REGIONAL FLOOD RELATIONS FOR UNREGULATED LAKES

IN WEST-CENTRAL FLORIDA

By M. A. Lopez and R. D. Hayes

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4015

Prepared in cooperation with the

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Tallahassee, Florida

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
Suite 3015
227 North Bronough Street
Tallahassee, Florida 32301

Copies of this report can be purchased from:

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U.S. Geological Survey
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GLOSSARY

Some of the technical terms used in this report are defined here for those who are not familiar with hydrologic and statistical terminology used in this report. See Dalrymple (1960) and Langbein and Iseri (1960) for additional information regarding flood-frequency analysis and associated hydrologic terminology. Statistical terms are defined with respect to flood analysis applications described in this report.

Annual maximum lake stage.--The highest observed or recorded independent instantaneous peak altitude for a climatic year.

Climatic year.--For this report, the 12-month period beginning June 1 and ending May 31 and is designated by the calendar year in which it ends.

Correlation.--Linear dependence between two or more hydrologic variables.

Correlation coefficient.--The degree of linear dependence of two hydrologic variables. The correlation coefficient can range from plus one (perfect correlation) to minus one (perfect inverse correlation). A coefficient of zero signifies no correlation.

Dependent variable.--The parameter for which the variation is explained by physical or meteorological factors in a regression analysis.

Equivalent years of record.--Number of years of lake-stage record that would be necessary to produce a frequency distribution with accuracy equal to that of the regression analysis.

Exceedance probability.--The probability that a flood will equal or exceed a specific magnitude in any climatic year. Recurrence interval is computed as the reciprocal of exceedance probability and, thus, has the stated probability of occurrence in any one year.

Frequency distribution.--A graph showing the flood magnitude that will, on the average, be exceeded once within a specified number of years (Riggs, 1968).

Independent variable.--Physical or meteorological factors that explain the variation in the dependent variable in a regression analysis.

Mean.--The arithmetic average of the sample.

Multiple correlation coefficient.--A measure of the explanatory power of a regression involving three or more hydrologic variables.

Outlier.--An annual flood that departs significantly from the trend of the remaining data.

R^2.--Square of the multiple correlation coefficient.

Recurrence interval.--The average interval of time within which a specified flood magnitude will be exceeded once.

Residual.--The difference between an observed value and a value estimated by a regression equation.

Serial correlation coefficient.--A measure of dependence of an annual event on the previous year event--used to test for degree of independence of the annual events.

Significance (level of).--The specified probability level at which a statistical test is made to determine whether or not the explained variation in the dependent variable that results from introduction of an independent variable in the regression analysis could have occurred by chance alone.

Skew coefficient.--Relative measure of the asymmetry of a frequency distribution.

Standard deviation.--A measure of the amount of variation in a sample population. The standard deviation is determined by taking the square root of the average squared deviations of the observations from the mean.

Stage.--The height of the water surface above a reference datum that is observed or recorded at a gaging station. In Florida, lake stage is published as altitude, in feet NGVD of 1929.

Standard error of estimate.--A measure of the reliability of a regression equation. In this report, the standard error is given as an average percent value that represents the average range about the regression equation, which includes about 68 percent of all regression data points. More technically, the standard error is the standard deviation of the residuals about the regression equation.

T-year event.--Specified recurrence interval, in years.

Watershed characteristics.--Parameters that describe the physical and climatic factors of a lake and its drainage basin.

DEFINITION OF VARIABLE NAMES USED IN THIS REPORT

AR, average annual rainfall for lake watershed, in inches.

AVAREA, lake surface area at the regional estimate of average lake altitude, in acres.

AVOL, lake volume at the regional estimate of average lake altitude, in acre-feet.

DA, drainage area of watershed, in square miles.

DELVOL, lake volume at the point of zero outflow minus lake volume at average lake altitude for the period of record at a gaged lake (OVOL - SVOL), in acre-feet.

DELVOLA, DELVOL per square mile of drainage area (OVOL - SVOL)/DA, in acre-feet per square mile.

MAPRAIN, map rain, in inches. The annual rainfall on the lake watershed for year that the topography on the U.S. Geological Survey 7-1/2-minute quadrangle map was determined (MAPYEAR).

MAPYEAR, map year. The calendar year that the topography on the U.S. Geological Survey 7-1/2-minute topographic quadrangle was determined.

OALT, altitude of point of zero outflow from lake, in feet NGVD of 1929.

OVOL, volume of lake at OALT, in acre-feet.

QUADAREA, area of lake shown on a U.S. Geological Survey 7-1/2-minute topographic quadrangle, in acres.

QUADALT, altitude of lake shown on a U.S. Geological Survey 7-1/2-minute topographic quadrangle, in feet NGVD of 1929.

QVOL, lake volume at QUADALT, in acre-feet.

R50YR_10, 50-year, 10-day rainfall, in inches.

RAVALT, regional estimate of average lake altitude, in feet NGVD of 1929.

RDELVOL, lake volume at the point of zero outflow minus lake volume at the regional estimate of average lake altitude (OVOL - AVOL), in acre-feet.

SOIL, soil-infiltration index, in inches. The potential maximum infiltration during an annual flood under average soil-moisture conditions. Determined from Soil Conservation Service curve numbers as defined by Chow (1964).

STALT, average lake altitude for gaged lakes, in feet NGVD of 1929. Computed as the average of mean-daily altitudes for the period of record.

STARAIN, average annual rainfall on the lake watershed for the period of stage record, in inches.

STAREA, lake surface area at average lake altitude for the period of record at a gaged lake, in acres.

SVOL, lake volume at average lake altitude (STALT), in acre-feet.

ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System (SI) of Units and abbreviations of units

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	hectare (ha)
acre-foot	1,233	cubic meter (m^3)

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National Geodetic Vertical Datum of 1929 (NGVD of 1929).--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

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REGIONAL FLOOD RELATIONS FOR UNREGULATED LAKES IN WEST-CENTRAL FLORIDA

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ABSTRACT

This report presents regional relations for estimating the magnitude and frequency of floods on natural, unregulated lakes in the Central Lake District and Ocala Uplift District physiographic regions of west-central Florida. Lake flood-altitude estimate equations for 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals can be used for flood-plain zoning and flood-insurance studies.

The long-term average lake altitude is used as a reference above which annual flood volumes are related in a multiple linear-regression analysis. Average lake altitude for surface-outflow lakes is related to altitude of water surface shown on a U.S. Geological Survey topographic quadrangle, lake-outlet altitude, and annual rainfall. The multiple correlation coefficient is higher than 0.99 and the average standard error of estimate is ±1.0 percent. Average lake altitude for closed-basin lakes is related to altitude of water surface shown on a U.S. Geological Survey topographic quadrangle. The correlation coefficient is 0.99, and the standard error of estimate is ±4.0 percent.

Annual flood volume above average altitude for surface-outflow lakes in the Central Lake District and Ocala Uplift District physiographic areas of west-central Florida is related to lake and watershed characteristics by multiple linear-regression analysis. The standard error of estimate for regional relations ranges from 29 to 54 percent in the Central Lake District and from 50 to 58 percent in the Ocala Uplift District. Standard error of estimate for regional relations of closed-basin lakes ranges from 22 to 40 percent.

Regional relations for average altitude and annual flood altitude are used to weight station annual flood-altitude data. Tables comparing station, regional, and weighted lake flood altitudes are shown for 47 lake stations used in the analysis.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the Southwest Florida Water Management District, recognized a need for a uniform method for estimating lake flood frequency to be used in zoning and flood-insurance studies and initiated this study in 1979. The results of this investigation will assist agencies in determining natural, unregulated lake levels for floods of 2- to 500-year recurrence intervals that are needed for effective flood-plain zoning and regulation.

Lakes in west-central Florida provide attractive settings for homes, are used for water sports, and provide passive recreation. As the State's population increases, demands for lake-front property will grow. Development around lakes has progressed from an occasional home or cottage to large subdivisions.

Rainfall during the past 20 years has been generally lower than normal, and lakes have experienced few notable floods. During this period of lower than average lake levels, urban development has encircled some lakes. Communities far from urban centers have been built along the shores of lakes, increasing the possibility of property damage by flooding.

Regulatory agencies have become concerned that the risk of flooding has not been adequately considered in many developments. Planning and zoning commissions have had to regulate development on a lake-by-lake basis without benefit of methods for making regional lake flood estimates. Regional lake flood-frequency information that covers recurrence intervals as great as 500 years is needed for flood insurance. Flood-frequency information for lesser recurrence intervals is needed for flood-plain management by local agencies.

Reliable flood-frequency information can be determined at lakes where long-term systematic lake-level records are available. At many lakes where short-term records are available, records were collected during periods of lower than normal rainfall. Thus, the records may not be representative of long-term conditions and are less reliable for use in flood-frequency analysis. Cost considerations make it impractical to collect lake-stage records for a sufficient length of time at every lake where flood data are needed. Thus, a need exists to define lake flood frequency at ungaged lakes as well as gaged lakes. This report provides a consistent and uniform procedure for estimating lake flood-frequency information throughout west-central Florida.

Lake flood-frequency information for gaged lakes of unincorporated areas and 10 communities in Polk County has been published by the U.S. Department of Housing and Urban Development in a series of flood-insurance reports (U.S. Department of Housing and Urban Development, 1979; 1980a; 1980b; 1980c; 1980d; 1980e; 1980f; 1981a; 1981b; 1981c; 1982). Flood-frequency data for ungaged lakes in these 10 communities and the unincorporated area were based on flow routing of synthetic hydrographs. Flood-frequency data for gaged lakes in Polk and Hillsborough Counties that are managed by the Southwest Florida Water Management District (Southwest Florida Water Management District, 1976; Malcolm Johnson, written commun., 1978) were also considered in preparing this regional analysis.

Purpose and Scope

The purpose of this study was to develop lake-stage flood-frequency relations for lakes in the Southwest Florida Water Management District. These relations are for lake flood stages having recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years. Lakes that had 10 years or more of annual peak lake-stage record located in and near the study area were included. Flood-stage data for 47 lakes that were not significantly affected by regulation or changes during the period of record through May 1979 were used in the analysis.

Regional relations were developed in a multiple linear-regression analysis of lake-stage flood-frequency data and watershed characteristics. These relations are provided in mathematical form and are supported by illustrated examples to demonstrate their use. Accuracy of the regression estimates is expressed in terms of equivalent years of record and standard errors of estimate.

The regional relations developed are applicable to lakes that have drainage areas between 0.1 mi^2 and 170 mi^2. Results do not apply to lakes that have had significant changes in outflow capacity, altitude-volume relation, or drainage area after the publication of the topographic map used to determine regression variables. Lakes significantly affected by tide, or lakes that have significant regulation or diversion, are also excluded.

DESCRIPTION OF THE STUDY AREA

The study area includes all of the Southwest Florida Water Management District, an area of approximately 10,000 mi^2 that includes all or part of 16 counties in west-central Florida. The following description summarizes physiographic, hydrologic, and climatic factors that influence lake-stage fluctuations.

Physiography

The study area lies in three major physiographic divisions as described by Brooks (1981): Central Lake District, Southwestern Flatwoods District, and Ocala Uplift District (fig. 1). The northern part of the study area in the Central Lake District is characterized by sand hill karst terrane with some low, swampy prairies. Altitude is generally between 100 and 150 feet NGVD. The Central Lake District narrows toward the south where it consists of ridges with hills up to 300 feet NGVD. The altitude along the boundary is generally about 100 feet NGVD.

Altitudes in the Southwestern Flatwoods District decrease to the southwest from the boundary with the Central Lake District. A series of low hills along the east boundary quickly merge with sloping plains that range in altitude from 90 to 30 feet NGVD.

Altitude in the Ocala Uplift District ranges from a very low coastal strip to over 200 feet NGVD in an area of karst and sand hills. The karst features are more prominent at higher altitudes, but are present throughout the District.

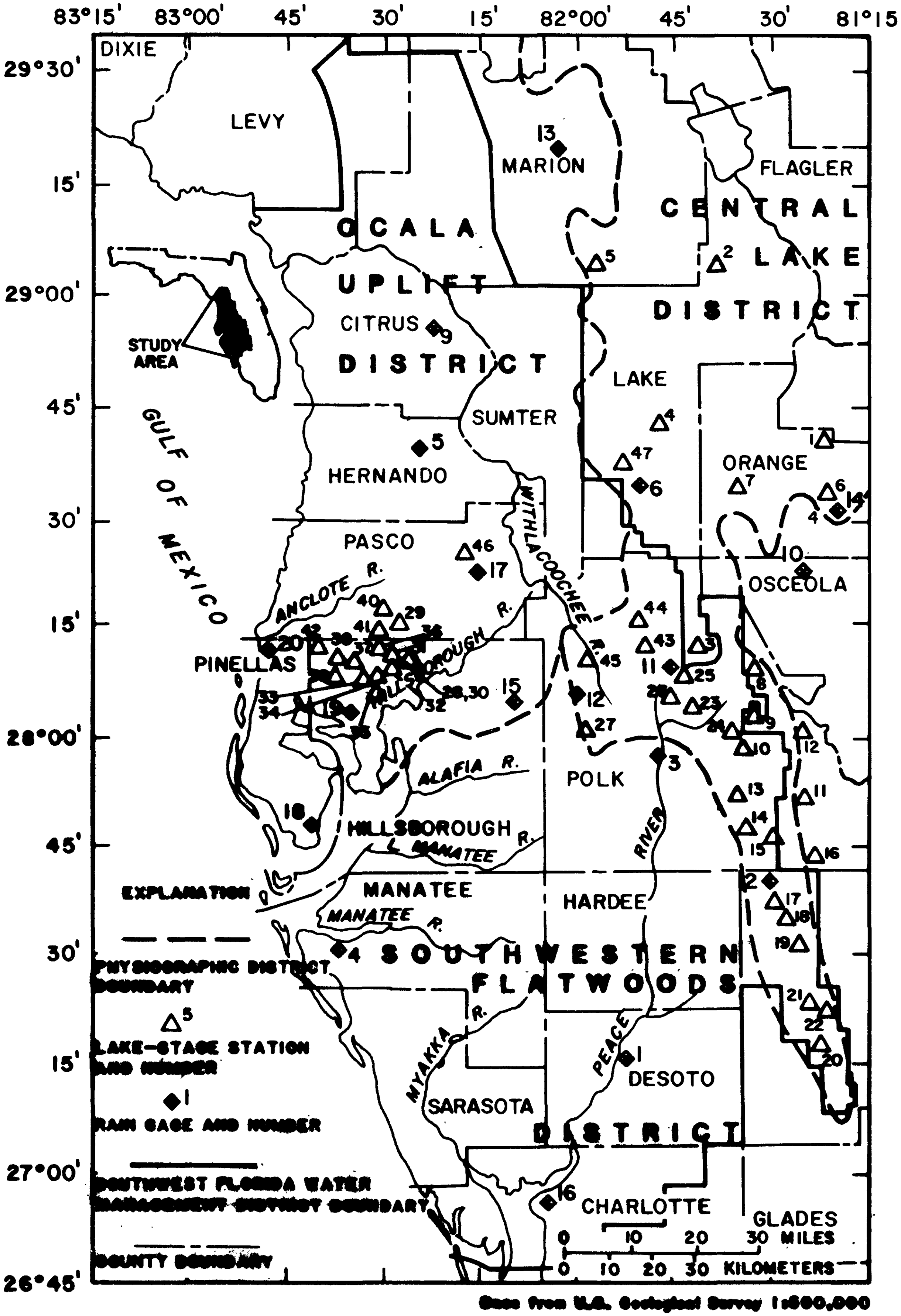

Figure 1.--Physiographic divisions (modified from Brooks, 1981), major drainage systems, and locations of lake-stage stations and long-term rain gages.

Hydrologic Setting

The uplifted limestones of the Floridan aquifer lie unconformably below surficial sands in the Central Lake District. Stewart (1980) indicates that the Central Lake District in the study area is an area of high recharge to the Floridan aquifer. The southern part of this District has well-drained upland areas characterized by a poorly developed stream-drainage system and many closed depressions, some of which contain water perennially. Some of the karst surface has been reduced to the water-table altitude, which results in large areas of swampy land and interconnected lakes in the northern part of the Central Lake District. Surface-water drainage from the Central Lake District is through the Peace, Alafia, and Hillsborough Rivers to the south and west, the Withlacoochee River to the north, and the Kissimmee River to the east and south.

South and east of Tampa Bay, the Southwestern Flatwoods District is a poorly drained plateau underlain by deeply weathered sand and clayey sand. Flatwoods and cypress heads exist throughout the headwaters of the major rivers that drain this area--Alafia, Little Manatee, Manatee, Myakka, and Peace. South of Tampa Bay, the sloping plain has maximum altitudes of from 90 to 30 feet NGVD. Except for the Peace River, the surface-drainage systems are disrupted by swamps. Except for areas along the coast and up the lower reaches of the Myakka and Peace Rivers, the Floridan aquifer is known to be overlain by relatively impermeable confining beds that allow very low recharge (Stewart, 1980). Generally, the coast and the lower reaches of the Myakka and Peace Rivers are natural discharge areas.

The Ocala Uplift District is a complex of hydrologically distinct subdivisions. They vary from an area of swamps and flatwoods at the headwaters of the Withlacoochee and Hillsborough Rivers to an area of high hills over 200 feet in altitude from about 40 miles north of Tampa Bay to just south and west of the Withlacoochee River. This area of high hills is characterized by poorly developed stream-drainage systems and many closed depressions. This is an area of high recharge according to Stewart (1980). The remainder of the Ocala Uplift District in the study area consists of areas of very low to moderate recharge. Surface drainage along the coast is from short streams draining swampy headwater areas. Flow in the lower reaches of the streams contains natural discharge from many springs.

Climate

The climate of west-central Florida is characterized by warm, humid summers and mild, moderately dry winters. The Gulf of Mexico moderates the extremes in temperature so that winter low temperatures are several degrees higher along the coast than in inland areas.

The average annual rainfall ranges from 50 to 56 inches (fig. 2). Rainfall varies seasonally with more than half the annual total occurring from June to September. Most summer rain comes from short-duration, high-intensity, afternoon showers or thunderstorms. Rainfall in the fall, winter, and spring generally occurs from less frequent, long-duration, frontal storms. Hurricanes, tropical storms, and depressions may cause heavy, sustained rainfall at irregular intervals. These storms can be a major cause of lake flooding.

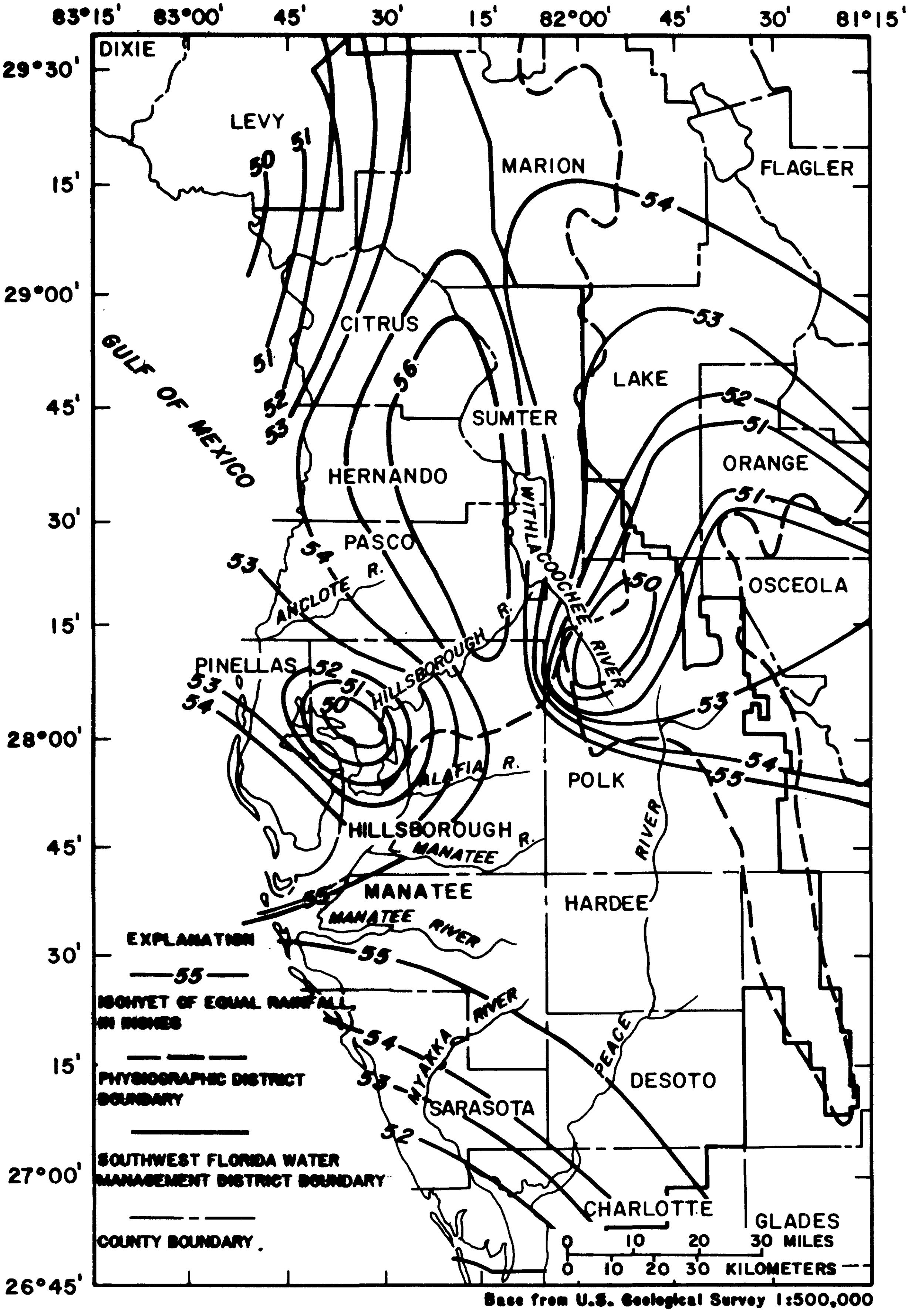

Figure 2.--Average annual rainfall, 1941-70, for the study area (modified from Southwest Florida Water Management District, 1978).

Differences in lake levels due to variations in evaporation are generally small. The decline in lake levels due to evaporation tends to be about the same for lakes in the same general area of Florida (Hughes, 1974).

RECORDS AVAILABLE

Lake Stage

Lake-stage records were collected by the U.S. Geological Survey in cooperation with state, local, and federal agencies. Historical flood-stage data were obtained from the Florida Department of Transportation, the Southwest Florida Water Management District, and from interviews with local residents.

Lake-stage stations were selected on the basis of length and accuracy of record and stability of watershed and outlet conditions. Lakes that had less than 10 years of record before 1979 were not used in this analysis. Also, lakes that were significantly affected by regulation or diversion and lakes whose watershed or outlet conditions had changed during gage operation were excluded. Some stations were used if the record was longer than 10 years before or after a change in watershed or outlet conditions was made.

All lakes that were within the study area and that met selection criteria were used in the analysis. In addition, lakes that were close to but outside the boundary of the study area that met selection criteria were included to provide continuity to the analysis. Thirty-one lakes are in the Central Lake District, and 16 lakes are in the Ocala Uplift District. There were no lakes that met the selection criteria in the Southwestern Flatwoods District. Locations of lakes used in the analysis are shown in figure 1, and drainage area and period of record are listed in table 1.

Rainfall

Annual rainfall for 1940 to 1980 at selected long-term rain gages is listed in table 2. These data are from National Weather Service Annual Summaries of Climatological Data for Florida. At some stations where data were missing, rainfall was estimated from nearby gages to compute the annual rainfall. Locations of rainfall stations are shown in figure 1.

METHODOLOGY

One method of evaluating lake-stage data in a regional analysis is to relate the flood stage to readily available data on lake, watershed, and rainfall characteristics through regression analysis. This is necessary if the results of the analysis are to have transfer value to ungaged lakes. The change in stage above a reference stage that has hydrologic significance and that can be consistently estimated for ungaged lakes is needed for the regional analysis. Average lake stage was selected as the reference stage because it is the net result of the long-term effects of climatic and hydrologic conditions at the lake (Hughes, 1974). This method of regional analysis was used to relate change in volume above average lake stage to lake and watershed characteristics for lakes in Putnam County (A. L. Putnam, written commun., 1978). The results of this regional analysis were used in the Flood Insurance Study, Town of Interlachen (U.S. Department of Housing and Urban Development, 1978).

Table 1.--Lake-stage stations used in regional analysis

Map No. (fig. 1)	Station No.	Station name	Drainage area (mi^2)	Period of record used in analysis	
1	2234300	Lake Maitland at Winter Park, Fla.	20.60	1945	1964
2	2235150	Lake Dorr near Altoona, Fla.	26.50	1965	1978
3	2236250	Lake Lowery near Haines City, Fla.	5.40	1960	1976
4	2236860	Lake Apshawa near Minneola, Fla.	1.48	1953	1977
5	2238800	Lake Weir at Oklawaha, Fla.	53.80	1943	1976
6	2262800	Lake Conway at Pine Castle, Fla.	12.70	1952	1977
7	2263900	Lake Butler at Windermere, Fla.	14.50	1933	1979
8	2266650	Lake Marion near Haines City, Fla.	35.70	1959	1976
9	2266900	Lake Pierce near Waverly, Fla.	58.90	1948	1971
10	2268200	Lake Wales at Lake Wales, Fla.	2.42	1965	1979
11	2268400	Lake Weohyakapka at Indian Lake Estates, Fla.	93.50	1958	1976
12	2268600	Lake Rosalie near Lake Wales, Fla.	133.00	1967	1977
13	2269200	Crooked Lake near Babson Park, Fla.	31.30	1945	1976
14	2269300	Lake Clinch at Frostproof, Fla.	42.00	1947	1976
15	2269400	Reedy Lake near Frostproof, Fla.	60.90	1947	1971
16	2269600	Lake Arbuckle near Avon Park, Fla.	170.00	1942	1977
17	2269790	Lake Lotela near Avon Park, Fla.	12.20	1951	1975
18	2269800	Lake Letta near Avon Park, Fla.	15.60	1951	1975
19	2270550	Lake Jackson at Sebring, Fla.	14.00	1945	1975
20	2270750	Lake Placid near Lake Placid, Fla.	20.20	1945	1975
21	2271560	Lake McCoy near Lake Placid, Fla.	0.30	1952	1966
22	2271580	Lake Huntley near Lake Placid, Fla.	9.54	1952	1963
23	2293670	Lake Otis at Winter Haven, Fla.	1.00	1955	1977
24	2293774	Mountain Lake near Lake Wales, Fla.	2.30	1945	1977
25	2293999	Lake Mariana near Auburndale, Fla.	2.85	1946	1977
26	2294028	Deer Lake near Winter Haven, Fla.	1.29	1946	1969
27	2300900	Scott Lake near Lakeland, Fla.	2.18	1953	1977
28	2303432	Hanna Lake near Lutz, Fla.	0.60	1946	1978
29	2303440	Lake Padgett near Lutz, Fla.	6.60	1965	1979
30	2303700	Lake Stemper near Lutz, Fla.	0.74	1946	1978
31	2304700	Lake Hobbs at Lutz, Fla.	0.92	1946	1976
32	2305200	Round Lake near Lutz, Fla.	0.07	1965	1979
33	2306200	Lake Magdalene near Lutz, Fla.	4.09	1946	1978
34	2306300	Bay Lake near Sulphur Springs, Fla.	5.22	1946	1978
35	2306600	Lake Carroll near Sulphur Springs, Fla.	1.66	1946	1978

Table 1.--Lake-stage stations used in regional analysis--Continued

Map No. (fig. 1)	Station No.	Station name	Drainage area (mi^2)	Period of record used in analysis	
36	2306704	Lake Harvey near Lutz, Fla.	1.70	1970	1979
37	2306723	Turkey Ford Lake near Lutz, Fla.	9.80	1970	1979
38	2307227	Calm Lake near Odessa, Fla.	0.58	1965	1976
39	2307384	Echo Lake near Citrus Park, Fla.	0.91	1957	1976
40	2309584	Lake Thomas at Drexel, Fla.	1.00	1968	1979
41	2309814	Camp Lake near Denham, Fla.	1.88	1968	1976
42	2310100	Lake Dan near Odessa, Fla.	0.38	1965	1976
43	2310760	Lake Juliana near Polk City, Fla.	18.00	1962	1979
44	2310850	Lake Helene near Polk City, Fla.	0.42	1961	1979
45	2310950	Lake Deeson near Lakeland, Fla.	0.96	1966	1979
46	2311600	Clear Lake at San Antonio, Fla.	0.92	1965	1979
47	2312670	Lake Catherine at Groveland, Fla.	4.53	1965	1979

Many combinations of lake, rainfall, and watershed characteristics were tested in the regression analysis until the most reliable equation was determined. Preliminary regression analysis indicated that flood stage expressed as change above average stage did not give consistent results. Better results were obtained when stage data were converted to volume of water in the lake. Because of the variations in lake sizes relative to their drainage areas, the volume available for storage of flood waters became a critical element in the analysis. For these reasons, the following steps were taken to express lake-stage data as volume for use in the regression analysis.

1. An altitude-area relation was determined from U.S. Geological Survey 7-1/2-minute topographic quadrangles. Generally, the areas at the water surface and two or more higher contour intervals were used. If some of the annual maximum lake stages were lower than the lake water-surface altitude on the topographic map, the starting altitude for the altitude-area curve was extended to the next lower foot. The unit of area used was acres.

2. The cumulative volume above the starting altitude was computed by 1-foot increments. The incremental trapezoidal volume is the product of the average of the lower and higher altitude areas multiplied by 1 foot. The volumes were expressed as acre-feet.

3. The volume for each annual maximum lake stage was determined from the altitude-volume relation.

4. The log-Pearson type III frequency distribution of annual maximum volume was computed to determine the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval volumes.

5. Change between the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval lake volumes and the volume at average stage were determined.

6. The change in volume above average lake stage for the selected recurrence interval was regressed against lake, watershed, and rainfall characteristics.

Table 2.--Annual rainfall at selected rain gages, 1940-80

[Annual rainfall, in inches]

Year	(1) Arcadia	(2) Avon Park	(3) Bartow	(4) Bradenton	(5) Brooksville	(6) Clermont	(7) Fort Myers
	Rain gage map No. (fig. 1) and rain gage name						
1940	57.55	57.27	44.83	48.25	49.61	47.83	56.55
1941	55.68	55.53	56.13	48.01	66.08	52.66	62.92
1942	53.82	53.67	56.30	47.81	54.25	47.11	53.92
1943	57.08	51.01	53.61	68.52	64.38	49.20	62.45
1944	41.57	47.68	48.99	29.45	61.05	56.11	34.17
1945	53.55	54.66	58.08	53.89	75.09	52.06	52.58
1946	49.55	50.70	50.22	42.04	48.19	48.18	42.45
1947	80.11	74.29	73.58	64.97	69.36	54.15	80.17
1948	54.98	70.39	56.58	53.37	57.79	46.51	47.81
1949	57.27	47.51	53.08	53.94	67.09	45.62	57.38
1950	46.49	36.55	37.19	64.70	65.19	54.79	36.19
1951	60.76	47.32	56.82	49.72	41.20	49.12	55.92
1952	66.41	55.89	54.72	51.60	56.44	42.01	54.43
1953	65.09	80.08	66.78	71.25	69.11	66.87	58.07
1954	55.16	54.55	51.19	56.68	37.46	35.63	49.73
1955	30.75	34.86	41.41	48.70	38.08	40.24	43.96
1956	33.49	46.74	46.34	41.54	41.50	49.22	39.85
1957	66.57	70.04	73.72	73.58	67.17	52.04	63.64
1958	63.99	55.09	61.82	60.75	54.12	62.35	66.67
1959	74.02	79.63	83.44	93.28	80.17	68.09	66.68
1960	62.32	65.87	73.85	69.47	77.49	66.27	54.33
1961	34.30	39.53	43.15	50.02	44.03	32.28	54.74
1962	57.95	45.62	51.55	59.98	49.71	40.33	58.15
1963	53.65	63.80	63.65	60.78	48.03	50.04	42.90
1964	49.68	47.45	45.31	44.30	71.35	55.15	32.83
1965	53.95	60.10	49.68	48.65	61.45	47.81	50.83
1966	51.62	59.14	48.70	50.99	55.43	56.62	44.99
1967	60.96	44.08	44.63	50.53	48.96	53.53	49.39
1968	54.71	55.60	51.85	59.79	47.07	53.39	70.29
1969	64.53	61.29	56.38	73.11	58.87	63.71	71.94
1970	45.62	48.85	49.18	49.02	52.92	48.21	58.84
1971	41.80	42.45	52.44	49.61	56.53	49.77	47.32
1972	40.12	50.42	42.55	41.03	58.61	46.67	56.71
1973	52.65	55.51	52.39	54.77	51.83	54.94	44.33
1974	52.35	47.55	42.48	49.28	58.92	45.39	52.83
1975	45.60	45.95	45.27	46.92	46.31	49.81	51.50
1976	37.33	47.69	51.26	51.15	50.78	55.96	48.67
1977	43.89	39.31	48.45	44.41	40.70	40.41	54.06
1978	46.45	49.57	55.35	65.40	45.33	50.79	53.10
1979	67.99	56.22	60.68	52.81	55.61	67.36	66.98
1980	37.06	44.32	46.11	51.19	53.75	40.10	45.00

Table 2.--Annual rainfall at selected rain gages, 1940-80--Continued

Year	Rain gage map No. (fig. 1) and rain gage name					
	(8) Gainesville	(9) Inverness	(10) Kissimmee	(11) Lake Alfred	(12) Lakeland	(13) Ocala
1940	48.89	48.95	49.58	40.03	44.22	37.51
1941	65.04	60.14	63.10	57.30	59.76	57.21
1942	47.30	53.88	45.50	44.99	39.57	55.35
1943	40.74	57.00	41.50	53.64	49.40	47.89
1944	56.73	55.14	43.84	58.02	40.70	51.50
1945	60.07	60.27	50.13	60.55	52.24	59.43
1946	53.93	64.52	48.75	51.89	47.05	64.97
1947	63.82	62.86	64.55	57.70	60.42	65.96
1948	58.46	60.62	50.16	59.43	62.80	57.15
1949	63.18	53.13	64.38	41.22	46.63	59.36
1950	46.73	55.51	52.73	50.01	43.81	62.87
1951	55.97	54.92	54.80	60.05	49.28	52.75
1952	42.14	50.15	44.85	60.92	51.45	55.13
1953	73.30	77.23	76.27	62.46	59.61	71.15
1954	35.24	44.29	41.60	38.27	36.30	50.48
1955	42.72	43.69	40.38	35.66	44.08	44.12
1956	47.98	36.50	52.41	44.40	45.12	42.58
1957	56.93	51.58	60.02	57.99	62.38	57.43
1958	59.86	65.24	49.18	49.89	41.74	66.01
1959	61.14	70.50	76.36	76.57	70.24	70.31
1960	62.94	87.27	80.38	69.18	65.42	66.38
1961	47.75	45.94	28.07	35.62	35.83	44.34
1962	48.28	49.43	42.53	41.11	38.06	41.45
1963	37.27	52.36	54.88	54.37	46.26	48.80
1964	76.95	68.72	49.04	48.27	47.53	70.61
1965	64.00	61.52	41.09	47.96	48.35	58.85
1966	54.70	52.89	51.12	53.28	45.47	52.97
1967	52.54	44.65	43.07	58.71	37.80	41.77
1968	49.83	53.99	48.92	54.26	55.37	57.78
1969	53.55	58.13	56.05	55.79	53.00	60.31
1970	60.53	52.10	41.88	43.36	46.56	58.94
1971	50.34	55.59	39.46	43.68	42.91	39.30
1972	67.78	52.41	40.04	49.61	38.29	46.06
1973	50.60	56.45	54.11	50.03	45.41	46.77
1974	50.51	48.04	36.71	43.33	43.89	50.98
1975	51.60	54.06	50.07	43.89	41.50	48.93
1976	48.11	50.03	40.08	48.53	49.94	63.67
1977	33.56	48.60	48.35	46.99	45.18	41.85
1978	49.20	52.64	43.48	47.77	46.15	49.35
1979	59.82	56.94	52.56	64.40	69.72	66.21
1980	41.56	56.28	30.96	42.75	46.80	50.72

Table 2.--Annual rainfall at selected rain gages, 1940-80--Continued

Year	(14) Orlando	(15) Plant City	(16) Punta Gorda	(17) St. Leo	(18) St. Peters-burg	(19) Tampa	(20) Tarpon Springs
1940	54.02	43.61	55.50	43.87	43.49	42.98	46.67
1941	59.65	61.20	45.44	60.05	45.77	54.25	62.46
1942	41.29	48.82	51.77	60.09	44.64	38.66	64.10
1943	39.61	57.98	48.90	63.30	56.20	44.89	59.59
1944	48.85	45.41	41.01	54.30	38.40	34.87	48.63
1945	55.95	59.78	56.54	81.93	62.66	66.65	58.75
1946	50.13	44.89	50.07	51.79	45.75	59.12	61.53
1947	67.47	79.20	88.10	68.46	72.59	65.95	64.24
1948	52.53	52.94	54.72	51.33	53.17	46.59	50.45
1949	44.28	60.00	63.06	58.62	43.75	48.24	59.49
1950	55.95	53.83	41.48	57.35	53.56	56.22	44.97
1951	57.92	45.42	51.70	50.12	50.13	43.83	43.92
1952	41.45	50.12	42.03	42.62	66.18	45.37	35.39
1953	65.85	75.82	51.22	81.13	79.30	57.18	63.60
1954	47.97	51.13	49.33	45.02	70.12	43.20	43.77
1955	42.26	48.27	35.07	41.37	64.73	48.81	40.86
1956	43.91	37.24	39.67	45.41	34.88	28.89	32.89
1957	50.93	70.65	60.92	58.83	73.88	70.43	77.78
1958	51.20	52.81	62.02	56.16	60.19	58.03	57.28
1959	63.77	86.68	87.09	70.41	87.62	76.57	83.20
1960	68.74	78.25	53.28	75.34	60.74	65.44	74.81
1961	41.78	32.96	41.16	36.61	47.25	35.04	42.60
1962	50.35	49.36	51.27	45.90	58.22	41.62	46.59
1963	45.28	53.63	54.07	61.00	61.51	43.42	50.13
1964	54.39	50.15	31.10	59.68	39.93	57.92	53.64
1965	47.40	57.42	48.51	57.82	41.90	42.78	55.05
1966	55.39	58.19	51.78	53.46	32.57	36.05	53.52
1967	40.91	43.98	48.29	43.47	42.68	39.36	38.21
1968	52.10	54.69	57.83	46.31	52.31	39.35	42.19
1969	55.18	67.18	57.52	65.75	59.15	54.22	67.64
1970	43.96	44.73	48.76	52.93	37.97	38.27	42.89
1971	40.09	53.77	38.11	52.27	60.66	46.33	63.51
1972	51.35	42.94	52.86	50.31	40.69	42.18	42.06
1973	55.37	52.66	49.30	58.38	48.36	49.71	51.95
1974	44.38	40.41	53.35	60.75	54.90	33.90	52.58
1975	47.04	54.55	40.42	49.87	44.14	43.44	56.60
1976	47.08	45.34	36.87	47.14	39.84	42.29	40.50
1977	38.12	39.52	50.25	49.66	38.03	31.47	44.74
1978	50.59	44.19	46.36	50.75	44.10	39.85	46.99
1979	50.23	66.00	52.73	66.95	54.52	66.46	64.17
1980	41.21	52.51	49.97	42.98	46.55	40.60	46.39

The regression models and lake, watershed, and rainfall characteristics used in the analyses are discussed in the following sections.

Regression Model

The regression procedure consisted of a variation of the step-forward regression analysis method for selecting independent variables (Wesolowsky, 1976, p. 26-149). The independent variables chosen are those that result in the greatest improvement of the R^2 statistic (square of the multiple correlation coefficient). The following criteria were used to evaluate acceptable regression results:

1. R^2, the square of the multiple correlation coefficient was greater than 0.7;
2. The independent variables are significant at the 10-percent confidence level; and
3. The independent variables are not significantly correlated at the 10-percent confidence level.

Rainfall, Lake, and Watershed Characteristics

Combinations of rainfall, lake, and watershed characteristics were entered as independent variables into the regression models. Correlations between independent variables were checked and only those variables that explained the largest variation in the dependent variable and that were not significantly correlated to other independent variables in the model were used. The variable names and descriptions are listed following the glossary. An explanation of the variables and the method of computation will be given in the text as they appear in the analysis.

CLASSIFICATION OF SURFACE-OUTFLOW AND CLOSED-BASIN LAKES

Average lake stages were regressed against rainfall, lake, and watershed characteristics (table 3). All 47 lakes were used in the initial analysis. Residual errors for each lake (the difference between the average lake altitude and the altitude computed from the regression equation) were plotted on a base map to evaluate them areally with respect to topographic and surface geologic features. Usually, high residuals were noted for lakes that did not have any apparent surface outflow.

Lakes that do not have any surface outflow or that do not have any historical flood outflow data are called closed-basin lakes in this report. Lakes that have an apparent surface outflow or that have historical flood outflow data are called surface-outflow lakes in this report.

Table 3.--Rainfall, lake, and watershed characteristics used in regression analysis

Map No. (fig. 1)	Station No.	Station name	STARAIN	AR	MAPRAIN	R50YR_10
1	2234300	Lake Maitland at Winter Park, Fla.	52.61	51.5	43.91	17
2	2235150	Lake Dorr near Altoona, Fla.	52.25	53.5	60.31	16
3	2236250	Lake Lowery near Haines City, Fla.	50.01	52.5	76.57	17
4	2236860	Lake Apshawa near Minneola, Fla.	51.96	52.0	56.62	17
5	2238880	Lake Weir at Oklawaha, Fla.	54.98	53.5	70.61	16
6	2262800	Lake Conway at Pine Castle, Fla.	49.54	52.0	65.85	17
7	2263900	Lake Butler at Windermere, Fla.	49.98	52.0	65.85	17
8	2266650	Lake Marion near Haines City, Fla.	51.27	52.5	62.46	17
9	2266900	Lake Pierce near Waverly, Fla.	51.77	53.5	60.05	17
10	2268200	Lake Wales at Lake Wales, Fla.	49.65	54.0	50.01	17
11	2268400	Lake Weohyakapka at Indian Lake Estates, Fla.	53.45	54.5	47.32	17
12	2268600	Lake Rosalie near Lake Wales, Fla.	50.02	54.0	60.05	17
13	2269200	Crooked Lake near Babson Park, Fla.	53.84	55.0	36.55	17
14	2269300	Lake Clinch at Frostproof, Fla.	53.91	55.0	36.55	17
15	2269400	Reedy Lake near Frostproof, Fla.	55.47	55.0	47.32	17
16	2269600	Lake Arbuckle near Avon Park, Fla.	53.60	55.0	47.32	17
17	2269790	Lake Lotela near Avon Park, Fla.	54.30	55.0	47.32	17
18	2269800	Lake Letta near Avon Park, Fla.	54.10	55.0	47.32	17
19	2270550	Lake Jackson at Sebring, Fla.	55.26	55.0	47.32	17
20	2270750	Lake Placid near Lake Placid, Fla.	54.56	55.0	47.32	17
21	2271560	Lake McCoy near Lake Placid, Fla.	57.23	55.0	47.32	17
22	2271580	Lake Huntley near Lake Placid, Fla.	57.64	55.0	47.32	17
23	2293670	Lake Otis at Winter Haven, Fla.	50.11	53.0	76.57	17
24	2293774	Mountain Lake near Lake Wales, Fla.	51.39	53.5	50.01	17
25	2293999	Lake Mariana near Auburndale, Fla.	51.37	52.0	43.68	17

Table 3.--Rainfall, lake, and watershed characteristics used in regression analysis--Continued

Map No. (fig. 1)	Station No.	Station name	STARAIN	AR	MAPRAIN	R50YR_10
26	2294028	Deer Lake near Winter Haven, Fla.	52.71	52.5	43.68	17
27	2300900	Scott Lake near Lakeland, Fla.	49.55	53.0	46.63	18
28	2303432	Hanna Lake near Lutz, Fla.	48.16	53.5	46.33	19
29	2303440	Lake Padgett near Lutz, Fla.	52.91	54.5	52.27	19
30	2303700	Lake Stemper near Lutz, Fla.	48.16	53.5	46.33	19
31	2304700	Lake Hobbs at Lutz, Fla.	48.16	53.5	46.33	19
32	2305200	Round Lake near Lutz, Fla.	43.62	53.5	28.89	19
33	2306200	Lake Magdalene near Lutz, Fla.	48.16	52.5	28.89	19
34	2306300	Bay Lake near Sulphur Springs, Fla.	48.16	52.0	28.89	20
35	2306600	Lake Carroll near Sulphur Springs, Fla.	48.16	52.0	28.89	20
36	2306704	Lake Harvey near Lutz, Fla.	43.14	53.5	46.33	19
37	2306723	Turkey Ford Lake near Lutz, Fla.	43.14	53.0	46.33	20
38	2307227	Calm Lake near Odessa, Fla.	50.56	53.0	63.51	20
39	2307384	Echo Lake near Citrus Park, Fla.	54.29	52.5	28.89	20
40	2309584	Lake Thomas at Drexel, Fla.	54.26	54.5	52.27	19
41	2309814	Camp Lake near Denham, Fla.	43.96	54.0	46.33	19
42	2310100	Lake Dan near Odessa, Fla.	50.84	53.0	63.51	20
43	2310760	Lake Juliana near Polk City, Fla.	49.74	50.5	43.68	17
44	2310850	Lake Helene near Polk City, Fla.	49.00	50.0	43.68	17
45	2310950	Lake Deeson near Lakeland, Fla.	47.22	50.0	42.91	17
46	2311600	Clear Lake at San Antonio, Fla.	53.72	56.0	45.02	18
47	2312670	Lake Catherine at Groveland, Fla.	52.29	52.0	56.62	17

Table 3.--Rainfall, lake, and watershed characteristics used in regression analysis--Continued

Map No. (fig. 1)	Station No.	DA	STAREA	QUADALT	STALT	OALT	QVOL	SVOL	OVOL	SOIL
1	2234300	20.6	456	66	66.03	66.0	10.0	24.5	10.0	5.38
2	2235150	26.5	1,750	43	43.22	44.0	736	1,210	2,910	5.38
3	2236250	5.40	559	130	128.68	132.5	1,890	966	5,670	5.38
4	2236860	1.48	122	83	85.79	102.5	1.0	323	3,240	5.38
5	2238800	53.8	6,290	57	56.91	57.4	18,200	17,600	21,000	5.38
6	2262800	12.7	1,830	86	85.97	85.8	6,720	6,660	6,360	5.38
7	2263900	14.5	2,760	98	99.13	97.5	4,920	7,950	3,650	5.38
8	2266650	35.7	2,520	67	66.08	65.8	5,070	2,540	1,980	5.38
9	2266900	58.9	4,030	76	76.62	75.0	9,900	12,400	6,270	5.38
10	2268200	2.42	154	112	104.04	122.5	2,190	380	6,450	5.38
11	2268400	93.5	6,290	62	61.30	60.4	13,300	8,370	2,490	4.05
12	2268600	133	4,420	53	52.82	52.5	7,700	6,940	5,600	2.92
13	2269200	31.3	5,460	118	118.12	120.0	29,600	30,300	41,000	2.05
14	2269300	42.0	1,200	103	104.79	105.3	1,200	3,360	3,980	5.38
15	2269400	60.9	3,530	78	78.30	77.0	3,360	4,450	10.0	5.38
16	2269600	170	3,950	53	53.78	51.0	3,640	6,680	1.0	3.42
17	2269790	12.2	808	106	105.54	106.3	4,610	4,240	4,830	5.38
18	2269800	15.6	540	99	98.24	99.2	2,450	2,040	2,570	5.38
19	2270550	14.0	3,190	102	101.64	101.9	3,880	2,390	3,460	5.38
20	2270750	20.2	3,430	92	92.64	93.0	6,580	8,760	9,990	5.38
21	2271560	.30	50.4	86	85.50	87.5	99.2	74.0	175	5.38
22	2271580	9.54	641	83	82.34	82.5	1,250	820	925	5.38
23	2293670	1.00	170	128	124.90	128.0	1,180	617	1,180	5.38
24	2293774	2.30	155	112	111.75	125.0	714	676	3,450	5.38
25	2293999	2.85	502	136	136.06	135.8	967	998	869	5.38

Table 3.--Rainfall, lake, and watershed characteristics used in regression analysis--Continued

Map No. (fig. 1)	Station No.	DA	STAREA	QUADALT	STALT	OALT	QVOL	SVOL	OVOL	SOIL
26	2294028	1.29	136	139	139.66	139.0	112	199	112	5.38
27	2300900	2.18	273	168	166.20	166.0	1,830	1,320	1,270	5.38
28	2303432	.60	24.6	61	60.57	61.2	50.0	39.4	56.7	3.89
29	2303440	6.60	265	69	69.84	69.4	10.0	203	102	3.89
30	2303700	.74	129	60	60.14	60.2	297	316	325	3.89
31	2304700	.92	63.2	64	64.60	67.5	157	195	420	3.89
32	2305200	.07	9.67	53	53.19	53.1	8.0	10.0	9.1	2.05
33	2306200	4.09	248	47	47.40	46.0	855	956	638	3.89
34	2306300	5.22	37.7	45	44.03	44.2	75.6	36.4	43.1	2.05
35	2306600	1.66	215	34	35.55	36.0	344	658	754	3.89
36	2306704	1.70	22.8	62	60.55	60.0	78.7	32.4	20.0	3.89
37	2306723	9.80	97.7	51	51.46	51.5	89.0	134	138	2.05
38	2307227	.58	112	48	47.38	52.5	220	150	810	2.05
39	2307384	.91	138	33	33.63	32.5	264	349	208	2.05
40	2309584	1.00	160	74	73.55	72.6	238	165	10.0	2.05
41	2309814	1.88	24.9	63	60.32	62.5	219	32.0	164	2.05
42	2310100	.38	35.5	26	27.69	32.5	59.8	115	345	2.05
43	2310760	18.0	2,340	130	130.68	130.6	4,510	6,030	5,860	5.38
44	2310850	.42	53.1	141	141.19	147.3	51.5	61.8	458	5.38
45	2310950	.96	52.3	124	124.79	139.2	70.0	110	1,490	5.38
46	2311600	.92	141	127	125.67	127.0	416	220	416	5.38
47	2312670	4.53	138	98	98.14	97.5	80.0	100	20.0	5.38

Using these criteria, 41 lakes were classified as surface-outflow and 6 as closed-basin lakes. To determine the classification objectively at ungaged lakes, a measure of the change in volume from average lake altitude to altitude of start of outflow per unit watershed area was determined for gaged lakes in this study. The test value,

$$\text{Test} = \frac{(\text{OVOL} - \text{SVOL})}{\text{DA}}, \text{ was computed,} \qquad (1)$$

where OVOL = lake volume at the altitude of the lowest point in the outlet, in acre-feet;

SVOL = volume at average lake altitude, in acre-feet; and

DA = watershed area, in square miles.

The magnitude of this expression ranged from 940 to 2,520 acre-ft/mi^2 for the 6 closed-basin lakes and from less than zero to 870 acre-ft/mi^2 for the 41 surface-outflow lakes.

At an ungaged lake, (OVOL - QVOL), lake volume at the altitude of the lowest point in the outlet minus the volume at the lake altitude from the topographic map, can be used in place of (OVOL - SVOL) to evaluate the test value. When $\frac{(\text{OVOL} - \text{QVOL})}{\text{DA}}$ was computed for the 47 gaged lakes, the magnitudes ranged from 970 to 2,190 acre-ft/mi^2 for closed-basin lakes and from less than zero to 750 acre-ft/mi^2 for surface-outflow lakes.

A test value of approximately 900 acre-ft/mi^2 will be used to classify lake type for those lakes that have no record or historical outflow data. For values of $\frac{(\text{OVOL} - \text{QVOL})}{\text{DA}}$ greater than 900 acre-ft/mi^2, an ungaged lake will be treated as a closed-basin lake; for values less than 900 acre-ft/mi^2, it will be treated as a surface-outflow lake.

After establishing a method of classifying surface-outflow and closed-basin lakes, two data subsets that consisted of 41 surface-outflow lakes and 6 closed-basin lakes were analyzed separately.

AVERAGE LAKE-ALTITUDE REGIONALIZATION

The average lake altitude during the period of record was used as an estimate of the long-term average for gaged lakes. The probability that the average altitude during the period of record is the long-term average increases with increasing length of record. On the other hand, the average lake altitude of lakes with short period of record may not be a representative sample of the long-term average. In this case, the estimate of the average altitude can be improved by weighting with a regional estimate.

Regional average lake-altitude relations were determined by multiple linear-regression analysis by relating average altitudes at gaged lakes to selected watershed characteristics and rainfall. This was done as a means of estimating average lake altitudes at ungaged lakes based on their watershed and rainfall characteristics. Estimated changes in volume could then be computed in a subsequent step. Results of the regression analysis for the lakes consist of a statistical equation that relates average lake altitude to watershed and rainfall characteristics and data that describe the equation's accuracy and reliability.

Regional Estimate of Average Altitude for Surface-Outflow Lakes

The regression equation for surface-outflow lake average altitude, $STALT_s$, is:

$$STALT_s = 0.390 + 0.992 \cdot QUADALT + 0.270 \cdot (OALT - QUADALT) + 0.0265 \cdot (STARAIN - MAPRAIN) \quad (2)$$

where QUADALT = altitude of the lake shown on the U.S. Geological Survey 7-1/2-minute topographic quadrangle, in feet NGVD;

OALT = altitude of outlet invert, in feet NGVD;

STARAIN = average calendar year rainfall for period of lake-stage record, in inches;

MAPRAIN = calendar year rainfall the year that the topography on the U.S. Geological Survey 7-1/2-minute quadrangle map was determined, in inches.

The standard error of estimate for this regression is ±0.88 foot or ±1.0 percent of the mean, and R^2 is practically equal to 1.00 (0.9993). This means that about two thirds of the estimates of average lake altitude fell within ±0.88 foot of the value computed by equation 2.

Although the altitude of the lake shown on the topographic map explained 99.9 percent of the variation in the estimate of average lake altitude, (OALT - QUADALT) and (STARAIN - MAPRAIN) improved the value of R^2 and were introduced in the regression at a significance level of 0.01. This indicates that the variation in STALT explained by (OALT - QUADALT) and (STARAIN - MAPRAIN) has less than a 1 percent probability of being caused by chance alone.

Equation 2 relates the average lake altitude for a time series equal to the lake surface at the time the topography was determined (QUADALT), the difference between the altitude of outlet invert and the altitude of the lake surface on the topographic quadrangle (OALT - QUADALT), and the difference between the average annual rainfall for the period of record and the annual rainfall for the year the lake surface altitude was determined (STARAIN - MAPRAIN). To estimate the long-term average lake altitude, the long-term average rainfall, AR, can be substituted for STARAIN. If all other variables in the equation remain unchanged, the regression coefficients in equation 2 remain the same. Therefore, equation 2 can be used to estimate the regional surface-outflow long-term lake average altitude, $RAVALT_s$, as follows:

$$RAVALT_s = 0.390 + 0.992 \cdot QUADALT + 0.270 \cdot (OALT - QUADALT) + 0.0265 \cdot (AR - MAPRAIN). \quad (3)$$

The logic in this argument is that the average lake altitude is a reflection primarily of the average rainfall during the period of record; therefore, using the long-term average rainfall in equation 3 will give a closer estimate of the long-term average lake altitude. If the average rainfall during the period of record is less than the long-term average rainfall, the average altitude for the period of record is very likely to be lower than the long-term average altitude. Conversely, if the average rainfall during the period of record is higher than the long-term average, the average lake altitude probably will be higher than the long-term average, all other variables being the same.

Regional Estimate of Average Altitude for Closed-Basin Lakes

The altitude of the lake surface, as shown on the topographic quadrangle, QUADALT, was the only independent variable significantly related to closed-basin lake average altitude, $STALT_c$, by regression analysis. The regression estimate of closed-basin lake average altitude, $RAVALT_c$, is:

$$RAVALT_c = 1.02 \cdot QUADALT^{0.994} \qquad (4)$$

The standard error for this regression is 4.1 feet or ±4.0 percent of the mean, and the R^2 is 0.99.

Accuracy of Regression Estimates

The standard error of estimate is one index of the accuracy of results obtained from regression equations. Accuracy of the prediction is also often expressed in terms of "equivalent years of record" that would be required to give results of equal accuracy. This information is used to compute a weighted estimate at gaged sites in the following section.

The equivalent years of record were computed by an equation presented by Hardison (1971, p. D214) for the regression equations for average lake altitude of surface-outflow and closed-basin lakes. The equivalent years of record, N_u, for surface-outflow lakes is 4.5 years and for closed-basin lakes is 6.7 years. Therefore, the regression estimate has approximately the same accuracy as an estimate based on 4.5 years of record at a surface-outflow lake and 6.7 years of record at a closed-basin lake.

Determination of Average Lake Altitude

Regional relations can be used to improve estimates of average altitudes at gaged lakes, as well as to estimate average altitudes at ungaged lakes. For gaged lakes, an improved estimate of average altitude is determined by weighting the average altitude for the period of record with the regional estimate. Accuracy, in equivalent years of record, for the weighted estimate is the sum of the accuracy of each estimate, assuming the two estimates are independent.

Gaged Lakes

Average lake altitude for gaged lakes that have 10 or more years of record was determined by giving proportional weight equal to years of record for the gaged lake and regional estimate. The weighted estimate, WSTALT, is computed as follows:

$$WSTALT = \frac{N_s \cdot (STALT) + N_u \cdot (RAVALT)}{N_s + N_u} \quad (5)$$

where N_s = number of years of stage record at a gaged lake;

N_u = equivalent years of record of regression equation;

STALT = average lake altitude from gage record, in feet NGVD; and

RAVALT = estimate of average lake altitude from equation 3 for flow-through lakes and equation 4 for closed-basin lakes, in feet NGVD.

Station, regional, and weighted estimates of average altitude for lakes used in the analysis are listed in table 4.

Ungaged Lakes

Average lake altitude for ungaged lakes or lakes that have less than 10 years of record can be determined by using equation 3 for surface-outflow lakes and equation 4 for closed-basin lakes.

PEAK CHANGE-IN-VOLUME FREQUENCY ANALYSIS

Lake change-in-volume frequency distributions were determined using methods patterned after guidelines for determining flood-flow frequency (U.S. Water Resources Council, 1981, p. 1-26). Although these guidelines were developed for stream flood-frequency determinations, the statistical principles also apply, assuming a log-Pearson type III distribution is valid, to lake peak altitude frequency analysis. These procedures are the basis for the methods of lake-data analysis incorporated in this report. A brief summary of the procedure is outlined below:

1. An altitude-volume relation was developed for each lake. This was done by first defining the altitude-area relation from the topographic quadrangles. Accumulative volume was computed starting at the QUADALT, STALT, or an altitude just below the lowest annual maximum lake altitude, whichever was lower.

2. The annual maximum lake altitude for each climatic year starting June 1 was determined for the period of record. The annual maximum altitude was selected to be independent of a receding altitude at the end of the previous year and not followed by a continuing rise to a higher altitude the next year. The lake volume corresponding to the annual maximum altitude was computed from the altitude-volume relation.

Table 4.--Station, regional, and weighted estimates of average annual lake altitude

Map No. (fig. 1)	Station No.	Station name	Average annual altitude, in feet NGVD		
			Station record	Regional estimate	Weighted estimate
		Surface-outflow lakes			
1	2234300	Lake Maitland at Winter Park, Fla.	66.03	66.06	66.04
2	2235150	Lake Dorr near Altoona, Fla.	43.22	43.14	43.20
3	2236250	Lake Lowery near Haines City, Fla.	128.68	129.39	128.84
5	2238800	Lake Weir at Oklawaha, Fla.	56.91	56.59	56.87
6	2262800	Lake Conway at Pine Castle, Fla.	85.97	85.28	85.86
7	2263900	Lake Butler at Windermere, Fla.	99.13	97.10	98.94
8	2266650	Lake Marion near Haines City, Fla.	66.08	66.27	66.12
9	2266900	Lake Pierce near Waverly, Fla.	76.62	75.34	76.41
11	2268400	Lake Weohyakapka at Indian Lake Estates, Fla.	61.30	61.65	61.37
12	2268600	Lake Rosalie near Lake Wales, Fla.	52.82	52.67	52.77
13	2269200	Crooked Lake near Babson Park, Fla.	118.12	118.47	118.16
14	2269300	Lake Clinch at Frostproof, Fla.	104.79	103.68	104.64
15	2269400	Reedy Lake near Frostproof, Fla.	78.30	77.70	78.21
16	2269600	Lake Arbuckle near Avon Park, Fla.	53.78	52.63	53.65
17	2269790	Lake Lotela near Avon Park, Fla.	105.54	105.83	105.59
18	2269800	Lake Letta near Avon Park, Fla.	98.24	98.86	98.34
19	2270550	Lake Jackson at Sebring, Fla.	101.64	101.75	101.65
20	2270750	Lake Placid near Lake Placid, Fla.	92.64	92.13	92.57
21	2271560	Lake McCoy near Lake Placid, Fla.	85.50	86.31	85.70
22	2271580	Lake Huntley near Lake Placid, Fla.	82.34	82.79	82.47
23	2293670	Lake Otis at Winter Haven, Fla.	124.90	126.74	125.21
25	2293999	Lake Mariana near Auburndale, Fla.	136.06	135.47	135.99
26	2294028	Deer Lake near Winter Haven, Fla.	139.66	138.51	139.47
27	2300900	Scott Lake near Lakeland, Fla.	166.20	166.67	166.27
28	2303432	Hanna Lake near Lutz, Fla.	60.57	61.15	60.69

Table 4.--Station, regional, and weighted estimates of average annual lake altitude--Continued

Map No. (fig. 1)	Station No.	Station name	Average annual altitude, in feet NGVD		
			Station record	Regional estimate	Weighted estimate
		Surface-outflow lakes--continued			
29	2303440	Lake Padgett near Lutz, Fla.	69.84	69.01	69.58
30	2303700	Lake Stemper near Lutz, Fla.	60.14	60.15	60.14
31	2304700	Lake Hobbs at Lutz, Fla.	64.60	65.01	64.66
32	2305200	Round Lake near Lutz, Fla.	53.19	53.65	53.31
33	2306200	Lake Magdalene near Lutz, Fla.	47.40	47.37	47.40
34	2306300	Bay Lake near Sulphur Springs, Fla.	44.03	45.43	44.20
35	2306600	Lake Carroll near Sulphur Springs, Fla.	35.55	35.27	35.52
36	2306704	Lake Harvey near Lutz, Fla.	60.55	61.54	60.86
37	2306723	Turkey Ford Lake near Lutz, Fla.	51.46	51.29	51.41
39	2307384	Echo Lake near Citrus Park, Fla.	33.63	33.62	33.63
40	2309584	Lake Thomas at Drexel, Fla.	73.55	73.48	73.53
41	2309814	Camp Lake near Denham, Fla.	60.32	62.95	61.27
42	2310100	Lake Dan near Odessa, Fla.	27.69	27.66	27.68
43	2310760	Lake Juliana near Polk City, Fla.	130.68	129.69	130.47
46	2311600	Clear Lake at San Antonio, Fla.	125.67	126.66	125.91
47	2312670	Lake Catherine at Groveland, Fla.	98.14	97.35	97.95
		Closed-basin lakes			
4	2236860	Lake Apshawa near Minneola, Fla.	85.79	82.44	85.06
10	2268200	Lake Wales at Lake Wales, Fla.	104.04	111.05	106.20
24	2293774	Mountain Lake near Lake Wales, Fla.	111.75	111.05	111.63
38	2307227	Calm Lake near Odessa, Fla.	47.38	47.84	47.55
44	2310850	Lake Helene near Polk City, Fla.	141.19	139.61	140.76
45	2310950	Lake Deeson near Lakeland, Fla.	124.79	122.87	124.14

3. A log-Pearson type III frequency distribution of annual maximum volumes was computed to define the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval volumes.

4. The annual maximum volume-frequency distribution was corrected for serial correlation.

5. The average lake volume, SVOL, was subtracted from the adjusted maximum lake volume for 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals to compute the corresponding changes in volume.

Steps 3 and 4 are explained in more detail in the following sections.

Log-Pearson Type III Analysis

The log-Pearson type III distribution with base 10 logarithmic transformation of annual maximum volume was used to define magnitude and frequency of lake annual maximum volume. Lake volumes of historic flood-stage data and high outliers were included in the analysis by assigning an estimate of the historic period of record. Because some of the lake records spanned a period of below average rainfall, some distributions were adjusted by excluding low outliers. The guidelines recommended by the U.S. Water Resources Council (1981) for flood frequency were used in the analysis.

Serial Correlation Adjustment

Because the frequency distribution of annual events that are serially correlated tend to have a biased variance that is lower than that expected for independent events, a method to test and adjust for this bias was devised by Gary D. Tasker (written commun., 1982). The correction is based on a comparison of three methods of estimating the standard deviation of hydrologic time series (Tasker and Gilroy, 1982, p. 1503-1508). Method EB (Empirical Bayes) was selected because this method gives the lowest probability of underdesign (close to 0.50). The correction was carried out in the following steps:

1. Compute the serial correlation coefficient, r;

2. If $0 < r \leq r_{crit}$, where

$$r_{crit} = (-1 + 1.65\sqrt{n - 2})/(n - 1), \qquad (6)$$

where n = number of observations,

assume no correction is needed. (This is a one-tailed Anderson Test for significance of the serial correlation coefficient at the 0.05 level of significance.)

3. If $r > r_{crit}$, compute W, a weighted serial correlation correction factor, and adjust the sample variance s^2 to obtain the approximately unbiased estimate, s_u^2, given by

$$s_u^2 = \frac{s^2}{(1 - \overline{W})} \quad (7)$$

where s_u^2 = unbiased estimate of variance;

s^2 = observed variance;

$\overline{W} = \frac{W + WL}{2}$;

W = variance correction factor computed using the Monte Carlo approximation of probability distribution;

WL = variance correction factor computed using the Leipnik distribution.

4. Compute

$$MVOL_T = x + K_T \cdot s_u \quad (8)$$

where $MVOL_T$ = maximum lake volume for recurrence interval T, in acre-feet;

x = mean of annual maximum volumes, in acre-feet;

K_T = standard normal deviate corresponding to exceedance probability p = 1/T;

s_u = unbiased estimate of the standard deviation, in acre-feet.

Corrections for serial correlation were used on four surface-outflow lakes and two closed-basin lakes in the Central Lake District that are identified by footnote in table 8. When the serial correlation adjustments to $MVOL_T$ for the selected recurrence intervals were converted to equivalent lake altitude, the altitude adjustment ranged from zero to +0.79 foot for the surface-outflow lakes and from +0.01 to +1.96 feet for the closed-basin lakes.

PEAK CHANGE-IN-VOLUME REGIONALIZATION

The change in volume above average lake altitude, $CVOL_T$, is computed as the difference between the volume at maximum lake altitude for the T-year recurrence interval and the volume at average altitude ($MVOL_T$ - SVOL), in acre feet.

$$CVOL_T = MVOL_T - SVOL \quad (9)$$

Regional peak change-in-volume relations were determined using multiple linear-regression analysis methods to relate change in volume to rainfall, lake, and watershed characteristics. These relations provide a basis for determining lake flood relations at lakes that do not have stage records or the records are of insufficient length. Results of the regression analysis and an assessment of reliability follow.

Results of Regression Analysis

Peak change in volume for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals was regressed against rainfall, lake, and watershed characteristics. All 47 lakes were used in the initial analysis. Distinct geographical residuals were not noted, but the standard errors of estimate were excessively high. The next trial consisted of two subsets: 41 surface-outflow lakes and 6 closed-basin lakes.

The closed-basin lakes regressions gave results that met the study criteria. For closed-basin lakes, drainage area (DA) was the only watershed characteristic that explained the variation in change in volume above average lake altitude. The average standard error varied from 22 percent for the 5-, 10-, and 25-year recurrence intervals to 40 percent for the 2-year recurrence interval (table 5).

The regressions for surface-outflow lakes had correlation coefficients lower than 0.70. Consequently, the surface-outflow lakes were subdivided into the 26 lakes that are in the Central Lake District physiographic region and the 15 lakes that are in the Ocala Uplift District (fig. 1).

Table 5.--Peak change-in-volume relations for 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for closed-basin lakes

Recurrence interval, T, in years	Regression equation for change in volume, $RCVOL_T$, in acre-feet	Multiple correlation coefficient, R	Average standard error, in percent	Equivalent years of record
2	$76.1 \cdot DA^{0.435}$	0.70	40	1
5	$284 \cdot DA^{0.779}$	.94	22	13
10	$427 \cdot DA^{0.814}$	.95	22	22
25	$609 \cdot DA^{0.823}$	.95	22	36
50	$743 \cdot DA^{0.820}$	.95	23	46
100	$874 \cdot DA^{0.812}$	.94	24	53
500	$1{,}170 \cdot DA^{0.790}$	.91	29	32

$RCVOL_T$ = change in volume above average lake altitude for T-year recurrence interval, in acre-feet.

DA = drainage area, in square miles.

For surface-outflow lakes in the Central Lake District, the significant independent variables were the lake area at average altitude (STAREA), the soil-infiltration index (SOIL) from figure 3, the volume at outlet altitude minus volume at average lake altitude divided by the drainage area (DELVOLA), and the 50-year recurrence interval 10-day rainfall (R50YR_10) from figure 4. The average standard error varied from 29 percent for the 5-year recurrence interval to 54 percent for the 500-year recurrence interval.

For surface-outflow lakes in the Ocala Uplift District, the significant independent variables were STAREA, SOIL, and DELVOL, the volume at outlet altitude minus the volume at average lake altitude. The average standard error varied from 50 percent for the 50-year recurrence interval to 58 percent for the 2-, 5-, and 10-year recurrence intervals.

In applying the regression equations for change in volume in ungaged surface-outflow lakes, the lake area and volume corresponding to the regional estimate of average lake altitude, RAVALT, are used. Therefore, AVAREA (the lake surface area for RAVALT) and AVOL (the lake volume at RAVALT) are used in computing RDELVOL and RDELVOLA in equations for ungaged lakes in the Central Lake District (table 6) and lakes in the Ocala Uplift District (table 7).

Accuracy of Regression Estimates

The accuracy of the change-in-volume regression equations was evaluated in terms of equivalent years of record as described by Hardison (1971). The method of computation of the weighted estimate was the same as that used for the average lake-altitude regressions as described previously. The equivalent years of record listed in tables 5, 6, and 7 were used to compute the weighted estimate.

Determination of Peak Change in Volume

The regional relations are used to improve estimates of change in volume above average altitude at gaged lakes as well as to estimate change in volume at ungaged lakes. For gaged lakes, an improved estimate of change in volume was determined by weighting the station-frequency data with the regional estimates.

Gaged Lakes

The station, regional, and weighted estimates of selected recurrence-interval peak change in volume above average altitude are listed in table 8. The estimate, based on the station record, is computed by subtracting the volume at average altitude, SVOL, from the T-year recurrence-interval maximum volume from the log-Pearson type III frequency distribution of the annual maximum volume (equation 9). The regional estimate is computed by the regression equations in table 5 for closed-basin lakes, table 6 for surface-outflow lakes in the Central Lake District, and table 7 for surface-outflow lakes in the Ocala Uplift District.

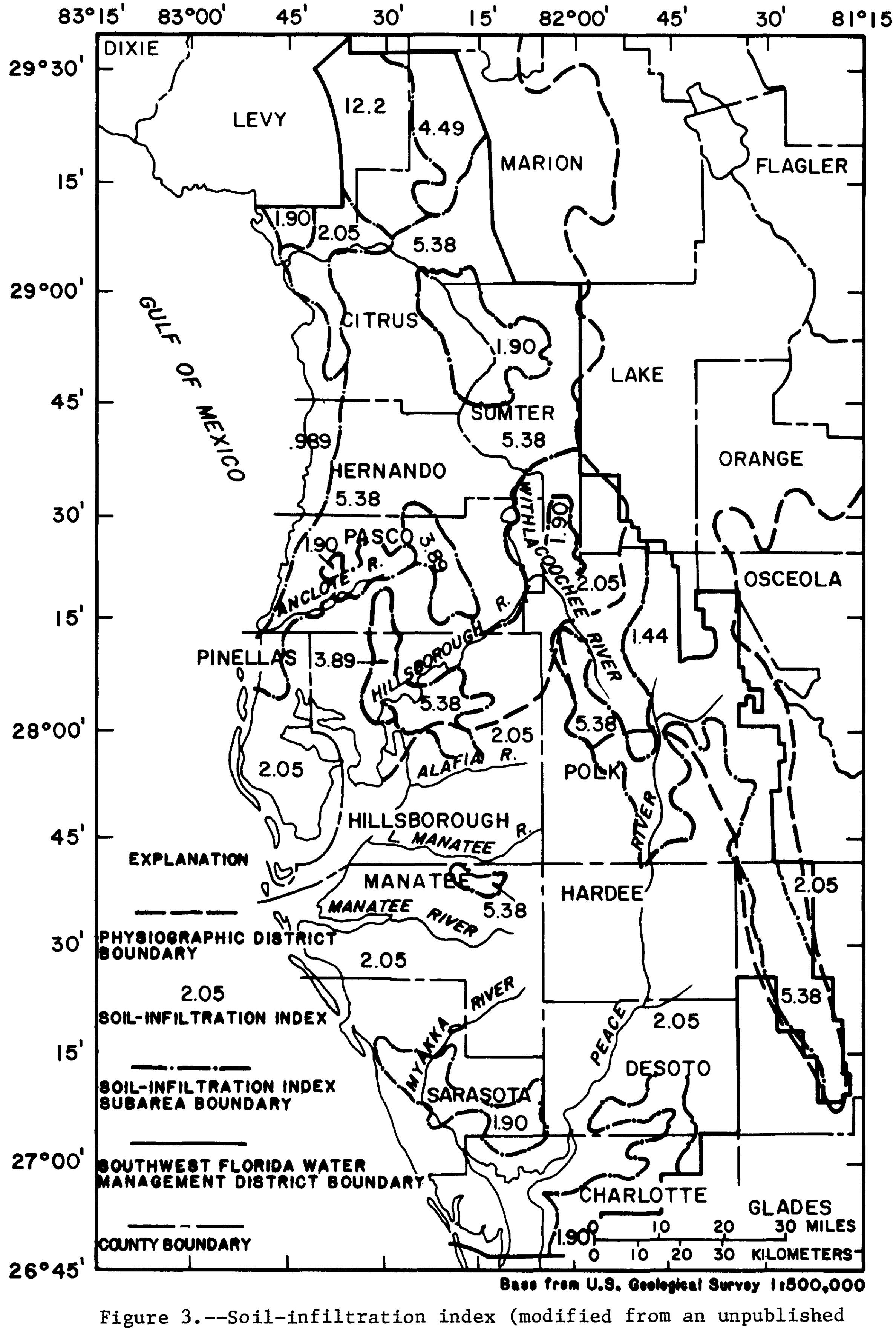

Figure 3.--Soil-infiltration index (modified from an unpublished map compiled by the Soil Conservation Service, U.S. Department of Agriculture) and physiographic district boundaries (modified from Brooks, 1981).

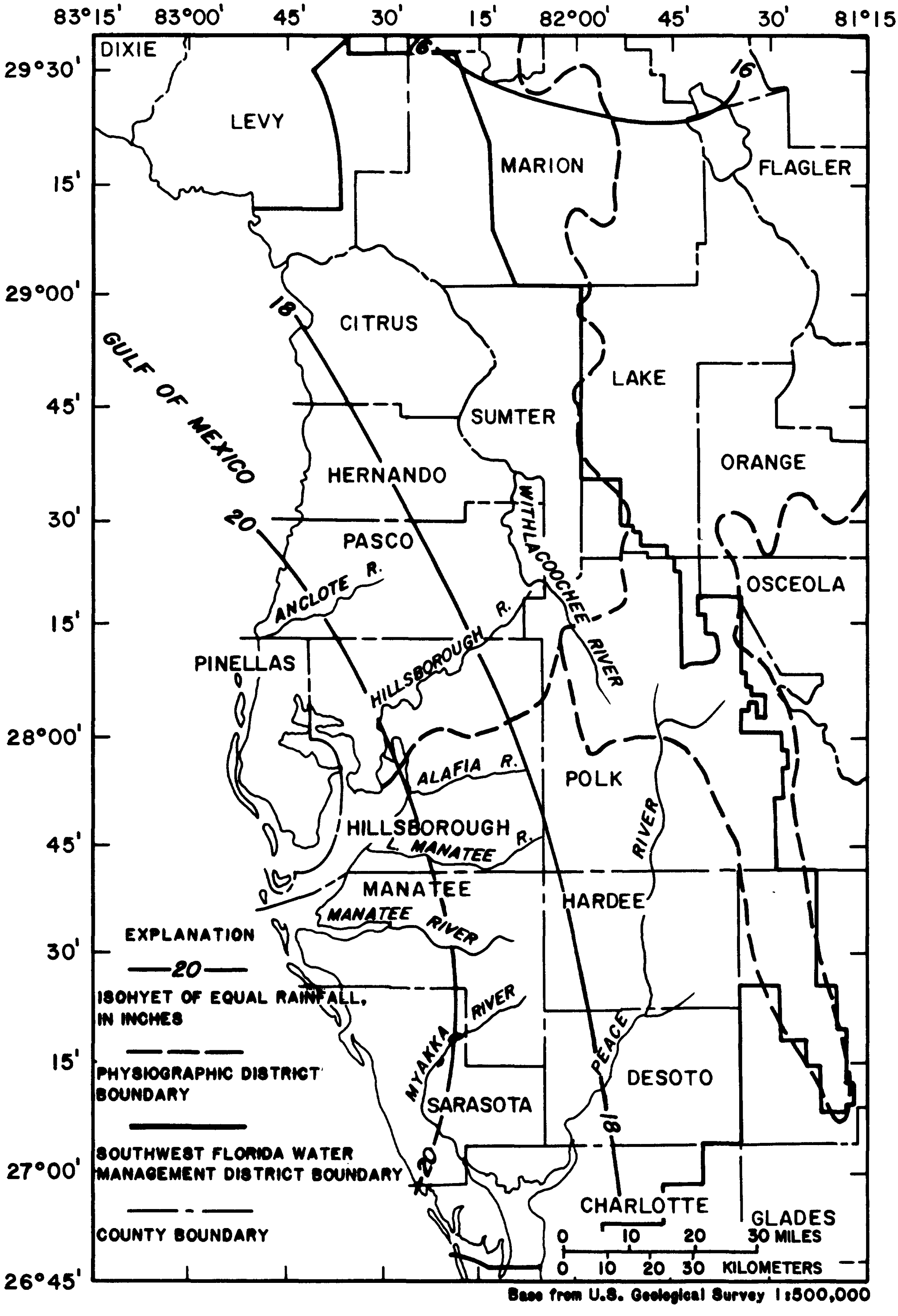

Figure 4.--Fifty-year, 10-day rainfall (modified from Miller, 1964).

Table 6.--Peak change-in-volume relations for 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for surface-outflow lakes in the Central Lake District

Recurrence interval, T, in years	Regression equation for change in volume, $RCVOL_T$, in acre-feet	Multiple correlation coefficient, R	Average standard error, in percent	Equivalent years of record, in years
2	$0.58 \cdot AVAREA^{1.07}$	0.97	35	1.0
5	$10^{-13.47} \cdot AVAREA^{1.08} \cdot (RDELVOLA + 1)^{0.107} \cdot SOIL^{-0.621} \cdot R50YR\_10^{11.25}$	.98	29	2.3
10	$10^{-15.70} \cdot AVAREA^{1.08} \cdot (RDELVOLA + 1)^{0.124} \cdot SOIL^{-0.640} \cdot R50YR\_10^{13.14}$	.98	32	2.8
25	$10^{-17.60} \cdot AVAREA^{1.08} \cdot (RDELVOLA + 1)^{0.138} \cdot SOIL^{-0.650} \cdot R50YR\_10^{14.75}$	.98	36	3.2
50	$10^{-18.72} \cdot AVAREA^{1.08} \cdot (RDELVOLA + 1)^{0.146} \cdot SOIL^{-0.651} \cdot R50YR\_10^{15.70}$	.97	39	3.3
100	$10^{-19.67} \cdot AVAREA^{1.09} \cdot (RDELVOLA + 1)^{0.153} \cdot SOIL^{-0.648} \cdot R50YR\_10^{16.50}$	.97	44	3.0
500	$10^{-21.54} \cdot AVAREA^{1.08} \cdot (RDELVOLA + 1)^{0.167} \cdot SOIL^{-0.633} \cdot R50YR\_10^{18.06}$	.95	54	3.0

RDELVOLA = (OVOL - AVOL)/DA, in acre-feet per square mile. Note--If RDELVOLA $\leq$ 0, then RDELVOLA = 0.
$RCVOL_T$ = change in volume above average lake altitude for recurrence interval T, in acre-feet.
R50YR_10 = 50-year recurrence interval 10-day rainfall, in inches.
SOIL = soil-infiltration index, in inches.
AVAREA = lake-surface area at regional estimate of average altitude, in acres.

Table 7.--Peak change-in-volume relations for 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for surface-outflow lakes in the Ocala Uplift District

Recurrence interval, T, in years	Regression equation for change in volume, $RCVOL_T$, in acre-feet	Multiple correlation coefficient, R	Average standard error, in percent	Equivalent years of record, in years
2	$5.73 \cdot AVAREA^{0.830} \cdot SOIL^{-0.681} \cdot (RDELVOL + 1)^{0.0654}$	0.86	58	0.6
5	$9.69 \cdot AVAREA^{0.850} \cdot SOIL^{-0.718} \cdot (RDELVOL + 1)^{0.110}$	.86	58	1.0
10	$13.2 \cdot AVAREA^{0.841} \cdot SOIL^{-0.754} \cdot (RDELVOL + 1)^{0.116}$	.86	58	1.5
25	$18.4 \cdot AVAREA^{0.825} \cdot SOIL^{-0.798} \cdot (RDELVOL + 1)^{0.116}$	.86	55	2.6
50	$22.8 \cdot AVAREA^{0.813} \cdot SOIL^{-0.828} \cdot (RDELVOL + 1)^{0.113}$	.87	53	3.5
100	$27.8 \cdot AVAREA^{0.798} \cdot SOIL^{-0.853} \cdot (RDELVOL + 1)^{0.109}$	.87	52	4.5
500	$41.8 \cdot AVAREA^{0.765} \cdot SOIL^{-0.905} \cdot (RDELVOL + 1)^{0.0974}$	.86	50	6.9

AVAREA = lake-surface area at regional estimate of average altitude, in acres.
RDELVOL = (OVOL - AVOL), volume at outlet altitude minus volume at regional estimate of average altitude, in acre feet. Note--If RDELVOL < 0, then RDELVOL = 0.
$RCVOL_T$ = change in volume above average lake altitude for recurrence interval T, in acre feet.
SOIL = soil-infiltration index, in inches.

Table 8.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak change in volume

[Change-in-volume estimates for each gaging station are presented as follows: top line--log-Pearson type III analysis; middle line--regression equations; bottom line--weighted, by equivalent years of record method]

Map No. (fig. 1)	Station No. and name	Change in volume, in acre-feet, for recurrence interval, in years						
		2	5	10	25	50	100	500
		Closed-basin lakes						
4	2236860	78.0	351.0	559.0	848.0	1,081.0	1,328.0	1,964.0
	Lake Apshawa near Minneola,	90.3	385.4	587.5	840.9	1,024.7	1,203.5	1,594.8
	Fla.	78.5	363.1	572.6	843.7	1,044.0	1,242.3	1,753.0
10	2268200	47.0	676.0	1,123.0	1,645.0	1,981.0	2,269.0	2,777.0
	Lake Wales at Lake Wales,	111.8	565.3	876.7	1,260.4	1,533.6	1,797.6	2,351.8
	Fla.1/	51.0	624.6	976.6	1,373.5	1,643.6	1,901.6	2,487.5
24	2293774	166.0	508.0	737.0	1,028.0	1,246.0	1,464.0	1,981.0
	Mountain Lake near Lake Wales,	109.3	543.4	841.2	1,208.7	1,471.0	1,724.6	2,259.2
	Fla.1/	164.2	518.5	780.2	1,125.1	1,380.4	1,628.4	2,122.3
38	2307227	92.0	252.0	343.0	440.0	499.0	549.0	637.0
	Calm Lake near Odessa, Fla.	60.0	185.8	274.1	389.0	475.3	560.4	760.8
		89.3	216.1	297.0	400.9	479.9	558.4	729.2
44	2310850	38.2	130.2	205.2	315.2	407.2	508.2	776.2
	Lake Helene near Polk City,	52.2	144.5	210.7	298.2	364.8	430.6	589.6
	Fla.	38.9	136.2	208.2	303.9	376.7	450.3	656.8
45	2310950	74.0	219.0	318.0	442.0	531.0	616.0	801.0
	Lake Deeson near Lakeland,	74.8	275.1	413.0	588.9	718.5	845.4	1,132.9
	Fla.	74.1	247.1	377.7	549.9	677.2	800.2	1,037.0

1/ Annual maximum volume frequency distribution adjusted for serial correlation.

Table 8.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak change in volume--Continued

Map No. (fig. 1)	Station No. and name	Change in volume, in acre-feet, for recurrence interval, in years						
		2	5	10	25	50	100	500
		Central Lake District						
1	2234300	311.5	536.5	658.5	780.5	851.5	906.5	997.5
	Lake Maitland at Winter Park,	404.2	612.6	750.9	894.8	974.7	1,103.7	1,286.3
	Fla.	316.7	545.6	671.6	798.6	871.5	936.1	1,040.8
2	2235150	1,298.0	1,736.0	1,966.0	2,209.0	2,364.0	2,500.0	2,767.0
	Lake Dorr near Altoona, Fla.	1,594.4	1,949.1	2,299.9	2,638.8	2,809.3	3,141.8	3,536.1
		1,319.2	1,768.0	2,025.2	2,293.9	2,454.1	2,620.3	2,911.2
3	2236250	347.0	1,796.0	3,245.0	5,806.0	8,371.0	11,614.0	22,734.0
	Lake Lowery near Haines City,	663.9	2,061.2	2,833.7	3,707.4	4,259.5	5,065.7	6,481.0
	Fla.1/	365.6	1,829.3	3,183.7	5,456.2	7,668.0	10,580.1	20,167.7
5	2238800	5,330.0	8,870.0	10,460.0	11,940.0	12,760.0	13,410.0	14,480.0
	Lake Weir at Oklawaha, Fla.	6,608.5	8,476.0	10,101.3	11,646.5	12,433.3	14,031.8	15,870.3
		5,367.6	8,844.3	10,431.9	11,914.1	12,730.3	13,461.8	14,595.9
6	2262800	1,413.0	3,082.0	3,910.0	4,740.0	5,240.0	5,660.0	6,430.0
	Lake Conway at Pine Castle,	1,739.4	4,230.5	5,603.5	7,093.9	7,998.5	9,399.5	11,636.4
	Fla.	1,425.6	3,178.8	4,080.6	5,007.1	5,561.7	6,060.7	6,987.8
7	2263900	2,770.0	4,870.0	5,830.0	6,710.0	7,200.0	7,590.0	8,220.0
	Lake Butler at Windermere,	2,454.0	5,945.9	7,875.3	9,961.6	11,226.5	13,208.6	16,338.3
	Fla.	2,763.0	4,923.4	5,952.4	6,930.4	7,480.9	7,948.6	8,738.2
8	2266650	1,954.0	2,886.0	3,409.0	3,989.0	4,376.0	4,731.0	5,467.0
	Lake Marion near Haines City,	2,603.0	4,000.8	4,929.8	5,875.0	6,399.2	7,310.0	8,518.8
	Fla.	1,990.1	3,018.9	3,624.1	4,287.8	4,704.9	5,117.8	5,924.8
9	2266900	3,200.0	5,700.0	7,290.0	9,250.0	10,680.0	12,100.0	15,400.0
	Lake Pierce near Waverly,	3,659.9	5,639.8	6,956.0	8,289.7	9,029.4	10,330.9	12,039.3
	Fla.	3,219.2	5,694.5	7,253.8	9,132.7	10,472.9	11,895.9	15,012.2

1/ Annual maximum volume frequency distribution adjusted for serial correlation.

Table 8.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak change in volume--Continued

Map No. (fig. 1)	Station No. and name	Change in volume, in acre-feet, for recurrence interval, in years						
		2	5	10	25	50	100	500
	Central Lake District--continued							
11	2268400	8,050.0	12,270.0	14,470.0	16,750.0	18,170.0	19,400.0	21,710.0
	Lake Weohyakapka at Indian	7,746.4	14,320.2	17,795.3	21,267.4	23,171.8	26,582.3	30,846.4
	Lake Estates, Fla.	8,034.0	12,502.3	14,917.6	17,431.9	18,944.9	20,426.0	23,015.2
12	2268600	7,230.0	12,930.0	15,600.0	18,010.0	19,290.0	20,260.0	21,700.0
	Lake Rosalie near Lake Wales,	4,460.6	10,061.3	12,561.4	15,061.5	16,415.5	18,764.6	21,668.1
	Fla.	6,978.2	12,393.6	14,935.3	17,295.2	18,576.8	19,914.9	21,692.6
13	2269200	4,740.0	20,430.0	30,790.0	43,750.0	53,280.0	62,710.0	84,500.0
	Crooked Lake near Babson	5,830.5	29,986.0	41,506.9	54,041.0	61,635.2	73,301.9	91,102.3
	Park, Fla.1/	4,774.1	21,090.0	31,677.8	44,712.9	54,083.8	63,644.6	85,082.6
14	2269300	939.0	2,705.0	3,879.0	5,362.0	6,466.0	7,570.0	10,160.0
	Lake Clinch at Frostproof,	1,134.4	2,619.8	3,439.3	4,326.6	4,860.6	5,682.5	6,990.3
	Fla.	945.5	2,698.7	3,840.3	5,259.1	6,302.0	7,393.0	9,862.8
15	2269400	2,255.0	4,344.0	5,850.0	7,910.0	9,550.0	11,300.0	15,810.0
	Reedy Lake near Frostproof,	3,474.9	5,352.7	6,601.0	7,866.5	8,568.5	9,801.2	11,422.0
	Fla.	2,303.8	4,432.2	5,928.5	7,904.9	9,431.4	11,133.5	15,322.4
16	2269600	8,580.0	13,680.0	16,440.0	19,380.0	21,230.0	22,850.0	25,930.0
	Lake Arbuckle near Avon	3,758.1	7,674.1	9,547.7	11,429.9	12,455.5	14,233.2	16,474.6
	Park, Fla.	8,446.1	13,309.7	15,929.5	18,714.0	20,474.0	22,169.7	25,183.5
17	2269790	1,281.0	2,358.0	2,767.0	3,085.0	3,231.0	3,329.0	3,453.0
	Lake Lotela near Avon Park,	747.2	1,640.0	2,134.3	2,668.1	2,986.8	3,474.1	4,247.1
	Fla.	1,259.6	2,295.2	2,700.9	3,036.0	3,201.5	3,345.1	3,541.2
18	2269800	676.0	1,334.0	1,543.0	1,676.0	1,725.0	1,752.0	1,778.0
	Lake Letta near Avon Park,	495.6	991.2	1,270.2	1,569.4	1,745.0	2,014.0	2,433.3
	Fla.	668.8	1,304.0	1,514.5	1,663.5	1,727.4	1,781.1	1,850.8

1/ Annual maximum volume frequency distribution adjusted for serial correlation.

Table 8.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak change in volume--Continued

Map No. (fig. 1)	Station No. and name	Change in volume, in acre-feet, for recurrence interval, in years						
		2	5	10	25	50	100	500
	Central Lake District--continued							
19	2270550	3,570.0	5,150.0	6,070.0	7,120.0	7,840.0	8,510.0	9,940.0
	Lake Jackson at Sebring,	3,247.4	7,424.8	9,748.2	12,234.1	13,725.7	16,106.7	19,767.0
	Fla.	3,559.6	5,312.0	6,384.0	7,612.9	8,423.3	9,200.6	10,833.4
20	2270750	3,540.0	8,020.0	10,270.0	12,490.0	13,780.0	14,830.0	16,620.0
	Lake Placid near Lake	3,442.4	9,050.6	12,150.6	15,529.5	17,605.3	20,854.0	26,063.8
	Placid, Fla.	3,536.9	8,093.4	10,430.5	12,783.0	14,159.1	15,377.6	17,478.5
21	2271560	39.0	90.0	120.0	154.0	178.0	199.0	242.0
	Lake McCoy near Lake Placid,	39.4	103.3	137.7	176.8	200.9	233.6	293.2
	Fla.	39.0	91.9	123.0	158.2	182.4	205.1	251.0
22	2271580	577.0	860.0	1,066.0	1,344.0	1,566.0	1,799.0	2,398.0
	Lake Huntley near Lake	600.7	913.0	1,120.4	1,335.2	1,454.4	1,650.0	1,922.9
	Placid, Fla.	579.0	869.2	1,077.0	1,342.0	1,540.2	1,767.1	2,296.2
23	2293670	228.0	649.0	836.0	993.0	1,069.0	1,121.0	1,190.0
	Lake Otis at Winter Haven,	149.3	403.9	541.9	697.3	793.6	929.6	1,169.7
	Fla.1/	224.6	625.8	802.8	955.5	1,033.1	1,098.0	1,187.6
25	2293999	482.0	815.0	973.0	1,122.0	1,207.0	1,275.0	1,390.0
	Lake Mariana near Auburndale,	436.4	1,022.3	1,343.0	1,694.2	1,906.3	2,221.8	2,740.8
	Fla.	480.6	829.3	1,003.6	1,175.5	1,274.3	1,358.5	1,509.2
26	2294028	110.0	191.0	246.0	316.0	369.0	423.0	553.0
	Deer Lake near Winter Haven,	90.8	203.7	265.1	333.1	373.9	431.7	530.4
	Fla.	109.2	192.2	248.1	318.1	369.6	424.0	550.4
27	2300900	308.0	616.0	788.0	979.0	1,106.0	1,223.0	1,465.0
	Scott Lake near Lakeland,	236.7	679.7	926.8	1,211.0	1,392.0	1,646.4	2,097.6
	Fla.	305.1	621.6	802.5	1,006.3	1,140.6	1,270.0	1,535.3

1/ Annual maximum volume frequency distribution adjusted for serial correlation.

Table 8.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak change in volume--Continued

Map No. (fig. 1)	Station No. and name	Change in volume, in acre-feet, for recurrence interval, in years						
		2	5	10	25	50	100	500
	Central Lake District--continued							
43	2310760	-270.0	4,100.0	6,980.0	10,440.0	12,830.0	15,060.0	19,660.0
	Lake Juliana near Polk	1,729.0	4,358.6	5,806.1	7,385.0	8,349.0	9,834.2	12,231.8
	City, Fla.[1/]	-158.9	4,130.8	6,814.0	9,956.0	12,101.6	14,276.1	18,545.8
47	2312670	60.0	97.0	123.0	158.0	184.0	212.0	283.0
	Lake Catherine at Groveland,	101.1	204.6	262.0	324.7	361.7	415.0	503.0
	Fla.	62.7	112.2	146.2	189.0	217.9	247.8	321.8
	Ocala Uplift District							
28	2303432	44.4	74.6	89.6	104.6	112.6	120.6	132.6
	Hanna Lake near Lutz, Fla.	42.1	75.9	96.0	119.3	135.8	151.4	187.2
		44.3	74.7	90.1	106.6	116.6	127.0	148.4
29	2303440	289.0	447.0	539.0	645.0	716.0	783.0	922.0
	Lake Padgett near Lutz, Fla.	227.3	496.2	631.1	762.7	841.0	900.5	1,008.6
		285.5	451.5	551.0	669.3	748.4	819.5	957.4
30	2303700	171.0	275.0	311.0	337.0	347.0	353.0	360.0
	Lake Stemper near Lutz, Fla.	147.9	287.7	361.7	439.3	489.9	532.3	620.0
		170.6	275.4	313.3	344.7	361.1	375.1	406.1
31	2304700	69.0	213.0	293.0	377.0	428.0	471.0	548.0
	Lake Hobbs at Lutz, Fla.	104.2	230.8	297.7	365.5	407.0	440.9	505.9
		69.8	213.6	293.2	376.0	425.6	466.7	539.4
32	2305200	12.7	23.7	33.0	47.6	60.8	76.2	123.0
	Round Lake near Lutz, Fla.	25.7	44.4	57.7	75.0	88.4	102.1	136.7
		13.3	25.3	35.7	52.5	67.0	83.3	128.0

1/ Annual maximum volume frequency distribution adjusted for serial correlation.

Table 8.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak change in volume--Continued

Map No. (fig. 1)	Station No. and name	Change in volume, in acre-feet, for recurrence interval, in years						
		2	5	10	25	50	100	500
	Ocala Uplift District--continued							
33	2306200	350.0	754.0	916.0	1,045.0	1,105.0	1,145.0	1,196.0
	Lake Magdalene near Lutz,	220.0	394.9	487.5	586.2	652.7	708.3	827.3
	Fla.	347.6	743.1	896.8	1,010.5	1,060.4	1,091.2	1,130.6
34	2306300	44.3	71.6	88.6	111.6	128.6	145.6	185.6
	Bay Lake near Sulphur Springs,	85.5	152.1	195.1	247.7	286.9	324.3	413.8
	Fla.	45.0	74.0	93.2	121.5	143.8	167.0	225.1
35	2306600	204.0	477.0	651.0	866.0	1,023.0	1,178.0	1,536.0
	Lake Carroll near Sulphur	267.6	600.0	764.7	921.7	1,012.9	1,079.7	1,195.8
	Springs, Fla.	205.2	480.7	656.1	870.2	1,022.0	1,165.9	1,475.7
36	2306704	45.0	81.6	105.6	133.4	153.6	172.6	215.6
	Lake Harvey near Lutz, Fla.	45.5	78.7	98.8	122.4	139.4	155.7	193.6
		45.0	81.3	104.7	131.3	149.9	167.4	206.6
37	2306723	307.0	550.0	718.0	936.0	1,096.0	1,266.0	1,656.0
	Turkey Ford Lake near Lutz,	189.6	392.6	509.5	639.8	727.7	803.9	966.5
	Fla.	300.4	535.7	690.8	874.9	1,000.5	1,122.6	1,374.5
39	2307384	194.0	389.0	492.0	599.0	665.0	721.0	824.0
	Echo Lake near Citrus Park,	209.9	381.4	484.3	604.6	691.1	768.7	946.3
	Fla.	194.5	388.6	491.4	599.7	669.1	730.1	856.6
40	2309584	135.0	263.0	347.0	450.0	526.0	600.0	769.0
	Lake Thomas at Drexel, Fla.	232.4	423.3	536.9	668.9	763.5	847.7	1,039.4
		140.0	276.4	369.8	491.8	583.3	671.9	873.2
41	2309814	172.0	426.0	548.0	643.0	684.0	708.0	733.0
	Camp Lake near Denham, Fla.	208.6	379.1	481.4	600.9	687.0	764.2	941.1
		174.6	420.8	537.5	632.7	684.9	728.2	829.4

Table 8.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak change in volume--Continued

Map No. (fig. 1)	Station No. and name	Change in volume, in acre-feet, for recurrence interval, in years						
		2	5	10	25	50	100	500
	Ocala Uplift District--continued							
42	2310100	115.0	224.0	287.0	358.0	404.0	445.0	526.0
	Lake Dan near Odessa, Fla.	96.0	214.7	284.9	363.4	415.6	461.9	559.5
		114.0	223.2	286.7	359.0	406.8	449.9	538.9
46	2311600	100.0	205.0	266.0	336.0	384.0	428.0	522.0
	Clear Lake at San Antonio,	151.8	318.1	399.2	476.8	522.7	557.9	622.1
	Fla.	102.1	212.5	278.9	358.1	411.7	459.6	555.1

Weighted estimates of change in volume for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for gaged lakes that have 10 or more years of record were determined by giving proportional weight to length of record and the computed equivalent years of record listed in tables 5, 6, and 7. The weighted estimate, $WCVOL_T$, is computed as follows:

$$WCVOL_T = \frac{N_s \cdot (CVOL_T) + N_T \cdot (RCVOL_T)}{N_s + N_T} \qquad (10)$$

where N_s = number of annual peaks;

N_T = equivalent years of record from regression equation for recurrence interval T;

$CVOL_T$ = change in volume from station data-frequency distribution for recurrence interval T, in acre-feet;

$RCVOL_T$ = change in volume from regression equation for recurrence interval T, in acre-feet.

Ungaged Lakes

Change in volume above average lake altitude for ungaged lakes and for lakes that have less than 10 years of record are determined by using equations in table 5 for closed-basin lakes, equations in table 6 for surface-outflow lakes in the Central Lake District, and equations in table 7 for surface-outflow lakes in the Ocala Uplift District.

DETERMINATION OF LAKE FLOOD-ALTITUDE MAGNITUDE AND FREQUENCY

The regional relations developed for average lake altitude and change in volume above average altitude are combined to give an estimated lake volume for 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. To do this, volume at average lake altitude is added to the change in volume for each selected recurrence interval. The result is the volume for the corresponding recurrence interval. The lake altitude corresponding to the computed volume is determined from the altitude-volume relation for the lake.

Gaged Lakes

At gaged lakes that have 10 years or more of annual peak stage record, two independent estimates of flood frequency and a weighted average can be determined: an estimate based on the station record, the regional estimate, and an average weighted on the basis of years of record. The flood-altitude estimate based on the station record is determined by converting the log-Pearson type III recurrence-interval lake volume ($MVOL_T$) computed by equation 8 to a corresponding altitude using the altitude-volume relation. This procedure is described on pages 21-25.

The regional flood estimate is the corresponding lake altitude for the sum of the volume at average lake altitude, RAVALT, computed by equation 3 for surface-outflow lakes or equation 4 for closed-basin lakes and the change-in-volume regression estimate, $RCVOL_T$, from table 5, 6, or 7.

$$RMVOL_T = AVOL + RCVOL_T \qquad (11)$$

where $RMVOL_T$ = lake volume for recurrence interval T, in acre-feet;

AVOL = lake volume at RAVALT, in acre-feet;

$RCVOL_T$ = change in volume from regression equation for recurrence interval T, in acre-feet.

A weighted estimate of flood altitude for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for gaged lakes that have 10 or more years of record can be determined by combining the lake volume for the weighted average lake altitude computed by equation 5 and the weighted change in volumes using equation 10. The weighted estimate of flood volume is computed as follows:

$$WMVOL_T = WVOL_T + WCVOL_T \qquad (12)$$

where $WMVOL_T$ = weighted estimate of lake volume for flood of recurrence interval T, in acre-feet;

$WVOL_T$ = lake volume at the weighted average lake altitude, in acre-feet;

$WCVOL_T$ = weighted change in volume above average altitude for the T-year recurrence-interval flood from equation 10, in acre-feet.

The result is the weighted lake volume for the corresponding recurrence interval. This volume is converted to lake altitude using the altitude-volume relation.

Station, regional, and weighted estimates of the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval flood altitude for lakes used in this study are listed in table 9. The estimates of flood altitude in table 9 are valid for future events only if the watershed and hydrologic conditions that existed during the period of record are not altered. Changes in the drainage area, outlet altitude or capacity, or lake altitude-volume relation may significantly change the flood characteristics of the lake. Permanent changes in the lake-aquifer connection or in the peizometric head differential may also result in different flood characteristics in the future.

Ungaged Lakes

Flood altitudes for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for ungaged lakes and lakes that have less than 10 years of record are determined by adding the volume at the regional estimate of average altitude

Table 9.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak lake altitude

[Peak lake-altitude estimates for each gaging station are presented as follows: top line--log-Pearson type III analysis of annual maximum lake volume; middle line--sum of regional estimate of average altitude and regional estimate of change in volume above average altitude; bottom line--sum of weighted estimate of average altitude and weighted estimate of change in volume above average altitude]

Map No. (fig. 1)	Station No. and name	Peak lake altitude, in feet NGVD, for recurrence interval, in years: 2	5	10	25	50	100	500
1	2234300	66.68	67.13	67.36	67.59	67.72	67.82	67.99
	Lake Maitland at Winter Park,	66.90	67.30	67.56	67.83	67.97	68.20	68.51
	Fla.	66.70	67.15	67.39	67.63	67.76	67.88	68.07
2	2235150	43.82	44.01	44.09	44.16	44.21	44.25	44.35
	Lake Dorr near Altoona, Fla.	43.87	44.03	44.14	44.25	44.30	44.41	44.54
		43.81	44.01	44.09	44.18	44.23	44.28	44.38
3	2236250	129.24	130.80	131.79	132.99	133.79	134.55	136.24
	Lake Lowery near Haines City,	130.19	131.33	131.82	132.26	132.51	132.87	133.35
	Fla.	129.37	130.91	131.80	132.87	133.60	134.35	135.98
4	2236860	86.42	88.51	90.01	91.95	93.41	94.87	98.24
	Lake Apshawa near Minneola,	83.27	85.81	87.41	89.29	90.58	91.78	94.19
	Fla.	85.71	87.95	89.48	91.35	92.64	93.85	96.71
5	2238800	57.75	58.30	58.55	58.78	58.90	59.00	59.17
	Lake Weir at Oklawaha, Fla.	57.64	57.93	58.18	58.42	58.54	58.79	59.07
		57.73	58.26	58.51	58.74	58.87	58.98	59.15
6	2262800	86.72	87.58	88.01	88.41	88.66	88.86	89.23
	Lake Conway at Pine Castle,	86.24	87.54	88.23	88.96	89.39	90.05	91.02
	Fla.	86.63	87.54	88.00	88.45	88.72	88.97	89.41
7	2263900	100.11	100.83	101.16	101.45	101.61	101.74	101.95
	Lake Butler at Windermere,	98.07	99.36	100.04	100.76	101.18	101.84	102.85
	Fla.	99.93	100.67	101.02	101.34	101.53	101.68	101.94
8	2266650	64.05	64.52	64.79	65.07	65.24	65.39	65.71
	Lake Marion near Haines	64.65	65.31	65.71	66.10	66.29	66.63	67.06
	City, Fla.	64.12	64.65	64.95	65.25	65.43	65.61	65.96

Table 9.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak lake altitude--Continued

Map No. (fig. 1)	Station No. and name	Peak lake altitude, in feet NGVD, for recurrence interval, in years						
		2	5	10	25	50	100	500
9	2266900	77.39	77.97	78.30	78.72	79.01	79.29	79.93
	Lake Pierce near Waverly,	76.50	77.00	77.30	77.60	77.77	78.06	78.42
	Fla.	77.38	77.94	78.27	78.67	78.95	79.23	79.84
10	2268200	104.34	107.64	109.51	111.42	113.52	114.36	115.80
	Lake Wales at Lake Wales,	111.41	113.88	114.79	115.86	116.60	117.29	118.70
	Fla.	106.46	108.90	110.38	111.78	113.61	114.38	116.04
11	2268400	62.38	62.91	63.16	63.42	63.58	63.72	63.97
	Lake Weohyakapka at Indian	62.65	63.42	63.81	64.18	64.37	64.72	65.14
	Lake Estates, Fla.	62.44	63.00	63.27	63.55	63.72	63.89	64.16
12	2268600	54.25	55.20	55.61	55.97	56.15	56.27	56.46
	Lake Rosalie near Lake Wales,	53.67	54.63	55.05	55.43	55.64	55.99	56.38
	Fla.	54.17	55.09	55.48	55.83	56.02	56.20	56.44
13	2269200	118.97	121.55	123.06	124.65	125.58	126.34	127.75
	Crooked Lake near Babson	119.51	123.22	124.63	125.83	126.41	127.21	128.20
	Park, Fla.	119.03	121.70	123.22	124.80	125.68	126.43	127.80
14	2269300	105.55	106.97	107.88	109.02	109.83	110.68	112.44
	Lake Clinch at Frostproof,	104.62	105.83	106.49	107.19	107.60	108.24	109.23
	Fla.	105.41	106.82	107.71	108.80	109.58	110.41	112.12
15	2269400	78.94	79.50	79.91	80.45	80.87	81.32	82.45
	Reedy Lake near Frostproof,	78.69	79.21	79.55	79.89	80.07	80.40	80.82
	Fla.	78.85	79.43	79.83	80.35	80.75	81.19	82.24
16	2269600	55.80	56.89	57.44	58.02	58.36	58.67	59.22
	Lake Arbuckle near Avon	53.62	54.59	55.04	55.46	55.69	56.08	56.55
	Park, Fla.	55.66	56.70	57.24	57.79	58.13	58.45	59.00
17	2269790	107.10	108.38	108.86	109.23	109.39	109.51	109.65
	Lake Lotela near Avon Park,	106.74	107.80	108.39	109.21	109.38	109.94	110.81
	Fla.	107.11	108.34	108.82	109.20	109.40	109.56	109.79

Table 9.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak lake altitude--Continued

Map No. (fig. 1)	Station No. and name	Peak lake altitude, in feet NGVD, for recurrence interval, in years						
		2	5	10	25	50	100	500
18	2269800	99.46	100.58	100.93	101.15	101.23	101.27	101.31
	Lake Letta near Avon Park,	99.74	100.58	101.04	101.53	101.81	102.24	102.90
	Fla.	99.53	100.61	100.96	101.21	101.31	101.40	101.51
19	2270550	102.62	103.08	103.33	103.62	103.82	104.01	104.41
	Lake Jackson at Sebring,	102.68	103.85	104.51	105.21	105.62	106.27	107.22
	Fla.	102.65	103.16	103.46	103.80	104.02	104.24	104.70
20	2270750	93.66	94.92	95.54	96.14	96.48	96.76	97.23
	Lake Placid near Lake	93.13	94.72	95.57	96.48	97.04	97.88	99.20
	Placid, Fla.	93.59	94.88	95.51	96.15	96.52	96.84	97.39
21	2271560	86.27	87.24	87.80	88.42	88.86	89.23	89.99
	Lake McCoy near Lake	87.06	88.25	88.87	89.56	89.98	90.55	91.55
	Placid, Fla.	86.46	87.46	88.04	88.68	89.11	89.51	90.31
22	2271580	83.21	83.62	83.92	84.30	84.60	84.91	85.67
	Lake Huntley near Lake	83.68	84.12	84.40	84.69	84.85	85.11	85.45
	Placid, Fla.	83.34	83.76	84.05	84.41	84.68	84.98	85.65
23	2293670	126.21	128.52	129.51	130.33	130.72	130.99	131.34
	Lake Otis at Winter Haven,	127.56	128.94	129.66	130.47	130.97	131.66	132.87
	Fla.	126.49	128.68	129.62	130.41	130.81	131.14	131.60
24	2293774	112.80	114.83	116.11	117.65	118.74	119.79	112.10
	Mountain Lake near Lake	111.76	114.41	116.09	118.02	119.31	120.49	122.81
	Wales, Fla.	112.67	114.78	116.24	118.05	119.30	120.46	122.61
25	2293999	137.00	137.62	137.91	138.17	138.32	138.44	138.64
	Lake Mariana near	136.34	137.46	138.05	138.66	139.03	139.55	140.36
	Auburndale, Fla.	136.92	137.58	137.90	138.21	138.38	138.53	138.79
26	2294028	140.42	140.94	141.25	141.63	141.92	142.19	142.81
	Deer Lake near Winter Haven,	139.27	140.10	140.50	140.94	141.17	141.49	142.03
	Fla.	140.25	140.78	141.12	141.51	141.79	142.08	142.6[illegible]

Table 9.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak lake altitude--Continued

Map No. (fig. 1)	Station No. and name	Peak lake altitude, in feet NGVD, for recurrence interval, in years						
		2	5	10	25	50	100	500
27	2300900	167.30	168.37	168.96	169.60	170.02	170.40	171.18
	Scott Lake near Lakeland,	167.51	169.04	169.86	170.79	171.36	172.16	173.52
	Fla.	167.36	168.46	169.08	169.76	170.20	170.62	171.46
28	2303432	61.94	62.51	62.78	63.04	63.13	63.23	63.37
	Hanna Lake near Lutz, Fla.	62.20	62.82	63.12	63.40	63.60	63.79	64.15
		62.02	62.57	62.85	63.10	63.22	63.34	63.60
29	2303440	70.87	71.36	71.63	71.95	72.15	72.34	72.73
	Lake Padgett near Lutz,	70.03	70.92	71.33	71.73	71.96	72.13	72.44
	Fla.	70.66	71.19	71.49	71.84	72.08	72.27	72.66
30	2303700	61.32	61.95	62.14	62.27	62.32	62.35	62.39
	Lake Stemper near Lutz,	61.19	62.03	62.41	62.81	63.06	63.24	63.62
	Fla.	61.31	61.95	62.15	62.31	62.40	62.47	62.63
31	2304700	65.63	67.33	68.09	68.74	69.10	69.35	69.79
	Lake Hobbs at Lutz, Fla.	66.40	67.75	68.32	68.84	69.12	69.32	69.70
		65.70	67.38	68.12	68.76	69.11	69.35	69.77
32	2305200	54.31	55.12	55.71	56.43	57.01	57.45	58.58
	Round Lake near Lutz, Fla.	55.55	56.50	57.06	57.56	57.95	58.25	58.97
		54.45	55.30	55.96	56.70	57.22	57.70	58.71
33	2306200	48.67	49.88	50.29	50.59	50.73	50.83	50.95
	Lake Magdalene near Lutz,	48.21	48.80	49.09	49.38	49.57	49.72	50.06
	Fla.	48.66	49.85	50.24	50.51	50.63	50.70	50.80
34	2306300	45.11	45.68	46.04	46.46	46.77	47.07	47.71
	Bay Lake near Sulphur	47.06	48.11	48.71	49.38	49.86	50.10	50.62
	Springs, Fla.	45.27	45.88	46.25	46.76	47.15	47.44	48.18
35	2306600	36.46	37.58	38.24	39.02	39.54	40.06	41.15
	Lake Carroll near Sulphur	36.48	37.83	38.44	39.01	39.31	39.53	39.92
	Springs, Fla.	36.44	37.57	38.24	39.01	39.52	40.00	40.95

Table 9.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak lake altitude--Continued

Map No. (fig. 1)	Station No. and name	Peak lake altitude, in feet NGVD, for recurrence interval, in years						
		2	5	10	25	50	100	500
36	2306704	61.96	62.64	63.05	63.41	63.67	63.91	64.34
	Lake Harvey near Lutz, Fla.	62.52	63.09	63.34	63.65	63.89	64.06	64.41
		62.10	62.76	63.13	63.47	63.71	63.94	64.32
37	2306723	53.52	54.33	54.77	55.28	55.62	55.99	56.69
	Turkey Ford Lake near Lutz,	52.93	53.80	54.18	54.52	54.75	54.95	55.31
	Fla.	53.47	54.28	54.69	55.14	55.41	55.71	56.17
38	2307227	48.18	49.51	50.23	50.96	51.38	51.74	52.34
	Calm Lake near Odessa, Fla.	48.35	49.40	50.10	50.97	51.59	52.18	53.48
		48.33	49.18	50.03	50.82	51.39	51.95	53.08
39	2307384	34.92	36.02	36.53	37.06	37.36	37.62	38.08
	Echo Lake near Citrus Park,	35.01	35.97	36.48	37.08	36.48	37.83	38.60
	Fla.	34.92	36.01	36.53	37.06	37.38	37.66	38.22
40	2309584	74.31	74.96	75.36	75.84	76.19	76.53	77.28
	Lake Thomas at Drexel, Fla.	74.76	75.67	76.20	76.80	77.22	77.57	78.10
		74.33	75.02	75.45	76.02	76.44	76.85	77.71
41	2309814	62.86	64.09	64.43	64.70	64.81	64.88	64.95
	Camp Lake near Denham, Fla.	63.99	64.47	64.75	65.06	65.22	65.36	65.68
		63.11	64.18	64.50	64.77	64.91	65.02	65.21
42	2310100	30.44	32.34	33.27	34.22	34.79	35.27	36.18
	Lake Dan near Odessa, Fla.	30.80	32.76	33.75	34.74	35.36	35.88	36.90
		31.18	32.91	33.78	34.70	35.27	35.75	36.70
43	2310760	130.56	132.14	132.94	133.74	134.24	134.68	135.52
	Lake Juliana near Polk	130.54	131.56	132.05	132.49	132.75	133.14	133.68
	City, Fla.	130.40	132.02	132.76	133.52	134.01	134.43	135.24
44	2310850	141.89	143.47	144.65	146.24	147.45	148.67	151.44
	Lake Helene near Polk	140.63	142.33	143.45	144.83	145.80	146.70	148.67
	City, Fla.	141.49	143.30	144.35	145.77	146.76	147.71	150.05

Table 9.--Station, regional, and weighted estimates of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval peak lake altitude--Continued

Map No. (fig. 1)	Station No. and name	Peak lake altitude, in feet NGVD, for recurrence interval, in years						
		2	5	10	25	50	100	500
45	2310950	126.11	128.30	129.63	131.16	132.18	133.10	134.91
	Lake Deeson near Lakeland,	124.60	127.90	129.76	131.88	133.28	134.52	136.97
	Fla.	125.55	128.55	129.97	132.03	133.38	134.59	136.62
46	2311600	126.36	127.06	127.44	127.89	128.18	128.45	129.02
	Clear Lake at San Antonio,	127.64	128.66	129.15	129.60	129.87	130.08	130.45
	Fla.	126.59	127.32	127.73	128.22	128.55	128.84	129.40
47	2312670	98.55	98.81	98.99	99.20	99.36	99.53	99.97
	Lake Catherine at	97.78	98.51	98.91	99.30	99.53	99.86	101.25
	Groveland, Fla.	98.36	98.70	98.94	99.21	99.39	99.57	100.01

(equation 3 for surface-outflow lakes or equation 4 for closed-basin lakes) to the regression estimate of change in volume above average altitude (equations in table 5 for closed-basin lakes, table 6 for surface-outflow lakes in the Central Lake District, or table 7 for surface-outflow lakes in the Ocala Uplift District). The maximum lake altitude that corresponds to the computed maximum lake volume is interpolated from the altitude-volume relation. The computation procedures are explained in detail by illustrated examples in the "Application of Technique" section.

Limitations of Relations

The regional lake-altitude flood-frequency relations are applicable to unregulated natural lakes that are not significantly affected by manipulation of outlet controls. Because the regression equations are empirical, the relations should be applied to lakes in the Central Lake District and Ocala Uplift District physiographic regions within the study area that have lake and watershed characteristics within the range of data used in developing the regional relations. The maximum and minimum values of the climatic and hydrologic characteristics used in the regression analysis are summarized in the following table:

Characteristic	Range
Closed-basin lakes (average altitude and change in volume)	
DA	0.42 to 2.42 mi^2
QUADALT	48 to 141 feet NGVD
Surface-outflow lakes (average altitude)	
(OALT - QUADALT)	-2.0 to 6.5 feet
(STARAIN - MAPRAIN)	-26.56 to 25.40 inches
QUADALT	26 to 168 feet NGVD
Surface-outflow lakes in Central Lake District (change in volume)	
DELVOLA	0 to 700 acre-ft/mi^2
R50YR_10	16 to 18 inches
SOIL	2.05 to 5.38 inches
STAREA	50.4 to 6,290 acres
Surface-outflow lakes in Ocala Uplift District (change in volume)	
DELVOL	0 to 231 acre-ft
R50YR_10	18 to 20 inches
SOIL	2.05 to 5.38 inches
STAREA	9.66 to 265 acres

The regression equations may not be applicable for lakes where drainage area, altitude-volume relation, or outflow capacity have been altered after the publication of the topographic map used to determine regression variables, or the outflow capacity has been reduced by backwater from a downstream source. For these lakes, other techniques such as hydrologic models should be considered.

APPLICATION OF TECHNIQUE

The technique described in this report can be used to improve the estimate of annual maximum altitude frequency at gaged lakes and to determine the regional estimate of annual maximum altitude frequency at ungaged lakes. The following steps should be taken to apply these techniques:

A. Improved estimate at gaged lakes--

I. Closed-basin lakes (no historical surface outflow)

1. Determine station, regional, and weighted estimates of average lake altitude.
2. Develop altitude-area and altitude-volume relations.
3. Test for classification as closed-basin lake.
4. Determine station, regional, and weighted change in volume above average lake altitude.
5. Determine station, regional, and weighted estimates of annual maximum altitude frequency.

II. Surface-outflow lakes--

1. Determine station, regional, and weighted estimates of average lake altitude.
2. Develop altitude-area and altitude-volume relations.
3. Determine station, regional, and weighted change in volume above average lake altitude.
4. Determine station, regional, and weighted estimates of annual maximum altitude frequency.

B. Regional estimates at ungaged lakes--

I. Closed-basin lakes (no apparent surface outflow)

1. Develop altitude-area and altitude-volume relations.
2. Test for classification as closed-basin lake.
3. Determine regional estimate of average lake altitude.
4. Determine regional estimate of change in volume above average lake altitude.
5. Determine regional estimate of annual maximum altitude frequency.

II. Surface-outflow lakes--

1. Determine regional estimate of average lake altitude.
2. Develop altitude-area and altitude-volume relations.
3. Determine regional change in volume above average lake altitude.
4. Determine regional estimate of annual maximum altitude frequency.

To illustrate the technique used in determining the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year annual maximum lake-altitude frequency, examples of a gaged surface-outflow lake and an ungaged lake with no historical surface outflow are given in the following sections.

Example of Improved Estimate at Gaged Lake

Clear Lake at San Antonio, Fla. (station number 02311600), is a gaged surface-outflow lake in the Ocala Uplift District (map No. 46 in fig. 1). The annual maximum altitude-frequency relation based on the period of record, 1965 to 1979, is one estimate of flood altitudes at the lake. Another estimate is determined from the regional relations developed for average lake altitude and change in volume above average altitude. Finally, a weighted estimate is computed based on the length of record and equivalent years of record of the applicable regression equations. These procedures are carried out in the following steps.

1. Determine station, regional, and weighted estimates of average lake altitude.

   a. The station estimate of average lake altitude is computed as the average of the daily mean altitude for the period of record. In the case of Clear Lake, the average altitude was computed as the average of all weekly staff-gage readings, 125.67 feet NGVD.

   b. The regional estimate of average lake altitude for surface-outflow lakes is computed by equation 3. The information needed to solve equation 3 follows:

   QUADALT--The lake surface altitude on the topographic map. Clear Lake is in the San Antonio U.S. Geological Survey 7-1/2-minute topographic quadrangle, and the altitude printed on the map is 127 feet NGVD.

   OALT--The altitude of the start of surface outflow from Clear Lake is the invert of a culvert under the road just north of the lake. The culvert invert altitude is 127.0 feet NGVD.

   AR--The average annual rainfall for the Clear Lake watershed is 56 inches (fig. 2).

   MAPRAIN--The annual rainfall for the Clear Lake watershed the year the topography was determined. The topography was by plane table survey in 1954. The annual rainfall at Clear Lake is estimated from the St. Leo rain gage (No. 17 in fig. 1 and table 2). The annual rainfall at St. Leo was 45.02 inches in 1954 (table 2).

   Solving equation 3 for the regional estimate of average altitude,

$$\begin{aligned} RAVALT &= 0.390 + 0.992 \cdot QUADALT + 0.270 \cdot (OALT - QUADALT) \\ &\quad + 0.0265 \cdot (AR - MAPRAIN) \\ &= 0.390 + 0.992 \cdot 127 + 0.270 \cdot (127.0 - 127) + 0.0265 \\ &\quad \cdot (56 - 45.02) \end{aligned}$$

   RAVALT = 126.66 feet NGVD.

   c. The weighted estimate of average lake altitude is computed by equation 5.

$$WSTALT = \frac{N_s \cdot STALT + N_u \cdot RAVALT}{N_s + N_u}$$

where N_s = years of record (1965-79), or 14 years;

STALT = average of the mean daily lake altitude for the period of record, 125.67 feet;

N_u = equivalent years of record for regression equation for surface-outflow lakes (equation 3), 4.5 years; and

RAVALT = regional estimate of average altitude from equation 3, 126.66 feet.

$$WSTALT = \frac{14 \cdot 125.67 + 4.5 \cdot 126.66}{14 + 4.5}$$

$$= 125.91 \text{ feet NGVD.}$$

2. Develop altitude-area and altitude-volume relations.

The altitude-area relation is determined by planimetering the area at lake altitude 127 feet and the next two higher contour lines, 130 and 140 feet. These areas, in acres, are plotted at their corresponding altitudes and joined by a smooth curve. In later computations, the lake volume will be needed at each annual maximum altitude, the altitude of the start of outflow, and at the altitude of the station, regional, and weighted estimate of average lake altitude. The lowest of these is the 1968 maximum altitude of 124.30 feet NGVD. Therefore, the altitude-area curve is extrapolated to 124 feet NGVD (fig. 5). The area is estimated at each 1-foot increment from 124 feet to 140 feet from the altitude-area relation. The average area for each 1-foot interval was computed, and then the incremental volume was accumulated from the starting altitude of 124 feet.

The altitude-volume relation was computed in tabular form as follows:

Altitude, in feet NGVD	Area, in acres	Average area, in acres	Incremental volume, in acre-feet	Accumulated volume, in acre-feet
124	120			0
125	134	127	127	127
126	145	139.5	139.5	266
127	154	149.5	149.5	416
128	162	158	158	574
129	168	165	165	739
130	173	170.5	170.5	910
131	178	175.5	175.5	1,080
132	182	180	180	1,260
133	186	184	184	1,450
134	190	188	188	1,640
135	194	192	192	1,830
136	197	195.5	195.5	2,020
137	200	198.5	198.5	2,220
138	204	202	202	2,420
139	207	205.5	205.5	2,630
140	211	209	209	2,840

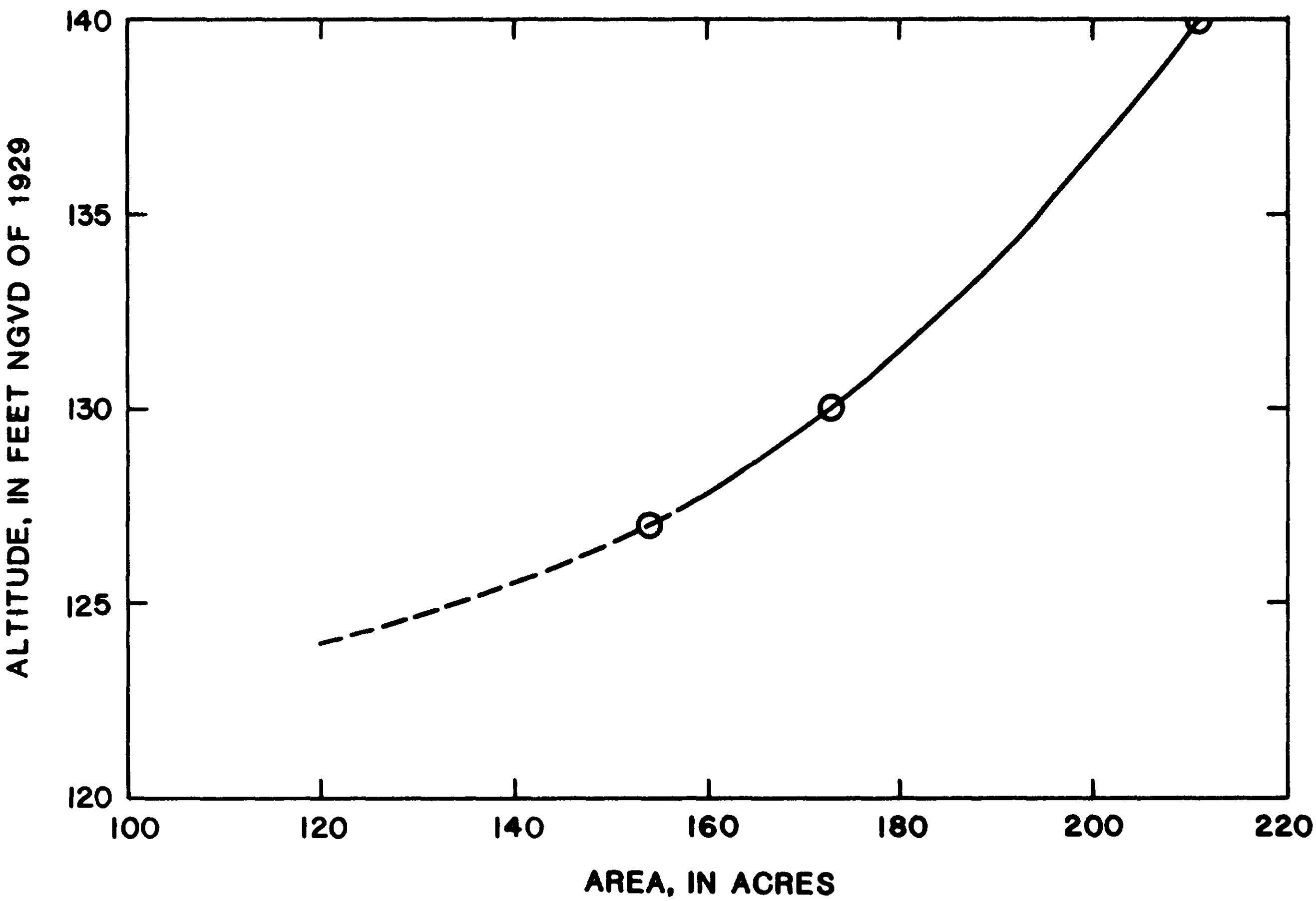

Figure 5.--Stage-area relation of Clear Lake at San Antonio.

3. Determine station, regional, and weighted estimates of change in volume above average altitude.

a. Station estimate.

The station estimate of change in volume above average altitude is the lake volume at average altitude subtracted from the frequency distribution of the annual maximum lake volume. The station record used in the frequency analysis was from 1965 to the end of the climatic year on May 31, 1979. The annual maximum altitude for each June 1 to May 31 climatic year was tabulated and the corresponding lake volume was computed from the preceeding altitude-volume relation. A log-Pearson type III frequency distribution was computed for the annual maximum lake volume.

The lag-one serial correlation coefficient of the annual maximum volume was computed to determine if the variance of the frequency distribution needed adjustment. The serial correlation coefficient, r, was -0.02. Therefore, no correction was needed. (See "Serial Correlation Adjustment" section of this report.)

The volume at average altitude, 125.67 feet, interpolated from the altitude-volume relation, is 220 acre-feet. The change in volume above average altitude is computed in tabular form below.

Recurrence interval, T, in years	Annual maximum volume, $MVOL_T$, in acre-feet	Volume at average altitude, SVOL, in acre-feet	Change in volume above average altitude, $CVOL_T$, in acre-feet
2	320	220	100
5	425	220	205
10	486	220	266
25	556	220	336
50	604	220	384
100	648	220	428
500	742	220	522

b. Regional estimate of change in volume above average altitude, $RCVOL_T$.

The change in volume above average altitude is computed using the equations in table 6. The data needed are:

AVAREA--Lake surface area at average altitude. The regional estimate of average altitude for Clear Lake was determined by equation 3 as 126.66 feet NGVD. Interpolation of the altitude-area relation (fig. 5) gives 151 acres.

RDELVOL + 1--RDELVOL = (OVOL - AVOL), where OVOL is the volume at the outlet altitude, 127.0 feet, and AVOL is the volume at the regional estimate of average altitude, 126.66 feet. The volumes for these two altitudes from the altitude-volume relation are 416 and 365 acre-feet, respectively. Therefore, RDELVOL + 1 = (416 - 365 + 1) = 52 acre-feet.

SOIL--The soil-infiltration index for the watershed is 5.38 inches, from figure 3.

The 10-year recurrence-interval regional estimate of change in volume above average altitude, $RCVOL_{10}$, is computed to illustrate the procedure. The above values are used in the equation for the 10-year recurrence interval in table 7.

$$
\begin{aligned}
RCVOL_{10} &= 13.2 \cdot AVAREA^{0.841} \cdot SOIL^{-0.754} \cdot (RDELVOL + 1)^{0.116} \\
&= 13.2 \cdot (151)^{0.841} \cdot (5.38)^{-0.754} \cdot (52)^{0.116} \\
&= 13.2 \cdot 68.0 \cdot 0.281 \cdot 1.58 \\
&= 399 \text{ acre-feet.}
\end{aligned}
$$

c. Weighted estimate of change in volume above average altitude.

The weighted estimate for selected recurrence-interval change in volume above average altitude, $WCVOL_T$, is computed by equation 10.

$$WCVOL_T = \frac{N_s \cdot CVOL_T + N_T \cdot RCVOL_T}{N_s + N_T}$$

The 10-year recurrence-interval weighted estimate of change in volume above average altitude, $WCVOL_{10}$, is computed to illustrate the procedure. The following values are used in the equation for the 10-year recurrence interval.

N_s = 14 years of station record at Clear Lake;
$CVOL_{10}$ = 266 acre-feet, computed previously;
N_{10} = 1.5 years, from table 7;
$RCVOL_{10}$ = 399 acre-feet, from previous computation.

Substituting the above values in equation 10

$$
\begin{aligned}
WCVOL_{10} &= \frac{14 \cdot 226 + 1.5 \cdot 399}{14 + 1.5} \\
&= \frac{3{,}724 + 598.5}{15.5} \\
&= 279 \text{ acre-feet.}
\end{aligned}
$$

4. Determine station, regional, and weighted estimates of annual maximum altitude frequency.

a. The station estimate of annual maximum altitude frequency is determined by converting the log-Pearson type III recurrence-interval maximum volume, $MVOL_T$, to altitude using the altitude-volume relation.

b. The regional estimate of annual maximum altitude frequency is determined as the corresponding altitude for the sum of the volume at the regional estimate average altitude, AVOL, and the recurrence-interval regional estimate, $RCVOL_T$ (equation 11). For example, the 10-year recurrence-interval regional maximum volume, $RMVOL_{10}$, is computed as:

$$RMVOL_{10} = AVOL + RCVOL_{10}$$

where $AVOL$ = 356 acre-feet, volume at the regional estimate of average lake altitude, 126.66 feet;

$RCVOL_{10}$ = 399 acre-feet, previously computed. Therefore,

$$RMVOL_{10} = 365 + 399$$
$$= 764 \text{ acre-feet.}$$

The corresponding altitude from the altitude-volume relation (page 50) is 129.15 feet NGVD.

c. The weighted estimate of annual maximum altitude frequency is the corresponding altitude for the sum of the volume at the weighted estimate of average altitude, WVOL, and the recurrence-interval weighted estimate of change in volume above average altitude, $WCVOL_T$ (equation 12).

For example, the 10-year recurrence-interval maximum volume, $WMVOL_{10}$, is computed as:

$$WMVOL_{10} = WVOL + WCVOL_{10}$$

where $WVOL$ = 253 acre-feet, volume at the weighted estimate of average lake altitude, 125.91 feet NGVD; and

$WCVOL_{10}$ = 279 acre-feet, as previously computed.

$$WMVOL_{10} = 253 + 279$$
$$= 532 \text{ acre-feet.}$$

The corresponding altitude from the altitude-volume relation is 127.73 feet NGVD.

The station, regional, and weighted estimates of maximum altitude frequency for Clear Lake are tabulated below.

Recurrence interval, T, in years	Station estimate		Regional estimate		Weighted estimate	
	$MVOL_T$, in acre-feet	Maximum altitude, in feet NGVD	$RMVOL_T$, in acre-feet	Maximum altitude, in feet NGVD	$WMVOL_T$, in acre-feet	Maximum altitude, in feet NGVD
2	320	126.36	517	127.64	355	126.59
5	425	127.06	683	128.66	466	127.32
10	486	127.44	764	129.15	532	127.73
25	556	127.89	842	129.60	611	128.22
50	604	128.18	888	129.87	665	128.55
100	648	128.45	923	130.08	713	128.84
500	742	129.02	987	130.45	808	129.40

Example of Regional Estimate at Ungaged Lake

Lake Lucerne is an ungaged lake located in the Central Lake District near Lake Alfred. The lake has no apparent outflow, and no historical information was found to indicate that outflow has occurred within the recent past. Estimates of maximum flood altitude frequency will be based on regional estimates of average lake altitude and change in volume above average altitude. The sum of the volume at average altitude and the recurrence-interval change in volume is then converted to lake altitude using the altitude-volume relation. These procedures are carried out in the following steps.

1. Develop altitude-area and altitude-volume relations.

The altitude-volume relation will be determined from the altitude of the lake on the topographic map, 129 feet NGVD, to the point of outflow. The lowest point on the drainage divide surrounding Lake Lucerne was determined by survey to be 139.2 feet NGVD. Outflow is assumed to begin at 139.2 feet NGVD. The lake-surface area at 129 feet and areas at the 130-foot, 135-foot, and 140-foot contours were planimetered. An altitude-area curve was drawn, and the altitude-area and altitude-volume relations are tabulated below.

Altitude, in feet NGVD	Area, in acres	Average area, in acres	Incremental volume, in acre-feet	Accumulated volume, in acre-feet
129	42	--	--	0
130	44	43	43	43
131	46	45	45	88
132	48	47	47	135
133	50	49	49	184
134	52	51	51	235
135	54	53	53	288
136	56	55	55	343
137	58	57	57	400
138	60	59	59	459
139	62	61	61	520
140	64	63	63	583

2. Test for classification as closed-basin lake.

The classification of closed-basin lake is verified by solving equation 1.

$$TEST = \frac{(OVOL - QVOL)}{DA}$$

From the altitude-volume relation, the volume at the altitude of outflow (OVOL), 139.2 feet NGVD, is 533 acre-feet, and the volume at the altitude of the lake shown on the topographic map, 129 feet NGVD, is zero acre-feet. The drainage area (DA) was determined from the topographic map as 0.27 mi^2.

Substituting in equation 1

$$\text{TEST} = \frac{533 - 0}{0.27}$$

$$= 1{,}974 \text{ acre-ft/mi}^2.$$

The TEST value exceeds the 900 acre-ft/mi^2 criteria for closed-basin lakes; therefore, the assumption that it is a closed-basin lake is verified.

3. Determine regional estimate of average altitude.

The regional estimate of average altitude for closed-basin lakes is computed by equation 4.

$$\text{RAVALT} = 1.02 \cdot \text{QUADALT}^{0.994}$$

where QUADALT is the altitude of the lake surface on the topographic map. Lake Lucerne is in the Winter Haven U.S. Geological Survey 7-1/2-minute topographic quadrangle. The altitude printed on the lake is 129 feet NGVD.

$$\text{RAVALT} = 1.02 \cdot 129^{0.994}$$

$$= 127.80 \text{ feet NGVD.}$$

4. Determine regional estimate of change in volume above average lake altitude.

The regional estimates for change in volume above average lake altitude for closed-basin lakes are computed with equations in table 5. For example, the 10-year recurrence-interval change in volume,

$$\text{RCVOL}_{10} = 427 \cdot \text{DA}^{0.814}$$

$$= 427 \cdot 027^{0.814}$$

$$= 147 \text{ acre-feet.}$$

The results of these computations are tabulated later in this section when computing the sum of the volume at average altitude and the recurrence-interval change in volume to determine the corresponding maximum lake altitudes.

5. Determine regional estimate of annual maximum altitude frequency.

The regional estimate of annual maximum altitude frequency is determined as the corresponding altitude of RMVOL_T (equation 11), the sum of the volumes at the regioanl estimate of average altitude, AVOL, and the recurrence-interval regional estimate, RCVOL_T. The values of RCVOL_T have been computed in the previous step, but the regional estimate of average altitude, 127.80 feet NGVD, is lower than the altitude-volume relation.

The altitude-volume relation is extrapolated to 127 feet NGVD by assuming the same change in surface area per foot of altitude. The volumes below 129 feet NGVD will be negative relative to the original tabulation, but for the computation of change in volume above average altitude, they are comparable to an altitude-volume relation with origin at 127 feet NGVD. The extrapolated values are tabulated as follows.

Altitude, in feet NGVD	Area, in acres	Average area, in acres	Incremental volume, in acre-feet	Accumulated volume, in acre-feet
127	38	39	-39	-80
128	40	41	-41	-41
129	42	--	--	0

The volume corresponding to 127.80 feet NGVD is interpolated from the extrapolated altitude-volume relation as -49 acre-feet.

The corresponding stages for the regional estimate of maximum volume, $RMVOL_T$, computed as the sum of $RCVOL_T$ + AVOL are tabulated as follows.

Recurrence interval, T, in years	Regional estimate			Corresponding maximum altitude, in feet NGVD
	AVOL, in acre-feet	$RCVOL_T$, in acre-feet	$RMVOL_T$, in acre-feet	
2	-49	43	-6	128.85
5	-49	102	53	130.22
10	-49	147	98	131.21
25	-49	207	158	132.47
50	-49	254	205	133.41
100	-49	302	253	134.34
500	-49	416	367	136.42

SUMMARY

Regional lake flood-altitude frequency relations were developed for natural unregulated lakes in the Central Lake District and Ocala Uplift District physiographic regions of west-central Florida. Annual maximum lake-altitude data during the June 1 to May 31 climatic year at 47 lakes in or near the Southwest Florida Water Management District were used in the analysis. The maximum lake altitudes were converted to lake volume, and the log transforms were used in a log-Pearson type III frequency distribution. Frequency distributions were corrected for serial correlation.

The long-term average lake altitude was used as a reference above which the change in volume to flood altitude was related. The lake volume between average altitude and the outlet altitude divided by drainage area was used to distinguish between closed-basin lakes and surface-outflow lakes. Six closed-basin lakes and 41 surface-outflow lakes were used in this analysis. Average altitude for closed-basin lakes was related to altitude of lake surface shown on the U.S. Geological Survey topographic quadrangle by multiple linear regression. The correlation coefficient is 0.99 and the standard error of estimate is ±4.0 percent. Regional estimate of average altitude for surface-outflow lakes was related to altitude of lake water surface shown on a U.S. Geological Survey topographic quadrangle, lake outlet altitude, and annual rainfall. The correlation coefficient is higher than 0.99 and the average standard error of estimate is ±1.0 percent.

Peak flood volume above average altitude for closed-basin lakes was related to drainage area by linear-regression analysis. The standard error of estimate for these regional relations ranged from ±22 percent for the 5-, 10-, and 25-year recurrence intervals to ±40 percent for the 2-year recurrence interval.

Peak flood volume above average altitude for surface-outflow lakes in the Central Lake District was related to the lake-surface area at average altitude, the lake volume between average altitude and outlet altitude divided by drainage area, soil-infiltration index, and the 50-year, 10-day rainfall. The standard error of estimate ranged from ±29 to ±54 percent.

Peak flood volume above average altitude for surface-outflow lakes in the Ocala Uplift District was related to the lake-surface area at average altitude, soil-infiltration index, and the lake volume between average lake altitude and the outlet altitude. The standard error of estimate ranges from ±50 percent for the 500-year recurrence interval to ±58 percent for the 2-, 5-, and 10-year recurrence intervals.

The regional estimate of change in volume above average altitude for a selected recurrence interval is added to the lake volume at the regional estimate of average altitude to determine the lake volume for that recurrence interval. The corresponding lake altitude is then estimated from the altitude-volume relation. Regional estimates for average altitude and annual flood altitude are used to weight station average altitude and annual flood-altitude data. Tables comparing station, regional, and weighted lake flood altitude are shown for 47 lake stations used in the analysis. The applications of the technique developed in this report are illustrated by examples using a gaged lake in the Ocala Uplift District and an ungaged lake in the Central Lake District.

SELECTED REFERENCES

Brooks, H. K., 1981, Physiographic divisions, State of Florida: Gainesville, Florida, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Chow, V. T., 1964, Handbook of applied hydrology: New York, McGraw-Hill, p. 9.28, 29; 21.11-21.28.

Dalrymple, T., 1960, Flood-frequency analysis: U.S. Geological Survey Water-Supply Paper 1543-A, 80 p.

Hardison, C., 1971, Prediction error of regression estimates of streamflow characteristics at ungaged sites: U.S. Geological Survey Professional Paper 650-D, p. D210-D214.

Hughes, G. H., 1974, Water-level fluctuations of lakes in Florida: Florida Bureau of Geology Map Series 62.

Langbein, W. B., and Iseri, K. T., 1960, General introduction and hydrologic definitions: U.S. Geological Survey Water-Supply Paper 1541-A, 29 p.

Miller, J. F., 1964, Two-to-ten-day precipitation for return periods of 2 to 100 years in the contiguous United States: Washington, D.C., U.S. Weather Bureau, 29 p.

Riggs, H. C., 1968, Some statistical tools in hydrology: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chapter A1.

Southwest Florida Water Management District, 1976, Flood-stage frequency relations for selected lakes in Polk County, Florida: Report No. 4-75.

----- 1978, Water use plan - 1978.

Stewart, J. W., 1980, Areas of natural recharge to the Floridan aquifer in Florida: Florida Bureau of Geology Map Series 98.

Tasker, G. D., and Gilroy, E. J., 1982, Comparison of estimators of standard deviation for hydrologic time series: Water-Resources Research, v. 18, p. 1503-1508.

U.S. Department of Housing and Urban Development, 1978, Flood insurance study, town of Interlachen, Putnam County, Florida.

----- 1979, Flood insurance study, city of Frostproof, Polk County, Florida.

----- 1980a, Flood insurance study, city of Bartow, Polk County, Florida.

----- 1980b, Flood insurance study, town of Davenport, Polk County, Florida.

----- 1980c, Flood insurance study, town of Dundee, Polk County, Florida.

----- 1980d, Flood insurance study, city of Fort Meade, Polk County, Florida.

----- 1980e, Flood insurance study, town of Lake Hamilton, Polk County, Florida.

----- 1980f, Flood insurance study, city of Mulberry, Polk County, Florida.

----- 1981a, Flood insurance study, city of Lakeland, Polk County, Florida.

----- 1981b, Flood insurance study, city of Haines City, Polk County, Florida.

----- 1981c, Flood insurance study, city of Winter Haven, Polk County, Florida.

----- 1982, Flood insurance study, unincorporated areas of Polk County, Florida.

U.S. Water Resources Council, 1981, Guidelines for determining flood flow frequency: Washington, D.C., U.S. Government Printing Office, Bulletin No. 17B, 182 p.

Wesolowsky, G. O., 1976, Multiple regression and analysis of variance: New York, John Wiley, p. 26-149.

White, W. A., 1970, The geomorphology of the Florida peninsula: Florida Bureau of Geology Bulletin 51, 164 p.