed stage hydrograph of Lake Lowery is used to develop a diversion hydrograph. Whenever Lake Lowery is above 130.00 ft NGVD and diversion potential exists, a discharge of 30 cfs is diverted from the lake. This discharge, and the storage change calculated from the observed daily change in stage, are used to calculate the current day's stage from the preceding day's stage. If the lake is below 130.00 ft NGVD or the diversion potential did not exist for a given day, the modified hydrograph reflects only the changes in the observed hydrograph. It is assumed in this analysis that the diverted water passes through the downstream lakes (Lake Henry and Lake Hamilton) without significantly affecting their stages. The observed hydrograph for Lake Lowery and the modified southward diversion hydrograph are shown for 1966-1984 in Fig. 7. During 1966-1984, diversion would have been made for three distinct periods: 1969-1971, 1980-1981, and 1983-1984.

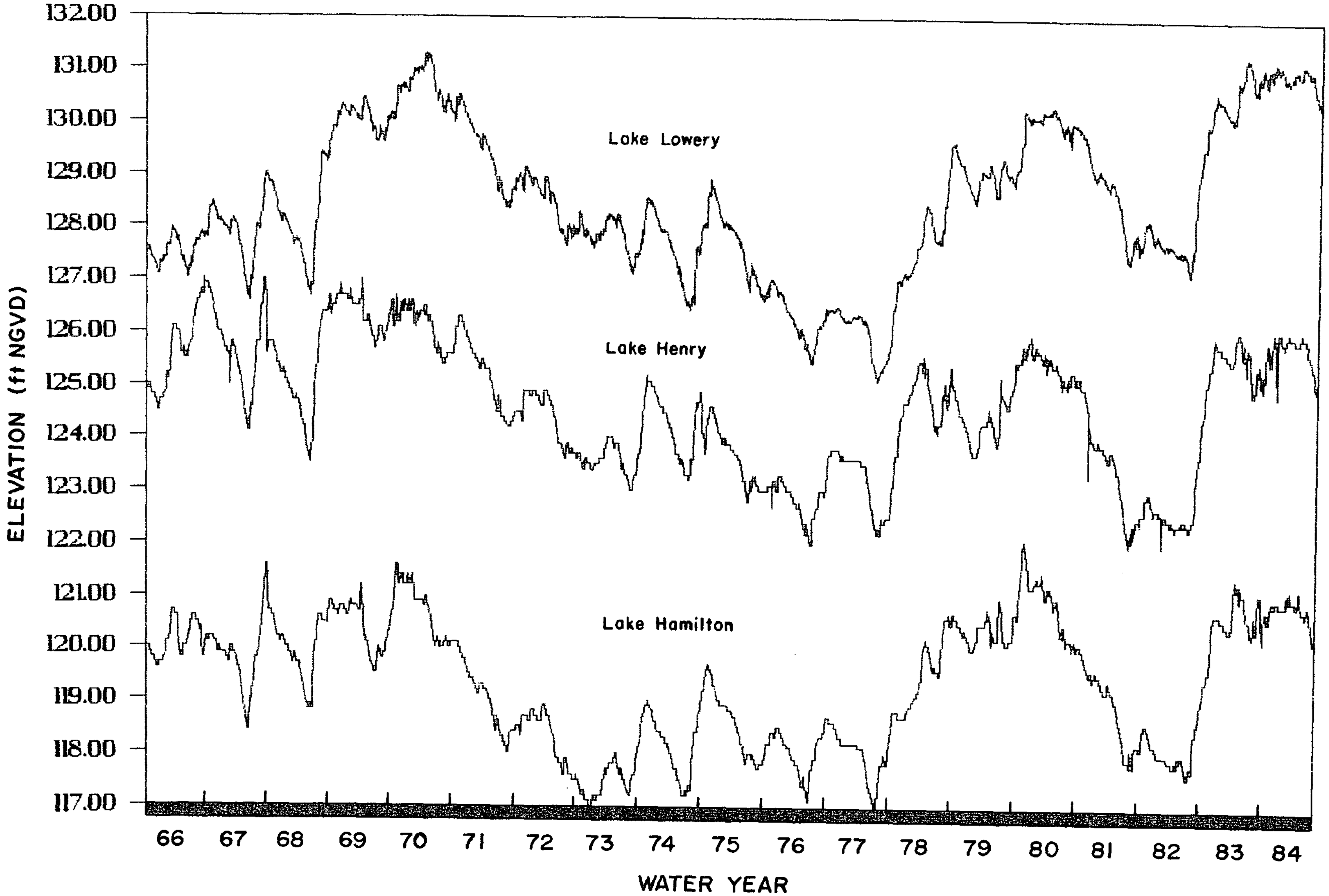


Figure 3. Stage hydrographs for Lake Lowery, Lake Henry, and Lake Hamilton

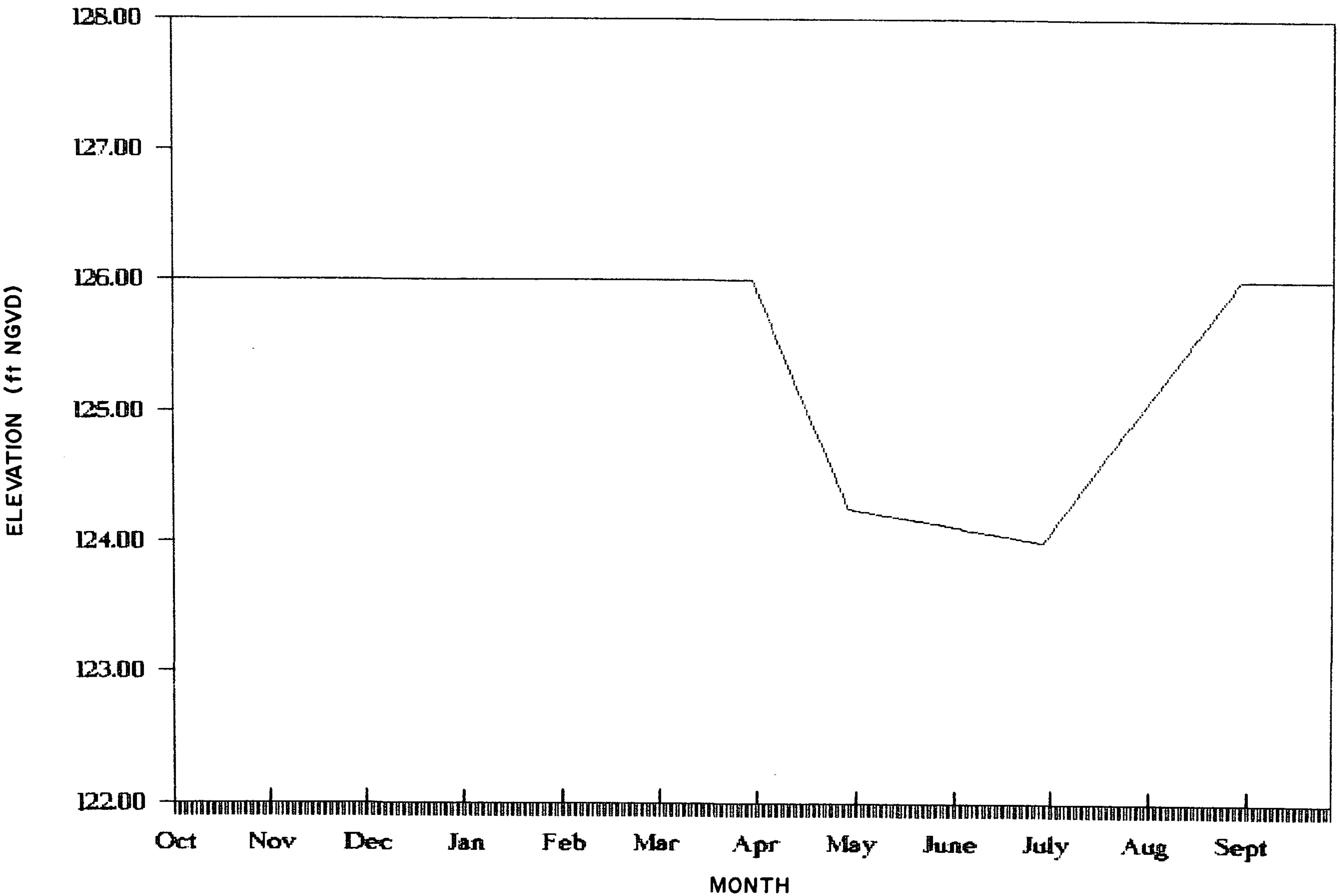


Figure 4. Lake Henry regulation schedule

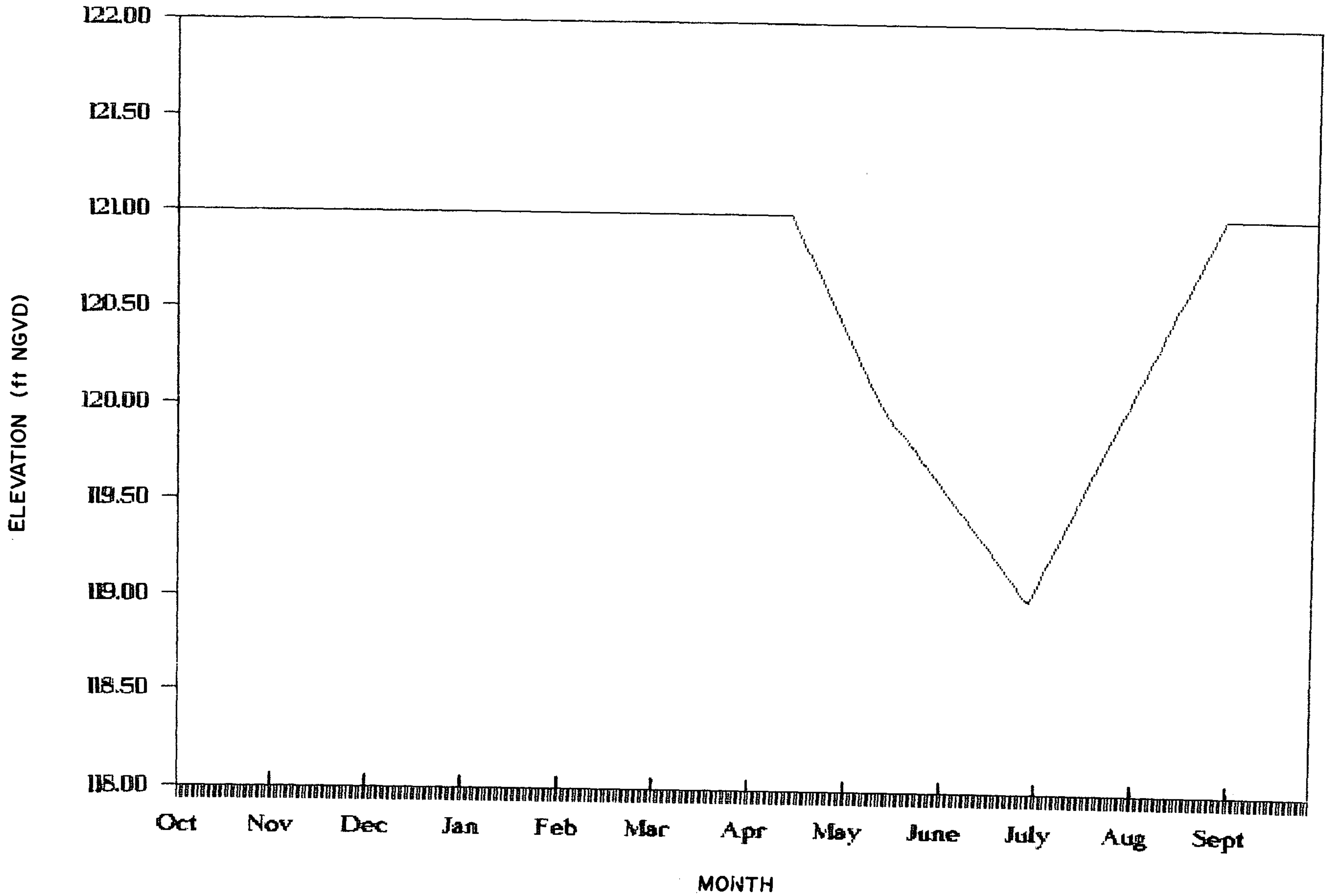


Figure 5. Lake Hamilton regulation schedule

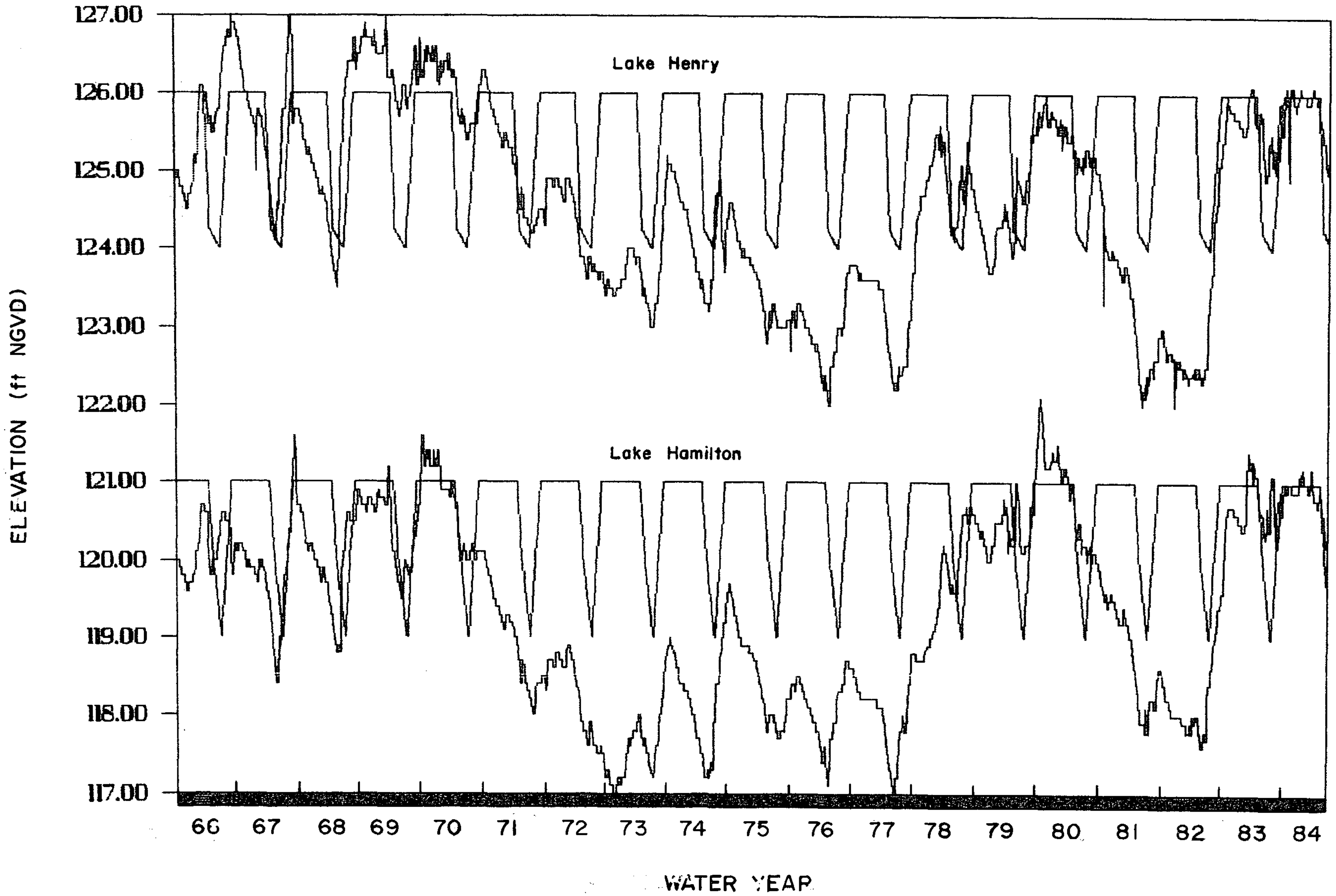


Figure 6. Stage hydrographs for Lakes Henry and Hamilton with regulation schedules superimposed

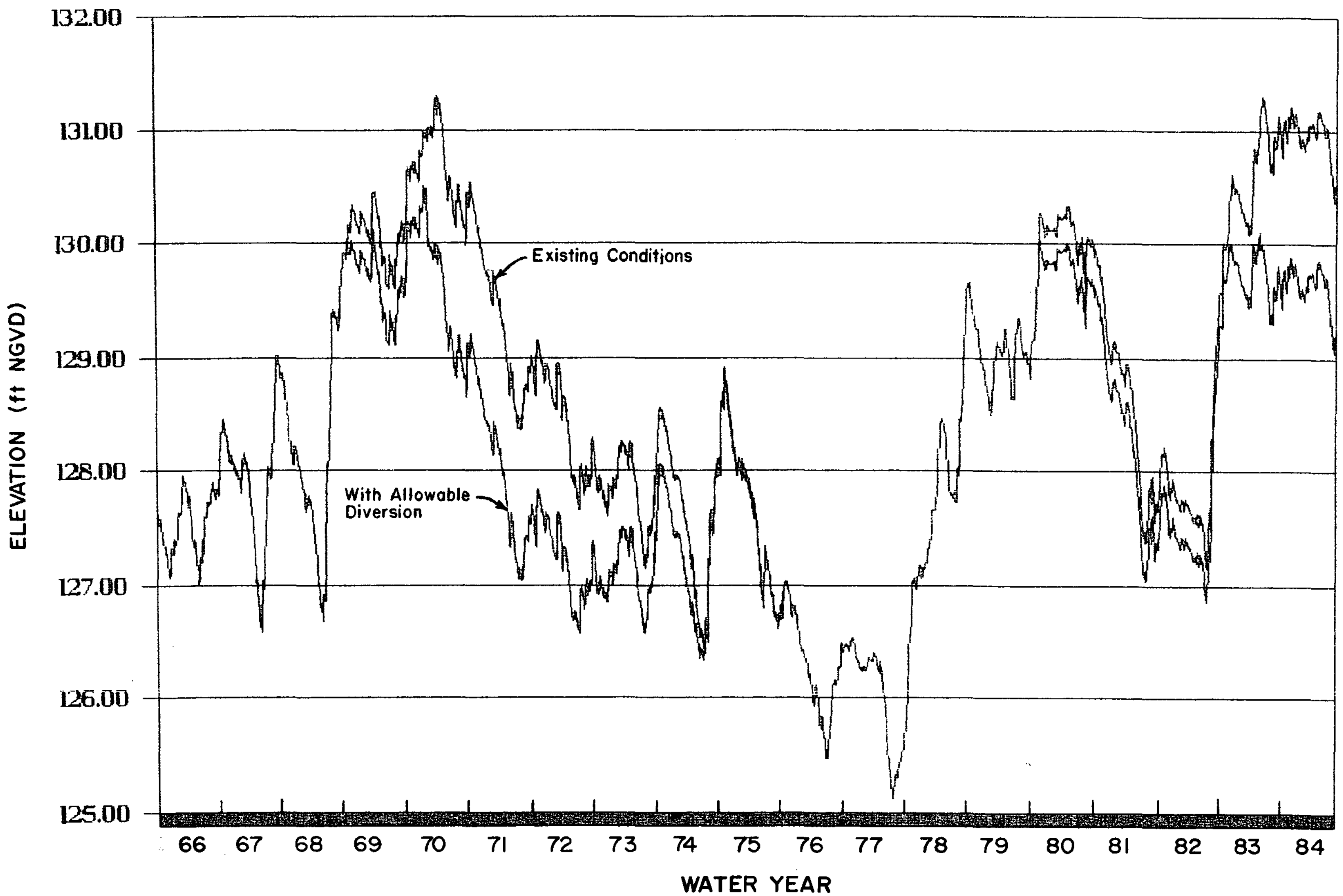


Figure 7. Lake Lowery stage hydrographs with and without diversion (Stages with diversion are computed using Method A)

Maximum Stage Data. Correction factors for modifying the previously generated simulated maximum stage data (Bethune and Tai 1987) are derived as illustrated by Table 1 for the 1-day peak stages. The maximum 1-day elevation and the number of days the stage exceeded 130.00 ft NGVD (columns 2 and 3, Table 1) are determined from observed data for each high-water year requiring diversion. (The years shown in Table 1 and various figures in this report are 'water years' for evaluating 'maximum' elevations and start with June in the preceding year). The cumulative reduction in peak (CRP) is the difference between the observed maximum elevation and the maximum elevation with diversion (column 4, Table 1) for a given year. The annual reduction in peak (ARP) for a given year is calculated by subtracting the previous year's CRP from the current year's CRP. For the beginning year of a diversion period, ARP equals CRP. The average daily reduction (column 7, Table 1) is the quotient of the ARP and the number of days elevation exceeded 130.00 ft NGVD for a given year. These calculations were performed for each of the three high water periods (i.e., 1969-1971, 1980-1981, and 1983-1984).

The average daily reduction values (from which the index for correcting the simulated stages would be derived) varied from 0.0004 ft to 0.0044 ft for the seven high-water years. For simplicity in application, however, an average daily reduction value based on all seven high-water years is derived. This value (0.0019 ft, Table 1) is calculated by dividing the sum of the ARP values (2.98 ft) by the sum of the number of days (1,548) the elevation exceeded 130.00 ft NGVD. This average value was used as a coefficient to derive adjusted stage/duration values for the modified southward diversion.

The ARP values also are determined for 7-day, 14-day, 30-day, 60-day, 120-day, and 183-day durations of high elevations by a similar method. Results are presented in Appendix A. The mean of the ARP values for the seven diversion years for all durations is found to be 0.43 ft.

Example of Calculations. The coefficient derived from the average daily reduction in peak elevations for the seven high-water years (0.0019 ft) was applied to the 1928-84 simulated elevations for the existing conditions (Bethune and Tai 1987). These calculations are shown in Table 2. The following is an example of these calculations:

Table 1. Lake Lowery maximum one-day stages						
Years of Diversion (1)	Observed Maximum (ft NGVD) (2)	Days Elev>130.00 (Observed) (3)	Maximum with Diversion (ft NGVD) (4)	Cumulative Reduction in Peak (ft) (5)	Annual Reduction in Peak (ft) (6)	Average Daily Reduction (ft/day) (7)
1969	130.46	190	130.12	0.34	0.34	0.0018
1970	131.30	298	130.51	0.79	0.45	0.0015
1971	130.60	176	129.28	1.32	0.53	0.0030
1980	130.34	220	130.06	0.28	0.28	0.0013
1981	130.06	26	129.72	0.34	0.06	0.0023
1983	131.30	272	130.11	1.19	1.19	0.0044
1984	131.22	366	129.90	1.32	0.13	0.0004
Total		1,548			2.98	
Average					0.43	0.0019

Table 2. Stages which were continuously exceeded for 1-, 7-, 14-, 30-, 60-, 120-, and 183-day durations

E.C. = Existing Condition
D.C. = Modified "Southward Diversion Alternative - #3" Condition (Method A)
Dur. = Duration

Year	E.C. 1-Day Dur. ft NGVD	D.C 1-Day Dur. ft NGVD	E.C. 7-Day Dur. ft NGVD	D.C 7-Day Dur. ft NGVD	E.C. 14-Day Dur. ft NGVD	D.C 14-Day Dur. ft NGVD	E.C. 30-Day Dur. ft NGVD	D.C 30-Day Dur. ft NGVD	E.C. 60-Day Dur. ft NGVD	D.C 60-Day Dur. ft NGVD	E.C. 120-Day Dur. ft NGVD	D.C 120-Day Dur. ft NGVD	E.C. 183-Day Dur. ft NGVD	D.C 183-Day Dur. ft NGVD	E.C. 274-Day Dur. ft NGVD	D.C 274-Day Dur. ft NGVD
1928	130.87	130.65	130.82	130.60	130.81	130.59	130.70	130.48	130.60	130.38	130.18	129.96	129.83	129.61	129.57	129.35
1929	131.50	131.15	131.42	131.07	131.35	131.00	131.33	130.98	131.11	130.76	130.65	130.30	130.29	129.94	129.36	129.01
1930	131.20	130.50	131.12	130.42	131.07	130.37	130.99	130.29	130.93	130.23	130.83	130.13	130.76	130.06	129.90	129.20
1931	131.00	130.19	130.95	130.14	130.89	130.08	130.81	130.00	130.73	129.92	130.46	129.65	130.45	130.64	130.43	130.62
1932	130.38	129.57	130.34	129.53	130.30	129.49	130.26	129.45	130.04	129.23	129.91	129.10	129.59	128.78	128.75	127.94
1933	128.66		128.63		128.57		128.48		128.42		128.19		128.02		127.37	
1934	129.89		129.89		129.88		129.85		129.75		129.44		129.16		127.38	
1935	132.52	132.00	132.47	131.95	132.40	131.88	132.23	131.71	132.10	131.58	131.77	131.25	131.27	130.75	130.54	130.02
1936	130.85	130.27	130.80	130.22	130.77	130.19	130.60	130.02	130.45	130.87	130.18	129.60	130.02	129.44	129.55	128.97
1937	130.75	130.14	130.70	130.09	130.62	130.01	130.45	129.84	130.36	129.75	130.14	129.53	129.77	129.16	129.72	129.11
1938	130.45	129.84	130.37	129.76	130.33	129.72	130.27	129.66	130.11	129.50	130.01	129.40	129.88	129.27	129.60	128.99
1939	129.22		129.16		129.15		129.04		128.80		128.71		128.62		128.02	
1940	130.86	130.63	130.79	130.56	130.73	130.50	130.64	130.41	130.49	130.26	130.05	129.82	129.88	129.65	129.69	129.46
1941	129.03		128.97		128.94		128.77		128.76		128.61		128.09		127.95	
1942	129.66		129.59		129.54		129.51		129.32		129.18		129.08		129.04	
1943	129.62		129.58		129.54		129.49		129.30		129.11		129.02		128.49	
1944	130.67	130.44	130.60	130.37	130.59	130.36	130.48	130.25	130.40	130.17	130.10	129.87	129.87	129.64	129.39	129.16
1945	131.59	131.01	131.52	130.94	131.46	130.88	131.34	130.76	131.17	130.59	131.03	130.45	130.63	130.05	130.06	129.48
1946	132.54	131.44	132.41	131.31	132.31	131.21	132.17	131.07	132.07	130.97	131.73	130.63	131.59	130.49	131.06	129.46
1947	132.05	130.60	131.95	130.50	131.87	130.42	131.84	130.39	131.79	130.34	131.48	130.03	131.21	129.76	130.87	129.42
1948	131.87	130.31	131.78	130.22	131.73	130.17	131.65	130.09	131.54	129.98	131.32	129.76	131.32	129.76	130.83	129.27
1949	132.69	130.90	132.59	130.80	132.55	130.76	132.42	130.63	131.99	130.20	131.61	129.82	131.28	129.49	130.62	128.83
1950	131.48	129.69	131.43	129.64	131.38	129.59	131.21	129.42	131.11	129.32	130.88	129.09	130.57	128.78	130.22	128.43
1951	131.18	129.39	131.11	129.32	131.03	129.24	131.01	129.22	130.80	129.01	130.79	129.00	130.62	128.83	129.78	127.99
1952	131.87	130.05	131.78	129.96	131.75	129.93	131.66	129.84	131.53	129.71	131.35	129.63	131.35	129.53	130.95	129.13
1953	132.55	130.62	132.45	130.52	132.36	130.43	132.25	130.32	132.03	130.10	131.68	129.75	131.37	129.44	131.06	129.13
1954	132.36	130.20	132.28	130.12	132.24	130.08	132.20	130.04	132.05	129.89	131.97	129.81	131.48	129.32	130.87	128.71
1955	131.08	128.92	131.01	128.85	130.94	128.78	130.84	128.68	130.75	128.59	130.50	128.34	130.48	128.32	130.10	127.94
1956	129.07		128.93		128.82		128.73		128.46		128.21		128.02		127.33	
1957	129.27		129.22		129.18		128.37		128.21		127.79		127.71		126.86	
1958	129.89		129.87		129.81		129.78		129.70		129.52		129.35		129.35	
1959	131.21	130.98	131.11	130.88	131.09	130.86	131.00	130.77	130.81	130.58	130.08	129.85	129.83	129.60	129.59	129.36
1960	133.02	132.10	132.93	132.01	132.82	131.90	132.66	131.74	132.34	131.42	132.15	131.23	131.88	130.96	131.63	130.71
1961	133.79	132.35	133.63	132.19	133.49	132.05	133.15	131.71	132.63	131.19	131.93	130.49	131.66	130.22	131.13	129.69
1962	130.53	129.18	130.47	129.03	130.38	128.94	130.32	128.88	130.23	128.79	130.09	128.65	129.56	128.12	128.86	127.42
1963	128.32		128.28		128.24		128.17		128.06		127.84		127.69		127.42	
1964	128.54		128.51		128.47		128.42		128.34		128.15		127.69		127.22	
1965	129.07		129.04		129.00		128.99		128.80		128.62		128.42		128.17	
1966	129.12		129.08		128.99		128.93		128.79		128.50		128.31		128.31	
1967	129.76		129.72		129.70		129.69		129.51		129.27		129.10		128.78	
1968	130.18	130.12	130.15	130.09	130.13	130.07	130.08	130.02	129.97	129.91	129.68	129.62	129.47	129.41	128.98	128.92
1969	131.00	130.48	130.93	130.41	130.90	130.38	130.72	130.20	130.68	130.16	130.64	130.12	130.45	129.93	130.32	129.80
1970	131.40	130.53	131.33	130.46	131.28	130.41	131.24	130.37	131.12	130.25	131.08	130.21	130.95	130.08	130.38	129.51
1971	130.80	129.93	130.74	129.87	130.72	129.85	130.55	129.68	130.47	129.60	130.37	129.50	130.30	129.43	129.77	128.90
1972	129.17		129.15		129.12		128.98		128.79		128.64		128.48		128.34	
1973	128.30		128.27		128.20		128.06		127.78		127.44		127.30		127.30	
1974	128.64		128.60		128.56		128.51		128.41		128.25		127.83		127.21	
1975	128.98		128.92		128.86		128.81		128.50		128.28		128.12		127.50	
1976	127.67		127.62		127.59		127.44		127.24		127.11		126.62		126.41	
1977	128.19		128.18		128.16		128.12		128.08		128.08		127.69		126.92	
1978	128.80		128.74		128.65		128.62		128.47		128.41		128.40		127.65	
1979	129.07		129.03		128.97		128.86		128.65		128.39		127.94		127.75	
1980	130.91	130.56	130.84	130.49	130.83	130.48	130.78	130.43	130.72	130.37	130.67	130.32	130.65	130.30	129.54	129.19
1981	130.69	130.23	130.63	130.17	130.61	130.15	130.54	130.08	130.46	130.00	130.19	129.73	129.63	129.16	129.16	128.70
1982	128.26		128.23		128.19		128.17		127.91		127.64		127.38		126.98	
1983	129.89		129.83		129.80		129.77		129.57		129.00		128.95		128.95	
1984	130.87	130.35	130.83	130.31	130.80	130.28	130.67	130.15	130.61	130.09	130.50	129.99	130.38	129.86	130.14	129.62

During the 1980 high-water period, Lake Lowery's elevation exceeded 130.00 ft NGVD for 183 consecutive days. The mean of the average daily reduction in peak elevations was multiplied by the number of high water days to obtain a figure for the diversion over a year:

0.0019 (ft/day) x 183 (days) = 0.35 ft

This figure was then subtracted from the 1-day high elevation from existing conditions to get 1-day high elevation under diversion conditions:

130.91 (ft NGVD) - 0.35 (ft) = 130.56 ft NGVD

The 7-day duration elevation for the diversion conditions is similarly computed by multiplying the mean of the average daily reduction values by the duration of high water days. As the mean of the average daily reduction is the same for the 7-day as for the 1-day elevation, the diversion over the year is the same:

130.84 (ft NGVD) - 0.35 (ft) = 130.49 ft NGVD

This process is continued for 14-day, 30-day, 60-day, 120-day, and 183-day durations of 1980 elevations.

In consecutive years, the effects of diversion from the previous years carry forward. The reduction in elevation due to diversion for the previous years is subtracted from the elevations of the current year before applying corrections for diversion. For example, the reduction in elevation due to diversion for the 1980 high-water period is 0.35 ft. This amount is subtracted from the original simulated elevations for 1981 to obtain the elevations before diversion for 1981 under the modified diversion alternative. For example, the peak elevations before diversion for 1-day, 60-day, and 120-day durations for 1981 are the following:

1-day: 130.69 (ft NGVD) - 0.35 (ft) = 130.34 (ft NGVD)
60-day: 130.46 (ft NGVD) - 0.35 (ft) = 130.11 (ft NGVD)
120-day: 130.19 (ft NGVD) - 0.35 (ft) = 129.84 (ft NGVD)

In 1981, the lake elevation was above 130.0 ft NGVD for slightly more than 60 days (between 60 and 120 days). The duration above 130.00 ft NGVD, therefore, is assumed to be 60 consecutive days.

The 1-day elevation before diversion in 1981 is 130.34 ft NGVD. The elevation after diversion is calculated by subtracting the daily reduction in elevation for a 60-day duration from the elevation before diversion. The reduction in lake elevation due to diversion for a 60-day duration (the time the lake was above 130.00 ft) is:

0.0019 (ft/day) x 60 (days) = 0.11 (ft)

Therefore, the 1981 1-day maximum stage is:

130.34 (ft NGVD) - 0.11 (ft) = 130.23 (ft NGVD)

These calculations are repeated for the 7-day, 14-day, 30-day, 60-day, 120-day, and 183-day duration maximum lake elevations for 1981.

A frequency analysis of the peak elevation data for the modified southward diversion conditions is presented in Table 3. Also listed in Table 3 are the results of the frequency analysis on simulated data for the existing conditions and for unrestricted diversion (when floodwaters are diverted regardless of downstream conditions up to a maximum of 125 cfs). As expected, elevations for the modified southward diversion condition, for the most part, lie between the elevations for the existing conditions and the unrestricted diversion conditions. Some values at low recurrence intervals deviated from this trend due to approximations made in this method.

<u>Method B</u>

Method B for calculating peak stages treats each high-water period as a discrete event; i.e., the effects from diversion during previous high-water periods are not considered. For each high-water period, the analysis starts from a diversion hydrograph that coincides with the existing conditions hydrograph (Figs. 8, 9, and 10).

Table 3. Frequency analysis for Method A

Recurrence Interval (Years)	1-Day Existing Condition	1-Day Unrestricted Diversion	1-Day Restricted Diversion	7-Day Existing Condition	7-Day Unrestricted Diversion	7-Day Restricted Diversion	14-Day Existing Condition	14-Day Unrestricted Diversion	14-Day Restricted Diversion
2	130.30	129.92	129.81	130.24	129.75	129.75	130.24	129.79	129.71
5	131.55	130.70	130.68	131.48	130.61	130.61	131.42	130.53	130.56
10	132.27	131.09	131.16	132.18	130.98	131.08	132.12	130.90	131.02
25	133.08	131.49	131.69	132.97	131.37	131.60	132.90	131.27	131.52
50	133.63	131.73	132.05	133.51	131.63	131.94	133.44	131.49	131.85
100	134.15	131.95	132.37	134.02	131.81	132.25	133.94	131.69	132.16
200	134.65	132.14	132.67	134.50	131.99	132.55	134.41	131.86	132.44

Recurrence Interval (Years)	30-Day Existing Condition	30-Day Unrestricted Diversion	30-Day Restricted Diversion	60-Day Existing Condition	60-Day Unrestricted Diversion	60-Day Restricted Diversion	120-Day Existing Condition	120-Day Unrestricted Diversion	120-Day Restricted Diversion
2	130.11	129.69	129.62	129.96	129.56	129.51	129.75	129.38	129.27
5	131.32	130.41	130.45	131.17	130.27	130.33	130.92	130.10	130.03
10	132.00	130.76	130.89	131.82	130.60	130.75	131.55	130.43	130.42
25	132.76	131.09	131.37	132.54	130.91	131.20	132.24	130.74	130.83
50	133.24	131.29	131.68	133.02	131.09	131.49	132.70	130.93	131.08
100	133.75	131.46	131.95	133.45	131.24	131.74	133.11	131.08	131.31
200	134.19	131.61	132.22	133.85	131.37	131.98	133.49	131.20	131.52

Recurrence Interval (Years)	183-Day Existing Condition	183-Day Unrestricted Diversion	183-Day Restricted Diversion
2	129.54	129.19	129.07
5	130.71	129.96	129.85
10	131.33	130.32	130.24
25	132.00	130.65	130.64
50	132.43	130.85	130.89
100	132.82	131.01	131.11
200	133.18	131.14	131.30

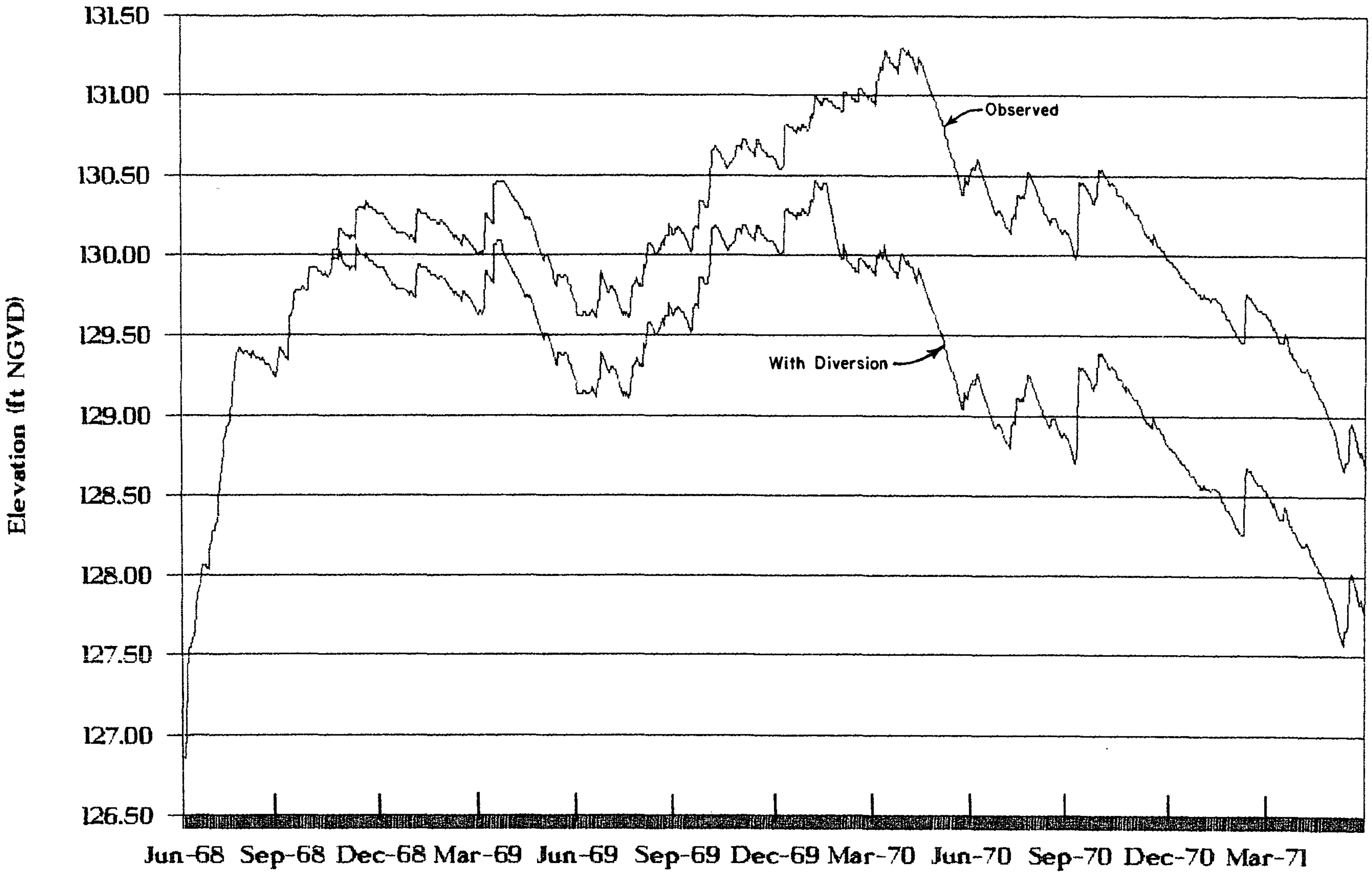


Figure 8. Lake Lowery stage hydrographs with and without diversion: 1968-71.
(Stages with diversion are computed using Method B)

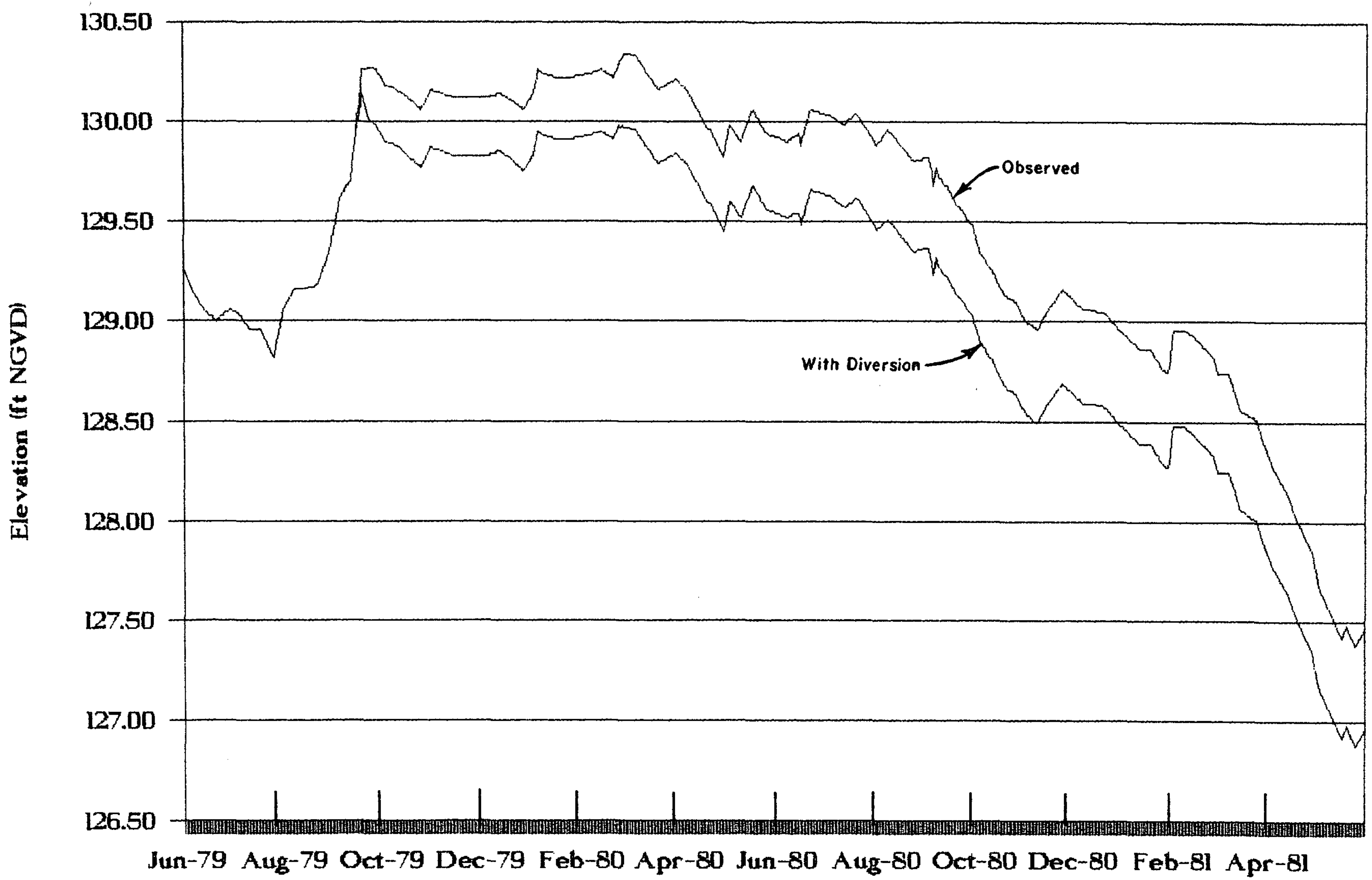


Figure 9. Lake Lowery stage hydrographs with and without diversion: 1979-81
(Stages with diversion are computed using Method B)

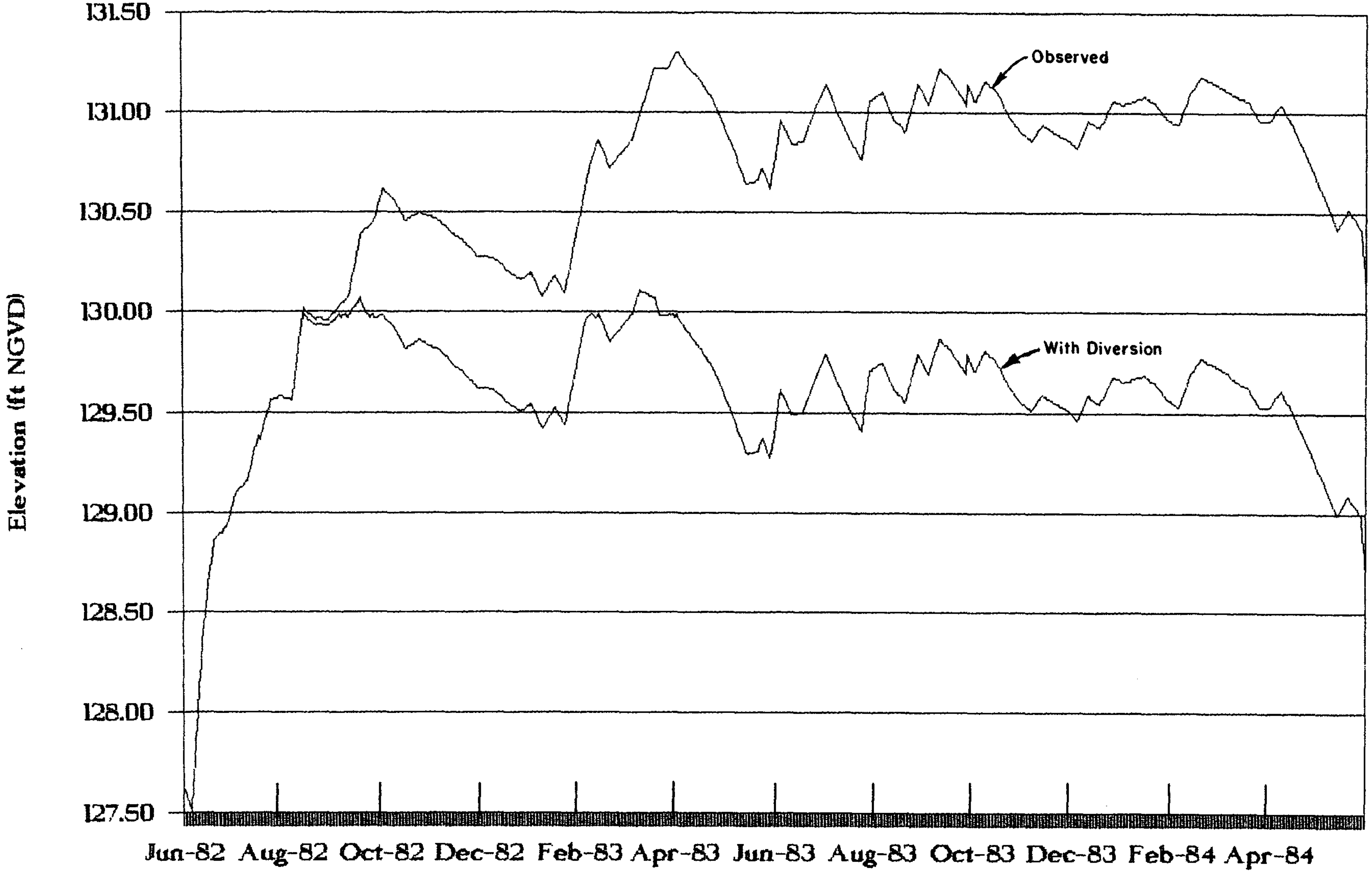


Figure 10. Lake Lowery stage hydrographs with and without diversion: 1982-84 (Stages with diversion are computed using Method B).

Table 4 lists the 1-day, 7-day, 14-day, 30-day, 60-day, 120-day, and 183-day duration maximum stages for Lake Lowery as computed by Method B for the modified southward diversion alternative (MSDA). These elevations are plotted on probability graphs to obtain stage-frequency curves for each of the various durations. Figure 11 shows stage-frequency curves for the 1-day duration flood for the following cases:

Case 1:	existing conditions
Case 2:	unrestricted diversion conditions
Case 3:	restricted diversion conditions using Method A
Case 4:	restricted diversion conditions using Method B

For the first two cases, the frequency curves are drawn from the results given by Bethune and Tai (1987). Table 3 gives stage-frequency data for Case 3. The frequency curve for Case 4 is developed as follows:

The maximum 1-day duration elevations that would have occurred during the three observed high-water periods (1969-71, 1980-81, and 1983-84) under the allowable diversion criteria are plotted on the graph (points 1, 2, and 3, Fig. 11). [To obtain plotting positions for these points, the observed maximum elevations of each high-water period for the existing conditions (131.30, 130.34, and 131.30 ft NGVD) are located on the existing conditions curve. The maximum elevation values for the modified southward diversion conditions are then plotted on vertical lines drawn from the preceding points on the existing conditions curve].

In general, for the range of the three observed maximum events, the frequency curve developed by Method A also appears to be the best representation for Method B. For more severe events, however, conservative estimates of maximum stages are obtained by assuming that diversion potential will not exist, and thus the stages will be similar to those that might occur with no diversion. The Method A curve is retained in the lower range, then a transition curve joins asymptotically the simulated existing conditions curve at the 100-year recurrence interval. Elevations for recurrence intervals less than 100 years are read directly from the curve; elevations for recurrence intervals equal to and greater than 100 years are identical to the simulated existing conditions values given by Bethune and Tai (1987). Table 5 contains the frequency values developed in Method B. Probability graphs for the 7-day, 14-day, 30-day, 60-day, 120-day, and 183-day duration elevations are shown in Appendix A.

Table 4. Lake Lowery maximum elevations for various durations, ft NGVD

Case and Duration	High Water Period #1 (1969-70)	High Water Period #2 (1980-81)	High Water Period #3 (1983-84)
Obs. 1-Day Duration	131.30	130.34	131.30
MSDA 1-Day Duration	130.51	130.06	130.11
Obs. 7-Day Duration	131.28	130.34	131.28
MSDA 7-Day Duration	130.48	130.00	130.07
Obs. 14-Day Duration	131.26	130.32	131.26
MSDA 14-Day Duration	130.47	129.99	130.03
Obs. 30-Day Duration	131.23	130.28	131.23
MSDA 30-Day Duration	130.39	129.97	130.01
Obs. 120-Day Duration	131.06	130.21	131.04
MSDA 120-Day Duration	130.22	129.90	129.82
Obs. 183-Day Duration	130.94	130.19	131.03
MSDA 183-Day Duration	130.11	129.89	129.77

MSDA = Modified Southward Diversion Alternative (Method B)

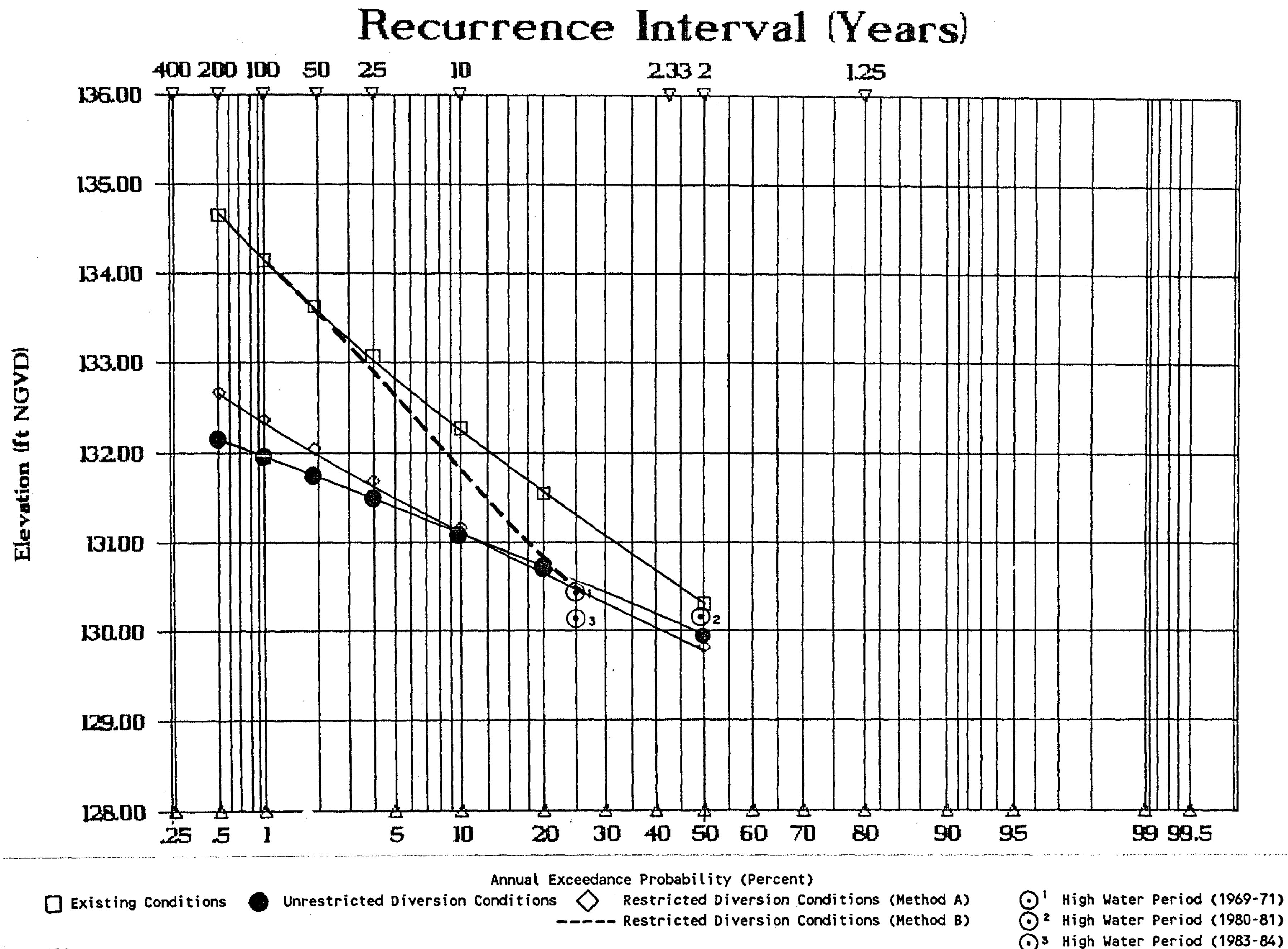


Figure 11. Elevation vs. frequency for 1-day duration

Table 5. Estimates of high elevations using Method B

Recurrence Interval (Years)	1-Day	7-Day	14-Day	30-Day	60-Day	120-Day	183-Day
2	129.92	129.85	129.79	129.69	129.56	129.38	129.19
5	130.85	130.75	130.70	130.48	130.32	130.10	129.96
10	131.82	131.75	131.70	131.35	131.00	130.80	130.45
25	132.90	131.85	132.75	132.35	132.10	131.90	131.48
50	133.52	133.40	133.40	133.10	132.75	132.52	132.21
100	134.15	134.02	133.94	133.75	133.46	133.11	133.82
200	134.65	134.50	134.41	134.19	133.85	133.49	133.18

IMPACT ON LAKE LOWERY

Diversion of floodwaters from Lake Lowery will reduce the maximum elevations and durations of high-water periods in the lake. The estimates of reduction in one-day high elevations are 0.87 ft, 1.11 ft, 1.39 ft, and 1.78 ft for the 5-year, 10-year, 25-year, and 100-year recurrence intervals, respectively, using Method A (Table 3). The estimates of reduction in one-day high elevations are 0.70 ft, 0.45 ft, 0.18 ft, and 0.00 ft for the 5-year, 10-year, 25-year, and 100-year recurrence intervals, respectively, using Method B (Tables 3 and 5). Both procedures maintain low lake elevations to within 0.20 ft of the existing conditions elevations.

IMPACT ON THE UPPER PEACE RIVER BASIN

The allowable diversion criteria restrict discharge into UPRB such that no adverse impact to Lake Henry or Lake Hamilton will result. The diversion should produce no significant increase to Lake Henry's and Lake Hamilton's high-water elevations.

HYDRAULIC DESIGN

The Polk County Engineering Department designed the original diversion system, which was subsequently modified by SJRWMD. The two general design considerations of the diversion system are flow regulation and conveyance. A control structure will regulate flow into the conveyance system. A slide gate on the structure should be capable of diverting the design discharge (30 cfs) when Lake Lowery reaches 130.00 ft NGVD. The conveyance system, a combination of reinforced concrete pipe and open channels, should carry a discharge of 30 cfs to Lake Henry.

PROPOSED ROUTE

Two routes were considered for the diversion system (Fig. 12). One of the routes was originally proposed by Polk County. The second route slightly altered the original proposal following field investigations to minimize environmental damage and achieve the design discharge. Most of the route is through marsh land, although the middle reach, between Old Dixie Highway and U.S. Highway 17/92, passes alongside an abandoned drive-in theater and through a citrus grove.

DIVERSION SYSTEM DESIGN

A profile of the proposed diversion system is shown in Figure 13. The system will have an open ditch between the canal on the southeast shore of Lake Lowery (Fig. 12) and the Seaboard Coast Line railroad tracks (Detail AA, Fig. 14). This ditch will be excavated to a depth of about 4 ft. For water to pass under the Seaboard Coast Line railroad tracks, pipe casings will be bored under the tracks and a conduit (36-in diameter reinforced concrete pipe) will be placed inside the casings. Two reinforced concrete headwalls will be constructed at the inlet and outlet of the conduit. On the downstream (south) headwall, a slidegate will

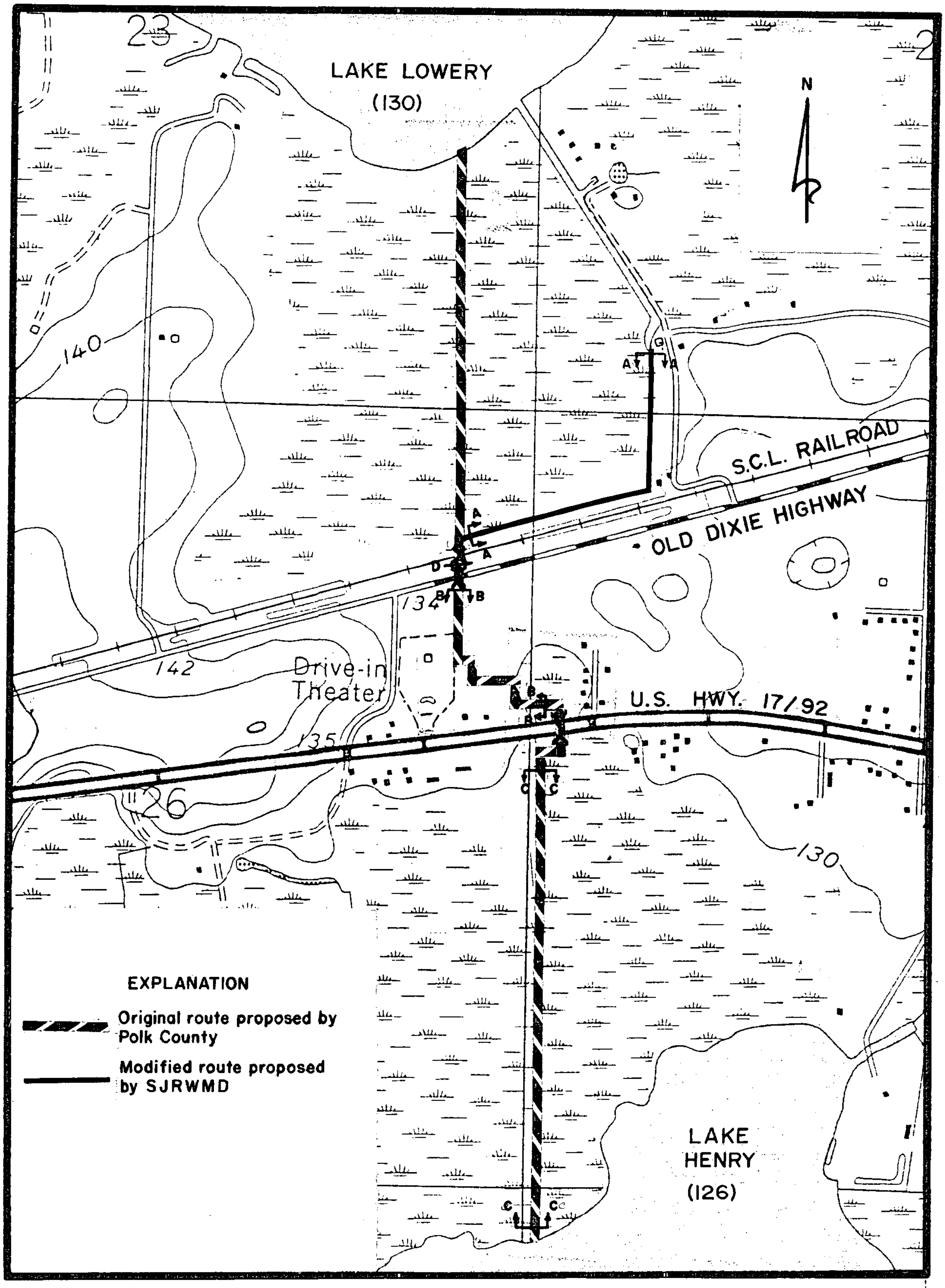


Figure 12. Proposed diversion route

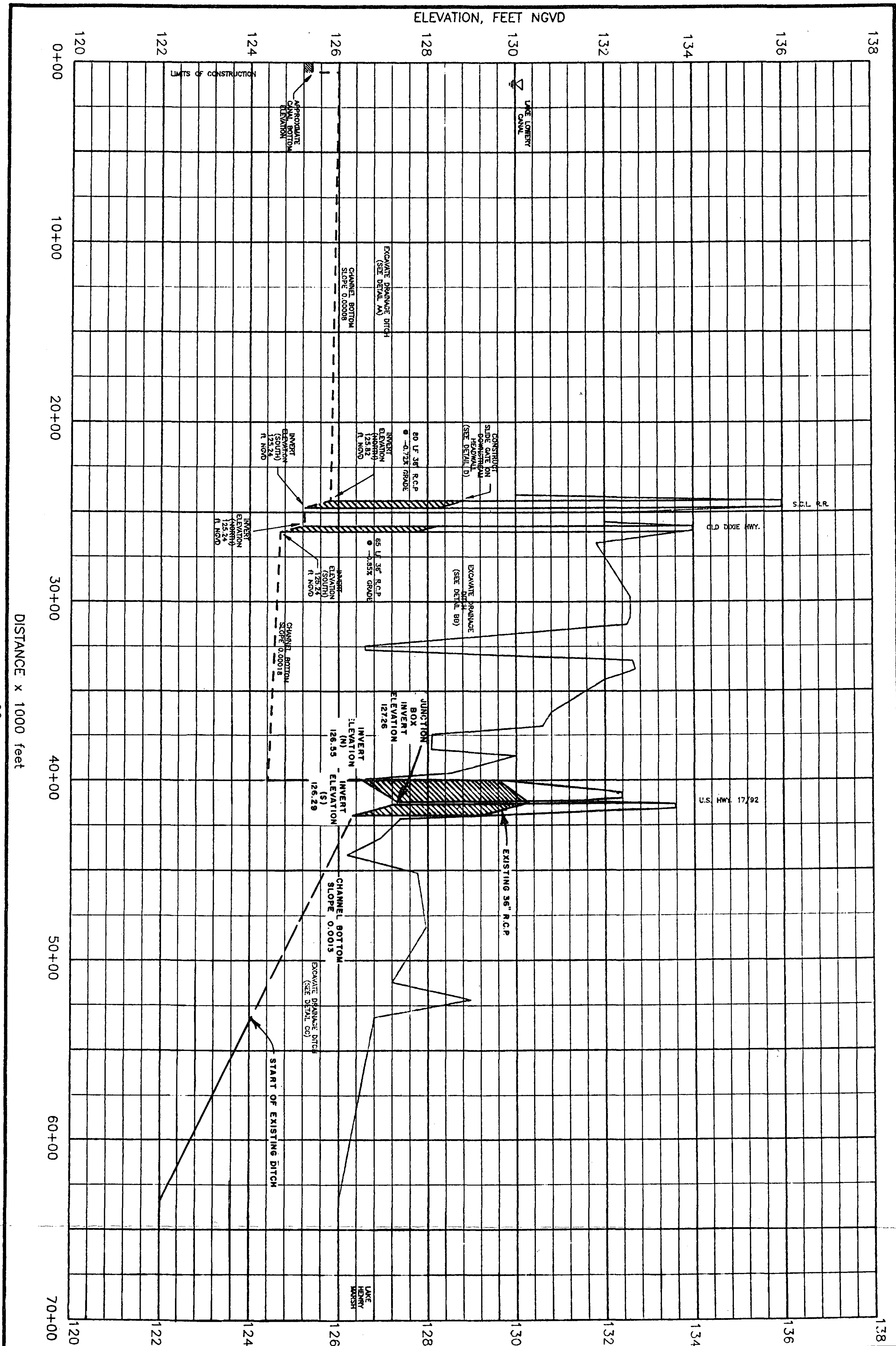
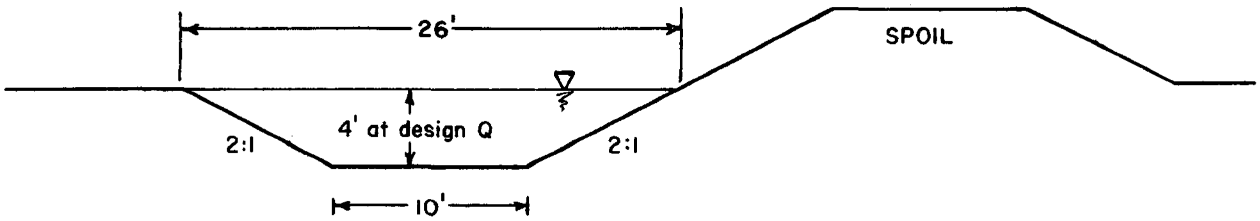


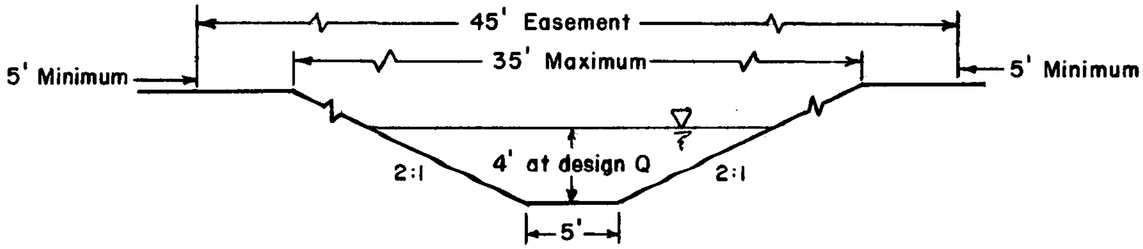
Figure 13

ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

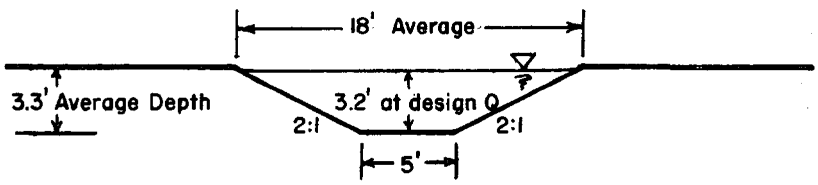
LAKE LOWERY DIVERSION ROUTE



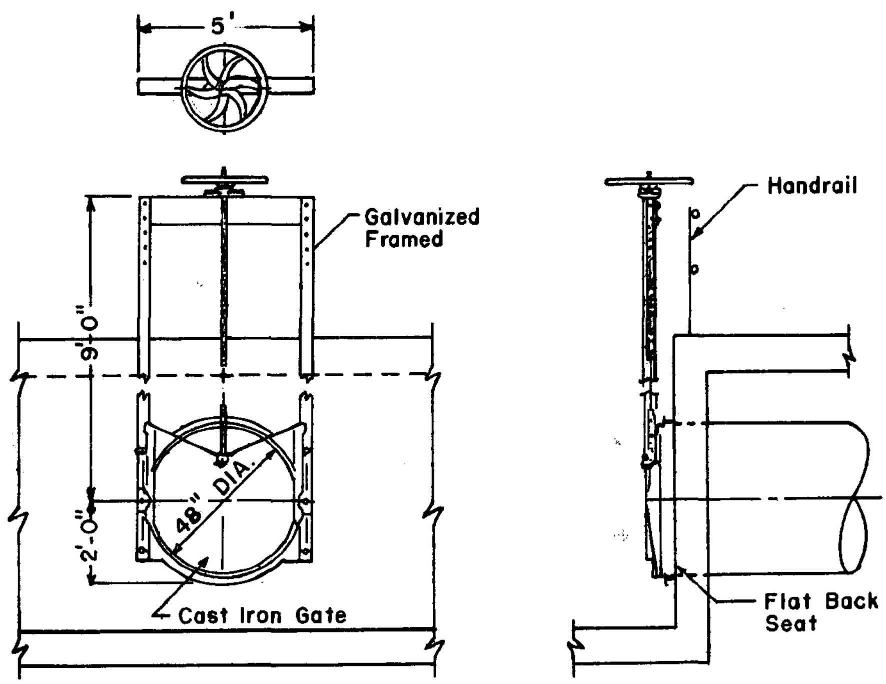
DETAIL AA



DETAIL BB



DETAIL CC



DETAIL D

Figure 14. Diversion system design

be installed to regulate flow. This headwall/slidegate structure will be fenced. Another section of 36-in conduit will be placed under Old Dixie Highway; this section can be installed by open-cutting the roadway. Headwalls will be constructed at the inlet and outlet of the conduit under Old Dixie Highway.

The middle reach between the railroad tracks and U.S. Highway 17/92 is an open ditch, which will be excavated alongside the abandoned drive-in theater, through citrus groves, to a point just north of U.S. Highway 17/92 (Detail BB, Fig. 14). This ditch will be excavated to an average depth of about 6 ft. An easement of 45 ft is required through this mostly undeveloped area. Under U.S. Highway 17/92 there is a culvert with a junction box having the invert at 127.26 ft NGVD. This invert is rather high and limits the conveyance of the culvert to about 20 cfs (i.e., less than design capacity) when Lake Lowery is at 131.50 ft NGVD. This limitation could moderately reduce the benefits of the diversion system.

The final reach from U.S. Highway 17/92 to Lake Henry is an open ditch. Only about 1,300 ft of new excavation is required, as this ditch intersects an existing ditch which already discharges into Lake Henry. The ditch will be excavated to an average depth of 3.3 ft over the entire final reach (Detail CC, Fig. 14).

The diversion system requires a total of approximately 5,000 linear feet of excavation for the drainage ditch, 150 ft of 36-in conduit, and four reinforced concrete headwalls.

ECONOMIC ANALYSIS

METHODOLOGY

For comparing the results of different conditions, the flood damage assessment model used by Bethune and Tai (1987) is used in this investigation. This model uses standard relationships between depth and damage developed by the Federal Flood Insurance Administration in 1970. Stage/frequency data for various durations are the model input.

BENEFIT/COST ANALYSIS

Flood damages are calculated for the existing conditions, the unrestricted diversion conditions, and the modified southward diversion alternative as developed in Methods A and B, for 171 residences on the north shore of Lake Lowery. Structure and contents values for 1984 were used with a 5 percent appreciation (compounded annually) added to represent 1988 worth. The program computes flood damages for 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year floods, and Probable Maximum Flood (PMF) and then integrates these values to yield average annual damages. Average annual benefits are calculated by subtracting the average annual damages for the diversion conditions from the average annual damages for the existing conditions. The benefit/cost ratio is the ratio of average annual benefits to average annual project costs. The total cost of constructing the diversion system is estimated at $130,000. Assuming an annual discount rate of 8.5 percent, a project life of 50 years, and an operation and maintenance cost of $1,000 per year, the annual project cost is calculated as $12,300. A summary of the flood damage economics is given in Table 6. The annual benefit is based on simulated stages and durations developed under the allowable diversion criteria. The system alignment is selected to minimize environmental damage. It is assumed that a 30 cfs discharge will be made when Lake Lowery is at or above 130.00 ft NGVD, and diversion is allowed. However, the existing culvert under U.S. Highway 17/92 has a

Table 6. Flood damage economics summary					
Condition	Average annual project cost	Average annual damage	Average annual benefits	Average annual net benefit	Benefit/ cost ratio
Existing conditions		$64,700			
Unrestricted diversion	$12,300	$8,510	$56,200	$43,900	4.6
Allowable diversion (Method A)	$12,300	$13,600	$51,100	$38,800	4.2
Allowable diversion (Method B)	$12,300	$47,200	$17,500	$5,200	1.4

capacity of about 20 cfs. To achieve the design discharge capacity of 30 cfs it would be necessary to expand the existing culvert. This would increase the project's annual cost by approximately $3,400.00 and the benefit/cost ratio under Method B would reduce to 1.1 from 1.4. The need for expanding the existing culvert, however, would be determined at a later date based on flooding experience.

SUMMARY

A residential area located on the north shore of Lake Lowery, in north-central Polk County, experienced localized flooding (primarily septic system failures) during high stages in the lake. A water management study completed by the SJRWMD in 1987 (Bethune and Tai 1987) identified diversion of floodwaters from the lake into the upper Peace River basin located in the Southwest Florida Water Management District (SWFWMD) as the most cost effective of several flood control alternatives evaluated. This alternative assumes diversion of floodwaters up to a maximum rate of 125 cubic feet per second (cfs) whenever elevation in Lake Lowery exceeds 130.00 ft NGVD. The downstream impacts of such diversion were not evaluated by the 1987 study.

To limit the downstream impact of the proposed diversion, SWFWMD provided allowable discharge criteria. According to these criteria, a maximum diversion of 30 cfs is allowed whenever Lake Lowery exceeds 130.00 ft NGVD and at least one of the two receiving water bodies (i.e., Lake Henry or Lake Hamilton) is below its regulation schedule elevation. This report presents the results of a re-evaluation of the diversion alternative under the allowable discharge criteria.

Lake Lowery peak stages for the diversion alternative with the allowable discharge criteria were evaluated using two methods. The first method (Method A) modifies the previously generated long-term (56 years) simulated peak stage data to reflect diversion under allowable discharge criteria. Correction factors for modifying the simulated stages were established based on observed data for 1965-1984 (20 years). The second method (Method B) applies a 'worst case' approximation to estimate maximum elevations for different return periods. The two methods give the average annual damages as $13,640 and $47,200, respectively. The annual damages for the existing conditions were calculated as $64,700 and for the diversion alternative of the previous (1987) study as $8,510.

The annual cost of the diversion project, using an existing culvert under U.S. Highway 17/92, was calculated as $12,300. This leads to a project benefit/cost ratio of 4.2 for the results

obtained with Method A and 1.4 for Method B. The actual ratio may fall between these extremes.

The existing culvert under U.S. Highway 17/92, however, has a discharge capacity of about 20 cfs. To achieve the design discharge capacity of 30 cfs, it would be necessary to expand this culvert, which would increase the project's annual cost by approximately $3,400. This would reduce the benefit/cost ratio from 1.4 to 1.1 for the results under Method B. The need for expanding the existing culvert, however, would be determined at a later date based on flooding experience.

REFERENCES

Bethune, G. and C. C. Tai. 1987. Lake Lowery basin surface water management study. St. Johns River Water Management District Technical Publication SJ 87-5. Palatka, Fla.

Appendix A

REDUCTIONS IN PEAK ELEVATIONS FOR VARIOUS FLOOD DURATIONS
METHOD A

This appendix presents calculations of Cumulative Reduction in Peak Elevations and Annual Reduction in Peak Elevations for the modified southward diversion alternative conditions for the 7-day, 14-day, 30-day, 60-day, 120-day, and 183-day duration maximum elevations.

Table A1. Lake Lowery maximum stages which exceeded 130.00 ft NGVD continuously for a 7-day period

Diversion Year	Observed Elevations (ft NGVD)	Diversion Elevations (ft NGVD)	Cumulative Reduction in Peak (ft)	Annual Reduction in Peak (ft)
1969	130.46	130.11	0.35	0.35
1970	131.28	130.48	0.80	0.45
1971	130.57	129.25	1.32	0.52
1980	130.34	130.00	0.34	0.34
1981	130.05	129.71	0.34	0.00
1983	131.28	130.07	1.21	1.21
1984	131.20	129.88	1.32	0.11
Total				2.98
Average				0.43

Table A2. Lake Lowery maximum stages which exceeded 130.00 ft NGVD continuously for a 14-day period

Diversion Year	Observed Elevations	Diversion Elevations	Cumulative Reduction in Peak (ft)	Annual Reduction in Peak (ft)
1969	130.45	130.04	0.41	0.41
1970	131.26	130.47	0.79	0.38
1971	130.53	129.21	1.32	0.53
1980	130.32	129.99	0.33	0.33
1981	130.04	129.70	0.34	0.01
1983	131.26	130.03	1.23	1.23
1984	131.17	129.85	1.32	0.09
Total				2.98
Average				0.43

Table A3. Lake Lowery maximum stages which exceeded 130.00 ft NGVD continuously for a 30-day period

Diversion Year	Observed Elevations	Diversion Elevations	Cumulative Reduction in Peak (ft)	Annual Reduction in Peak (ft)
1969	130.38	129.96	0.42	0.42
1970	131.23	130.39	0.84	0.42
1971	130.44	129.12	1.32	0.48
1980	130.28	129.97	0.31	0.31
1981	130.02	129.68	0.34	0.03
1983	131.23	130.01	1.22	1.22
1984	131.13	129.81	1.32	0.10
Total				2.98
Average				0.43

Table A4. Lake Lowery maximum stages which exceeded 130.00 ft NGVD continuously for a 60-day period

Diversion Year	Observed Elevations	Diversion Elevations	Cumulative Reduction in Peak (ft)	Annual Reduction in Peak (ft)
1969	130.26	129.94	0.32	0.32
1970	131.16	130.30	0.86	0.54
1971	130.38	129.06	1.32	0.46
1980	130.26	129.95	0.31	0.31
1983	131.12	129.97	1.15	1.15
1984	131.11	129.79	1.32	0.17
Total				2.98
Average				0.43

Table A5. Lake Lowery maximum stages which exceeded 130.00 ft NGVD continuously for a 120-day period

Diversion Year	Observed Elevations	Diversion Elevations	Cumulative Reduction in Peak (ft)	Annual Reduction in Peak (ft)
1969	130.21	129.90	0.31	0.31
1970	131.06	130.22	0.84	0.53
1971	130.32	129.00	1.32	0.48
1980	130.21	129.90	0.31	0.31
1983	130.92	129.82	1.10	1.10
1984	131.04	129.72	1.32	0.22
Total				2.98
Average				0.43

Table A6. Lake Lowery maximum stages which exceeded 130.00 ft NGVD continuously for a 183-day period

Diversion Year	Observed Elevations	Diversion Elevations	Cumulative Reduction in Peak (ft)	Annual Reduction in Peak (ft)
1969	130.21	129.88	0.33	0.33
1970	130.94	130.11	0.83	0.50
1971	130.30	128.98	1.32	0.49
1980	130.19	129.89	0.30	0.30
1983	130.68	129.77	0.91	0.91
1984	131.03	129.70	1.33	0.42
Total				2.99
Average				0.43

Appendix B

PROBABILITY GRAPHS

This appendix presents probability graphs for the 7-day, 14-day, 30-day, 60-day, 120-day, and 183-day duration maximum elevations.

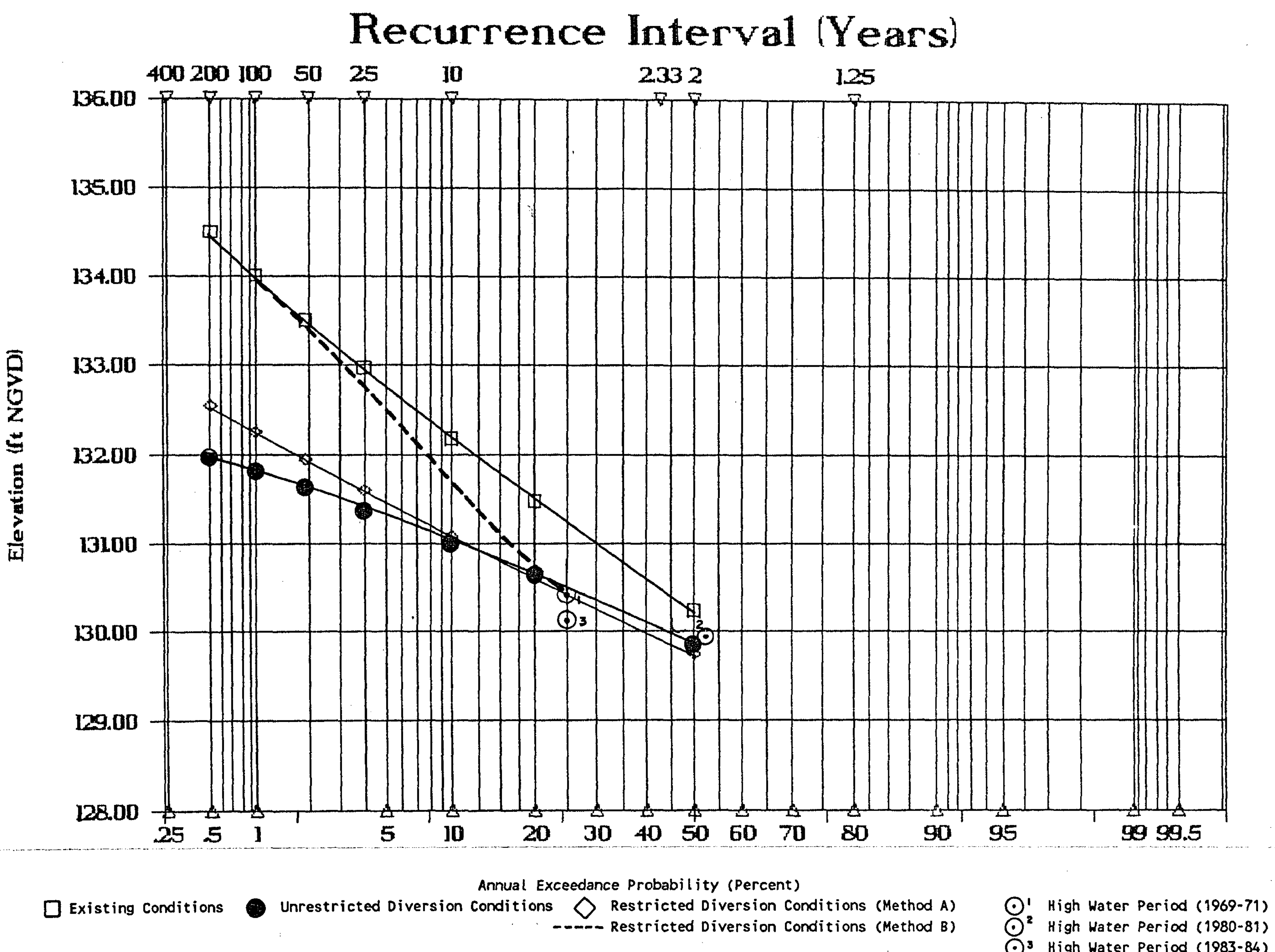


Figure B1. Elevation vs. frequency for 7-day duration

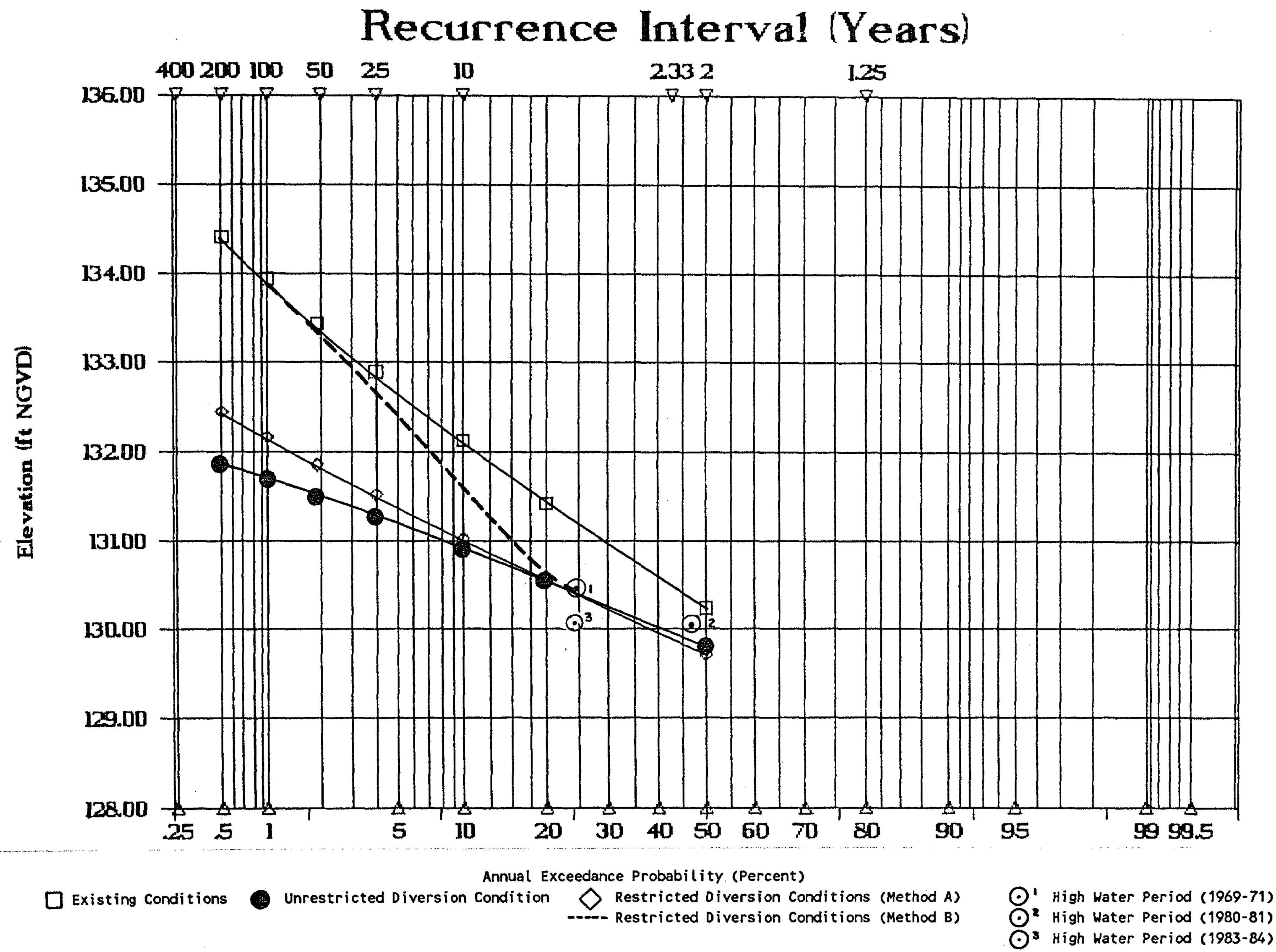


Figure B2. Elevation vs. frequency for 14-day duration

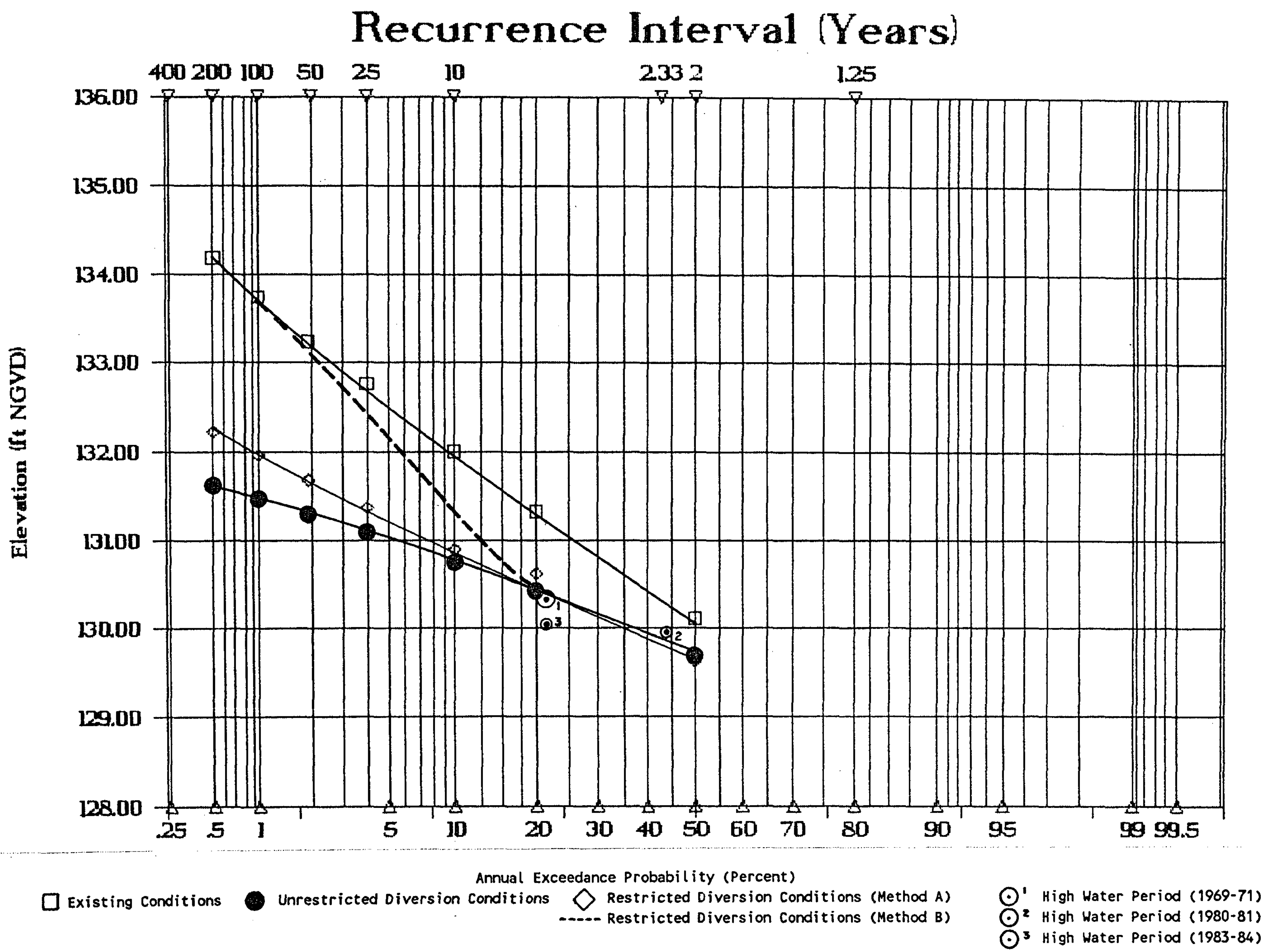


Figure B3. Elevation vs. frequency for 30-day duration

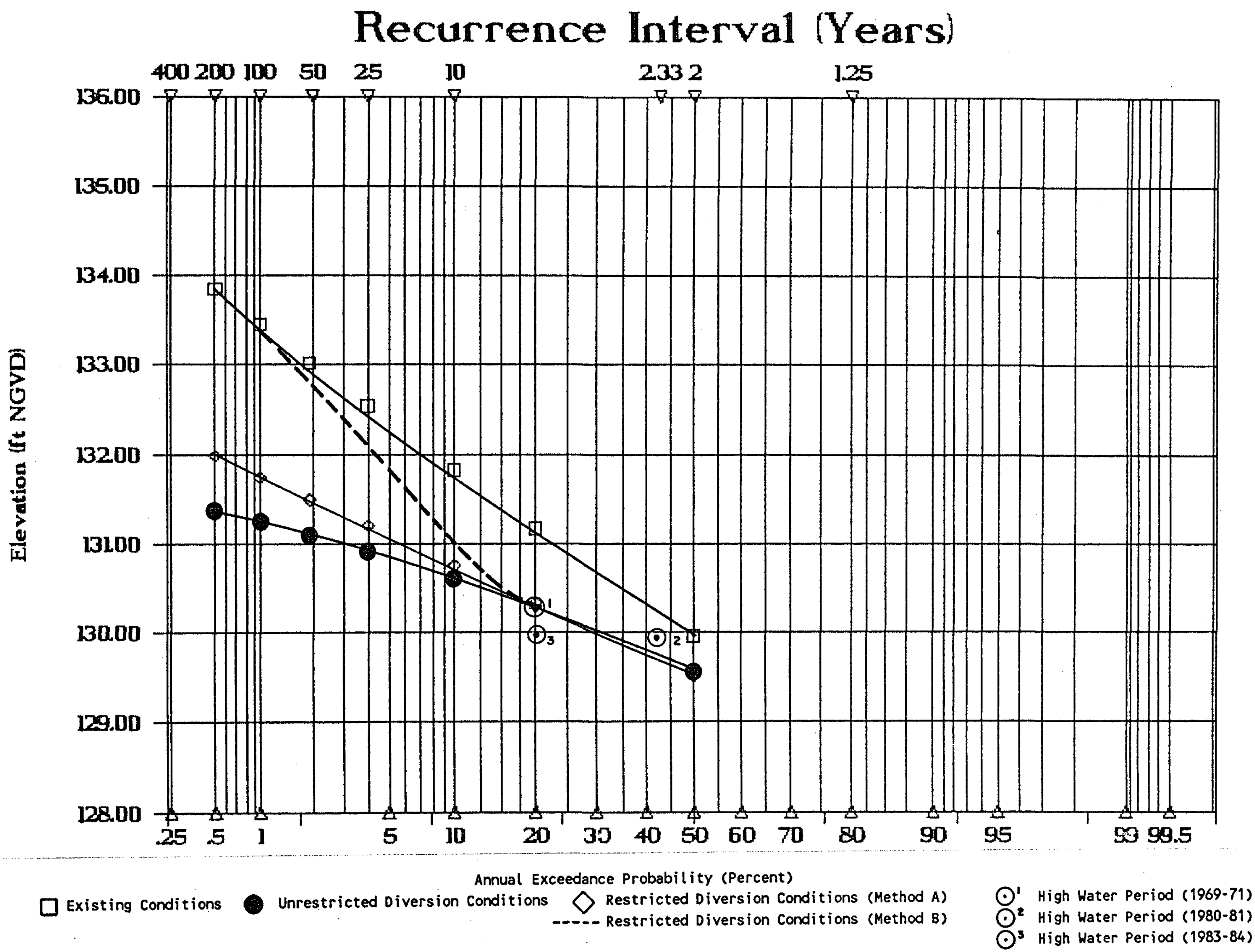


Figure B4. Elevation vs. frequency for 60-day duration

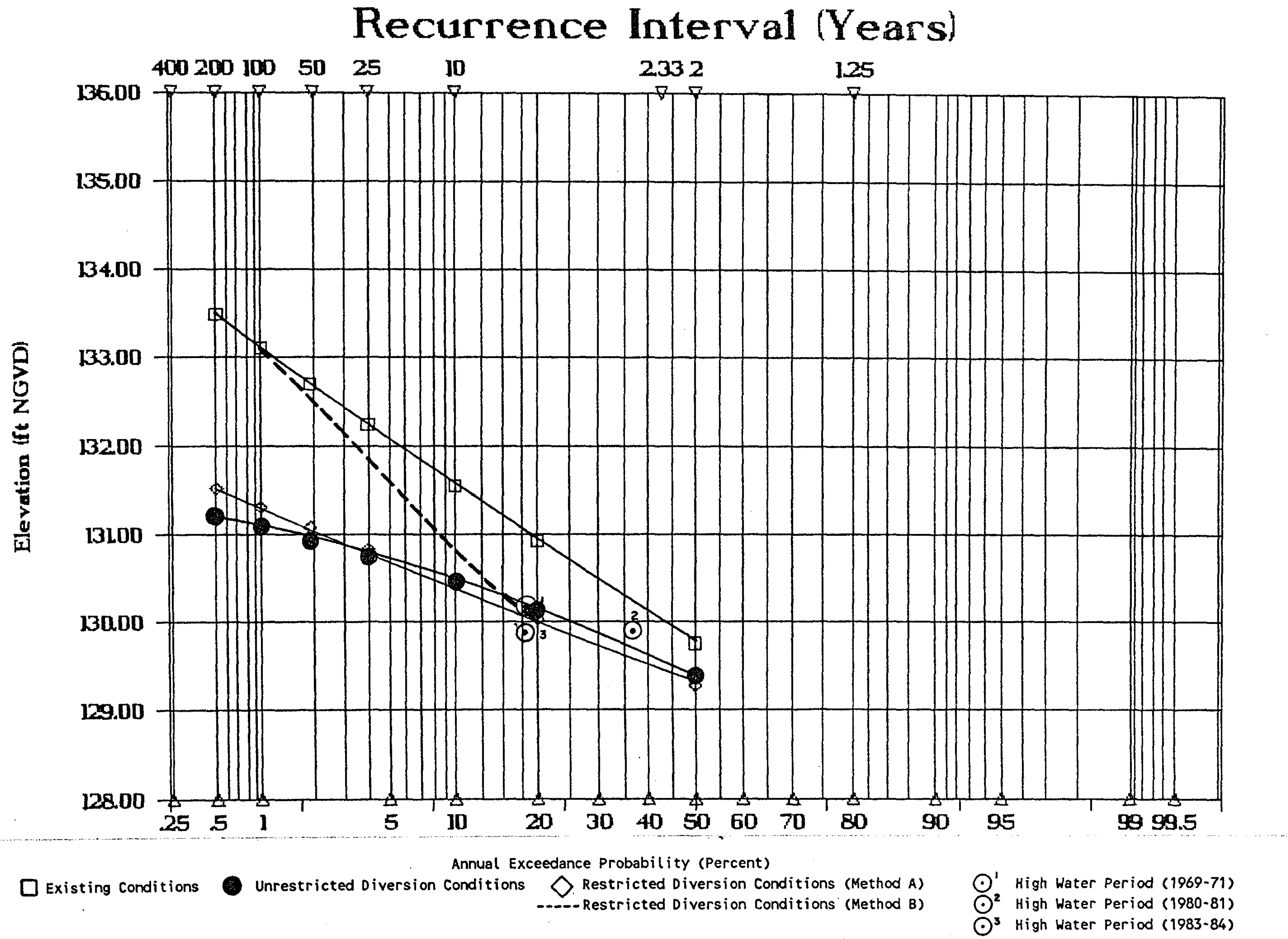


Figure B5. Elevation vs. frequency for 120-day duration

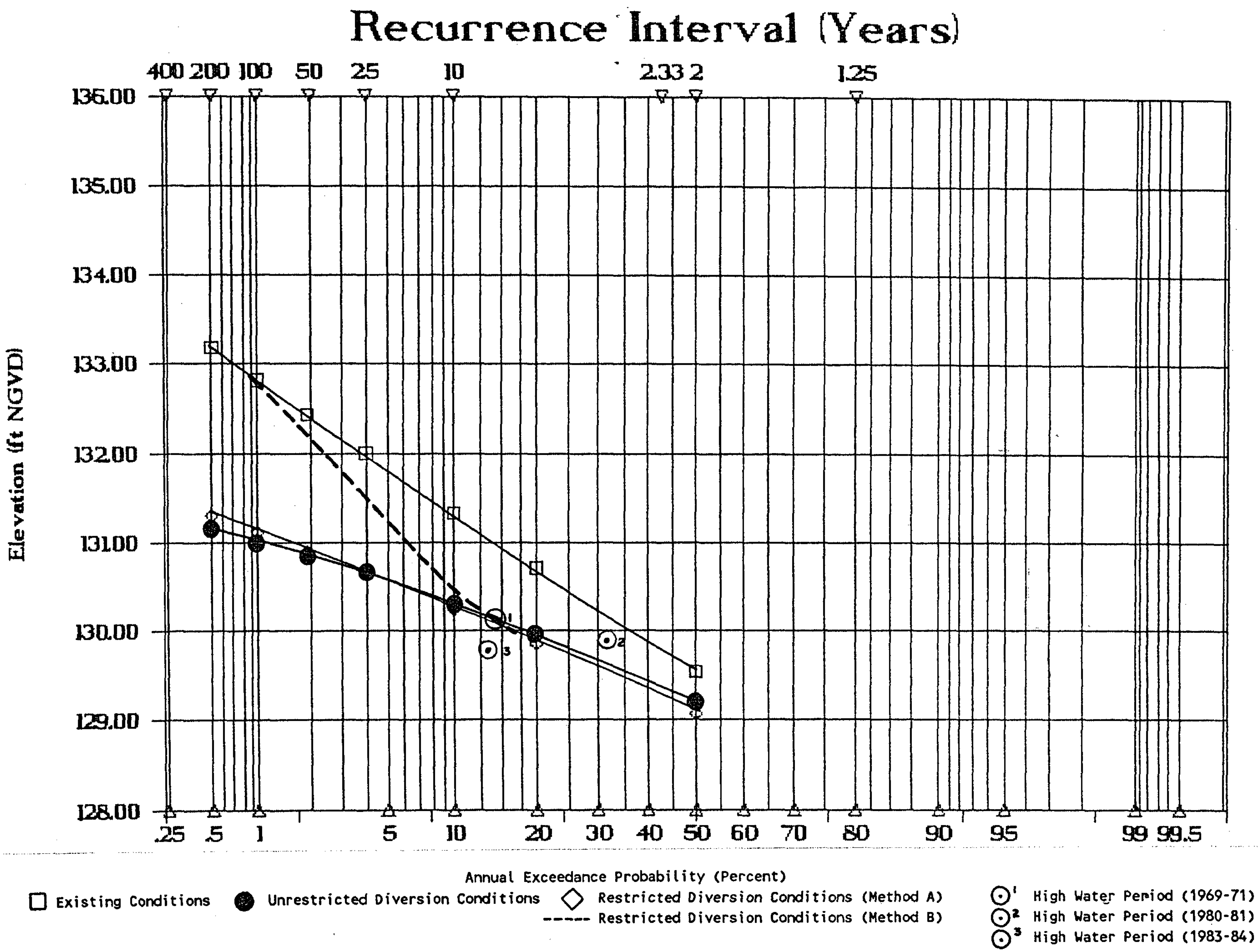


Figure B6. Elevation vs. frequency for 183-day duration

St. Johns River Water Management District
P. O. Box 1429
Palatka, Florida 32178-1429
(904) 328-8321