UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TECHNIQUE FOR ESTIMATING DEPTH OF 100-YEAR FLOODS IN NEW JERSEY

Open-file Report 79-419

Prepared in Cooperation with the
New Jersey Department of Environmental Protection
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FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC UNITS

For those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile $(ft^3/s)/mi^2$	0.01093	cubic meters per second per square kilometer $(m^3/s)/km^2$
feet (ft)	0.3048	meters (m)
feet per second (ft/s)	0.3048	meters per second (m/s)
inches (in)	25.40	millimeters (mm)
miles (mi)	1.609	kilometers (km)
square feet (ft^2)	0.0929	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)

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ABSTRACT

Techniques are developed for use in estimating 100-year flood depths on New Jersey streams. Equations and graphs are presented relating the 100-year flood depth above the mean annual flood to drainage area and area of lakes and swamps. Separate relations for the coastal plain and noncoastal plain streams in the four hydrologic areas in New Jersey are shown. A method of mapping flood-prone areas on U.S. Geological Survey 7-1/2 minute topographic quadrangles is detailed in this report.

INTRODUCTION

Maps outlining areas of potential flood hazards are a useful tool in flood-plain management. Preparations of these maps usually require estimating the flood depth for a particular recurrence interval. The 100-year flood depth, an event having a probability of about 1 in 100 of being equaled or exceeded in any year, is generally used in their preparation.

The purpose of this study is to extend the flood-depth estimating procedures presented in Thomas (1964b) to include the 100-year flood and to simplify application of the procedure. Presented in this report are methods that can be used to quickly identify flood-prone areas.

Planners, engineers, builders, and others interested in determining flood depths will find the techniques outlined in this report useful. The depth of the 100-year flood above the mean annual flood can easily be estimated for a site on a stream using the graphs, equations, and maps in this report, along with topographic maps. The method outlined is especially useful where approximate results are required quickly and economically.

The method presented in this report was used by the New Jersey District of the U.S. Geological Survey to delineate flood-prone areas on 7-1/2 minute U.S. Geological Survey topographic quadrangle maps (scale 1:24,000) where historic profile data were not available.

METHOD OF ANALYSIS

The relation of flood depth to flood discharge, developed by Leopold and Maddock (1953), is of the form $d = cQ^f$, where d is the average cross section depth, Q is the discharge of a given frequency, and c and f are constants for a given frequency. Using this equation, Thomas (1964b) developed a method for predicting flood depths for various frequencies in New Jersey. He presented graphs showing the relation between mean annual flood discharge ($Q_{2.33}$) and flood depth for recurrence intervals of 1.5 to 50 years; where depth is measured above the average stream bottom. Thomas (1964a), in an earlier report, presented graphs showing the relation of mean annual flood discharge to drainage area and area of lakes and swamps.

The relation of flood depth to discharge was extrapolated in this study to include the 100-year flood. Flood depth was then related directly to drainage area and area of lakes and swamps in percentage of drainage area. Thomas (1964b) defined flood depth to be the height above average stream bottom. In this study, the 100-year flood depth is the difference between the depth of the 100-year flood and the mean annual flood.

Equations and graphs presented in this report show the results of this study for the four hydrologic areas (fig. 1) and the coastal plain and noncoastal plain streams (fig. 2) in New Jersey.

APPLICATION OF RESULTS

The procedure for determining the depth of the 100-year flood above mean annual flood, at a given point on a stream is as follows:

1. Determine the drainage area in square miles.
2. Determine the area of lakes and swamps, in percentage of total drainage area.
3. Compute the 100-year flood depth above mean annual flood using the appropriate equation from table 1, or graphs in figures 3-6.

Drainage area and area of lakes and swamps should be consistent with the data gathered in determining the relationships presented in this report. U.S. Geological Survey 7-1/2 minute topographic maps were used in determining drainage area and lakes and swamps area for the study. A tabulation of drainage area and surface storage index for selected gaging stations is given in Stankowski (1974). The percentage of area of lakes and swamps can be determined by subtracting 1 percent from the surface storage index.

Flood-prone areas can be delineated on 7-1/2 minute U.S. Geological Survey topographic maps using the procedures described in this report along with information found on the topographic maps. To facilitate flood-prone area mapping, several assumptions must be made. To convert the flood depth as determined above to flood elevation, the assumption is made that the elevation of mean annual flood is equal to the bankfull stage at every point along the stream. Another assumption made is that on a topographic map the elevation of the streambank (bankfull elevation) is equal to the contour elevation at the point where a contour line crosses the stream. Based on these assumptions, the 100-year flood elevation can be determined by adding the 100-year flood depth to the bankfull elevation. A third assumption is that elevations between contour lines can be located by linear interpolation in directions both along and perpendicular to the stream. Other interpretations can be made as to the variation in the land surface elevations between contours, based on field inspection or map symbols (for example, swamp, railroad grades, gravel pits). Once the 100-year inundation limits at the points of contour crossing are located, the 100-year inundation lines can be drawn in general conformance with the shape of the contour lines along the stream.

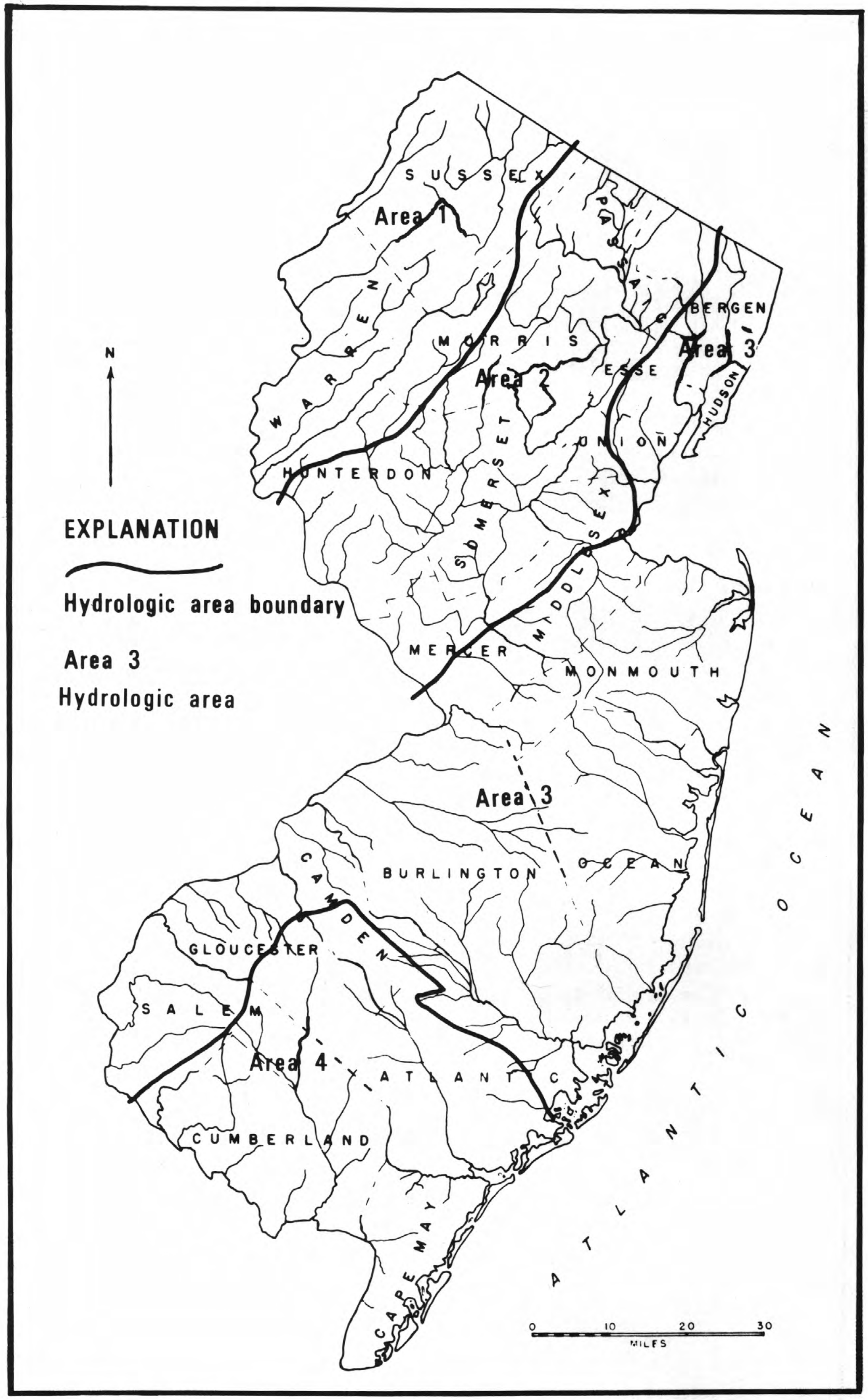

Figure 1.-- Map of New Jersey showing hydrologic areas. Map modified from New Jersey Water Resources Circular 14 (Thomas, 1964b).

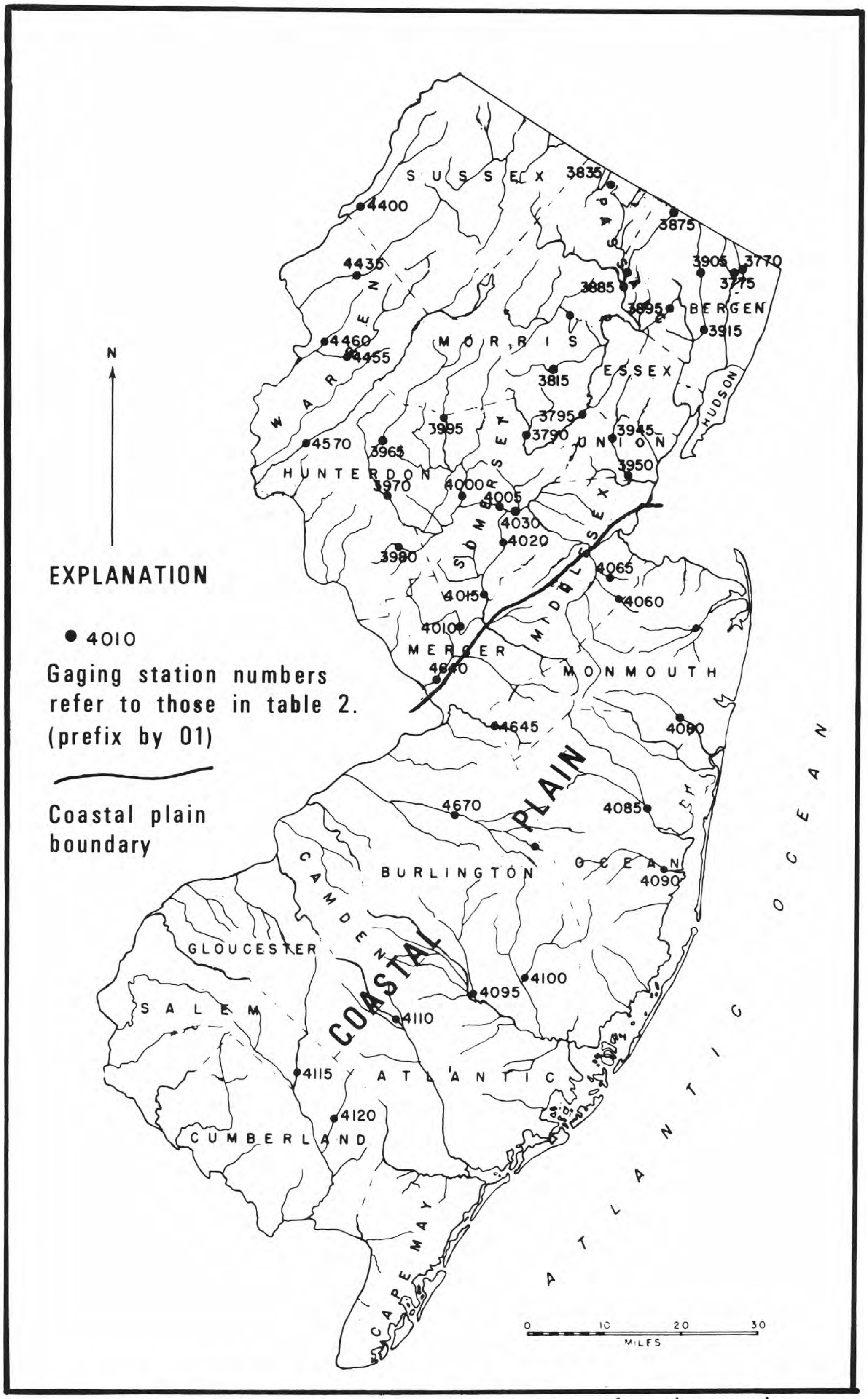

Figure 2.-- Map of New Jersey showing location of gaging stations used in the study and boundary of coastal plain. Map modified from New Jersey Water Resources Circular 14 (Thomas,1964b).

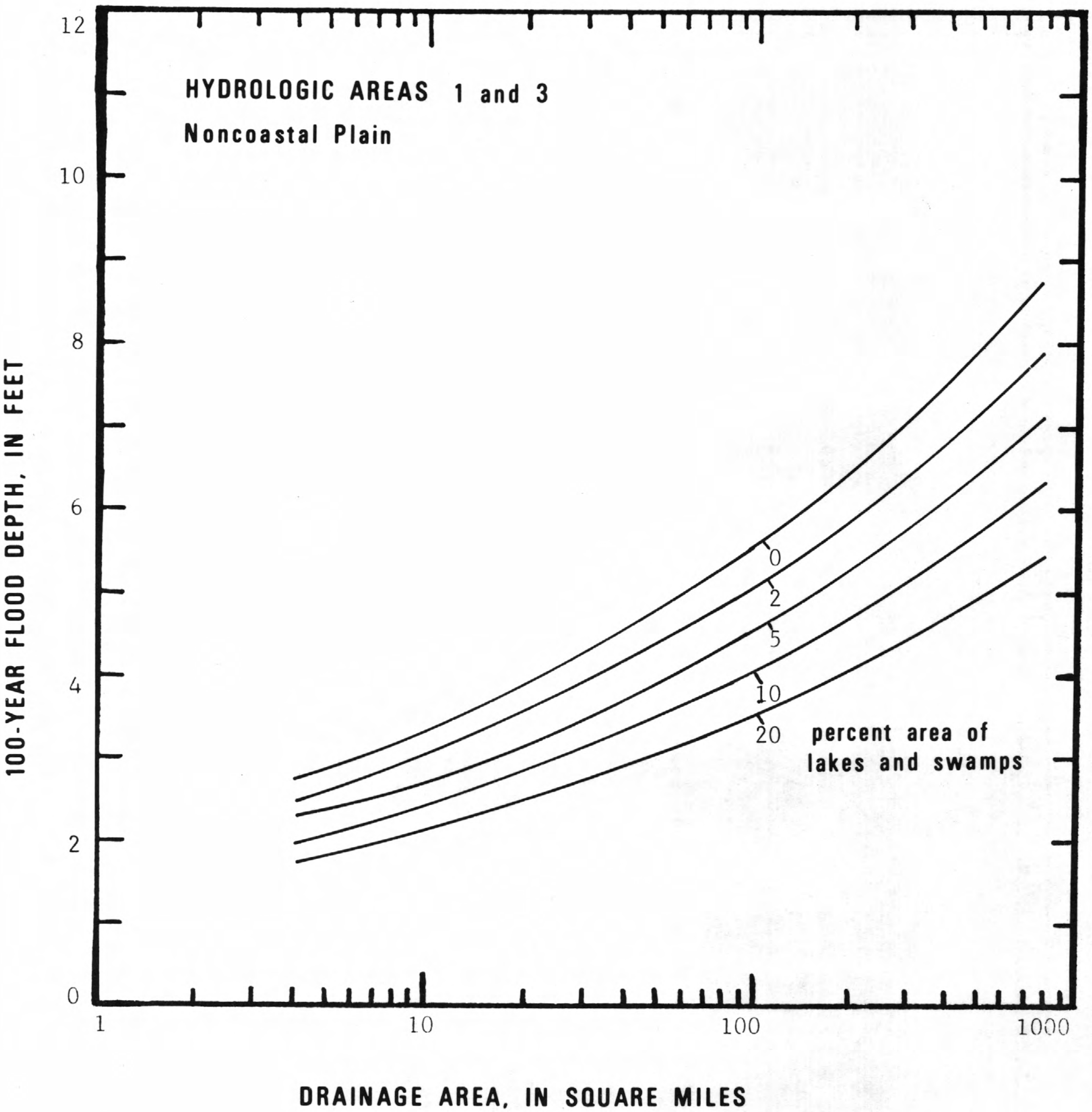

Figure 3.-- Relation between 100-year flood depth, drainage area, and area of lakes and swamps for coastal plain sites in hydrologic areas 1 and 3 in New Jersey.

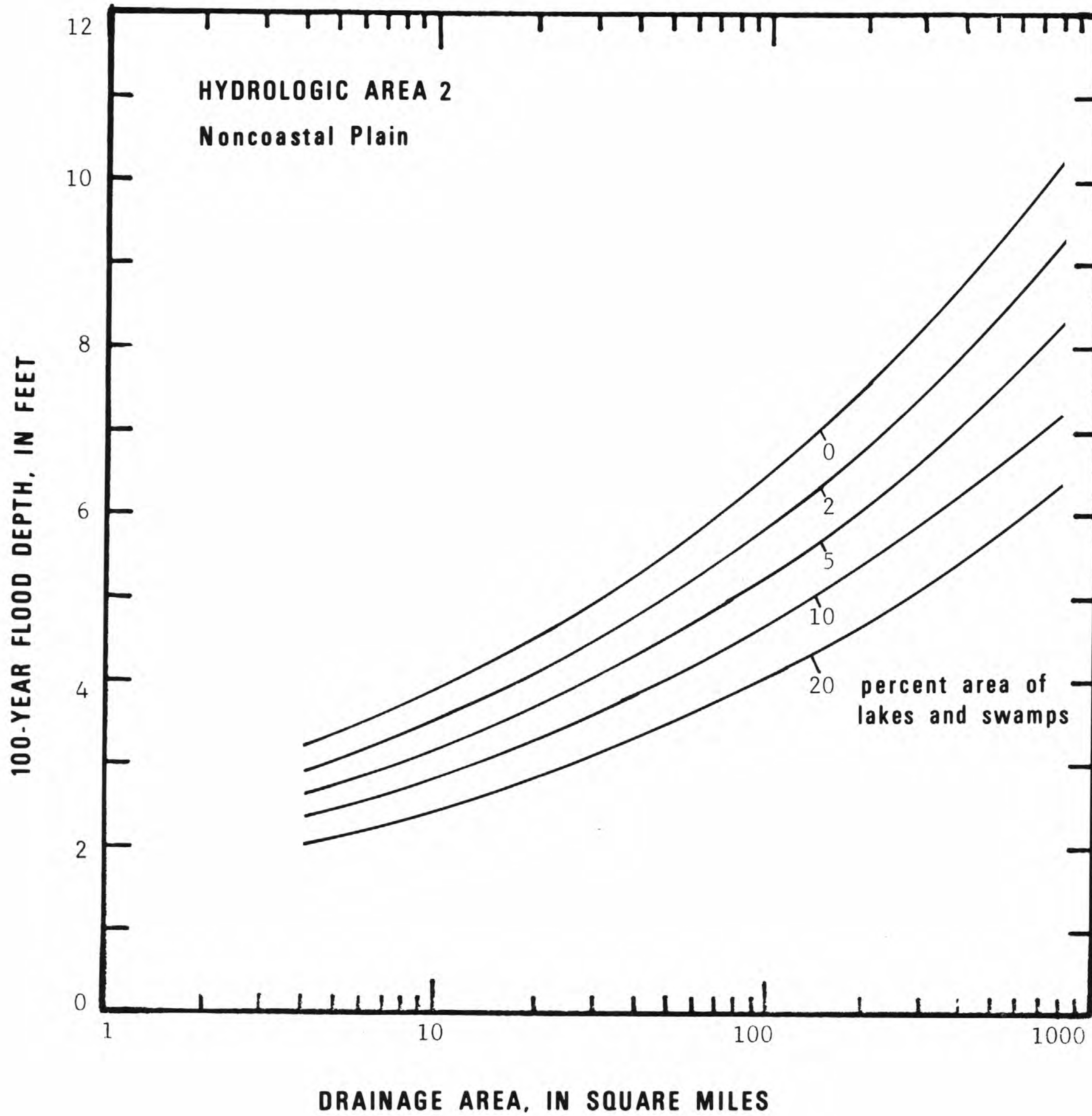

Figure 4.-- Relation between 100-year flood depth, drainage area, and area of lakes and swamps for coastal plain sites in hydrologic area 2 in New Jersey.

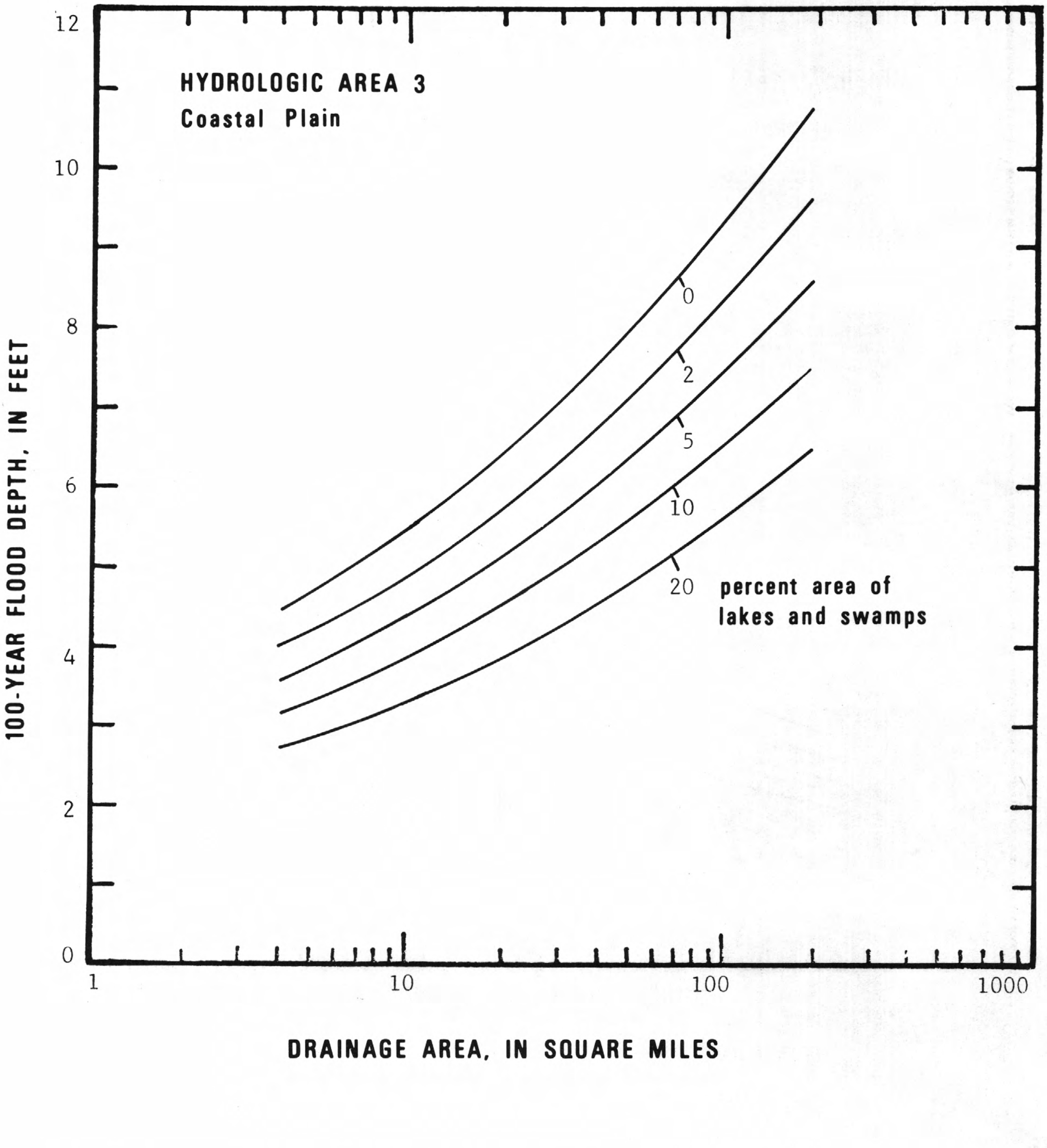

Figure 5.-- Relation between 100-year flood depth, drainage area, and area of lakes and swamps for coastal plain sites in hydrologic area 3 in New Jersey.

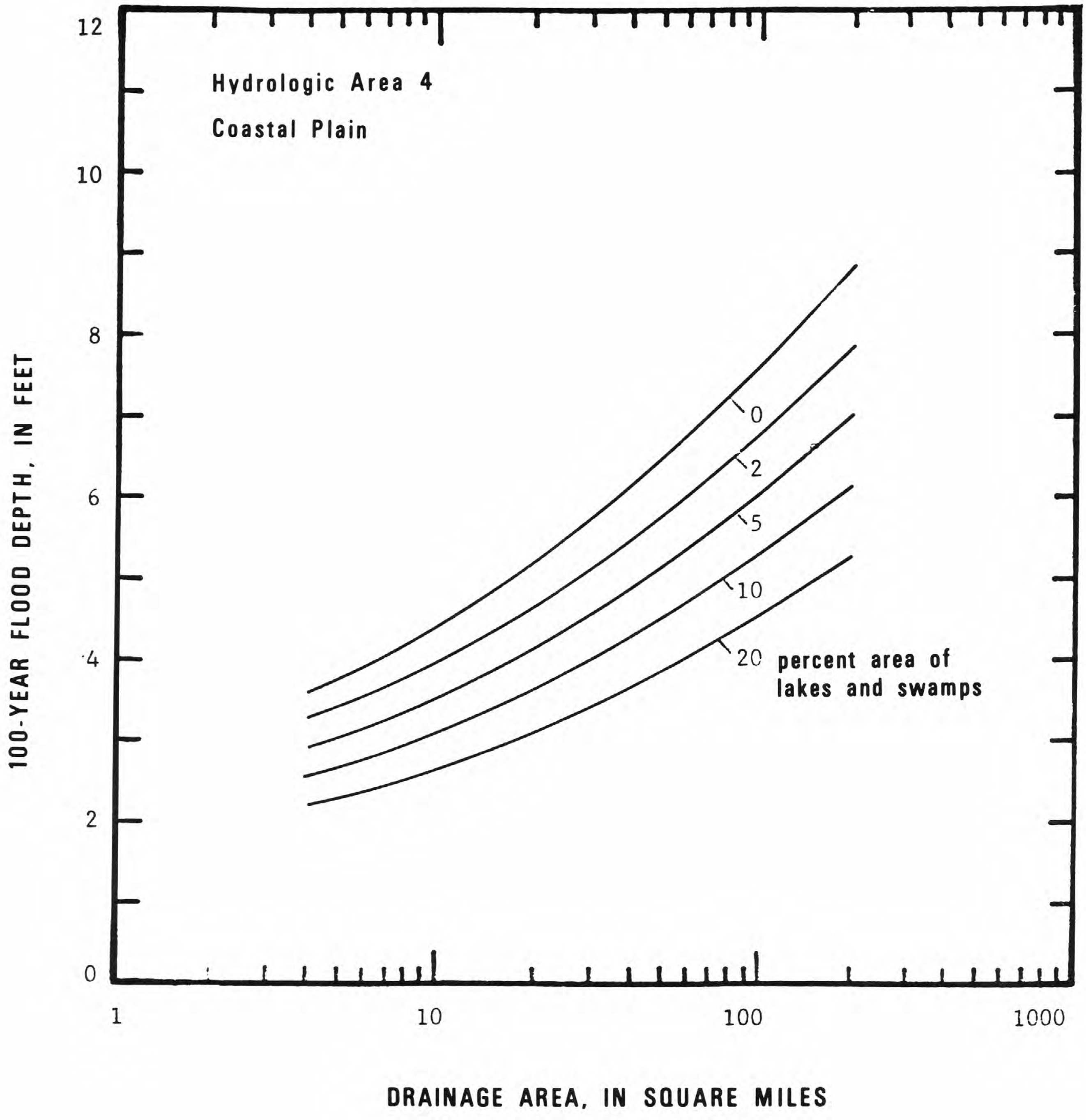

Figure 6.-- Relation between 100-year flood depth, drainage area, and area of lakes and swamps for coastal plain sites in hydrologic area 4 in New Jersey.

Table 1.--Summary of estimating equations

NONCOASTAL PLAIN AREA

Hydrologic area	Equation
1 and 3	$D = 2.97\ A^{0.22}\ (S + 4)^{-0.27}$
2	$D = 3.46\ A^{0.22}\ (S + 4)^{-0.27}$

For: $S < 20$

$4 < A < 800$

COASTAL PLAIN

Hydrologic area	Equation
3	$D = 4.83\ A^{0.23}\ (S + 4)^{-0.29}$
4	$D = 3.93\ A^{0.23}\ (S + 4)^{-0.29}$

For: $S < 20$

$4 < A < 200$

where:

D = Depth in feet of 100-year flood above mean annual flood
A = Drainage area above site, in square miles
S = Area of lakes and swamps, in percent of drainage area.

ACCURACY AND LIMITATIONS

Methods for determination of flood frequency have changed since Thomas (1964b) developed the flood-depth frequency relationships. Consequently, current data was used to test the validity of the 100-year flood-depth prediction equations presented in this report.

The accuracy of the mathematical relations was measured by comparing 100-year flood depths computed using the equations with observed depths at gaged sites. Observed flood depths were obtained by frequency analyses of annual peak discharges, using techniques recommended by the U.S. Water Resources Council (1977). Annual peak-discharge data for 41 gaging stations through the 1975 water year were used. The 100-year and 2.33-year flood stages at the gaged sites were computed using the latest stage-discharge rating available. Two-thirds of the estimated depths were found to be within 27 percent of the observed values (table 2) at the selected gages.

The 100-year flood-depth relations presented in this report are applicable for any site on New Jersey streams where flood flow is not significantly affected by manmade changes or backwater, where drainage areas are greater than 4 mi^2, and where lake and swamp area is less than 20 percent of the total drainage area. Because of the effects of urbanization on flood frequency (Stankowski, 1974), the flood-depth relations are not considered to be reliable where manmade impervious cover exceeds 15 percent in the basin.

Reliability of the equations for estimating flood depths is unknown outside of the range of drainage area and lake and swamp area of the gaging-station data (table 2) used in checking their accuracy. The main stem Delaware River was excluded from the study because of major regulation by reservoirs.

The methods described in this report are intended for use where a broad appraisal over a large area is required. The results should be used as approximate studies in low flood-risk areas or as a guide in deciding if a more detailed investigation is needed. The methods are not intended to be used for making final decisions on land use. Accuracy of flood prone areas delineated on U.S. Geological Survey 7-1/2 minute topographic maps can only be consistent with National Map Accuracy Standards.

Table 2.--Summary of gaging-station data and depth of 100-year flood

Gaging station no.	Station name	Drainage area (square miles)	Area of lakes and swamps (percent)	Hydro-logic area	Depth of 100-yr flood above 2.33-yr flood stage (feet)
	HACKENSACK RIVER BASIN				
01377000	Hackensack River at Rivervale	58.0	4.1	3	5.3
	PASSAIC RIVER BASIN				
01377500	Pascack Brook at Westwood	29.6	2.7	3	5.1
01379000	Passaic River near Millington	55.4	18.1	2	3.6
01379500	Passaic River near Chatham	100	11.2	2	4.6
01381500	Whippany River at Morristown	29.4	1.0	2	3.7
01383500	Wanaque River at Awosting	40.4	3.6	2	1.8
01387500	Ramapo River near Mahwah	118	4.6	2	3.3
01388500	Pompton River at Pompton Plains	355	6.4	2	4.3
01389500	Passaic River at Little Falls	785	8.6	2	6.4
01390500	Saddle River at Ridgewood	21.6	4.6	3	5.4
01391500	Saddle River at Lodi	54.6	15.6	3	9.2

Table 2.--Summary of gaging-station data and depth of 100-year flood--Continued

Gaging station no.	Station name	Drainage area (square miles)	Area of lakes and swamps (percent)	Hydro-logic area	Depth of 100-yr flood above 2.33-yr flood stage (feet)
	RAHWAY RIVER BASIN				
01394500	Rahway River at Springfield	25.5	0.4	3	4.1
01395000	Rahway River at Rahway	40.9	0.5	3	3.9
	RARITAN RIVER BASIN				
01396500	SB Raritan River at High Bridge	65.3	1.7	1	2.7
01397000	SB Raritan River at Stanton	147	0.8	1	6.3
01398000	Neshanic River at Reaville	25.7	0.1	2	4.7
01399500	Lamington River near Pottersville	32.8	4.8	2	3.4
01400000	NB Raritan River near Raritan	190	1.0	2	5.1
01400500	Raritan River at Manville	490	0.7	2	8.3
01401000	Stony Brook at Princeton	44.5	0.2	2	8.3
01401500	Millstone River near Kingston	171	2.6	2	4.6
01402000	Millstone River at Blackwells Mills	258	1.9	2	6.5
01403000	Raritan River at Bound Brook	779	1.1	2	9.3
01406000	Deep Run near Browntown	8.07	0.1	3*	5.4
01406500	Tennant Brook near Browntown	5.25	9.9	3*	2.0

Table 2.--Summary of gaging-station data and depth of 100-year flood--Continued

Gaging station no.	Station name	Drainage area (square miles)	Area of lakes and swamps (percent)	Hydro-logic area	Depth of 100-yr flood above 2.33-yr flood stage (feet)
	MANASQUAN RIVER BASIN				
01408000	Manasquan River at Squankum	43.4	1.2	3*	5.5
	TOMS RIVER BASIN				
01408500	Toms River near Toms River	124	13.6	3*	4.5
	CEDAR CREEK BASIN				
01409000	Cedar Brook at Lanoka Harbor	56.0	12.3	3*	1.3
	MULLICA RIVER BASIN				
01409500	Batsto River near Batsto	70.5	12.9	3*	5.5
01410000	Oswego River at Harrisville	64.0	14.8	3*	4.8
	GREAT EGG HARBOR RIVER BASIN				
01411000	Great Egg Harbor River at Folsom	56.3	13.9	4*	3.5
	MAURICE RIVER BASIN				
01411500	Maurice River at Norma	113	8.9	4*	3.9
01412000	Manantico Creek near Millville	22.3	7.2	4*	3.9

Table 2.--Summary of gaging-station data and depth of 100-year flood--Continued

Gaging station no.	Station name	Drainage area (square miles)	Area of lakes and swamps (percent)	Hydro-logic area	Depth of 100-yr flood above 2.33-yr flood stage (feet)
	DELAWARE RIVER BASIN				
01440000	Flat Brook at Flatbrookville	65.1	1.5	1	5.7
01443500	Paulins Kill at Blairstown	126	5.9	1	4.2
01445500	Pequest River at Pequest	108	5.0	1	2.5
01446000	Beaver Brook at Belvidere	36.2	3.0	1	2.0
01457000	Musconetcong River near Bloomsbury	143	5.1	1	3.3
01464000	Assunpink Creek at Trenton	89.4	2.6	2	6.2
01464500	Crosswicks Creek at Extonville	83.6	7.8	3*	7.0
01467000	NB Rancocas Creek at Pemberton	111	14.0	3*	5.2

*Station in Coastal Plain of New Jersey

SUMMARY

Equations are presented relating the 100-year flood depth above the mean annual flood to drainage area and area of lakes and swamps. Estimates of the 100-year flood depth can be made for sites on most New Jersey streams using the equations or graphs presented in this report. The 100-year flood depth is referenced above bankfull stage (mean annual flood) to facilitate using the technique for delineating flood-prone areas on topographic maps. Estimates using the procedures outlined in this report are suitable only for approximate studies in low-risk areas. More detailed studies should be used where loss of life, threat of injury, or moderate property damage is involved.

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