FLOOD MAGNITUDE AND FREQUENCY OF POCHACK CREEK AT TWO SITES, AT PENNSAUKEN TOWNSHIP, NEW JERSEY

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CONVERSION FACTORS

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot per mile (ft/mi)	0.189	meter per kilometer
inch per hour (in/hr)	25.4	millimeter per hour
cubic foot per second (ft^3/s)	0.028	cubic meter per second

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ABSTRACT

Six methods were used to estimate the magnitude and frequency of floods at Pochack Creek at the downstream end of the culvert on United States Route 130 and at a second site about 1,600 feet upstream at Pennsauken Township, New Jersey. Flood magnitude and frequency calculated by the six methods, as well as drainage-basin characteristics, are included in this report. The 100-year-flood estimates for the culvert site range from 280 cubic feet per second to 2,600 cubic feet per second. The 100-year-flood estimates for the upstream site range from 216 cubic feet per second to 1,800 cubic feet per second. Flood magnitude and frequency estimates obtained by using the New Jersey Department of Environmental Protection Special Report 38 method fall within the range of values estimated by using the U.S. Geological Survey transfer method with data collected from three nearby crest-stage gages.

INTRODUCTION

Information on the magnitude and frequency of floods is critical to the planning and design of highway culverts and bridges. Such information is not available for many stream crossings in New Jersey. To fulfill this information need, the U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Transportation, began an analysis of flood data from stream-crossing sites on New Jersey streams. This report presents results of the analysis for Pochack Creek at the downstream end of the culvert on U.S. Route 130 (site A) and at a second site about 1,600 feet upstream (site B), at Pennsauken Township, N.J. The culvert is located about 600 feet southwest of the intersection of U.S. Route 130 and Westfield Avenue (fig. 1). The drainage area upstream from site A is 1.10 mi^2. The drainage area upstream from site B is 0.78 mi^2. A field reconnaissance was performed on April 30, 1993, to verify the locations of the drainage divides and land use. Because the direction of storm-sewer drainage in some parts of the basin is uncertain, the calculated drainage area is approximate.

The flooding problem in this area has been depicted in newspaper articles. According to a report in a local newspaper (Courier-Post Newspaper, 1993), 1 inch of rain fell during 4 hours, causing minor flooding that closed U.S. Route 130 for several hours. Another article (Courier-Post Newspaper, 1989) reported that 1 inch of rain fell during about 1 hour, temporarily closing parts of U.S. Route 130. It is unclear whether Pochack Creek, specifically, experienced flooding. The recurrence interval and discharge of these floods are undetermined.

The flood-insurance study for Pennsauken Township (Federal Emergency Management Agency, 1976) did not include a detailed study of this stream; therefore flood discharges were not determined previously.

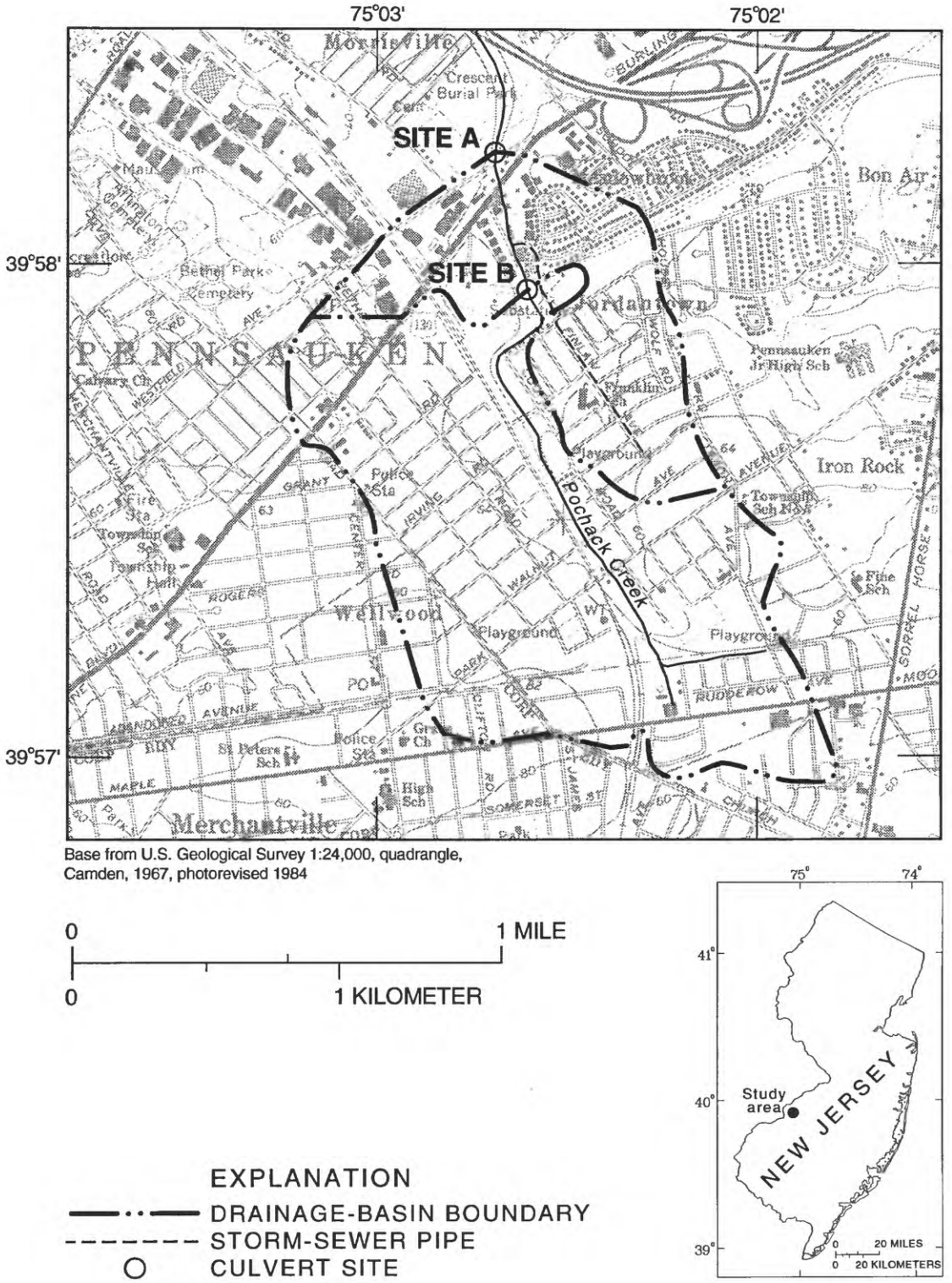

Figure 1. Location of Pochack Creek at the downstream end of the culvert on United States Route 130 (site A), and at a site 1,600 feet upstream from the culvert on United States Route 130 (site B), at Pennsuaken Township, New Jersey

METHODS USED TO ESTIMATE FLOOD MAGNITUDE AND FREQUENCY

Various methods for estimating flood magnitude and frequency were used to determine the flood magnitudes that are likely to be exceeded at this site within a given number of years (recurrence interval). The methods used include the rational method (Chow and others, 1988), New Jersey Department of Environmental Protection (NJDEP) Special Report 38 method (Stankowski, 1974), USGS index-flood method (Thomas, 1964), USGS transfer method (N.J. Department of Environmental Protection and Energy, 1993), U.S. Soil Conservation Service (SCS) Technical Release 55 (TR-55) method (U.S. Soil Conservation Service, 1986), and the U.S. Army Hydrologic Engineering Center (HEC) Special Projects Memo 480 method (U.S. Army Corps of Engineers, 1977).

Data and computations used in this study can be obtained from the U.S. Geological Survey, 810 Bear Tavern Road, Suite 206, West Trenton, NJ 08628.

Rational Method

The rational method is based on the concept that if a rainfall of a particular intensity begins instantaneously and continues indefinitely across a watershed, the runoff rate will increase until the time of concentration is reached, which is the time when the entire watershed is contributing to the flow at the outlet (Chow and others, 1988). The time of concentration (the time needed for water to travel from the farthest point in the watershed to the outlet) is computed by summing the travel times for consecutive components of a drainage system (U.S. Soil Conservation Service, 1986). Many factors, including channel shape, surface roughness, and slope, affect the time of concentration.

The equation that expresses this method is:

$$Q = CiA,$$

where Q is the rate of peak discharge at the time of concentration, in cubic feet per second; i is the rainfall intensity, in inches per hour; A is the watershed area, in acres; and C is the runoff coefficient. The runoff coefficient depends on various watershed characteristics, including the composition and condition of the soil, the type and condition of land use, and the percent imperviousness of the watershed. Appropriate runoff-coefficient values based on these watershed characteristics were chosen from a table (N.J. Department of Environmental Protection, 1993). This method is recommended for the calculation of peak discharges in homogeneous drainage areas up to 0.5 mi^2 in size (N.J. Department of Environmental Protection, 1993).

Special Report 38 Method (New Jersey Department of Environmental Protection)

This method consists of the development and use of a set of regression equations for the 2-, 5-, 10-, 25-, 50-, and 100-year floods based on the watershed characteristics drainage area, basin storage (percent area of lakes and swamps, plus 1.0 percent in order to avoid zero values), and impervious cover (based on population density). This method is recommended for use in drainage areas of 1 to 1,000 mi^2 (Stankowski, 1974).

Index-Flood Method (U.S. Geological Survey)

Flood estimates are made with this method by using two graphical curves. One curve expresses the relation between the mean annual flood and the size of the drainage basin; the other expresses the ratio between the mean annual flood and floods of other recurrence intervals. The mean annual flood is adjusted on the basis of the percentage of lakes and swamps in the drainage basin. This method is recommended for drainage areas greater than 4 mi^2 and is most accurate for drainage areas of 10 to 200 mi^2 (Thomas, 1964).

Technical Release 55 Graphical Peak Discharge Method (U.S. Soil Conservation Service)

For this method, an SCS curve number, which represents the overall soil type, land use, and antecedent soil-moisture conditions, is determined for the basin. This curve number is used to account for the initial abstraction and infiltration losses. Other required input parameters are the 24-hour rainfall associated with the desired frequency, the drainage-basin area, and the time of concentration (total travel time). The time of concentration for a basin is determined by using a set of equations describing the travel time for the overland- flow or sheet-flow segment, the shallow-concentrated-flow segment, and the open-channel-flow segment. The time of concentration is the sum of the ratios of flow length to flow velocity for each segment. This value depends on the surface type, hydraulic radius, cross-sectional-flow area, wetted perimeter, land slope, channel slope, and Manning's roughness coefficient. This method is recommended for drainage areas of less than 5 mi^2 (U.S. Soil Conservation Service, 1986).

Special Projects Memo 480 Method (U.S. Army Hydrologic Engineering Center)

This method is based on multiple-regression equations for the mean, standard deviation and skewness of the logarithms of the annual peak flows at 58 long-record streamflow-gaging stations; the equations are based on three watershed characteristics (drainage area, main channel slope, and forest cover). An adjustment is made by estimating a generalized skew coefficient based on the log-Pearson Type III distribution (Interagency Advisory Committee on Water Data, 1982). This method is recommended for use for drainage areas of 10 to 300 mi^2 (U.S. Army Corps of Engineers, 1977).

Transfer Method (U.S. Geological Survey)

The relation that is used to calculate flood estimates is based on a ratio of drainage areas raised to an exponent:

$$\frac{Q_{PI}}{Q_{PG}} = \left(\frac{A_{PI}}{A_{PG}}\right)^{0.75}$$

where Q_{PI} is the design flood at the point of interest, Q_{PG} is the design flood at the gaged point, A_{PI} is the drainage area at the point of interest, and A_{PG} is the drainage area at the gaged

point. An exponent of 0.75 is used; the exponent is based on studies of 10-year recurrence interval floods in New Jersey (New Jersey Department of Environmental Protection and Energy, 1993). This method is recommended for drainage areas that are either less than twice or more than half the drainage area of the gaged point (New Jersey Department of Environmental Protection and Energy, 1993).

COMPARISON OF RESULTS

The explanatory variables used in applying the methods described above at site A and site B are listed in tables 1 and 2, respectively. The flood-magnitude and -frequency estimates for the sites were obtained by using each of the various methods and are shown in tables 3 and 4. The range in the estimates is large; estimates of the 100-year flood discharge at site A range from 280 to 2,600 ft^3/s, and the estimates of the 100-year flood discharge at site B range from 216 to 1,800 ft^3/s.

Flood data from nearby streamflow-gaging or crest-stage gaging stations provide a good indication of the flood magnitude and frequency that can be expected at an ungaged site, particularly if drainage area and other basin characteristics are similar and the record length is sufficiently large. The estimates developed by using the various methods are compared with discharge data that have been transferred to the culvert sites by using the USGS transfer method.

In New Jersey, for streams that drain areas between 1 and 5 mi^2, the NJDEP Special Report 38 method or the TR-55 method are the most frequently used (New Jersey Department of Environmental Protection and Energy, 1993). The drainage area of site A falls within these limits. The discharge values estimated by using the TR-55 method, as well as the rational method and the HEC Special Project Memo 480 method, are much greater than the values estimated by using the USGS transfer method with data collected from three nearby crest-stage gages (stations 01467057, 01467305, and 01467317; Bauersfeld and others, 1993). The discharge values estimated by using the NJDEP Special Report 38 method fall within the range of peak discharges estimated by using the USGS transfer method.

For streams draining areas between 0.5 and 1 mi^2, the TR-55 method is the most frequently used (New Jersey Department of Environmental Protection and Energy, 1993). The drainage area of site B falls within this limit. The discharge values estimated by using the TR-55 method range from 2 to 7 times the values estimated by using the USGS transfer method with data collected from the three nearby crest-stage gages. Newton and Herrin (1982) summarized a U.S. Water Resources Council report on estimating flood magnitude and frequency for ungaged sites by using various methods and concluded that the TR-55 method tends to overestimate flood magnitudes. The drainage area of site B falls just outside the recommended range for using the NJDEP Special Report 38 method; however, results estimated by using the NJDEP Special Report 38 method fall within the range of values estimated by using the USGS transfer method with data collected from the three nearby crest-stage gages.

The drainage areas of both sites are outside the recommended ranges for using the USGS index-flood method (Thomas, 1964) and the HEC Special Project Memo 480 method (U.S. Army Corps of Engineers, 1977). The rational method is not recommended by the New Jersey Department of Environmental Protection and Energy (1993) for sites with these drainage areas. The use of the NJDEP Special Report 38 method seems to be appropriate for both sites.

Table 1. Explanatory variables for the flood-magnitude and -frequency methods, Pochack Creek at the downstream end of the culvert on United States Route 130 (site A), Pennsauken Township, New Jersey

Drainage area: 1.10 square miles
Latitude: 39°58'14"
Longitude: 75°02'41"
Highway: United States Route 130
U.S.Geological Survey 7-1/2-minute Quadrangle: Camden

Variable	Value	Unit
Drainage area	= 1.10	square miles
Main channel slope	= 26.4	feet per mile
Total stream length	= 1.36	miles
Surface storage index	= 1.0	percent
Population density (1990)	= 3,508	persons per square mile
Impervious cover	= 24.4	percent
Forest cover	= 2.0	percent
Regional skew coefficient[1]	= 0.3	
Lake and swamp area	= 0.0	percent
Hydrologic area[2]	= 3	
Flood-frequency region[2]	= C	
Rational method runoff coefficient[3]	= 0.60	
Runoff curve number[4]	= 85	
Time of concentration[4]	= 0.87	hours
2-year, 24-hour rainfall[5]	= 3.30	inches
5-year, 24-hour rainfall	= 4.40	inches
10-year, 24-hour rainfall	= 5.20	inches
25-year, 24-hour rainfall	= 5.90	inches
50-year, 24-hour rainfall	= 6.60	inches
100-year, 24-hour rainfall	= 7.30	inches
2-year rainfall intensity[6]	= 1.58	inches per hour
5-year rainfall intensity	= 1.99	inches per hour
10-year rainfall intensity	= 2.28	inches per hour
25-year rainfall intensity	= 2.69	inches per hour
50-year rainfall intensity	= 3.01	inches per hour
100-year rainfall intensity	= 3.33	inches per hour

[1]From U.S. Army Corps of Engineers, 1977
[2]From Thomas, 1964
[3]From New Jersey Department of Environmental Protection and Energy, 1993
[4]From U.S. Soil Conservation Service, 1986
[5]All rainfall values from Hershfield, 1961
[6]All rainfall intensity values from Frederick and others, 1977

Table 2. Explanatory variables for the flood-magnitude and -frequency methods, Pochack Creek, 1,600 feet upstream from the culvert on United States Route 130 (site B), Pennsauken Township, New Jersey

Drainage area: 0.78 square miles
Latitude: 39°57'57"
Longitude: 75°02'35"
U.S.Geological Survey 7-1/2-minute Quadrangle: Camden

Variable	Value	Unit
Drainage area	= 0.78	square miles
Main channel slope	= 34.2	feet per mile
Total stream length	= 1.06	miles
Surface storage index	= 1.0	percent
Population density (1990)	= 3,597	persons per square mile
Impervious cover	= 24.6	percent
Forest cover	= 2.5	percent
Regional skew coefficient[1]	= 0.3	
Lake and swamp area	= 0.0	percent
Hydrologic area[2]	= 3	
Flood-frequency region[2]	= C	
Rational method runoff coefficient[3]	= 0.57	
Runoff curve number[4]	= 85	
Time of concentration[4]	= 0.77	hours
2-year, 24-hour rainfall[5]	= 3.30	inches
5-year, 24-hour rainfall	= 4.40	inches
10-year, 24-hour rainfall	= 5.20	inches
25-year, 24-hour rainfall	= 5.90	inches
50-year, 24-hour rainfall	= 6.60	inches
100-year, 24-hour rainfall	= 7.30	inches
2-year rainfall intensity[6]	= 1.91	inches per hour
5-year rainfall intensity	= 2.40	inches per hour
10-year rainfall intensity	= 2.74	inches per hour
25-year rainfall intensity	= 3.24	inches per hour
50-year rainfall intensity	= 3.62	inches per hour
100-year rainfall intensity	= 4.00	inches per hour

[1]From U.S. Army Corps of Engineers, 1977
[2]From Thomas, 1964
[3]From New Jersey Department of Environmental Protection, 1988
[4]From U.S. Soil Conservation Service, 1986
[5]All rainfall values from Hershfield, 1961
[6]All rainfall intensity values from Frederick and others, 1977

Table 3. Estimates of flood magnitude for selected flood frequencies, Pochack Creek at the downstream end of the culvert on United States Route 130 (site A), Pennsauken Township, New Jersey

[Q, flood-magnitude estimates in cubic feet per second along with number, indicating the frequency of the recurrance interval in years; DA, drainage area, in square miles; S, main-channel slope, in feet per mile; St, surface storage index, in percent; I, index of manmade impervious cover, in percent of drainage area; YR, years of record; D, distance from station used in USGS transfer method from flood site; NJDEP, New Jersey Department of Environmental Protection; NJDEPE, New Jersey Department of Environmental Protection and Energy; USGS, U.S. Geological Survey; SCS, Soil Conservation Service; HEC, Hydrologic Engineering Center; SPM, Special Projects Memo; TR, Technical Release; SR, Special Report; --, not applicable]

Drainage area: 1.10 square miles
Latitude: 39°58'14"
Longitude: 75°02'41"
Highway: United States Route 130
U.S.Geological Survey 7-1/2-minute Quadrangle: Camden

Estimating method	Q2	Q5	Q10	Q25	Q50	Q100	DA	S	St	I	Yr	D
Rational method	667	840	963	1,140	1,270	1,410	--	--	--	--	--	--
NJDEP SR 38[1,2]	140	204	269	365	440	540	1.10	26.4	1.0	24.4	--	--
USGS index method	79	131	169	221	268	322	--	--	--	--	--	--
SCS TR-55[2]	484	745	939	1,110	1,290	1,470	--	--	--	--	--	--
HEC SPM 480	382	729	1,050	1,560	2,030	2,600	--	--	--	--	--	--
USGS transfer method												
Station 01467057[2]	162	253	323	424	507	597	5.77	12.3	1.0	15.2	14	4.6
Station 01467305[2]	150	183	206	234	256	280	1.34	48.8	1.4	33.0	26	4.3
Station 01467317[2]	68	141	214	343	473	637	.63	57.5	1.0	38.0	27	6.4

[1] This method recommended by Stankowski (1974) for a drainage basin of this size
[2] This method recommended by NJDEPE (1993) for a drainage basin of this size

Table 4. Estimates of flood magnitude for selected flood frequencies, Pochack Creek, 1,600 feet upstream from the culvert on United States Route 130 (site B), Pennsauken Township, New Jersey

[Q, flood-magnitude estimates in cubic feet per second along with number, indicating the frequency of the recurrance interval in years; DA, drainage area, in square miles; S, main-channel slope, in feet per mile; St, surface storage index, in percent; I, index of manmade impervious cover, in percent of drainage area; YR, years of record; D, distance from station used in USGS transfer method from flood site; NJDEP, New Jersey Department of Environmental Protection; NJDEPE, New Jersey Department of Environmental Protection and Energy; USGS, U.S. Geological Survey; SCS, Soil Conservation Service; HEC, Hydrologic Engineering Center; SPM, Special Projects Memo; TR, Technical Release; SR, Special Report; --, not applicable]

Drainage area: 0.78 square miles
Latitude: 39°58'14"
Longitude: 75°02'41"
Highway: United States Route 130
U.S.Geological Survey 7-1/2-minute Quadrangle: Camden

Estimating method	Q2	Q5	Q10	Q25	Q50	Q100	DA	S	St	I	Yr	D
Rational method	543	682	779	921	1,030	1,140	--	--	--	--	--	--
NJDEP SR 38	111	162	214	292	352	433	0.78	34.2	1.0	24.6	--	--
USGS index method	60	99	128	168	203	244	--	--	--	--	--	--
SCS TR-55[1]	484	745	939	1,110	1,290	1,470	--	--	--	--	--	--
HEC SPM 480	252	489	706	1,060	1,400	1,800	--	--	--	--	--	--
USGS transfer method												
Station 01467057	125	195	249	327	392	461	5.77	12.3	1.0	15.2	14	4.6
Station 01467305[1]	116	141	159	181	198	216	1.34	48.8	1.4	33.0	26	4.3
Station 01467317[1]	52	109	165	265	366	492	0.63	57.5	1.0	38.0	27	6.4

[1] This method recommended by NJDEPE (1993) for a drainage basin of this size

SELECTED REFERENCES

Bauersfeld, W.R., Moshinsky, E.W., and Gurney, C.E., 1993, Water resources data, New Jersey, water year 1992, Volume 1. Surface-water data: U.S. Geological Survey Water Data Report NJ-92-1, 507 p.

Chow, V.T., Maidment, D.R., and Mays, L.W., 1988, Applied hydrology: New York, McGraw-Hill Book Co., 572 p.

Courier-Post Newspaper, 1989, Strong wind, rain knock out power, flood area roads: Cherry Hill, New Jersey, Courier-Post Newspaper, October 21, 1989.

Courier-Post Newspaper, 1993, Storm drenches region: Cherry Hill, New Jersey, Courier-Post Newspaper, April 17, 1993.

Federal Emergency Management Agency, 1976, Flood insurance study of the Township of Pennsauken, Camden County, New Jersey: Federal Emergency Management Agency, October 1976, 19 p.

Frederick, R.H., Myers, V.A., and Auciello, E.P., June 1977, Five- to 60-minute precipitation frequency for the eastern and central United States: National Oceanic and Atmospheric Administration Technical Memorandum NWS HYDRO-35, Silver Spring, Md., 36 p.

Hershfield, D.M., 1961, Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years: U.S. Weather Bureau Technical Paper No. 40, Washington, D.C., 115 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: Bulletin 17B of the Hydrology Subcommittee, Office of Water Data Coordination, U.S. Geological Survey, Reston, Va., 183 p.

New Jersey Department of Environmental Protection and Energy, 1993, Technical manual for stream encroachment permits: New Jersey Department of Environmental Protection and Energy, 100 p., 6 app.

Newton, D.W., and Herrin, J.C., 1982, Assessment of commonly used methods of estimating flood frequency: Transportation Research Record 896, Transportation Research Board, Washington, D.C., p. 10-30.

Stankowski, S.J., 1974, Magnitude and frequency of floods in New Jersey with effects of urbanization: New Jersey Department of Environmental Protection, Special Report 38, 46 p.

Thomas, D.M., 1964, Floods in New Jersey, magnitude and frequency: New Jersey Department of Conservation and Economic Development, Water Resources Circular 13, 145 p.

Tice, R.H., 1968, Magnitude and frequency of floods in the United States. Part 1-B. North Atlantic slope basins, New York to York River: U.S. Geological Survey Water-Supply Paper 1672, 585 p.

SELECTED REFERENCES--Continued

U.S. Army Corps of Engineers, 1977, Generalized skew study for the State of New Jersey: U.S. Army Corps of Engineers, Hydrologic Engineering Center, Special Projects Memo 480, 43 p., 3 app.

U.S. Soil Conservation Service, 1966, Soil survey, Camden County, New Jersey: Washington, D.C., U.S. Soil Conservation Service, 94 p.

U.S. Soil Conservation Service, 1986, Urban hydrology for small watersheds: Engineering Division Technical Release 55, Washington, D.C., 162 p.