

ND 650.290 Purpose of North Dakota Supplement

The purpose of this supplement is to assist Area and Field Staff in utilizing the most current rainfall data available, National Oceanic and Atmospheric Administration Atlas 14 (NOAA Atlas 14, Version 2, Volume 8), for the design of conservation practices. This supplement replaces all previous EFH Chapter 2 Supplements for estimating runoff. The user of this supplement should be thoroughly familiar with any handbook, manual, or technical guide applicable to hydrology and estimating runoff. The updated rainfall and rainfall distributions replace rainfall data from Weather Bureau Technical Paper 40 (TP-40) and the standard NRCS rainfall distribution Type I, previously used in the state (depths and types).

This supplement updates rainfall depths and rainfall distributions used in estimating runoff and peak discharges described in NEH Part 650, Engineering Field Handbook Chapter 2 (EFH-2); and updates the rainfall database used in the computer program, EFH-2. This supplement releases the statewide GIS shapefile for design rainfall data.

This supplement describes the implementation process, the technical background, and the procedure for loading of the updated rainfall data in the EFH-2 computer program. This supplement addresses rural watersheds; please discuss urban watersheds with the NRCS North Dakota State Hydrologist.

ND 650.291 Implementation of North Dakota Supplement

Effective upon receipt, NRCS Area and Field staff are to use the updated rainfall depths and rainfall distribution types when estimating runoff and peak discharges described in NEH 650, Chapter 2. The implementation is two parts: (1) updating the NEH 650, Chapter 2 Supplement for North Dakota and (2) updating the databases for the EFH-2 computer program.

- (1) The methods and data described in this supplement supersede any applicable methods and data from the previous NEH 650, Chapter 2 Supplement for North Dakota. The design rainfall table in Appendix 4 supersedes all rainfall data of the previous supplement and the rainfall depths from the Weather Bureau Technical Paper 40 (TP-40). The new rainfall distribution types (2_ND, 3_ND, and 4_ND) in Appendix 4 replace the previous standard NRCS rainfall distributions.
- (2) To implement this supplement, replace the rainfall database (COUNTY.ND), and rainfall distribution types (type.rf) used with the EFH-2 computer program. Appendix 1 presents the procedure for loading the updated rainfall database.

ND 650.292 Technical Background

Rainfall data summarized by duration and return period are integral pieces of information used for hydrologic analyses within NRCS.

North Dakota is included in Volume 8 of NOAA Atlas 14 released in 2013. Volume 8 provides the precipitation frequency estimates for durations of 5-minutes through 60-days at average recurrence intervals of 1-year through 1,000-year. NOAA used 425 observation stations in North Dakota for the update of the frequency-duration values. The link to a PDF version of this document is accessible through NOAA's website:

https://www.weather.gov/media/owp/oh/hdsc/docs/Atlas14_Volume8.pdf

This new data supersedes precipitation-frequency data found in the previously published documents U.S. Weather Bureau Technical Paper 40 (1961 – 30 min to 24 hour durations), U.S. Weather Bureau Technical Paper 49 (1961 – 2 day to 10 day durations) and NWS Hydro 35 (1977 – 5 min to 60 min durations).

NRCS uses 24-hour rainfall data by return interval for estimating peak discharges and runoff volumes required for sizing and design of several conservation practices such as waterways, water and sediment control basins, animal waste storage facilities, grade stabilization structures, etc. With the release of the new data, both rainfall depths and rainfall distributions change, which may impact conservation practice design. This supplement provides guidance recommendation for NRCS adoption of the new data. Appendix 7 describes the procedure for estimating annual yield.

(a) Rainfall Depths

NOAA used periods of record for rainfall stations up through October 2011 to compute precipitation-duration-frequency values. The period of record for the data issued by TP-40 ended prior to 1961. The updated rainfall data and distribution types of NOAA Atlas 14 account for the addition of the 50 years since the release of TP-40. Updated rainfall frequency maps are included in Appendix 6 of this supplement.

There are two methods to obtain rainfall design data. Use option 1 for the majority of cases. In special situations, use option 2.

1. Representative county values developed by NRCS from the NOAA Atlas 14 study for use with EFH-2. GIS was used to tabulate county wide average 24-hour rainfall depths by frequency. These are the default values seen in the EFH-2 computer program when the updated rainfall database (COUNTY.ND) is loaded. The data is also included in Appendix 5 of this supplement and on the Engineering page of the North Dakota NRCS website under the Engineering Field Handbook (EFH) – (NEH Part 650) section. The county data are good representative values when using a model and there are only minor variations of rainfall depths over a typical North Dakota county. For a more precise rainfall estimate, obtain data using the procedure described in the site-specific method that follows.
2. Site-specific NOAA Atlas 14 rainfall values for EFH-2 and other hydrology programs available using the NOAA website. Below are the steps for using NOAA's online application:
 - a. Browse to <http://hdsc.nws.noaa.gov/hdsc/pfds/> in a web browser.
 - b. Click on North Dakota on the national map.
 - c. In the map, drag the red crosshair icon to the project site location. Another option is to enter a latitude and longitude (from a GPS, for example) or select by station (list of ND stations) from a pull-down list. Typically choose the centroid of your drainage area.
 - d. Scroll down on the screen below the map to view a table of PDS-based precipitation frequency data for the selected location.
 - e. At the bottom of the screen, click "Submit" button to display the option to save the data in a comma-separated-variable (csv) format.
 - f. Replace/Enter the default rainfall values on the EFH-2 Rainfall/Discharge data tab with the 24-hour duration NOAA values from the table.

(b) Rainfall Distribution Types

Three new rainfall distribution types (2_ND, 3_ND, and 4_ND), unique to the EFH-2 computer program and for use in North Dakota, were developed NRCS by combining the NOAA Atlas 14 data derived distribution types MSE2, MSE3, and MSE4 and a dimensionless unit hydrograph with a peak rate factor of 325. See Section (c), Dimensionless Unit Hydrograph, for a discussion of the Peak Rate Factor (PRF).

These new rainfall distribution types (type.rf) replace the previous NRCS TP-40 distribution Type I used in North Dakota EFH-2. Do not use any of the previous distributions unless recreating an old estimate. Figure 2-1 displays appropriate rainfall distribution types to use per county.

The EFH-2 uses equations to estimate the unit peak discharge (cubic feet per second per inch of runoff per square mile of drainage area) from the time of concentration and excess runoff volume. NRCS developed the equation coefficients for the new rainfall distribution – dimensionless unit hydrograph combination; labeled types 2_ND, 3_ND, and 4_ND using the NOAA Atlas 14 data in combination with a PRF of 325. The type.rf file includes the equations, coefficients, and plots for the NOAA Atlas 14 rainfall derived distribution types, these plots are summarized in Appendix 4.

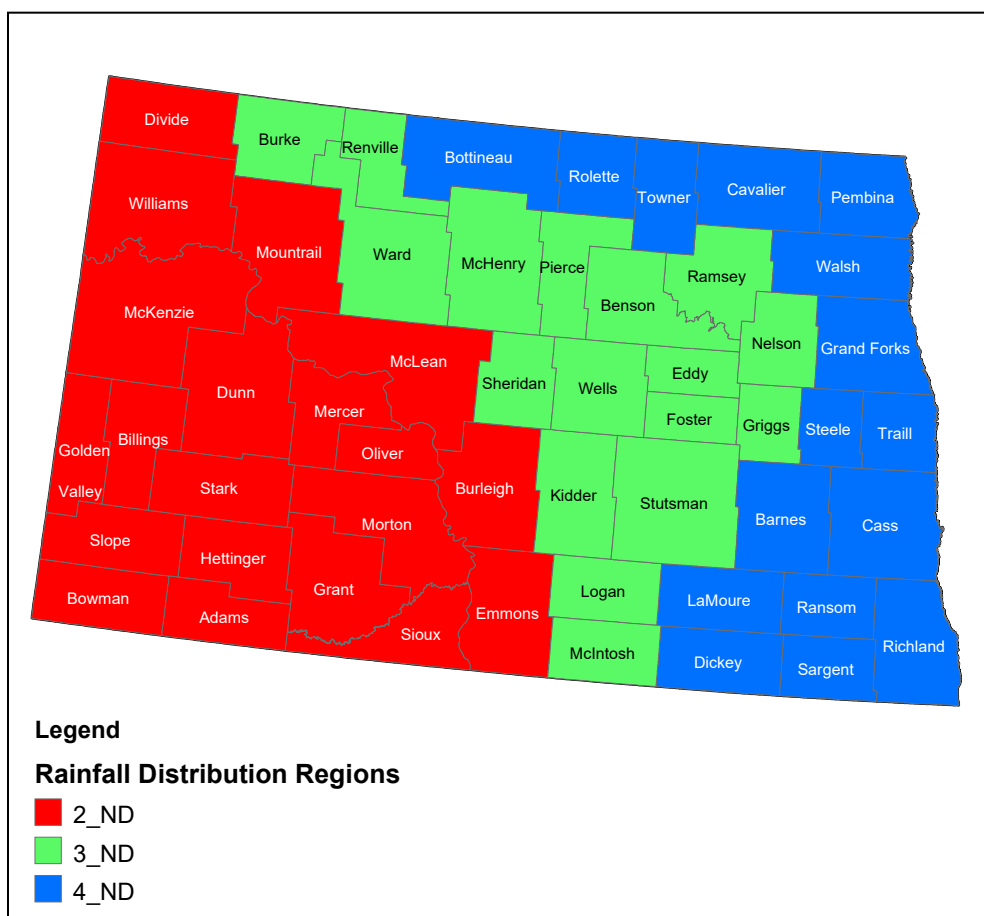


Figure 2-1: EFH-2 Rainfall Distribution Types for North Dakota

(c) Dimensionless Unit Hydrograph

The standard SCS dimensionless unit hydrograph has a Peak Rate Factor (PRF) of 484. For locations in North Dakota, using the dimensionless unit hydrograph with the new NOAA Atlas 14 derived rainfall distributions (MSE 2, MSE 3, and MSE 4) resulted in considerably higher peak discharges than using the SCS Type I rainfall distribution with TP-40 rainfall data. For this reason, North Dakota NRCS analyzed alternate regional PRF reports in conjunction with North Dakota stream gage PRF calculations in an effort to produce more comparable peak flows in conjunction with the NOAA Atlas 14 data. There are numerous references that found and adopted PRF as low as 284. The Delmarva PRF of 284 was determined and adopted for flat relief watersheds along the Atlantic Ocean coastal plain (New Jersey Department of Agriculture, 2004). Instructional textbooks identify the commonly applied range of PRF is between 284 and 484 for North Dakota's rural slight slopes to rolling hills landscapes (Wanielista, 1997). Regional reports with similar landscape descriptions as North Dakota contained extensive calibration data where the typical range is from 284 to 484, with the average PRF from 320 to 330, including Illinois (Melching et al., 1997), Florida (Solanki et al., 1996), North Carolina, and Georgia (Sheridan et al., 2002). The North Dakota analysis found the average and median PRF for small streams is between 320 and 330. For more data or explanation on this analysis, contact the NRCS North Dakota State Hydrologist (Jonathan Petersen, 701-530-2082). The new rainfall distributions derived from the NOAA Atlas 14 data used with the calibrated North Dakota hydrograph with a PRF of 325 resulted in increased, but more applicable and reasonable discharges, for the 2-year to 100-year, 24 hour storms. The distributions are named 2_ND, 3_ND, and 4_ND.

A 1992 USGS Water-Resources Investigations Report 92-4020 titled: "*Techniques for Estimating Peak-Flow Frequency Relations for North Dakota Streams*" (Williams-Sether, 1992) classified the state into three different Hydrologic Regions (A, B, & C). The three new NOAA Atlas 14 derived distributions are applied closely to those defined regions A, B, and C of the USGS report as shown: 2_ND = Region B, 3_ND = Region C, 4_ND = Region A.

References:

Melching, C.S., and Marquardt, J.S. 1997. "Equations for Estimating Synthetic Unit-Hydrograph Parameter Values for Small Watersheds in Lake County, Illinois": U.S. Geological Survey Water-Resources Investigations Report 96-474.

New Jersey Department of Agriculture, 2004. "NRCS change in stormwater modeling for NJ Coastal Plain". Technical Bulletin: 2004-2.0, July 12, 2004.

North Dakota Natural Resource Conservation Service, 1974. "Hydrology Manual for North Dakota, Chapter 7: Annual Yield Maps".

Sheridan, J.M., Merkel, W.H., and Bosch, D.D. 2002. "Peak Rate Factors For Flatland Watersheds", *Transactions of the ASAE Vol. 18(1): 65-69, ISSN: 0883-8542*.

Solanki, H. and S. Suau. 1996. "Reconciliation of Hydraulic Models to Coastal Flatland Watersheds." *Journal of Water Management Modeling* RI91-04. doi: 10.14796/JWMM.RI91-04.
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Wanielista, Martin, Robert Kersten, & Ron Eaglin, 1997. *Hydrology : Water Quantity and Quality Control*, 2nd Edition, Wiley and Sons, Inc., New York, NY.

Williams-Sether, T. 1992. "Techniques for Estimating Peak-Flow Frequency Relations for North Dakota Streams": U.S. Geological Survey Water-Resources Investigations Report 92-4020.

Appendix 1 ND 650.29-1 Updating Input File in EFH-2

The EFH-2 computer program for estimating runoff and peak discharges requires a rainfall database (**COUNTY.ND**) and rainfall distribution types (**type.rf**) databases. A hydrologic soil group database (**Soils.hg**) is optional. These databases are available on the Engineering page of the North Dakota NRCS website and replace the TP-40 based databases. The following steps describe the process of updating the databases within the EFH-2 computer program and its general use.

1. Navigate to the Engineering page of the North Dakota NRCS website [NRCS Engineering Manuals and Handbooks | Natural Resources Conservation Service \(usda.gov\)](#) Find the files under the Engineering Field Handbook (EFH) – (NEH Part 650) section.
2. Set up the file save location.
 - a. Enable hidden files and folders for this step.
 - i. In Windows Explorer click on Organize in the top left hand corner and then “Folder and search options”. Under the View tab and in the Advanced Settings box confirm that the radio button for “Show hidden files, folders, and drives” is clicked. Click “OK” to exit.
 - b. Verify that the file save location is set up at C:\Users\user.name\AppData\Local\VirtualStore\Program Files (x86)\USDA\EFH2
 - i. **Navigate to C:\Users\user.name\AppData\Local\VirtualStore and manually create the required subfolders;** i.e. Program Files (x86) within VirtualStore, USDA within Program Files (x86), EFH2 within USDA.
 - ii. To create a new folder: Right click within the desired destination folder and hover over “New”. Click on “Folder” then rename it with the appropriate name.
3. From the website individually click on the COUNTY.ND, and type.rf files and chose “SaveAs”. Navigate to C:\Users\user.name\AppData\Local\VirtualStore\Program Files (x86)\USDA\EFH2 and click “Save”. It may tell you that the file already exists and if you want to replace it. If so then click “Yes”. Repeat this process for each database.
4. The databases of the EFH-2 computer program should now be up to date, and provide the runoff and peak discharge using the updated NOAA Atlas 14 derived rainfall data.

Appendix 2 ND 650.29-2 EFH-2 Application Instructions

1. The EFH-2 computer program under the Basic Data tab, type “ND” in the text box after State. Clicking the down arrow next to the text box after County displays every county and corresponding rainfall region in North Dakota.
2. Choose your county of interest and enter the remaining data in the Basic Data tab. The drainage area and runoff curve number can be entered manually if known and documentation is provided. Alternatively, the RCN tab (see Step 6) can be used to calculate the total drainage area and weighted curve number.

- a. Watershed Length is the longest flow path from the hydraulically most remote point in the watershed to the outlet; i.e. the longest path water will travel in the watershed to get to the outlet. Pay special attention if the watershed has features that could divert the flow path from its natural course; e.g. terraces or diversions.
- b. Watershed Slope is the average watershed slope of the land and not the watercourse. It may be estimated using the sum of contours method as described below.

$$\text{Average Watershed Slope (\%)} = \frac{C * I}{A * 43,560} * 100$$

Where: C = Sum length of all contours within the delineated watershed drainage area in feet

I = Contour interval in feet

A = Watershed drainage area in acres

- c. Time of Concentration is calculated when all other values above it are populated. It can be entered manually if known and documentation is provided.
3. The RCN tab can be used to calculate the accumulated drainage area and the weighted curve number. Enter the appropriate acres under each hydrologic soil group for the cover type(s) that is present within the defined watershed. Values can also be entered as percentages by clicking the Percentage radio button. Clicking Accept will populate the corresponding values on the Basic Data tab.
 - a. It is recommended to determine hydrologic soil group (HSG) values using the NRCS Web Soil Survey located at <http://websoilsurvey.nrcs.usda.gov/app/> and clicking on the Green START WSS button.
 - i. Define or import the Area of Interest.
 - Use the appropriate AOI tool above the Interactive Map and define area.
 - Import an ArcMap shapefile by expanding the box Area of Interest and then Import AOI.
 - ii. Within the Soil Data Explorer tab select the Soil Properties and Qualities tab and then select Hydrologic Soil Group. Choose View Rating to run the report.
 4. Under the Rainfall/Discharge Data tab, click the down arrow next to the box after Rainfall – Type. This displays the updated rainfall distribution regions. Be sure to select the correct distribution region that corresponds with the county selected in Step 4.

Appendix 3 ND 650.29-3 Peak Discharge Equations and Examples

The EFH-2 computer program estimates peak discharges using equations that simulate results from other more detailed rainfall/runoff models such as Win TR-20. To simplify the estimation of peak discharge, Win TR-20 was run for times of concentration (T_c) of 0.1 to 10 hours and I_a/P ratios of 0.1, 0.25, 0.3, 0.4, and 0.5. Initial abstraction, I_a , includes all losses before runoff begins and is in units of inches. The equation for I_a is shown in Eq. ND2-1. P is the storm rainfall with units of inches and $CN =$ NRCS Runoff Curve Number.

$$I_a = 0.2 * ((1000/CN) - 10) \quad \text{Eq. ND2-1}$$

From EFH-2, Time of Concentration (T_c) is calculated as:

$$T_c = L^{0.8} * ((1000/CN) - 9)^{0.7} / (1140 * Y^{0.5}) \quad \text{Eq. ND2-2}$$

Where $L =$ Watershed Flow Length (feet) and $Y =$ Average Watershed Slope (%)

The equation used by the EFH-2 computer program to relate time of concentration to unit peak discharge (q_u) is:

$$q_u = 10 ^ (C_0 + C_1 * \log (T_c) + C_2 (\log (T_c))^2) \quad \text{Eq. ND2-3}$$

Appendix 3 shows the coefficients used with each rainfall distribution.

The peak discharge (q_p) is computed as the product of the unit peak discharge (q_u), the drainage area (A) in sq. miles (acres/640), and the runoff (Q) in inches.

$$q_p = q_u * A * Q \quad \text{Eq. ND2-4}$$

$$\text{Where Runoff } (Q) = (P - (200 / CN) + 2)^2 / (P + (800 / CN) - 8) \quad \text{Eq. ND2-5}$$

The equation for Runoff (Q) is derived from the SCS runoff equation and curve number approach.

$$Q = (P - 0.2S)^2 / (P + 0.8S) \quad \text{Eq. ND2-6}$$

$$\text{Where } S = (1000/CN) - 10 \quad \text{Eq. ND2-7}$$

Example:

A site is located in a county shown to be within the rainfall distribution Region 3_ND. The site is determined to have the following watershed characteristics:

Drainage Area – 250 acres

Curve Number – 75

Watershed Flow Length – 10,250 ft

Average Watershed Slope – 2%

For a 25-yr design storm of 4.19" and using the coefficient values of Region 3_ND as shown in Appendix 3, compute the total peak discharge:

Example Answered:Calculate I_a/P ratio:

$$I_a = 0.2 * ((1000/CN) - 10) \quad (\text{Eq. ND2-1})$$

$$I_a = 0.2 * ((1000/75) - 10) = 0.667$$

$$I_a/P = 0.667/4.19 = \boxed{0.159}$$

Since this is between I_a/P ratios 0.1 and 0.25 interpolation will need to be done with the coefficients of Region 3_ND.

$$\text{For } C_0: (2.3976 - 2.4438) / (0.25 - 0.10) = (2.3976 - x) / (0.25 - 0.159) \rightarrow C_0 = 2.4256$$

$$\text{For } C_1: (-0.6987 - -0.7027) / (0.25 - 0.10) = (-0.6987 - x) / (0.25 - 0.159) \rightarrow C_1 = -0.7011$$

$$\text{For } C_2: (-0.0878 - -0.1164) / (0.25 - 0.10) = (-0.0878 - x) / (0.25 - 0.159) \rightarrow C_2 = -0.1051$$

Calculate Time of Concentration:

$$T_c = L^{0.8} * ((1000/CN) - 9)^{0.7} / (1140 * \gamma^{0.5}) \quad (\text{Eq. ND2-2})$$

$$T_c = 10,250^{0.8} * ((1000/75) - 9)^{0.7} / (1140 * 2^{0.5})$$

$$\boxed{T_c = 2.80 \text{ Hours}}$$

Calculate Unit Peak Discharge:

$$q_u = 10 ^ (C_0 + C_1 * \log (T_c) + C_2 (\log (T_c))^2) \quad (\text{Eq. ND2-3})$$

$$q_u = 10 ^ (2.4256 - 0.7011 * \log (2.80) - 0.1051 (\log (2.80))^2)$$

$$\boxed{q_u = 123.3 \text{ cfs/sq. mile/in}}$$

Calculate Runoff Volume:

$$Q = (P - (200 / CN) + 2)^2 / (P + (800 / CN) - 8) \quad (\text{Eq. ND2-5})$$

$$Q = (4.19 - (200 / 75) + 2)^2 / (4.19 + (800 / 75) - 8)$$

$$\boxed{Q = 1.81 \text{ inches}}$$

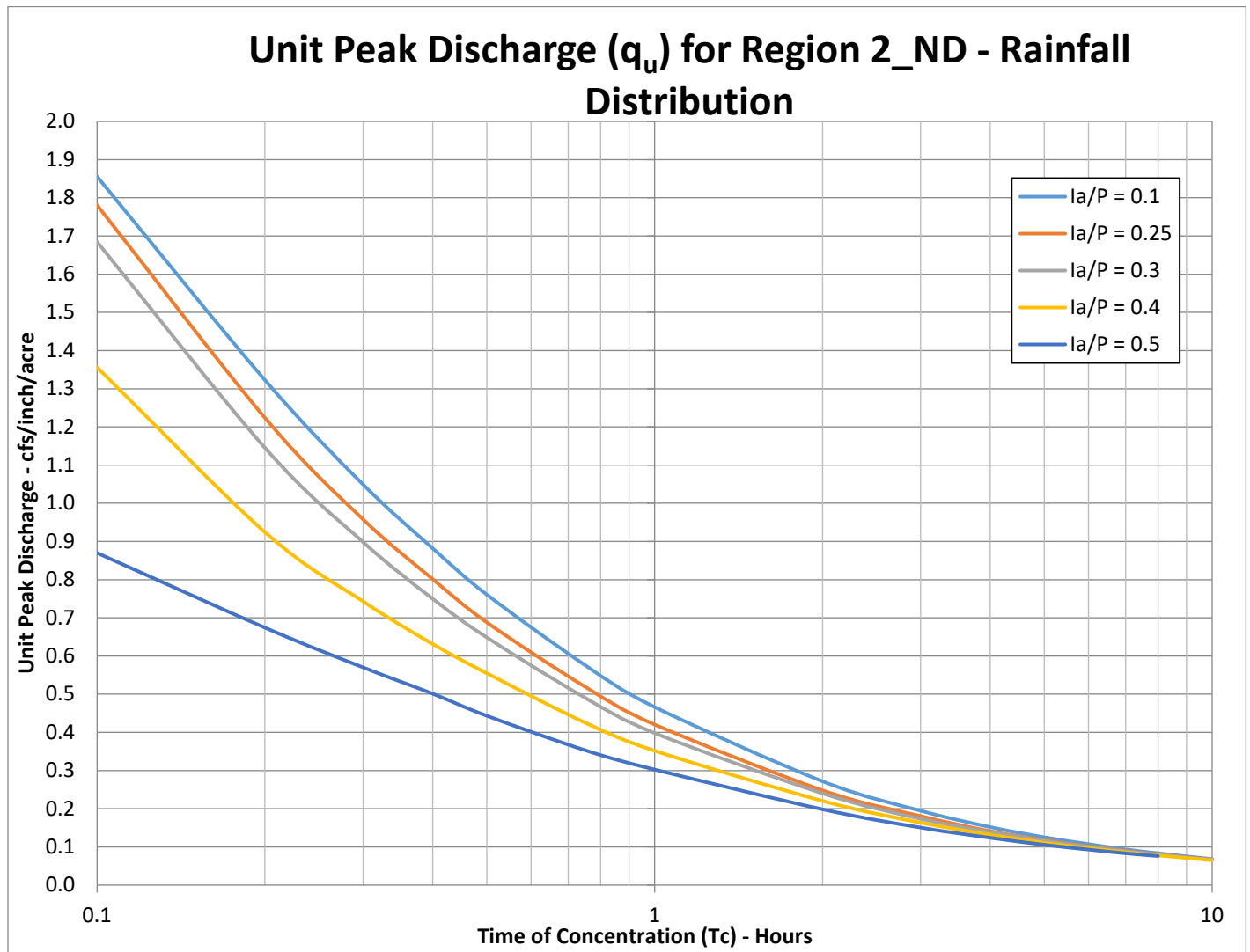
Calculate Peak Discharge:

$$q_p = q_u * A * Q \quad (\text{Eq. ND2-4})$$

$$q_p = 123.3 * (250/640) * 1.81$$

$$\boxed{q_p = 87.2 \text{ cfs} \rightarrow \text{use } 87 \text{ cfs}}$$

Appendix 4 ND 650.29-4 Plots Relating to NOAA Rainfall Distribution Regions

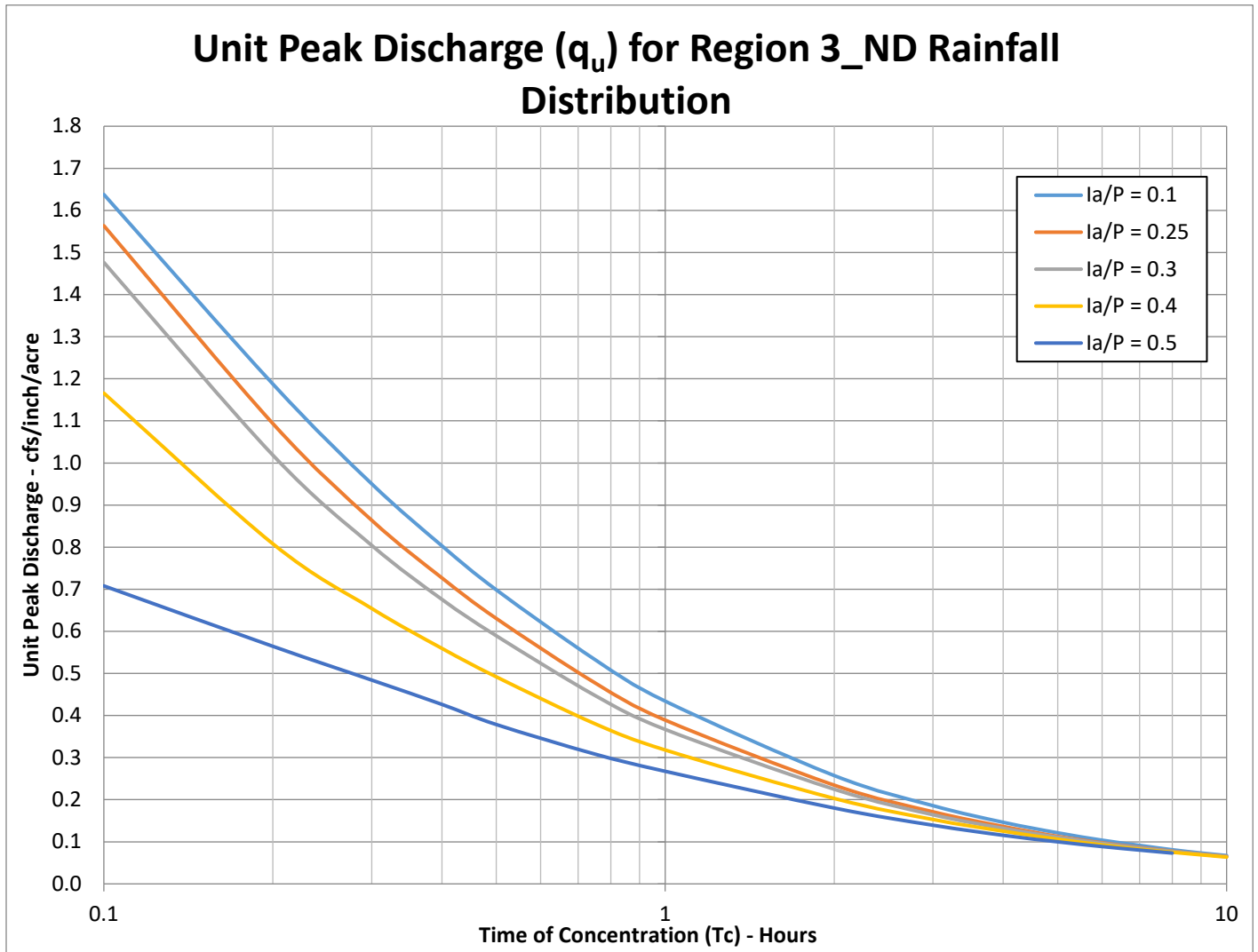


EFH-2 Unit Discharge Curves for Region 2_ND

Ia/P	C ₀	C ₁	C ₂
0.1	2.4748	-0.7259	-0.1168
0.25	2.4302	-0.7208	-0.0861
0.3	2.4074	-0.7077	-0.0767
0.4	2.3535	-0.6599	-0.0761
0.5	2.2879	-0.5736	-0.1106

EFH-2 Unit Discharge Equation Coefficients for Region 2_ND

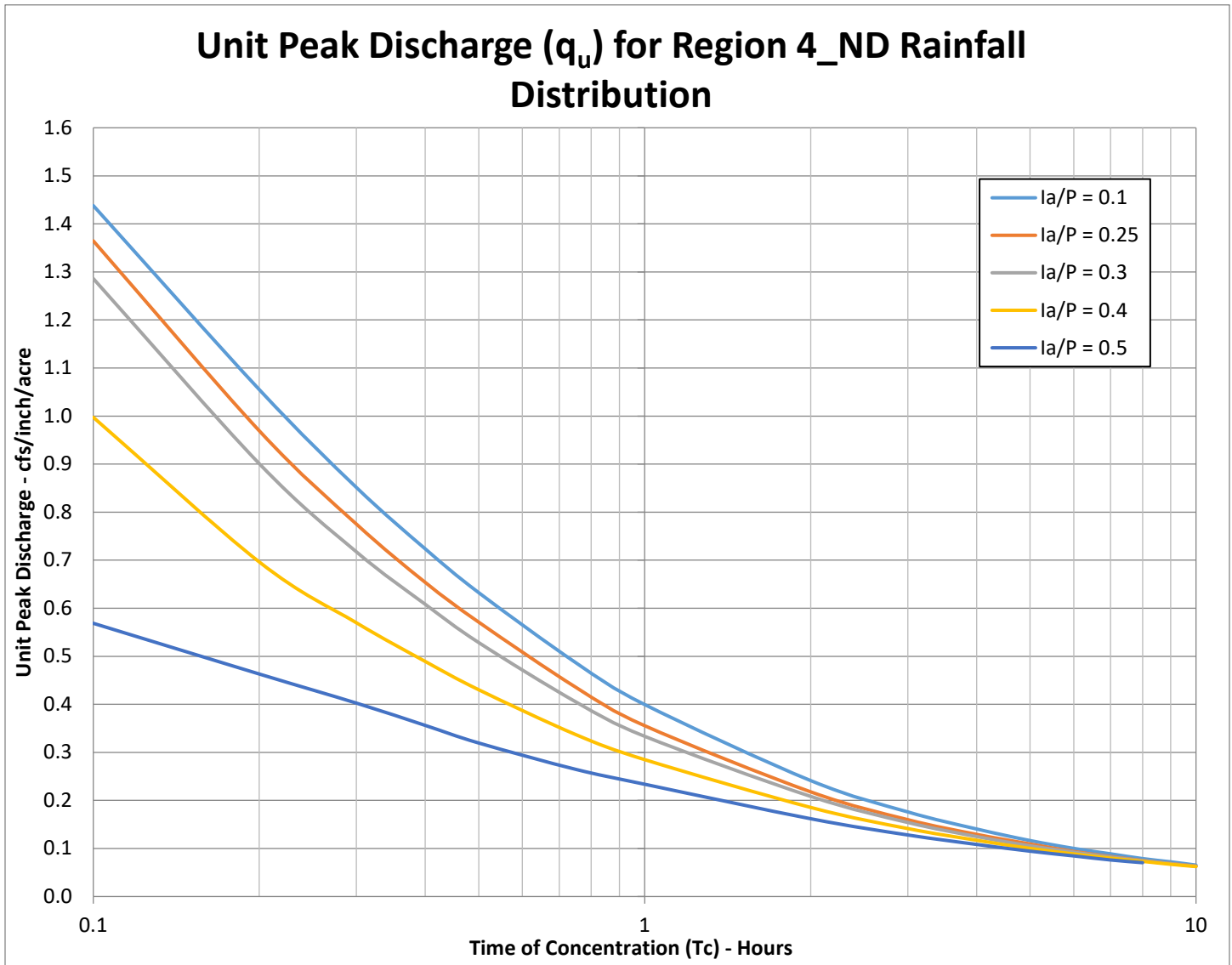
(ND_210_NEH_650_2, October 2017)



EFH-2 Unit Discharge Curves for Region 3_ND

la/P	C_0	C_1	C_2
0.1	2.4438	-0.7027	-0.1164
0.25	2.3976	-0.6987	-0.0878
0.3	2.3714	-0.6851	-0.0753
0.4	2.3098	-0.6326	-0.0697
0.5	2.2336	-0.5344	-0.1052

EFH-2 Unit Discharge Equation Coefficients for Region 3_ND



EFH-2 Unit Discharge Curves for Region 4_ND

la/P	C_0	C_1	C_2
0.1	2.4082	-0.6785	-0.1140
0.25	2.3601	-0.6757	-0.0855
0.3	2.3314	-0.6617	-0.0704
0.4	2.2606	-0.6035	-0.0588
0.5	2.1738	-0.4915	-0.0989

EFH-2 Unit Discharge Equation Coefficients for Region 4_ND

Appendix 5 ND 650.29-5 County Rainfall Data (COUNTY.ND)

Note: Rainfall distributions for each county are shown with their respective region. The 24-hour rainfall duration values are in units of inches.

Rainfall Values and Regional Codes for North Dakota Counties

County	REGION	1-year	2-year	5-year	10-year	25-year	50-Year	100-Year
ADAMS	2_ND	1.74	2.04	2.55	3.01	3.68	4.24	4.82
BARNES	4_ND	1.94	2.29	2.92	3.50	4.37	5.11	5.90
BENSON	3_ND	1.75	2.07	2.61	3.08	3.77	4.33	4.91
BILLINGS	2_ND	1.64	1.93	2.43	2.85	3.47	3.96	4.47
BOTTINEAU	4_ND	1.74	2.09	2.65	3.14	3.81	4.35	4.89
BOWMAN	2_ND	1.62	1.90	2.37	2.78	3.38	3.87	4.38
BURKE	3_ND	1.67	1.94	2.42	2.84	3.48	4.01	4.57
BURLEIGH	2_ND	1.79	2.10	2.66	3.17	3.95	4.61	5.31
CASS	4_ND	2.00	2.37	3.04	3.66	4.62	5.44	6.32
CAVALIER	4_ND	1.80	2.14	2.72	3.23	3.98	4.60	5.25
DICKEY	4_ND	2.06	2.44	3.08	3.65	4.47	5.14	5.84
DIVIDE	2_ND	1.54	1.79	2.24	2.65	3.26	3.78	4.33
DUNN	2_ND	1.74	2.03	2.53	2.97	3.60	4.12	4.66
EDDY	3_ND	1.82	2.17	2.77	3.29	4.06	4.68	5.34
EMMONS	2_ND	1.77	2.09	2.65	3.15	3.91	4.54	5.21
FOSTER	3_ND	1.88	2.24	2.86	3.40	4.20	4.85	5.53
GOLDEN VALLEY	2_ND	1.56	1.85	2.34	2.75	3.33	3.79	4.26
GRAND FORKS	4_ND	1.95	2.27	2.88	3.44	4.32	5.08	5.91
GRANT	2_ND	1.76	2.06	2.58	3.05	3.74	4.32	4.93
GRIGGS	3_ND	1.91	2.24	2.84	3.39	4.23	4.95	5.72
HETTINGER	2_ND	1.73	2.02	2.53	2.98	3.66	4.22	4.81
KIDDER	3_ND	1.81	2.09	2.62	3.12	3.89	4.56	5.28
LAMOURE	4_ND	2.04	2.41	3.04	3.61	4.44	5.13	5.85
LOGAN	3_ND	1.90	2.24	2.82	3.35	4.11	4.75	5.42
MCHENRY	3_ND	1.78	2.10	2.65	3.10	3.74	4.24	4.74

County	REGION	1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
MCINTOSH	3_ND	1.93	2.27	2.86	3.38	4.13	4.74	5.38
MCKENZIE	2_ND	1.62	1.89	2.35	2.75	3.32	3.77	4.25
MCLEAN	2_ND	1.70	2.01	2.53	2.98	3.62	4.12	4.65
MERCER	2_ND	1.71	2.01	2.52	2.97	3.64	4.18	4.76
MORTON	2_ND	1.73	2.01	2.53	3.01	3.75	4.37	5.05
MOUNTRAIL	2_ND	1.66	1.96	2.46	2.88	3.47	3.94	4.41
NELSON	3_ND	1.88	2.19	2.76	3.29	4.09	4.77	5.51
OLIVER	2_ND	1.71	1.99	2.49	2.96	3.68	4.29	4.95
PEMBINA	4_ND	1.89	2.24	2.87	3.43	4.27	4.96	5.70
PIERCE	3_ND	1.77	2.07	2.59	3.05	3.71	4.25	4.82
RAMSEY	3_ND	1.74	2.04	2.57	3.04	3.76	4.36	5.00
RANSOM	4_ND	2.03	2.39	3.04	3.63	4.52	5.26	6.06
RENVILLE	3_ND	1.69	2.01	2.54	2.98	3.59	4.06	4.54
RICHLAND	4_ND	2.06	2.41	3.04	3.60	4.44	5.15	5.90
ROLETTE	4_ND	1.85	2.20	2.80	3.33	4.09	4.72	5.38
SARGENT	4_ND	2.02	2.37	2.99	3.55	4.39	5.09	5.83
SHERIDAN	3_ND	1.74	2.04	2.56	3.02	3.68	4.21	4.77
SIOUX	2_ND	1.78	2.10	2.66	3.15	3.88	4.47	5.10
SLOPE	2_ND	1.62	1.88	2.33	2.73	3.33	3.83	4.35
STARK	2_ND	1.75	2.04	2.55	3.00	3.66	4.21	4.78
STEELE	4_ND	1.96	2.28	2.90	3.47	4.36	5.13	5.97
STUTSMAN	3_ND	1.91	2.25	2.85	3.38	4.19	4.85	5.56
TOWNER	4_ND	1.80	2.13	2.70	3.21	3.95	4.55	5.19
TRAILL	4_ND	2.05	2.40	3.05	3.67	4.62	5.44	6.34
WALSH	4_ND	1.86	2.20	2.79	3.33	4.15	4.84	5.58
WARD	3_ND	1.71	2.04	2.59	3.03	3.64	4.11	4.57
WELLS	3_ND	1.77	2.10	2.67	3.16	3.88	4.47	5.09
WILLIAMS	2_ND	1.56	1.81	2.25	2.65	3.23	3.71	4.22

Appendix 6 ND 650.29-6 North Dakota 24-HR Rainfall Maps

1-Year Frequency – 24-Hour Duration Rainfall

2-Year Frequency – 24-Hour Duration Rainfall

5-Year Frequency – 24-Hour Duration Rainfall

10-Year Frequency – 24-Hour Duration Rainfall

25-Year Frequency – 24-Hour Duration Rainfall

50-Year Frequency – 24-Hour Duration Rainfall

100-Year Frequency – 24-Hour Duration Rainfall

Appendix 7 ND 650.29-7 Annual Yield (Runoff)

Information on annual runoff is very limited on small watersheds. The annual runoff from a watershed has a direct relationship to the watershed yield. The water yield of a watershed by years, seasons or months is used in the planning and design of some water resource projects, especially those involving irrigation and stockwater.

Figures 7-1 and 7-2 (North Dakota NRCS, 1974) show the annual runoff values developed from USGS gaging stations. The majority of gaging stations are located in hydrologic soil group B, with low slope landscapes, and numerous depressions for storing runoff. The expansive Glacial Drift Prairie, between the Missouri Plateau and the Red River Valley of the North, reflects a large amount of runoff stored in numerous potholes and depressions. The regions of North Dakota are identified in Figure 3 (North Dakota NRCS, 1974). The retention of water in these various potholes and depressions is particularly significant for the smaller frequency floods.

When selecting runoff values for smaller frequency floods within the Glacial Drift Prairie (see Figure 7-3), it may be necessary to increase the runoff values for the well-defined drainage areas that do not have numerous potholes and depressions. Figures 7-1 and 7-2 reflect a storage condition within the Glacial Drift Prairie. When this condition does not exist, the runoff values need to be increased.

Individual judgement and the accuracy required is the basis for the final determination. In some cases, a special study may be necessary. The NRCS State Hydrologist can supply estimates of water yields, as required, or supply a method to determine the water yield at a particular site.

Yield Determination

The volume of reliable annual water yield from a given drainage area can be the governing factor in determining the feasibility of

- (1) Waterspreading
- (2) Fish and Wildlife Structures
- (3) Recreation Structures,
- (4) Irrigation Impoundments
- (5) Stockwater Developments.

Figures 7-1 and 7-2 may be used to determine the volume of runoff that can be expected annually for the designated percent chance. Runoff (R) from snowmelt for the dependable (80 percent chance) and questionable (50 percent chance) should be used for waterspreading.

Annual runoff (R) for the 80% chance (Figure 7-1) should be used to offset annual use, seepage and evaporation losses for impoundment type structures.

The 80% chance annual runoff curve (Figure 7-1) can be used to estimate the period (usually 1 to 3 years) for the initial filling of reservoirs. The 50% chance annual runoff curve for higher risk (Figure 7-2) can be used to estimate filling periods for successive years of higher runoff.

Example of use of Figures 7-1 and 7-2:

1. Find: The total annual runoff that can be expected from a 160-acre watershed in Burleigh County 80 years out of 100 years (80% chance).

Solution: From Figure 6-1, read (interpolate) 16 acre-feet per square mile.

$$\frac{160 \text{ ac.}}{640 \text{ ac./sq mile}} \times 16 = 0.25 \times 16 = 4.0 \text{ acre - feet}$$

2. Find: The total annual snowmelt runoff that can be expected from a 160-acre watershed in Burleigh County 80 years out of 100 years (80% chance).

Solution: From problem 1, total annual runoff equals 4 acre-feet. From Figure 7-1, read (interpolate) that 56% of the annual runoff is snowmelt.

$$56\% \times 4.0 \text{ acre} - \text{feet} = 2.24 \text{ acre} - \text{feet}$$

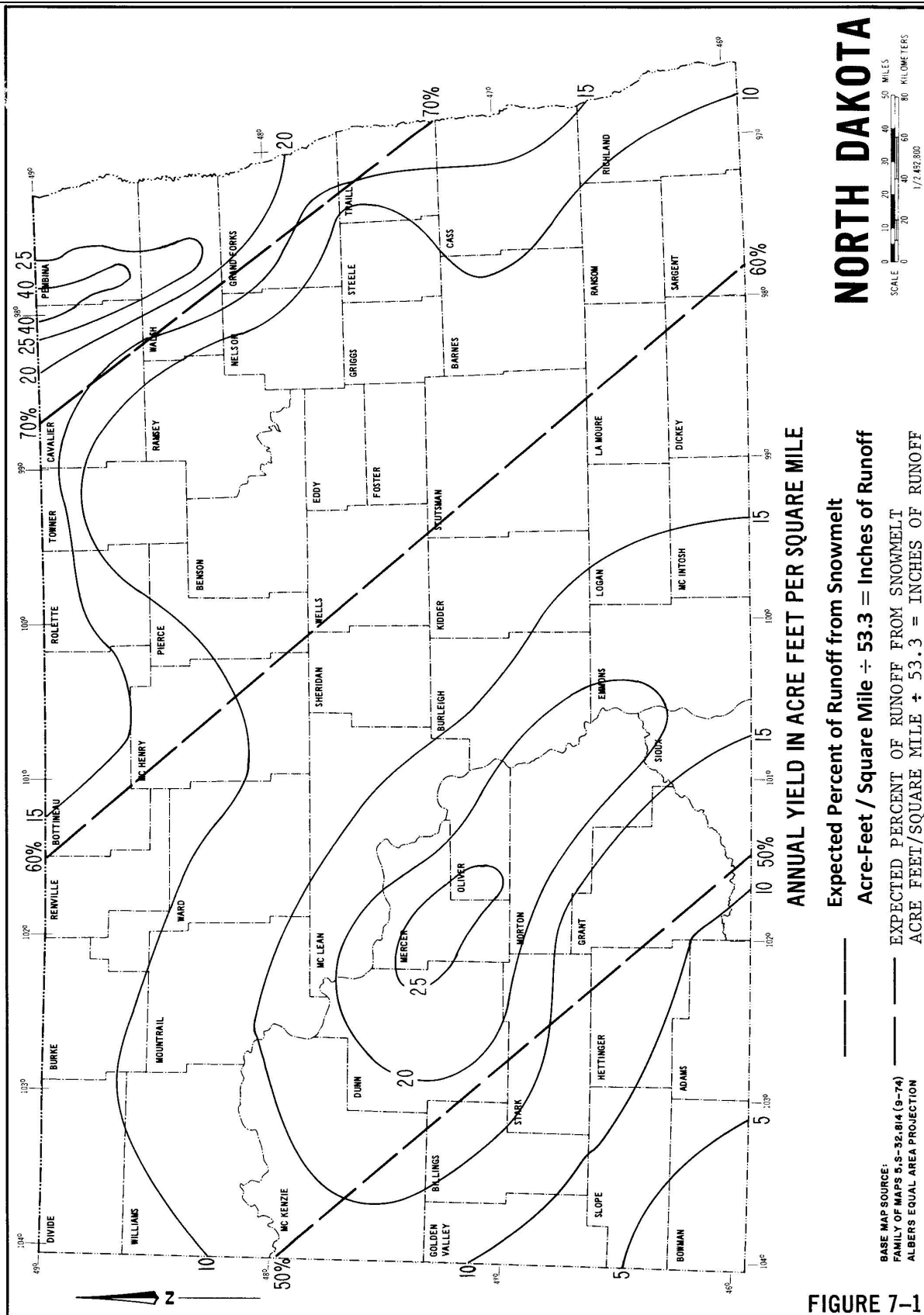


Figure 7-1: Annual Yield – 80% Chance (North Dakota NRCS, 1974)

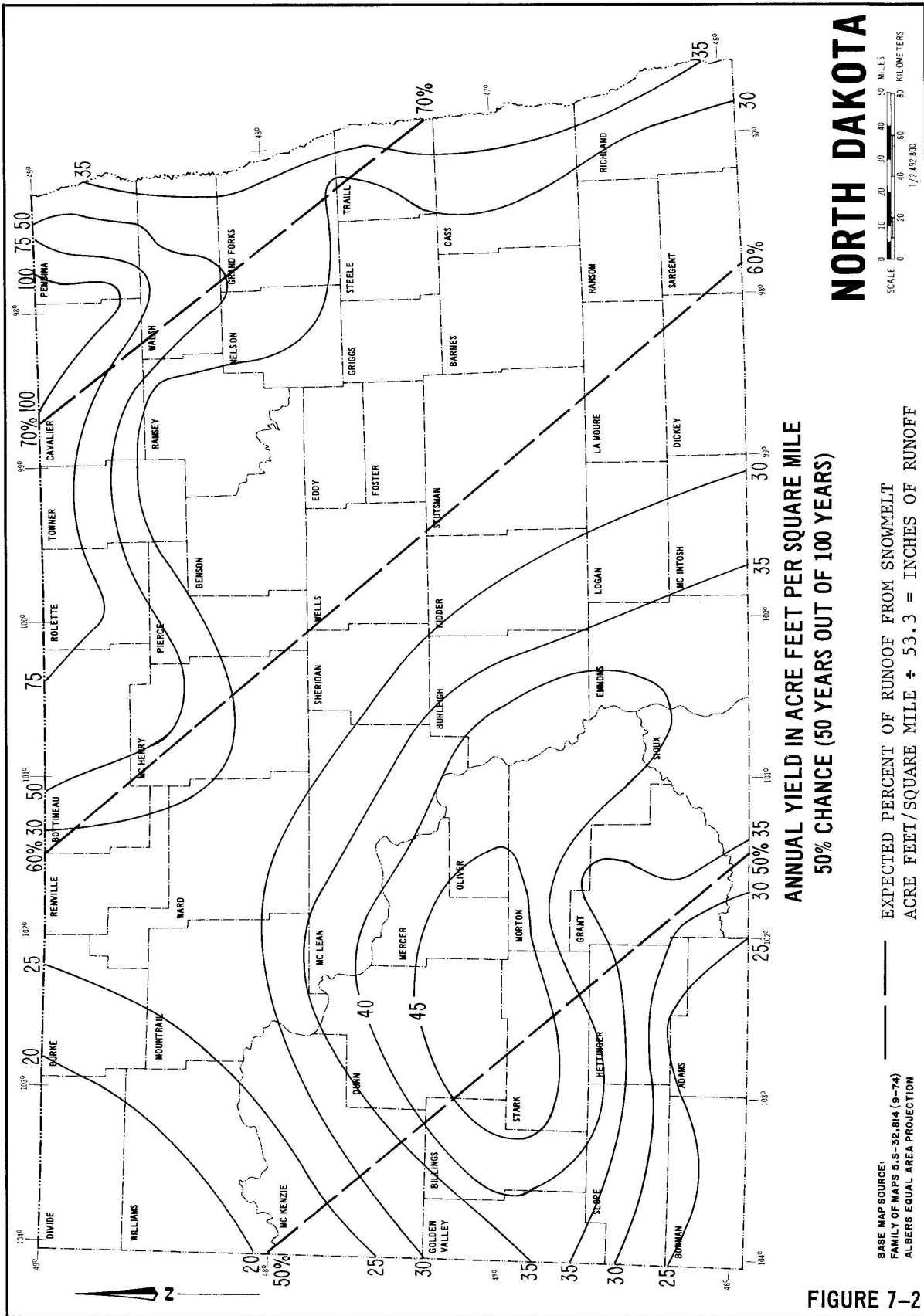


Figure 7-2: Annual Yield – 50% Chance (North Dakota NRCS, 1974)

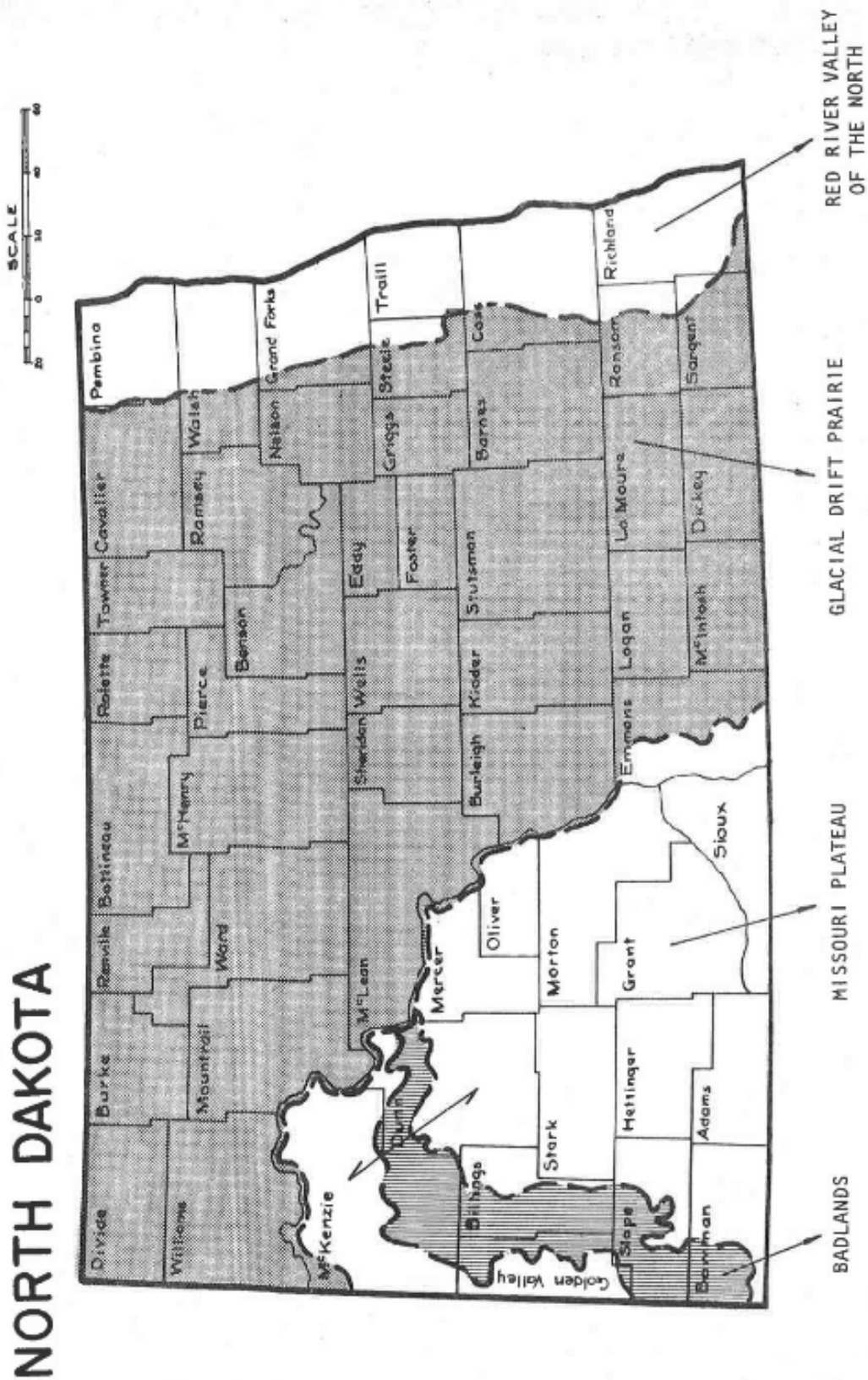


Figure 7-3: Regions of North Dakota (North Dakota NRCS, 1974)