Antecedent Moisture Conditions For North Dakota Runoff Predictions

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The distribution and amount of rainfall occurring during the growing season not only has significant effects on yields of small grains and forages but also has major impacts on sediment pond designs for entrapment of runoff. Both federal and state laws require all runoff and eroded sediments within the boundaries of coal mines in North Dakota be caught in sediment ponds to prevent possible contamination of soils outside the mining areas.

Currently, runoff volume from ungaged watersheds is estimated by the Soil Conservation Service curve number (CN) method (5). This procedure is commonly used and has been incorporated into several other hydrological models such as CREAMS (2). Detailed descriptions of the origin and use of the CN method can be found in articles by Rullison (3) and Boughton (1), respectively.

The CN method uses soil type, surface condition (i.e. fallow, small grain, pasture or range, etc.), and antecedent moisture condition (AMC) to describe the hydrologic properties of the catchment basin before rainfall. Once a CN value has been developed, estimates of direct runoff from rainfall amounts are calculated either from equations (4) or a graphical form of the equations (Figure 1).

Antecedent moisture conditions are determined from the previous five-day rainfall totals which are grouped as shown in Table 1. These groups are qualitatively defined as follows (4):

1. AMC I: Lowest runoff potential. Watershed soils are dry enough for satisfactory cultivation to take place.
2. AMC II: Average condition.
3. AMC III: Highest runoff potential. Watershed soils practically saturated from antecedent rains.

The validity of these AMC groups are suspect in North Dakota due to high potential evapotranspiration and low average monthly rainfall amounts (less than 4 inches) during the growing season. Therefore, the objectives of this study were to: 1) develop frequency distributions for the three AMC groups during the North Dakota growing season for determining validity in a semi-arid climate, 2) develop frequency distributions based on smaller increments within AMC groups I and II, and 3) compare long-term average five-day precipitation totals at the 50 percent probability level between the growing and dormant seasons.

Table 1. Seasonal precipitation limits for AMC for use in the SCS curve number method.

AMC Group	Total five-day antecedent rainfall	
	Growing Season	Dormant Season*
	inches	
I	< 1.4	< 0.5
II	1.4 to 2.1	0.5 to 1.1
III	> 2.1	> 1.1

*Limits apply where vegetative growth is minimal and there is no snow on the ground.

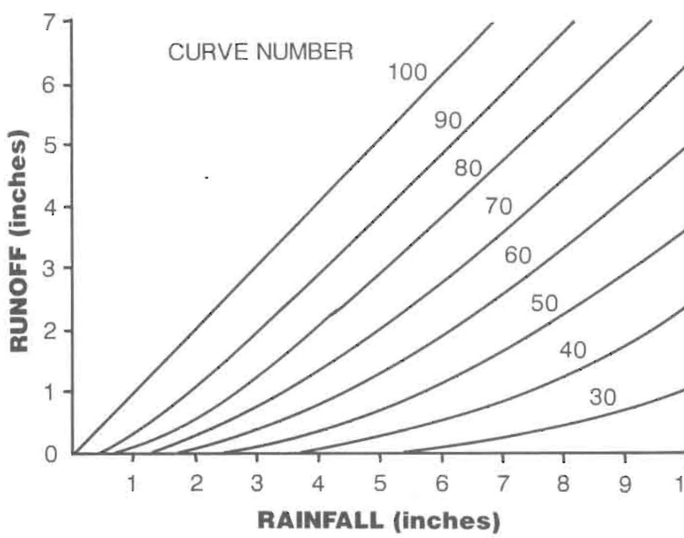

Figure 1. Graphical illustration of estimating runoff from rainall using the SCS curve number method.

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METHODS

U.S. National Weather Service daily precipitation data for the years 1948 through 1986 from 19 locations within North Dakota (Table 2) were used in this study. Precipitation amounts for the preceding five days were calculated for each day from April 1 through October 31 (growing season for this study) for each year. The five-day totals were categorized into the AMC groups shown in Table 1 to determine frequency of occurrence for each AMC group. Frequencies were converted to percentages by dividing by total number of observations for qualitative comparisons.

Frequency distributions for smaller increments within AMC I and II over the same period were also determined by the method described above. Amounts expected 50 percent of the time also were determined for five-day periods for the growing and dormant (November 1 through March 31 for this study) seasons.

RESULTS

Results of this analysis show that dry conditions, defined by AMC I, are dominant throughout the growing season in North Dakota (Table 2). AMC I occurs more than 96 percent of the time in the northwest, decreasing to about 92 percent in the southeast (Figure 2). Antecedent Moisture Condition II, the so called average, ranged from only 2.5 percent in the northwest to 4.5 percent in the southeast. However, the 3.5 region also extends into southwestern North Dakota. This range represents only 5.4 to 9.6 days of "average conditions" during the growing season defined in this study as April through October. Wet conditions (AMC III) exist only 1 to 2.5 percent (2.2 to 5.4 days) per growing season on the average (Figure 2). This means that AMC III does not occur in many years.

In general, these patterns are similar to those for total growing season rainfal (Table 2, Figure 3), which decreases from about 18 inches in the southeast to nearly 11 inches in the northwest. This pattern reflects the increasing distance

Table 2. North Dakota locations used in this study, the percentages of time for each AMC group, and average rainfall during the growing season.*

Location	AMC Group**			Average Rainfall***
	I	II	III	
	% of time			(inches)
Beulah	95.1	3.4	1.5	14.8
Bottineau	94.6	3.4	2.0	15.4
Bowman	95.3	3.0	1.7	13.5
Crosby	96.4	2.5	1.1	12.6
Dickinson	94.7	3.7	1.6	14.2
Dunn Center	94.4	3.6	2.0	14.4
Fargo	93.7	3.9	2.4	16.4
Fessenden	94.6	3.5	1.9	15.0
Grand Forks	93.6	4.0	2.4	14.8
Jamestown	94.1	4.0	1.9	17.1
Langdon	93.8	4.4	1.8	15.8
Mandan	94.9	3.5	1.6	13.9
Minot	94.7	3.1	2.2	14.3
Mohall	93.9	4.1	2.0	14.2
Napoleon	94.6	3.3	2.1	14.9
Oakes	93.6	4.1	2.3	16.3
Wahpeton	92.2	4.9	2.9	18.4
Washburn	93.1	4.7	2.2	15.8
Williston	95.9	2.9	1.2	11.2
Mean	94.4	3.7	1.9	—
Std. Deviation	1.0	0.6	0.4	—

* Growing season defined as April 1 through October 31.
** Based on data from 1948-1986.
*** National Oceanic and Atmospheric Administration data for years 1951-1980.

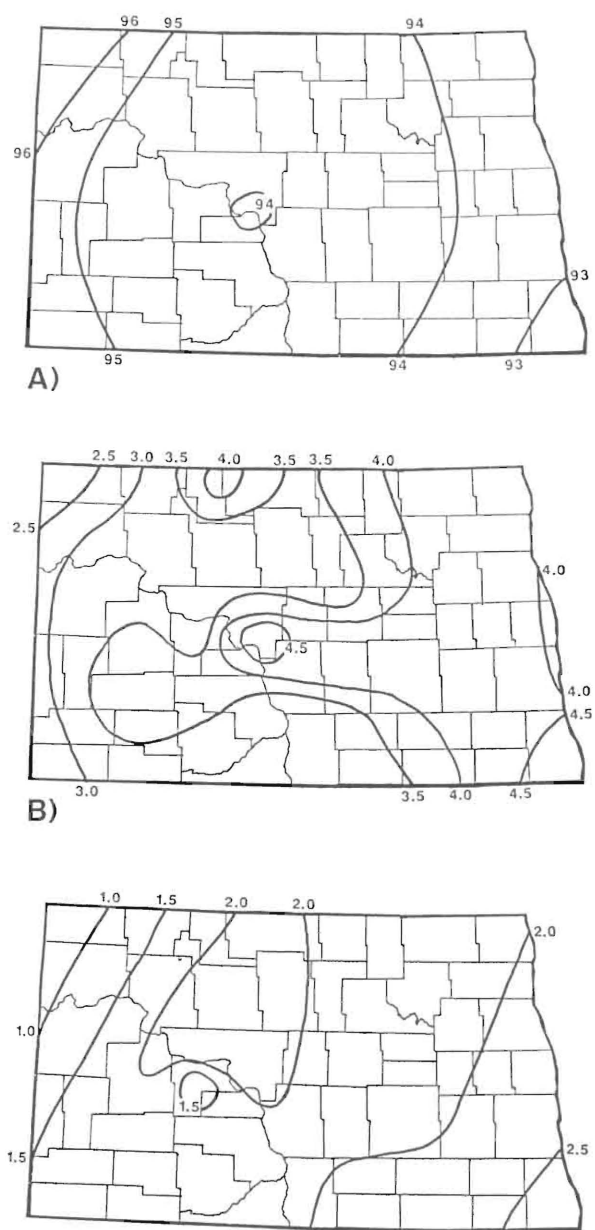

Figure 2. Average time of occurrence (percent) during the April to October growing season of antecedent moisture conditions. A) AMC I. B) AMC II. C) AMC III.

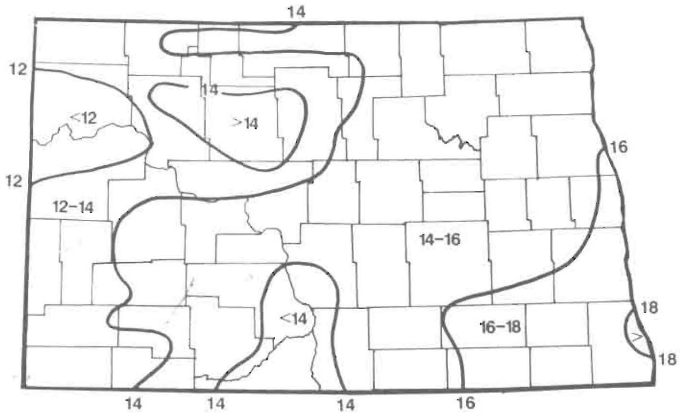

Figure 3. Average growing season (April to October) precipitation for the years 1948-1986.

from the Gulf of Mexico, the source of most of North Dakota's water.

There is surprisingly little variation between eastern and western North Dakota in time of occurrence for each AMC group. For example, AMC II conditions vary from only 2.5 percent to 4.5 percent from west to east across the state despite the 8-inch difference in average growing season precipitation. This small range is dictated by the wide ranges of rainfall amounts in the definitions of the AMC groups (Table 1). There are few days with rainfall totaling more than 0.5 inches in North Dakota. Also, five-day totals are greater in eastern compared to western North Dakota, but in most cases they are still less than 1.4 inches.

These results are very interesting because they are in stark contrast from the rainfall amounts defining the antecedent moisture conditions. According to the definition (Table 1), AMC I, II, and III should represent dry, average, and wet conditions, respectively. Based on these definitions, it is expected that the AMC II conditions should dominate the growing season. That is, AMC II should exist more than 50 percent of the time, especially over such a long time period.

Frequency Analysis

Over 92 percent of the time North Dakota falls into the dry category of AMC I of less than 1.4 inches. Thus further analyses were warranted to determine the true average condition in North Dakota.

A frequency distribution for smaller amounts within AMC I and II is shown in Table 3. Most striking is that zero five-day total rainfall occurs from 25 to 35 percent of the time from eastern to western North Dakota. In addition, five-day totals of 0 to 0.19 inches also occur about 25 to 35 percent of the time. Thus the average (50 percent of the time) condition across the state ranges from 0.08 to 0.16 inches (Figure 4). This is very much smaller than that defined by AMC II. As is evident from Table 3, larger amounts occur with steadily decreasing frequency and with little variation statewide (as measured by the standard deviation). This is not unexpected, since 1-inch rainfalls occur only two to four times a year on the average across the state.

Table 3. Frequency distributions of antecedent rainfall amounts for selected locations in North Dakota.*

	Five-day Antecedent Rainfall (inches)						
	AMC I					AMC II	
Location	0	0.01 to 0.19	0.20 to 0.49	0.50 to 0.99	1.00 to 1.39	1.40 to 1.69	1.70 to 2.09
	% of time						
Beulah	35.6	24.6	17.6	12.2	5.1	1.9	1.5
Bottineau	27.1	31.2	17.9	13.7	4.7	1.8	1.6
Bowman	30.8	30.3	17.6	12.8	3.8	1.6	1.4
Crosby	34.2	27.7	18.6	11.6	4.3	1.3	2.5
Dickinson	29.7	31.0	16.7	12.8	4.5	2.0	1.7
Dunn Center	31.4	27.9	17.3	13.2	4.6	2.2	1.4
Fargo	24.6	31.2	19.4	14.2	4.3	2.2	1.7
Fessenden	33.7	24.3	17.4	14.2	5.0	2.0	1.5
Grand Forks	24.1	32.0	18.2	14.2	5.1	2.1	1.9
·Jamestown	34.2	23.3	17.5	14.2	4.9	2.5	1.5
Langdon	26.4	28.6	18.6	14.0	5.4	2.5	1.9
Mandan	31.3	29.8	16.7	12.1	5.0	1.9	1.6
Minot	30.2	30.2	17.6	12.3	4.4	1.8	1.3
Mohall	33.0	26.7	17.2	12.9	4.1	2.0	2.1
Napoleon	29.3	28.6	17.9	13.7	5.1	1.7	1.6
Oakes	32.5	25.4	16.6	13.7	5.4	2.8	1.3
Wahpeton	24.8	26.7	19.0	15.7	6.0	2.5	2.4
Washburn	35.2	22.1	18.3	12.9	4.6	2.7	2.0
Williston	30.6	36.1	16.5	9.8	2.9	1.8	1.1
Mean	30.5	28.3	17.7	13.2	4.7	2.1	1.7
Std. Deviation	3.6	3.5	0.8	1.3	0.7	0.4	0.4

*Based on data from 1948-1986 for April through October 31.

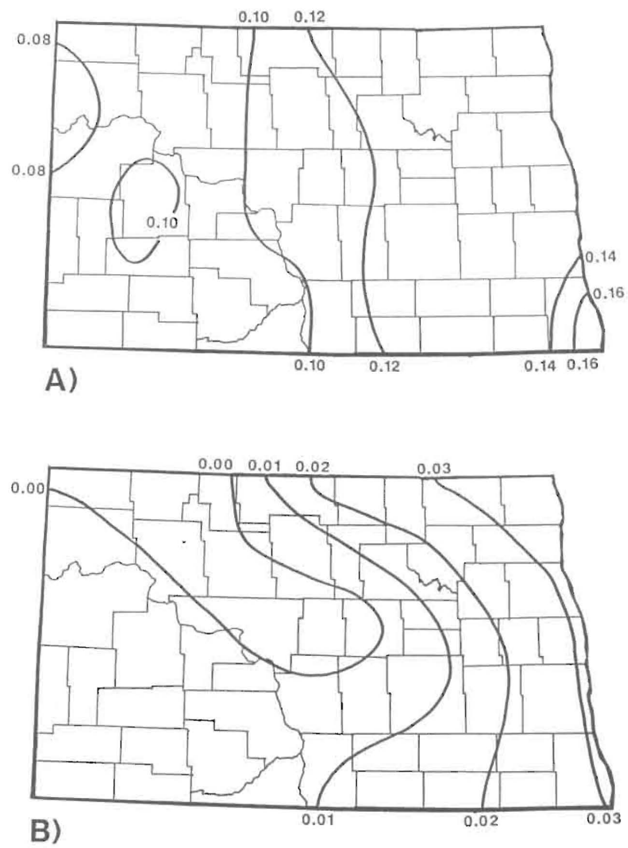

Figure 4. Average five day total precipitation (inches) expected at least 50 percent of the time during the A) April to October growing season. B) November to March dormant season.

A similar analysis during the dormant season shows that average five-day amounts range from 0.00 to 0.03 inches west to east. This is not surprising since the dormant season (November to March) in North Dakota is typically a very dry period. Normal precipitation amounts during this entire period range from 2.5 to 4.0 inches across the state. Precipitation amounts greater than 0.5 inches are extremely rare, occurring on average only once every three years in the west and about once per year in the east.

Thus, even though the definitions for AMC classes are different for the dormant season (Table 1) they are still much too large. However, this is not of great significance because runoff during this period is confined to the spring melt period. Usually this is dependent upon soil water content at freeze-up and the depth of frost in the soil.

CONCLUSIONS

Based on these data, use of the SCS curve number method AMC I grouping in North Dakota during the growing season would be appropriate more than 90 percent of the time. AMC II (SCS average condition) accounts for less than 5 percent of the time and would overestimate expected runoff amounts for average statewide conditions. When designing sediment ponds for mining operations, this could very well mean unnecessary increased construction time and costs. Therefore, since the AMC groupings are not as applicable for semi-arid climates as for humid climates with frequent rainfall events and larger rainfall amounts, this methodology must be used more cautiously in a semi-arid environment to ensure accurate estimation of runoff amounts from rainfall amounts.

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