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UPPER OKLAWAHA RIVER BASIN WATER MANAGEMENT STUDY, PART 1: LAKE GRIFFIN REGION STUDY

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INTRODUCTION

PURPOSE AND SCOPE

This Part I study report is part of a comprehensive surface water management study for the Upper Oklawaha River Basin being conducted by the St. Johns River Water Management District. The Upper Oklawaha River Basin includes all of the Oklawaha River Drainage Basin south of the Moss Bluff Spillway, covering portions of Marion, Lake, Orange, and Polk Counties (Figure 1).

The purpose of the Oklawaha River Basin Surface Water Management Study is to investigate with mathematical models the response of the lake levels to various storm events and water management alternatives. These models will be used specifically to 1) evaluate the present adopted lake level regulation range; 2) develop a procedures manual for emergency structure operation; and 3) improve understanding of the hydrology of the Upper Oklawaha River Basin.

For study convenience, the Upper Oklawaha Basin has been divided into four regions:

1. Lake Griffin Region: This region includes all the drainage area between Burrell and Moss Bluff water control structures and also receives streamflow from upstream basins at the Burrell water control structure.
2. Middle Reach Region: This region consists of Lakes Eustis, Harris, and Beauclair, and also the immediate runoff basins, and receives streamflow from the Palatlakaha Basin and the Lake Apopka Basin through the Apopka-Beauclair water control structure.
3. Lake Apopka Basin Region
4. Palatlakaha Basin Region

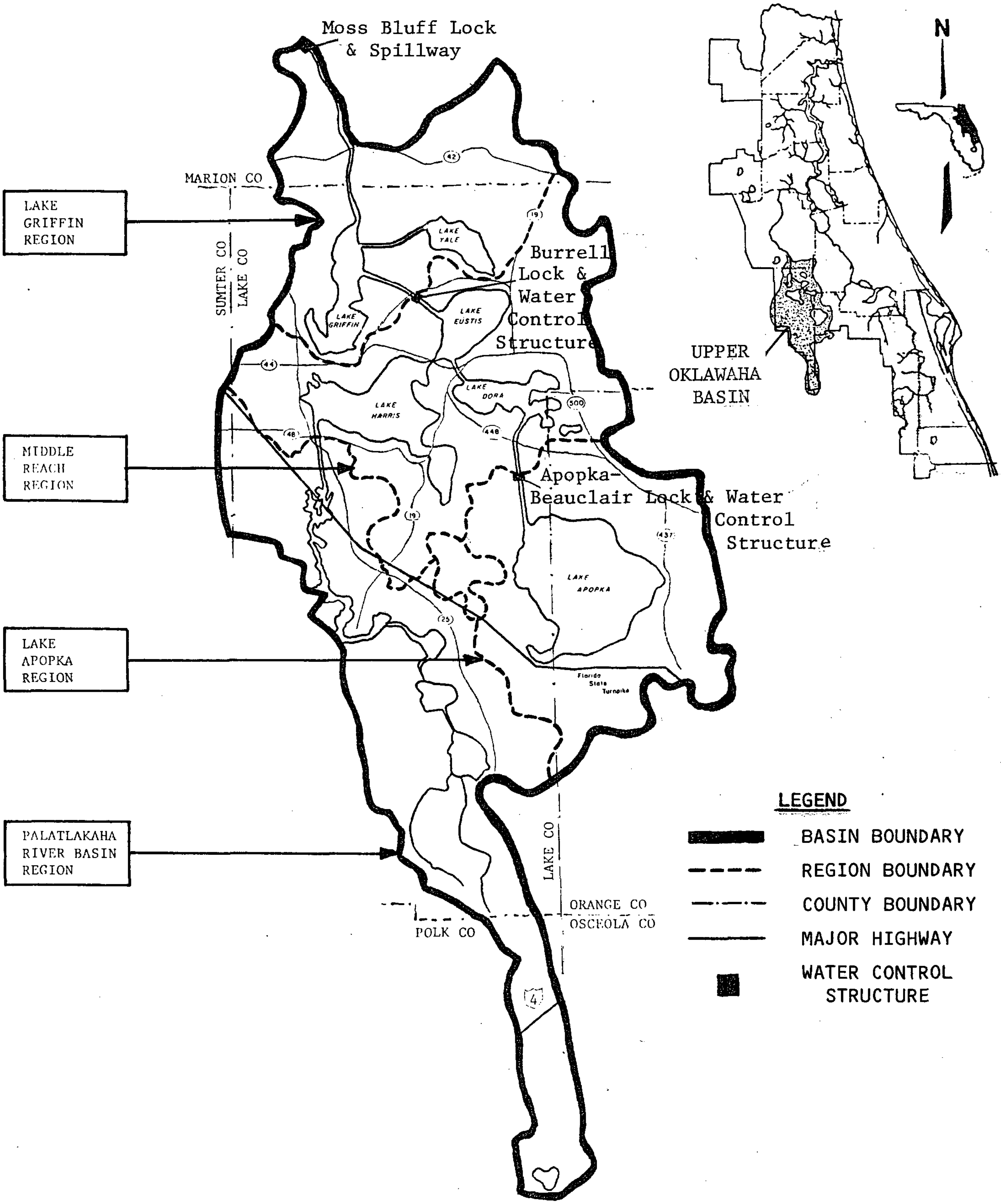


FIGURE 1. -- Upper Oklawaha River Drainage Basin

This Part I study report covers only the Lake Griffin Region. Additional reports for other regions will be published as each phase of the project is completed.

BACKGROUND

The outflow from the Lake Griffin Region is controlled by the Moss Bluff Spillway which is located on the Oklawaha River 12 miles downstream from Lake Griffin. This structure essentially controls the water surface elevation of Lake Griffin which is currently regulated to allow a narrow fluctuation range of 1.50 feet, from 58.0 to 59.50 feet msl (Figure 2). This fluctuation range is designed to facilitate navigation and to provide limited flood water storage capacity.

Because of the shallow nature of the lake, any minor change in water surface elevation beyond the specified operating range would either create flooding to water front properties or cause navigation problems. Specifically, when the water level reaches or exceeds 60.0 feet msl, some shoreline properties will be inundated; and if the water level falls below 58.0 feet msl, many areas become too shallow for normal boating activities.

This narrow fluctuation range has limited the storm runoff storage capacity of the lake; and consequently, the system cannot be operated effectively to provide necessary flood control benefit without a very delicate monitoring and operation procedure. The currently adopted operation schedule with rainy season regulation stage of 58.50 feet msl may not be adequate to prevent flooding to shoreline properties upstream and to reduce stages downstream of the Moss Bluff Spillway. Additionally, the 58.50 feet msl stage is maintained only in June and July, while some of the largest recorded storms have occurred during other months (most frequently in September and October) when the stage is somewhat higher.

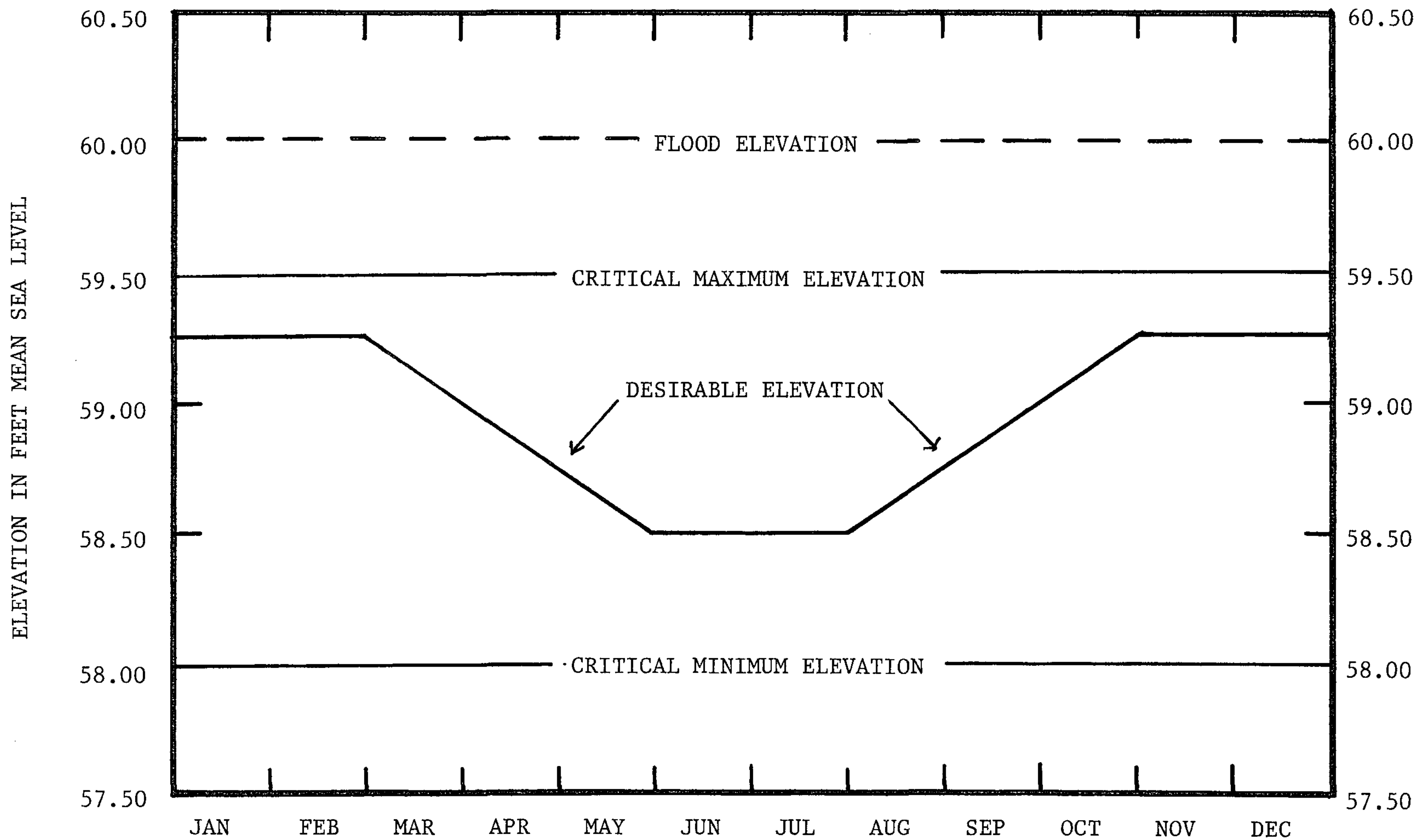


FIGURE 2. -- Regulation Schedule for Lake Griffin

The fluctuation of the water level within such a narrow range has also caused environmental concerns in the lakes regions. Suggestions have been made by environmental groups to consider a wider range of fluctuation. A comprehensive study of the lake regulation schedules will be conducted in the future to include all environmental issues, but this report will discuss only the adequacy of the Moss Bluff structure and the storage capacities of Lake Griffin and related areas for reducing flooding stages and duration within the Lake Griffin Region and the Middle Oklawaha River Basin (from Moss Bluff Spillway to Silver Springs).

LAKE GRIFFIN REGION DRAINAGE BASIN HYDROLOGY

PHYSIOGRAPHY

The Lake Griffin Region, a lower portion of the Upper Oklawaha River Basin, is located in Lake and Marion Counties of central peninsular Florida (Figure 1). The total drainage area of the region is approximately 159 square miles of which 30 percent or 48 square miles is open water area consisting of a number of lakes. Lake Griffin, the largest lake in this region, is also the last of the so-called Upper Oklawaha Chain of Lakes. This lake, serving as the region's major receiving water body, is a very shallow but elongated water body with surface area of about 16.7 square miles at 58.50 feet msl.

The total drainage area between the Burrell structure and Moss Bluff Spillway is approximately 97 square miles excluding the Lake Yale basin. Two major tributaries, Haines Creek and the Yale-Griffin Canal, discharge directly into Lake Griffin. Haines Creek receives discharge from upstream basins at Burrell structure. The Yale-Griffin Canal connects the two lakes and delivers flow into Lake Griffin.

Most land surface areas around the lakes and river are low lying wetland and have been developed for agricultural production, predominantly truck farms. In most such areas, drainage systems with perimeter levee and pump stations were constructed to provide flood protection. Most upland areas or ridges were developed for citrus groves with most of them requiring only minimal drainage. There is urban or community development all over the region, both in water front and ridge areas.

CLIMATE

The region is included by the National Oceanographic and Atmospheric Administration (NOAA) in the north central climatic division of Florida. Generally, the climate in this region is sub-tropical with very long, warm and humid summers and mild, dry winters.

There are a total of four(4) rainfall stations throughout this region (Figure 3), of which only the Lisbon station is a NOAA climatological station which also reports temperature and pan evaporation. The other three(3) stations are maintained by the St. Johns River Water Management District. The mean monthly temperature, rainfall, and evaporation using data recorded at Lisbon from 1959 to 1978 are included in Table 1 to indicate the region's general climatic conditions. The overall rainfall data for the Upper Oklawaha Basin indicates that, for the period 1959 to 1978, the average rainfall was 49.3 inches, ranging from 51.4 inches at Clermont to 47.2 inches at Lisbon. The areal variations in the Lake Griffin Region cannot be defined due to lack of long term records. The monthly rainfall distribution, as shown in Table 1, indicates that 60 percent of annual rainfall occurs during the five-month rainy season, May through September. All available rainfall data were used to derive the rainfall depth-frequency relation. The summary of such relations is shown in Table 2.

LAND USE AND HYDROLOGICAL SOIL GROUP

Lake Griffin, Emeralda Marsh, and the other directly connected marsh areas cover a total area of about 24.6 square miles at elevation 59.0 feet msl in this 159-square mile region. The remainder of the watershed, covering a total drainage area of 135 square miles was divided into 25 sub-basins as shown in Figure 3. Sub-basin 25, a 62-square mile area, is the Lake Yale drainage basin wherein Lake Yale itself accounts for 6.3 square miles of surface area. However, this basin was treated as a point source for modeling since outflow from the lake is controlled.

A general land use map (Figures 4A and 4B) was developed based on the following six major land use types recognized in this region:

1. Urban - Open - Recreational
2. Agricultural - (citrus-farm)
3. Range Land

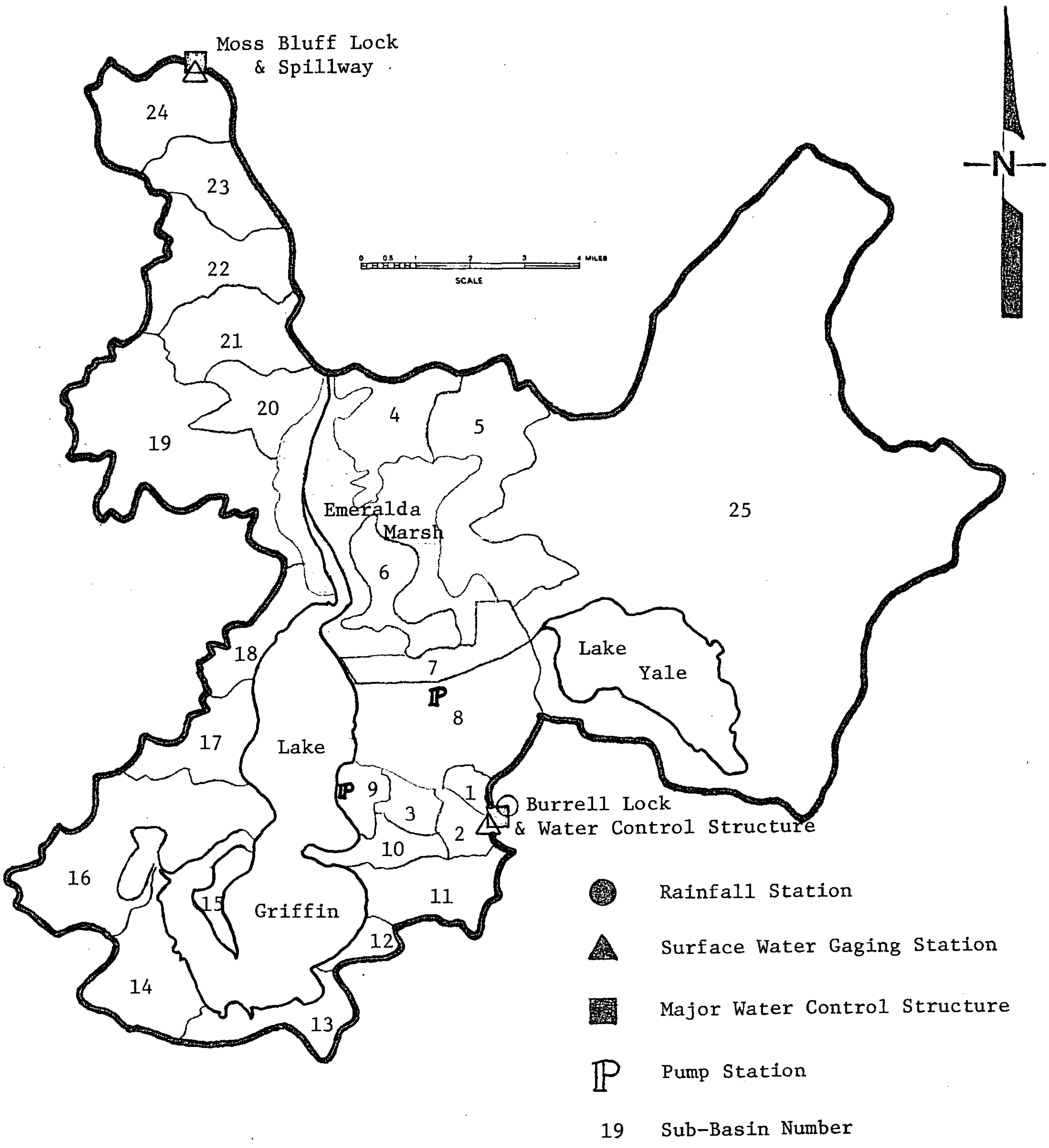


FIGURE 3. -- Lake Griffin Region Drainage Basin and Sub-Basin Delineation

TABLE 1. -- Mean Monthly Temperature, Precipitation, and Pan Evaporation for the Lake Griffin Region, Recorded at NOAA Lisbon Climatological Data Station

Month	Temperature, ° Fahrenheit (1959-1978)	Precipitation, Inches (1959-1978)	Pan Evaporation, Inches (1960-1978)
January	58.7	2.65	2.73
February	59.8	3.78	3.28
March	65.5	3.75	5.00
April	70.9	2.05	6.59
May	76.2	3.69	6.74
June	79.9	5.67	6.58
July	81.8	6.68	6.50
August	81.3	6.77	5.99
September	79.6	5.12	5.09
October	73.6	2.72	4.55
November	65.6	1.57	3.24
December	60.1	2.75	2.76
Annual Average	71.1	--	--
Annual Total	--	47.19	59.06

TABLE 2. -- Storm Rainfall Data for Lake Griffin Region

a) Point Rainfalls in the Study Area, Inches

	Return Period, Years					
Duration	2	5	10	25	50	100
24-Hours	4.6	6.1	7.1	8.1	9.1	10.1
2 - Days	5.2	6.9	8.0	9.3	10.8	12.0
4 - Days	6.3	8.0	9.4	11.0	12.8	14.8

b) Areal Rainfalls in the Study Area, Inches
(Watershed Area = 159 Square Miles)

	Return Period, Years					
Duration	2	5	10	25	50	100
24-Hours	4.27	5.66	6.59	7.52	8.44	9.37
2 - Days	4.91	6.52	7.56	8.79	10.21	11.34
4 - Days	6.02	7.64	8.98	10.50	12.22	14.13

c) Assumed Rainfall Distribution for a 4-Day Storm, Inches

	Return Period, Years					
Day	2	5	10	25	50	100
1st Day	4.27	5.66	6.59	7.52	8.44	9.37
2nd Day	0.64	0.86	0.97	1.27	1.77	1.97
3-4 Days	1.11	1.12	1.42	1.71	2.01	2.79
Total	6.02	7.64	8.98	10.50	12.22	14.13

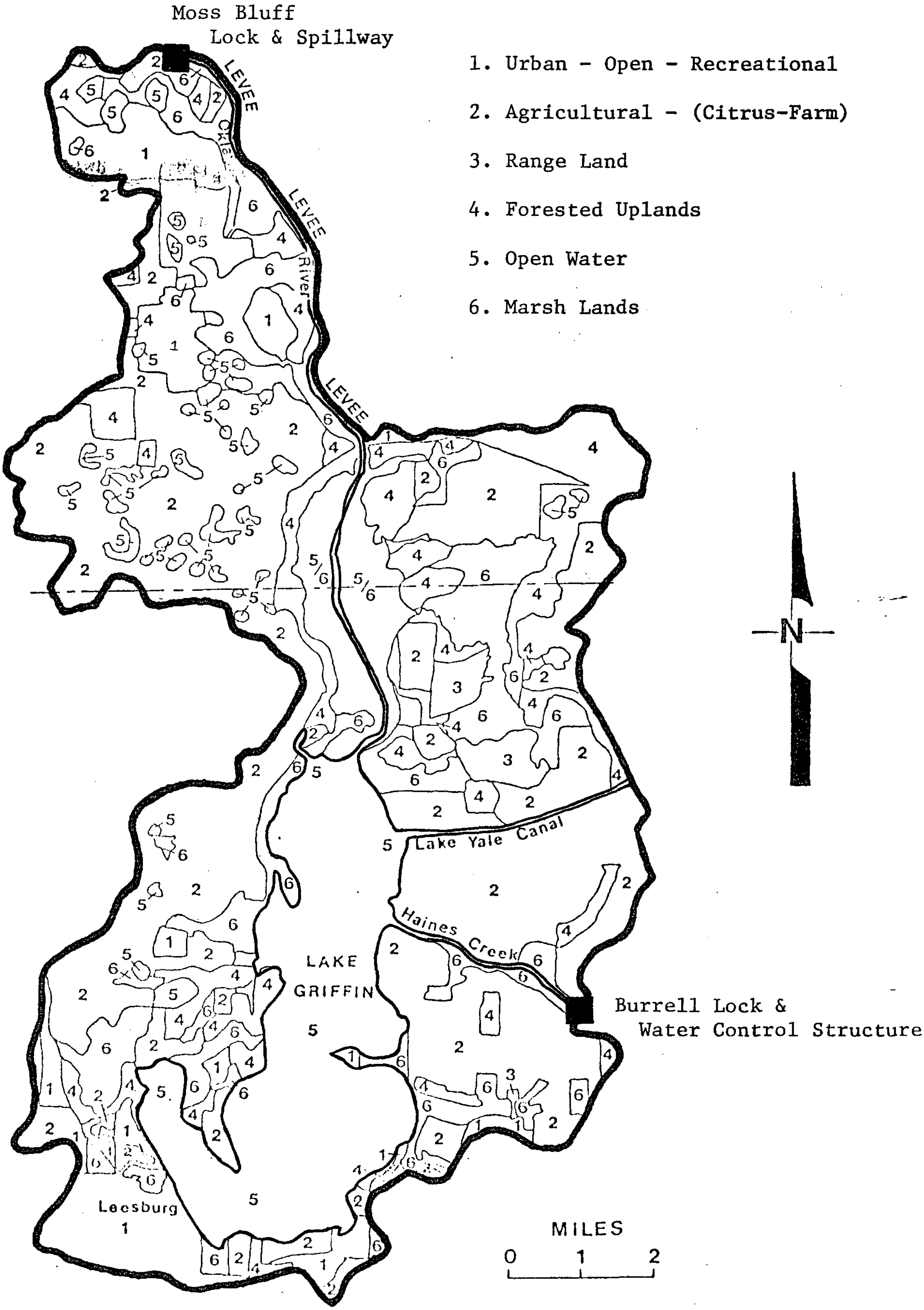


FIGURE 4A.-- Lake Griffin Region, Generalized Land Use Map

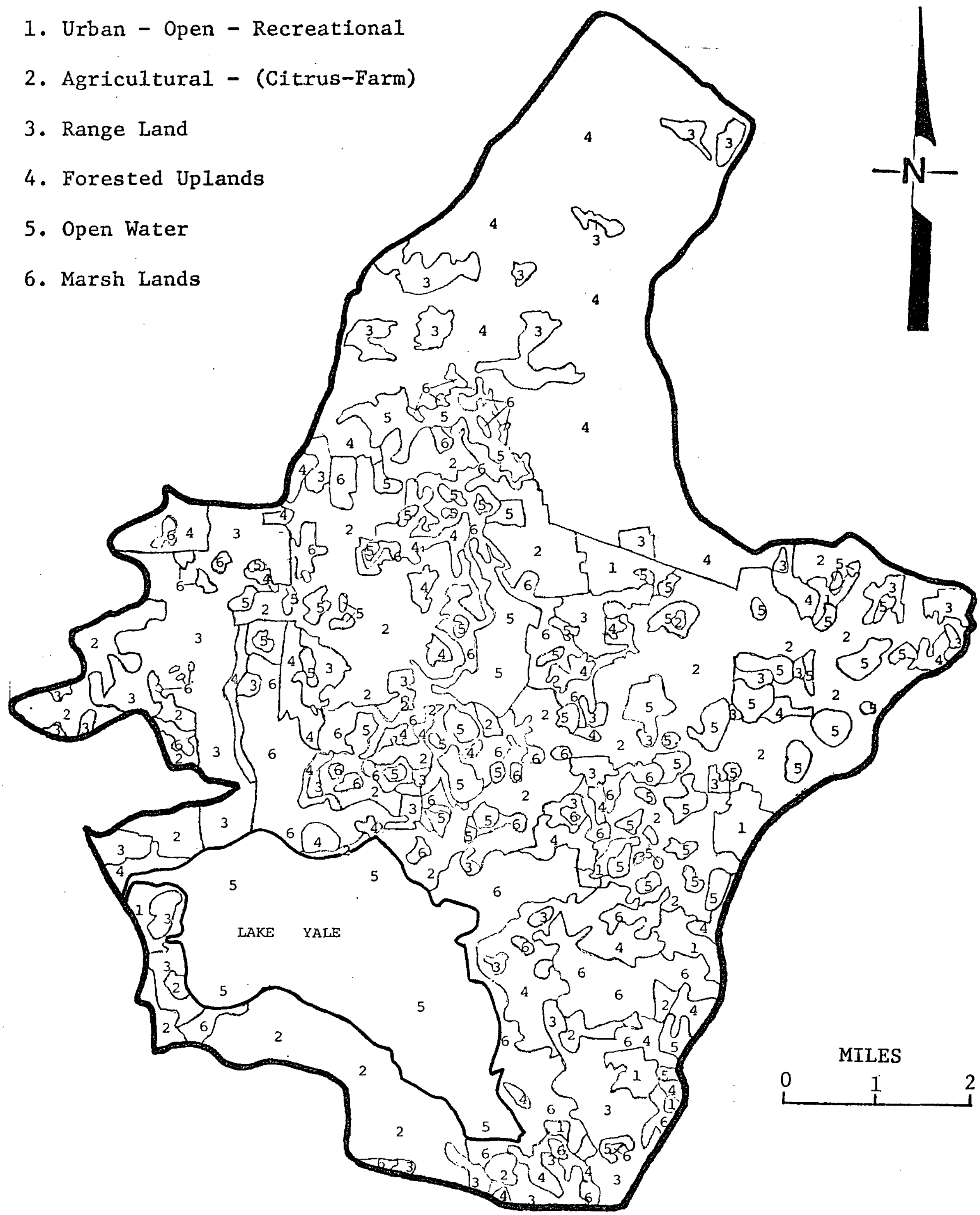


FIGURE 4B. -- Lake Griffin Region (Lake Yale Basin) Generalized Land Use Map

4. Forested Uplands

5. Open Water

6. Marsh Lands

A generalized soil map, Figure 5 for this region, shows that the soils in this region fall into the following six associations:

Soil Type	Hydrologic Soil Group
Astatula - Apopka Association	A
Sparr - Lochloosa - Tavares Association	A/D
Myakka - Placid - Swamp Association	A/D
Tavares - Myakka Association	A/D
Anclote - Iberia Association	D
Montverde - Ocoee - Bringhton Association	A/D

Each association can be translated into U. S. Soil Conservation Service hydrologic soil group. Such a hydrological soil group system was used to estimate runoff from each soil type. Two hydrological soil groups for an association such as A/D indicate the drained/undrained situation.

The land areas in each of the 25-sub-basins were divided into smaller elements, and areas were calculated according to land use type and hydrological soil classification as shown in Table 3. The SCS runoff curve number based on these criteria is presented in Table 4 to facilitate runoff simulation. Additionally, the hydraulic length and average slope of the basin were determined, as shown in Table 4, to complete basic input data needed for runoff hydrograph generation.

SURFACE WATER

The main streamflow in this region, beginning at Burrell structure, follows Haines Creek, and then empties into Lake Griffin, which, in turn, is drained by the Oklawaha River. The flow in the Oklawaha River enters the Middle Oklawaha River

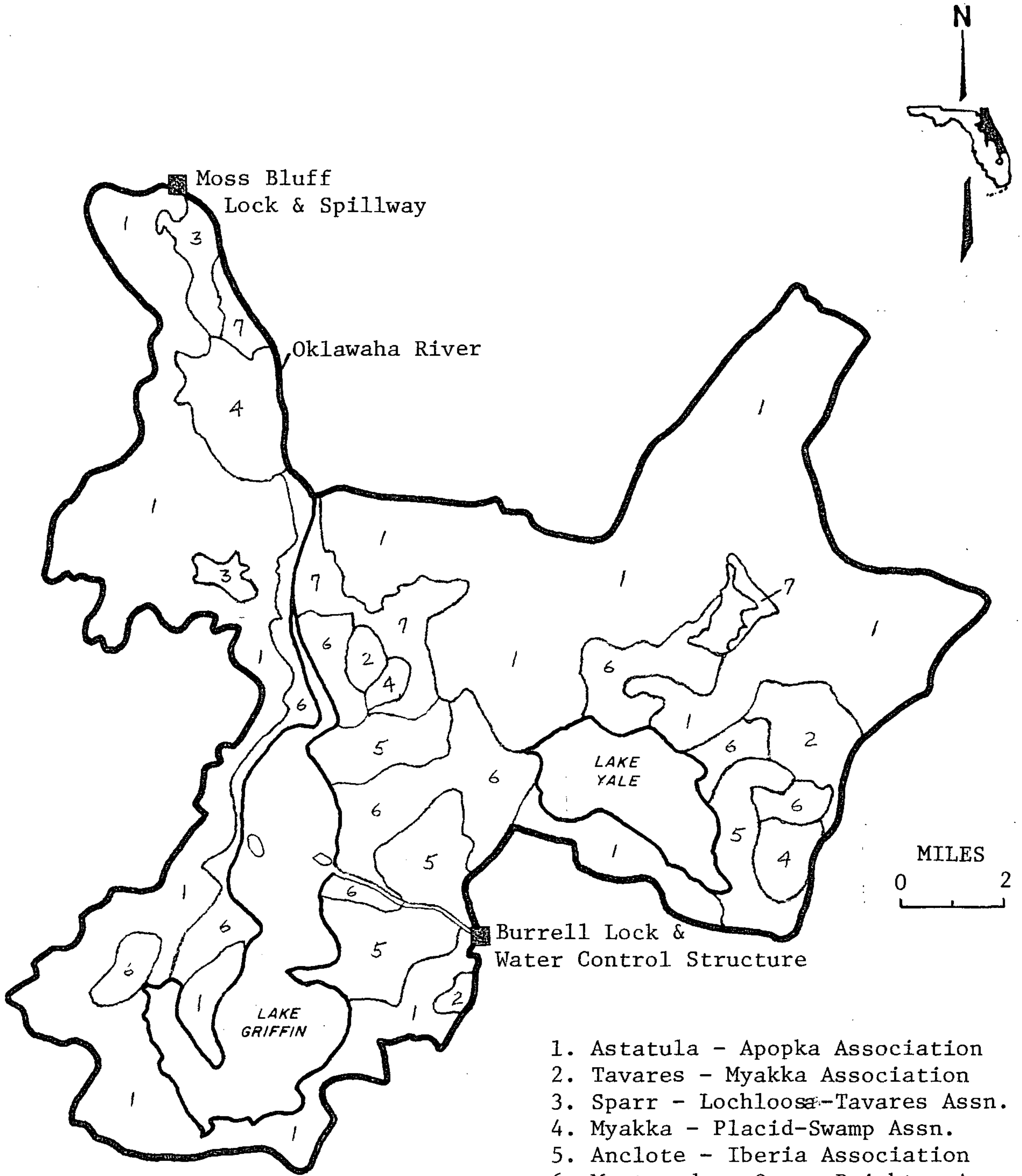


FIGURE 5. -- Lake Griffin Region, Generalized Soil Map

TABLE 3. -- Sub-basin Land Use and Soil Type Summary
(Land Area in Acres)

Hydrological Soil Group	Urban-Open Recreational	Agricultural-Citrus	Range Land	Forested Upland	Open Water	Marsh Land
	1	2	3	4	5	6
		Sub-basin No. 1 (331 Acres)				
D		132				199
		Sub-basin No. 2 (600 Acres)				
A		330				
D		270				
		Sub-basin No. 3 (447 Acres)				
A/D						31
D		268		54		94
		Sub-basin No. 4 (2351 Acres)				
A		1157		578		193
A/D	21			402		
		Sub-basin No. 5 (4879 Acres)				
A		1072	976	2440	293	98
		Sub-basin No. 6 (1896 Acres)				
A/D		284	379	284		
D		190	522	237		

TABLE 3. (continued)

H.S.G.	1	2	3	4	5	6
		Sub-basin No. 7 (1421 Acres)				
A		57		57		
A/D		1080		57		
D		170				
		Sub-basin No. 8 (3920 Acres)				
A/D		1897		259		
D		1711		53		
		Sub-basin No. 9 (611 Acres)				
A/D		214				
D		397				
		Sub-basin No. 10 (830 Acres)				
A		66				
D	42	597		42		83
		Sub-basin No. 11 (1892 Acres)				
A	222	590	44	177		442
A/D		114		91		23
D		123		19		47
		Sub-basin No. 12 (432 Acres)				
A	129			173		130
		Sub-basin No. 13 (1391 Acres)				
A	557	417		139		278

TABLE 3. (continued)

H.S.G.	1	2	3	4	5	6
		Sub-basin No. 14 (2116 Acres)				
A	1714	148				254
		Sub-basin No. 15 (522 Acres)				
A	78	172		209		63
		Sub-basin No. 16 (4186 Acres)				
A	214	1802		158	110	402
A/D		479		719	60	242
		Sub-basin No. 17 (1586 Acres)				
A		951				
A/D		159				476
		Sub-basin No. 18 (1263 Acres)				
A		821		133		
A/D						309
		Sub-basin No. 19 (6051 Acres)				
A		3768		786	949	90
A/D		229			229	
		Sub-basin No. 20 (1559 Acres)				
A		956		206	110	103
A/D				184		
		Sub-basin No. 21 (2114 Acres)				
A	381	381			190	
A/D	349	174		116	174	349

TABLE 3. (continued)

H.S.G.	1	2	3	4	5	6
		Sub-basin No. 22 (2164 Acres)				
A	535	244		98	98	
A/D	179			119	60	831
		Sub-basin No. 23 (1645 Acres)				
A	431	69		75		
A/D	480			258	11	321
		Sub-basin No. 24 (2296 Acres)				
A	803	161		401	201	40
A/D		206		104	104	276
		Sub-basin No. 25 (39,680 Acres)				
A	1008	10150	3548	6341	2024	2278
A/D	259	1877	520	1123	1500	2254
D			326	1325		1103
Lake Yale						4044

TABLE 4. -- Input Data for Sub-basin Runoff Simulation

Sub-basin Number	Area Mi.^{2}	Weighted Runoff Curve Number	Hydraulic Length, Feet	Average Slope, Ft./Ft.	Time of Concentration, Hours
01	.517	80	3,300	.0060	1.9
02	.938	79	4,290	.0050	2.7
03	.698	79	2,640	.0060	1.7
04	3.67	78	9,900	.0010	12.0
05	7.62	78	9,900	.0080	4.4
06	2.96	79	3,300	.0050	2.2
07	2.22	78	12,500	.0004	23.0
08	6.13	78	7,000	.0003	16.8
09	.955	78	7,140	.0007	11.2
10	1.30	78	6,600	.0020	6.2
11	2.96	64	18,500	.0008	34.7
12	.675	66	4,950	.0060	4.2
13	2.17	67	8,250	.0240	2.9
14	3.31	66	13,200	.0020	15.8
15	.816	61	1,650	.0120	1.4
16	6.54	73	13,200	.0070	7.2
17	2.48	72	9,075	.0070	5.4
18	1.97	66	4,125	.0145	2.3
19	9.45	70	23,100	.0020	22.2
20	2.44	66	13,200	.0070	8.3
21	3.30	69	19,010	.0050	12.5
22	3.38	72	16,530	.0070	8.6
23	2.57	71	9,926	.0080	5.5
24	3.59	68	18,100	.0040	13.5
25	62.0	(This basin was treated as a point source.)			
	134.7				

Total Area of Sub-basins	134.7 Mi.^{2}
Lake Griffin and Marsh Areas	24.6 Mi.^{2}
Total Region Area	159.3 Mi.^{2}

Basin through the Moss Bluff Spillway. Since the hydraulic gradient throughout this entire flow system is extremely slight, the system termed the Lake Griffin system can be considered as a connected reservoir system for hydraulic considerations. A general flow system diagram is included in Figure 6.

Inflow into Lake Griffin consists of runoff from the surrounding drainage area, structural discharges from the Burrell structure, and the contribution from Lake Yale. Outflow and lake elevations are controlled by the Moss Bluff Spillway. The channel between the Starkes Ferry Bridge and Moss Bluff Spillway is diked in the east, but is directly connected to floodplain and marshes in the west. The runoff from drainage basins east of the channel is collected in a secondary channel east of the dike and discharged into the river downstream of Moss Bluff Spillway, and therefore, does not affect the study area.

Ground water exchange with the Floridan aquifer has not been included in this study because the water surface elevation of Lake Griffin is almost always near the potentiometric level of the Floridan aquifer in this area. The U. S. Geological Survey has estimated that the average annual recharge to the aquifer is approximately two inches. Such a small amount has very little impact on storm runoff. The historical records generally indicate that the water level of the Lake Griffin system is essentially that of the Leesburg gage due to the very slight hydraulic gradient in the region. During periods of large inflow and outflow, the differential water surface elevation between downstream of the Burrell structure and upstream of the Moss Bluff Spillway was rather moderate, on the order of about one foot. Large gate openings at Moss Bluff Spillway do cause a drawdown curve in the channel, but its effect is felt only a few hundred feet upstream. Strong winds are known to have affected the water levels by almost one-half foot. Therefore, during the low flow periods, the lake and river system between Moss Bluff Spillway and Burrell water control structure could be basically a single reservoir with an outlet at

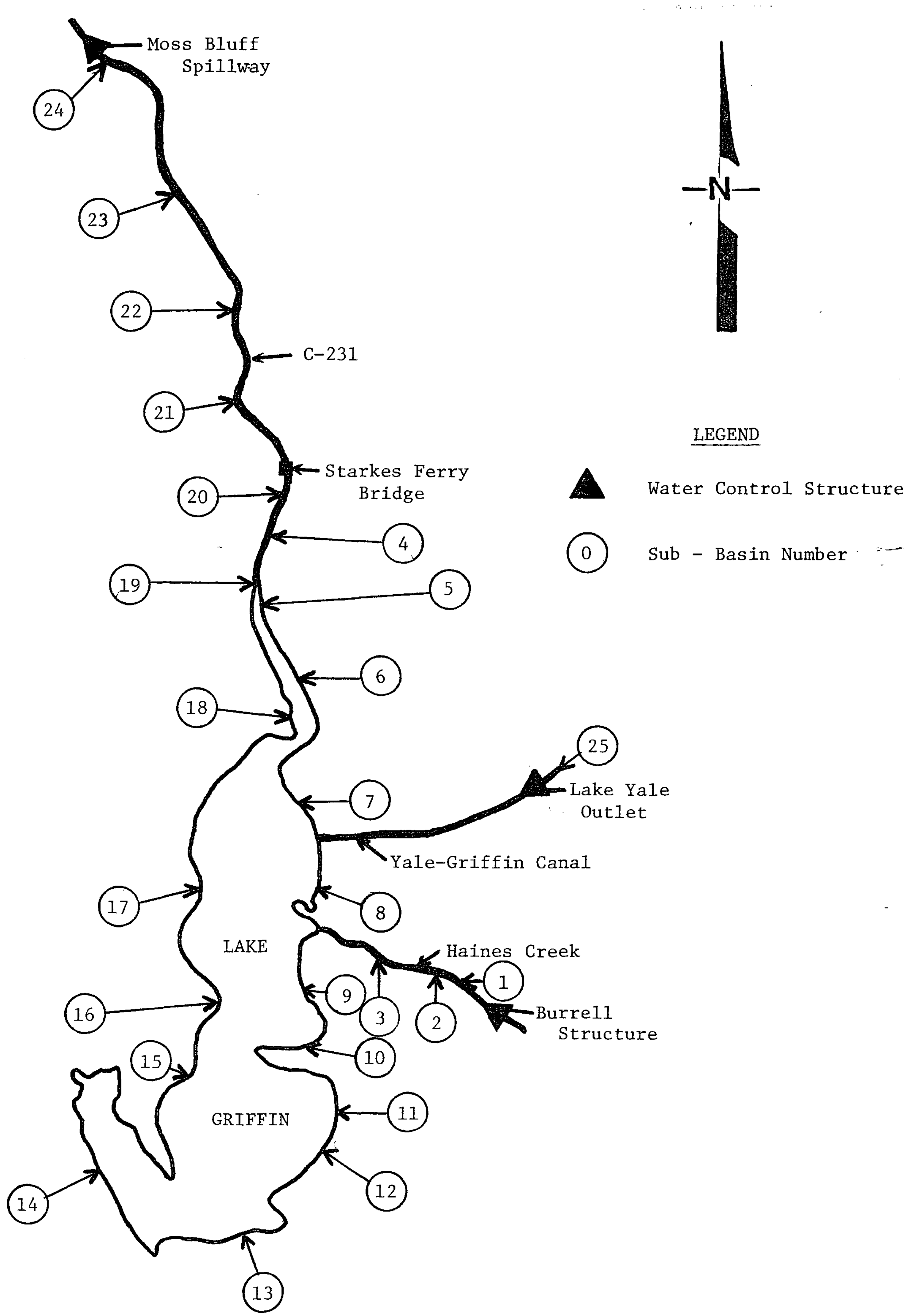
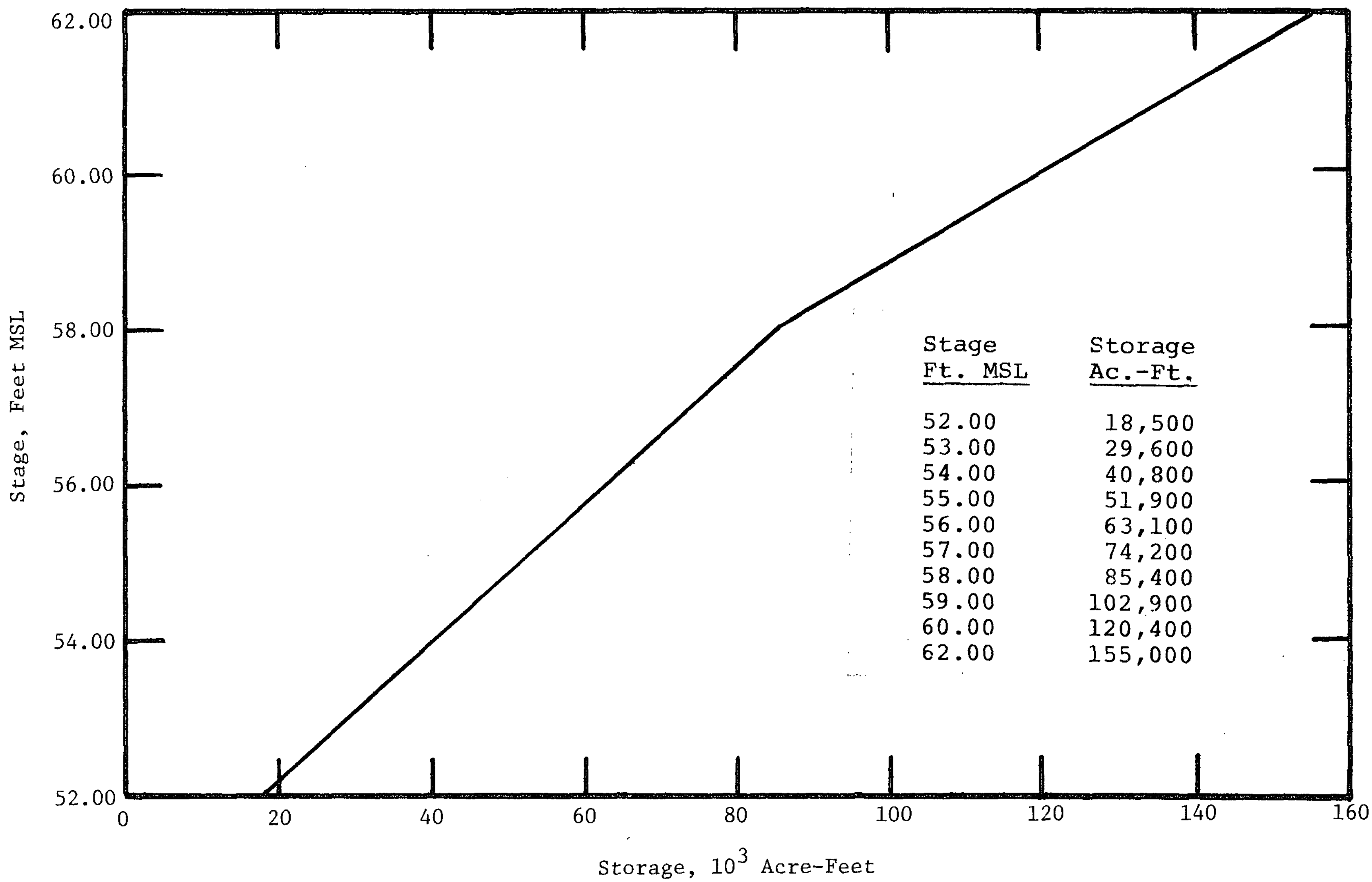


FIGURE 6. -- Lake Griffin With Its Contributary Sub-Basins Flow Diagram

Moss Bluff Spillway. A stage storage curve for the Lake Griffin system is included in Figure 7. The rating curves for the two gated structures (20 feet wide x 12.4 feet high with sill elevation at 48.10 msl) at Moss Bluff Spillway are shown in Figure 8 (also Table 5).

Table 6 is a summary of surface water gaging station records for the Lake Griffin Region, including one station immediately upstream of the Burrell water control structure at Lisbon. The monthly stage for Lake Griffin at Leesburg and Lake Yale at Grand Island are shown in Figures 9 and 10. Tables 7 and 8 show the highest elevations which occurred for different periods each year in Lake Yale and Lake Griffin, respectively. Since these stages are generally controlled, a frequency analysis of this data will not be meaningful.



Stage Ft. MSL	Storage Ac.-Ft.
52.00	18,500
53.00	29,600
54.00	40,800
55.00	51,900
56.00	63,100
57.00	74,200
58.00	85,400
59.00	102,900
60.00	120,400
62.00	155,000

FIGURE 7. -- Stage-Storage Relation for Lake Griffin System

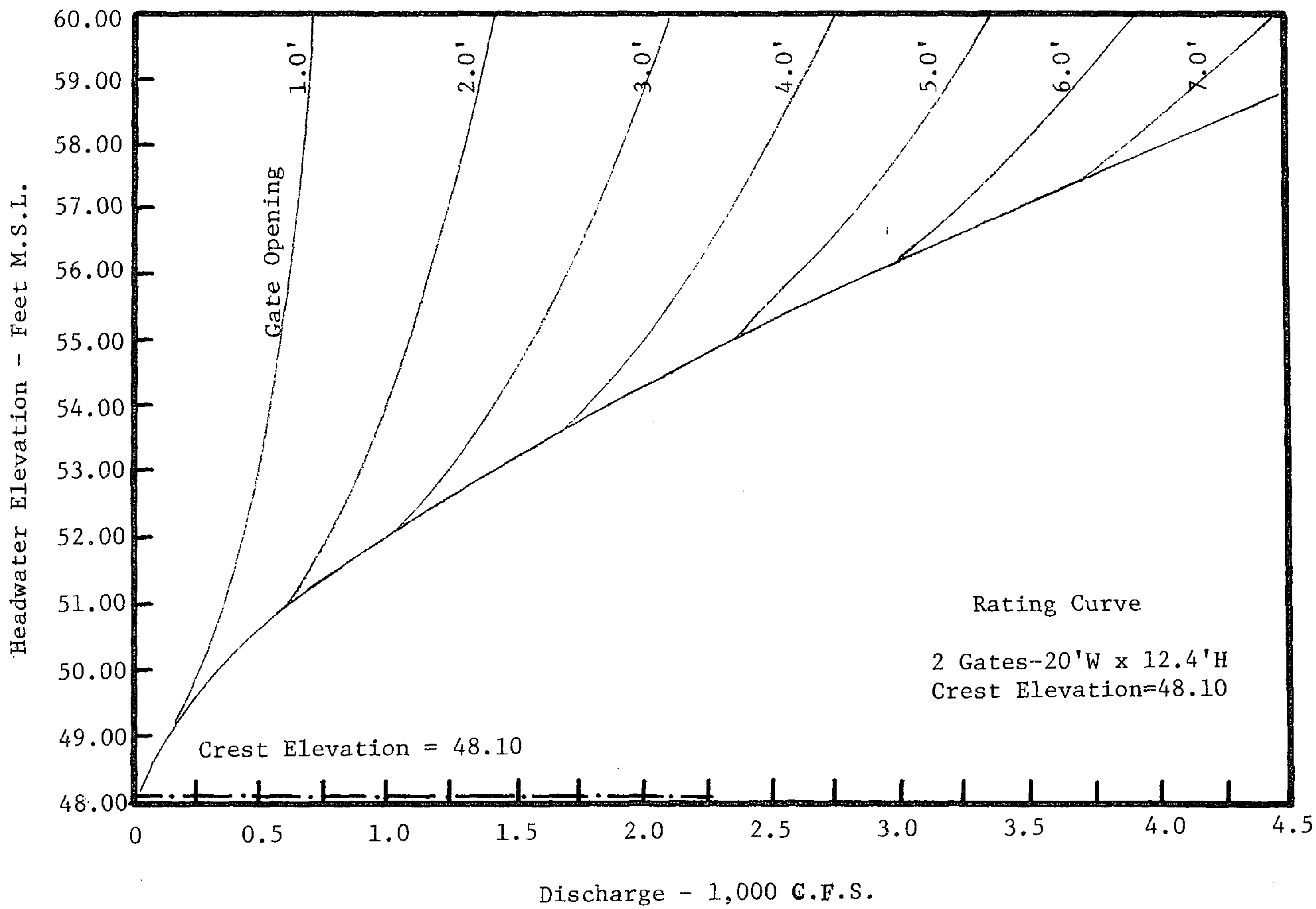


FIGURE 8. -- Moss Bluff Rating Curves (Two Gates Open Uniformly)

TABLE 5. — Stage Discharge Data for Moss Bluff Spillway
(Discharge in cfs)

Gate Opening at Moss Bluff, Feet

Stage Ft.MSL	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	7.00
62.00	375	795	1160	1550	1875	2200	2590	2980	3315	3650	3950	4250	4950
60.00	370	730	1100	1400	1800	2130	2450	2770	3060	3350	3630	3920	4450
59.00	360	705	1055	1350	1710	2020	2230	2640	2915	3190	3450	3700	4170
58.00	350	680	1010	1300	1620	1910	2205	2500	2760	3025	3250	3490	3870
57.00	325	655	955	1250	1530	1800	2070	2350	2580	2830	3030	3225	3400
56.00	310	630	910	1170	1440	1690	1940	2180	2380	2600	2770	2850	2850
55.00	300	600	850	1100	1340	1580	1780	1980	2150	2330	2330	2330	2330
54.00	290	550	780	1020	1220	1430	1610	1780	1820	1820	1820	1820	1820
53.00	250	490	700	910	1075	1250	1350	1380	1380	1380	1380	1380	1380
52.00	220	430	610	775	930	980	980	980	980	980	980	980	980

TABLE 6. -- Summary of Surface Water Gaging Station Records

Gaging Station No. and Location	Drainage Area (Sq. Mi.)	Period of Record	Average Flow (cfs)	Extremes: Stage (feet) Max.	Extremes: Stage (feet) Min.	Extremes: Flow (cfs) Max.	Extremes: Flow (cfs) Min.	Remarks
2238000 Haines Creek at Lisbon	648	July 1942 to current year	292 (1942-56) 269 (1956-75)	64.50	60.30	1350	--	Flow regulated since Dec. 1956. Gates closed and no flow for many days in 1975.
2238001 Haines Creek below Burrell Dam at Lisbon	648	March 1957 to current year (gage height only)	--	61.48	55.32	--	--	Affected by wind.
2234899 Oklawaha River above Moss Bluff Dam	879	October 1965 to June 1967 October 1969 to current year (gage heights only)	--	59.80	45.45	--	--	The minimum gage record was a result of dike failure.
2238200 Lake Yale at Grand Island	67.6 (6.30)*	Sept. 1959 to current year	--	61.29	57.23	--	--	Water is diverted into Lake Griffin.
2238300 Lake Griffin at Leesburg	774 (16.7)*	May 1936 to current year	--	60.74	55.36	--	--	Located in the Oklawaha River headwaters. Lake levels partially controlled.

* Value in parentheses indicates surface area of lake.

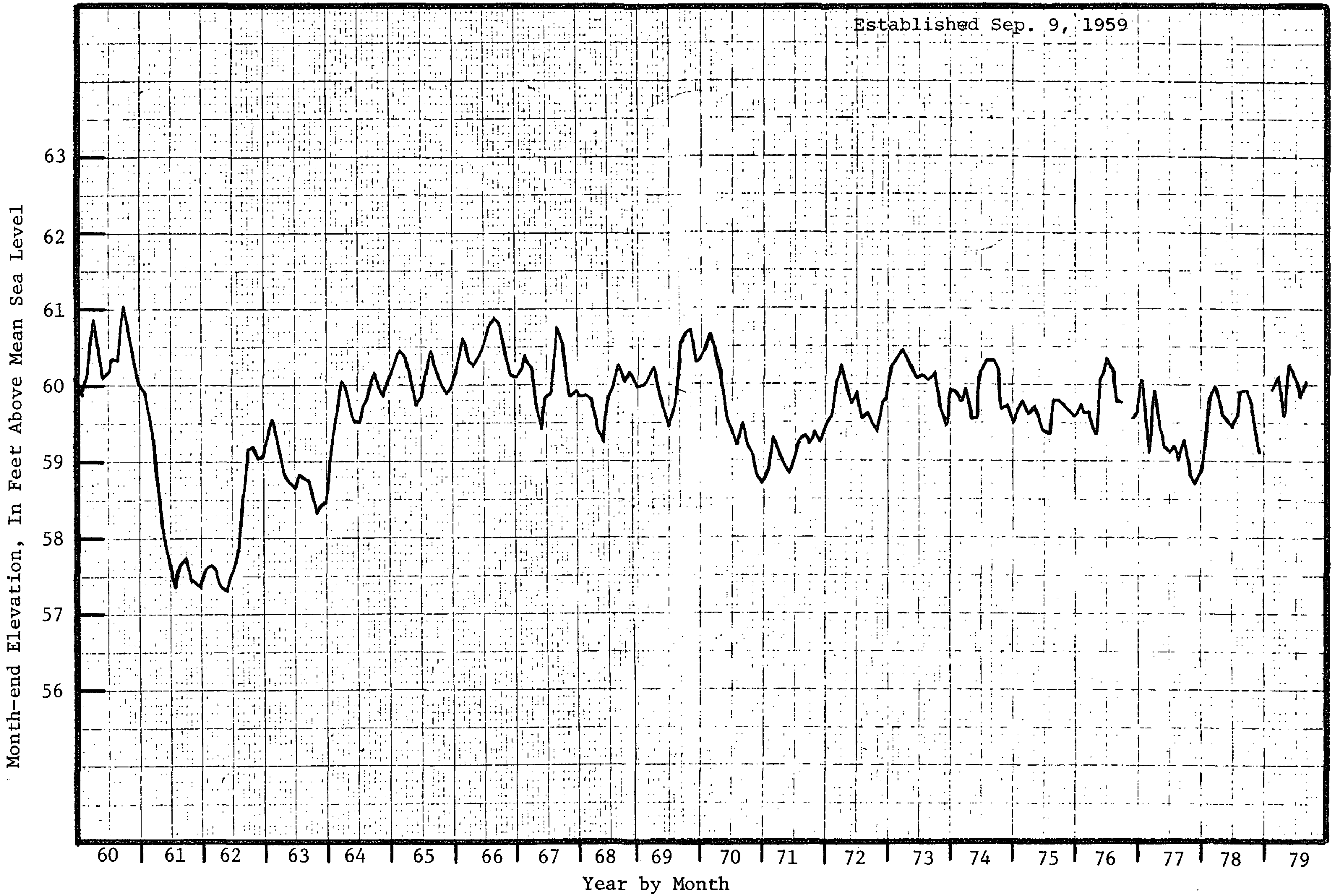


FIGURE 9.- Monthly Stage, Lake Yale at Grand Island, Florida

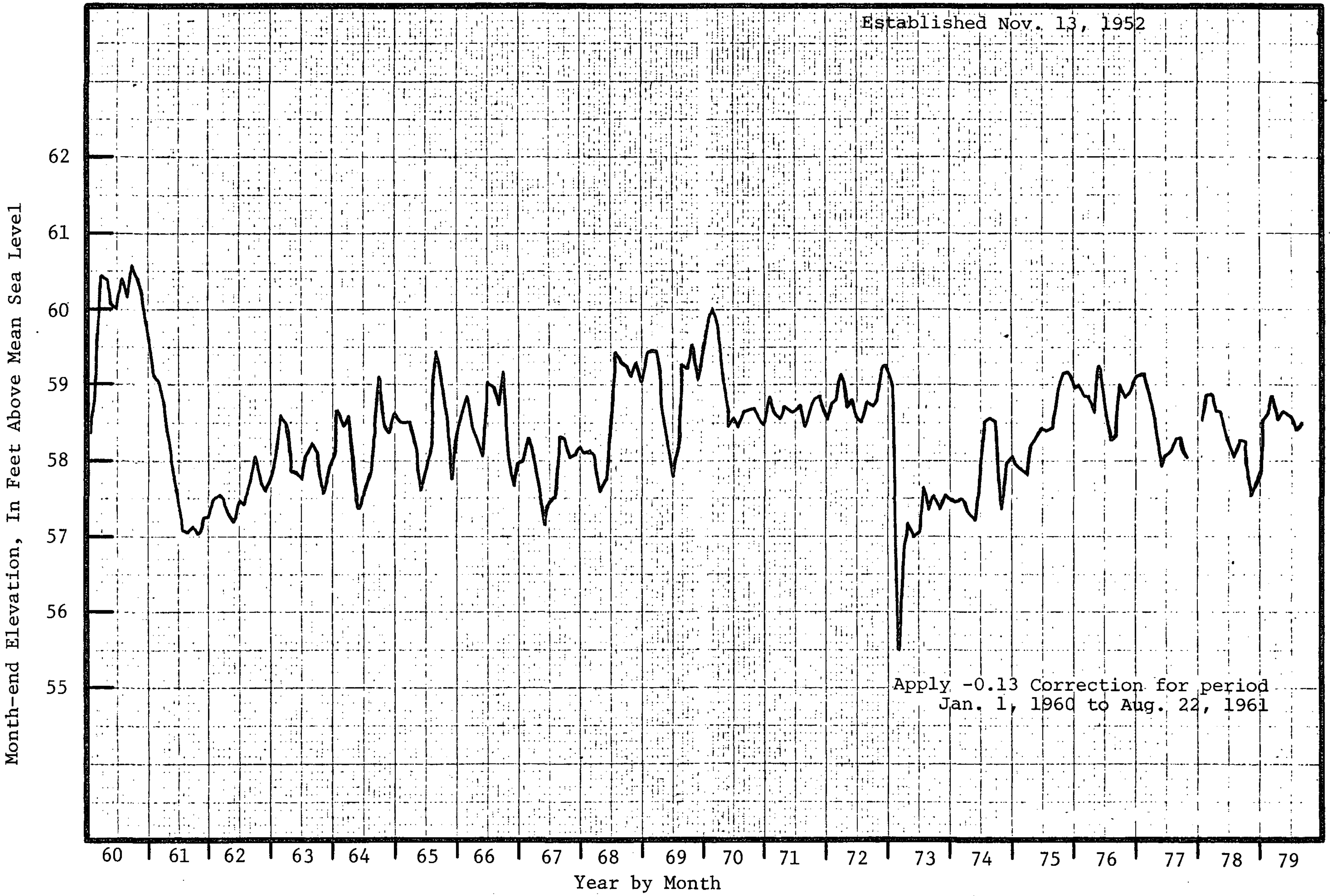


FIGURE 10. -- Monthly Stage, Lake Griffin at Leesburg, Florida

TABLE 7. -- High Stage Data for Lake Yale (Elevations, Feet, M.S.L.)

HIGHEST MEAN VALUES FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

YEAR	1	3	7	15	30	60	90	120	183
1961	61.29	61.28	61.25	61.17	61.07	60.96	60.79	60.70	60.50
1962	59.21	59.17	59.11	59.02	58.85	58.56	58.28	58.09	57.92
1963	59.67	59.63	59.59	59.55	59.54	59.49	59.38	59.28	59.25
1964	60.10	60.07	60.00	59.93	59.81	59.67	59.41	59.16	58.90
1965	60.60	60.54	60.49	60.48	60.45	60.42	60.33	60.25	60.16
1966	60.68	60.66	60.64	60.60	60.53	60.40	60.29	60.21	60.13
1967	61.00	60.98	60.95	60.94	60.87	60.80	60.76	60.69	60.58
1968	60.77	60.76	60.74	60.67	60.60	60.52	60.40	60.29	60.16
1969	60.33	60.33	60.31	60.29	60.20	60.14	60.14	60.10	60.07
1970	61.10	61.08	61.04	60.95	60.85	60.75	60.65	60.58	60.62
1971	60.61	60.59	60.56	60.51	60.40	60.09	59.87	59.71	59.57
1972	60.25	59.97	59.94	59.92	59.89	59.82	59.71	59.65	59.52
1973	60.49	60.45	60.43	60.42	60.40	60.39	60.27	60.15	59.90
1974	60.62	60.61	60.57	60.53	60.46	60.34	60.26	60.23	60.19
1975	60.45	60.45	60.44	60.40	60.35	60.34	60.32	60.24	60.02
1976	59.91	59.90	59.87	59.87	59.84	59.82	59.79	59.75	59.73
1977	60.50	60.48	60.48	60.45	60.41	60.32	60.22	60.13	59.96
1978	60.24	60.22	60.20	60.19	60.13	59.87	59.63	59.44	59.27

TABLE 8. -- High Stage Data for Lake Griffin (Elevations, Feet, MSL)

HIGHEST MEAN VALUES FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

YEAR	1	3	7	15	30	60	90	120	183
1957	58.87	58.80	58.75	58.64	58.51	58.40	58.30	58.30	58.22
1958	60.17	60.17	60.15	60.09	59.90	59.09	58.69	58.48	58.42
1959	60.29	60.26	60.21	60.17	60.09	59.88	59.49	59.24	58.89
1960	60.41	60.40	60.39	60.31	60.07	60.00	59.96	59.96	59.92
1961	60.74	60.74	60.71	60.64	60.53	60.46	60.36	60.32	60.16
1962	58.73	58.70	58.65	58.55	58.39	58.13	57.89	57.70	57.47
1963	58.71	58.71	58.69	58.67	58.63	58.50	58.30	58.13	58.02
1964	59.02	58.99	58.96	58.89	58.80	58.65	58.54	58.39	58.17
1965	59.68	59.68	59.64	59.52	59.28	58.94	58.75	58.70	58.65
1966	59.58	59.55	59.53	59.48	59.39	59.20	58.99	58.83	58.60
1967	59.35	59.30	59.26	59.17	59.05	58.95	58.93	58.93	58.72
1968	58.34	58.32	58.31	58.27	58.26	58.24	58.18	58.15	58.15
1969	59.74	59.72	59.69	59.62	59.55	59.52	59.45	59.42	59.31
1970	60.31	60.30	60.27	60.23	60.14	60.04	59.94	59.80	59.68
1971	59.82	59.82	59.78	59.74	59.55	59.02	58.84	58.73	58.67
1972	59.16	59.09	59.05	59.00	58.90	58.86	58.81	58.79	58.78
1973	59.52	59.46	59.44	59.42	59.34	59.29	59.17	59.08	58.94
1974	57.74	57.69	57.68	57.64	57.59	57.55	57.52	57.51	57.51
1975	58.62	58.61	58.59	58.51	58.37	58.07	58.02	58.00	57.86
1976	59.20	59.20	59.19	59.19	59.17	59.13	59.10	59.09	59.04
1977	59.44	59.41	59.36	59.29	59.23	59.19	59.16	59.12	59.04
1978	59.28	59.23	59.18	59.08	59.05	58.89	58.72	58.57	58.39

BASIN MODEL DESCRIPTION AND CALIBRATION

METHODOLOGY

As stated, the drainage area of the Lake Griffin Region was delineated and divided into 25 sub-basins to facilitate basin model development. Of all the sub-basins, two discharge into Haines Creek, one into the Yale-Griffin Canal, four into the Oklawaha River downstream of the Starkes Ferry Bridge, and the others into Lake Griffin (see Figure 6).

The simulation of flood stages in Lake Griffin and in the Oklawaha River consists of the following steps:

1. Sub-basin runoff hydrographs generation;
2. Determination of the composite hydrographs at major inflow points of the Lake Griffin system; and
3. Routing of the storm water through the Lake Griffin system and establishment of outflow and stage hydrographs according to proposed operation schedules.

A detailed description of the above steps is given below:

<u>Sub-Basin Runoff Hydrographs Generation</u>

Runoff hydrographs for sub-basins are developed using procedures described in the SCS National Engineering Handbook, Section 4(4), with modifications where needed. The following is a brief description of the steps involved.

1. <u>Developing sub-basin unit hydrographs using SCS dimensionless unit hydrograph</u> -- The SCS dimensionless hydrograph has its ordinate values expressed in a dimensionless ratio q/q_p and its abscissa values at t/T_p, where q is the discharge at time t, q_p is the peak discharge, and T_p is time from the beginning of rise to the peak (Figure 11). Thus, the watershed unit hydrograph can be constructed if the values of q_p and T_p are determined.

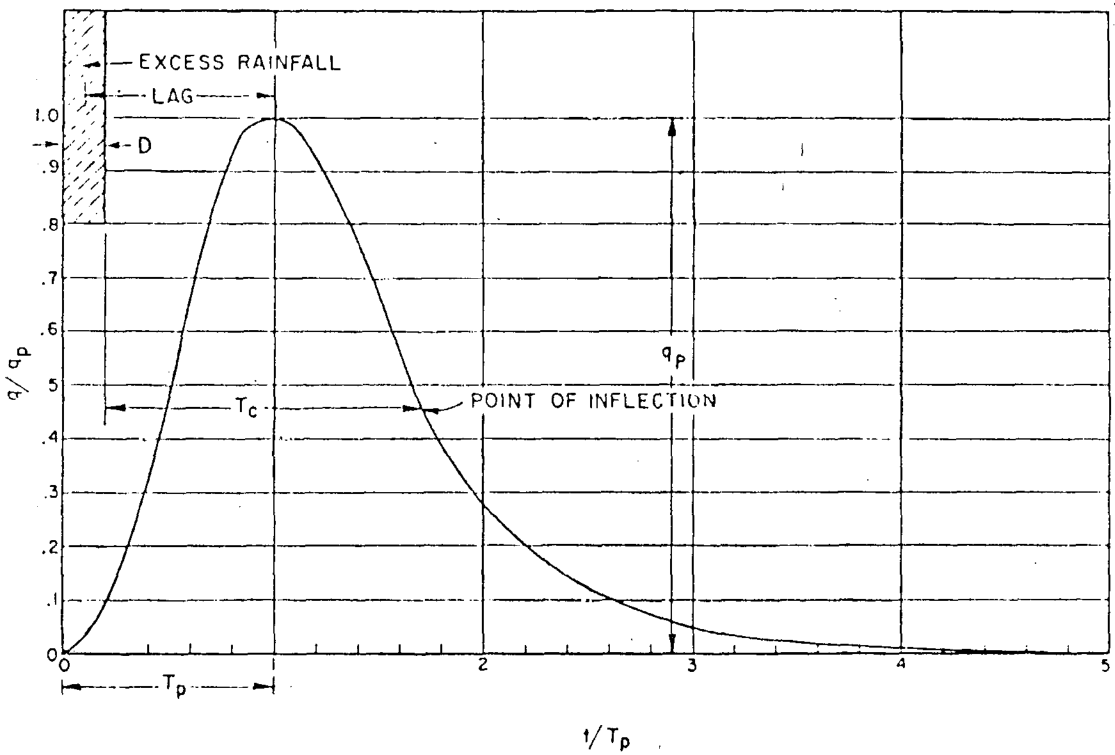


FIGURE 11. -- Elements of the Soil Conservation Service Dimensionless Unit Hydrograph

In this study, the following equations developed by the SCS were used to determine different elements of unit hydrograph.

$$L = \frac{\ell^{0.8} (S + 1)^{0.7}}{1900\ Y^{0.5}} \qquad \text{. . . . . (1)}$$

$$T_c = L/0.6 \qquad \text{. . . . . (2)}$$

$$D = 0.133\ T_c \qquad \text{. . . . . (3)}$$

$$T_p = D/2 + L \qquad \text{. . . . . (4)}$$

$$q_p = \frac{484\ A}{T_p} \qquad \text{. . . . . (5)}$$

in which L = lag time in hours

ℓ = hydraulic length of watershed, feet

$S = \frac{1000}{CN'} - 10$, where $CN' \simeq CN$, the hydrologic soil cover complex number

Y = average watershed land slope in percent

T_c = time of concentration in hours

D = duration of unit rainfall excess in hours

A = watershed area in square miles

and T_p and q_p are as defined earlier

For convenience in computerized calculations, D was rounded off to 0.25, 0.5, or 1.0 hours, and T_p was adjusted to be a multiple of D. Although Equation 1 was originally developed for watershed areas less than 2,000 acres, it has also been used as an approximation for larger areas in this study. The number 484 appearing in Equation 5 is known as peak rate factor which may vary depending on the nature of the terrain. However, this value was used since no recorded hydrographs were available for the area. Moreover, these sub-basins discharge into a huge reservoir system which has a great attenuating effect on the inflow hydrograph, hence the above approximations are justified. Finally, the unit graph was adjusted to ensure that the area of the graph was equal to one-inch direct runoff from the basin.

2. "Rainfall excess" (i.e. direct runoff) Determination -- The storm period was divided into a number of time steps. At the end of each time step, runoff was calculated using the SCS equation given below.

$$Q = \frac{(P - 0.2S)^2}{P + 0.2S} \qquad \ldots\ldots\ldots\ldots \quad (6)$$

in which Q = accumulated direct runoff in inches

P = accumulated rainfall in inches

S = potential maximum retention

$$= \frac{1000}{CN} - 10 \qquad \ldots\ldots\ldots\ldots \quad (7)$$

Each sub-basin was divided into different sub-areas depending on the land use and soil cover, and a curve number was assigned to each sub-area. A weighted curve number for the entire sub-basin was determined by

$$CN = \frac{\sum_{i=1}^{n} (CN_i)\, A_i}{\sum_{i=1}^{n} A_i} \qquad \ldots\ldots\ldots\ldots \quad (8)$$

where A_i = area of ith sub area

CN_i = curve number for the ith sub area

n = number of sub-areas

Rainfall excess for each time step of the storm period is the difference between the runoffs calculated for the previous and the given time steps as calculated by Equation 6.

3. Sub-basin Runoff Hydrograph Generation -- Construction of runoff hydrograph for a given storm event consists of converting rainfall excess of each time step into the corresponding runoff hydrograph and combining these hydrographs into a single runoff hydrograph. In this study, hourly rainfalls were obtained for each storm event, and rainfall was assumed to have uniform intensity during each hour.

Determination of Inflow Hydrograph for the Lake Griffin System

The inflow hydrograph for the Lake Griffin System was determined on an hourly basis and consisted of the following components: i) flows released from Burrell structure; ii) direct rainfall on the lake; and iii) runoff contributed by the 25 sub-basins. However, no specific values were assigned to inflows from Lake Yale as no records are available. Nevertheless, they may be expected to have little impact on flood stages in Lake Griffin. Presently, a major portion of the Yale-Griffin Canal is choked up with hyacinths, and the highest outflow when the canal was clear was only on the order of 70 cfs.

Three of the 25 sub-basins discharge storm runoff by pumping. In these cases, the storm hydrographs were first determined as described in the foregoing section, and then modified as follows: The rising limb of the hydrograph is unaltered until the rate of discharge reaches the effective pumping capacity of the pump, then it will have a uniform rate equal to the capacity of the pump. The excess runoff is assumed to be stored in the detention reservoir provided. The uniform rate continues until the stored waters are pumped out, then in the recession, the hydrograph assumes its natural form again.

Lake Griffin System Reservoir Routing

To establish the outflow hydrograph at Moss Bluff and the stage hydrograph for Lake Griffin for a given storm event, the inflow hydrograph is routed through the Lake Griffin System by the Goodrich method (2). The routing equation is given as:

$$\left(\frac{I_1 + I_2}{2}\right) t - \left(\frac{0_1 + 0_2}{2}\right) t = S_2 - S_1 \quad \ldots\ldots\ (9)$$

in which

t = routing period

I = inflow

0 = outflow

S = reservoir storage

Subscripts 1 and 2 refer to the values at the beginning and the end of routing period, respectively.

In the Goodrich method, Equation 9 is rearranged as:

$$I_1 + I_2 + (2\ S_1/t - 0_1) = 2\ S_2/t + 0_2 \quad \ldots\ldots\ (10)$$

In the above equation, t is expressed in days, S in sfd, and I and 0 in cfs. A routing equation, 2 S/t + 0 vs. 0 is established first for each gate opening at Moss Bluff. All terms in the left hand side of Equation 10 are known, and a value of $2\ S_2/t + 0_2$ can be determined from the routing relation. The computation is then repeated for succeeding routing periods. A routing period of one hour, i.e. 1/24 day, was used in this study.

BASIN MODEL CALIBRATION

To ensure that the computer model satisfactorily simulates discharges and stages of the Lake Griffin System for a given rainfall event, runoff simulations were made (by using the model) for five historic storm events representing different seasons of a year. Rainfall records at Lisbon, Moss Bluff, and Leesburg were used

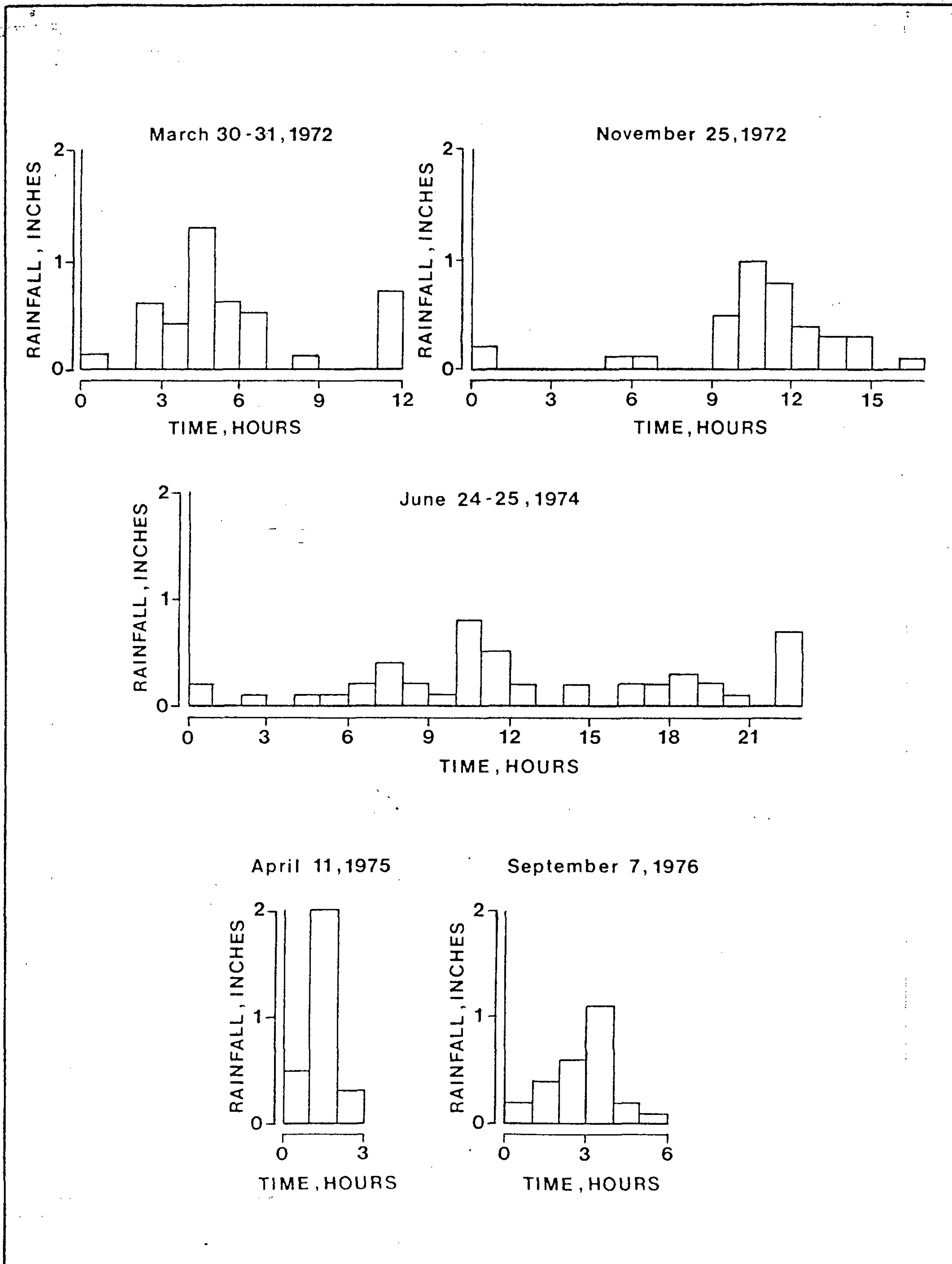


FIGURE 12. -- Hyetographs of Storm Events Used in Model Calibration

TABLE 9. -- Results of Calibration for Basin Model, BMSTRO

Date of Storm	Storm Duration Hours	Storm Rainfall, Inches Lisbon	Storm Rainfall, Inches Leesburg	Storm Rainfall, Inches Moss Bluff	Rise in Lake Griffin, Feet Observed	Rise in Lake Griffin, Feet Computed	RFRTIO	RFADJ Used
March 30, 1972	12	4.30	N.A.*	4.10	0.50	0.51	--	0.90
April 11, 1975	3	2.80	2.75	2.95	0.35	0.36	1.00	1.00
June 24, 1974	23	4.80	5.90	5.82	0.52	0.55	1.15	0.80
September 7, 1976	6	2.60	2.00	4.80	0.41	0.41	1.21	1.18
November 25, 1972	17	3.80	3.80	1.75	0.30	0.30	0.82	0.84

* N.A. = Not Available

Even though Lisbon, Leesburg, and Moss Bluff showed high point rainfalls, June 24, 1974 event may be presumed to be a result of thunderstorm activity. In such an event, high variation in areal rainfall distribution may be expected which resulted in an RFADJ = 0.8 for the computed lake rise to equal the observed. In general, the above results show that the computer model approximately reproduces the rises in Lake Griffin for different storm events if the average rainfall over the watershed is correctly determined.

STORM RUNOFF SIMULATION

The Lake Griffin Region basin hydrological model discussed in the foregoing sections was used to simulate the hydrologic response of the Lake Griffin system under a wide variety of storm and operation conditions. Hypothetical storms of four-day duration having return periods of 2 to 100 years were investigated for different initial lake stages and flow conditions. A detailed description of the studies conducted is as follows.

RAINFALL DEPTH AND DISTRIBUTION

The point rainfalls expected in the Lake Griffin Region for various return periods were taken from U. S. Weather Bureau Technical Papers Numbers 40 and 49 (6, 7). These publications also give the correction factors to be applied to the point rainfalls to obtain approximate areal rainfalls over a watershed of given size. The Lake Griffin Region has an area of about 159 square miles for which the above correction factors were found to be 0.928 and 0.955 for 24-hour and 4-day duration rainfalls, respectively. Table 2 summarizes the rainfall data for the study area. The time distribution of rainfall is discussed as follows.

The 24-hour rainfalls were assumed to have the SCS type II distribution (Figure 13). In this distribution, the rainfall intensity slowly increases, reaching its peak during the 30 minutes between 11.5 and 12 hours with 38 percent of the total rainfall occurring during this 1/2 hour, and then the intensity decreases.

Several distribution patterns are possible for a 4-day storm. However, it was assumed that the 24-hour rainfall is a portion of the 4-day rainfall. The general concept of SCS type II distribution, i.e., that the rainfall intensity gradually increases during a storm, to reach its peak and then tapers off, is

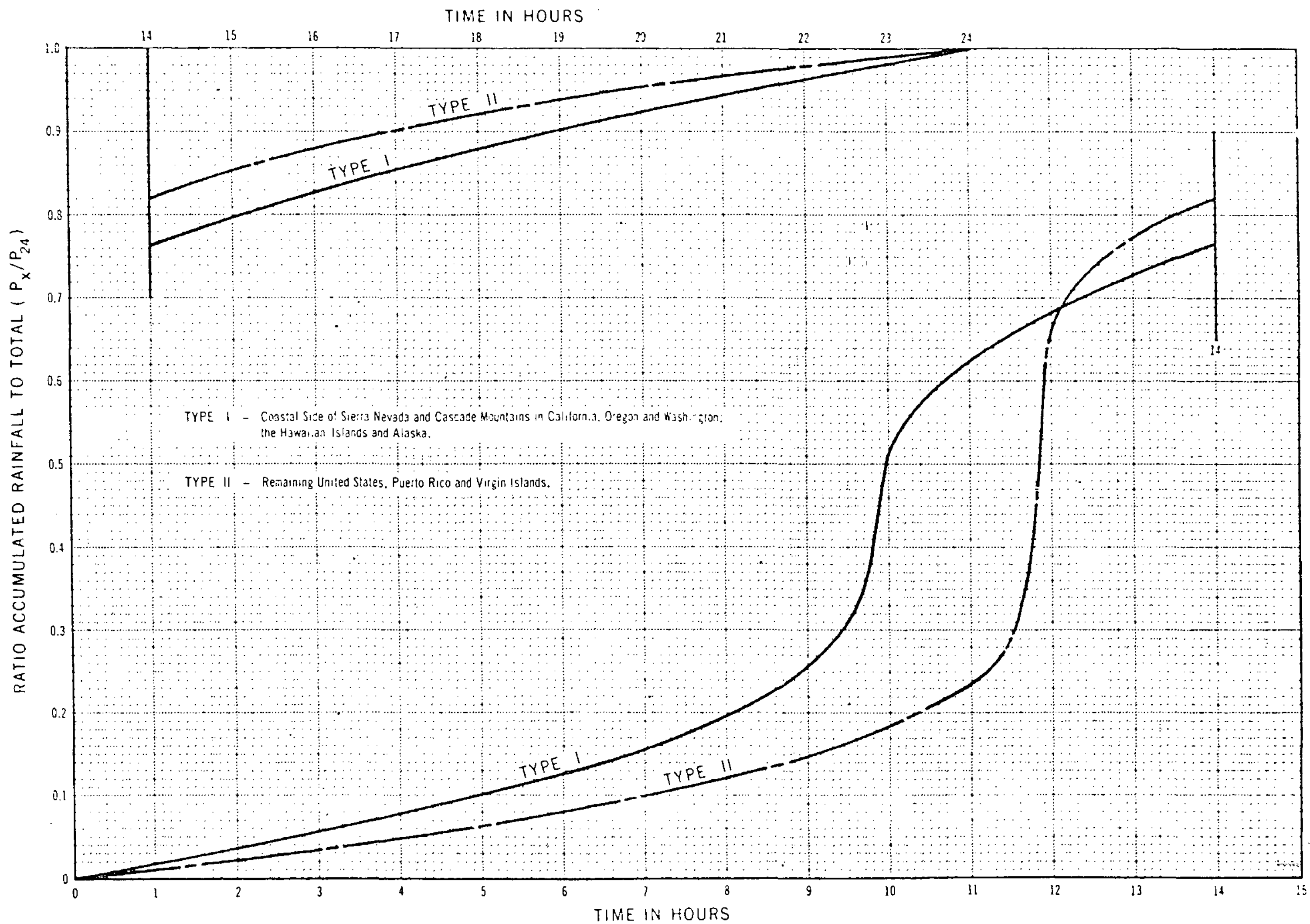


FIGURE 13. -- Twenty-four Hour Rainfall Distributions (SCS)

retained for 4-day storm. In this study for the distribution of the 4-day storm, it was assumed that the 24-hour rainfall occurred on the first day, and the difference of 2-day and 24-hour rainfall on the second day and the difference of 4-day and 2-day rainfall amount evenly distributed on the third and the fourth days.

The SCS runoff equation given by Equation 6 was developed for rainfall durations of 24 hours or less. Two approaches were suggested for its extension to longer durations (3). In the first approach, the runoff is calculated for each day separately, assuming design moisture condition for the first day and wetter moisture conditions for the subsequent days. For example, if the Antecedent Moisture Condition II (AMC II) is assumed for the first day, the subsequent days will have AMC III. Reference Number 4 gives the variation in CN values as the AMC varies from I to III. In the second approach, the runoff is calculated on a continuous basis using CN values of the first day AMC. To obtain runoff for the third day rain in this approach, for example, accumulated runoff at the end of the third day and second days are calculated by Equation 6, and the difference between the two values is taken as the third day runoff. The two approaches were found to give widely differing results for the runoff of later days in a longer duration rainfall. For the fourth day of 4-day rainfalls used in this study, with CN=80 and AMC II on the first day, the first and second approaches give, respectively, runoffs of 0.17 inches and 0.50 inches for 2-year fourth day rainfall of 0.56 inches, and 0.9 inches and 1.32 inches for the 100-year fourth day rainfall of 1.4 inches.

In this study, the second approach was used to calculate runoff, but the loss due to evapotranspiration was taken into account for the second and subsequent days. The first day of the storm receives the heaviest rainfall (Table 2), hence evapotranspiration loss is negligible.

BURRELL STRUCTURE DISCHARGE

In this study it was assumed, for simplicity, that flows were released at a uniform maximum rate from Burrell structure during the simulation period (10 days). Since the program has provision to accept varying flows, several different flow rates were studied. The results for the cases of 200, 500, 1,000, and 1,500 cfs discharges from the Burrell structure are presented and discussed in this report.

INITIAL WATER SURFACE ELEVATIONS

Since the severe storm may occur any time of the year, the initial stage in the Lake Griffin System could be anywhere between 58.00 to 59.50 feet msl. (Some extreme high or low may exist, however.) However, it is more likely such severe event would occur in rainy season when lake level is maintained at a lower elevation designed to allow for a greater storm runoff storage.

SIMULATION ANALYSIS

The pertinent questions to be answered in this study are (1) What is the operation schedule which would achieve the least flooding damage while maintaining optimum conservation stages? and (2) What is the resulting Moss Bluff discharge under such regulation schedule? Due to the difficulty of estimating or forecasting storm rainfall amount prior to the storm event, a timely release of the storage normally cannot be made until actual rainfall is observed. In this study, two index parameters were suggested to guide operations schedule. These are rainfall depth and lake stages.

The operation based on stage observation can be easily conducted by the field personnel following an established guideline. The shortcoming of this type of operation scheme is that it fails to react quickly to storm conditions. This type of operation scheme will only be briefly discussed even though this is the method that is currently utilized.

The second method of operation scheme, termed a predictive operation scheme, is based on the observed rainfall, pre-storm storage conditions, and discharge at Burrell structure. The advantage of this type of operation scheme is that an appropriate operation schedule can be enacted before critical stage is reached. Therefore, the basin can be better prepared for the severe storm. The pre-requisite of this operation scheme is a better monitoring system and better communication between field personnel and technical staff so that the situation can be evaluated and action can be taken quickly. Therefore, this type of operation scheme is recommended so that better water management can be achieved. In order to develop an operation guide for the predictive operating scheme, it is necessary to determine necessary gate openings at Moss Bluff Spillway during various storm events. The minimum gate openings necessary to release excess runoff would depend upon the storm rainfall amount, initial lake stage, discharge from Burrell structure, and above all, maximum allowable lake stage. To cover many possible situations, each storm was studied for several combinations of initial lake stages, Burrell structure discharge, and Moss Bluff gate openings.

DESCRIPTION AND DISCUSSION OF SIMULATION RESULTS

The objective of the simulation experiments is to evolve viable guidelines for the operation of Moss Bluff Spillway and Burrell structure when major storms strike the region. It was assumed that the lake elevation before the occurrence of a storm would be known. However, it was assumed that no action would be taken by the operator for 20 hours on the time scale of storm since the operation personnel will alter the discharges at Moss Bluff and Burrell structure only after realizing that substantial rainfall has occurred in the basin. In this 20-hour period, about 95 percent of 24-hour rainfall would occur (see Figure 13) which is also about 65 percent of 4-day rainfall. By this time, the operator would easily be prompted to 'act'; he would know from his gage the amount of rainfall that already occurred. The decision he is required to make is: To what extent should the gates at Moss Bluff be opened if certain flow is released at Burrell structure in order that the lake would not rise above 60.00 msl (or any other desired value) in the event the storm continues for more days?

To obtain a generalized solution to the above question, rather extensive simulation experiments were performed. Six storm events of 4-day duration (return periods 2, 5, 10, 25, 50, and 100 years) were chosen for study. For these events, the 24-hour rainfall varied from 4.27 to 9.37 inches and the 4-day rainfall from 6.02 to 14.13 inches. Each storm event was analyzed for 144 hypothetical situations given rise by the combination of following basin and operation conditions:

I. Lake elevation at the beginning of storm

(a) 58.00 feet, (b) 58.50 feet, and (c) 59.00 feet msl

II. Discharge from Burrell structure during the critical period

(a) 200 cfs, (b) 500 cfs, (c) 1,000 cfs, and (d) 1,500 cfs

III. Gate opening at Moss Bluff Spillway (2-24 feet wide gates)

Twelve values were considered: 1 to 6 feet at 0.5 foot interval and 7.0 feet

The above conditions give rise to 144 cases (3 x 4 x 12) in all. It was assumed that only nominal flows of 30 cfs were released at Burrell structure and Moss Bluff during the first 20 hours of storm. The lake would rise to some extent during this period. At the end of this period, the operator would decide to open gates at Moss Bluff by a value in the range of 1 to 7 feet and would release flows from Burrell structure in the range of 200 to 1,500 cfs. (For a few cases in which gate opening at Moss Bluff is 1 to 2 feet, flows of 1,000 or 1,500 cfs from Burrell structure exceed flows at Moss Bluff. In these cases, the peak stage will be reached only at the end of hydrograph period.)

The following results were evaluated by the computer program:

1. Stage and discharge hydrographs for 10 days beginning the storm for each hypothetical situation (144 for each storm event). However, the hydrographs were terminated before 10 days when stage falls down to 58.50 msl after reaching the peak (Table 10). It was assumed that the flow from Burrell structure and gate opening at Moss Bluff were unchanged from the 20th hour to the end of the hydrograph.

2. For each storm event, a summary of the following results for 144 cases were obtained in a tabular form.

   (a) Peak stage and time to its occurrence (from the beginning of storm) (Tables 11A and 11B).

   (b) Peak discharge and time to its occurrence (Tables 12A and 12B).

   (c) Time lapse (from the beginning of storm) for the stage to recede to 58.50 msl (after reaching the peak) or the stage at the end of 10-day period if the stage did not fall to 58.50 msl during the 10-day period (Tables 13A and 13B).

Tables 11A through 13B are presented here as examples. Other tables are presented as a separate appendix to this report.

TABLE 10. -- Typical Routing Results Giving Inflows, Outflows, and Stage Hydrograph Data

**** STORM RUNOFF STUDIES FOR LAKE GRIFFIN REGION, OKLAWAHA RIVER BASIN ****

RUN INFORMATION: RUNOFF FOR 25-YEAR 4-DAY STORM

FLOW FROM BURREL STRUCTURE: 200. CFS(FROM 20 HRS OF STORM)
FLOW AT MOSS BLUFF AT 20 HOURS OF STORM: 2611. CFS
STAGE AT MOSS BLUFF AT 0 HOURS OF STORM: 58.00 FT ABOVE MSL, GATE OPENING: 4.00 FT(FROM 20 HRS OF STORM)

--- ROUTING RESULTS ---

TIME HRS	INFLOW CFS	OUTFLOW CFS	STAGE MSL	I-O CFS-HRS	CUM(I-O) CFS-HRS
1	1186.	30.			
6	1712.	30.			
12	50005.	30.			
19	11788.	30.			
20	11161.	2611.	58.79	8550.	8550.
24	8605.	2630.	58.93	5975.	35377.
30	5280.	2644.	59.03	2636.	56168.
36	4201.	2652.	59.09	1549.	67853.
42	3717.	2656.	59.13	1060.	75249.
48	3476.	2660.	59.15	816.	80673.
54	2761.	2661.	59.16	100.	82371.
60	2541.	2661.	59.16	-120.	82117.
66	2436.	2660.	59.16	-225.	80991.
72	2386.	2659.	59.15	-274.	79452.
78	2361.	2658.	59.14	-297.	77720.
84	2351.	2657.	59.13	-306.	75899.
90	2350.	2656.	59.12	-306.	74058.
96	2199.	2655.	59.11	-456.	71759.
102	1057.	2651.	59.08	-1594.	64499.
108	606.	2644.	59.03	-2038.	53261.
114	353.	2636.	58.97	-2282.	40099.
120	319.	2626.	58.90	-2307.	26039.
126	249.	2617.	58.84	-2368.	12089.
132	184.	2608.	58.77	-2424.	-2345.
138	161.	2598.	58.70	-2438.	-16950.
144	134.	2588.	58.63	-2455.	-31641.
150	137.	2579.	58.56	-2442.	-46279.

PEAK STAGE= 59.16, TIME TO PEAK = 56 HRS, PEAK RUNOFF= 2661. CFS

TABLE 11A. -- Peak Stages (ft. M.S.L.) in Lake Griffin for 10-Year 4-Day Storm

RAINFALL= 8.98 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
0 HRS	20 HRS		1.0	1.5	2.0	2.5	3.0	3.5
58.00	58.67	200.	59.41(104)	59.28(100)	59.17(98)	59.06(75)	58.99(66)	58.93(52)
58.00	58.67	500.	59.54(110)	59.39(103)	59.28(100)	59.15(97)	59.06(74)	58.98(64)
58.00	58.67	1000.	59.87(240)*	59.60(115)	59.47(107)	59.33(101)	59.21(98)	59.11(76)
58.00	58.67	1500.	60.39(240)*	60.01(240)*	59.71(240)*	59.52(109)	59.40(103)	59.28(100)
58.50	59.17	200.	59.91(104)	59.77(100)	59.66(97)	59.55(74)	59.48(61)	59.42(51)
58.50	59.17	500.	60.03(110)	59.88(103)	59.77(100)	59.63(97)	59.54(74)	59.47(60)
58.50	59.17	1000.	60.36(240)*	60.09(114)	59.96(106)	59.81(101)	59.70(98)	59.59(75)
58.50	59.17	1500.	60.88(240)*	60.50(240)*	60.19(157)	60.01(108)	59.88(103)	59.76(99)
59.00	59.67	200.	60.41(104)	60.27(99)	60.15(97)	60.04(74)	59.97(58)	59.92(50)
59.00	59.67	500.	60.53(109)	60.38(103)	60.26(99)	60.12(96)	60.03(73)	59.96(57)
59.00	59.67	1000.	60.85(240)*	60.59(113)	60.46(105)	60.30(100)	60.18(98)	60.08(75)
59.00	59.67	1500.	61.37(240)*	60.99(240)*	60.68(137)	60.50(108)	60.37(102)	60.24(99)

* - FLOW FROM BURRELL STRUCTURE EXCEEDS THE SPILLWAY CAPACITY AT MOSS BLUFF FOR THIS GATE OPENING

VALUES IN PARENTHESES INDICATE TIME TO PEAK IN HOURS FROM THE BEGINNING OF STORM

TABLE 11B. -- Peak Stages (ft. M.S.L.) in Lake Griffin for 10-Year 4-Day Storm

RAINFALL= 8.98 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
			4.0	4.5	5.0	5.5	6.0	7.0
0 HRS	20 HRS							
58.00	58.67	200.	58.89(48)	58.86(42)	58.83(38)	58.81(35)	58.80(33)	58.77(31)
58.00	58.67	500.	58.93(52)	58.89(48)	58.86(43)	58.84(38)	58.82(35)	58.79(32)
58.00	58.67	1000.	59.03(73)	58.97(58)	58.92(51)	58.89(48)	58.86(43)	58.82(36)
58.00	58.67	1500.	59.17(98)	59.08(75)	59.01(72)	58.96(57)	58.92(51)	58.86(44)
58.50	59.17	200.	59.38(48)	59.35(41)	59.33(37)	59.31(34)	59.29(33)	59.27(30)
58.50	59.17	500.	59.42(50)	59.38(48)	59.35(41)	59.33(37)	59.31(35)	59.28(31)
58.50	59.17	1000.	59.51(72)	59.45(55)	59.41(50)	59.38(47)	59.35(40)	59.31(35)
58.50	59.17	1500.	59.65(97)	59.56(75)	59.50(71)	59.45(54)	59.41(49)	59.35(41)
59.00	59.67	200.	59.87(46)	59.84(39)	59.82(36)	59.80(34)	59.79(32)	59.76(29)
59.00	59.67	500.	59.91(50)	59.88(46)	59.85(40)	59.82(36)	59.80(34)	59.77(31)
59.00	59.67	1000.	60.00(71)	59.94(53)	59.90(49)	59.87(44)	59.84(39)	59.80(34)
59.00	59.67	1500.	60.13(96)	60.05(74)	59.98(63)	59.93(52)	59.89(48)	59.84(38)

VALUES IN PARENTHESES INDICATE TIME TO PEAK IN HOURS FROM THE BEGINNING OF STORM

TABLE 12A. -- Peak Discharges at Moss Bluff for 10-Year 4-Day Storm

RAINFALL= 8.98 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
0 HRS	20 HRS		1.0	1.5	2.0	2.5	3.0	3.5
58.00	58.67	200.	715.(104)	1068.(100)	1359.(98)	1715.(75)	2018.(66)	2322.(52)
58.00	58.67	500.	718.(110)	1073.(103)	1364.(100)	1723.(97)	2026.(74)	2328.(64)
58.00	58.67	1000.	727.(240)	1082.(115)	1374.(107)	1740.(101)	2044.(98)	2343.(76)
58.00	58.67	1500.	743.(240)	1100.(240)	1385.(240)	1757.(109)	2064.(103)	2364.(100)
58.50	59.17	200.	728.(104)	1090.(100)	1383.(97)	1759.(74)	2072.(61)	2381.(51)
58.50	59.17	500.	731.(110)	1095.(103)	1389.(100)	1767.(97)	2080.(74)	2387.(60)
58.50	59.17	1000.	742.(240)	1103.(114)	1398.(106)	1783.(101)	2096.(98)	2401.(75)
58.50	59.17	1500.	759.(240)	1115.(240)	1414.(157)	1800.(108)	2117.(103)	2421.(99)
59.00	59.67	200.	743.(104)	1108.(99)	1412.(97)	1801.(74)	2126.(58)	2440.(50)
59.00	59.67	500.	747.(109)	1111.(103)	1420.(99)	1804.(96)	2131.(73)	2445.(57)
59.00	59.67	1000.	758.(240)	1118.(113)	1434.(105)	1811.(100)	2136.(98)	2455.(75)
59.00	59.67	1500.	774.(240)	1130.(240)	1451.(137)	1819.(108)	2143.(102)	2467.(99)

VALUES IN PARENTHESES INDICATE TIME TO PEAK OUTFLOW IN HOURS FROM THE BEGINNING OF STORM

TABLE 12B. -- Peak Discharges at Moss Bluff for 10-Year 4-Day Storm

RAINFALL= 8.98 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
			4.0	4.5	5.0	5.5	6.0	7.0
0 HRS	20 HRS							
58.00	58.67	200.	2625.(48)	2893.(42)	3162.(38)	3413.(35)	3657.(33)	4102.(31)
58.00	58.67	500.	2630.(52)	2898.(48)	3167.(43)	3417.(38)	3661.(35)	4106.(32)
58.00	58.67	1000.	2643.(73)	2910.(58)	3177.(51)	3428.(48)	3670.(43)	4116.(36)
58.00	58.67	1500.	2662.(98)	2927.(75)	3192.(72)	3442.(57)	3683.(51)	4129.(44)
58.50	59.17	200.	2690.(48)	2966.(41)	3242.(37)	3505.(34)	3764.(33)	4244.(30)
58.50	59.17	500.	2695.(50)	2971.(48)	3246.(41)	3509.(37)	3768.(35)	4248.(31)
58.50	59.17	1000.	2707.(72)	2981.(55)	3256.(50)	3518.(47)	3777.(40)	4257.(35)
58.50	59.17	1500.	2724.(97)	2997.(75)	3269.(71)	3530.(54)	3789.(49)	4267.(41)
59.00	59.67	200.	2754.(46)	3037.(39)	3321.(36)	3594.(34)	3873.(32)	4383.(29)
59.00	59.67	500.	2759.(50)	3042.(46)	3325.(40)	3598.(36)	3877.(34)	4387.(31)
59.00	59.67	1000.	2770.(71)	3052.(53)	3334.(49)	3606.(44)	3885.(39)	4394.(34)
59.00	59.67	1500.	2783.(96)	3066.(74)	3347.(63)	3618.(52)	3896.(48)	4404.(38)

VALUES IN PARENTHESES INDICATE TIME TO PEAK OUTFLOW IN HOURS FROM THE BEGINNING OF STORM

TABLE 13A. -- 10-Year 4-Day Storm, Lake Griffin: Stage at the End of 10-Day Period/Time for Stage to Recede to 58.50 ft. M.S.L.

RAINFALL= 8.98 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
			1.0	1.5	2.0	2.5	3.0	3.5
0 HRS	20 HRS							
58.00	58.67	200.	59.06(240)	58.70(240)	58.50(223)	58.50(178)	58.50(153)	58.50(134)
58.00	58.67	500.	59.36(240)	59.00(240)	58.70(240)	58.50(214)	58.50(177)	58.50(152)
58.00	58.67	1000.	59.87(240)	59.51(240)	59.21(240)	58.84(240)	58.53(240)	58.50(198)
58.00	58.67	1500.	60.39(240)	60.01(240)	59.71(240)	59.33(240)	59.02(240)	58.72(240)
58.50	59.17	200.	59.54(240)	59.17(240)	58.87(240)	58.50(240)	58.49(206)	58.50(180)
58.50	59.17	500.	59.85(240)	59.48(240)	59.18(240)	58.80(240)	58.50(239)	58.50(204)
58.50	59.17	1000.	60.36(240)	59.98(240)	59.68(240)	59.29(240)	58.98(240)	58.67(240)
58.50	59.17	1500.	60.88(240)	60.50(240)	60.18(240)	59.79(240)	59.47(240)	59.16(240)
59.00	59.67	200.	60.03(240)	59.65(240)	59.35(240)	58.96(240)	58.64(240)	58.50(224)
59.00	59.67	500.	60.34(240)	59.96(240)	59.65(240)	59.26(240)	58.94(240)	58.63(240)
59.00	59.67	1000.	60.85(240)	60.47(240)	60.15(240)	59.75(240)	59.43(240)	59.11(240)
59.00	59.67	1500.	61.37(240)	60.99(240)	60.65(240)	60.26(240)	59.93(240)	59.60(240)

VALUES IN PARANTHESES INDICATE TIME TO STAGE IN HOURS FROM THE BEGINNING OF STORM

TABLE 13B. -- 10-Year 4-Day Storm, Lake Griffin: Stage at the End of 10-Day Period or Time for Stage to Recede to 58.50 ft. M.S.L.

RAINFALL= 8.98 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
			4.0	4.5	5.0	5.5	6.0	7.0
0 HRS	20 HRS							
58.00	58.67	200.	58.50(120)	58.49(110)	58.49(100)	58.49(90)	58.49(82)	58.50(70)
58.00	58.67	500.	58.50(134)	58.50(121)	58.49(111)	58.49(102)	58.49(92)	58.49(78)
58.00	58.67	1000.	58.49(167)	58.49(147)	58.49(132)	58.50(120)	58.49(111)	58.49(94)
58.00	58.67	1500.	58.50(225)	58.50(188)	58.50(163)	58.50(145)	58.50(131)	58.50(112)
58.50	59.17	200.	58.49(161)	58.50(147)	58.49(136)	58.49(127)	58.50(119)	58.50(107)
58.50	59.17	500.	58.50(179)	58.50(162)	58.50(148)	58.50(137)	58.50(128)	58.49(115)
58.50	59.17	1000.	58.49(224)	58.50(196)	58.49(176)	58.49(160)	58.50(147)	58.50(129)
58.50	59.17	1500.	58.85(240)	58.58(240)	58.49(218)	58.50(193)	58.50(174)	58.49(149)
59.00	59.67	200.	58.49(200)	58.50(182)	58.49(168)	58.49(157)	58.49(147)	58.49(132)
59.00	59.67	500.	58.50(223)	58.50(201)	58.50(183)	58.49(170)	58.49(158)	58.49(141)
59.00	59.67	1000.	58.81(240)	58.53(240)	58.49(218)	58.49(198)	58.49(182)	58.50(158)
59.00	59.67	1500.	59.29(240)	59.01(240)	58.74(240)	58.49(239)	58.49(215)	58.49(182)

VALUES IN PARANTHESES INDICATE TIME TO STAGE IN HOURS FROM THE BEGINNING OF STORM

For each storm event, an analysis of lake stages indicated the following results:

1. The rise in lake level during the first 20 hours of storm is same with reference to the three initial lake elevations selected for study. (See lake elevation at 0 and 20 hours, Table 11A).

2. For a given flow release at Burrell structure and given gate opening at Moss Bluff, the maximum lake rise above the initial lake elevation is practically the same for the three initial lake elevations chosen for study. For example, consider the 10-year storm event (Table 11A) with a 2-foot gate opening at Moss Bluff and 1,000 cfs discharge from Burrell structure. The peak stages attained for the three cases in which the initial lake elevations were 58.00, 58.50, and 59.00 are 59.47, 59.96, and 60.46 feet msl, respectively, giving net lake rises of 1.47, 1.46, and 1.46 feet, respectively. The net rise is slightly higher for the lower initial elevation because of the slightly lower hydraulic head on the gate opening giving a lower discharge capacity.

The particular stage storage relations obtained for the Lake Griffin System are responsible for the above results. These results lead to the conclusion that a storm of given magnitude would produce about the same net rise in Lake Griffin over any initial lake elevation between 58.00 and 59.00 feet msl under similar operation conditions at Moss Bluff and Burrell structure; 58.00 to 59.00 msl is the most practical and likely range for the lake to prevail at the incidence of storm. The results of simulation experiments were translated into more comprehensive graphical form as described below:

It was noticed that the 24-hour rainfalls were well correlated to the 4-day rainfalls of the same frequency (Figure 14). As a result, the 24-hour rainfall rather than 4-day rainfall was used as an index and related to lake rise for different gate openings at Moss Bluff. Figures 15 through 18 show these relations

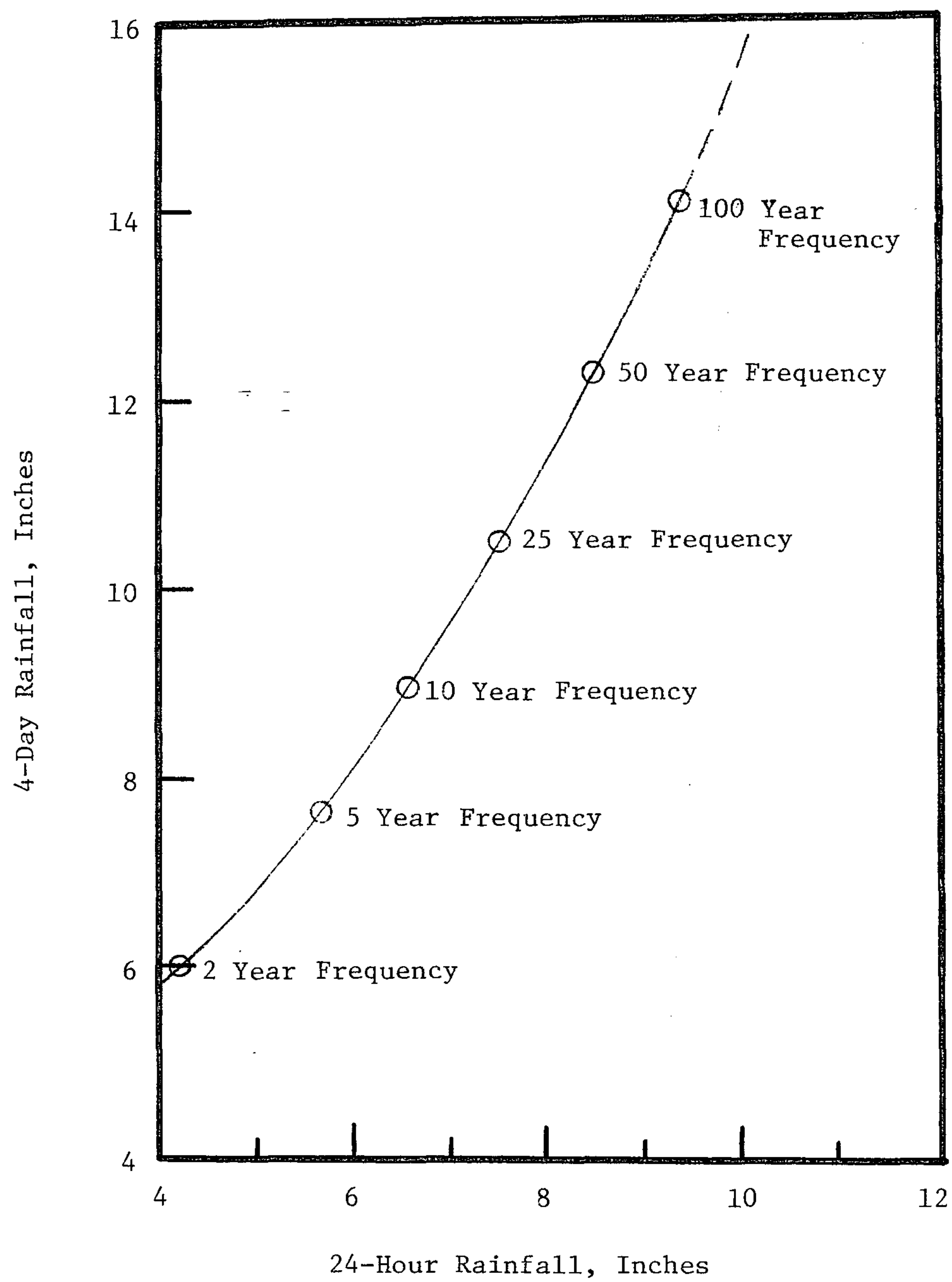


FIGURE 14. -- Relation Between 24-Hour and 4-Day Rainfalls for Lake Griffin Region

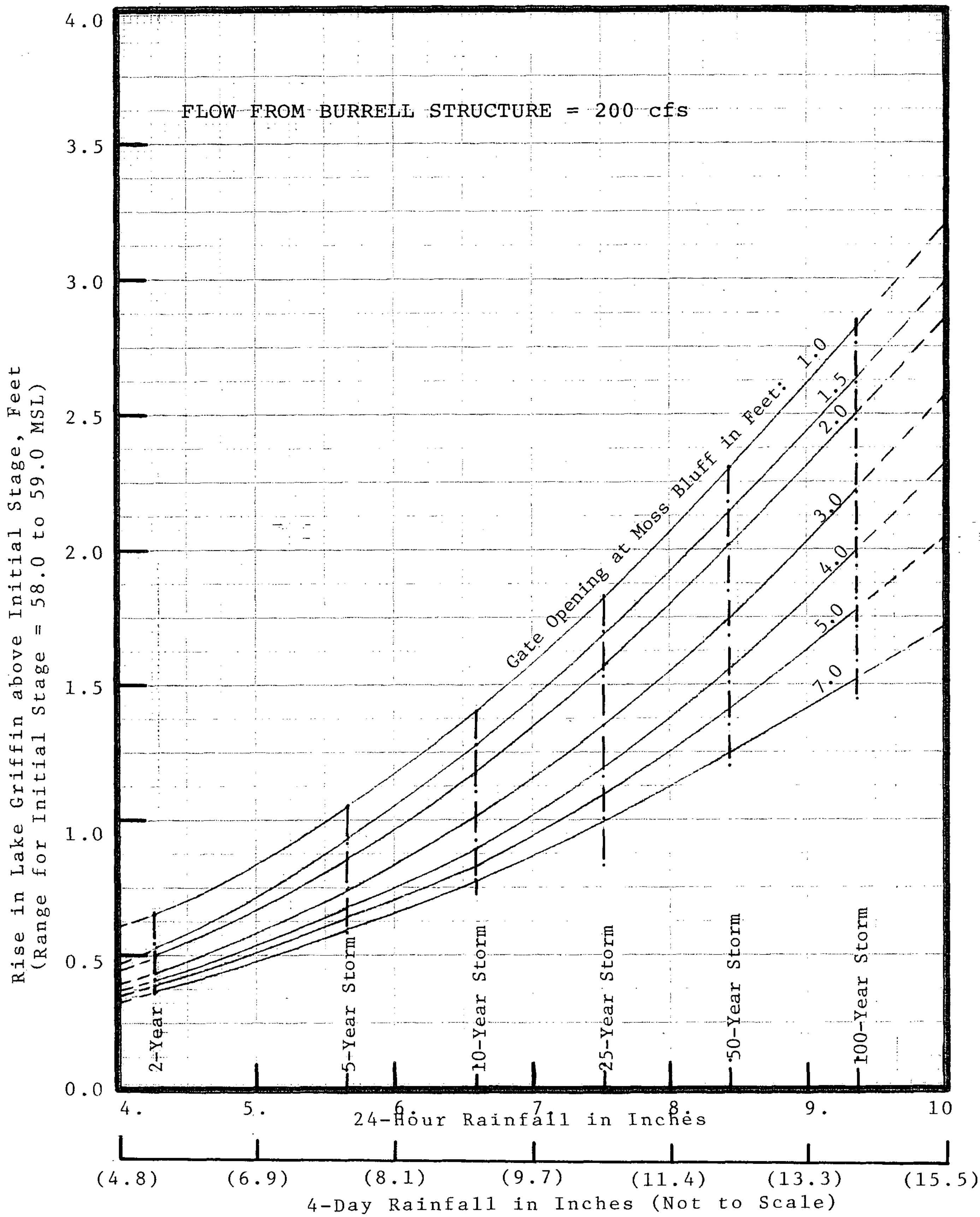


FIGURE 15. -- The Rainfall - Lake Rise Relationships for Lake Griffin (Flow from Burrell Structure = 200 cfs)

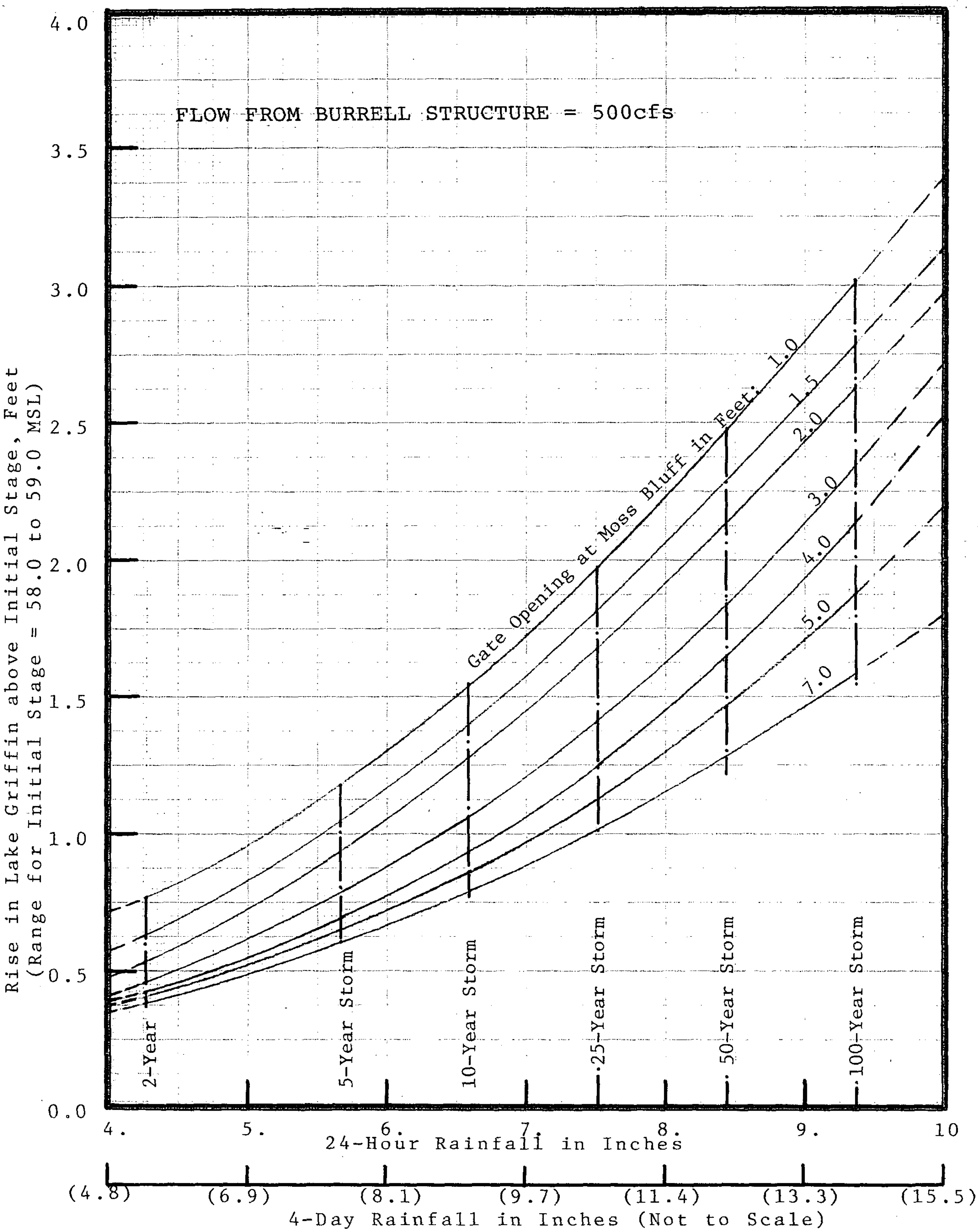


FIGURE 16. -- The Rainfall - Lake Rise Relationships for Lake Griffin (Flow from Burrell Structure = 500 cfs)

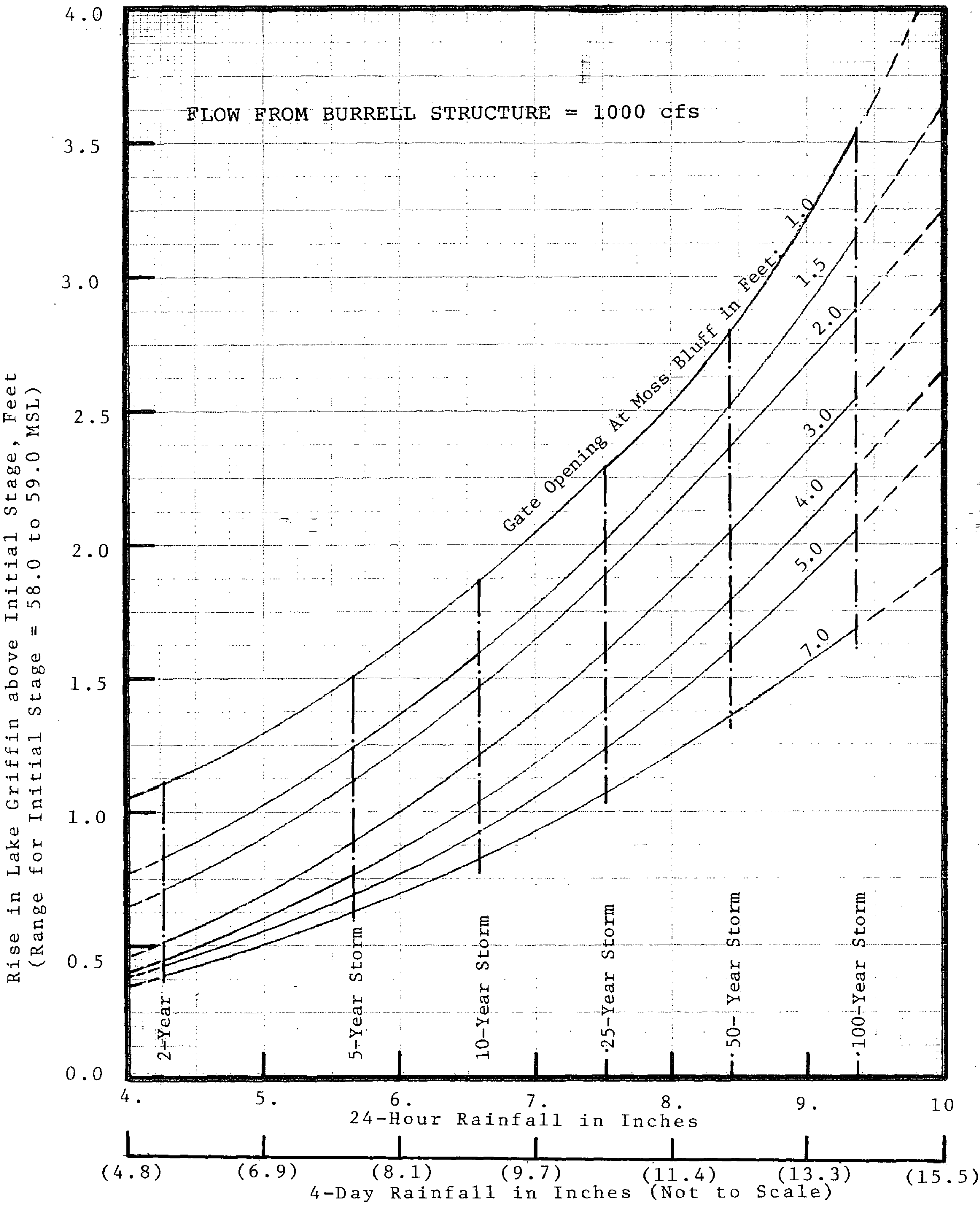


FIGURE 17. -- The Rainfall - Lake Rise Relationships for Lake Griffin (Flow from Burrell Structure = 1,000 cfs)

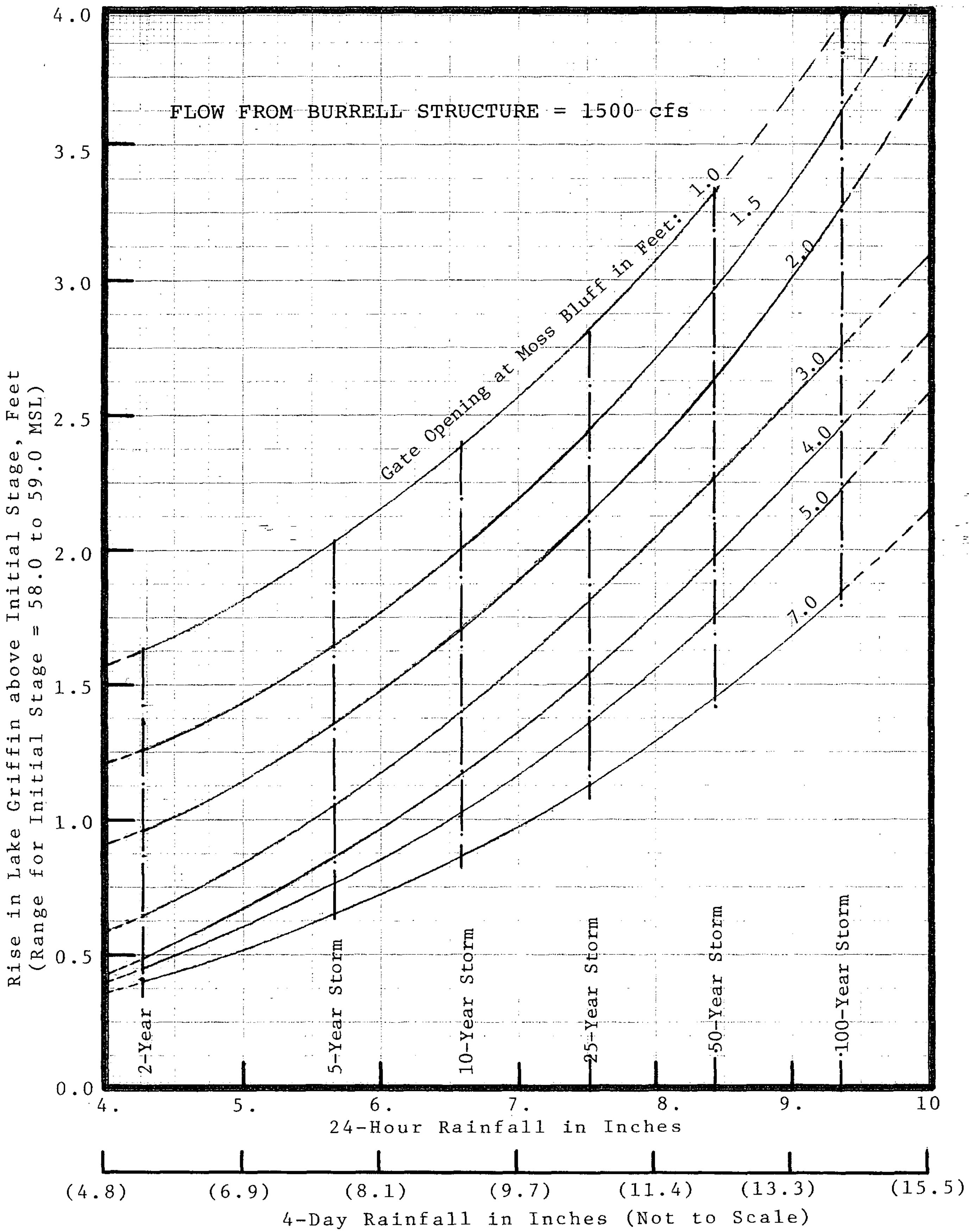


FIGURE 18. -- The Rainfall - Lake Rise Relationships for Lake Griffin (Flow from Burrell Structure = 1,500 cfs)

for four different flow releases (200, 500, 1,000, and 1,500 cfs) from Burrell structure. Each of these figures shows the maximum rise expected in Lake Griffin (above the stage at beginning of the storm) due to a 4-day storm if gates at Moss Bluff are opened in the range of 1 to 7 feet and the 24-hour rainfall of a 4-day storm is known. The applicable range for initial lake elevation is 58.00 to 59.00 feet msl, but if the peak elevation calculated on the basis of these figures exceeds 62.00 feet msl, it only indicates that the peak will exceed 62.00 feet msl rather than the exact rise above 62.00 feet msl. (Example: For 24-hour rainfall = 9 inches with Burrell structure flow of 1,000 cfs and Moss Bluff gate opening = 1.0 foot, the lake rise = 3.22 feet from Figure 17. If the initial lake elevation is 59.00 msl, the peak elevation of 62.22 is an approximate value, but indicates that the peak will exceed 62.00 feet msl). Other pertinent information such as time to peak, peak outflow, and time for stage to recede to 58.50 feet msl, or stage at the end of 10-day period beginning from storm may be found in the appendix for specific cases of simulation experiments.

The minimum gate openings and the corresponding (minimum) flow releases required at Moss Bluff to limit peak elevation to 60.00 feet msl in Lake Griffin for different 4-day storm events are summarized in Tables 14 and 15, respectively. These tables show that if the lake is maintained at 58.50 feet msl (minimum desirable elevation as per regulation schedule, Figure 2), all storms of frequencies up to 25 years can be quite easily managed by appropriate gate operation at Moss Bluff. Peak stages can be limited to 60.00 feet msl or even lower, especially for 2 to 10-year storms. However, for a 50-year storm, the downstream flow will exceed 3,000 cfs if 60.00 feet msl were not to be exceeded; and for the 100-year storm, the peak will exceed 60.00 feet msl invariably for all gate openings up to 7.0 feet (see Tables 16 through 19). If Moss Bluff flow releases are confined to about 3,000 cfs and the Burrell structure discharges at its near capacity of 1,500 cfs, the 50 and 100-year peak stages in Lake Griffin will be about 60.50 and 61.00 feet msl, respectively.

TABLE 14. -- Minimum Gate Openings Required at Moss Bluff to Limit Peak Lake Elevation to 60.00 Feet MSL for a 4-Day Storm

Initial Lake Elevation, Feet, MSL	Flow from Burrell Structure, cfs	Storm Return Period, Years					
		2	5	10	25	50	100
58.00	200	1.0	1.0	1.0	1.0	2.1	4.0
	500	1.0	1.0	1.0	1.0	2.4	4.5
	1,000	1.0	1.0	1.0	1.6	3.2	5.4
	1,500	1.0	1.0	1.5	2.3	4.0	6.3
58.50	200	1.0	1.0	1.0	2.3	4.1	7.0
	500	1.0	1.0	1.1	2.7	4.6	*
	1,000	1.0	1.0	1.8	3.4	5.5	*
	1,500	1.2	1.7	2.5	4.3	6.5	*
59.00	200	1.0	1.2	2.8	6.0	*	*
	500	1.0	1.6	3.2	6.5	*	*
	1,000	1.2	2.3	4.0	*	*	*
	1,500	1.9	3.3	4.9	*	*	*

* Not possible to limit peak elevation to 60.00 feet MSL even with gates at maximum opening.

TABLE 15. -- Minimum Flow Releases Required at Moss Bluff to Limit Peak Lake Elevation to 60.00 Feet MSL for a 4-Day Storm

Initial Lake Elevation, Feet, MSL	Flow from Burrell Structure, cfs	Storm Return Period, Years: 2	5	10	25	50	100
58.00	200	700	710	710	730	1,480	2,770
	500	700	710	720	730	1,720	3,060
	1,000	710	720	730	1,160	2,560	3,570
	1,500	720	730	1,100	1,640	2,770	4,070
58.50	200	710	720	800	1,640	2,830	4,450
	500	710	720	770	1,930	3,120	*
	1,000	720	730	1,280	2,390	3,630	*
	1,500	880	1,220	1,800	2,940	4,180	*
59.00	200	720	880	2,000	3,920	*	*
	500	720	1,160	2,260	4,180	*	*
	1,000	880	1,640	2,770	*	*	*
	1,500	1,340	2,310	3,290	*	*	*

* Not possible to limit peak elevation to 60.00 feet MSL with gates at maximum opening.

TABLE 16. -- Peak Stages (Feet, M.S.L.) in Lake Griffin for 50-Year 4-Day Storm

RAINFALL=12.22 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
0 HRS	20 HRS		4.0	4.5	5.0	5.5	6.0	7.0
58.00	58.92	200.	59.53(96)	59.46(63)	59.41(57)	59.36(54)	59.32(51)	59.26(49)
58.00	58.92	500.	59.63(97)	59.53(96)	59.46(64)	59.41(57)	59.37(54)	59.30(50)
58.00	58.92	1000.	59.81(100)	59.71(98)	59.61(97)	59.52(96)	59.45(63)	59.37(54)
58.00	58.92	1500.	60.00(104)	59.89(101)	59.79(99)	59.69(98)	59.60(97)	59.45(63)
58.50	59.43	200.	60.01(80)	59.94(61)	59.89(56)	59.85(53)	59.81(51)	59.74(49)
58.50	59.43	500.	60.11(97)	60.01(84)	59.95(61)	59.90(56)	59.85(53)	59.78(49)
58.50	59.43	1000.	60.29(99)	60.19(98)	60.08(97)	59.99(72)	59.93(60)	59.85(53)
58.50	59.43	1500.	60.48(103)	60.37(101)	60.26(99)	60.16(97)	60.06(96)	59.93(59)
59.00	59.93	200.	60.50(72)	60.44(60)	60.39(55)	60.34(52)	60.30(50)	60.22(48)
59.00	59.93	500.	60.60(97)	60.50(72)	60.44(60)	60.39(55)	60.34(52)	60.26(49)
59.00	59.93	1000.	60.78(99)	60.67(98)	60.56(96)	60.48(66)	60.42(58)	60.33(52)
59.00	59.93	1500.	60.97(103)	60.85(100)	60.74(98)	60.64(97)	60.53(96)	60.41(57)

VALUES IN PARENTHESES INDICATE TIME TO PEAK IN HOURS FROM THE BEGINNING OF STORM

TABLE 17. -- Peak Flow (cfs) at Moss Bluff for 50-Year 4-Day Storm

RAINFALL=12.22 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
			4.0	4.5	5.0	5.5	6.0	7.0
0 HRS	20 HRS							
58.00	58.92	200.	2709.(96)	2981.(63)	3255.(57)	3515.(54)	3771.(51)	4242.(49)
58.00	58.92	500.	2722.(97)	2992.(96)	3264.(64)	3524.(57)	3781.(54)	4253.(50)
58.00	58.92	1000.	2746.(100)	3018.(98)	3288.(97)	3543.(96)	3800.(63)	4273.(54)
58.00	58.92	1500.	2770.(104)	3044.(101)	3316.(99)	3574.(98)	3831.(97)	4297.(63)
58.50	59.43	200.	2771.(80)	3052.(61)	3333.(56)	3603.(53)	3878.(51)	4377.(49)
58.50	59.43	500.	2782.(97)	3061.(84)	3341.(61)	3611.(56)	3887.(53)	4388.(49)
58.50	59.43	1000.	2801.(99)	3084.(98)	3362.(97)	3628.(72)	3905.(60)	4408.(53)
58.50	59.43	1500.	2821.(103)	3107.(101)	3389.(99)	3656.(97)	3930.(96)	4430.(59)
59.00	59.93	200.	2822.(72)	3116.(60)	3408.(55)	3685.(52)	3969.(50)	4506.(48)
59.00	59.93	500.	2833.(97)	3124.(72)	3416.(60)	3692.(55)	3976.(52)	4516.(49)
59.00	59.93	1000.	2852.(99)	3145.(98)	3434.(96)	3707.(66)	3990.(58)	4533.(52)
59.00	59.93	1500.	2872.(103)	3169.(100)	3461.(98)	3732.(97)	4008.(96)	4553.(57)

VALUES IN PARENTHESES INDICATE TIME TO PEAK IN HOURS FROM THE BEGINNING OF STORM

TABLE 18. -- Peak Stages (Feet, M.S.L.) in Lake Griffin for 100-Year 4-Day Storm

RAINFALL=14.13 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
			4.0	4.5	5.0	5.5	6.0	7.0
0 HRS	20 HRS							
58.00	59.06	200.	59.99(98)	59.88(97)	59.78(97)	59.69(96)	59.61(67)	59.52(54)
58.00	59.06	500.	60.10(99)	59.99(98)	59.89(97)	59.79(97)	59.70(96)	59.57(59)
58.00	59.06	1000.	60.28(102)	60.17(100)	60.07(99)	59.97(98)	59.87(97)	59.69(96)
58.00	59.06	1500.	60.48(106)	60.36(103)	60.25(101)	60.15(100)	60.05(99)	59.87(97)
58.50	59.56	200.	60.47(98)	60.37(97)	60.26(97)	60.16(96)	60.09(62)	60.00(52)
58.50	59.56	500.	60.58(99)	60.47(98)	60.37(97)	60.27(97)	60.16(96)	60.04(56)
58.50	59.56	1000.	60.77(102)	60.66(100)	60.55(99)	60.44(98)	60.34(97)	60.15(96)
58.50	59.56	1500.	60.96(106)	60.84(103)	60.73(101)	60.62(100)	60.52(99)	60.32(97)
59.00	60.06	200.	60.96(98)	60.85(97)	60.74(96)	60.64(85)	60.57(60)	60.48(51)
59.00	60.06	500.	61.07(99)	60.96(98)	60.85(97)	60.74(97)	60.64(96)	60.53(54)
59.00	60.06	1000.	61.25(101)	61.14(100)	61.02(99)	60.92(98)	60.82(97)	60.62(69)
59.00	60.06	1500.	61.45(105)	61.33(103)	61.21(101)	61.10(99)	60.99(98)	60.79(97)

VALUES IN PARENTHESES INDICATE TIME TO PEAK IN HOURS FROM THE BEGINNING OF STORM

TABLE 19. -- Peak Flow (cfs) at Moss Bluff for 100-Year 4-Day Storm

RAINFALL=14.13 INCHES

LAKE ELEVATION AT THE BEGINNING OF STORM FEET ABOVE MSL		FLOW FROM BURRELL STRUCTURE CFS	SPILLWAY GATE OPENING AT MOSS BLUFF, FEET					
			4.0	4.5	5.0	5.5	6.0	7.0
0 HRS	20 HRS							
58.00	59.06	200.	2768.(98)	3043.(97)	3315.(97)	3574.(96)	3833.(67)	4315.(54)
58.00	59.06	500.	2780.(99)	3059.(98)	3332.(97)	3593.(97)	3853.(96)	4329.(59)
58.00	59.06	1000.	2800.(102)	3082.(100)	3360.(99)	3624.(98)	3891.(97)	4365.(96)
58.00	59.06	1500.	2820.(106)	3106.(103)	3388.(101)	3654.(100)	3928.(99)	4412.(97)
58.50	59.56	200.	2820.(98)	3107.(97)	3389.(97)	3656.(96)	3934.(62)	4449.(52)
58.50	59.56	500.	2831.(99)	3120.(98)	3405.(97)	3673.(97)	3947.(96)	4461.(56)
58.50	59.56	1000.	2851.(102)	3144.(100)	3432.(99)	3701.(98)	3976.(97)	4488.(96)
58.50	59.56	1500.	2871.(106)	3168.(103)	3460.(101)	3730.(100)	4006.(99)	4531.(97)
59.00	60.06	200.	2871.(98)	3168.(97)	3461.(96)	3732.(85)	4015.(60)	4571.(51)
59.00	60.06	500.	2882.(99)	3182.(98)	3477.(97)	3749.(97)	4026.(96)	4582.(54)
59.00	60.06	1000.	2902.(101)	3205.(100)	3504.(99)	3777.(98)	4055.(97)	4605.(69)
59.00	60.06	1500.	2922.(105)	3229.(103)	3531.(101)	3806.(99)	4084.(98)	4646.(97)

VALUES IN PARENTHESES INDICATE TIME TO PEAK IN HOURS FROM THE BEGINNING OF STORM

From the foregoing discussion, it is clear that 58.50 feet msl is, in general, an optimum low elevation which should be maintained during rainy season. By appropriate gate operation at Moss Bluff, peak stage in Lake Griffin can be limited to 60.00 feet msl for major storm events except in case of rare events having 50 to 100-year return periods in which case the stage will reach 61.00 feet msl. However, the lake regulation schedule (Figure 2) shows that the low elevation of 58.50 feet msl will be maintained only during June and July, and the stage is gradually increased to 59.25 feet msl by the end of October. If major storms occur in other months, the peak stages will be higher compared to 58.50 feet msl initial stage case by an amount equal to the difference between the prevailing stage and 58.50 feet msl. Historically, peak stages exceeded 60.00 feet msl in Lake Griffin on several occasions, the recorded highest being 60.74 feet on October 11 and 12, 1960. However, with the construction of new Moss Bluff Dam in 1969 and channelization of the Oklawaha River as a part of the Four River Basins Project, better regulation of lake stages is currently possible.

SUMMARY AND CONCLUSIONS

Water level fluctuations in Lake Griffin are regulated within a narrow elevations range of 58.00 to 60.00 msl for navigation as well as flood control purpose. The objective of this study was to investigate whether runoff due to major storm events could be safely passed through Lake Griffin without violating the above elevation limits. The major steps were, by using appropriate hydrologic and hydraulic procedures: (1) to determine the runoff generated in the lake basin for 4-day storms of return periods ranging from 2 to 100 years and (2) to route the storm hydrograph through the lake for a variety of lake, inflow and outflow conditions, and thereby evaluate the peak stage, peak outflow and stage and discharge hydrographs for each condition covered.

Extensive results generated by this study will serve as an operation manual for the system for storm water management. These results (manual) will help to determine the gate opening required at Moss Bluff (for releasing flows downstream) to limit peak stage in Lake Griffin to the desirable elevation on the basis of 24-hour rainfall and the flows released at Burrell structure.

The conclusions from this study are:

1. Lake Griffin, in general, has a large storage capacity which can receive and pass safely runoff due to major storms.

2. A storm of given rainfall will produce approximately equal net rises in the lake over any initial lake elevation between 58.00 and 59.00 msl under similar operation conditions at Moss Bluff and Burrell structure.

3. If the lake is maintained at a low elevation of 58.50 feet msl during rainy season, the following conditions will occur:

   i) The peak stages will be below 60.00 feet msl in Lake Griffin for all storms up to and including 25 years frequency for

Burrell structure flows ranging from 200 to 1,500 cfs; Moss Bluff releases will be below 3,000 cfs.

ii) For a 50-year storm, the Moss Bluff flow releases will exceed 3,000 cfs if peak stage in Lake Griffin is to be limited to 60.00 feet msl. For a 100-year storm, it will not be possible to limit peak stage to 60.00 feet msl.

iii) If Moss Bluff flow releases are confined to about 3,000 cfs and the Burrell structure discharges at its near capacity of 1,500 cfs, the 50 and 100-year peak stages in Lake Griffin will be about 60.50 and 61.00 feet msl, respectively.

4. If the lake elevation is different from 58.50 feet msl at the incidence of storm, the peak stages stated in Conclusion Number 3 will differ by an amount equal to the difference between the initial lake stage and 58.50 feet msl in the same direction. This is a corollary to Conclusion Number 2.

RECOMMENDATIONS

The results obtained in this study will greatly help in the operation of Lake Griffin for storm water management. Figures 15 to 18 and the tables of results (Appendix to this report) derived for many possible situations covering different lake elevations and inflow and outflow conditions will serve as a reference manual for gate operation at Moss Bluff and Burrell structure during storm events. Although a particular storm distribution was assumed for rainfalls in this study, the results may approximately represent the storm events of different distribution, but having the same amount of rainfall. The following steps provide guidelines for practical application of the results of the present study.

1. Watch the weather reports carefully, and lower the lake elevation to 58.50 msl if a storm of large magnitude is imminent. Note the lake elevation at the beginning of storm.

2. The rainfall distribution during a storm will be generally erratic and may not exactly conform to the distribution assumed in this study. Disregard the distribution, but note the total rainfall occurred in approximately 24 hours or less period. Compute the basin average. Assume that the storm is likely to develop into a major storm of longer duration.

3. On the basis of rainfall in the upstream reaches, determine the flow releases required at the Burrell structure.

4. Calculate the difference between 60 feet and the lake elevation at the beginning of storm. This is normally the maximum permissible rise in the lake. Enter Figures 15 through 18, and determine the gate opening for Moss Bluff for the above rise. (Example: Burrell structure flow = 1,000 cfs. Initial lake elevation = 58.75 feet msl, 24-hour rainfall = 7 inches; therefore, maximum permissible rise = 60.00 - 58.75 = 1.25 feet. From Figure 17, Moss Bluff gate

opening = 3.6 feet.) If flow from Burrell structure is different from those shown in Figures 15 to 18, compute Moss Bluff gate opening from the two figures to which Burrell structure flow is intermediate and determine final value by interpolation.

5. Check whether the discharge released at Moss Bluff is too high. If so, a smaller gate opening should be used in which case the peak stage will exceed 60.00 msl. Make a compromise between the peak stage and downstream discharge.

6. In the current study, it was assumed that the heaviest rainfall would occur on the first day followed by less rainfall activity. In practice, however, substantial rainfall may occur on the day(s) prior to the 24-hour period having the heaviest rainfall. In such cases, an approximation will be to include a portion of the previous rainfall (at least 50%) in the 24-hour storm rainfall described in Step 2.

7. In case of general heavy rainfall activity for several days, different results should be evaluated on a continuous update basis by using the basin model. Rainfall records should be obtained at closer intervals, preferably every six hours. The basin model should be run on the computer every six hours for the current operating conditions and alternative strategies and optimal operation strategies be evaluated. The process should continue until the storm event ends.

8. To the extent possible, see that high flow releases from Burrell structure will not synchronize with the storm flows of Lake Griffin basin.

NEEDED FURTHER STUDIES

The present study needs to be extended to the chain of lakes and drainage basin upstream of Burrell water control structure. In the present study, only a wide range of flow releases was assumed from Burrell structure to Lake Griffin. Since the flows and stages, in general, are controlled by gated structures at different locations throughout the upstream basin, modeling on the lines of the present study will be necessary to determine flow releases upstream for different storm events.

Further, in the water management study completed by Camp, Dresser & McKee, Inc. (1) for the Middle Oklawaha River Basin (Moss Bluff to Rodman Pool), some flood damages were identified at Silver Springs commercial complex for return periods 10 years and above. One of the alternatives suggested for relief was to store flood waters in the upstream lakes of Dora, Eustis, Harris, and Griffin by lowering the minimum water elevations in the lakes by approximately 0.6 feet. The flood control potential of the above lakes can be determined only after a complete modeling of Upper Oklawaha Basin for storm water management.

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