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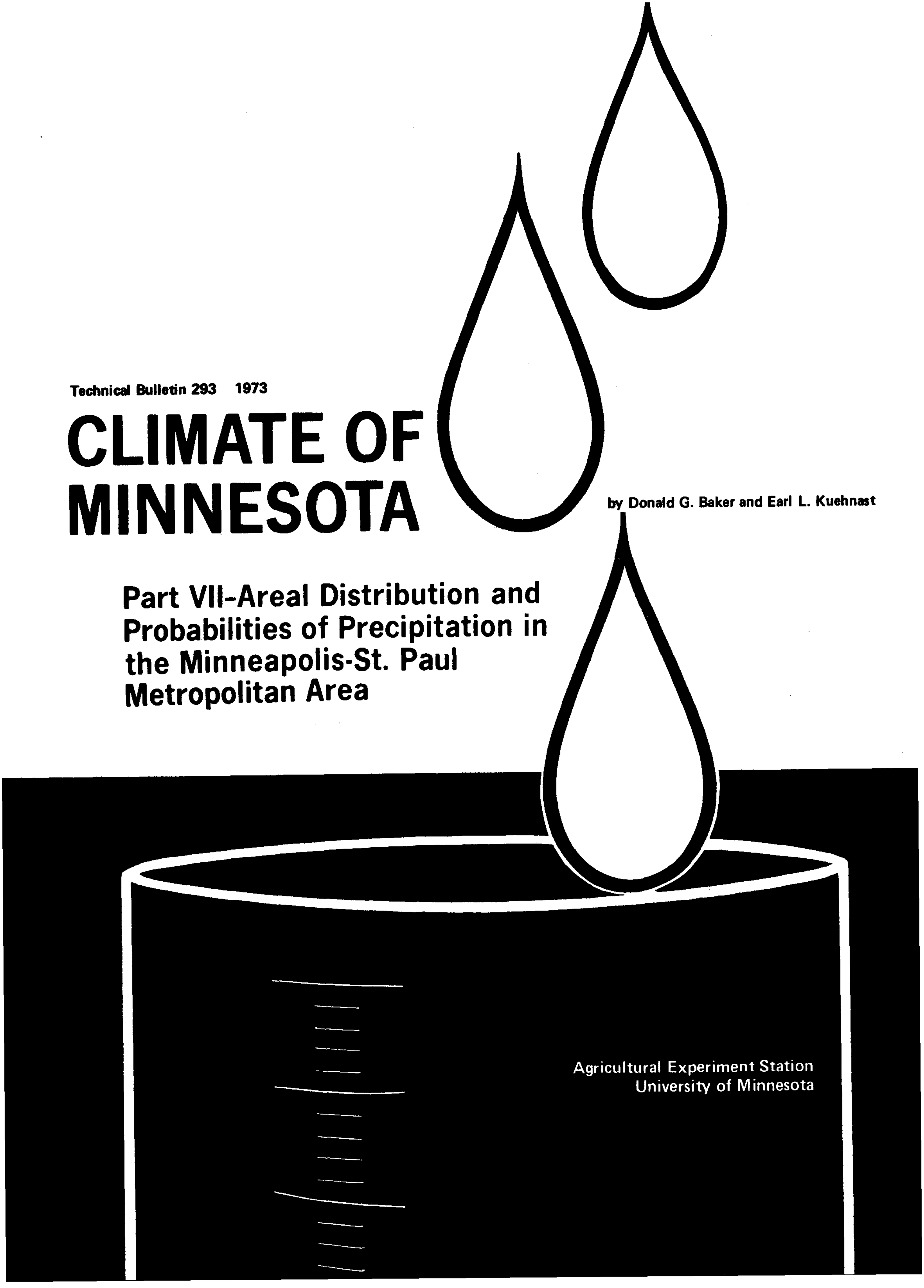
by Donald G. Baker and Earl L. Kuehnast

Part VII-Areal Distribution and Probabilities of Precipitation in the Minneapolis-St. Paul Metropolitan Area



Agricultural Experiment Station
University of Minnesota

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Donald G. Baker is a professor, Department of Soil Science, University of Minnesota, and Earl L. Kuehnast is State Climatologist for Minnesota, National Weather Service.

INTRODUCTION

Spatial precipitation variation can be great within limited areas of uniform topography, but is seldom measured because rain gage networks ordinarily are not extensive. This is accentuated in summer when localized convective showers are most common.

Several questions arise about the degree of variation possible in small areas: (a) how well can a single rain gage represent the area, (b) how many gages are required for adequate sampling, (c) what is the expected areal extent of given amounts of precipitation within the defined area, and (d) how great a precipitation variation may be expected within the defined area.

These are important when applied to urban areas. For example, precipitation in an urban area may be of immediate consequence since a large share is lost at once as runoff. As a result, urban drainage engineering designs require accurate precipitation data.

The primary objective of this bulletin is to answer these questions for the Minneapolis-St. Paul (Twin Cities) metropolitan area. The results of this study are based upon a dense precipitation network which has been in existence for several years. A secondary objective is to determine the occurrence probability of various amounts of precipitation in the metropolitan area and to compare these probabilities with those at the National Weather Service[1] airport station.

Results obtained in this study may be applicable to other parts of Minnesota as well, since precipitation characteristics probably do not differ greatly in the state.

The impetus for this study came from two sources—the realization that much more detailed precipitation information than that presently available is required for various engineering projects and basic resources studies; and a memorandum by Hughes (8) suggesting that an "Areal Coverage of Precipitation" project be initiated at each of the first order weather stations in the central region.

MATERIALS AND METHODS

The Twin Cities metropolitan area was defined as a 30-mile radius extending outward from the Minneapolis-St. Paul International Airport where the National Weather Service forecasting station is located (figure 1). Twenty-four other precipitation recording stations within the area were selected. This area equals about 3000 square miles[2]. This network with a concentration of about 0.88 stations per 100 square miles is much superior to the state average of about 0.22 stations per 100 square miles (1). However, it is exceeded by certain other networks (6).

Stations chosen had the same observing time and complete daily records (with a few exceptions) of rainfall from May-September for the 5-year period 1964-1968. A standard observation time was necessary to have a uniform "precipitation day." The standard observation time selected was 7 a.m. to give the most stations for the analysis.

[1]The National Weather Service replaced the Weather Bureau as an entity by executive order on October 3, 1970.

[2] The exact area is 2826 square miles. However, the staions within the 30-mile radius are not ideally located. For this reason a rigorously defined area is deceiving.

Nine of the stations selected were part of the National Weather Service cooperative network. The remainder cooperated in the weather observation network established by the Metropolitan Mosquito Commission. The 25 station locations are shown in figure 1 with additional details for each station listed in table 1. Station elevations range from a minimum of 695 feet along the Mississippi River at Hastings to an estimated 1110 feet above mean sea level at New Market.

It was assumed that precipitation probability was equal throughout the Twin Cities. This is also assumed by a meteorologist when making a forecast for the area. However, the frequency of rain days in the Twin Cities was found to range from 25.6 percent at New Prague to a maximum of 39.6 percent at St. Louis Park for amounts of 0.01 inch or greater. For amounts of 0.10 inch or greater, the frequency varied from 20.1 percent to 25.8 percent (figure 1). An investigation beyond the scope of this study would be required to determine if these variations were physically significant, a factor of the short record period, or due to other undetermined factors. Spatial variations in the frequency of rain days were also found by Beebe for the Atlanta and Birmingham areas (2).

DISCUSSION

1. Number of Rain Gages Required for an Adequate Sample

The precipitation frequencies of certain amounts at the centrally located airport station were calculated and plotted. The frequencies were determined for the airport station plus four other stations. Each one of the four was selected to represent one quarter of the circular area surrounding the airport. This was repeated for nine stations, then 18 stations, and finally all 25 stations.

Results of these precipitation frequency calculations at a 1-, 5-, 9-, 18-, and 25-gage network for each month from May through September plus the full 5-month season are shown in figures 2-7. These figures demonstrate that a single gage anywhere within this area inadequately represents the rainfall frequency. Table 2 emphasizes the discrepancy between a 25-gage and single-gage network and lists the difference in precipitation frequencies between the two networks. A forecaster dependent only upon information from the single gage at the airport station would seriously underestimate the precipitation frequency even in his immediate forecast area.

Observers at the airport site are required to take four precipitation measurements per day while all other observers normally take only one measurement per day. There is, therefore, a greater likelihood that the airport site will record a greater number of small precipitation amounts. This is common at stations where precipitation is measured more frequently than once a day and thus less subject to evaporation losses (5). This would be apparent in table 2 were it not for the nonuniform increments of precipitation used.

The precipitation ranges used in this study are similar to those commonly used by the National Weather Service in various climatological studies (12) and were used for this reason. The nonuniformity of the ranges can be deceiving when frequencies are considered. With rainfall measured to the nearest 0.01 inch, the reader should keep in mind that there are only

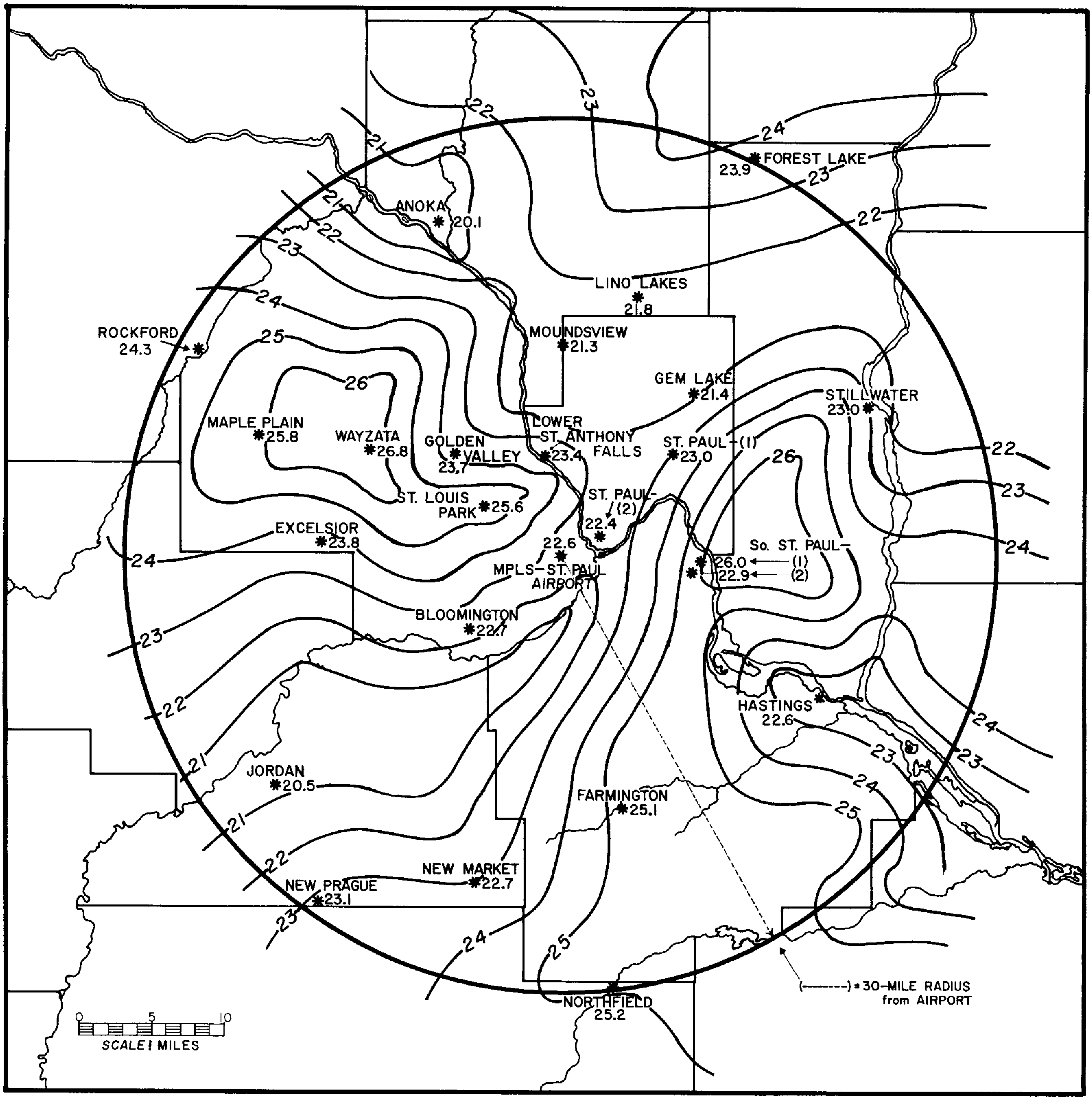

Figure 1. Location of the 25 precipitation observing stations in the metropolitan area. This figure also shows the percent frequency that days with 0.10 inch or greater precipitation were observed in the May-September period, 1964-1968.

Table 1. Addresses and names of observers at the 25 metropolitan area precipitation stations.

Station Name	Altitude[1]	Address	Name of Observer
1. Anoka	E870	11949 Crooked Lake Blvd.	M. Bodine
2. Bloomington	E870	10542 Vessey Rd.	J. Linton
3. Excelsior	940	Sewage Treatment Plant	E. M. Hafner C. Zieman
4. Farmington	E900	Spruce St.	R. E. Rademacher
5. Forest Lake	940	No. Shore Dr.	V. Loren
6. Gem Lake	E930	U.S. Highway 61-Co. Rd. E	C. D. Barnum
7. Golden Valley	915	7800 Golden Valley Rd.	J. Westlake
8. Hastings	695	U. S. Corps of Engineers Lock No. 2	J. L. Brewer Lockmaster
9. Jordan	E780	Hdqtrs., Scott County Mosquito Headquarters Control	
10. Lino Lakes	E900	441 Birch St.	J. Speiser
11. Lower St. Anthony Falls	755	U. S. Corps of Engineers Lock No. 1	M. G. Pratt
12. Maple Plain	970	Residence	D. McKown, R. Rhuby
13. Minneapolis - St. Paul Airport	834	FAA Bldg., 6301-34th Ave. S., Mpls.	National Weather Service
14. Mounds View	E900	1801 County Rd. H	C. D. Barnum
15. New Market	E1110	Webster St.	R. Simon
16. New Prague	E1000	405 Lincoln Ave.	E. P. Wermerskirchen
17. Northfield	890	Goodsell Observatory Carleton College	Prof. Matthews
18. Rockford	E940	Residence	H. M. Thompson
19. St. Louis Park	E900	4510 W. 36th St.	K. Shoberg
20. St. Paul (1)	920	707 Montana St.	J. Riddell
21. St. Paul (2)	E940	1709 Rome Ave.	A. W. Buzicky
22. So. St. Paul (1)	E820	649-6th Ave. So.	R. Neary
23. So. St. Paul (2)	750	Water Works Pumping Station No. 4	H. Weimer
24. Stillwater	710	Sewage Treatment Plant	J. Schelton
25. Wayzata	E990	Highway 101-12th Ave. N.	C. Martin

[1]Altitude in feet above mean sea level; E indicates that the altitude was estimated from U.S. Geological Survey topographic sheets.

Table 2. The difference in the average number of precipitation days per month and season for given amounts of precipitation between the 25-gage network and the single-gage at the Minneapolis-St. Paul International Airport, May-September, 1964-1968.[1]

	Months					
Amount (in)	May	June	July	August	September	Season (May-Sept.)
$\geq$0.01	8.6	6.8	10.4	10.6	7.6	44.0
$\geq$0.05	10.0	8.4	10.4	10.8	8.2	47.8
$\geq$0.10	10.8	8.6	9.6	9.6	7.8	46.4
$\geq$0.50	5.0	7.2	7.0	7.2	4.2	30.6
$\geq$1.00	2.6	5.2	4.6	3.2	4.0	19.6
$\geq$2.00	0.8	1.4	2.6	1.8	1.6	8.2

[1]All values are positive; that is, the rain days observed in the 25-gage network were greater in every case than observed at the single gage.

and an adequate or acceptable sample might be about 30 gages or about one gage per 100 square miles.

assumed for the "true" samples at Atlanta, Peoria, and the

[3] Huff has defined gage density as square miles per gage.