CHAPTER 1 - RAINFALL

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CHAPTER 1 - RAINFALL

Stream gauge measurements are rarely available for small watersheds although generalized rainfall data are normally available at all locations. The rainfall data may be local records or published data. Various federal and state agencies will often make field surveys after an unusually large storm to collect "bucket survey" data, which is measurements of rainfall caught in buckets, watering troughs, bottles, and similar containers. Ordinarily these data are used to give more detail to rainfall maps based on standard gauge data. Data from bucket surveys are generally not published but are available in the offices of the gathering agency. Many newspaper offices, banks, Future Farmers of America chapters, water treatment plants, and other local offices collect measurements at their own gauges and keep daily records.

Generally for Soil Conservation Service hydrologic studies, it is unnecessary to use actual rainfall data since published analyses of data provides the required information in a more usable form.

This chapter contains the rainfall maps from the following sources:

1. "Rainfall Frequency Atlas of the United States", U.S. Weather Bureau Technical Paper No. 40.

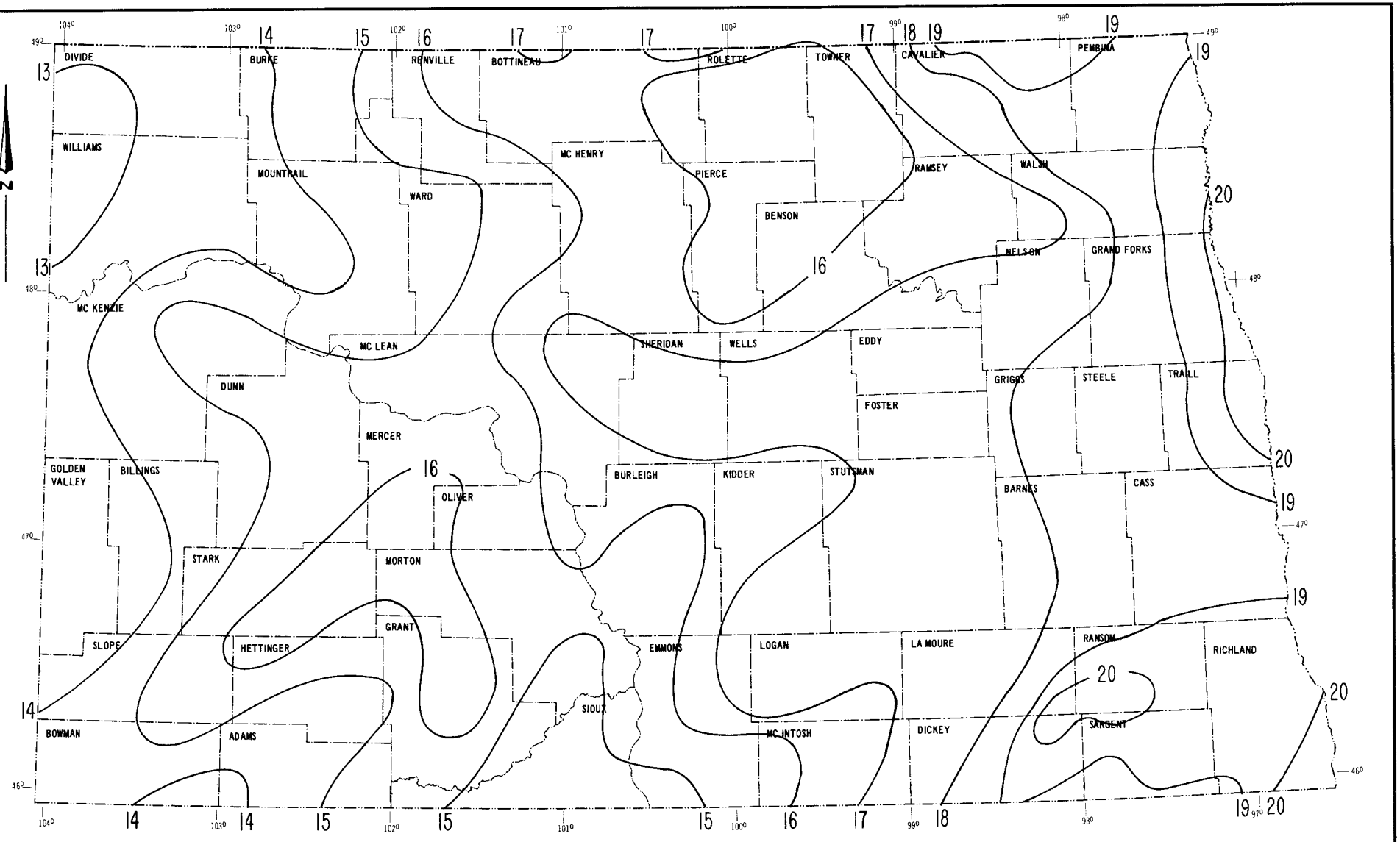
2. "Two to Ten-Day Precipitation for Return Periods of 2 to 100-Years in the Contiguous United States", U.S. Weather Bureau Technical Paper No. 49.

3. "Seasonal Variation of the Probable Maximum Precipitation East of the 105 Meridian for Areas from 10 to 100 Square Miles and Duration of 6, 12, 24 and 48 Hours", U.S. Weather Bureau and Corps of Engineers. Hydrometeorological Report 51. With adjustments by the National Weather Service in 1978.

4. "NOAA Technical Memo NWS HYDRO-35, Five (5)-to Sixty (60)-Minute Precipitation Frequency for Eastern and Central U.S.". Weather Service (NOAA), June 1977.

5. "Earth Dams and Reservoirs", Technical Release No. 60, Soil Conservation Service.

For a more detailed discussion of storm rainfall data, see Chapter 4 of Section 4, "Hydrology", National Engineering Handbook, Soil Conservation Service.



ANNUAL NORMAL PRECIPITATION IN INCHES

NORTH DAKOTA

REFERENCE:
U.S.W.B.

BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-1

TABLE 1-1 MINIMUM PRINCIPAL SPILLWAY HYDROLOGIC CRITERIA FOR DAMS DESIGNED IN ACCORDANCE WITH TECHNICAL RELEASE 60

(For Class (a) dams with a product of storage times the effective height of the dam of 3,000 or more; those more than 35 feet in effective height and all Class (b) and (c) dams.)

Class of Dam	Purpose of Dam	Product of Storage x Effective Height	Existing or Planned Upstream Dams	Precipitation Data for Maximum Frequency 1/ of Use of Emergency Spillway Types:	
				Earth	Vegetated
(a)	single 2/ irrigation only	less than 30,000	none	1/2 design life	1/2 design life
		greater than 30,000		3/4 design life	3/4 design life
	single or multiple 4/	less than 30,000	none	P_{50}	P_{25} 3/
		greater than 30,000		$1/2\ (P_{50} + P_{100})$	$1/2\ (P_{25} + P_{50})$
		all	any 5/	P_{100}	P_{50}
(b)	single or multiple	all	none or any	P_{100}	P_{50}
(c)	single or multiple	all	none or any	P_{100}	P_{100}

1/ Precipitation amounts by return periods in years. See 10-day runoff curve number (Table 3-2) when rainfall exceeds 6 inches. In some areas direct runoff amounts determined by figure 1-12 should be used in lieu of precipitation data. See page 1-23 for details.

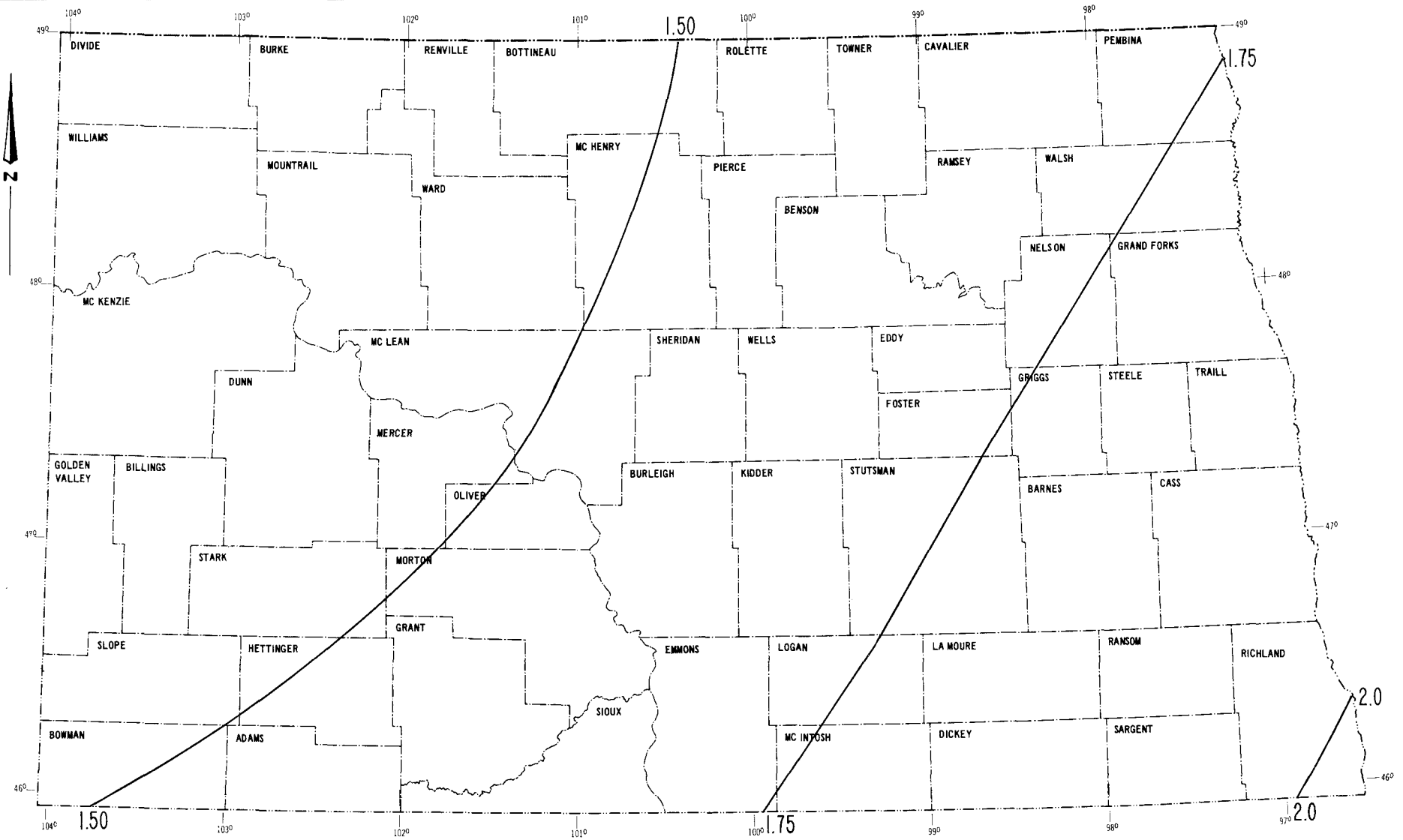
2/ Applies to irrigation dams on ephemeral stream in areas where the annual rainfall is less than 25 inches.

3/ The minimum criteria are to be increased from P_{25} to P_{100} for a ramp spillway.

4/ Class (a) dams involving industrial or municipal water are to be designed with a minimum cirteria equivalent to that of class (b).

5/ Applies when the upstream dam is located so that its failure could endanger the lower dam.

Reference: Technical Release No. 60



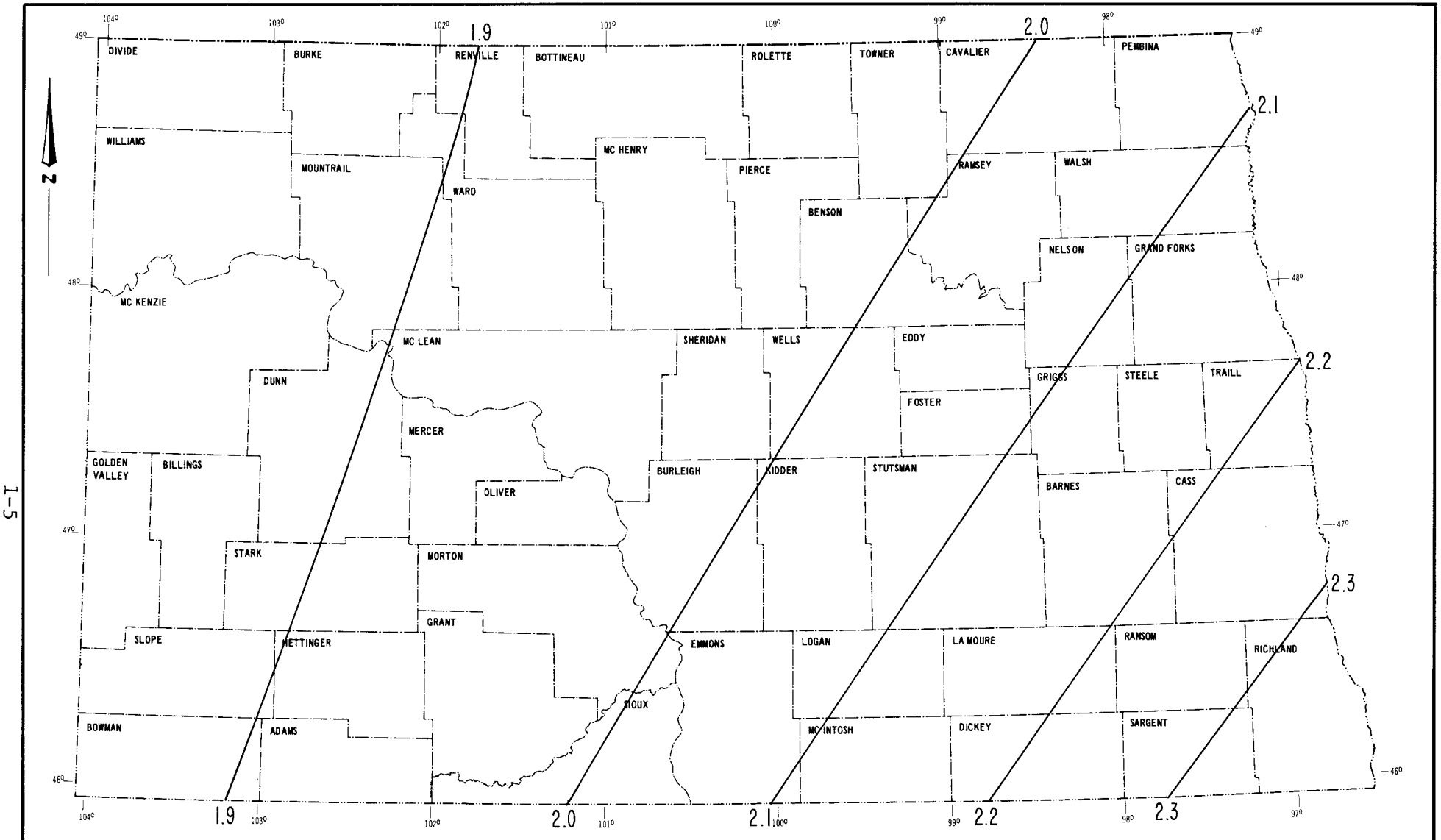
100% CHANCE (1-YEAR) 24-HOUR RAINFALL (INCHES)

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

REFERENCE:
U.S.W.B. T.P. – 40
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

FIGURE 1-2



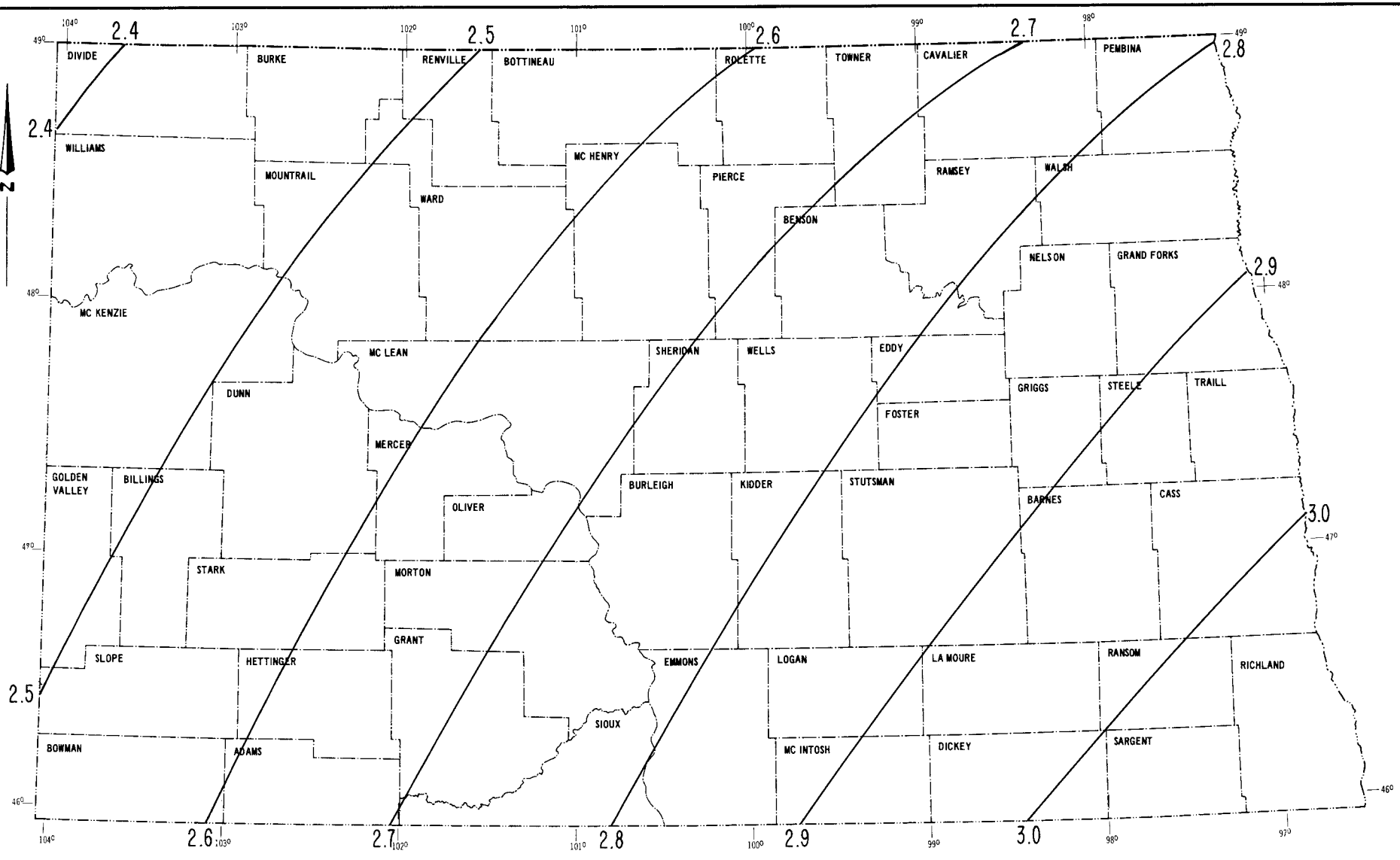
50% CHANCE (2-YEAR) 24-HOUR RAINFALL (INCHES)

NORTH DAKOTA

REFERENCE:
U.S.W.B. T.P. – 40
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-3



20% CHANCE (5–YEAR) 24–HOUR RAINFALL (INCHES)

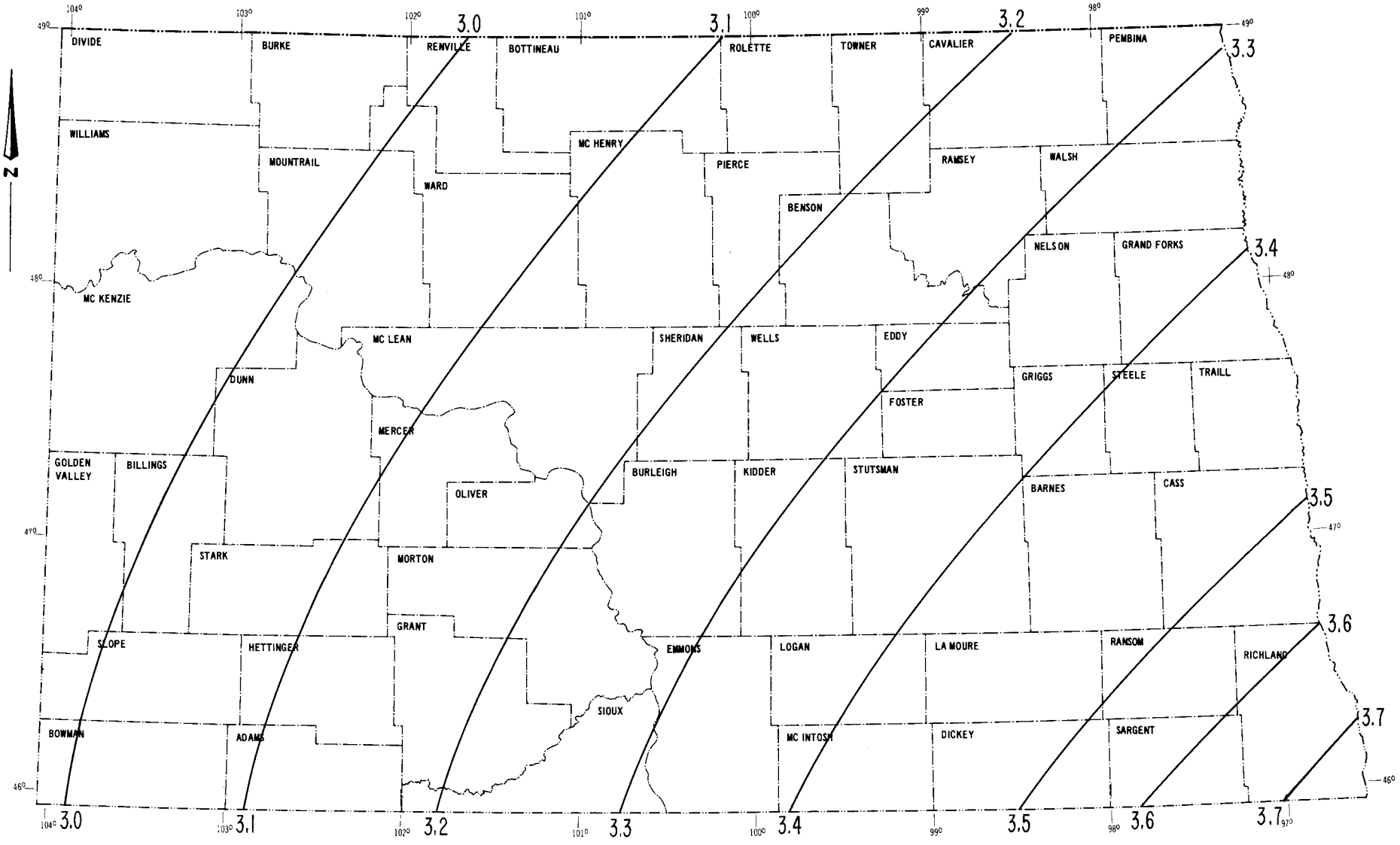
NORTH DAKOTA

REFERENCE:
U.S.W.B. T.P. – 40

BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1–4



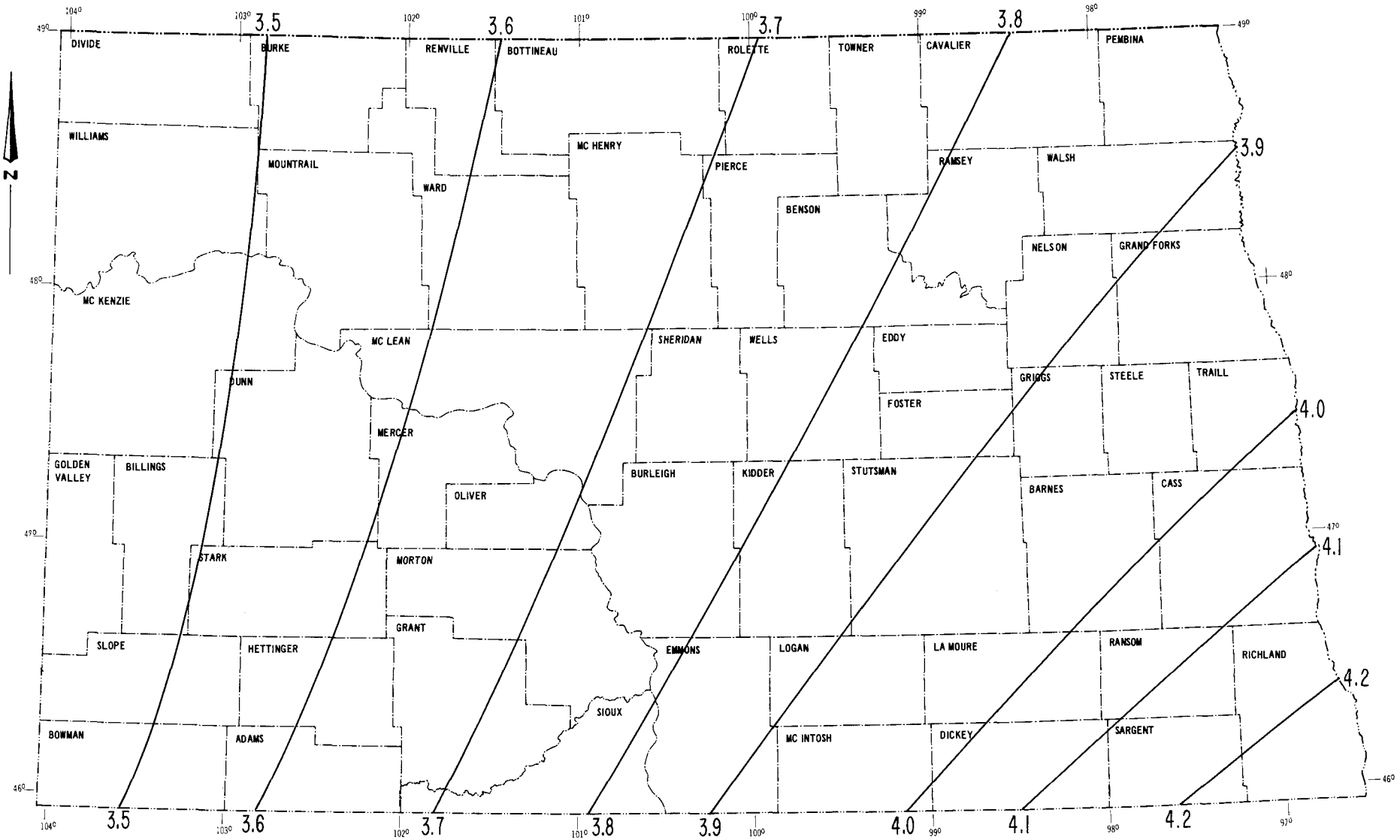
10% CHANCE (10-YEAR) 24-HOUR RAINFALL (INCHES)

NORTH DAKOTA

REFERENCE:
U.S.W.B. T.P. -40
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-5



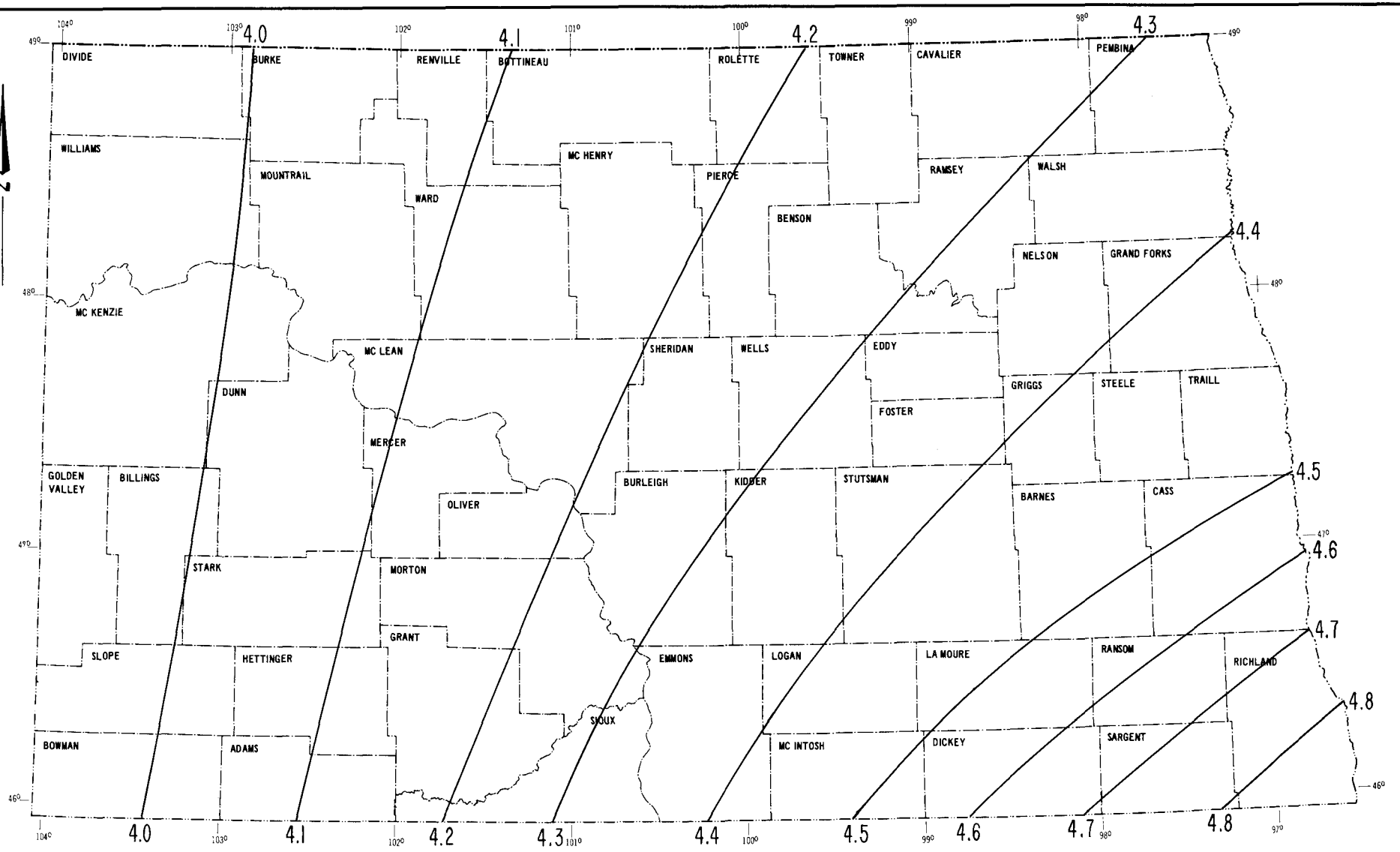
4% CHANCE (25–YEAR) 24–HOUR RAINFALL (INCHES)

REFERENCE:
U.S.W.B. T.P. – 40
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1–6



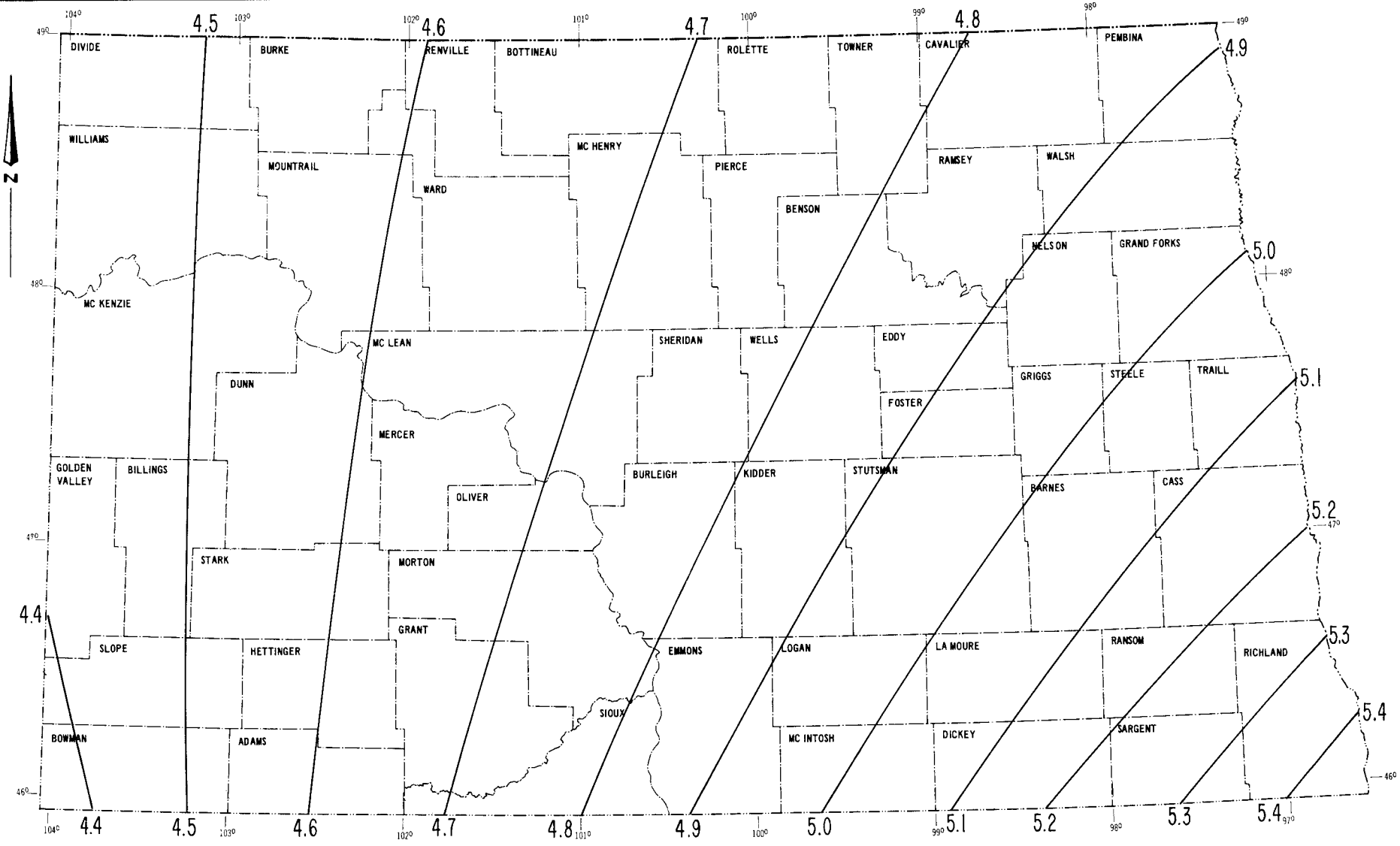
2% CHANCE (50–YEAR) 24–HOUR RAINFALL (INCHES)

NORTH DAKOTA

REFERENCE:
U.S.W.B. T.P. – 40
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-7



1% CHANCE (100–YEAR) 24–HOUR RAINFALL (INCHES)

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

REFERENCE:
U.S.W.B. T.P. – 40
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

FIGURE 1-8

TABLE 1-2 MINIMUM EMERGENCY SPILLWAY HYDROLOGIC CRITERIA FOR DAMS DESIGNED IN ACCORDANCE WITH TECHNICAL RELEASE 60

(For Class (a) dams with a product of storage times the effective height of the dam of 3,000 or more; those more than 35 feet in effective height; and all Class (b) and (c) dams.)

Class of Dam	Product of Storage x Effective Height	Existing or Planned Upstream Dams	Precipitation Data for 1/	
			Emergency Spillway Hydrograph	Freeboard Hydrograph
(a) 2/	less than 30,000	none	P_{100}	$P_{100} + 0.12\ (PMP-P_{100})$
	greater than 30,000	none	$P_{100} + 0.06\ (PMP-P_{100})$	$P_{100} + 0.26\ (PMP-P_{100})$
	all	any 3/	$P_{100} + 0.12\ (PMP-P_{100})$	$P_{100} + 0.40\ (PMP-P_{100})$
(b)	all	none or any	$P_{100} + 0.12\ (PMP-P_{100})$	$P_{100} + 0.40\ (PMP-P_{100})$
(c)	all	none or any	$P_{100} + 0.26\ (PMP-P_{100})$	PMP

1/ P_{100}=Precipitation for 100-year return period. PMP = Probable maximum precipitation. (6 hour precipitation)
2/ Dams involving industrial or municipal water are to use minimum criteria equivalent to that of class (b).
3/ Applies when the upstream dam is located so that its failure could endanger the lower dam.

Reference: Technical Release 60

STEPS IN DETERMINING RAINFALL FOR POND STRUCTURES

(For dams with a product of storage times the effective height of the dam of less than 3,000 and with an effective height of the dam of 35 feet or less.)

A. Principal Spillway Hydrograph Rainfall

1. Obtain design frequency from Table 1-7, Page 1-30.

2. Read appropriate 24-hour duration rainfall from Figures 1-2 through 1-8.

3. If the time of concentration exceeds 24 hours, adjust for increased duration. See Table 1-3.

4. If the drainage area exceeds 10 square miles, apply the area reduction factor from Table 1-4 for the 1 day duration. (This step can be neglected if the DAMS-2 computer program is used.)

B. Emergency Spillway Hydrograph Rainfall

1. Obtain design frequency from Table 1-7, Page 1-30.

2. Read appropriate 24-hour duration rainfall from Figures 1-2 through 1-8.

3. If the time of concentration exceeds 24 hours, adjust for increased duration. See Table 1-3.

4. If the drainage area exceeds 10 square miles, apply the area reduction factor from Table 1-4 for the 1 day duration. (This step can be neglected if the DAMS-2 computer program is used.)

STEPS IN DETERMINING RUNOFF
FOR
DAMS DESIGNED IN ACCORDANCE WITH TECHNICAL RELEASE 60

A. Principal Spillway Hydrograph Rainfall

1. Read design frequency from Table 1-1.

2. Read appropriate 10-day duration rainfall from Figures 1-9 through 1-11.

3. If the drainage area exceeds 10 square miles, apply the area reduction factor from Table 1-4 for the 10-day duration.

4. Read the reduced 10-day runoff curve number from Table 3-4.

5. Determine the inches of runoff from Table 3-5.

6. Read and determine the inches of runoff from Figure 1-12.

7. If the value from step 6 is greater than the value from step 5, record the value from step 6 on the Q DIRECT card in the DAMS-2 program. Enter 1-day runoff equal to 0.5 times the 10-day runoff on the Q DIRECT card.

8. If the runoff from step 5 is greater, then determine the 1-day rainfall by reading the appropriate 24-hour duration rainfall from Figures 1-6 through 1-8.

9. If the drainage area exceeds 10 square miles, apply the area reduction factor from Table 1-4 for the 1-day duration.

10. Determine the inches of runoff from Table 3-5. Record the Q1 and the Q10 (Step 5) on the Q DIRECT card in the DAMS-2 program.

B. Emergency Spillway and Freeboard Hydrograph Rainfall (6 Hour Rainfall)

1. Read the design frequency or frequency equation from Table 1-2.

2. Read the P_{100} and the PMP from Figures 1-14 and 1-15 respectively.

3. If the time of concentration exceeds 6 hours, increase each for increased duration. See Table 1-6.

4. Reduce the rainfall amounts by correction factors in Table 1-5 if drainage area is larger than 10 square miles.

5. Compute the Emergency Spillway and Freeboard Rainfall amounts by the appropriate equations from step 1.

6. If DAMS-2 program is used and if the time of concentration is less than 6 hours, record the two rainfall values on the P DIRECT card in the DAMS-2 program. The appropriate area reduction will be made automatically if the DAMS-2 computer program is used.

7. When the time of concentration exceeds 6 hours, make the appropriate area reduction using Table 1-5. Convert the rainfall to runoff using the appropriate hydrologic curve number and record the two runoff values on the Q DIRECT card in the DAMS-2 program.

NOTE:

Rainfall and Runoff Values are determined by following the steps shown on pages 1-12 to 1-14.

Hydrographs for these values may be developed by:

1. Dams 2 program (TR 48).
2. Other computer programs.
3. Manually in accordance with Chapter 21, Sec. 4, NEH. (Page 21.12, 21.13, 21.15 and 21.17)
4. Manually in accordance to Chapter 16, Sec. 4, NEH.
5. Manually in accordance to Chapter 6 - North Dakota Hydrology Manual.

TABLE 1-3

RAINFALL STORM DURATION FACTORS
FOR
PRINCIPAL SPILLWAY DESIGN STORMS

(For Class a dams with a product of storage times the effective height of the dam of less than 3,000 and with an effective height of the dam of 35 feet or less.)

Storm Duration (Hours)	Ratio: $\frac{\text{Rainfall Amount X Hours}}{\text{Rainfall Amount 24 Hours}}$
24	1.00
30	1.06
36	1.10
48	1.16

Note:

1. Design storm durations will equal the time of concentration when Tc equals or exceeds 24 hours.

2. Design storm rainfall amounts shall be increased by the factor shown for storm durations greater than 24 hours.

3. This adjustment is not automatically made in the DAMS-2 or TR-20 computer programs.

TABLE 1-4

RAINFALL AREA REDUCTION FACTORS
FOR
PRINCIPAL SPILLWAY DESIGN STORMS

Area Sq. mi.	Area/point ratio for: 1 day	10 days	Area Sq. mi.	Area/point ratio for: 1 day	10 days
10 or less	1.000	1.000	40	0.953	.977
15	.978	.991	50	.948	.974
20	.969	.986	60	.944	.972
25	.964	.983	70	.940	.970
30	.960	.981	80	.937	.968
35	.957	.979	100	.932	.966

TABLE 1-5

RAINFALL AREA REDUCTION FACTORS
FOR
EMERGENCY SPILLWAY AND FREEBOARD HYDROGRAPHS

Watershed Area (sq. mi.)	Ratio: Point Rainfall to Area Rainfall Correction Factor
0 to 10	1.00
20	0.95
30	0.91
50	0.86
75	0.82
100	0.78

Note:

Point rainfall amounts may be reduced by the factor value shown, based upon the size of drainage area under consideration.

TABLE 1-6

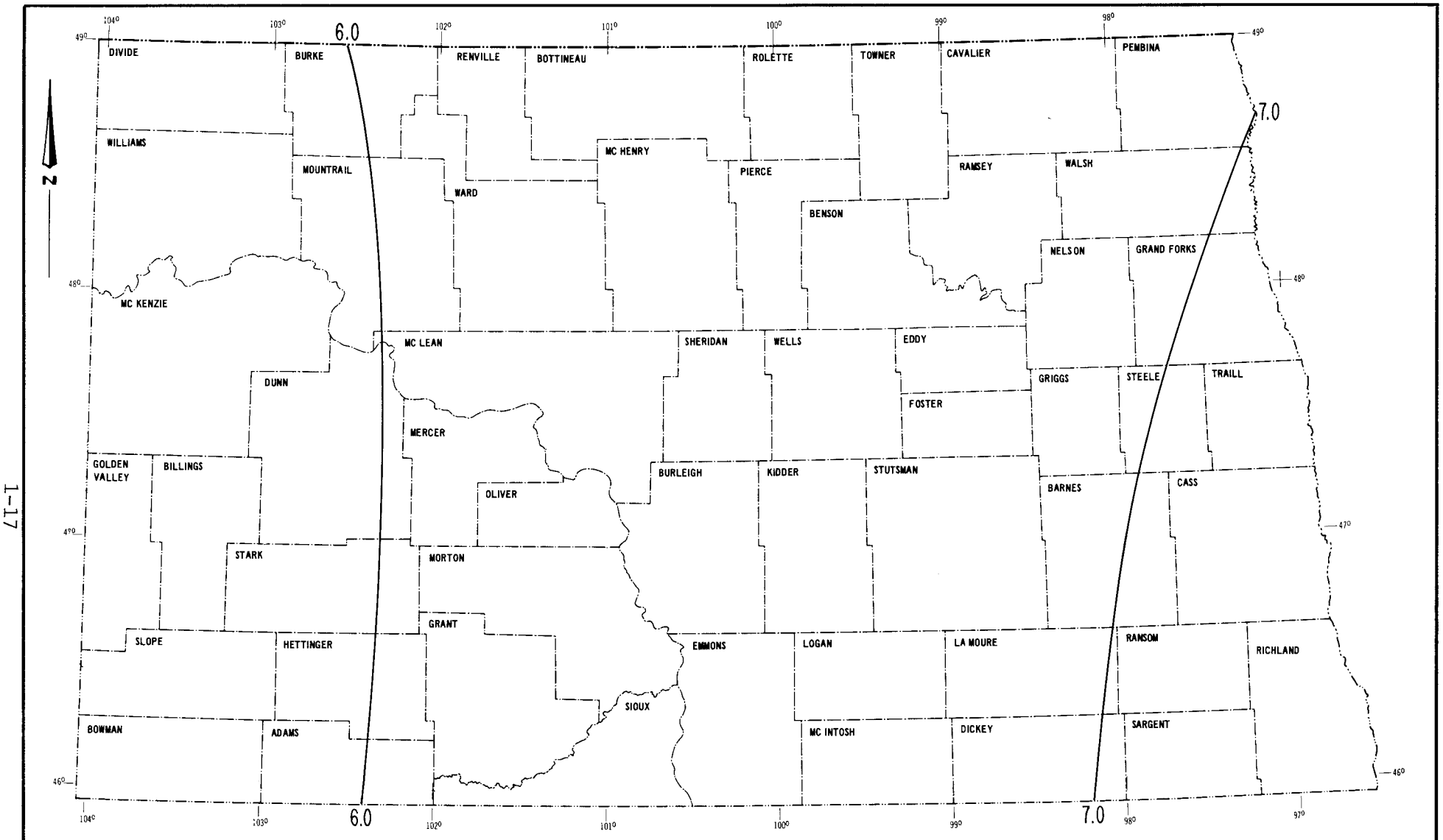
RAINFALL STORM DURATION FACTORS
FOR
EMERGENCY SPILLWAY AND FREEBOARD HYDROGRAPHS

Storm Duration (Hours)	Ratio: $\frac{\text{Rainfall Amount X Hours}}{\text{Rainfall Amount 6 Hours}}$	
	Adjustment for P_{100}	Adjustment for PMP
6	1.0	1.0
8	1.06	1.05
10	1.12	1.09
12	1.17	1.12
16	1.24	1.17
18	1.27	1.20
20	1.30	1.21
24	1.36	1.25
30	1.43	1.29
36	1.49	1.33
48	1.58	1.38

Note:

1. Storm durations will equal the Time of Concentration when Tc equals or exceeds 6 hours.
2. The equation for the adjustment for the P_{100} is:

   Ratio = .673 (Storm duration in Hrs.)$^{.221}$



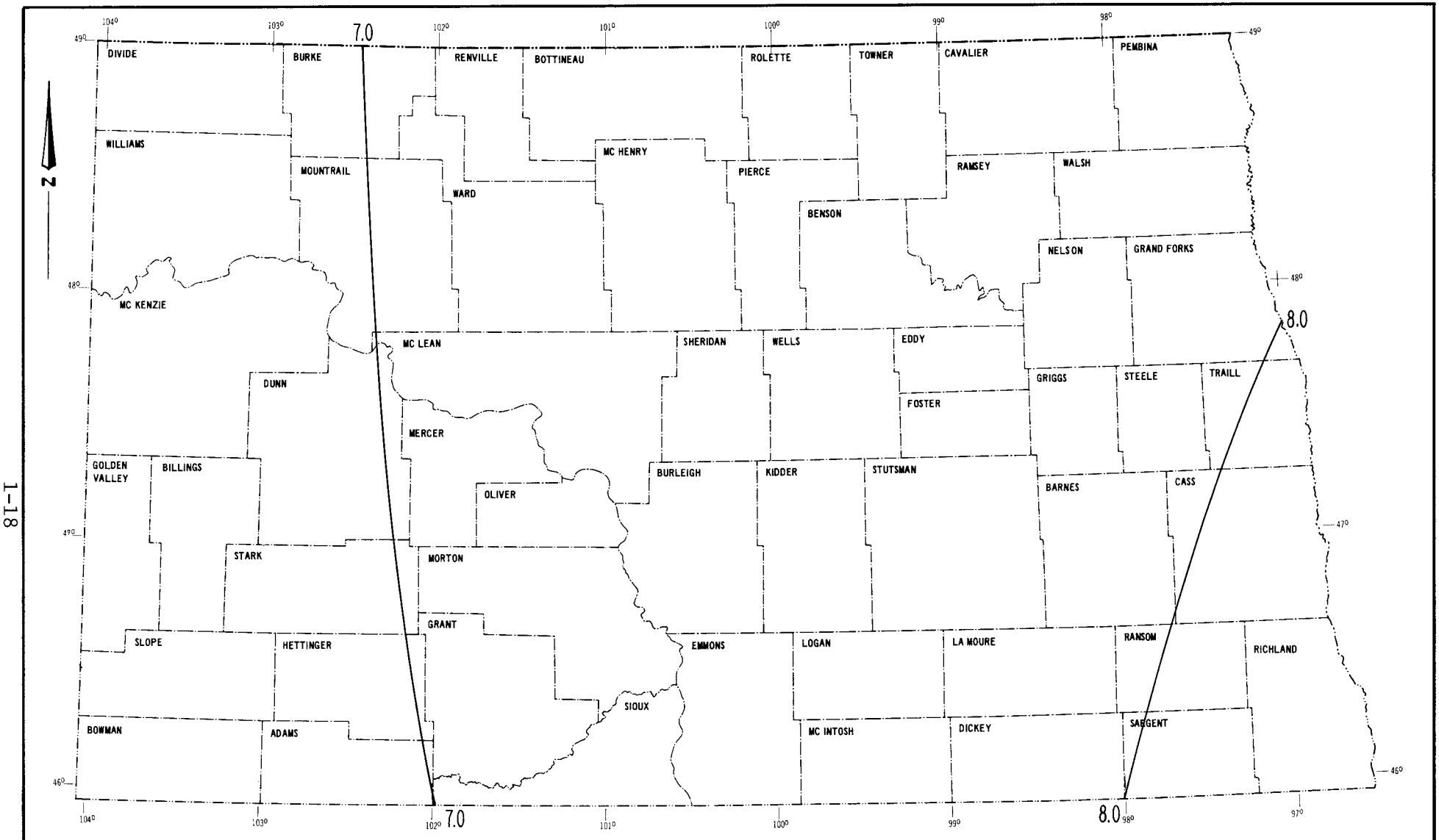
4% CHANCE (25–YEAR) 10–DAY RAINFALL (INCHES)

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

SOURCE:
U.S.W.B. T.P.–49
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

FIGURE 1-9



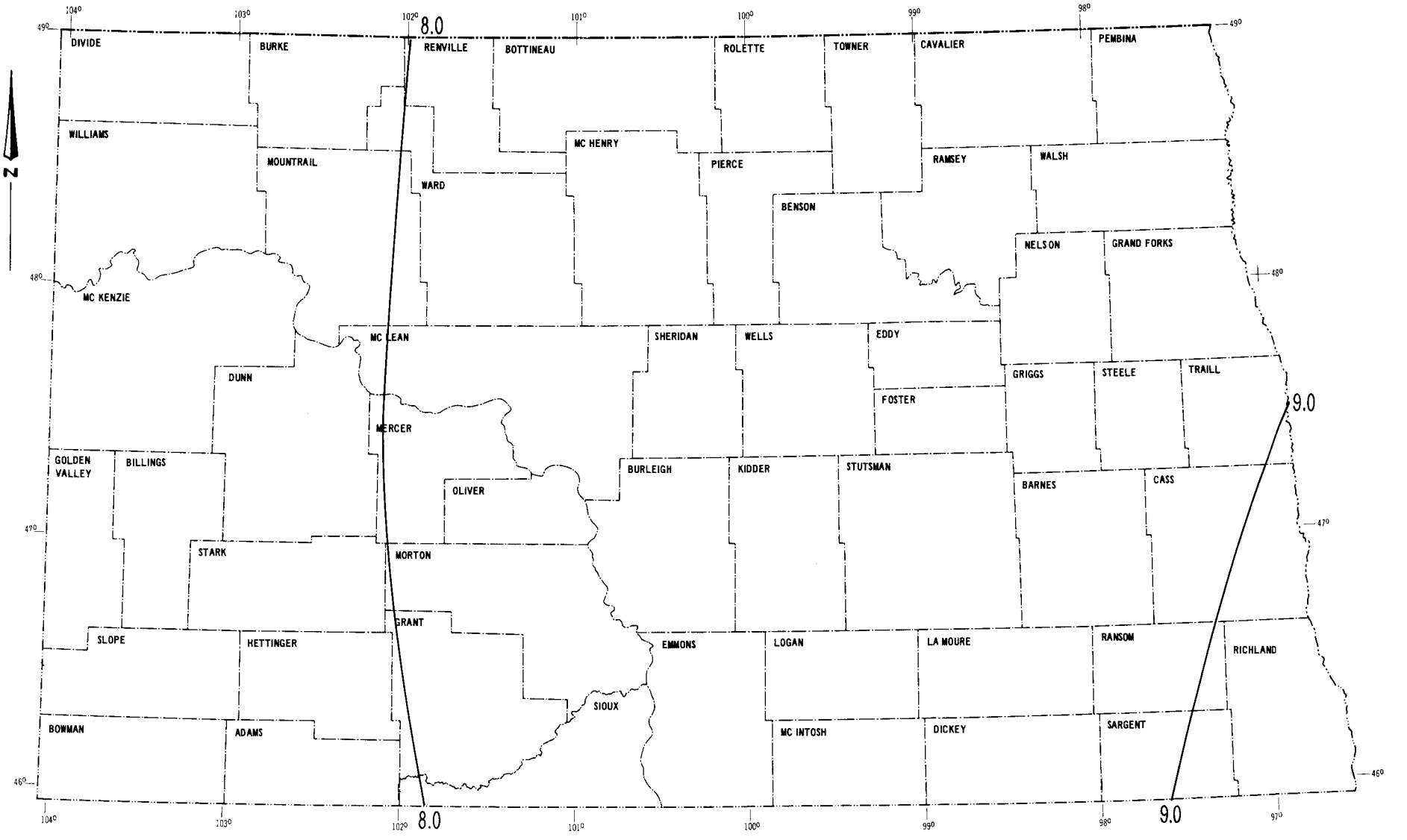
2% CHANCE (50-YEAR) 10-DAY RAINFALL (INCHES)

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

SOURCE:
U.S.W.B. T.P.-49
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

FIGURE 1-10



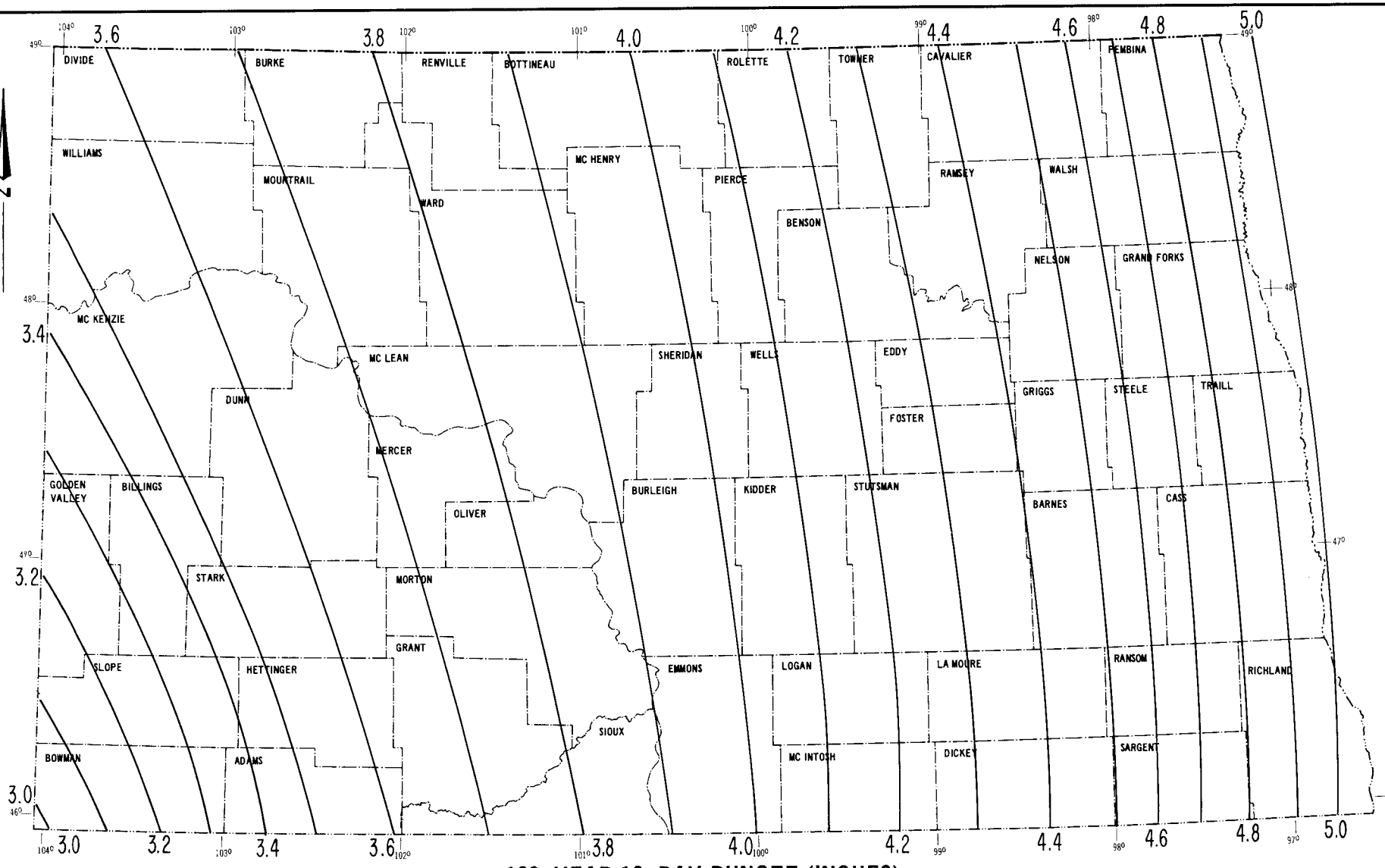
1% CHANCE (100-YEAR) 10-DAY RAINFALL (INCHES)

SOURCE:
U.S.W.B. T.P.-49
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-11



100-YEAR 10-DAY RUNOFF (INCHES) FOR DEVELOPING THE PRINCIPAL SPILLWAY HYDROGRAPH

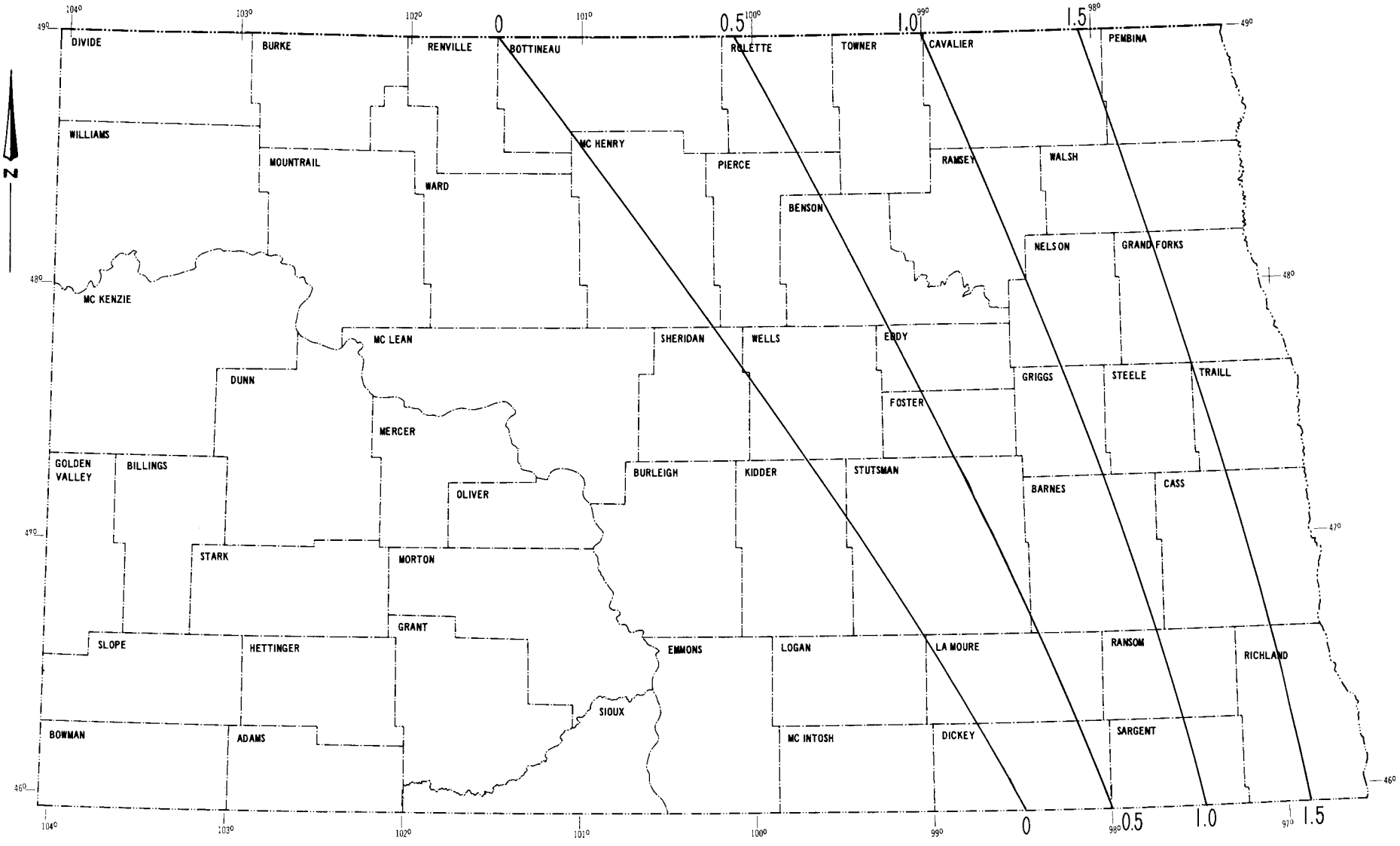
NORTH DAKOTA

RATIO FOR 50 AND 25-YEAR 10-DAY RUNOFF VOLUMES TO OBTAIN:	MULTIPLY MAP VALUES BY:
50-YEAR 10-DAY RUNOFF	0.85
25-YEAR 10-DAY RUNOFF	0.70

BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-12



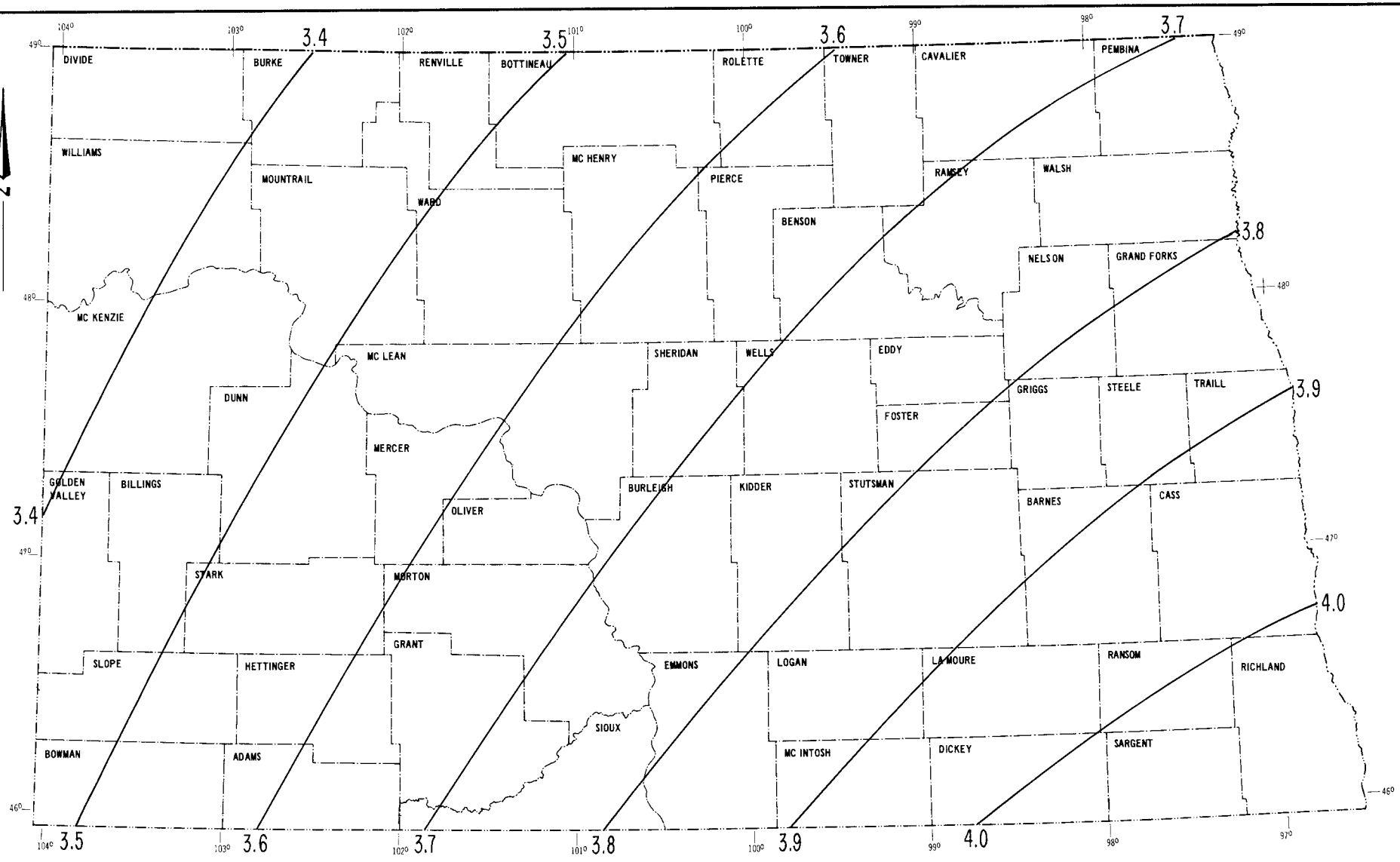
QUICK – RETURN FLOW (CSM) FOR DEVELOPING THE PRINCIPAL SPILLWAY HYDROGRAPH

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

FIGURE 1-13



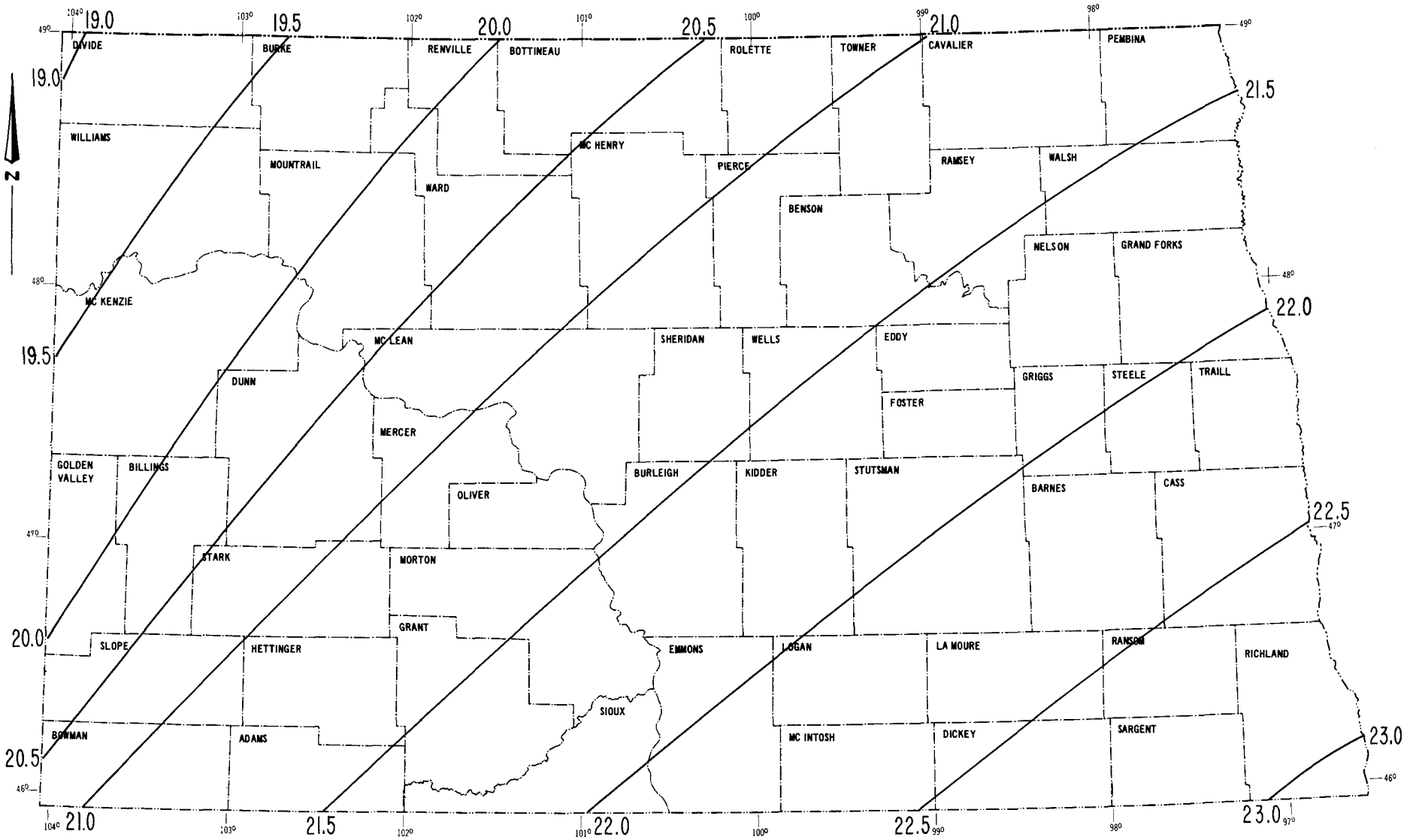
MINIMUM 1% CHANCE (100–YEAR) PRECIPITATION IN INCHES
6 – HOUR – 10 – SQUARE MILES

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

SOURCE:
TECH. PAPER 40 (1961)
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

FIGURE 1-14



ALL SEASON PROBABLE MAXIMUM PRECIPITATION
(INCHES)
FOR
6-HOUR, 10 SQUARE MILES
(EMERGENCY SPILLWAY AND FREEBOARD HYDROGRAPHS)

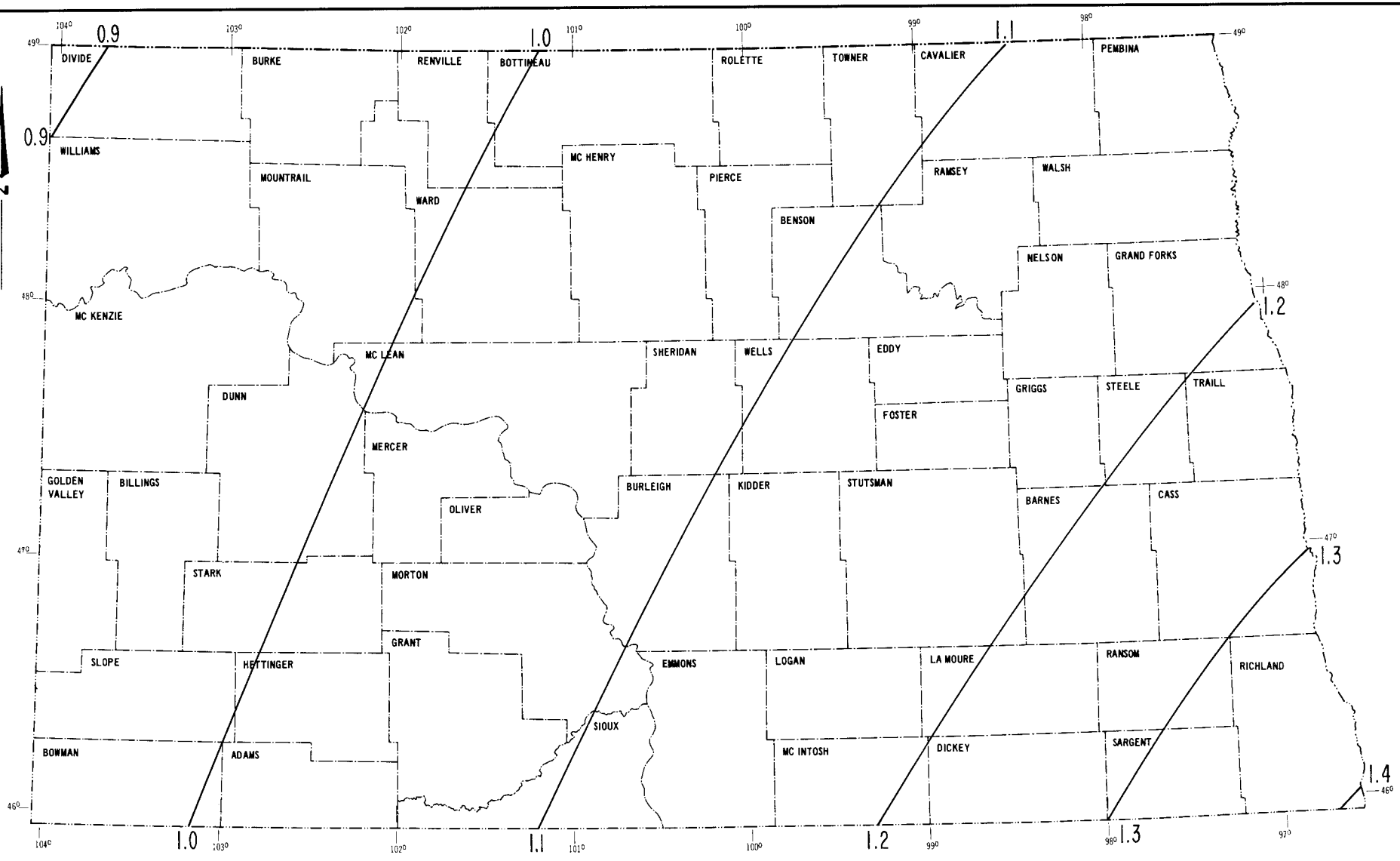
SOURCE:
HYDROMETEORLOGICAL
REPORT NO. 51
N.O.A.A. (JUNE 1978)

BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-15



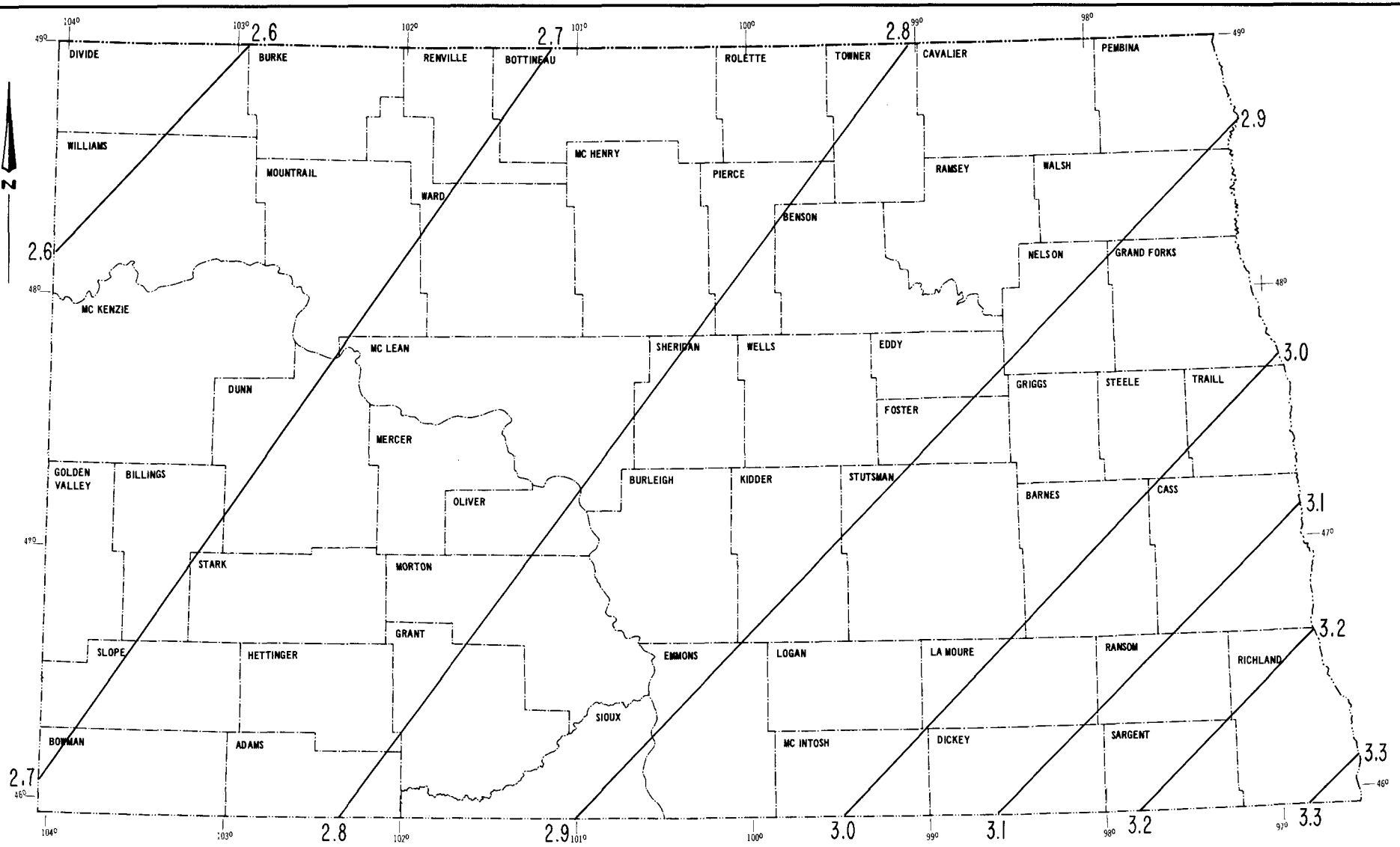
50% CHANCE (2-YEAR) 60-MINUTE PRECIPITATION (INCHES)

SOURCE:
N.O.A.A. TECH. MEMO NWS
HYDRO-35 (JUNE 1977)
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-16



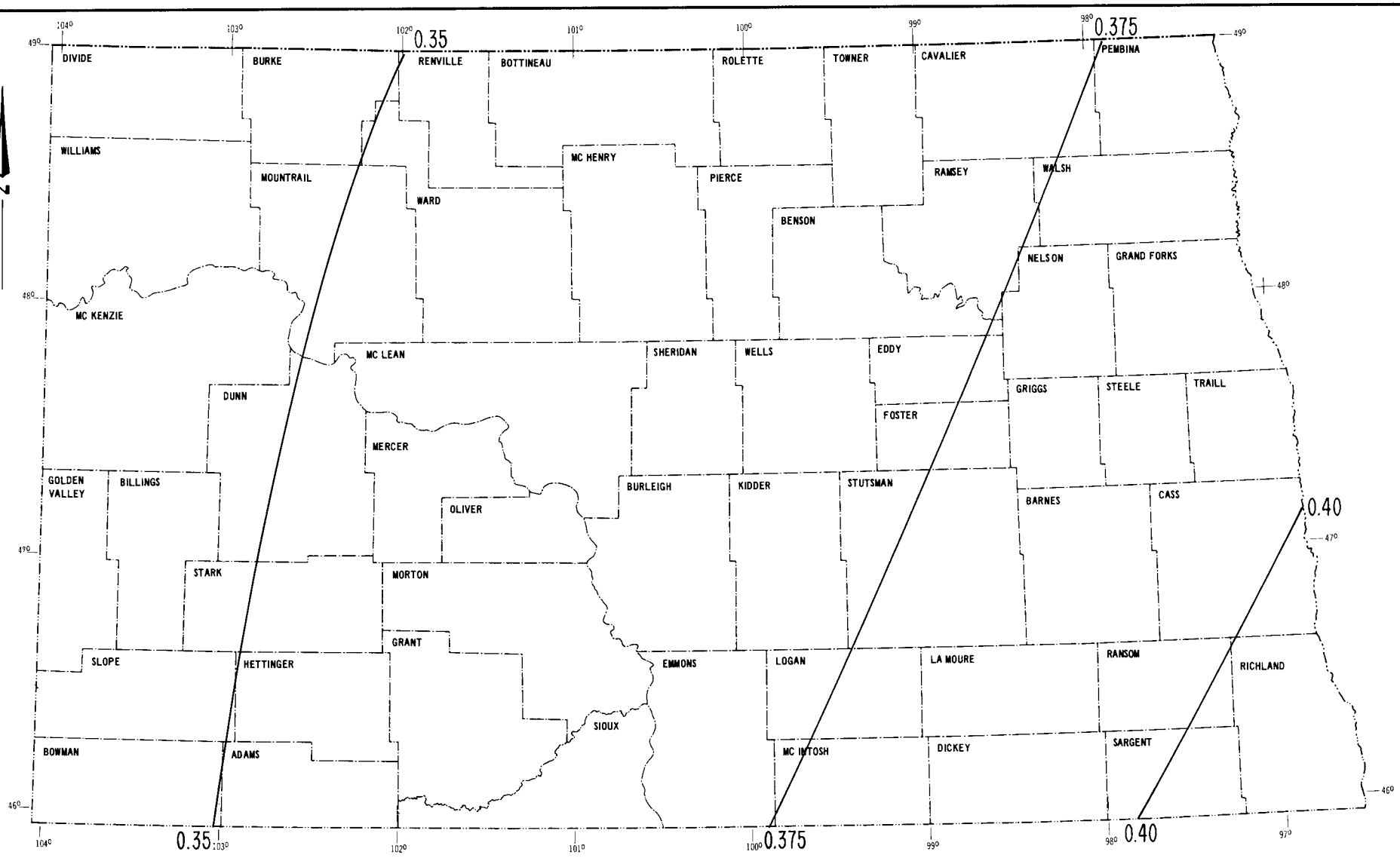
1% CHANCE (100-YEAR) 60-MINUTE PRECIPITATION (INCHES)

SOURCE:
N.O.A.A. TECH. MEMO NWS
HYDRO-35 (JUNE 1977)
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-17



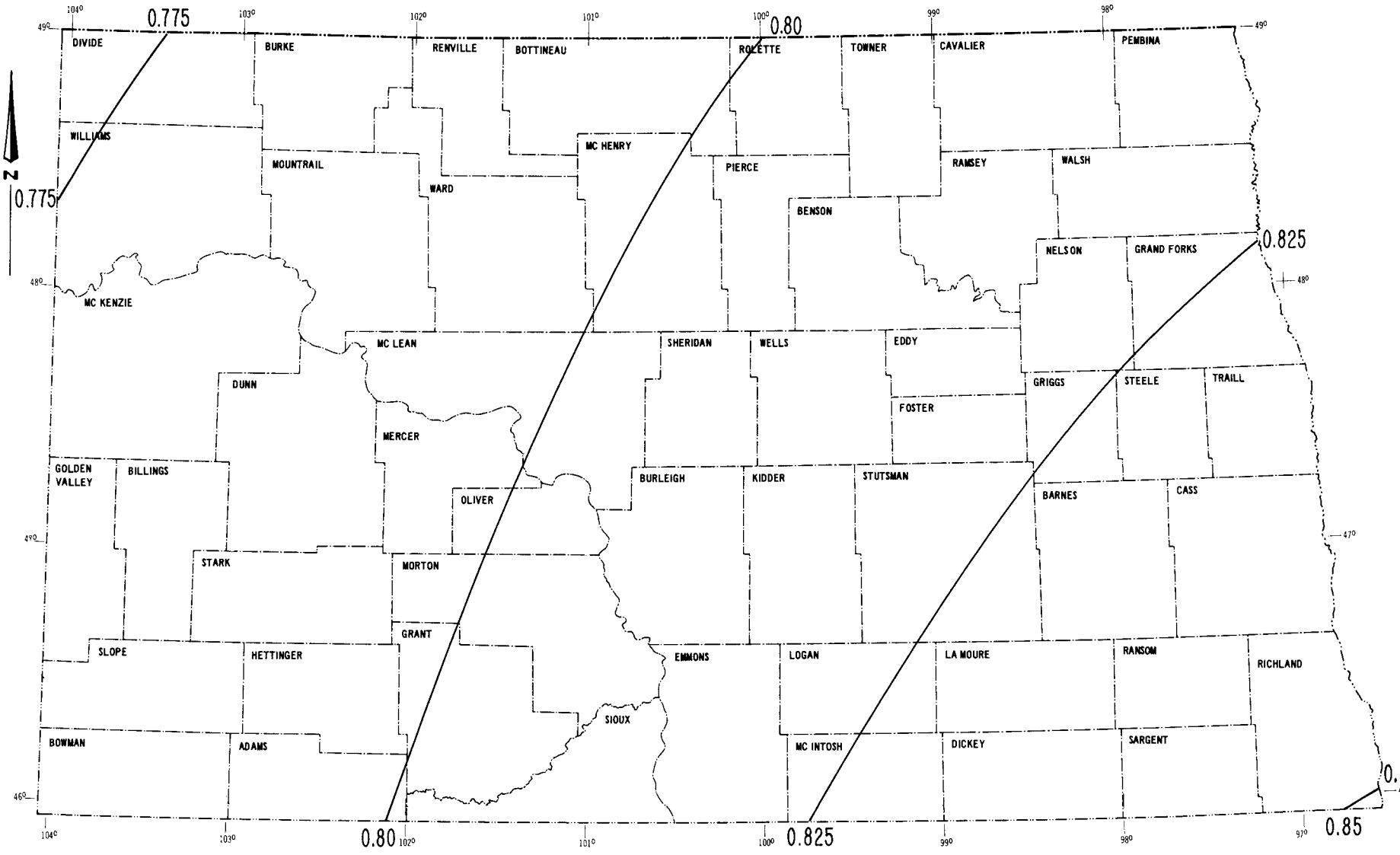
50% CHANCE (2-YEAR) 5-MINUTE PRECIPITATION (INCHES)

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

SOURCE:
N.O.A.A. TECH. MEMO. NWS
HYDRO-35 (JUNE 1977)
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

FIGURE 1-18



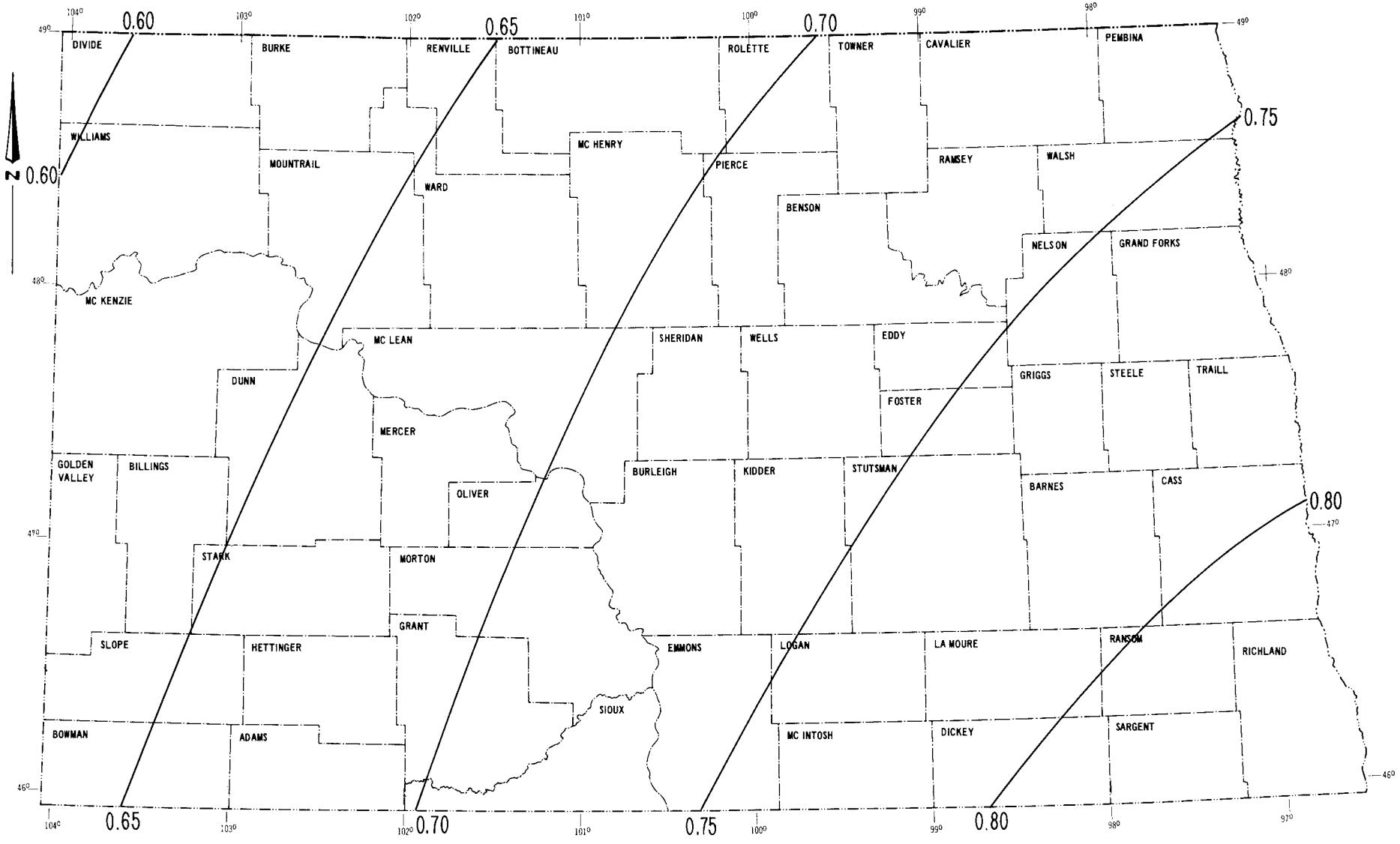
1% CHANCE (100-YEAR) 5-MINUTE PRECIPITATION (INCHES)

SOURCE:
N.O.A.A. TECH. MEMO. NWS
HYDRO-35 (JUNE 1977)
BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-19



50% CHANCE (2-YEAR) 15-MINUTE PRECIPITATION (INCHES)

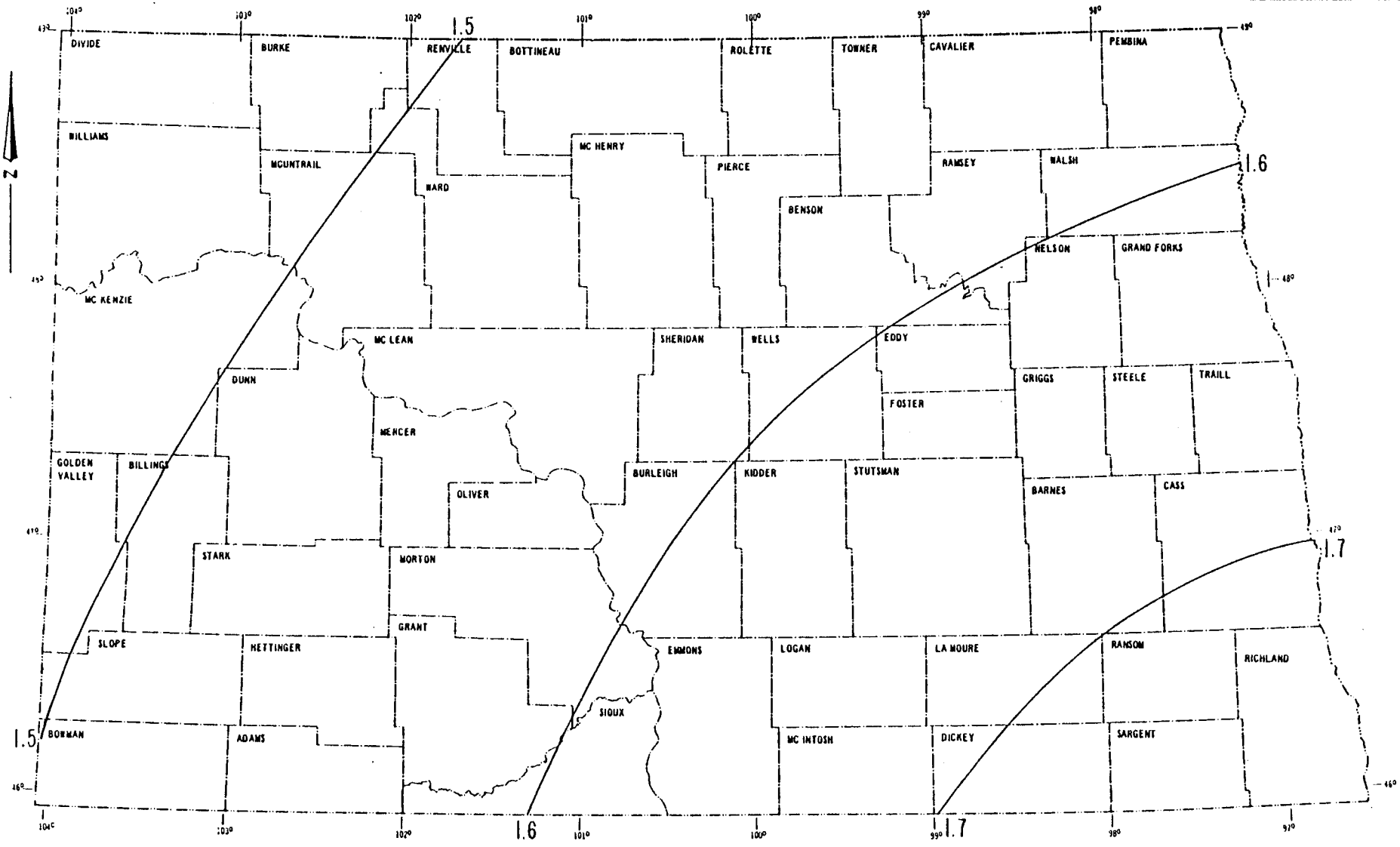
SOURCE:
N.O.A.A. TECH. MEMO. NWS
HYDRO-35 (JUNE 1977)

BASE MAP SOURCE:
FAMILY OF MAPS 5,S-32,814 (9-74)
ALBERS EQUAL AREA PROJECTION

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2,492,800

FIGURE 1-20



1% CHANCE (100-YEAR) 15-MINUTE PRECIPITATION (INCHES)

SOURCE:
N.O.A.A. TECH. MEMO. NWS
HYDRO-35 (JUNE 1977)
BASE MAP SOURCE:
FAMILY OF MAPS 5.5-52.814 (9-74)
ALBERS EQUAL AREA PROJECTION

NORTH DAKOTA

SCALE 0 10 20 30 40 50 MILES
0 20 40 60 80 KILOMETERS
1/2 492 800

FIGURE 1-21

TABLE 1-7

MINIMUM PRINCIPAL AND EMERGENCY SPILLWAY HYDROLOGIC CRITERIA

Class a dams with storage x effective height less than 3000 and the effective height less than 35 feet. 1/

PRINCIPAL SPILLWAY

Where Principal Spillway is required	-	Minimum Capacity 2 yr. - 24 hr.

EMERGENCY SPILLWAY

Drainage Area (Acres)	Height of Dam (Feet)	Storage (Ac.Ft.)	Minimum Design Rainfall Frequency	Duration (Hours)
20 or less	20 or less	less than 50	25 year	24
20 or less	over 20	less than 50	25 year	24
over 20	20 or less	less than 50	25 year	24
all others			50 year	24

1/ See North Dakota Technical Guide, Section IV, Standards and Specifications Pond (Embankment) - (378A).

2/ For drainage areas less than 640 acres, the use of a principal spillway is optional and the need will be determined by Ponds #378. For drainage areas equal to or greater than 640 acres, a principal spillway shall be installed.

3/ The minimum capacity of the principal spillway shall be that required to pass the peak flow, less any reduction because of detention storage.