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AGNPS, Agricultural Non-Point-Source Pollution Model

A Watershed Analysis Tool

ABSTRACT

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Agricultural Non-Point-Source Pollution Model (AGNPS) is a computer simulation model developed to analyze the water quality of runoff from Minnesota watersheds. The model predicts runoff volume and peak rate, eroded and delivered sediment, and nitrogen, phosphorus, and chemical oxygen demand concentrations in the runoff and the sediment for single storm events for all points in the watershed.

Keywords: Computer models, non-point-source pollution, runoff, water quality, watersheds

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- U.S. Department of Agriculture Soil Conservation Service
- Minnesota State planning Agency, Land Management Information Center
- University of Minnesota Department of Agricultural Engineering
- University of Minnesota Department of Soil Science

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A WATERSHED ANALYSIS TOOL

Robert A. Young, Charles A. Onstad, David D. Bosch, and Wayne P. Anderson

INTRODUCTION

The importance of runoff from agricultural lands as a nonpoint source of pollution has brought about an effort in Minnesota to develop a uniform method of analyzing the quality of runoff from agricultural watersheds. Federal Law 92-500, Section 208, has required that all States evaluate upland erosion and determine its effect on water quality. As part of this effort, objectively evaluating potential pollution problems on agricultural watersheds within the State of Minnesota is necessary.

A few years ago the Minnesota Pollution Control Agency (MPCA) realized the need for a uniform method for evaluating agricultural watersheds in the State. The MPCA, the Minnesota Soil and Water Conservation Board, and the U.S. Department of Agriculture's Soil Conservation Service and Agricultural Research Service entered into a memorandum of understanding to develop a model that could analyze both sediment and nutrient transport in a watershed. The model was to be developed for a large computer system to analyze agricultural watersheds. The objectives of the model were to obtain uniform and accurate estimates of runoff quality with primary emphasis on sediment and nutrients, to compare the effects of various conservation alternatives on implementation as part of the management practices of the watershed, and to develop a flexible and easy-to-use model.

The Agricultural Non-Point-Source Pollution Model (AGNPS) presents the user with a means of objectively evaluating non-point-source pollution from agricultural watersheds. The input data for the model can be obtained from readily available records and visual reconnaissance in about 1 person month for larger watersheds (up to 23,000 acres in size), and about 3 person days for smaller watersheds (up to 500 acres in size). Analysis of pollutant loads from feedlots, investigation into the effects of implementing various conservation practices including impoundment terraces, and the ability to output water-quality characteristics at intermediate points throughout the watershed network are all within the model's capabilities. AGNPS is a single-event-based model intended to simulate sediment and nutrient transport primarily from agricultural watersheds in the State of Minnesota, although the principles on which the model is based are not limited to Minnesota. Proceeding from the headwaters of the watershed to the outlet, pollutants are routed in a stepwise fashion so the flow at any point may be examined.

The model works on a cell basis. These cells are uniform square areas that divide up the watershed. This division makes it possible to analyze any area in the watershed. The basic components of the model are hydrology; erosion; sediment transport; and transport of nitrogen, phosphorus, and chemical oxygen demand. In the hydrology portion of the model, calculations are made for runoff volume and peak concentrated flow. Total upland erosion, total channel erosion, and a breakdown of these two sources into five particle size classes (clay, silt, small aggregates, large aggregates, and sand) for each of the cells are calculated in the erosion portion. Sediment transport is also calculated for each of the cells, in the five particle classes as well as the total. The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment-attached pollutants.

Introduction to User's Guide

This section explains how to collect and compile information needed to run AGNPS. It will also serve the computer programmer as a reference in the establishment of data files.

This section outlines and explains the variables needed for the model and describes where they may be obtained. It also explains and provides examples of two methods of establishing input files. The first method is the manual collection method. In this particular method, the user collects all the variables needed for running the model without aid from an outside data source. The second method makes use of the Minnesota Land Management Information System (MLMIS),[1] a geographic information system that contains detailed data for many parts of the State. Much of this information fits the needs of the model and can be used to establish a part of the input file.

AGNPS was written in the FORTRAN IV computer language and developed on a Hewlett-Packard 1000 computer system. Further technical information on the model may be found in the second section of this book, "Model Documentation," which documents the methods and equations used in the model.

Model Basics

AGNPS is intended to provide basic information on water quality to be used to classify non-point-source pollution problems in agricultural watersheds. The model provides outputs on hydrology, with estimates of both volume and peak runoff, and on sediment, with estimates of upland erosion, channel erosion, and sediment yield. Along with these, the user will receive estimates of the pollutants nitrogen (N), phosphorus (P), and chemical oxygen demand (COD), in units of concentration and mass, contained in the runoff and the sediment. The outputs can be examined for either a single cell or for the entire watershed. This information may then be used to rate the watershed objectively against other watersheds, to further pinpoint water-quality problems, and to investigate possible solutions to these problems.

Watersheds examined by the model must be segmented into square working areas called cells. This allows the model to provide water-quality information for specific locations within the analyzed watersheds. Groupings of the cells, determined by drainage pattern, make up numerous subwatersheds. These subwatersheds may be separately analyzed to provide further information on individual watershed sections.

Data required for model execution may be obtained through MLMIS, visual analysis, maps (both topographic and soils) and various technical publications, tables, and graphs, either included in this manual or easily acquired elsewhere. Data can be classified into two categories: watershed data and cell data. Watershed data include information applying to the entire watershed and to the storm event to be simulated. Cell data include physical information describing each of the cells as well as information based on the land practices in the cell. A numbering system is used to label each of the cells and to organize the collected data. Sample data collection forms are illustrated in figures 1-6.

---

[1] Minnesota State Planning Agency
Land Management Information Center
LL45 Metro Square
7th and Robert
St. Paul, MN 55101

Watershed Data File

Sheet Number ________

Watershed Name ______________________________

Cell Number	Receiving Cell Number	SCS Curve Number	Land Slope %	Slope Shape Factor	Field Slope Length ft.	Channel Slope %	Channel Side Slope %	Mannings Roughness Coefficient for the Channel	Soil Erodibility Factor	Cropping Factor	Practice Factor	Surface Condition Constant	Aspect	Soil Texture Number	Fertilization Level	Availability Factor %	Point Source Indicator	Gully Source Level Tons	Chemical Oxygen Demand Factor	Impoundment Factor	Channel Indicator
XXX	XXX	XXX	XX.X	X	XXX	XX.X	XX.X	.XXX	.XX	.XX	X.XX	.XX	X	X	X	XXX	X	XXX	XXX	XX	X

Figure 1
Cell data collection sheet.

Watershed Name ______________________________

Operator ______________________________

File Description ______________________________

____

____

Watershed Data

Watershed Identification ______________________

Area of each cell ________ acres

Number of watershed cells ________

Storm precipition ______ inches

Storm Energy - Intensity ______

Figure 2
Watershed data collection sheet.

Feedlot Data:

Cell Number ________

Feedlot Number ________

	Area (acres)	Curve number
Area 1 Feedlot	________	________
Area 2a	________	________
Area 2b	________	________
Area 2c	________	________
Area 2d	________	________
Area 2e	________	________
Area 2f	________	________
Area 2r Roof area	________	________
Area 3a	________	________
Area 3b	________	________
Area 3c	________	________
Area 3d	________	________
Area 3e	________	________
Area 3f	________	________

Buffer Areas

Section a	Slope	________
	Surface condition constant	________
	Travel distance	________
Section b	Slope	________
	Surface condition constant	________
	Travel distance	________
Section c	Slope	________
	Surface condition constant	________
	Travel distance	________

Animal Type Factors

Animal type	Number	COD factor	P factor	N factor
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________

Figure 3
Feedlot data collection sheet.

Impoundment Data

Watershed Name ____________________

Cell Number	Impoundment Number 1		2		3		4		5		6		7		8		9		10		11		12		13	
	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area	Diameter
XXX	XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX		XX . XXX	

Figure 4
Impoundment data collection sheet.

Watershed Name ____________________

Operator ____________________

File Description ____________________

Supplemental Watershed Information

Sheet Number __________

Cell Number	Soil Type	Hydrologic Soil Group	Surface Texture	Soil Erodibility Factor	Crop Type	Tillage Practices		Management Practice
						Fall	Spring	

Figure 5
Supplementary data collection sheet.

Edit File

Sheet Number ______

Watershed Name ______________________________

Cell Number	Aspect	Land Use Code Number	SCS Curve Number	Land Slope %	Slope Shape Factor	Channel Slope %	Channel Side Slope %	Mannings Roughness Coefficient for the Channel	Soil Erodibility Factor	Cropping Factor	Practice Factor	Fertilization Level	Availability Factor %	Point Source Indicator	Gully Source Level Tons	Impoundment Factor
XXX	X	XX	XXX	XX.X	X	XX.X	XX.X	.XXX	.XX	.XX	.XX	X	XXX	X	XXX	XX

Figure 6
Edit file data collection sheet.

Establishing a Watershed Data File

Preliminary Examination

A preliminary investigation of the watershed is necessary before the input data file can be established. The steps to this preliminary examination are:

Step 1
Obtain a detailed topographic map of the watershed to be analyzed. We recommend a U.S. Geological Survey map, scale 1:24,000. Although this particular map is not required, accuracy and uniformity make it desirable.

Step 2
Using the topographic lines of the map, establish the drainage boundaries of the watershed. If MLMIS is to be used as a data source, the boundaries of the watershed will be documented by them. The boundaries on their files must match those used in the preliminary examination if their data are to be used.

Step 3
Divide the watershed into cells as shown in figure 7. By quartering first the sections and then the quarters, you can divide the watershed into 40-acre cells. If necessary, the cells can again be quartered down to 10 acres. The guidelines for the cell sizes are:

Watershed area (acres)	Cell area (acres)	Cell dimensions (ft)
<2,000	10	660 x 660
>2,000	40	1,320 x 1,320

Only those cells with more than 50 percent of their area within the watershed boundaries should be included. If the MLMIS data files are to be used, their cells must match those drawn up by the user for compatibility in later analyses.

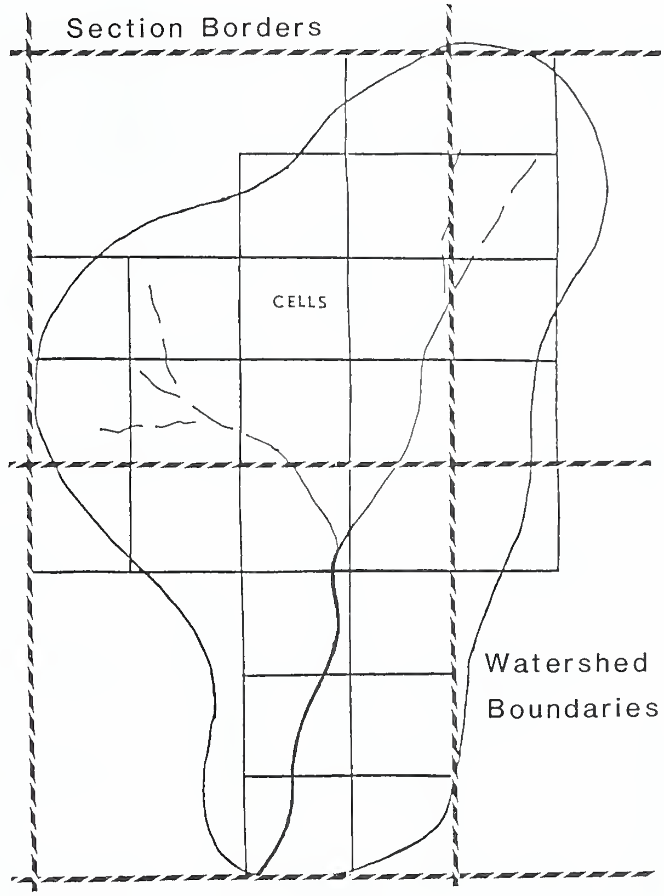

Figure 7
Sample division of a watershed into cells.

On receiving the MLMIS file, lay out the grid system used on the map.

Step 4
Number the cells consecutively from 1 to the number of cells, beginning at the cell in the northwest corner of the watershed and proceeding from west to east southward (fig. 8). This numbering system is used in the model for labeling cells and will aid in quickly identifying the cells in program output.

Step 5
Establish the watershed drainage pattern from the cells. The cell drainage direction is defined as the direction of flow leaving the cell. This can be one of eight possible directions, directly out

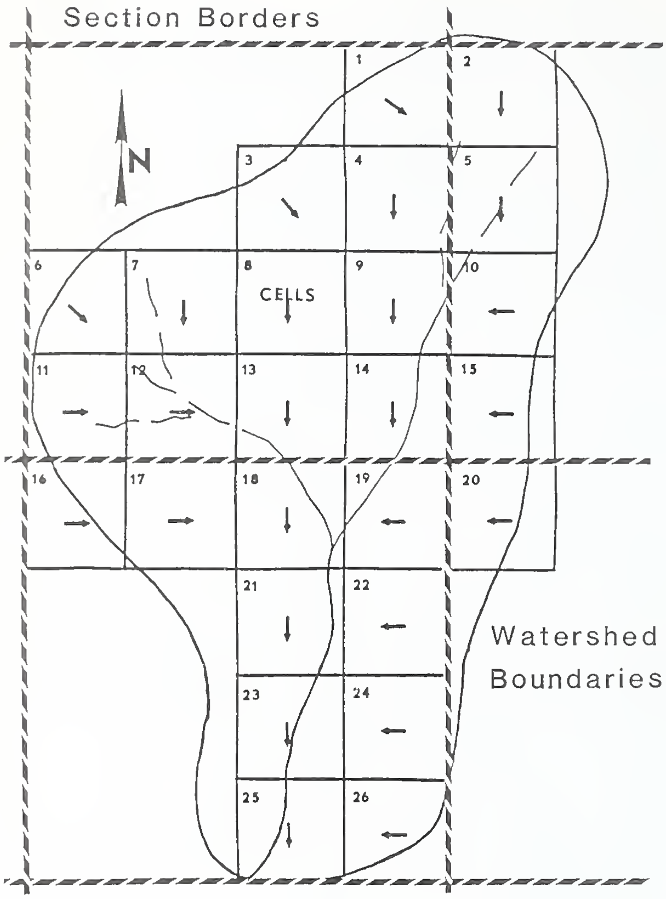

Figure 8
An example of the numbering system used to identify cells and the drainage patterns in the cells.

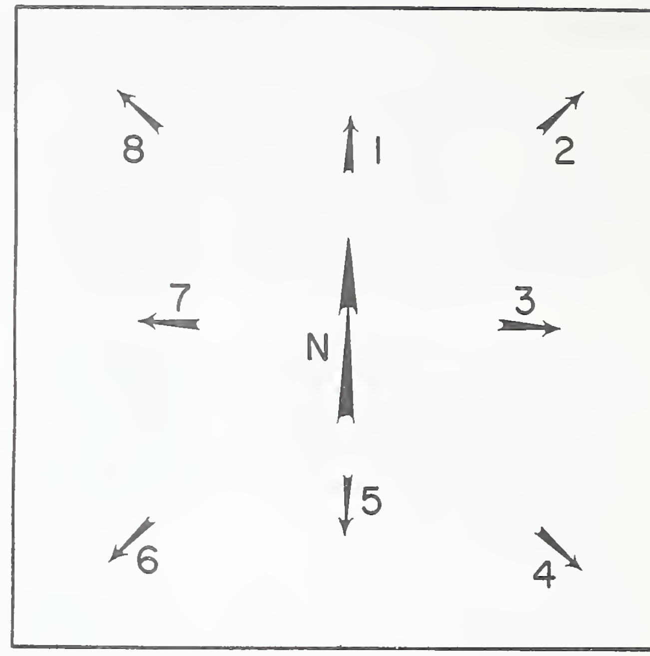

Figure 9
Identification numbers given to each drainage path leaving the cell.

the sides of the cells or out of the corners (fig. 9). This step is most easily accomplished by drawing an arrow out of the cell in the direction of flow, as in figure 8.

Forming a Data File

Once the preliminary examination is complete, the input data file can be established. The data can be obtained from public records and personal inspection and through use of the information in this book. An MLMIS data file can also be used to provide all or part of the information. The data file parameters and the required format for input of this file into the computer model are shown in table 1. An explanation of the data file and information outlining the collection of the data follows. The steps required repeat and expand on some of the steps used in the preliminary examinations.

Line 1
Watershed identification: This is a name, 30 characters or fewer, given to each watershed. It identifies the input and output data files for the watershed.

Line 2
Area of each cell: Each watershed is divided into square, uniform units called cells (fig. 7). The size of these cells depends on the degree of detail desired in the analyses and on the size of the watershed. For watersheds up to 2,000 acres in size, we recommend 10-acre cells, and for larger watersheds, 40-acre cells. But, if a very detailed investigation is desired, you can use 2.5-acre cells for the smaller watersheds and 10-acre cells for the larger ones. Likewise, you can use larger than recommended cells.

Table 1.
Data file parameter explanation and input format

Basic watershed (no impoundment terraces or feedlots)[1]

Line	Parameter
1	Watershed identification (description, 30-character maximum)
2	Area of each cell (acres)/number of cells/precipitation (inches)/ energy-intensity value of the storm/description Format (F4.1, I4,2F6.1,10X,A)
3-end of file	Cell parameters

Column	Content
1	cell number
2	receiving cell number
3	SCS curve number (table 2)
4	land slope (percent)
5	slope shape factor: 1--uniform, 2--convex, 3--concave
6	field slope length (feet) (table 4)
7	channel slope (percent)
8	channel sideslope (percent)
9	Manning's roughness coefficient for the channel (table 5)
10	soil erodibility factor
11	cover and management factor (appendix 5)
12	support practice factor (Wischmeier and Smith 1978)
13	surface condition constant (table 2)
14	aspect (number showing direction of drainage, fig. 9)
15	soil texture: 0--water, 1--sand, 2--silt, 3--clay, 4--peat
16	fertilization level: 0--none, 1--low, 2--medium, 3--high
17	fertilizer availability factor (percentage of fertilizer left in top one-half inch of soil, table 7)
18	point source indicator (a single-digit number other than 0 denotes the number of sources in the cell)
19	gully source level (tons)
20	chemical oxygen demand (COD) factor (table 8)
21	impoundment factor (number of ponds in the impoundment terrace system, maximum of 13)
22	channel indicator (a single-digit number other than 0 denotes the number of channels in the cell)
Format	(3I4,F5.1,I2,I4,2F5.1,F5.3,2F4.2,F5.2,F4.2,3I2,I4,I2, 2I4,I3,I2)

See footnote at end of table.

Table 1.--Continued
Data file parameter explanation and input format

Watersheds with one or more point sources[1]	
Line	Nonfeedlot point source parameters
1	1/flow (cfs)/TN (p/m)/TP(p/m)/COD(p/m) Format (I1,I5,3F7.1)
	Feedlot parameters
1	2/feedlot area (acres)/feedlot curve number Format (I1,F6.2,I4)
2	Acres of roofed area/area 2 subareas area (acres)/subareas curve numbers (up to six subareas) Format (7F6.2,6I4)
3	Area 3 subareas area/subareas curve numbers Format (6F6.2,6I4)
4	Buffer area slope/surface condition constant/flow length (feet) (up to 3 sets of data for a buffer area) Format (F5.1,F5.2,I4, F5.1,F5.2,I4,F5.1,F5.2,I4)
5	Number of animal type/COD factor/phosphorus factor/nitrogen factor (up to three different animal types) Format (I5,3F5.2, I5,3F5.2,I5,3F5.2)

Watershed with one or more impoundment terraces[1]	
Line	Parameter
1	Area draining into the impoundment (acres)/diameter of impoundment's pipe outlet (inches) Format (F4.1,I2) (up to 13 pairs of data in this format)

[1]If an impoundment terrace or a point source such as an animal feedlot, spring, waste treatment plant, etc., is in the cell, more information is needed--one line of impoundment data or nonfeedlot point-source data, if any, followed by 5 lines of feedlot data, if any.

Number of cells: The number of cells in the watershed.

Precipitation: To make uniform comparisons among watersheds, you will normally input a precipitation value in inches appropriate for the particular watershed area for a 24-hour, 25-year storm frequency. If further analysis is desired, different storms can also be simulated by the model. See appendix 1 for the rainfall frequency values for Minnesota.

Energy-intensity value: This value is the rainfall erosion index used in the universal soil loss equation (USLE). The value must be for a single storm event only, in units of foot-tons per acre-inch. The energy-intensity values appear along with the rainfall frequency curves in appendix 1.

Description (optional): A brief statement describing specific conditions that the data represents, i.e., year, conservation practices installed, etc.

Line 3 to end of file

Cell Parameters

1. Cell numbers: Each cell in the watershed is identified by a number. The cells are numbered consecutively from the cell in the northwest corner and proceeding from west to east southward (fig. 8).

2. Receiving cell number: The number of the cell into which the most significant portion of the runoff drains. Drainage direction is determined by cell topography. An example is shown in figure 8. An arrow represents the drainage direction from cell number 17 as east, so its receiving cell would be number 18. The receiving cell number for the watershed outlet must be a number greater than the total number of cells in the watershed. Thus the number for the receiving cell for cell number 25 in figure 8 would be any number greater than 26.

3. SCS curve number: The runoff curve number or hydrologic soil-cover complex number used in the SCS (U.S. Department of Agriculture, Soil Conservation Service) equation for estimating direct runoff from storm rainfall. Although the curve number for any antecedent moisture condition may be used, we recommend a value for moisture condition II to keep the analyses consistant. Table 2 gives curve numbers for various land-use conditions in rural areas. For other conditions not listed, refer to the Hydrology Guide for Minnesota (U.S, Department of Agriculture, Soil Conservation Service 1976). For moisture condition I or III, equivalent curve numbers are given in table 3. If more than one land-use condition exists within a cell, use a weighted average value if possible.

4. Land slope: The major slope, in percent of rise, of the cell. This can be obtained from topographic maps, existing data, or actual measurements. Assume an average slope if the cell is irregular. If the cell is mainly water or marsh, enter a value of 0.

5. Slope shape factor: An identification number used to indicate the dominant slope shape of the cell: 1, a uniform slope; 2, a convex slope; and 3, a concave slope (fig. 10).

6. Field slope length: Field slope length can be found by using figure 11 along with table 4. If the cell is mainly water or marsh, enter a value of 0.

Table 2.
Runoff curve numbers and surface-condition constants for various land-use situations

Land-use condition	Surface-condition constant[1] c	Runoff curve number[2]			
		Soil group A	Soil group B	Soil group C	Soil group D
Fallow	0.22	77	86	91	94
Row crop					
Straight row	.05	67	78	85	89
Contoured	.29	65	75	82	86
Small grain	.29	63	74	82	85
Legumes or rotation meadow	.29	58	72	81	85
Pasture[3]					
Poor	.01	68	79	86	89
Fair	.15	49	69	79	84
Good	.22	39	61	74	80
Permanent meadow	.59	30	58	71	78
Woodland	.29	36	60	73	79
Forest with heavy litter	.59	25	55	70	77
Farmsteads	.01	59	74	82	86
Urban (21%-27% impervious surfaces)	.01	72	79	85	88
Grass waterway	1.00	49	69	79	84
Water	0	- - - - - - - - - 100 - - - - - - - - -			
Marsh	0	- - - - - - - - - 85 - - - - - - - - -			
Animal lot					
Unpaved		- - - - - - - - - 91 - - - - - - - - -			
Paved		- - - - - - - - - 94 - - - - - - - - -			
Roof area		- - - - - - - - - 100 - - - - - - - - -			

[1]Source: Young et al. (1982a).

[2]Source: U.S. Department of Agriculture, Soil Conservation Service (1976). Values given are for Antecedent Moisture Condition II.

[3]Pasture should be considered "poor" if it is heavily grazed with no mulch. "Fair" pasture has between 50% and 75% plant cover and is moderately grazed. "Good" pasture is lightly grazed and has more than 75% plant cover.

Table 3.
Runoff curve numbers for AMC I and III corresponding to AMC II

Curve number for condition II	Curve number for conditions--	
	I	III
94	85	98
91	80	97
89	80	97
86	72	94
85	70	94
84	68	93
82	66	92
81	64	92
80	63	91
79	62	91
78	60	90
77	59	89
75	57	88
74	55	88
73	54	87
72	53	86
71	52	86
70	51	85
69	50	84
68	48	84
67	47	83
65	45	82
63	43	80
61	41	78
60	40	78
59	39	77
58	38	76
55	35	74
49	30	69
39	21	59
36	19	56
30	15	50
25	12	43

Source: U.S. Department of Agriculture, Soil Conservation Service (1972).

Table 4.
Slope length in feet according to major field slope length area and land slope

Major field slope length area	Slope length (feet) by slope steepness category (%)--			
	0-2	3-6	7-12	≥13
1	100	125	100	75
2	100	250	200	150
3	200	250	200	150
4	200	200	200	200

Source: Otterby and Onstad (1978).

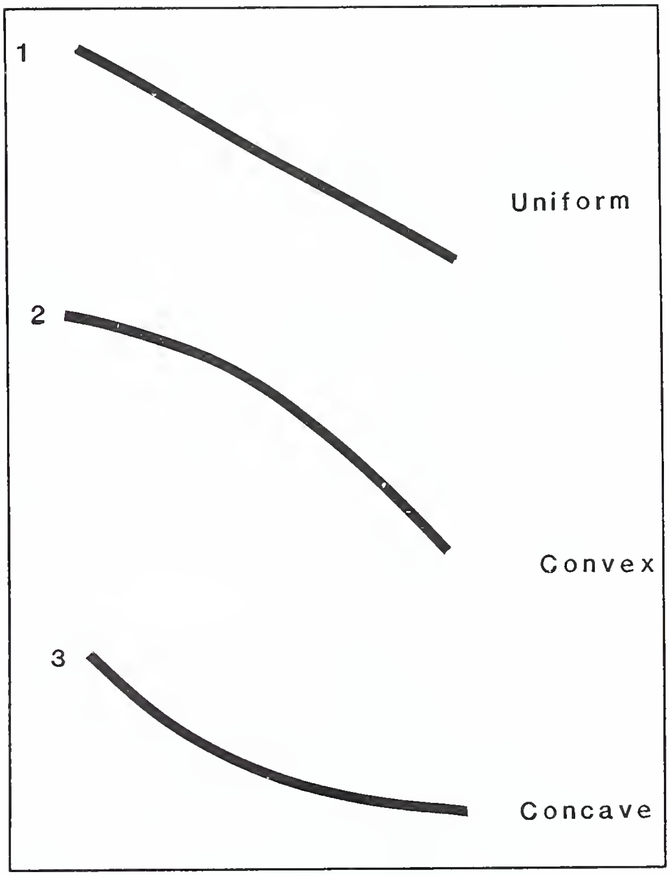

Figure 10
Examples of various slope shapes and the identification numbers given to each.

Figure 11
Division of Minnesota into major field slope length areas.

7. Channel slope: The average slope, in percent, of the channel or channels, in the cell. This can be obtained from the topographic maps, existing data, or actual measurements. If there is no definable channel within the cell, assume a series of small channels, with an average slope equal to half the land slope. If the cell is mainly water or marsh, enter a value of 0.

8. Channel sideslope: The average sideslope, in percent, of the channel or channels in the cell. If no value can be measured or estimated, assume a sideslope of 10 percent. If the cell is mainly water or marsh, enter a value of 0.

9. Manning's roughness coefficient for the channel: Values of various roughness coefficients for different land-use conditions at the time of the storm are shown in table 5. If there is no definable channel within the cell, select a roughness coefficient appropriate for the main surface condition in the cell.

10. Soil erodibility factor: The K-factor used in the USLE, obtained from SCS soils data. If the cell is mainly water or marsh, enter a value of 0.

11. Cover and management: The C-factor used in the USLE. Since we are working on a storm basis, the value to be used is the soil loss ratio corresponding to the appropriate period of the growing season. In order to keep the analyses consistent among different watersheds, you will normally examine the worst-case condition occurring during the fallow or seedbed periods. Appropriate soil loss ratio values can be obtained from the tables in appendix 5. These tables were copied in their entirety from Wischmeier and Smith (1978). If the cell is mainly water or marsh, enter a value of 0. If the cell is mostly urban or residential, enter a value of 0.01.

12. Support practice factor: The P-factor used in the USLE. To examine a worst-case situation, assume a practice factor of 1.0. Other values for various conservation practices can be found in Wischmeier and Smith (1978). P-factors for terraced fields can be found in table 6. If the cell is mainly water or marsh, enter a value of 0. If the cell is mostly urban or residential, enter a value of 1.0.

13. Surface condition constant: A value based on land use at the time of the storm to make adjustments for the time it takes overland runoff to channelize. Values are shown in table 2.

Table 5.
Manning's roughness coefficients for channelized flow

Natural channels[1]	
Description	**n**
Excavated or dredged channels	
Ordinary concrete	0.013
Earth, straight, uniform, and clean	.022
Same, but with some short grass or weeds	.027
Earth, winding and sluggish, with no vegetation	.025
Same, but with some grass or weeds	.030
Channels not maintained; weeds and some brush	.080
Natural streams	
Clean and straight; no rifts or deep pools	.030
Clean and winding; some pools and shoals	.040
Clean and winding; some weeds, stones, and pools	.048
Sluggish reaches with weeds and deep pools	.070

Cultivated land and waterways[2]	
Cover and cover density	**n**
Smooth, bare soil	
less than 1 inch deep	0.030
1-2 inches deep	.033
2-4 inches deep	.038
4-6 inches deep	.045
Cornstalks (assumes residue stays in place and is not washed away)	
1 ton/acre	.050
2 tons/acre	.075
3 tons/acre	.100
4 tons/acre	.130
Wheat straw (assumes residue stays in place and does not wash away)	
1 ton/acre	.060
1.5 tons/acre	.100
2 tons/acre	.150
4 tons/acre	.250
Grass (assumes grass is erect and as deep as flow)	
Sparse	.040
Poor	.050
Fair	.060
Good	.080
Excellent	.130
Dense	.200
Very dense	.300

See footnotes at end of table.

Table 5.--Continued
Manning's roughness coefficients for channelized flow

Cultivated land and waterways[2]	
Cover and cover density	n
Small grain (20% to full maturity--rows with flow)	
Poor, 7-inch rows	0.130
Poor, 14-inch rows	.130
Good, 7-inch rows	.300
Good, 14-inch rows	.200
Water or marsh[3]	.990

[1]Source: Chow (1959).

[2]Source: Foster et al. (1980).

[3]Value serves as a flag only to tell the computer that the surface is water.

Table 6.
Sediment delivery subfactor, P, for terraces[1]

Terrace grade (%)	P
Closed outlet[2]	[3]0.05
0 (level)	.10
.1	.13
.2	.17
.4	.29
.6	.49
.8	.83
≥.9	1.00

[1]Source: Foster and Highfill (1983). Potential for net erosion in terrace channels depending upon flow hydraulics and soil erodibility in the channels. If net erosion occurs, P>1.

[2]Includes terraces with underground outlet.

[3]Wischmeier and Smith (1978).

14. Aspect: A single digit designating the principal direction of drainage from the cell. This can be one of eight possible directions, 1 being north and proceeding clockwise, 8 being northwest (fig. 9). If there is no drainage from the cell, input a 0.

15. Soil texture: The major soil texture classification for the cell. The major soil texture can be determined from the texture triangle shown in figure 12. The texture classes and numbers to designate each are:

Texture	Input value
Water	0
Sand	1
Silt	2
Clay	3
Peat	4

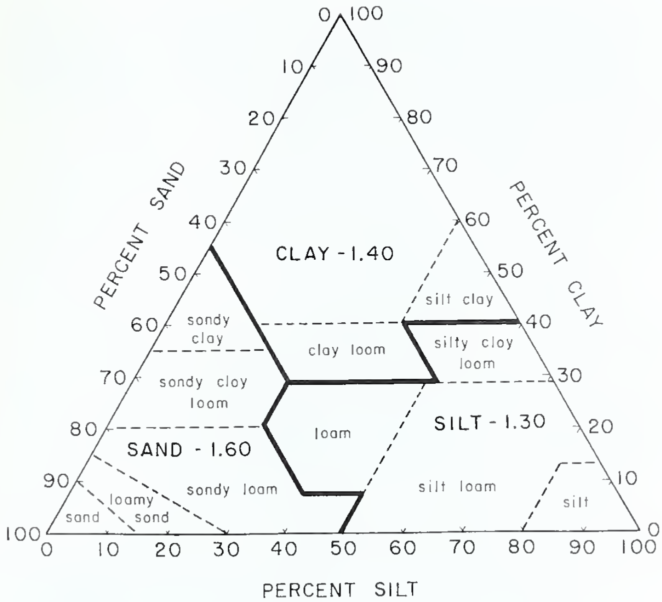

Figure 12
Soil bulk density (g/cm^3) for each of the major soil textures.

16. Fertilization level: A single digit designation of the level of fertilization on the field. The number to be input and the levels are:

Level of fertilization	Assumed fertilization (lb/acre) N	P	Input
None	0	0	0
Low	50	20	1
Medium	100	40	2
High	200	80	3

For a manure-applied field, assume low fertilization for an average application of manure and medium fertilization for a heavy application of manure. If the cell is mainly water or marsh, the fertilization level is 0. If the cell is mainly urban or residential, the normal input would be a value of 0. But if high levels of fertilization are known to be practiced locally (for example, lawns), then input an appropriate fertility level.

17. Fertilizer availability factor: The percentage of fertilizer left in the top half inch of soil at the time of the storm. The worst case would be if none of the fertilizer had been incorporated into the soil, an availability factor of 100 percent. Availability factors for various tillage practices are shown in table 7. If the cell is mainly water or marsh, enter a value of 0. If it is mostly urban or residential, enter a value of 100.

18. Point source designator: A single-digit designator of point sources in the cell, such as feedlots, springs, and waste treatment plants: 0 denotes no point sources; any other number designates the number of

Table 7.
Fertilizer availability factors according to tillage practice

Tillage practice[1]	Fertilizer availability factor (%)
Large offset disk	40
Moldboard plow	10
Lister	20
Chisel plow	67
Disk	50
Field cultivator	70
Row cultivator	50
Anhydrous applicator	85
Rod weeder	95
Planter	85
Smooth	100

[1]If more than one tillage has been made since the fertilizer application, use the product of the two factors divided by 100.

Source: Williams (1983).

point sources discharging within the cell boundaries. If one or more point sources are in the cell, the appropriate point source data will need to be input using the format specified in table 1.

19. Gully source level: If desired, an estimate can be made for the tons of gully erosion occurring in the cell. This value will then be included in the total amount of sediment eroded in the cell.

20. Chemical oyxgen demand (COD) factor: A value for the COD concentration from the cell, based on the land use in the cell. The COD factors for various land-use situations are shown in table 8.

21. Impoundment factor: A factor indicating the presence of an impoundment terrace system within the cell. Zero would indicate no terrace in the cell; any other number would be the number of impoundments in the terrace system, with a maximum of 13. The area in acres draining into each impoundment and the diameter in inches of the outlet pipe of each impoundment will need to be input using the format specified in table 1.

22. Channel indicator: A single digit indicating the presence of a defined channel within the cell: 0 denotes no defined channel; any other number indicates the number of channels in the cell.

Point Source Inputs

Nonfeedlot: If there is a point source in a cell that is not a feedlot, such as a spring or a waste treatment plant discharge, the information describing the source must come immediately after the basic cell data. As described in table 1, the input information includes a 1 as the first digit, to indicate that the source is not a feedlot. The remaining information includes the incoming flow rate in cubic feet per second and the inflow concentration of N, P, and COD in parts per million. These data are entered as a separate line for each nonfeedlot point source in the cell.

Feedlots: In the event that the point source input in any of the cells in the watershed is from an animal feedlot, the feedlot variables mentioned in the data file format (table 1) will have to be input. The first digit will be a 2 to indicate that the source is a feedlot. For an explanation of the remaining variables, refer to Young et al. (1982a). All variables required for input, except the nitrogen factor, can be found in Young

Table 8.
Chemical oxygen demand (COD) factors for various land-use situations

Land use[1]	COD factor (mg/L)
Row crops	170
Small grain	80
Pasture and open	60
Alfalfa	20
Forested	65
Fallow	115
Farmsteads and urban nonresidential	80
Water	0
Marsh	25

[1]Sources of data are as follows: Row crops and fallow, Thompson et al. (1978), Harms et al. (1974); small grain and alfalfa, Harms et al. (1974); pasture and open land, Crow et al. (1979), Thompson et al. (1978), Harms et al. (1974); forested land, Timmons et al. (1977), R. A. Young, unpublished data; and farmstead and urban nonresidential, Weibel (1969).

et al. (1982a). The nitrogen factors can be obtained from table 9. The feedlot data can be recorded as shown in figure 3.

Impoundment Terraces

Item number 21 indicates the number of impoundments in the cell. The data describing the impoundments will come immediately after the basic cell data. As described in table 1, the impoundment variables include the area draining into the impoundment in acres and the diameter of the impoundment outlet pipe in inches. These variables are entered in pairs, describing each impoundment in the terrace system. The impoundment data can be collected as shown in figure 4.

Table 9.
Ratio of total nitrogen produced by various animals to that produced by a 1,000-pound slaughter steer

Animal type[1]	Design weight[2] (pounds)	Ratio N
Slaughter steer	1,000	1.00
Young beef	500	.60
Dairy cow	1,400	1.68
Young dairy stock	500	.46
Swine	200	.26
Feeder pig	50	.07
Sheep	100	.13
Turkey	10	.02
Chicken	4	.01
Duck	4	.01
Horse	1,000	.81

[1]Data from Midwest Plan Service (1975) except for swine, which is from American Society of Agricultural Engineers (1982).
[2]Interpolation of values should be based on the maximum weight animals would be expected to reach.

Recording Data

The data file can be collected and organized on data sheets. Separate sheets are provided for collection of the watershed data (fig. 2), the cell data (fig. 1), the impoundment data (fig. 4), and the feedlot data (fig. 3). In most cases, general information about the soil characteristics and the land use in each cell must be collected before many of the cell parameters can be established. Supplementary data collection sheets are provided for this purpose (fig. 5). It should be noted that values given in the tables and figures are based mainly on average values found in the literature. If, for any variable, you recognize that the value given in the table or figure is not correct for that particular cell, input a value you know to be more accurate.

For those cells where you cannot decide what value to input for a particular variable because of nonuniform conditions in a cell, use a weighted average whenever possible. If this is not practical because of time or labor limitations, a value should be selected corresponding to the predominant condition in the cell. This applies to parameters 3, 4, 7, 8, 9, 10, 11, 12, 13, 17, and 20.

Appendix 2 contains a demonstration of how to set up a data file for input into the model.

Using MLMIS Data

A data file containing many of the cell parameters required as input can be obtained from MLMIS (see "Introduction to User's Guide"). Using the MLMIS data file[2] can minimize the actual number of

[2]An explanation of the MLMIS data file can be found in appendix 3.

parameters you must search for. Collect the information not provided by MLMIS and record it in a computer file called an edit file. Along with these data, you may also enter values into the edit file to override the MLMIS data. A separate computer program (DBDFL) has been written to combine the two files and form the required model input data file. The requirements for establishing a data file through this method are:

1. A data file on the watershed obtained from MLMIS, which contains the following information:

    a. row designation
    b. column designation
    c. township number
    d. range number
    e. section number
    f. 40-acre parcel/or 10-acre parcel
    g. minor watershed
    h. primary land use
    i. forest cover
    j. soil erodibility code
    k. land slope (percent)
    l. soil texture
    m. river slope (percent)
    n. 30° aspect
    o. river-channel designation
    p. eight-way aspect

    The base level of information used in this data file must be compatible with the one you set up. That is, the cell division established must be identical for both data sources. The MLMIS data file begins in the northwest corner of the watershed and proceeds in the same fashion as the numbering system described in step 4 of the preliminary examination.

2. A name to be applied to the output data file (up to six characters).

3. A 30-character name to be applied to the watershed and the data file.

4. A desired area (acres) for each cell.

5. Storm characteristics. The user has the option of using a default storm such as one of 25-year, 24-hour frequency, or of entering different storm characteristics. If the user chooses to enter a different storm, the following data will be required:

    a. storm precipitation (inches)[3]
    b. storm energy-intensity value[3]

6. Field slope length area number. This number can be obtained from figure 11.

7. If no value has been recorded in the MLMIS data file for the soil erodibility of the cell, one will have to be input.

In using DBDFL to generate a parameter file, you can input as many known values as desired. DBDFL takes the information previously mentioned and generates a preliminary data file. This contains variable estimates, or default values, made by the computer using the available information. Since the computer can only make rough estimates of the variables, we do not recommend watershed analysis using the default file. Through use of a separate file containing parameter values you have chosen, you can edit the preliminary data file. Through the editing process, you can input as many known values into the final data file as desired.

A listing of the parameters in the edit file is shown in table 10. Item 3, land-use code, can be determined using table 11. All other items are as

---

[3]Refer to appendix 1 for rainfall frequency and energy-intensity curves.

Table 10.
Parameter explanation for the edit file

Edit file

Line 1 to end of file--Cell parameters
 	
1. Cell number
2. Aspect[1]--number indicating direction of drainage (fig. 9)
3. Land-use code (table 11)
4. SCS curve number (table 2)
5. Land slope (%)
6. Slope shape factor (fig. 10)
    1--uniform slope
    2--convex slope
    3--concave slope
7. Channel slope (%)
8. Channel sideslope (%)
9. Manning's roughness coefficient for the channel (table 5)
10. Soil erodibility factor
11. Cropping factor
12. Practice factor
13. Fertilization level
    1--low fertilization
    2--average fertilization
    3--high fertilization
    4--no fertilization
14. Fertilizer availability factor (%) (table 7)
15. Point source designator (a single digit number other than 0 designates the number of sources in the cell)
16. Gully source level (tons)
17. Impoundment factor (indicates the number of impoundments)
 	
Format (I4,I2,I3,I4,F5.1,I2,2F5.1,F5.3,3F4.2,I2,I4,I2,I4,I3)

[1]At the present time, the aspects given by the MLMIS data file have been found to be inaccurate. For this reason, input of the aspects of all of the cells into the edit file is required.

described in "Establishing a Watershed Data File." In the edit file, you may input the values for whichever items are known and leave the rest blank. When a 0 value or a blank is found by the computer, no change will be made for that item in the data file. An example of the use of DBDFL and the various options available, including the edit file, are shown in appendix 4.

A collection form for the edit file can be found in figure 6.

Table 11
Land-use codes for the edit file.

Land-use category	Code
Fallow	1
Row crop	
Straight row	2
Contoured	3
Small grain	4
Legumes or rotation meadow	5
Pasture	
Poor	6
Fair	7
Good	8
Permanent meadow	9
Woodland	10
Forest with heavy litter	11
Farmsteads	12

Model Output

The basic output from AGNPS includes hydrology, with estimates of both volume and peak runoff; sediment, with estimates of upland erosion, channel erosion, and sediment yield; and nutrients, with estimates for nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) in concentration and mass units. Sediment results are available for five particle-size classes: clay, silt, small aggregates, large aggregates, and sand.

AGNPS allows various output options. The outputs can be examined for a single cell or for the entire watershed. A preliminary output, given for all watersheds being examined, includes watershed and cell areas, storm precipitation and erosivity, estimated values at the watershed outlet of runoff volume and peak flow rate, and a detailed analysis of the sediment and nutrient yields (fig. 13). The detailed sediment analysis includes area-weighted erosion rates for both upland and channel, sediment delivery ratios, sediment enrichment ratios, mean sediment concentrations, area-weighted yields, and net sediment yields. These values are given for each of the five particle-size classes of sediment, as well as for the total sediment. The detailed nutrient analysis includes the N and P mass per unit area for sediment-adsorbed nutrients; the soluble N, P, and COD mass per unit area in runoff; and the N, P, and COD concentration in the runoff.

Additional information is also available for selected individual cells in the watershed when requested (fig. 14). Information given when examining individual cells includes runoff and sediment analyses for each cell. Runoff analysis provides estimates for each cell of drainage area, runoff volume, percent of runoff volume entering the cell from above, and peak runoff rate. Sediment analysis provides estimates for each cell of upland erosion rate, amount of sediment generated within the cell, amount entering the cell from above, the sediment yield leaving the cell, and percent deposition in the cell. A negative sign preceding percent of deposition indicates channel scouring in the cell. An option also exists to provide the cell sediment analysis broken down into the five particle-size classes: clay, silt, small aggregates, large aggregates, and sand.

A detailed nutrient analysis for each cell is also available that provides estimates of adsorbed and soluble nutrients in mass per unit area and the concentration of these nutrients in the runoff.

Execution of AGNPS simply requires the input of a data file name and choosing the output options desired. Detailed sediment and nutrient options provide a great deal of information and should only be requested if a very extensive investigation of the watershed is taking place.

```
******************************************************************************************
* AGNPS Version 2.2      Input file: MB045                                               *
* AGRICULTURAL NON-POINT SOURCE POLLUTION MODEL   1:08 PM  FRI.,  9  JAN., 1987          *
* Watershed studied: MEADOW BROOK WTSHD#045 1983                                         *
******************************************************************************************

The area of the watershed is:              8680 acres
The area of each cell is:                  40.0 acres
The characteristic storm precipitation is:  4.4 inches
The storm energy-intensity value is:         56
The cell parameters are derived for:

              OUTFLOW FROM FEEDLOT   1
               Nitrogen concentration at the discharge point (ppm)    112.2
               Phosphorous concentration at discharge point (ppm)     55.12
               COD concentration at discharge point (ppm)             1622.
               Nitrogen mass at the discharge point (lbs)             298.7
               Phosphorous mass at discharge point (lbs)              146.7
               COD mass at discharge point (lbs)                      4318.

======================================================
== VALUES AT THE WATERSHED OUTLET, CELL NUMBER  213 ==
======================================================

RUNOFF:
-------
Runoff volume (in.):       2.37
Peak runoff rate (cfs):    3916

NUTRIENTS:
----------
Total nitrogen in sediment (lbs/acre):                               3.16
Total soluble nitrogen in runoff (lbs/acre):                         1.92
Soluble nitrogen concentration in runoff (ppm):                       3.6
Total phosphorus in sediment (lbs/acre):                             1.58
Total soluble phosphorus in runoff (lbs/acre):                        .37
Soluble phosphorus concentration in runoff (ppm):                      .7
Total soluble chemical oxygen demand (lbs/acre):                    66.24
Soluble chemical oxygen demand concentration in runoff (ppm):         123

SEDIMENT ANALYSIS:
------------------
```

Particle Type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	.17	.00	99	3.0	615	.2	1433.8
SILT	.26	.00	80	3.0	769	.2	1793.5
SAGG	1.62	0.00	38	1.0	2319	.6	5406.6
LAGG	1.00	.00	0	0.0	12	.0	27.5
SAND	.19	.00	1	0.0	4	.0	8.6
TOTL	3..23	0.00	31	1.0	3719	1.0	8670.0

Figure 13
AGNPS output for a 8,680-acre watershed.

== CONDENSED SUMMARY FOR SELECTED CELLS ==

Cell Number	Drainage Area (Acres)	RUNOFF: Volume (in.)	RUNOFF: Generated Above (%)	RUNOFF: Peak Rate (cfs)	SEDIMENT: Cell Erosion (t/a)	SEDIMENT: Generated Above (tons)	SEDIMENT: Generated Within (tons)	SEDIMENT: Yield (tons)	SEDIMENT: Deposition (%)
18	80	2.7	47	249	5.1	37.5	203.4	155.0	36
26	80	2.1	46	181	5.3	7.6	211.6	127.4	42
27	120	2.1	65	220	5.3	127.4	211.6	207.8	39
70	2560	2.4	99	1849	.1	2981.3	3.2	2882.5	3
208	400	2.2	90	598	5.3	412.3	211.6	508.0	19

		NITROGEN					PHOSPHORUS					CHEMICAL OXYGEN DEMAND		
		Sediment		Water Soluble			Sediment		Water Soluble			Water Soluble		
Cell Number	Drainage Area (acres)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Conc. (ppm)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Conc. (ppm)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Conc. (ppm)
18	80	11.62	5.37	5.97	4.13	7	5.81	2.68	1.30	.87	1	109.00	77.35	127
26	80	12.00	4.59	2.56	1.46	3	6.00	2.30	.51	.27	1	85.00	59.74	128
27	120	12.00	4.91	2.56	1.83	4	6.00	2.45	.51	.35	1	85.00	68.20	143
70	2560	.42	3.48	7.83	2.37	4	.21	1.74	3.69	.50	1	142.00	69.01	128
208	400	12.00	3.83	2.56	1.71	3	6.00	1.92	.51	.32	1	85.00	55.75	112

Figure 14
AGNPS output for selected cells.

Introduction to Model Documentation

This section provides the technical background for the water quality model AGNPS. AGNPS was written in Fortran IV and developed on a Hewlett-Packard 1000 computer system. The program developed on that system was then modified to run on a Hewlett-Packard 41 CV hand-held calculator system for use with smaller watersheds.

This section also discusses the computer program DBDFL, which is operated in conjunction with AGNPS. DBDFL was developed to assist the user in creating model input data files for the computer system.

The calculations made by AGNPS occur in three stages, or loops. Initial calculations for all cells in the watershed are made in the first loop. These calculations include estimates for upland erosion, overland runoff volume, time until overland flow becomes concentrated, level of soluble pollutants leaving the watershed via overland runoff, sediment and runoff leaving impoundment-terrace systems, and pollutants coming from point-source inputs such as tile lines or feedlots.

The second loop calculates the runoff volume leaving the cells containing impoundments and the sediment yields for primary cells. A primary cell is one that no other cell drains into. The sediment from these and other cells is broken down into five particle-size classes: clay, silt, small aggregates, large aggregates, and sand. Table 12 shows the diameter range for each particle size, the densities, the particle fall velocities, and the equivalent sand diameters.

The sediment and nutrients are routed through the rest of the watershed in loop 3. Calculations are made to establish the concentrated flow rates, to derive the channel transport capacity, and to calculate the actual sediment and nutrient flow rates.

Preliminary Calculations

Base values for each of the cells in the watershed are established in loop 1 of the programs. Estimates are made to determine overland runoff volume and duration, erosion, and soluble pollutant flow occurring in each of the cells. The first execution made in this loop is to read in the data file for the watershed. The parameters of the data files are shown in table 1.

Total detached sediment and the breakdown into the particle-size classes are made on a per cell basis. A modified USLE is used to predict upland erosion for single storm events (Wischmeier and Smith 1978).

$$E=EI*K_s*L_f*S_f*C_f*P_f*SSF, \quad [1]$$

where

E=soil loss in tons/acre,
EI=rainfall energy-intensity in hundred foot-ton inch/acre hour,
K_s=soil erodibility factor in ton-acre hour/hundred-acre foot-ton inches,
L_f=slope-length factor,
S_f=slope-steepness factor,
C_f=cover and management factor,
P_f=support practice factor, and
SSF=a calculated factor to adjust for slope shape.

The variables EI, K_s, L_f, S_f, C_f, and P_f are as defined in Wischmeier and Smith (1978). The slope shape factors were calculated using complex slope factors found in Wischmeier and Smith (1978). The factors were developed to adjust the erosion estimates for convex and concave slopes. Calculations for a convex slope were based on a 75-foot slope the upper third of which had a gradient of 2 percent, the middle third 7 percent, and the lower third 12 percent. For the concave slope, a 75-foot slope was again used, with the upper third having a gradient of 12 percent, the middle third 7 percent, and the lower third 2 percent. Table 13 shows the slope shapes and the factors used for each.

Soil texture is used to determine the fractional distribution of the eroded sediment into particle classes (table 14). The runoff volume from each cell is determined using the U.S. Department of Agriculture, Soil Conservation Service (1972) curve number method. The equation is

$$RF=\frac{(RL-0.2*S)^2}{RL+0.8*S}, \qquad [2]$$

where

RF=runoff in inches,
RL=storm precipitation in inches, and
S=a retention factor in inches.

The retention factor is defined as

$$S=1,000/CN-10, \qquad [3]$$

where

CN is the curve number.

The curve number is a cell characteristic dependent on land use, soil type, and hydrologic soil conditions.

The overland runoff duration, or the time needed for concentrated flow to occur, is calculated using the runoff velocity as determined in U.S. Department of Agriculture, Soil Conservation Service (1972).

The equation used for computation is

$$OFT=L_s/V_o, \qquad [4]$$

where

OFT=overland flow time in seconds,
L_s=field slope length in feet, and
V_o=overland flow velocity in feet per second.

The velocity is calculated as

$$V_o=10^{0.5*LOG_{10}(S_1*100)-SCC}, \qquad [5]$$

where

S_1=land slope in feet/foot, and
SCC=overland surface condition constant.

The surface condition constant is a cell characteristic that accounts for the effects of land use and vegetation.

The methods used to predict N and P yields from the cells and watershed were developed by Frere et al. (1980) and appear in CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems). The contributions of soluble N and P from each of the cells are calculated in loop 1 and routed into the channel. Once the soluble nutrients reach concentrated flow, they are assumed to remain. That is, the amount arriving in the overland flow from any particular cell is simply added to what is already present in the channel, with no losses of soluble nutrients in the channel allowed.

Figure 15 illustrates the concepts used in the nutrient portion of the model with regard to soluble forms of N and P in runoff waters. As the figure shows, the soluble N and P calculations account for the effects of rainfall, fertilization, and leaching. The basic equation to predict the soluble N and P concentration in the runoff is

$$RO^{-}=\overline{C}*EXK^{-}{}_2*RO*0.01, \qquad [6]$$

Table 12.
Particle-size breakdown and physical description

Particle	Particle range (mm)	Density (g/cm^3)	Fall velocity (ft/s)	Equivalent sand diameters (micrometers)
Clay	<0.002	2.60	$0.102 * 10^{-4}$	2
Silt	0.002-.050	2.65	$.263 * 10^{-3}$	10
Small aggregates	.020-.075	1.80	$.125 * 10^{-2}$	20
Large aggregates	.200-1.000	1.60	$.542 * 10^{-1}$	158
Sand	.050-2.000	2.65	$.759 * 10^{-1}$	201

Source: Foster et al. (1980).

Table 13.
Slope shapes and calculated universal soil loss equation multiplication factors

Slope type	SSF[1]
Uniform	1.00
Convex	1.30
Concave	.88

[1]Slope shape multiplication factor.

Table 14.
Sediment particle-size distribution (%) of the major soil texture groups

Soil texture	Clay	Silt	Small aggregates	Large aggregates	Sand
High clay soils	0.10	0.06	0.57	0.25	0.02
Silt soils	.05	.08	.50	.31	.06
High sand soils	.02	.02	.16	.20	.60
Peat soils	1.00	0	0	0	0

Source: Foster et al. (1980).

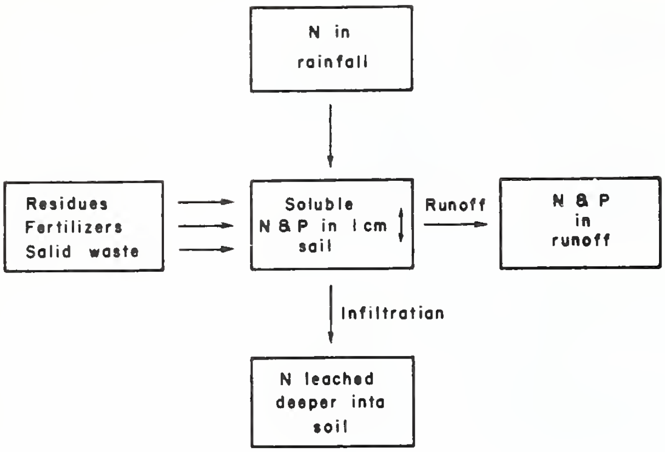

Figure 15
Diagram for estimating nutrient losses in runoff.

where

$\overline{RO}$=N or P concentration in the runoff,
$\overline{C}$=mean concentration of the soluble portion of the nutrient in the soil surface during runoff,
$\overline{EXK}_2$=an extraction coefficient for movement into the runoff; and
RO=total runoff in millimeters.

The equation used to predict soluble N concentration in the model is

RON=0.892*((CZERON-CHECKN)*EXP(-XKFN1*EFI)-(CZERON-CHECKN)*EXP(-XKFN1*EFI-XKFN2*RO))/COEFF+RN*RO/EFRAIN, [7]

where

RON=soluble N in the runoff in pounds per acre,
CZERON=available soluble N content in the soil in kilograms per hectare,
CHECKN=available N due to the rainfall in kilograms per hectare,
XKFN1=a rate constant for downward movement of N into the soil,
EFI=total infiltration for the storm in millimeters,
XKFN2=a rate constant for N movement into the runoff
RO=total storm runoff in millimeters,
COEFF=a porosity factor,
RN=N contribution due to the rain in kilograms per hectare, and
EFRAIN=effective rainfall in millimeters.

The available N in the soil is calculated by accounting for organic matter N, fertilizer N, and soil porosity:

CZERON=(SOLN+FN(X)*FA(X))*COEFF, [8]

where

SOLN=soluble N in the surface centimeter of the original soil in kilograms per hectare,
FN(X)=N fertilizer application in cell X in kilograms per hectare, and
FA(X)=fraction of this application remaining in the top centimeter of the soil.

The initial soluble N in the top centimeter of the original soil is estimated by

SOLN=0.10*CSN*POR, [9]

where

CSN=concentration of N in the pore water of the surface centimeter of soil in parts per million, and
POR=soil porosity.

Because very few areas have the soluble nutrient values for the original soils, a CSN value of 5 p/m from an observed range of 2 p/m to 5 p/m (Frere et al. 1980) is assumed. The soil porosity is determined by

POR=1-(bulk density/2.65). [10]

The soil bulk density, in grams per cubic centimeter, is determined using the major soil texture of the cell as shown in figure 12. The fertilizer application and the fraction remaining are both variable inputs. The porosity factor, COEFF, is solved by using the porosity as

COEFF=0.00001/POR. [11]

The available N due to the rainfall is solved by using the relation

CHECKN=RCN*1.0E-06, [12]

where

RCN=N concentration in the rainfall.

A value of 0.8 mg/L was chosen for use in the model.

The equation for the rate constant for downward movement of soluble N is

XKFN1=EXKN1/(10*POR), [13]

where

EXKN1=extraction coefficient for downward movement.

EXKN1 is assumed constant and equal to 0.25.

The effective infiltration is defined as

EFI=EFRAIN-RO, [14]

where

EFRAIN=effective rainfall in millimeters, and
RO=total storm runoff in millimeters.

The EFRAIN term is calculated using the equation

EFRAIN=R-(10*POR), [15]

where

R=storm rainfall in millimeters.

The rate constant for movement of soluble N into the runoff is

XKFN2=EXKN2/(10*POR), [16]

where

EXKN2=extraction coefficient for movement into runoff.

EXKN2 is assumed constant and equal to 0.050.

The N contribution due to the rain, RN, is calculated as

RN=RCN*R*0.01. [17]

The equation used to predict soluble P in the runoff is similar to the equation for N except that the effects of rainfall are omitted. Since very little soluble P is found in rainfall, its net contribution to the runoff is negligible. The equation is

ROP=0.892*((CZEROP-CHECKP)*EXP(-XKFP1 *EFI)-(CZEROP-CHECKP)*EXP(-XKFP1 *EFI-XKFP2*RO))/COEFF+CHECKP*XKFP2 *RO/COEFF), [18]

where

ROP=soluble P in the runoff in pounds per acre,
CZEROP=available P due to natural and fertilizer nutrient level in kilograms per hectare,
CHECKP=available P due to the initial soil in kilograms per hectare,
XKFP1=a rate constant for downward movement of P into the soil, and
XKFP2=the rate constant for movement into runoff.

The available soluble P in the soil is calculated as

$$CZEROP=(SOLP+FP(X)*FA(X))*COEFF, \quad [19]$$

where

SOLP=soluble P in the top centimeter of the original soil in kilograms per hectare, and
FP(X)=P fertilizer application in cell X in kilograms per hectare.

The initial soluble P in the top centimeter of the original soil is solved by using the relation

$$SOLP=0.10*CSP*POR, \quad [20]$$

where

CSP=concentration of P in the pore water of the surface centimeter of soil in parts per million.

A CSP value of 2 p/m is assumed in the model. The COEFF term is the same as described for the soluble N equation.

The available P due to the initial soil is solved as

$$CHECKP=SOLP*COEFF. \quad [21]$$

The equation for the rate constant for downward movement of P is

$$XKFP1=EXKP1/(10*POR), \quad [22]$$

where

EXKP1=extraction coefficient for downward movement, assumed equal to 0.25.

The rate constant for movement into the runoff is

$$XKFP2=EXKP2(10*POR), \quad [23]$$

where

EXKP2=extraction coefficient for movement into runoff.

EXKP2 is also assumed constant and equal to 0.025.

Chemical oxygen demand (COD) in the model is assumed soluble. Calculations of the amount of soluble COD in the runoff are based on the runoff volume and the average concentration of COD in that volume. Various background concentrations of COD of runoff waters are shown in table 15. Estimates made from these values are used as a basis for predicting COD concentration in runoff from each cell. Soluble COD is assumed to accumulate only after flow has become channelized, without any allowable losses.

Sediment and runoff routing through impoundment terrace systems is simulated using relationships developed by Laflen et al. (1978) and Foster et al. (1980). These relationships were developed for terrace systems that concentrate the overland flow into pipe-outlet ponds. The fraction of each specific particle class that passes through the impoundment is expressed as

$$F_{pi}=A_1[EXP(B_1*Du)-EXP(B_1*D_s)]/(B_1*\Delta D), \quad [24]$$

where

F_{pi}=fraction of that particle class passing through the impoundment,
A_1=a coefficient,
B_1=a coefficient,
Du=equivalent sand diameter for that particle class in micrometers,

Table 15.
Background concentrations of chemical oxygen demand of runoff waters from different land sources

Source	COD (mg/L)	Reference
Native prairie--Minnesota	48	Timmons and Holt (1977)
Grassland--Michigan	98	Thompson et al. (1978)
Grazed prairie--Oklahoma	36	Crow et al. (1979)
Aspen-birch forest--Minnesota	54	Timmons et al. (1977)
Aspen-birch forest--Minnesota	78	Young, unpublished data
Corn stubble--Michigan	121	Thompson et al. (1978)
Corn--South Dakota	225	Harms et al. (1974)
Fallow--Michigan	118	Thompson et al. (1978)
Fallow--South Dakota	109	Harms et al. (1974)
Alfalfa--South Dakota	22	Harms et al. (1974)
Pasture--South Dakota	49	Harms et al. (1974)
Oats--South Dakota	82	Harms et al. (1974)
Urban--Ohio	111	Weibel (1969)

D_s=equivalent sand diameter for the next smallest particle class in micrometers, and
ΔD=difference between the two classes in micrometers.

The coefficients A_1 and B_1 are expressed as

$$A_1=1.136\ EXP(Z_s),\ \text{and} \quad [25]$$

$$B_1=-0.152\ EXP(Y_s), \quad [26]$$

with Z_s and Y_s given by

$$Z_s=-6.68E-06*f-0.0903*B+1.19E-04*C_{or}-3.42E-06*RO_p-20400*I,\ \text{and} \quad [27]$$

$$Y_s=3.28E-05*f+0.123*B-2.4E-04*C_{or}+8.10E-06*RO_p-11880*I, \quad [28]$$

where f is a coefficient and B is an exponent in a power equation relating surface area to depth expressed as

$$S_a=f*Y_p^B, \quad [29]$$

where

S_a=surface area of the pond in square feet, and
Y_p=depth in the pond in feet.

The coefficient C_{or} is related to the diameter of the pipe outlet by

$$C_{or}=13,968*d_{or}^2, \quad [30]$$

where

d_{or}=diameter in feet,
RO_p=volume of runoff held in the pond in cubic feet, and
I=infiltration rate in the pond in feet per second.

The equivalent sand diameters for each of the particle-size classes are included in table 12. The terms f and B are assumed constant, equal to 7,500 and 1.5, respectively, developed from a range of values from 9,465 to 4,485 and 1.77 to

Table 16.
Infiltration rates for each of the major soil texture classes

Soil texture	Infiltration rate (inches/h)
High clay soils	0.05
Silt soils	.40
High sand soils	.70
Peat soils	1.50

1.10. The infiltration rates for each of the major soil textures are shown in table 16.

The flow rate leaving the impoundment is expressed as

$$Q_{pp}=Y_p^{0.5}C_{or}/3,600, \quad [31]$$

where

Q_{pp}=peak flow rate leaving the impoundment in cubic feet per second.

If the pond is assumed to be trapezoidal in shape, the volume held in the pond may be presented as

$$RO_p=1/3(S_a*Y_p). \quad [32]$$

The pond depth can then be solved as

$$Y_p=(3*RO_p/f)^{1/(B+1)}. \quad [33]$$

Estimates for pollutant yields from feedlots in the cells are also calculated in loop 1. Pollutant contributions due to these feedlots are treated as point-source pollutants and are routed into the channel with the others. P and COD contributions due to the feedlots are calculated using a model developed by Young et al. (1982b) to analyze feedlot runoff. The feedlot model calculates P and COD concentration and mass at both the feedlot edge and at the point of discharge into a channel or body of water. Concentration at the feedlot edge is determined using the general relationship

$$C_F*RO_F=C_1*RO_1+C_2*RO_2, \quad [34]$$

where

C_F=concentration at the feedlot edge,
RO_F=volume of runoff at the feedlot edge,
C_1=concentration of runoff in the feedlot,
RO_1=volume of runoff from the feedlot itself,
C_2=concentration of runoff from the area above the feedlot, and
RO_2=volume of runoff from the area above the feedlot.

The net reduction due to filtering in the buffer strip is calculated as

$$C_R=C_F*(1-D_1/100)*(1-D_2/100), \quad [35]$$

where

C_R=reduced pollutant concentration,
D_1=percent reduction of pollutant concentration in overland flow, and
D_2=percent reduction of pollutant concentration in any existing grass waterway.

The final concentration following the buffer is then calculated as

$$C_T*RO_T=C_R*RO_F+C_3*RO_3, \quad [36]$$

where

C_T=final concentration at the discharge point,
RO_T=total runoff at the discharge point,
C_3=concentration of runoff from the area below the feedlot, and
RO_3=runoff volume from the area below the feedlot.

Table 17.
Background values for the total nitrogen concentration in runoff from feedlots with unpaved surfaces

Location	Total Nitrogen concentration (mg/L)	Stocking rate (ft^2/head)	Reference
Minnesota	56	212	Young et al. (1980)
Ontario	356	122	Coote and Hore (1978)
Kansas	675	...	Manges et al. (1975)
Nebraska	854	200	Gilbertson et al. (1975)
Nebraska	310	200	Gilbertson et al. (1970)
Kansas	494	...	Fields (1971)
Ohio	31	290	Edwards et al. (1972)
Kansas	364	355	Manges et al. (1971)
South Dakota	996	570	Madden and Dornbush (1971)
Kansas	300	220	Miner et al. (1966)
Oregon	132	260	Willrich et al. (1974)
	486	260	Willrich et al. (1974)
Wisconsin	42	500	Madison et al. (1979)

Equations used to predict the concentration of total N in runoff from feedlots were developed using data from several feedlot studies done in the Northern United States and Southern Canada. Background values for total N concentration in runoff from unpaved feedlots were obtained from 12 of these studies and appear in table 17. From these values, we chose 300 mg/L as a representative concentration. We assumed that concentrations decrease linearly with percent manure pack below 100 percent. The percent manure pack of a feedlot may be found by determining its potential loading. This can be done by standardizing the potential pollutant produced by the animal type in the lot to that produced by a 1,000-pound beef feeder or slaughter steer. Comparative factors for various animal types developed using data from Midwest Plan Service (1975) and the American Society of Agricultural Engineers (1982) are shown in table 18. A background concentration of 12 mg/L was chosen from the values in table 19, to represent the concentration of total N in runoff from areas contributing runoff to the feedlot discharge.

To adjust for a reduction in pollutant due to filtration occurring in overland flow once the runoff leaves the feedlot, the equation is

$$DN1=-16.8+42.3*LOG_{10}OFT, \qquad [37]$$

where

DN1=percent reduction in total N concentration due to overland flow, and
OFT=overland flow time in seconds.

Table 18.
Ratio of total nitrogen produced by various animals to that produced by a 1,000-pound slaughter steer

Animal type[1]	Design weight (pounds)	Ratio N
Slaughter steer	1,000	1.00
Young beef	500	.60
Dairy cow	1,400	1.68
Young dairy stock	500	.46
Swine	200	.26
Feeder pig	50	.07
Sheep	100	.13
Turkey	10	.02
Chicken	4	.01
Duck	4	.01
Horse	1,000	.81

[1]Data from Midwest Plan Service (1975) except for swine, which is from American Society of Agricultural Engineers (1982).

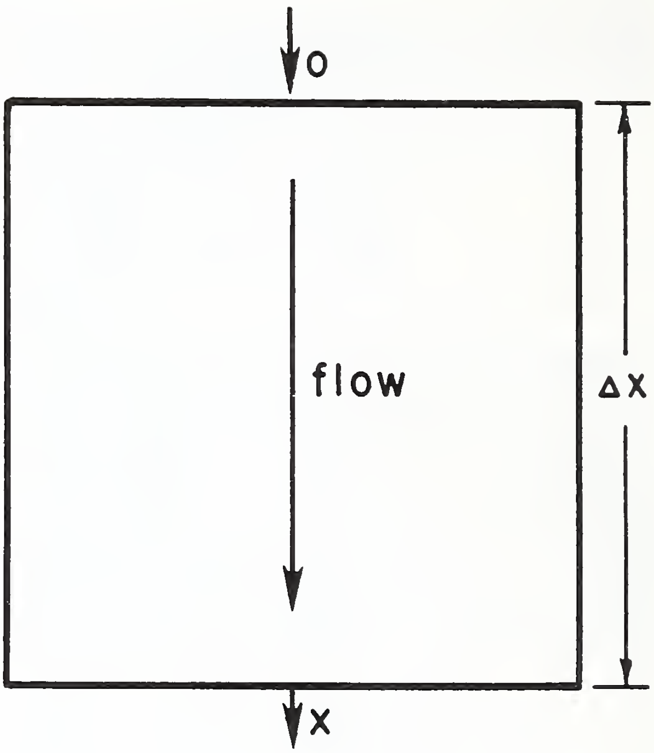

Figure 16
Representative watershed cell with flow distance along the cell noted.

This relationship was developed using background information from three feedlot studies (Bingham et al. 1978, Dickey and Vanderholm 1979, and Young et al. 1980). To adjust for a reduction in pollutant due to filtration occurring in concentrated flow, the equation is

$$DN2=25.53+0.047*GWTC, \quad [38]$$

where

DN2=percent reduction in total N concentration due to channel flow, and
GWTC=flow time in the grassed waterway or channel in seconds.

This equation was developed using data by Dickey and Vanderholm (1979).

The pollutants from the feedlot are treated as soluble and routed with the runoff flow just as the other soluble pollutants are. Once they reach the channel, they are assumed to remain and accumulate in the flow.

Sediment and Nutrient Routing

The sediment routing through the watershed is done in loops 2 and 3 of the programs. The primary cells are routed in loop 2 and the rest of the cells in loop 3. The routing is done on a per cell and per particle-size basis proceeding from the headwaters of the watershed to its outlet. Figure 16 is a representative cell with the point 0 showing where all sediment and runoff enter the cell and point X showing where they exit the cell.

Table 19.
Background concentrations for total nitrogen of runoff waters from different land sources

Source	Total nitrogen concentration (mg/L)	Reference
Native prairie--Minnesota	5	Timmons and Holt (1977)
Native prairie--Oklahoma	9	Crow et al. (1979)
Continuous corn--Minnesota	91	Young and Holt (1977)
Rotation corn--Minnesota	44	Young and Holt (1977)
Continuous corn--Minnesota	131	Burwell et al. (1975)
Wheat--Oklahoma	2	Olness et al. (1975)
Oats--Minnesota	49	Burwell et al. (1975)
Rotation pasture--Oklahoma	2	Olness et al. (1975)
Continuous pasture--Oklahoma	3	Olness et al. (1975)
Alfalfa--Oklahoma	4	Olness et al. (1975)
Alfalfa--Minnesota	60	Burwell et al. (1975)
Fallow--Minnesota	186	Burwell et al. (1975)
Aspen-birch forest--Minnesota	0	Timmons et al. (1977)

The method used for sediment routing involves equations for sediment transport and deposition described by Foster et al. (1981) and Lane (1982). The equation is derived from the steady state continuity equation.

$$Q_s(x)=Q_s(o)+Q_{s1}\Delta x/L_r-\int_o^x D(x)\ W\ dx, \quad [39]$$

where

$Q_s(x)$=sediment discharge at the downstream end of the channel reach in pounds per second,
$Q_s(o)$=sediment discharge at the upstream end of the channel reach in pounds per second,
Q_{s1}=lateral sediment inflow rate in pounds per second,
x=downslope distance in feet,
L_r=reach length in feet,
D(x)=sediment deposition rate at point X in pounds per second-square foot, and
W=channel width in feet.

Assuming a constant width, the deposition is approximated by

$$\int_o^x D(x)Wdx=W*\Delta x/2*(D(o)+D(x)), \quad [40]$$

where

D(o)=sediment deposition rate at the upstream end of the channel in pounds per second-square foot.

The deposition is calculated as

$$D(i)=V_{ss}/q*(q_s-g_s), \quad [41]$$

where

D(i)=sediment deposition rate at the point i between points X and 0 in pounds per second-square foot,

V_{ss}=particle fall velocity in feet per second,
q=runoff rate in cubic feet per second-foot,
q_s=sediment flow rate in pounds per second-foot, and
g_s=effective sediment transport capacity in pounds per second-foot.

Effective sediment transport capacity, g_s, is determined using a modification of the Bagnold (1966) stream power equation:

$$g_s=\eta*k*\tau*V_c^2/V_{ss}, \quad [42]$$

where

η=an effective transport factor,
k=the transport capacity factor,
τ=shear stress in pounds per square foot, and
V_c=average channel velocity in feet per second.

The transport capacity factor is calculated as

$$k=(1-e_b)*e_s*\left(\frac{\gamma_w}{\gamma_s-\gamma_w}\right), \quad [43]$$

where

e_b=bedload transport efficiency,
e_s=suspended load transport efficiency,
γ_s=sediment specific weight in pounds per cubic foot, and
γ_w=specific weight of water in pounds per cubic foot.

From flume studies, the combined efficiency term, $(1-e_b)*e_s$, has been found to be about 0.01 (Simons and Senturk 1976). However, this value was determined from studies using mostly sand. Since the actual value of $(1-e_b)*e_s$ would vary with the size of the particle being transported, the combined efficiency term was adjusted by an effective transport factor, η (Young et al. 1986). The value of η can be estimated by

$$\eta=0.74Ef^{-1.98}, \quad [44]$$

where Ef is an entrainment function (Simons and Senturk 1976) calculated as

$$Ef=\tau/((\gamma_s-\gamma_w)*Pd), \quad [45]$$

where Pd is the particle diameter in feet.

The calculated transport capacity factors, sediment specific weights, and particle diameters for the five particle-size classes appear in table 20. The sediment discharge equation for each

particle size is

$$Q_{si}(x)=\left[\frac{2*q(x)}{2*q(x)+\Delta xV_{ssi}}\right]*\left[Q_{si}(o)+Q_{sli} - \frac{\overline{W}*\Delta x}{2}*\left[\frac{V_{ssi}}{q(o)}*(q_{si}(o)-g_{si}(o)) - V_{ssi}/q(x)*g_{si}(x)\right]\right], \quad [46]$$

where

$Q_{si}(x)$=particle discharge at the cell outlet in pounds per second,
$q(x)$=discharge per unit width exiting the cell in cubic feet per second-foot,
Δx=change in channel length across the cell in feet,

Table 20.
Sediment specific weights, particle diameters, and transport capacity factors for the 5 particle-size classes

Particle	Specific weight, (lb/ft^3)	Particle diameters, Pd (ft)	Transport capacity factor, k
Clay	162.37	$6.56 * 10^{-6}$	$6.242 * 10^{-3}$
Silt	165.49	$3.28 * 10^{-5}$	$6.053 * 10^{-3}$
Small aggregates	112.41	$1.15 * 10^{-4}$	$12.478 * 10^{-3}$
Large aggregates	99.92	$1.64 * 10^{-3}$	$16.631 * 10^{-3}$
Sand	165.49	$6.56 * 10^{-4}$	$6.053 * 10^{-3}$

$Q_{si}(o)$=particle discharge into the cell in pounds per second,
$\bar{W}$=average channel width in feet,
$q(o)$=discharge per unit of width into the cell in cubic feet per second-foot,
$q_{si}(o)$=particle discharge per unit of width into the cell in pounds per second-foot,
$g_{si}(o)$=particle transport capacity into the cell in pounds per second-foot,
$g_{si}(x)$=particle transport capacity out of the cell in pounds per second-foot, and
Q_{sli}=lateral particle inflow rate in pounds per second.

The sediment discharge is calculated in two periods: the first period during which the eroded sediment from the upland portions of the cell enter the channel and the remaining period during which upland erosion has stopped but channel flow continues. During both periods, the sediment flow at point 0 remains constant. It equals the total sediment of that particular particle size delivered to that point from all drainage patterns entering the cell flowing over the average flow duration calculated at points 0 and X.

The first period lasts until overland flow has ended, the duration being equal to the time of overland flow. During the second period, up until channel flow has stopped, the contribution of sediment from overland flow equals 0.

The flow rates in equation 46, q(o) and q(x), are peak flow rates divided by the appropriate channel width. The equation used to determine the peak flow rate was developed by Smith and Williams (1980) for use in CREAMS.

$$QP=8.484*A^{0.7}*S_c^{0.159}*RF^{(0.824*A^{0.0166})}(L_c^2/(A*43560))^{-0.187}, \quad [47]$$

where

QP=peak discharge in cubic feet per second,
A=drainage area in acres,
S_c=channel slope in feet per foot,
RF=runoff volume in inches, and
L_c=channel length in feet.

At point 0, the drainage area is the entire drainage area above the cell that emptied into the cell, the channel slope is that of the cell in question, the runoff is the average effective runoff for all the area draining into the cell, and the length of flow is the longest path of flow into the cell. At point X, the drainage area includes the area of the cell itself plus the area above, the channel slope is that of the cell, the runoff is the average effective runoff including that of the cell itself, and the length is the longest drainage path to the bottom of the cell. For the primary cells, the area is assumed to be the cell area and the length is assumed to be half the length across the cell.

The effective runoff volume for each of the cells in the watershed is also calculated in loop 2. This volume incorporates the effects of impoundment terrace systems into the model's runoff calculations. These terraces will change the runoff hydrograph for any cell with a terrace, as well as that for any cell in the drainage network. The change in the runoff hydrograph is incorporated into the model by calculating an effective runoff volume for each of the cells in the watershed. Because of the ponding in the terrace system and the delay due to ponding, the actual peak flow leaving the cell will decrease. So the effective runoff volume--the volume that contributes to the peak flow leaving the cell--will be less for a cell containing an impoundment terrace system. To obtain this effective runoff volume, the peak flow leaving the terrace system is added to the peak flow for the rest of the cell. The effective runoff is then derived using this total peak flow, solving equation 47 for the runoff.

The length of the drainage path is calculated by summing the individual drainage lengths across each of the cells that a specific drainage path may cross. This summation is made for each of the alter native paths that enter the cell in question, and a comparison is made to determine the longest. Flow across a cell may be one of four lengths, as shown in figure 17.

When the discharge rates are calculated, duration of channelized flow is also

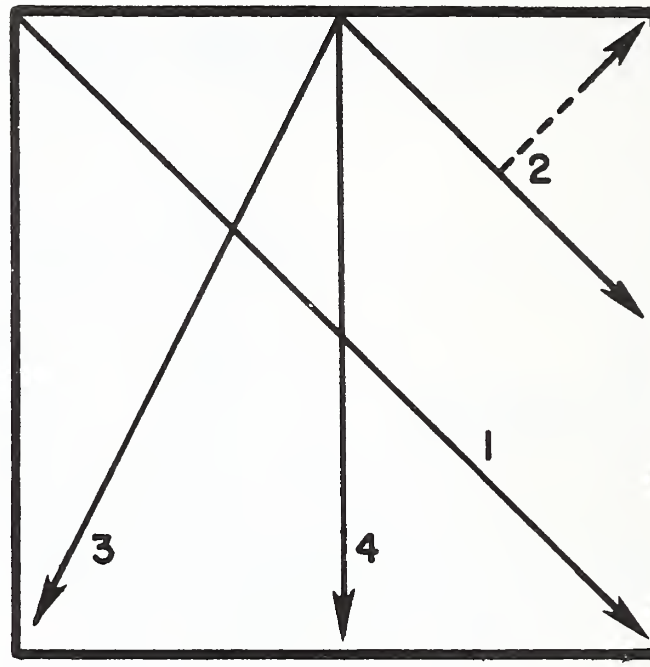

Figure 17
Possible drainage paths across a cell.

determined. The equation used to determine the channelized flow duration at both 0 and X is

$$D=RF*3{,}630*A/QP, \qquad [48]$$

where

D=duration in seconds, and
QP=peak discharge in cubic feet per second.

To maintain consistent rate between the 0 and X points, an average of these two durations is taken. This average is then used to determine the particle discharge rate into the cell and eventually the mass of sediment leaving the cell.

The width of the channel, in feet, at point 0 or point X is calculated using the equation

$$W=2.05*z^{(-0.625)}*(1+z^2)^{0.125}*(QP*n/S_c^{0.5})^{0.375}, \qquad [49]$$

where

z=channel sideslope in feet per foot, and
n=Manning's roughness coefficient for the channel.

This equation is based on the assumption that the channel is triangular and that the flow is uniform. These widths are used to transform the appropriate terms in equation 46 into a per unit of width basis.

The lateral sediment flow rate is determined by dividing the amount of eroded sediment of each particle-size class by the duration of overland flow. The mass of eroded sediment is found using equation 1 and the particle-size breakdown as described in table 14. The duration of overland flow is defined in equations 4 and 5.

The transport capacity is calculated as shown in equation 42. The shear stress in this equation is solved by using the relation

$$\tau=\gamma_w*R_h*S_c, \quad [50]$$

where

R_h=hydraulic radius in feet.

For a triangular channel, the hydraulic radius is

$$R_h=y/(2*(1+z^2)^{0.5}), \quad [51]$$

where

y=channel depth in feet.

By assuming uniform flow, the velocity in the channel can be calculated using Manning's equation

$$V_c=(1.49/n)*S_c^{0.5}*R_h^{0.667}. \quad [52]$$

Combining these equations and the flow rate equation

$$Q=A_c*V_c, \quad [53]$$

where

Q=channel flow rate in cubic feet per second, and
A_c=cross-sectional area of the channel in square feet,

we can solve for the shear stress.

Equation 50 becomes

$$\tau=\gamma_w*z^{0.375}/(2*(1+z^2)^{0.5})^{0.75}*S_c^{0.813}*(n*QP/1.49)^{0.375}. \quad [54]$$

The velocity then becomes

$$V_c=(1.49/n)^{0.75}*z^{0.25}/(2*(1+z^2)^{0.5})^{0.5}*S_c^{0.375}*QP^{0.25}. \quad [55]$$

The nutrient yield associated with the sediment is calculated using the total sediment yield from each cell. Sediment-transported nutrients are estimated using an equation from the CREAMS nutrient submodel (Frere et al. 1980). The equation is

$$SED-=SOIL*SED*ER*0.892, \quad [56]$$

where

SED-=N or P transported by the sediment in pounds per acre,
SOIL=N or P concentration in the soil,
SED=sediment yield in kilograms per hectare, and
ER=enrichment ratio for N or P.

The N concentration in the soil is estimated as 0.001 lb N/lb of soil, and the P as 0.0005 lb P/lb of soil (Frere et al. 1980). The enrichment ratio is calculated as

$$ER=a*SED^{b}*T_f \qquad [57]$$

where

a=coefficient,
b=exponent, and
T_f=a correction factor for soil texture.

Factors a and b are assumed constant and equal to 7.4 and -0.20, respectively. The adjustment factors, T_f, appear in table 21 according to soil texture.

Supplementary Program--DBDFL

DBDFL is a computer program written to generate parameter files for AGNPS. Although use of DBDFL is not necessary to execute the model, it greatly eases the job of creating the input data file for the model.

DBDFL was designed to read data from MLMIS and transform it into a preliminary data file for use in the model. DBDFL also contains options for entering measured and observed parameter values obtained by the user. Since the preliminary data file is based on estimates made by the computer using the MLMIS data, as many observed parameters as possible should be input into the data file.

Table 21.
Adjustment factors (T_f) used to correct sediment-adsorbed nutrient enrichment ratios for sand and clay soils

Soil texture	T_f
Clay	1.15
Silt	1.00
Sand	.85
Peat	1.50

Table 22.
Parameters assumed constant throughout the watershed under default conditions using program DBDFL

Parameter	Constant
Slope shape factor	1 (uniform slope)
Channel sideslope	10%
Practice factor	1
Fertilization level	2 (average fertilization)
Fertilizer availability factor	10%
Point source identification	0
Gully source level (tons)	0
Impoundment factor	0

Since not all of the variables needed to run the model are available from the MLMIS data file, some assumptions need to be made in order to derive the unknown values. To create a preliminary data file, the computer makes estimates for the unknown. These estimates are referred to as default values. They simulate characteristics for an average watershed under worst-case storm conditions. Under these conditions, some of the parameters are assumed constant throughout the watershed (table 22).

The actual parameters used in the preliminary data file are selected as:

1. Cell number: Cells are numbered linearly, beginning in the northwest corner and proceeding from west to east southward (fig. 8).

2. Receiving cell number: Determined by the computer using the cell aspect.

Table 23.
Parameter selection using MLMIS land-use classification

Land use	Curve number for hydrologic soil group A	B	C	D	Surface condition constant	Cropping factor	Roughness coefficient	COD factor (mg/L)
Forested	25	55	70	77	0.59	0.02	0.10	60
Cultivated	77	86	91	94	.22	.43	.06	120
Water	100	100	100	100	.01	0	...	0
Marsh	85	85	85	85	.01	0	...	25
Urban (Residential)	77	85	90	92	.01	.01	.02	110
Extractive	30	58	71	78	.80	.10	.10	80
Pasture	49	69	79	84	.15	.03	.10	50
Urban (Nonresidential)	89	92	94	95	.01	.01	.02	80
Transportation	98	98	98	98	.01	.01	.02	110

3. Curve number: Determined using the land-use (an MLMIS input) and hydrologic soil classifications derived from MLMIS soil texture information. Table 23 shows the curve numbers for each land use given in the MLMIS data files, and table 24 shows the MLMIS soil texture groups the hydrologic soil classifications are derived from.

4. Land slope (percent): Taken directly from MLMIS data file--wherever a value of 0 is recorded, the program assumes a slope of 0.1 percent.

5. Slope shape factor: Constant shown in table 22.

6. Field slope length: Chosen using the field slope length area number (fig. 11) and the land slope (table 25).

7. Channel slope (percent): Taken directly from MLMIS data file. If no channel exists in the cell, the channel is represented by concentrated interrill flow, with a slope of one-half the land slope. Channel slopes of zero are assumed equal to 0.5 percent.

8. Channel sideslope (percent): Constant shown in table 22.

9. Manning's roughness coefficient: Determined using an average value for the land-use category of the cell (table 23).

10. Soil erodibility factor: Derived value is a medium for the range given in MLMIS records. Values are rounded upward to two digits. If no value exists in the MLMIS file, one has to be input by the user.

11. Cropping factor: Determined using the established value for the given land use (table 23).

12. Practice factor: Constant shown in table 22.

13. Surface condition constant: Determined using established value for the given land use (table 23).

Table 24.
Breakdown of MLMIS soil classifications into major soil textures and hydrologic soil classes

Soil texture	MLMIS soil descriptions	Hydrologic soil classification
Sand	Sand	A
	Sand to loamy sand	A
	Loamy sand	A
	Loamy sand to sandy loam	B
	Sandy loam	B
	Sandy loam to loam	B
	Loam to sand and gravel	B
Silt	Loam	B
	Loam to clay loam	B
	Loam to silt loam	B
	Loam to silty clay	B
	Loam, clay loam, sand, and gravel	B
	Clay loam	C
	Clay loam to silty clay loam	C
	Silt loam	C
	Silty clay loam	C
	Silt loam to silty clay loam	C
Clay	Silty clay loam to silty clay	C
	Silty clay	C
	Silty clay to clay	C
	Clay	D
Peat	Peat	D

14. Aspect: An MLMIS parameter.

15. Soil texture: MLMIS soil classes are broken down into four soil textures as shown in table 24.

16. Fertilization level: Constant shown in table 22.

17. Fertilizer availability factor: Constant shown in table 22.

18. Point source identification: Constant shown in table 22.

19. Gully source level: Constant shown in table 22.

20. Chemical oxygen demand (COD) factor: Determined using the established value for the given land use (table 23).

21. Impoundment factor: Constant shown in table 22.

Using these methods to determine the parameter values, along with the

Table 25.
Slope length in feet according to major field slope length area and land slope

Major field slope length area	Slope steepness category (%)			
	0-2	3-6	7-12	≥13
1	100	125	100	75
2	100	250	200	150
3	200	250	200	150
4	200	200	200	200

Source: Otterby and Onstad (1978).

information contained in the MLMIS file, the program DBDFL can be used to generate input data files for AGNPS. Further discussion of the use of DBDFL can be found in the AGNPS guide to model users.

Sensitivity Analysis

We performed a sensitivity analysis on the model to determine the relative change in model output with respect to the change in inputs and model variables. After determining standard input variables and computing base output values, we varied the input variables over a range of values and repeated the computations. These show how the model outputs vary with changes in input values. Results show how the model functions and how important each of the variables is in determining the output. This analysis is intended to aid in variable estimation.

We performed the sensitivity analysis using an agricultural watershed located in west-central Minnesota. The watershed, drained by the Meadow Brook, has a drainage area of about 8,680 acres and outlets into the Big Stone Lake on the Minnesota-South Dakota border. The characteristics of the watershed for the year analyzed are summarized in table 26.

Table 26.
A summary of the watershed characteristics and management practices for the Meadow Brook watershed during the 1983 growing season

Item	Description
Area	8,680 acres
Soil	43% loam 38% clay loam 16% clay 3% silty clay loam
Land use	36% row crops 26% small grain 3% permanent meadow 6% pasture 2% alfalfa 26% idle 1% farmstead
Management practices	Conventional tillage Below average fertilization

The inputs varied in the sensitivity analysis are described in table 27. Using U.S. Department of Agriculture's Soil Conservation Service records for the Meadow Brook watershed during the 1983 growing season, we established the base data file and determined the base output values. Each variable was decreased and increased by 50 and 25 percent, while the others were kept constant. In the case of the cell variables, each of the cell values for the particular variable being adjusted was altered by the percentage factor. The output values described in table 28 were then analyzed to determine their change in relation to the base values. As each variable was varied about the base value, we compared the mean

Table 27.
A summary of the input parameters used in the sensitivity analysis

Parameter	Description
Rain	Storm rainfall; base values for a 25-year, 24-hour storm were assumed
EI	Storm energy-intensity
CN	SCS curve number
LS	Land slope
FSL	Field slope length
CS	Channel slope
CSS	Channel sideslope
N	Manning's roughness coefficient for the channel
K	Soil erodibility factor
C	Cropping factor
P	Practice factor
AVAIL	Fertilizer availability factor

output values with the means from the base value predictions as a measure of sensitivity.

The analysis for the variables affecting sediment yield and sediment-associated nutrient yields is summarized in table 29. The first two columns show which parameters were varied and by how much. The variables most significantly affecting the sediment yield and the sediment-associated nutrient yields are the cell land slope, the soil erodibility, the cropping factor, and the curve numbers. Care should be taken in estimating these, as well as the practice factor, which also significantly affects the output.

We also analyzed the water soluble nutrient yield predictions for sensitivity. This analysis appears in table 30. It can be seen from table 30 that the

Table 28.
A summary of the output parameters at the watershed outlet analyzed in the sensitivity analysis

Parameter	Description
SD	Sediment yield (tons/acre)
N_s	Nitrogen yield associated with the sediment (lb/acre)
N_q	Soluble nitrogen yield (lb/acre)
P_s	Phosphorus yield associated with the sediment (lb/acre)
P_q	Soluble phosphorus yield (lb/acre)
COD_q	Soluble chemical oxygen demand yield (lb/acre)

water soluble nutrient yields are strongly influenced by the choice in curve numbers. Watershed management practices and crop covers should be closely examined to derive accurate estimates for the cell curve numbers.

From the sensitivity analysis outlined in tables 29 and 30, it is possible to determine which variables need to be closely estimated to make accurate predictions of the watershed yields. Although close estimates are desirable for all input parameters, greater justification can be made for coarsely estimating those that least affect the major outputs of the model.

Table 29.
A summary of the sensitivity analysis for the predicted sediment yield and the predicted sediment-associated nutrient yields

		Sediment (tons/acre)		Nitrogen (lb/acre)		Phosphorus (lb/acre)	
Parameter[1] (1)	Variation (2)	SD (3)	SD/base (4)	N_s (5)	N_s/base (6)	P_s (7)	P_s/base (8)
Base	%	1.00	1.00	3.16	1.00	1.58	1.00
Rain	-50	0.62	0.62	2.17	0.69	1.08	0.69
	-25	.85	.85	2.77	.88	1.38	.88
	+25	1.11	1.11	3.44	1.09	1.72	1.09
	+50	1.19	1.20	3.65	1.15	1.82	1.15
EI	-50	.50	.50	1.83	.58	.91	.58
	-25	.75	.75	2.52	.80	1.26	.80
	+25	1.25	1.25	3.77	1.19	1.89	1.19
	+50	1.49	1.50	4.36	1.38	2.18	1.38
CN	-50	.29	.29	1.16	.37	.58	.37
	-25	.70	.70	2.38	.75	1.19	.75
	+25	1.17	1.17	3.58	1.13	1.79	1.13
	+50	1.20	1.20	3.65	1.16	1.83	1.16
LS	-50	.51	.51	1.85	.58	.92	.58
	-25	.71	.72	2.42	.76	1.21	.76
	+25	1.35	1.35	4.02	1.27	2.01	1.27
	+50	1.68	1.69	4.80	1.52	2.40	1.52
FSL	-50	.76	.76	2.55	.81	1.27	.81
	-25	.89	.89	2.88	.91	1.44	.91
	+25	1.09	1.09	3.39	1.07	1.69	1.07
	+50	1.17	1.17	3.58	1.13	1.79	1.13
CS	-50	.89	.89	2.88	.91	1.44	.91
	-25	.95	.95	3.04	.96	1.52	.96
	+25	1.03	1.03	3.25	1.03	1.62	1.03
	+50	1.06	1.06	3.32	1.05	1.66	1.05
CSS	-50	.76	.77	2.55	.81	1.28	.81
	-25	.90	.90	2.90	.92	1.45	.92
	+25	1.07	1.08	3.35	1.06	1.68	1.06
	+50	1.14	1.14	3.50	1.11	1.75	1.11
N	-50	1.16	1.16	3.57	1.13	1.78	1.13
	-25	1.07	1.07	3.33	1.05	1.66	1.05
	+25	.95	.95	3.04	.96	1.52	.96
	+50	.91	.91	2.93	.93	1.47	.93
K	-50	.50	.50	1.83	.58	.91	.58
	-25	.75	.75	2.52	.80	1.26	.80
	+25	1.25	1.25	3.77	1.19	1.89	1.19
	+50	1.49	1.50	4.36	1.38	2.18	1.38

Table 29--Continued
A summary of the sensitivity analysis for the predicted sediment yield and the predicted sediment-associated nutrient yields

		Sediment (tons/acre)		Nitrogen (lb/acre)		Phosphorus (lb/acre)	
Parameter[1] (1)	Variation (2)	SD (3)	SD/base (4)	N_s (5)	N_s/base (6)	P_s (7)	P_s/base (8)
C	-50	.50	.50	1.83	.58	.91	.58
	-25	.75	.75	2.52	.80	1.26	.80
	+25	1.25	1.25	3.77	1.19	1.89	1.19
	+50	1.37	1.38	4.08	1.29	2.04	1.29
P	-50	.50	.50	1.83	.58	.91	.58
	-25	.75	.75	2.52	.80	1.26	.80
	+25	1.00	1.00	3.16	1.00	1.58	1.00
	+50	1.00	1.00	3.16	1.00	1.58	1.00

[1]EI = storm energy-intensity value, CN = runoff curve number, LS = land slope, FSL = field slope length, CS = channel slope, CSS = channel sideslope, N = Manning's roughness, K = soil erodibility factor, C = cropping management factor, and P = conservation practice factor. The upper limit for the parameter CN was set at 100; the upper limit for the parameters K, C, and P was set at 1.00.

Table 30.
A summary of the sensitivity analysis for the predicted soluble nutrient yields

Parameter[1] and variation (%)	Nitrogen (lb/acre)		Phosphorus (lb/acre)		COD (lb/acre)	
	N_q	N_q/base	P_q	P_q/base	COD_q	COD_q/base
Base	2.37	1.00	0.84	1.00	66.24	1.00
Rain:						
-50	1.51	.64	.57	.67	20.39	.31
-25	2.04	.86	.75	.89	41.99	.63
+25	2.59	1.09	.90	1.06	91.99	1.39
+50	2.77	1.17	.93	1.10	118.67	1.79
CN:						
-50	.07	.03	.02	.03	4.08	.06
-25	.36	.15	.11	.13	26.63	.40
+25	21.55	9.11	8.40	9.96	109.42	1.65
+50	31.23	13.20	12.24	14.50	117.52	1.77
AVAIL:						
-50	1.43	.61	.47	.56	66.24	1.00
-25	1.90	.80	.66	.78	66.24	1.00
+25	2.83	1.20	1.03	1.22	66.24	1.00
+50	3.30	1.39	1.22	1.44	66.24	1.00

[1]The upper limit for the parameters CN (runoff curve number) and AVAIL (fertilizer availability factor) was set at 100.

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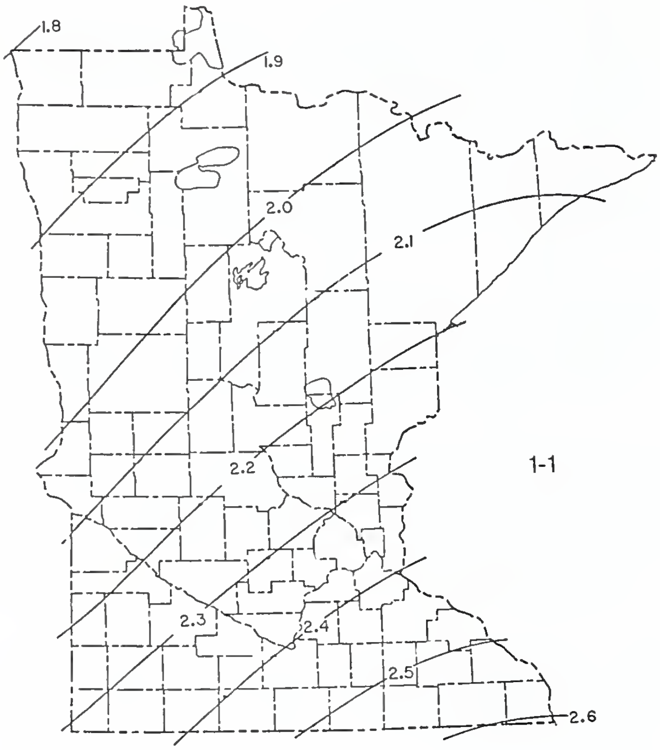
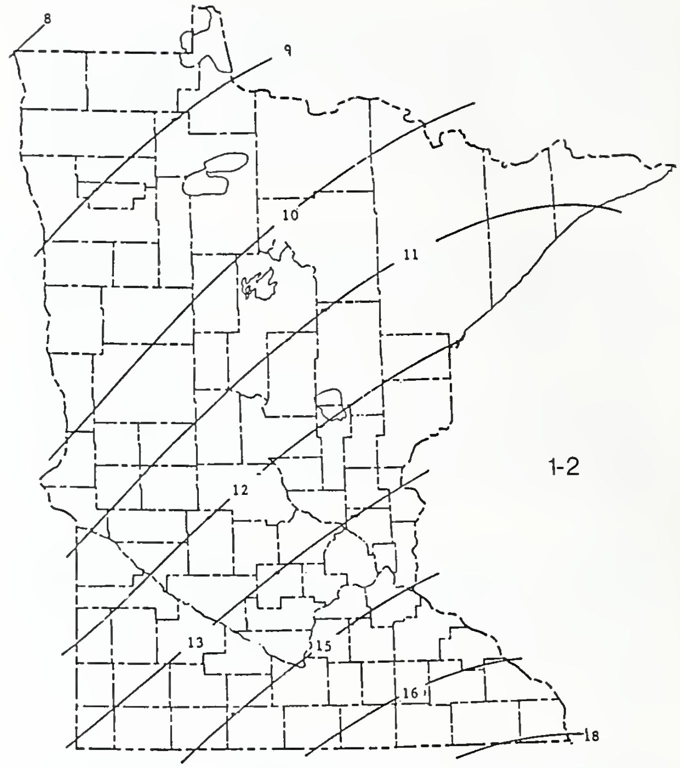
APPENDIX 1. STORM RAINFALL VOLUME AND ENERGY-INTENSITY FREQUENCY CURVES FOR MINNESOTA





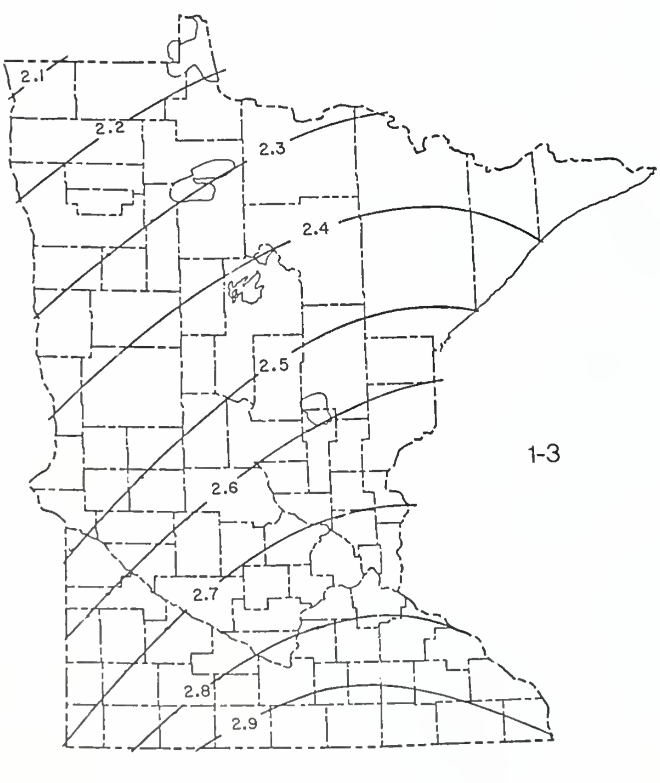
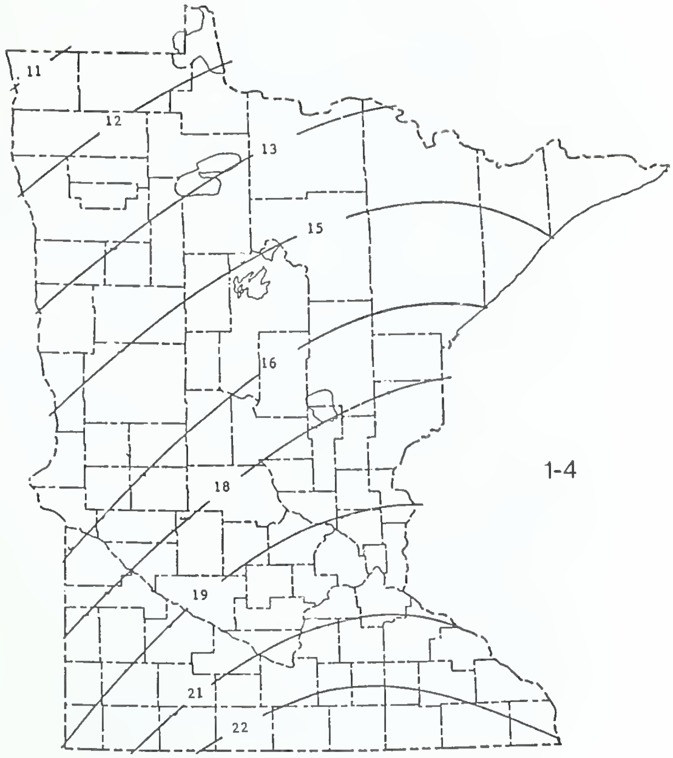


Figure 1-1
1-year, 24-hour rainfall (inches). Source: U.S. Department of Commerce, Weather Bureau (1961).

Figure 1-2
1-year, 24-hour EI. Source: U.S. Department of Commerce, Weather Bureau (1961).

Figure 1-3
2-year, 24-hour rainfall (inches). Source: U.S. Department of Commerce, Weather Bureau (1961).



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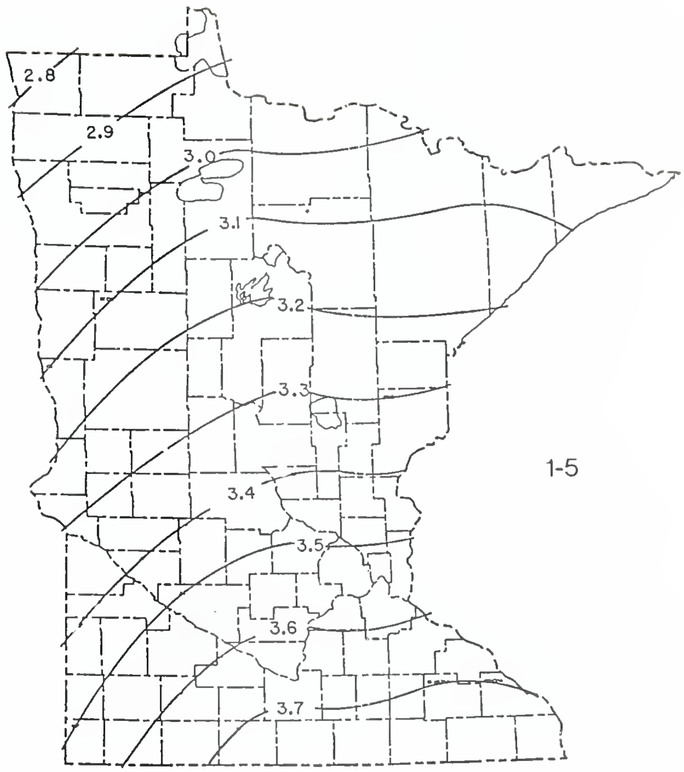

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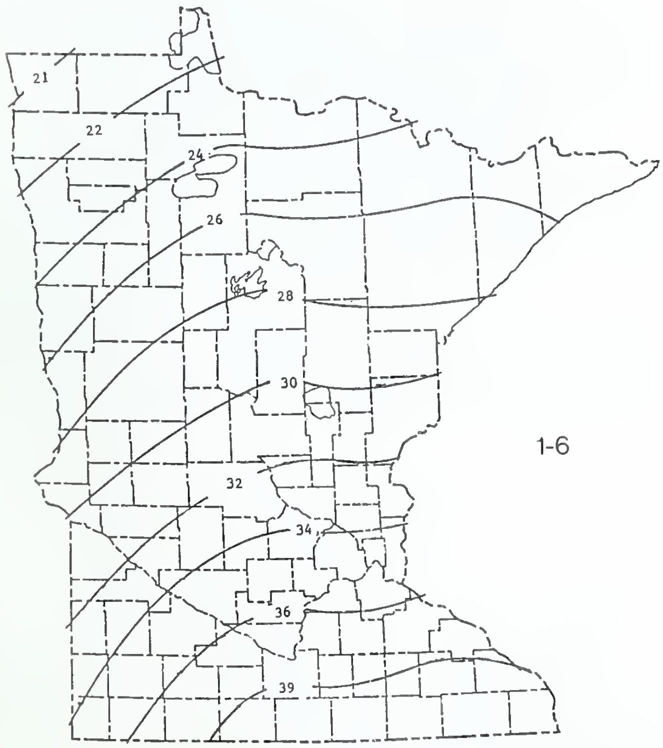
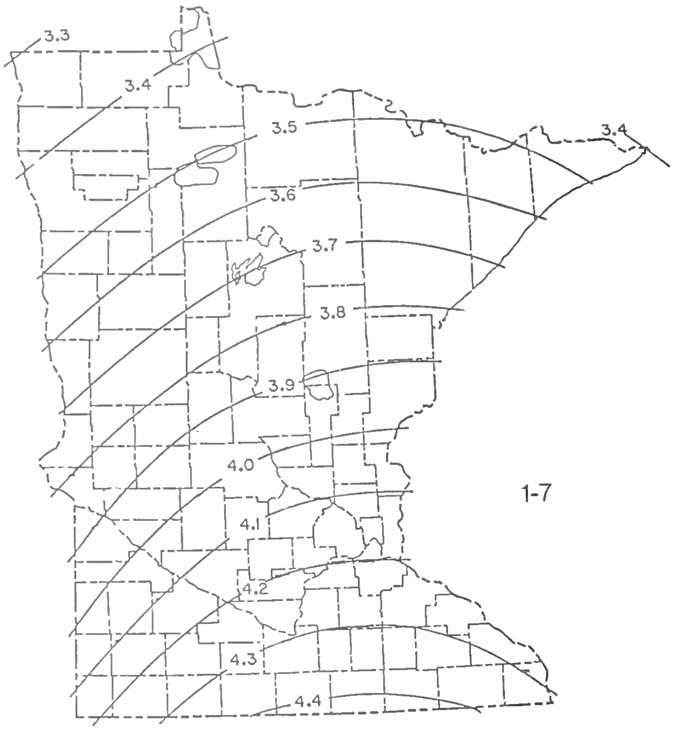


1-6

Figure 1-4
2-year, 24-hour EI. Source: U.S. Department of Commerce, Weather Bureau (1961).

Figure 1-5
5-year, 24-hour rainfall (inches). Source: U.S. Department of Commerce, Weather Bureau (1961).

Figure 1-6
5-year, 24-hour EI. Source: U.S. Department of Commerce, Weather Bureau (1961).



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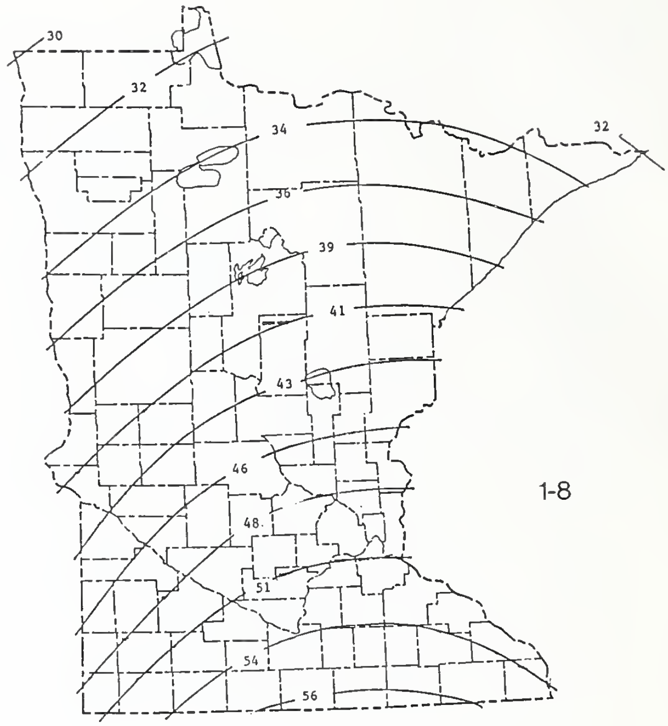

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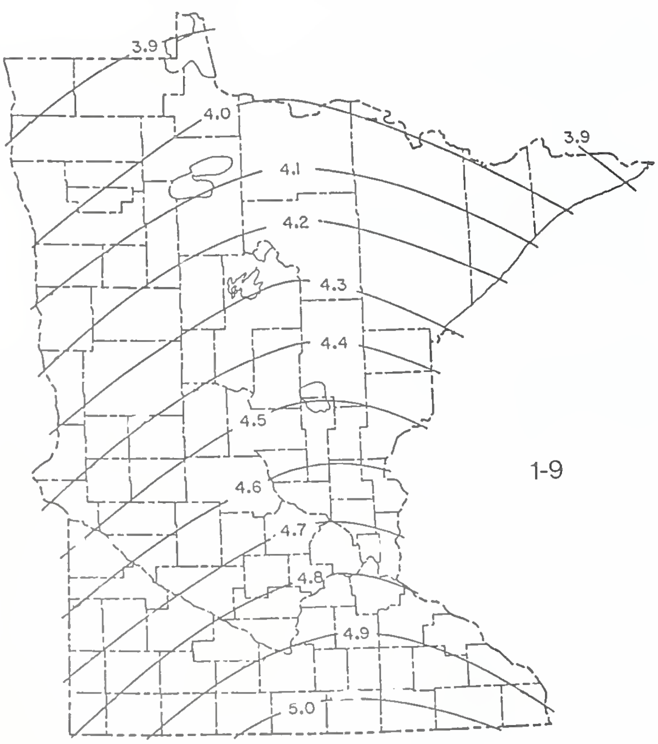

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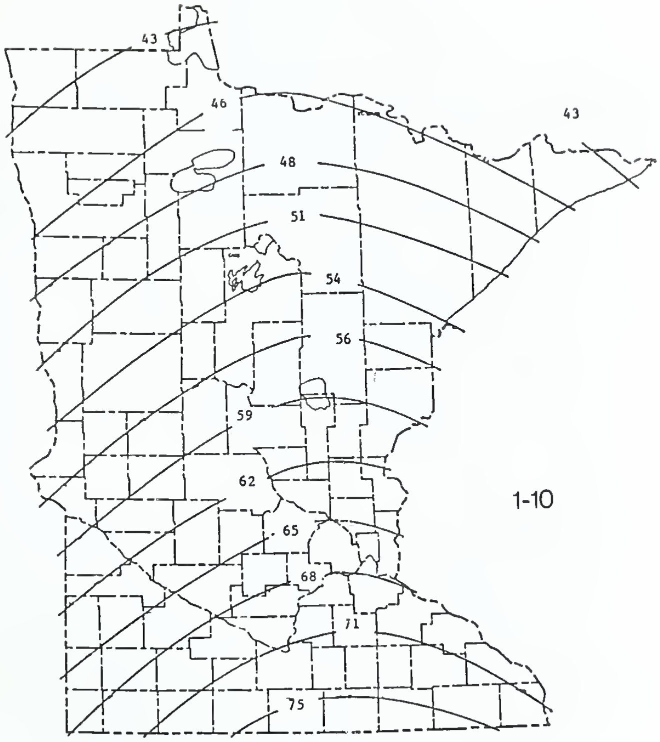
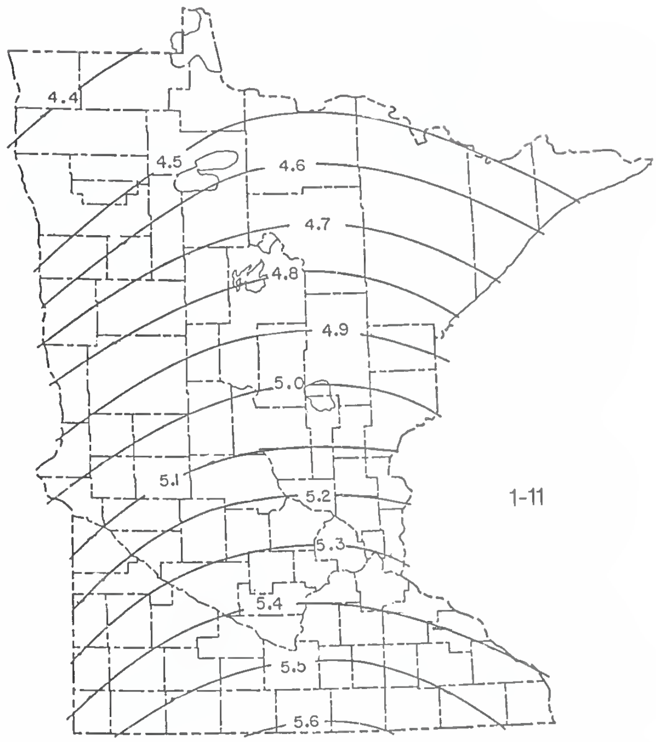
Figure 1-7
10-year, 24-hour rainfall (inches). Source: U.S. Department of Commerce, Weather Bureau (1961).

Figure 1-8
10-year, 24-hour EI. Source: U.S. Department of Commerce, Weather Bureau (1961).

Figure 1-9
25-year, 24-hour rainfall (inches). Source: U.S. Department of Commerce, Weather Bureau (1961).





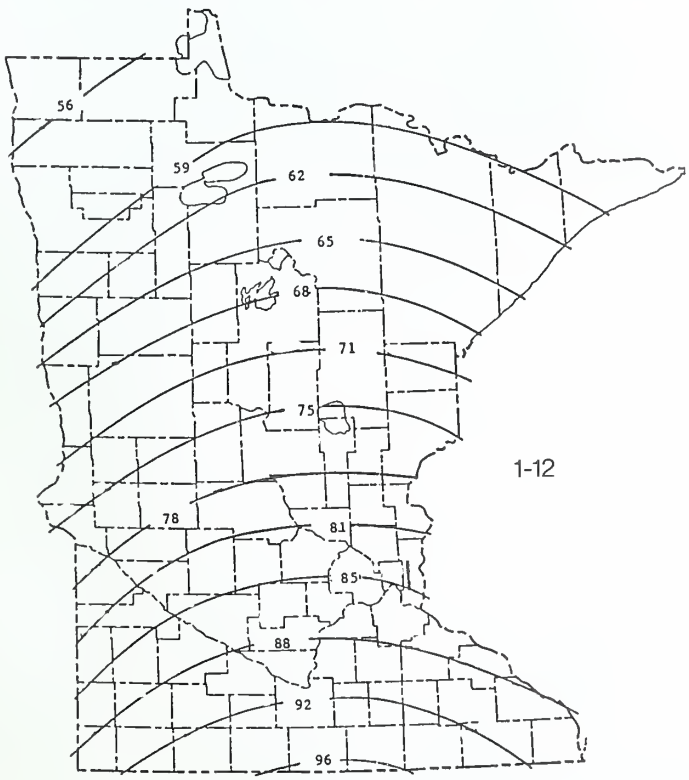


Figure 1-10
15-year, 24-hour EI. Source: U.S. Department of Commerce, Weather Bureau (1961).

Figure 1-11
50-year, 24-hour rainfall (inches). Source: U.S. Department of Commerce, Weather Bureau (1961).

Figure 1-12
50-year, 24-hour EI. Source: U.S. Department of Commerce, Weather Bureau (1961).

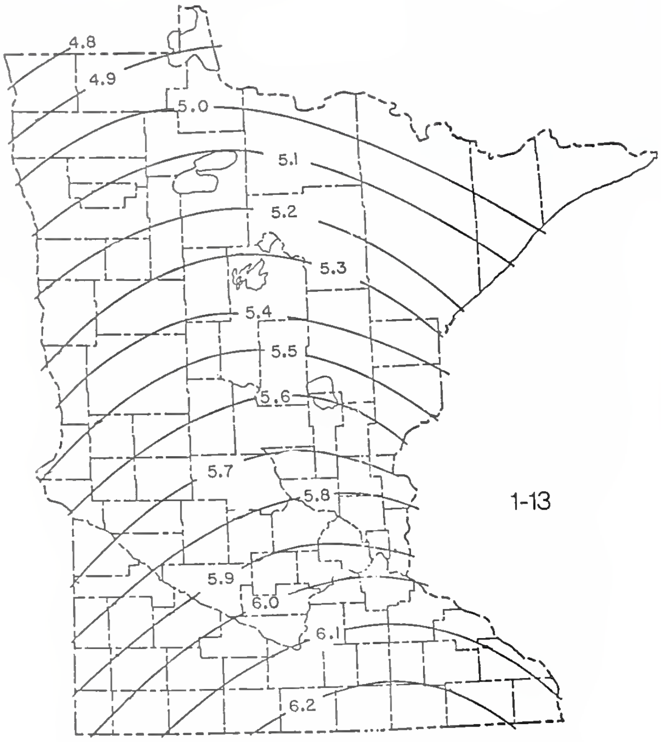


Figure 1-13
100-year, 24-hour rainfall (inches). Source: U.S. Department of Commerce, Weather Bureau (1961).

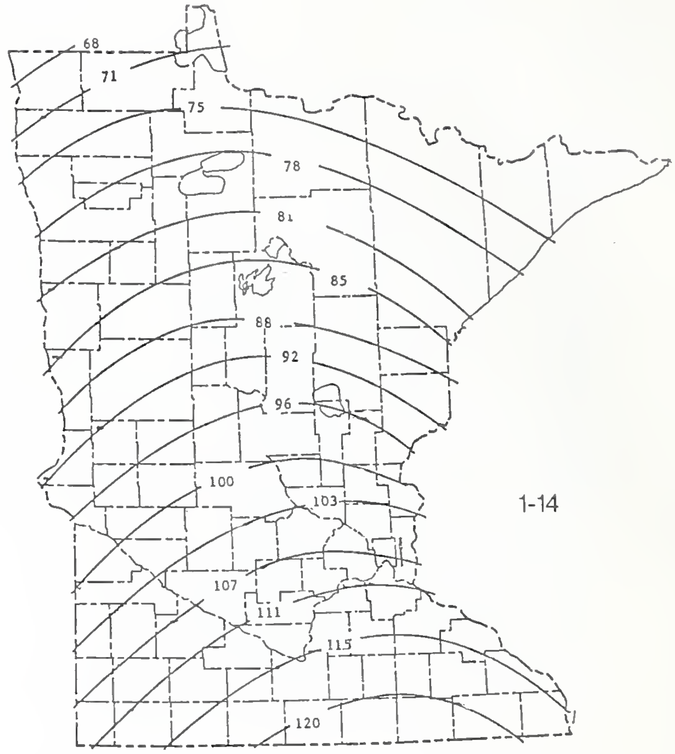


Figure 1-14
100-year, 24-hour EI. Source: U.S. Department of Commerce, Weather Bureau (1961).

APPENDIX 2. ESTABLISHING A DATA FILE

Background Information

To demonstrate how to set up a data file, we have used an ARS experimental watershed located near Treynor, IA. A map of this watershed appears in figure 2-1. After the map was obtained, we divided the watershed into cells. Because the watershed was small, it was necessary to use 2.5-acre cells even though they are not normally used in model analyses. After creating the cells, we numbered them and established the drainage pattern of each (fig. 2-2).

Since the watershed was field-sized, many of the variables were the same for all the cells. The soil types of the watershed were predominantly Ida and Manona silt loams, with a soil erodibility factor of 0.32, and hydrologic soil group B. The field was also kept in continuous corn farmed on the contour. The channel through the watershed was a natural channel but in poor condition, with a roughness coefficient of 0.048. The particular storm simulated in this example was the default storm, with a precipitation of 4.4 inches and an energy-intensity value of 56.0. The parameter file appears in figure 2-3.

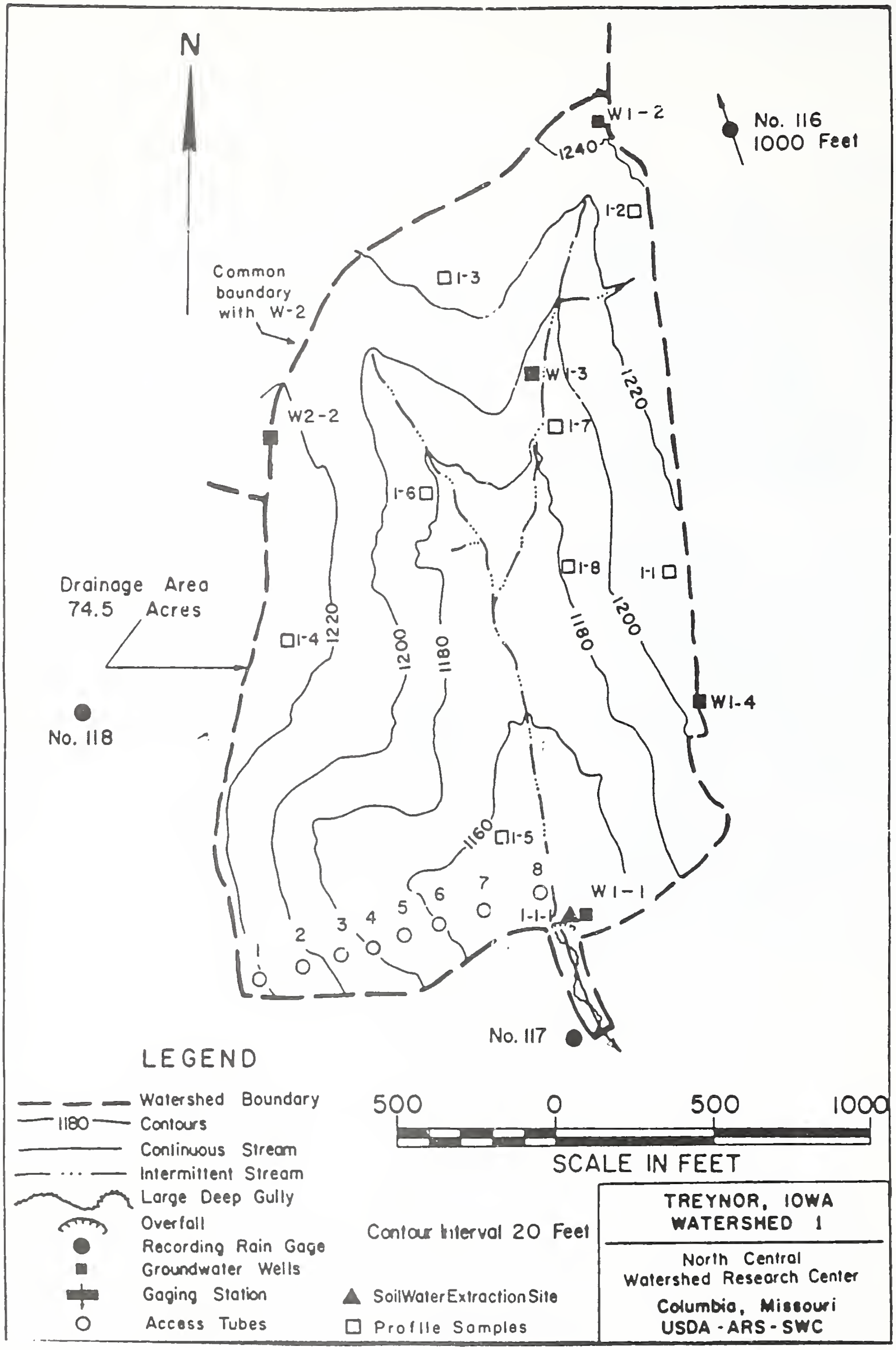


Figure 2-1
A contour map for the example watershed.

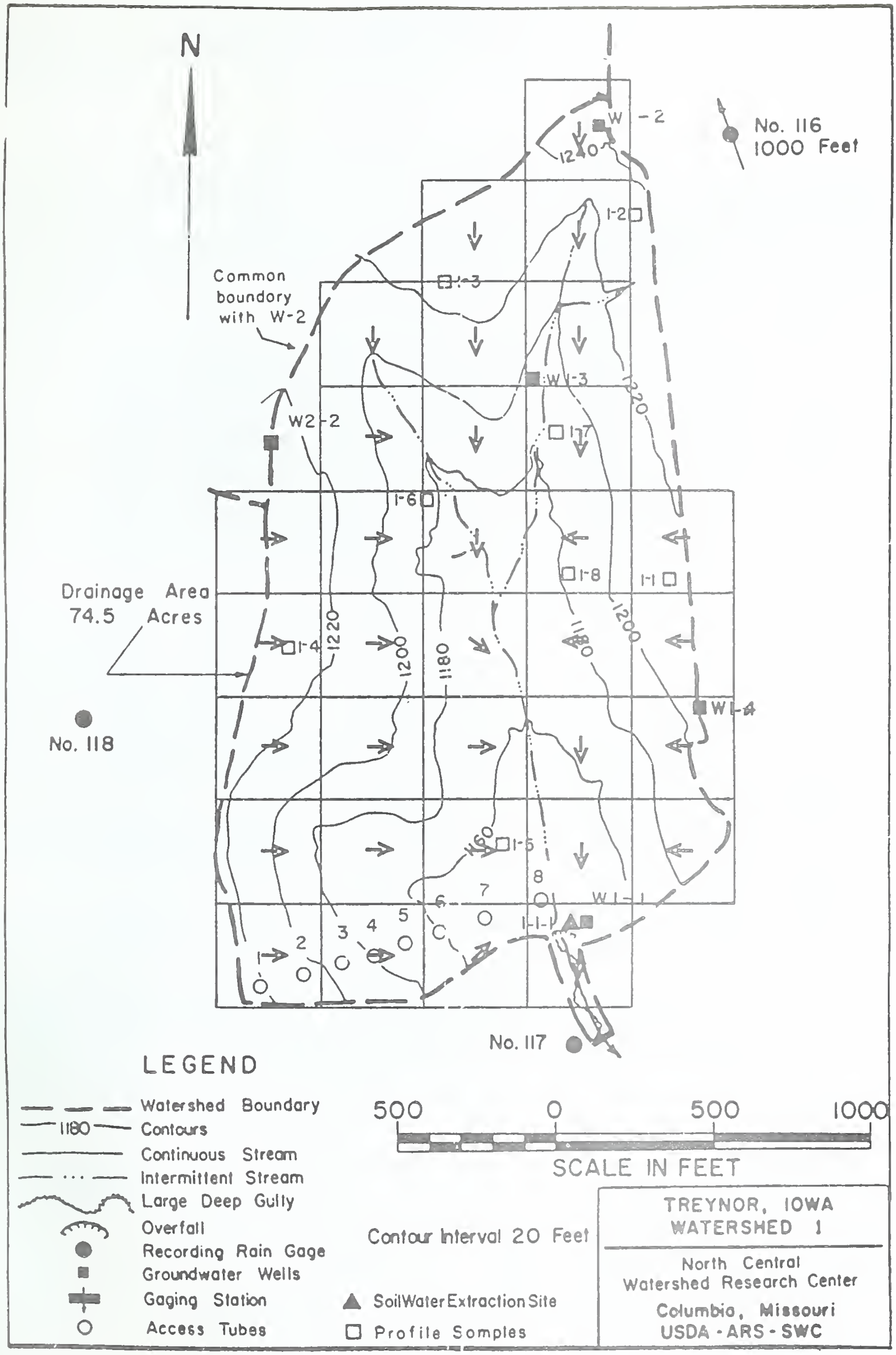


Figure 2-2
The example watershed with the cells and drainage patterns.

TREYNOR IOWA WATERSHED FILE[1]

2.5 33 4.4 56.0

1	3	75	12.0[2]	1	200	6.0[3]	5.0[4]	.050[5]	.32	.68[6]	1.00	.29	5	2	0[7]	10	0[8]	0	170	0
2	5	75	6.0	1	250	3.0	5.0	.050	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
3	6	75	6.0	1	250	5.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
4	7	75	9.0	1	200	6.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
5	8	75	6.0	1	250	3.0	5.0	.050	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
6	9	75	9.0	1	200	3.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
7	8	75	12.0	1	200	6.0	5.0	.048	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
8	12	75	7.0	1	200	4.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
9	13	75	10.0	1	200	4.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
10	11	75	6.0	1	250	3.0	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
11	12	75	12.0	1	200	6.0	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
12	17	75	4.0	1	250	2.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
13	12	75	10.0	1	200	2.0	5.0	.048	.32	.68	1.00	.29	7	2	0	10	0	0	170	0
14	13	75	8.0	1	200	4.0	5.0	.050	.32	.68	1.00	.29	7	2	0	10	0	0	170	0
15	16	75	5.0	1	250	2.5	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
16	17	75	7.0	1	200	3.5	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
17	23	75	5.0	1	250	2.0	5.0	.048	.32	.68	1.00	.29	4	2	0	10	0	0	170	0
18	17	75	8.0	1	200	4.0	5.0	.050	.32	.68	1.00	.29	7	2	0	10	0	0	170	0
19	18	75	6.0	1	250	3.0	5.0	.050	.32	.68	1.00	.29	7	2	0	10	0	0	170	0
20	21	75	7.0	1	200	3.5	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
21	22	75	6.0	1	250	3.0	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
22	23	75	8.0	1	200	4.0	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
23	28	75	7.0	1	200	1.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
24	23	75	10.0	1	200	5.0	5.0	.050	.32	.68	1.00	.29	7	2	0	10	0	0	170	0
25	26	75	13.0	1	150	6.5	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
26	27	75	6.0	1	250	3.0	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
27	28	75	7.0	1	200	3.5	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
28	33	75	4.0	1	250	1.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0
29	28	75	8.0	1	200	4.0	5.0	.050	.32	.68	1.00	.29	7	2	0	10	0	0	170	0
30	31	75	10.0	1	200	5.0	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
31	32	75	11.0	1	200	5.5	5.0	.050	.32	.68	1.00	.29	3	2	0	10	0	0	170	0
32	28	75	9.0	1	200	4.5	5.0	.050	.32	.68	1.00	.29	2	2	0	10	0	0	170	0
33	34	75	3.0	1	250	1.0	5.0	.048	.32	.68	1.00	.29	5	2	0	10	0	0	170	0

[1]All parameters used in the file are for a worst case situation.

[2]Assume a uniform slope.

[3]If no channel exists within the cell use a channel slope of 1/2 the land slope.

[4]Assume a channel sideslope of 5%.

[5]Assume a residue level of one ton.

[6]Conventional tillage leaving residues on the field, seedbed condition.

[7]Assume no fertilization.

[8]No feedlots in the watershed.

Figure 2-3
An example parameter file for input into the model for the Treynor watershed.

APPENDIX 3. MINNESOTA LAND MANAGEMENT INFORMATION SYSTEM (MLMIS) DATA FILE EXPLANATION

MLMIS Data File Format

Line 1 to end of file

Column No.	
1	Row designation
2	Column designation
3	Township number
4	Range number
5	Section number
6	40-acre parcel
7	Minor watershed number
8	Land use/land cover
9	Forest cover
10	Soil erodibility code
11	Land slope (percent)
12	Soil texture number
13	River slope (percent)
14	360° aspect
15	River/no river identification
16	Eight-way aspect

Parameter Explanation[1]

Item 3: Public Land Survey (PLS) Township Number

Description: This variable records the actual township number from the original Public Land Survey. This variable, along with the other three PLS variables, is used to geographically link other data files to MLMIS.

Data Source: The PLS township numbers were recorded by MLMIS staff from two sets of county highway maps. One set was the current general county highway maps prepared by the Minnesota Highway Department in the late 1960's when the data were being recorded. The other set of county highway maps was also prepared by the Highway Department. This set of 1936 maps was and is the only set of statewide maps showing government lot numbers from the PLS.

Coding Procedure: PLS section numbers were recorded on coding sheets and keypunched into the MLMIS file.

Contact Person: Les Maki, SPA/LMIC, (612) 296-1208.

Data Classes: PLS township number is recorded as a three-digit number that varies from 26° N. to 168 N.

Item 4: Public Land Survey (PLS) Range Number

Description: This variable records the actual range number from the original Public Land Survey. Codes were developed for range numbers that are east and west of the origin line. This variable, along with the other three PLS variables, is used to geographically link other data files to MLMIS.

Data Source: The PLS range numbers were recorded by MLMIS staff from two sets of county highway maps. One set was the current general county highway maps prepared by the Minnesota Highway Department in the late 1960's when the data were being recorded. The other set of county highway maps was also prepared by the Highway Department. This set of 1936 maps was and is the only set of statewide maps showing government lot numbers from the PLS.

Coding Procedure: PLS section numbers were recorded on coding sheets and keypunched into the MLMIS file.

[1] Quoted verbatim from "Manual 40--MLMIS Statewide 40-Acre Data." Land Management Information Center, Minnesota State Planning Agency, LL-45 Metro Square, 7th and Robert, St. Paul, MN 55101.

Contact Person: Les Maki, SPA/LMIC, (612) 296-1208.

Data Classes: PLS range numbers are recorded as three-digit numbers. The first two digits record the actual range number from the Public Land Survey. The third digit records east or west of the origin line, -1 for west and 2 for east.

Item 5: Public Land Survey (PLS) Section Number

Description: This variable records the actual section number from the original Public Land Survey. This variable, along with the other three PLS variables, is used to geographically link other data files to MLMIS.

Data Source: The PLS section numbers were recorded by MLMIS staff from two sets of county highway maps. One set was the current general county highway maps prepared by the Minnesota Highway Department in the late 1960's when the data were being recorded. The other set of county highway maps was also prepared by the Highway Department. This set of 1936 maps was and is the only set of statewide maps showing government lot numbers from the PLS.

Coding Procedure: PLS section numbers were recorded on coding sheets and keypunched into the MLMIS file.

Contact Person: Les Maki, SFM/LMIC, (612) 296-1208

Data Classes: PLS sections are recorded as two-digit numbers ranging from 01 to 36.

Item 6: Public Land Survey (PLS) 40-acre parcel

Description: This variable records the quarter-quarter section defined in the Public Land Survey. It records both quarter-quarter sections from regular sections and irregular parcels. This variable, along with the other three PLS variables, is used to geographically link other data files to MLMIS.

Data Source: The PLS section numbers were recorded by MLMIS staff from two sets of county highway maps. One set was the current general county highway maps prepared by the Minnesota Highway Department in the late 1960's when the data were being recorded. The other set of county highway maps was also prepared by the Highway Department. This set of 1936 maps was and is the only set of statewide maps showing government lot numbers from the PLS.

Coding Procedure: PLS section coding numbers were recorded on coding sheets and keypunched into the MLMIS file.

Contact Person: Les Maki, SPA/LMIC, (612) 296-2613.

Data Classes: PLS 40-acre parcels are recorded as two-digit numbers. The [16] codes for regular parcels are listed below. The [16] codes for irregular 40-acre parcels can be obtained from the contact person listed above.

Legend:

11	NE 1/4 of the NE 1/4
12	NW 1/4 of the NE 1/4
13	SW 1/4 of the NE 1/4
14	SE 1/4 of the NE 1/4
21	NE 1/4 of the NW 1/4
22	NW 1/4 of the NW 1/4
23	SW 1/4 of the NW 1/4
24	SE 1/4 of the NW 1/4
31	NE 1/4 of the SW 1/4
32	NW 1/4 of the SW 1/4
33	SW 1/4 of the SW 1/4
34	SE 1/4 of the SW 1/4
41	NE 1/4 of the SE 1/4
42	NW 1/4 of the SE 1/4
43	SW 1/4 of the SE 1/4
44	SE 1/4 of the SE 1/4

22	21	12	11
23	24	13	14
32	31	42	41
33	34	43	44

Item 7: Minor Watersheds

Contact Person: Earl Nordstrand, SPA/LMIC, (612) 296-1202

Documentation incomplete--work in progress.

Item 8: Land Use/Land Cover, 1969

Description: Nine land-use/land-cover classes, interpreted from high-altitude air photos, are recorded for each 40-acre parcel in the State.

Data Source: The primary information source was 1:90,000 scale air photos from black and white panchromatic film. The State south of St. Cloud was flown in April 1968 and the northern half in April 1969. In both cases, the flights were flown east to west, with flight lines about 10 miles apart. Current county highway maps (ca. 1968), which at that time indicated such cultural features as individual houses, were used as a secondary source.

Coding Procedure: Land-use/land-cover interpretations were made at the University of Minnesota by a team of students headed by a professional photo interpreter. The data were coded by a recorder as the photo was being interpreted by a team of two. Each township was covered by a Mylar overlay with section lines delineated. Each section was normally divided into sixteen 40-acre parcels. Actual roads and field lines were used to identify 40-acre parcels on the ground; the grid was used where no boundaries occurred.

It is important to recognize that the classification scheme uses two different criteria--dominant economic activity (use) and dominant spatial area (cover)--to determine the class of any 40-acre parcel. Spatial dominance was confined to the undeveloped (in terms of structures) land classes and generally refers to cover type. The "undeveloped" classes are determined by dominant economic activity. Both urban categories and some transportation types supercede other cover types, and "urban mixed" will supercede all other classes except airports and railyards in the "transportation" category.

Contact Person: Mary Louise Dudding, SPA/LMIC, (612) 296 2720.

Data Classes: Data are coded as one-digit numbers for the nine classes.

Legend:

1. Forested--a forty in which the dominant land use consists of trees. To be considered forested, the forty must contain a scattering of trees whose crowns cover at least 10 percent of the land area.

2. Cultivated--a forty in which the dominant use is land that has been recently tilled or harvested mechanically.

3. Water--a forty in which the dominant land use is open and permanent water.

4. Marsh--a forty in which the dominant land use consists of nonforested, shallow, permanently wet, vegetated areas.

5. Urban Residential--a forty containing five or more residential dwellings and commercial buildings.

6. Extractive--a forty in which the dominant land use consists of the extraction of minerals, including ancillary facilities. Examples are mines, tailing piles, and gravel pits.

7. Pasture and Open--a forty on nonforested land not used for any identifiable purpose. Examples are grazing land or abandoned farmland.

8. Urban Non-residential or Mixed Residential Development--a forty containing at least one commercial, industrial, or institutional facility (including golf courses and cemeteries) and possibly containing residential development.

9. Transportation--a forty in which the dominant land use consists of facilities for the conveyance of people or materials.

Item 9: Major Forest Types, 1977

Description: The major forest types are groups of tree species that commonly grow in association. Each variable class refers to a distinct forest type, based on standard U.S. Department of Agriculture, Forest Service (FS) definitions of "commercial" forest lands.

Data Source: Source data for this variable were collected by the FS as part of the required decennial inventory of Minnesota forest resources. The Resources Evaluation Unit, North Central Forest Experiment Station, FS, St. Paul, MN, determined forest types between spring 1975 and summer 1977 by interpreting the most recent 1:15,840-1:40,000 scale aerial photographs for each county. The currency of these photographs ranges between 1967 and 1977, depending on the county. The FS recorded forest cover data on 1:24,000 ozalid air photo prints from the 1968-69 high-altitude flight. These prints were provided by the Minnesota State Planning Agency (SPA), and are permanently on file at the North Central Forest Experiment Station.

Coding Procedure: The Environmental Planning Division of SPA, in cooperation with LMIC, coded forest-cover information in 1977. The most detailed land record maps available, generally U.S. Geological Survey topographic maps, were used to draft public land survey section lines on to the air photo prints described above. A 40-acre grid was placed over each section, and the dominant forest type was recorded for each 40-acre cell that was mainly forest land.

Contact Person: Don Yaeger, SPA/MIC, (612) 296-2613. For information on the data collection program, contact Burt Essex, Resources Evaluation Unit, U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station, (612) 642-5282.

Data Classes: A one-digit code records the six major forest types in Minnesota. Unproductive forest land and nonforest land have also been recorded.

Legend:

1. Pine: predominantly white pine, red pine, or jack pine, singly or in combination.

2. Spruce-fir: predominantly balsam fir, white spruce, black spruce, tamarack, or northern white-cedar, singly or in combination.

3. Oak: predominantly northern red oak, white oak, or burr oak, singly or in combination.

4. Elm-ash-cottonwood: predominantly lowland elm, black ash, cottonwood, or red maple, singly or in combination.

5. Maple-basswood: predominantly sugar maple, basswood, yellow birch or upland elm, and red maple, singly or in combination.

6. Aspen-birch: predominantly aspen, balsam, poplar, or paper birch, singly or in combination.

7. Unproductive forest land: land incapable of producing industrial wood under natural conditions because of poor site. (Note: Usually poorly drained swamp conifers).

9. Non-forest land: a 40-acre parcel that is not dominantly covered by forest trees or is within built-up urban areas.

Item 10: Surface K-factor for Minnesota Soil Atlas Data

Description: The soil erodibility factor (K) in the Universal Soil Loss Equation is a quantitative value experimentally determined for a given soil. Generally speaking, a soil type becomes less erodible with a decrease in the silt fraction regardless of the corresponding increase in sand fraction or clay fraction. The interpretations were developed for soil landscape units (upper 5 feet of soil material only) within their respective geomorphic regions.

Primary Data: Surface K-factor is an interpretation based on the consideration of soil landscape units and their respective geomorphic position. A soil landscape unit is a group of soils generalized into a homogeneous unit based on subsurface soil texture, surface soil texture, drainage characteristics, and surface color. A geomorphic region is a physiographic area defined by topographic relief and soil parent material. For a more detailed description of soil landscape units and geomorphic regions, refer to their Manual 40 descriptions.

Method of Modification: Professional interpretations of soils and geomorphic information were done by staff of the Department of Soil Science, University of Minnesota, in cooperation with the U.S. Department of Agriculture, Soil Conservation Service.

Contact Person: Bob Smekofski, SPA/LMIC at (612) 296-1204.

Legend:

01	0.10-0.17
02	.10- .20
03	.10- .24
04	.10- .32
05	<.15
06	.15- .20
07	.15- .24
08	0.15-0.28
09	.15- .32
10	.15- .37
11	.15- .43
12	.17- .24
13	.17- .28
14	.17- .32
15	<.18
16	.20- .24
17	.20- .32
18	.20- .37
19	<.21
20	.24- .28
21	.24- .32
22	.24- .37
23	.24- .43
24	<.25
25	.28- .32
26	.28- .37
27	.28- .43
28	<.29
29	>.29
30	.32- .37
31	<.32
32	.32- .43
33	<.33
34	.37- .43
35	<.38
36	<.39
37	No Rating
38	Water

Item 11: Land slope percent

Standard (run/rise) for all forties.

Item 12: Soil Texture in the Rooting Zone for Minnesota Soil Atlas Data

Description: Soil texture in the rooting zone describes the dominant presence of sand, silt, or clay in the upper 5 feet of the soil profile. The interpretations were developed for soil landscape units within their respective geomorphic regions.

Primary Data: Soil texture in the rooting zone is an interpretation based on the consideration of soil landscape units and their respective geomorphic position. A soil landscape unit is a group of soils generalized into a homogeneous unit based on subsurface soil texture, surface soil texture, drainage characteristics, and surface color. A geomorphic region is a physiographic area defined by topographic relief and soil parent material. For a detailed description of soil landscape units and geomorphic regions refer to their Manual 40 descriptions.

Method of Modification: Professional interpretations of soils and geomorphic information were done by staff of the Department of Soil Science, University of Minnesota in cooperation with the U.S. Department of Agriculture, Soil Conservation Service.

Contact Person: Bob Smekofski, SPA/LMIC at (612) 296-1204.

Legend:

01	Sand
02	Sand to loamy sand
03	Loam sand
04	Loamy sand to sandy loam
05	Sandy loam

06	Sandy loam to loam
07	Loam to sand and gravel
08	Loam
09	Loam to clay loam
10	Loam to silt loam
11	Loam to silty clay
12	Loam, clay loam, sand and gravel
13	Clay loam
14	Clay loam to silty clay loam
15	Silt loam
16	Silt loam to silty clay loam
17	Silty clay loam
18	Silty clay loam to silty clay
19	Silty clay
20	Silty clay to clay
21	Peat
22	Clay
23	Mine dumps
24	Water

Item 13: River Slope (percent)

Medium slope of 100-m river slopes for a 40-acre parcel that contains rivers

Item 14: 360° Aspect

Item 15: River or no River

Nonriver = 0, river = 1

Item 16: Aspect

Calculated from vector average of the eight nearest neighbors

<u>Legend</u>:

0	Peak/dip
1	North
2	Northeast
3	East
4	Southeast
5	South
6	Southwest
7	West
8	Northwest

APPENDIX 4. EXAMPLE USE OF THE SUPPLEMENTARY PROGRAM--DBDFL

Background Information

The watershed chosen to demonstrate the program used to generate data files from MLMIS data is the same watershed described and used in appendix 2. All options of the program DBDFL were run and appear in the tables of this appendix.

Figure 4-1 shows the file used to simulate the MLMIS file. Since this is not a Minnesota watershed, no actual MLMIS file could be obtained. Thus, many of the variables appearing in the file are only examples to show what might be in a file for this watershed. Figure 4-2 shows the edit file created for the watershed. The variables of this file and an explanation of each may be found in table 14. Edited values were inserted for the land-use code, the curve number, the roughness coefficient, the soil erodibility, the cropping factor, and the fertilization level.

Figure 4-3 shows the computer interaction and the eventual data file generated when only the MLMIS file was used. In this file, as in the other files generated, the storm characteristics were simulated. To obtain a better estimate of the curve number, a hydrologic soil classification of A was used.

Figure 4-4 shows the results of using an edit file along with the MLMIS file. In figure 4-4, all edit variables were transferred. The total edit process allowed us to alter the preliminary data file into the same file generated manually in appendix 2.

1	4	106	122	31	1	51	2	9	26	12	10	6	0	0	5
2	3	106	122	31	1	51	2	9	26	6	10	3	0	0	5
2	4	106	122	31	1	51	2	9	26	6	10	5	0	1	5
3	2	106	122	31	1	51	2	9	26	9	10	6	0	1	5
3	3	106	122	31	1	51	2	9	26	6	10	3	0	0	5
3	4	106	122	31	1	51	2	9	26	9	10	3	0	1	5
4	2	106	122	31	1	51	2	9	26	12	10	6	0	1	3
4	3	106	122	31	1	51	2	9	26	7	10	4	0	1	5
4	4	106	122	31	1	51	2	9	26	10	10	4	0	1	5
5	1	106	122	31	1	51	2	9	26	6	10	3	0	0	3
5	2	106	122	31	1	51	2	9	26	12	10	6	0	0	3
5	3	106	122	31	1	51	2	9	26	4	10	2	0	1	5
5	4	106	122	31	1	51	2	9	26	10	10	2	0	1	7
5	5	106	122	31	1	51	2	9	26	8	10	4	0	0	7
6	1	106	122	31	1	51	2	9	26	5	10	3	0	0	3
6	2	106	122	31	1	51	2	9	26	7	10	4	0	0	3
6	3	106	122	31	1	51	2	9	26	5	10	2	0	1	4
6	4	106	122	31	1	51	2	9	26	8	10	4	0	0	7
6	5	106	122	31	1	51	2	9	26	6	10	3	0	0	7
7	1	106	122	31	1	51	2	9	26	7	10	4	0	0	3
7	2	106	122	31	1	51	2	9	26	6	10	3	0	0	3
7	3	106	122	31	1	51	2	9	26	8	10	4	0	0	3
7	4	106	122	31	1	51	2	9	26	7	10	1	0	1	5
7	5	106	122	31	1	51	2	9	26	10	10	5	0	0	7
8	1	106	122	31	1	51	2	9	26	13	10	7	0	0	3
8	2	106	122	31	1	51	2	9	26	6	10	3	0	0	3
8	3	106	122	31	1	51	2	9	26	7	10	4	0	0	3
8	4	106	122	31	1	51	2	9	26	4	10	1	0	1	5
8	5	106	122	31	1	51	2	9	26	8	10	4	0	0	7
9	1	106	122	31	1	51	2	9	26	10	10	5	0	0	3
9	2	106	122	31	1	51	2	9	26	11	10	6	0	0	3
9	3	106	122	31	1	51	2	9	26	9	10	5	0	0	2
9	4	106	122	31	1	51	2	9	26	3	10	1	0	1	5

Figure 4-1
An example MLMIS file for the demonstration watershed. Refer to "MLMIS Data File Format", appendix 3, for identification of columns.

1	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
2	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
3	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
4	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
5	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
6	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
7	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
8	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
9	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
10	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
11	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
12	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
13	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
14	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
15	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
16	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
17	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
18	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
19	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
20	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
21	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
22	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
23	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
24	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
25	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
26	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
27	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
28	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0
29	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
30	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
31	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
32	0	3	75	0.0	0	0.0	0.0	.050	.32	.68	.00	4	0	0	0	0
33	0	3	75	0.0	0	0.0	0.0	.048	.32	.68	.00	4	0	0	0	0

Figure 4-2
An example edit file for the demonstration watershed. Refer to table 10 for identification of columns.

```
TREYNOR IOWA DEFAULT FILE
 2.5  33   4.4  56.0
   1   3  86 12.0 1 200  6.0  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
   2   5  86  6.0 1 250  3.0  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
   3   6  86  6.0 1 250  3.0  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
   4   7  86  9.0 1 200  4.5  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
   5   8  86  6.0 1 250  3.0  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
   6   9  86  9.0 1 200  4.5  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
   7   8  86 12.0 1 200  6.0  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
   8  12  86  7.0 1 200  3.5  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
   9  13  86 10.0 1 200  5.0  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
  10  11  86  6.0 1 250  3.0  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  11  12  86 12.0 1 200  6.0  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  12  17  86  4.0 1 250  2.0  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
  13  12  86 10.0 1 200  5.0  5.0 .060 .33 .43 1.00 .22 7 2 2  10 0   0 120  0
  14  13  86  8.0 1 200  4.0  5.0 .060 .33 .43 1.00 .22 7 2 2  10 0   0 120  0
  15  16  86  5.0 1 250  2.5  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  16  17  86  7.0 1 200  3.5  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  17  23  86  5.0 1 250  2.5  5.0 .060 .33 .43 1.00 .22 4 2 2  10 0   0 120  0
  18  17  86  8.0 1 200  4.0  5.0 .060 .33 .43 1.00 .22 7 2 2  10 0   0 120  0
  19  18  86  6.0 1 250  3.0  5.0 .060 .33 .43 1.00 .22 7 2 2  10 0   0 120  0
  20  21  86  7.0 1 200  3.5  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  21  22  86  6.0 1 250  3.0  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  22  23  86  8.0 1 200  4.0  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  23  28  86  7.0 1 200  3.5  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
  24  23  86 10.0 1 200  5.0  5.0 .060 .33 .43 1.00 .22 7 2 2  10 0   0 120  0
  25  26  86 13.0 1 150  6.5  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  26  27  86  6.0 1 250  3.0  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  27  28  86  7.0 1 200  3.5  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  28  33  86  4.0 1 250  2.0  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0
  29  28  86  8.0 1 200  4.0  5.0 .060 .33 .43 1.00 .22 7 2 2  10 0   0 120  0
  30  31  86 10.0 1 200  5.0  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  31  32  86 11.0 1 200  5.5  5.0 .060 .33 .43 1.00 .22 3 2 2  10 0   0 120  0
  32  28  86  9.0 1 200  4.5  5.0 .060 .33 .43 1.00 .22 2 2 2  10 0   0 120  0
  33  34  86  3.0 1 250  1.5  5.0 .060 .33 .43 1.00 .22 5 2 2  10 0   0 120  0

   USER INTERACTION

   Input MLMIS filename (ex: #MLMIS):#DEMO
   Input the name to be assigned to the output file (ex: @FILEN):@DEMO
   Do you intend to use an edit file (Yes or No)?  NO
   Input the watershed name (1 to 30 characters): TREAYNOR/IOWA DEFAULT FILE
   Input the cell area chosen (10 or 40 acres): 2.5
   Do you wish to input storm parameters (Yes or No)? NO
   Input the major field slope length area number: 2
   Normal close, the new data file is: @DEMO
```

Figure 4-3
User interaction and an example data file for program DBDFL. Example showing the use of only MLMIS data file to generate a preliminary default parameter file.

```
TREYNOR IOWA EDITTED FILE
 2.5  33   4.4  56.0
   1   3  75 12.0 1 200  6.0  5.0 .050 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
   2   5  75  6.0 1 250  3.0  5.0 .050 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
   3   6  75  6.0 1 250  3.0  5.0 .048 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
   4   7  75  9.0 1 200  4.5  5.0 .048 .32 .68 1.00 .29 5 2 0  10 C   0 170  0
   5   8  75  6.0 1 250  3.0  5.0 .050 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
   6   9  75  9.0 1 200  4.5  5.0 .048 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
   7   8  75 12.0 1 200  6.0  5.0 .048 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
   8  12  75  7.0 1 200  3.5  5.0 .048 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
   9  13  75 10.0 1 200  5.0  5.0 .048 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
  10  11  75  6.0 1 250  3.0  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  11  12  75 12.0 1 200  6.0  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  12  17  75  4.0 1 250  2.0  5.0 .048 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
  13  12  75 10.0 1 200  5.0  5.0 .048 .32 .68 1.00 .29 7 2 0  10 0   0 170  0
  14  13  75  8.0 1 200  4.0  5.0 .050 .32 .68 1.00 .29 7 2 0  10 0   0 170  0
  15  16  75  5.0 1 250  2.5  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  16  17  75  7.0 1 200  3.5  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  17  23  75  5.0 1 250  2.5  5.0 .048 .32 .68 1.00 .29 4 2 0  10 0   0 170  0
  18  17  75  8.0 1 200  4.0  5.0 .050 .32 .68 1.00 .29 7 2 0  10 0   0 170  0
  19  18  75  6.0 1 250  3.0  5.0 .050 .32 .68 1.00 .29 7 2 0  10 0   0 170  0
  20  21  75  7.0 1 200  3.5  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  21  22  75  6.0 1 250  3.0  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  22  23  75  8.0 1 200  4.0  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  23  28  75  7.0 1 200  3.5  5.0 .048 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
  24  23  75 10.0 1 200  5.0  5.0 .050 .32 .68 1.00 .29 7 2 0  10 0   0 170  0
  25  26  75 13.0 1 150  6.5  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  26  27  75  6.0 1 250  3.0  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  27  28  75  7.0 1 200  3.5  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  28  33  75  4.0 1 250  2.0  5.0 .048 .32 .68 1.00 .29 5 2 0  10 0   0 170  0
  29  28  75  8.0 1 200  4.0  5.0 .050 .32 .68 1.00 .29 7 2 0  10 0   0 170  0
  30  31  75 10.0 1 200  5.0  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  31  32  75 11.0 1 200  5.5  5.0 .050 .32 .68 1.00 .29 3 2 0  10 0   0 170  0
  32  28  75  9.0 1 200  4.5  5.0 .050 .32 .68 1.00 .29 2 2 0  10 0   0 170  0
  33  34  75  3.0 1 250  1.5  5.0 .048 .32 .68 1.00 .29 5 2 0  10 0   0 170  0

 USER INTERACTION

 Input MLMIS filename (ex: #MLMIS):#DEMO
 Input the name to be assigned to the output file (ex: @FILEN):@DEMO
 Do you incend to use an edit file (Yes or No)?  YES
 Input the Edit filename (ex: .EDITF): .DEMO
 Input the watershed name (1 to 30 characters): TREYNOR/IOWA EDITTED FILE
 Input the cell area chosen (10 or 40 acres): 2.5
 Do you wish to input storm parameters (Yes or No)? NO
 Input the major field slope length area number: 2
 Normal close, the new data file is: @DEMO
```

Figure 4-4
User interaction and an example data file for program DBDFL. Example shows the complete use of the edit file as well as the MLMIS data file.

APPENDIX 5. CROPPING FACTOR TABLES

The cropping factor tables in this appendix have been reproduced from table 5 in Wischmeier and Smith (1978).

TABLE 5.—*Ratio of soil loss from cropland to corresponding loss from continuous fallow*

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5]: F	SB	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
	CORN AFTER C, GS, G OR COT IN MEADOWLESS SYSTEMS										
	Moldboard plow, conv till:										
1	RdL, sprg TP	4,500	—	31	55	48	38			20	23
2		3,400	—	36	60	52	41	—	24	20	30
3		2,600	—	43	64	56	43	32	25	21	37
4		2,000	—	51	68	60	45	33	26	22	47
5	RdL, fall TP	HP[2]	—	44	65	53	38	—	—	20	—
6		GP		49	70	57	41	—	24	20	—
7		FP	—	57	74	61	43	32	25	21	—
8		LP		65	78	65	45	32	26	22	
9	RdR, sprg TP	HP	—	66	74	65	47	—	—	22	56
10		GP	—	67	75	66	47	—	27	23	62
11		FP	—	68	76	67	48	35	27	—	69
12		LP	—	69	77	68	49	35		—	74
13	RdR, fall TP	HP	—	76	82	70	49	—	—	22	—
14		GP	—	77	83	71	50	—	27	23	—
15		FP	—	78	85	72	51	35	27	—	—
16		LP	—	79	86	73	52	35	—	—	—
17	*Wheeltrack pl, RdL, TP*[8]	4,500	—	—	31	27	25	—	—	18	23
18		3,400	—	—	36	32	30	—	22	18	30
19		2,600	—	—	43	36	32	29	23	19	37
20		2,000	—		51	43	36	31	24	20	47
21	*Deep off-set disk or disk plow*	4,500	10	—	45	38	34	—		20	23
22		3,400	10	—	52	43	37	—	24	20	30
23		2,600	5	—	57	48	40	32	25	21	37
24		2,000	—	—	61	51	42	33	26	22	47
25	*No-till plant in crop residue*[9]	6,000	95	—	2	2	2	—		2	14
26		6,000	90	—	3	3	3	—	—	3	14
27		4,500	80	—	5	5	5	—	—	5	15
28		3,400	70	—	8	8	8	—	8	6	19
29		3,400	60	—	12	12	12	12	9	8	23
30		3,400	50	—	15	15	14	14	11	9	27
31		2,600	40	—	21	20	18	17	13	11	30
32		2,600	30	—	26	24	22	21	17	14	36
	Chisel, shallow disk, or fld cult, as only tillage:										
33	On moderate slopes	6,000	70	—	8	8	7	—	—	7	17
34			60	—	10	9	8	—	—	8	17
35			50	—	13	11	10	—	—	9	18
36			40	—	15	13	11		—	10	19
37			30	—	18	15	13		—	12	20
38			20	—	23	20	18	—	—	16	21
39	Do.	4,500	70		9	8	7	—	—	7	18
40			60	—	12	10	9	—	—	8	18
41			50		14	13	11	—	—	9	19
42			40	—	17	15	13	—	—	10	20
43			30	—	21	18	15	—	—	13	21
44			20	—	25	22	19	—	—	16	22

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5]: F	SB	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
	CORN AFTER WC OF RYEGRASS OR WHEAT SEEDED IN C STUBBLE										
	WC reaches stemming stage:										
79	No-till pl in killed WC	4,000			7	7	7	—	7	6	([13])
80		3,000	—	—	11	11	11	11	9	7	
81		2,000	—	—	15	15	14	14	11	9	
82		1,500	—	—	20	19	18	18	14	11	
	Strip till one-fourth row space										
83	Rows U/D slope	4,000	—	—	13	12	11	—	11	9	([13])
84		3,000	—	—	18	17	16	16	13	10	
85		2,000		—	23	22	20	19	15	12	
86		1,500			28	26	24	22	17	14	
87	Rows on contour[11]	4,000	—	—	10	10	10	—	10	8	([13])
88		3,000	—	—	15	15	15	15	12	9	
89		2,000	—	—	20	20	19	19	15	12	
90		1,500	—	—	25	24	23	22	17	14	
91	TP, conv seedbed	4,000	—	36	60	52	41	—	24	20	([13])
92		3,000	—	43	64	56	43	31	25	21	
93		2,000	—	51	68	60	45	33	26	22	
94		1,500	—	61	73	64	47	35	27	23	
	WC succulent blades only:										
95	No-till pl in killed WC	3,000			11	11	17	23	18	16	([13])
96		2,000	—		15	15	20	25	20	17	
97		1,500			20	20	23	26	21	18	
98		1,000	—		26	26	27	27	22	19	
99	Strip till one-fourth row space	3,000	—		18	18	21	25	20	17	([13])
100		2,000	—	—	23	23	25	27	21	18	
101		1,500	—	—	28	28	28	28	22	19	
102		1,000	—		33	33	31	29	23	20	
	CORN IN SOD-BASED SYSTEMS										
	No-till pl in killed sod:										
103	3 to 5 tons hay yld	—	—		1	1	1	—	1	1	1
104	1 to 2 tons hay yld	—	—	—	2	2	2	2	2	2	2
	Strip till, 3-5 ton M:										
105	50 percent cover, tilled strips	—			2	2	2	—	2	2	4
106	20 percent cover, tilled strips	—		—	3	3	3	—	3	3	5
	Strip till, 1-2 ton M:										
107	40 percent cover, tilled strips	—			4	4	4	4	4	4	6
108	20 percent cover, tilled strips		—	—	5	5	5	5	5	5	7
	Other tillage after sod:			([11])	([11])	([11])	([11])	([14])	([14])	([14])	([11])
	CORN AFTER SOYBEANS										
109	*Sprg TP, conv till*	HP	—	40	72	60	48	—	—	25	29
110		GP		47	78	65	51	—	30	25	37
111		FP	—	56	83	70	54	40	31	26	44
112	*Fall TP, conv till*	HP	—	47	75	60	48	—	—	25	—
113		GP	—	53	81	65	51	—	30	25	—
114		FP	—	62	86	70	54	40	31	26	—

--Continued

TABLE 5.—*Ratio of soil loss from cropland to corresponding loss from continuous fallow*

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5] F	S8	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
45	Do.	3,400	60		13	11	10		10	8	20
46			50		16	13	12		12	9	24
47			40		19	17	16		14	11	25
48			30		23	21	19		17	14	26
49			20		29	25	23		21	16	27
50			10		36	32	29		24	20	30
51	Do.	2,600	50		17	16	15	15	13	10	29
52			40		21	20	19	19	15	12	30
53			30		25	23	22	22	18	14	32
54			20		32	29	28	27	22	17	34
55			10		41	36	34	32	25	21	37
56	Do.	2,000	40		23	21	20	20	15	12	37
57			30		27	25	24	23	19	15	39
58			20		35	32	30	28	22	18	42
59			10		46	42	38	33	26	22	47
	On slopes > 12 percent.										
60	Lines 33-59 times factor of:	—	—	—	1.3	1.3	1.1	1.0	1.0	1.0	1.0
	Disk or harrow after spring chisel or fld cult:										
	Lines 33-59 times factor of:										
61	On moderate slopes	—	—	—	1.1	1.1	1.1	1.0	1.0	1.0	1.0
62	On slopes > 12 percent	—	—	—	1.4	1.4	1.2	1.0	1.0	1.0	1.0
	Ridge plant:[10]										
	Lines 33-59 times factor of:										
63	Rows on contour[11]	—	—	—	.7	.7	.7	.7	.7	.7	.7
64	Rows U/D slope < 12 percent	—	—	—	.7	.7	1.0	1.0	1.0	1.0	1.0
65	Rows U/D slope > 12 percent	—	—	—	.9	.9	1.0	1.0	1.0	1.0	1.0
	Till plant:										
	Lines 33-59 times factor of:										
66	Rows on contour[11]	—	—	—	.7	.85	1.0	1.0	1.0	1.0	1.0
67	Rows U/D slope < 7 percent	—	—	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Strip till one-fourth of row spacing:										
68	Rows on contour[11]	4,500	[12]60	—	12	10	9		—	8	23
69		3,400	50	—	16	14	12		11	10	27
70		2,600	40	—	22	19	17	17	14	12	30
71		2,000	30	—	27	23	21	20	16	13	36
72	Rows U/D slope	4,500	[12]60	—	16	13	11			9	23
73		3,400	50	—	20	17	14		12	11	27
74		2,600	40	—	26	22	19	17	14	12	30
75		2,000	30	—	31	26	23	20	16	13	36
	Vari-till:										
76	Rows on contour[11]	3,400	40	—	13	12	11			11	22
77		3,400	30	—	16	15	14	14	13	12	26
78		2,600	20	—	21	19	19	19	16	14	34

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[1]	Soil loss ratio[4] for cropstage period and canopy cover[5] F	S8	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
115	Fall & sprg chisel or cult	HP	[13]30		40	35	29			23	29
116		GP	25		45	39	33		27	23	37
117		GP	20		51	44	39	34	27	23	37
118		FP	15		58	51	44	36	28	23	44
119		LP	10		67	59	48	36	28	23	54
120	No-till pl in crop res'd	HP	[13]40		25	20	19		14	11	26
121		GP	30		33	29	25	22	18	14	33
122		FP	20		44	38	32	27	23	18	40
	BEANS AFTER CORN										
123	Sprg TP, RdL, conv till	HP		33	60	52	38		20	17	([16])
124		GP		39	64	56	41		21	18	
125		FP		45	68	60	43	29	22		
126	Fall TP, RdL, conv till	HP		45	69	57	38		20	17	([16])
127		GP		52	73	61	41		21	18	
128		FP		59	77	65	43	29	22		
	Chisel or fld cult:			([17])	([17])	([17])	([17])	([17])	([17])	([17])	([16])
	BEANS AFTER BEANS			([18])	([18])	([18])	([18])	([18])	([18])	([18])	([16])
	GRAIN AFTER C, G, GS, COT[19]										
129	In disked residues:	4,500	70		12	12	11	7	4	2	([20])
130		3,400	60		16	14	12	7	4	2	
131			50		22	18	14	8	5	3	
132			40	—	27	21	16	9	5	3	
133			30	—	32	25	18	9	6	3	
134			20	—	38	30	21	10	6	3	
135	Do.	2,600	40	—	29	24	19	9	6	3	([20])
136			20	—	43	34	24	11	7	4	
137			10	—	52	39	27	12	7	4	
138	Do.	2,000	30	—	38	30	23	11	7	4	([20])
139			20	—	46	36	26	12	7	4	
140			10	—	56	43	30	13	8	5	
141	In disked stubble, RdR		—	—	79	62	42	17	11	6	([20])
142	Winter G after fall TP, RdL	HP	—	31	55	48	31	12	7	5	([20])
143		GP	—	36	60	52	33	13	8	5	
144		FP	—	43	64	56	36	14	9	5	
145		LP	—	53	68	60	38	15	10	6	
	GRAIN AFTER SUMMER FALLOW										
146	With grain residues	200	10		70	55	43	18	13	11	([21])
147		500	30	—	43	34	23	13	10	8	
148		750	40	—	34	27	18	10	7	7	
149		1,000	50	—	26	21	15	8	7	6	
150		1,500	60	—	20	16	12	7	5	5	
151		2,000	70	—	14	11	9	7	5	5	
152	With row crop residues	300	5	—	82	65	44	19	14	12	([21])
153		500	15	—	62	49	35	17	13	11	
154		750	23	—	50	40	29	14	11	9	
155		1,000	30	—	40	31	24	13	10	8	
156		1,500	45	—	31	24	18	10	8	7	
157		2,000	55	—	23	19	14	8	7	5	
158		2,500	65	—	17	14	12	7	5	4	
	POTATOES										
159	Rows with slope		—	43	64	56	36	26	19	16	
160	Contoured rows, ridged when canopy cover is about 50 percent[11]			43	64	56	18	13	10	8	

--Continued

Footnotes for table 5.

[1] Symbols: B, soybeans; C, corn; conv till, plow, disk and harrow for seedbed; cot, cotton; F, rough fallow; fld cult, field cultivator; G, small grain; GS, grain sorghum; M, grass and legume meadow, at least 1 full year; pl, plant; RdL, crop residues left on field; RdR, crop residues removed; SB, seedbed period; sprg, spring; TP, plowed with moldboard; WC, winter cover crop; —, insignificant or an unlikely combination of variables.

[2] Dry weight per acre after winter loss and reductions by grazing or partial removal: 4,500 lbs represents 100 to 125 bu corn; 3,400 lbs, 75 to 99 bu; 2,600 lbs, 60 to 74 bu; and 2,000 lbs, 40 to 59 bu; with normal 30-percent winter loss. For RdR or fall-plow practices, these four productivity levels are indicated by HP, GP, FP and LP, respectively (high, good, fair, and low productivity). In lines 79 to 102, this column indicates dry weight of the winter-cover crop.

[3] Percentage of soil surface covered by plant residue mulch *after* crop seeding. The difference between spring residue and that on the surface after crop seeding is reflected in the soil loss ratios as residues mixed with the topsoil.

[4] The soil loss ratios, given as percentages, assume that the indicated crop sequence and practices are followed consistently. One-year deviations from normal practices do not have the effect of a permanent change. Linear interpolation between lines is recommended when justified by field conditions.

[5] Cropstage periods are as defined on p. 18. The three columns for cropstage 3 are for 80, 90, and 96 to 100 percent canopy cover at maturity.

[6] Column 4L is for all residues left on field. Corn stalks partially standing as left by some mechanical pickers. If stalks are shredded and spread by picker, select ratio from table 5-C. When residues are reduced by grazing, take ratio from lower spring-residue line.

[7] Period 4 values in lines 9 to 12 are for corn stubble (stover removed).

[8] Inversion plowed, no secondary tillage. For this practice, residues must be left and incorporated.

[9] Soil surface and chopped residues of *matured* preceding crop undisturbed except in narrow slots in which seeds are planted.

[10] Top of old row ridge sliced off, throwing residues and some soil into furrow areas. Reridging assumed to occur near end of cropstage 1.

[11] Where lower soil loss ratios are listed for rows on the contour, this reduction is in addition to the standard field contouring credit. The *P* value for contouring is used with these reduced loss ratios.

[12] Field-average percent cover; probably about three-fourths of percent cover on undisturbed strips.

[13] If again seeded to WC crop in corn stubble, evaluate winter period as a winter grain seeding (lines 132 to 148). Otherwise, see table 5-C.

[14] Select the appropriate line for the crop, tillage, and productivity level and multiply the listed soil loss ratios by sod residual factors from table 5-D.

[15] Spring residue may include carryover from prior corn crop.

[16] See table 5-C.

[17] Use values from lines 33 to 62 with appropriate dates and lengths of cropstage periods for beans in the locality.

[18] Values in lines 109 to 122 are best available estimates, but planting dates and lengths of cropstages may differ.

[19] When meadow is seeded with the grain, its effect will be reflected through higher percentages of cover in cropstages 3 and 4.

[20] Ratio depends on percent cover. See table 5-C.

[21] See item 12, table 5-B.

TABLE 5-A.—*Approximate soil loss ratios for cotton*

Practice Number	Tillage operation(s)	65	80	95
	Expected final canopy percent cover:	65	80	95
	Estimated initial percent cover from defoliation + stalks down:	30	45	60
		Soil loss ratio[1]		
	COTTON ANNUALLY:	Percent		
1	*None:*			
	Defoliation to Dec. 31	36	24	15
	Jan. 1 to Feb. or Mar. tillage:			
	Cot Rd only	52	41	32
	Rd & 20 percent cover vol veg[2]	32	26	20
	Rd & 30 percent cover vol veg	26	20	14
2	*Chisel plow soon after cot harvest:*			
	Chiseling to Dec. 31	40	31	24
	Jan. 1 to sprg tillage	56	47	40
3	*Fall disk after chisel:*			
	Disking to Dec. 31	53	45	37
	Jan. 1 to sprg tillage	62	54	47
4	*Chisel plow Feb-Mar, no prior tillage:*			
	Cot Rd only	50	42	35
	Rd & 20 percent vol veg	39	33	28
	Rd & 30 percent vol veg	34	29	25
5	*Bed ("hip") Feb-Mar, no prior tillage:*			
	Cot Rd only	100	84	70
	Rd & 20 percent vol veg	78	66	56
	Rd & 30 percent vol veg	68	58	50
	Split ridges & plant after hip, or Disk & plant after chisel (SB):			
	Cot Rd only	61	54	47
	Rd & 20 percent vol veg	53	47	41
	Rd & 30 percent vol veg	50	44	38
	Cropstage 1:			
	Cot Rd only	57	50	43
	Rd & 20 percent vol veg	49	43	38
	Rd & 30 percent vol veg	46	41	36
	Cropstage 2	45	39	34
	Cropstage 3	40	27	17
6	*Bed (hip) after 1 prior tillage:*			
	Cot Rd only	110	96	84
	Rd & 20 percent veg	94	82	72
	Rd & 30 percent veg	90	78	68
	Split ridges after hip (SB):			
	Cot Rd only	66	61	52
	Rd & 20 to 30 percent veg	61	55	49
	Cropstage 1:			
	Cot Rd only	60	56	49
	Rd & 20 to 30 percent veg	56	51	46
	Cropstage 2	47	44	38
	Cropstage 3	42	30	19
7	*Hip after 2 prior tillages:*			
	Cot Rd only	116	108	98
	Rd & 20-30 percent veg	108	98	88
	Split ridges after hip (SB)	67	62	57
8	*Hip after 3 or more tillages:*	120	110	102
	Split ridges after hip (SB)	68	64	59
9	*Conventional moldboard plow and disk:*			
	Fallow period	42	39	36
	Seedbed period	68	64	59
	Cropstage 1	63	59	55
	Cropstage 2	49	46	43
	Cropstage 3	44	32	22
	Cropstage 4 (See practtices 1, 2, and 3)			

COTTON AFTER SOD CROP:

For the first nr second crop after a grass or grass-and-legume meadow has been turnplowed, multiply values given in the last five lines above by sod residual factors from table 5-D.

COTTON AFTER SOYBEANS:

Select values from above and multiply by 1.25.

See footnotes at right.

[1] *Alternate procedure for estimating the soil loss ratios:*

The ratios given above for cotton are based on estimates for reductions in percent cover through normal winter loss and by the successive tillage operations. Research is underway in Mississippi to obtain more accurate residue data in relation to tillage practices. This research should provide more accurate soil loss ratios for cotton within a few years.

Where the reductions in percent cover by winter loss and tillage operations are small, the following procedure may be used to compute soil loss ratios for the preplant and seedbed periods: Enter figure 6 with the percentage of the field surface covered by residue mulch, move vertically to the upper curve, and read the mulch factor on the scale at the left. Multiply this factor by a factor selected from the following tabulation to credit for effects of land-use residual, surface roughness and porosity.

Productivitty level	No tillage	Rough surface	Smoothed surface
High	0.66	0.50	0.56
Medium	.71	.54	.61
Poor	.75	.58	.65

Values for the bedded period on slopes of less than 1 percent should be estimated at twice the value computed above for rough surfaces.

[2] Rd, crop residue; vol veg, volunteer vegetation.

TABLE 5-B.—*Soil loss ratios for conditions not evaluated in table 5*

COTTON:
See table 5-A.
CROPSTAGE 4 FOR ROWCROPS:
Stalks broken and partially standing: Use col. 4L.
Stalks standing after hand picking: Col. 4L times 1.15.
Stalks shredded without soil tillage: See table 5-C.
Fall chisel: Select values from lines 33-62, seedbed column.
CROPSTAGE 4 FOR SMALL GRAIN:
See table 5-C.
DOUBLE CROPPING:
Derive annual C value by selecting from table 5 the soil loss percentages for the successive cropstage periods of each crop.
ESTABLISHED MEADOW, FULL-YEAR PERCENTAGES:

Grass and legume mix, 3 to 5 t hay	0.4
Do. 2 to 3 t hay	.6
Do. 1 t hay	1.0
Sericea, after second year	1.0
Red clover	1.5
Alfalfa, lespedeza, and second-year sericea	2.0
Sweetclover	2.5

MEADOW SEEDING WITHOUT NURSE CROP:
Determine appropriate lengths of cropstage periods SB, 1, and 2 and apply values given for small grain seeding.
PEANUTS:
Comparison with soybeans is suggested.
PINEAPPLES:
Direct data not available. Tentative values derived analytically are available from the SCS in Hawaii or the Western Technical Service Center at Portland, Oreg. (Reference 5).
SORGHUM:
Select values given for corn, on the basis of expected crop residues and canopy cover.
SUGARBEETS:
Direct data not available. Probably most nearly comparable to potatoes, without the ridging credit.
SUGARCANE:
Tentative values available from sources given for pineapples.
SUMMER FALLOW IN LOW-RAINFALL AREAS, USE GRAIN OR ROW CROP RESIDUES:
The approximate soil loss percentage after each successive tillage operation may be obtained from the following tabulation by estimating the percent surface cover after that tillage and selecting the column for the appropriate amount of initial residue. The given values credit benefits of the residue mulch, residues mixed with soil by tillage, and the crop system residual.

Percent cover by mulch	Initial residue (lbs/A)			
	>4,000	3,000	2,000	1,500
90	4	—	—	—
80	8	[1]8	—	—
70	12	13	[1]14	—
60	16	17	[1]18	[1]19
50	20	22	24	[1]25
40	25	27	30	32
30	29	33	37	39
20	35	39	44	48
10	47	55	63	68

[1] For grain residue only.

WINTER COVER SEEDING IN ROW CROP STUBBLE OR RESIDUES:
Define cropstage periods based on the cover seeding date and apply values from lines 129 to 145.

TABLE 5-C.—*Soil loss ratios (percent) for cropstage 4 when stalks are chopped and distributed without soil tillage*

Mulch cover[1]	Corn or Sorghum: Tilled seedbed[2]	Corn or Sorghum: No-till	Soybeans: Tilled seedbed[2]	Soybeans: No-till in corn rd[3]	Grain Stubble[4]
20	48	34	60	42	48
30	37	26	46	32	37
40	30	21	38	26	30
50	22	15	28	19	22
60	17	12	21	16	17
70	12	8	15	10	12
80	7	5	9	6	7
90	4	3	—	—	4
95	3	2	—	—	3

[1] Part of a field surface directly covered by pieces of residue mulch.
[2] This column applies for all systems other than no-till.
[3] Cover after bean harvest may include an appreciable number of stalks carried over from the prior corn crop.
[4] For grain with meadow seeding, include meadow growth in percent cover and limit grain period 4 to 2 mo. Thereafter, classify as established meadow.

TABLE 5-D.—*Factors to credit residual effects of turned sod*[1]

Crop	Hay yield	Factor for cropstage period: F	SB and 1	2	3	4
	Tons					
First year after mead:						
Row crop or grain	3-5	0.25	0.40	0.45	0.50	0.60
	2-3	.30	.45	.50	.55	.65
	1-2	.35	.50	.55	.60	.70
Second year after mead:						
Row crop	3.5	.70	.80	.85	.90	.95
	2-3	.75	.85	.90	.95	1.0
	1-2	.80	.90	.95	1.0	1.0
Spring grain	3-5	—	.75	.80	.85	.95
	2-3	—	.80	.85	.90	1.0
	1-2	—	.85	.90	.95	1.0
Winter grain	3-5	—	.60	.70	.85	.95
	2-3	—	.65	.75	.90	1.0
	1-2	—	.70	.85	.95	1.0

[1] These factors are to be multiplied by the appropriate soil loss percentages selected from table 5. They are directly applicable for sod-forming meadows of at least 1 full year duration, plowed not more than 1 month before final seedbed preparation.

When sod is fall plowed for spring planting, the listed values for all cropstage periods are increased by adding 0.02 for each additional month by which the plowing precedes spring seedbed preparation. For example, September plowing would precede May disking by 8 months and 0.02(8—1), or 0.14, would be added to each value in the table. For nonsod-forming meadows, like sweetclover or lespedeza, multiply the factors by 1.2. When the computed value is greater than 1.0, use as 1.0.

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