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An Evaluation System To Rate Feedlot Pollution Potential

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An Evaluation System To Rate Feedlot Pollution Potential

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An Evaluation System To Rate Feedlot Pollution Potential

Robert A. Young,[1] Michael A. Otterby,[2] and Amos Roos[3]

Introduction

A uniform means of objectively evaluating potential pollution problems from animal feedlots has long been needed in Minnesota. Since 1971, the Minnesota Pollution Control Agency (MPCA), the State water quality agency, has had a permitting program for regulating feedlots. No standard method exists, however, for evaluating abatement measures of water pollution from feedlots and, consequently, MPCA felt a need for objective criteria to evaluate the water quality impacts of open feedlots.

In the past, dispensing of public funds for cost sharing to help alleviate pollution problems stemming from the operation of animal feedlots has usually been based on subjective evaluation by county committees or others responsible for their disbursement. Concrete guidelines or any uniform means of objectively evaluating these potential problems have been lacking. Specific guidelines are necessary for the equitable distribution of Federal and State cost-sharing funds to livestock producers. Such guidelines are necessary so limited funds will go as far as possible toward alleviating the severity of water pollution from feedlots.

Four Federal and State agencies—the Agricultural Stabilization and Conservation Service, the Soil Conservation Service (SCS), the State Soil and Water Conservation Board, and the MPCA—recognized the need to coordinate their animal waste control programs so that Federal and State cost-sharing funds, the Federal technical assistance program, and the State permit program could all work together to efficiently combat this source of potential pollution. MPCA, using a section 208 grant from the U.S. Environmental Protection Agency, gathered these agencies together, along with the cooperative extension service, in an advisory committee and contracted with the U.S. Department of Agriculture, Agricultural Research Service, to develop an animal waste-hazard analysis system. As a result, a system was developed that is impartial, relatively simple to operate, reasonably accurate, and is based on current research data. This system can be applied to any of the approximately 90,000 animal feedlot operations in the State of Minnesota.

The Model

The animal lot evaluation system consists of two parts. The first, a short screening form (Appendix A), consists of five simple questions concerning an operation, all of which can be answered by the feedlot operator, allowing the person making the evaluation to disregard the feedlot immediately if it is definitely not a pollution hazard. Information from the first three questions deal with the pollution potential of surface water, and the last two deal with the potential pollution hazard to ground water. Answers to the first three questions relating to surface-water pollution can be fed into a small desktop, programmable calculator, which uses a short program (Appendix D) to get a preliminary indication of whether or not a pollution hazard exists. If no calculator is available, a simple manual calculation will provide the same result. The methods used in this program or calculation procedure are discussed in Appendix A.

If, after completing the screening calculations, no apparent pollution hazard is indicated, no further evaluation is necessary. However, if the screening procedure indicates a potential hazard, then a more detailed evaluation form must be completed (Appendix B).

To carry out screening on the basis of information readily available to the feedlot operator, we used an ex-

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tremely "coarse" screen. Many feedlots "fall through" the screen with a "yes" answer, indicating that they are potential pollution hazards. Experience shows that, on detailed evaluation, relatively few of these are found to be polluters. In other words, the screening method has a large factor of safety for protecting water quality.

Preliminary evaluation provides a "finer" screen, that is, one which is better able to identify feedlots that are not potential pollution hazards. We included a preliminary evaluation method in the appendices. This method may be useful where programmable calculators are available to field personnel.

Local Watershed

With the longer evaluation form, which must be filled out by the person making the evaluation rather than the feedlot operator, the first step is to study the animal lot and the area around it to determine the local watershed. A detailed sketch must be made of this watershed.

For this evaluation system, we divided the local watershed into three parts (fig. 1). The first part (Area 1) consists of the animal lot itself. Animal lot in this context refers to an open lot or a combination of open lots intended for the confined feeding, breeding, raising, or holding of animals. It is specifically designed as a confinement area in which manure may accumulate or where the concentration of animals is such that vegetative cover cannot be maintained within the enclosure. This includes poultry ranges, but it does not include pastures. "Animal area" is equivalent to animal lot. Roof areas of buildings are not included in this part.

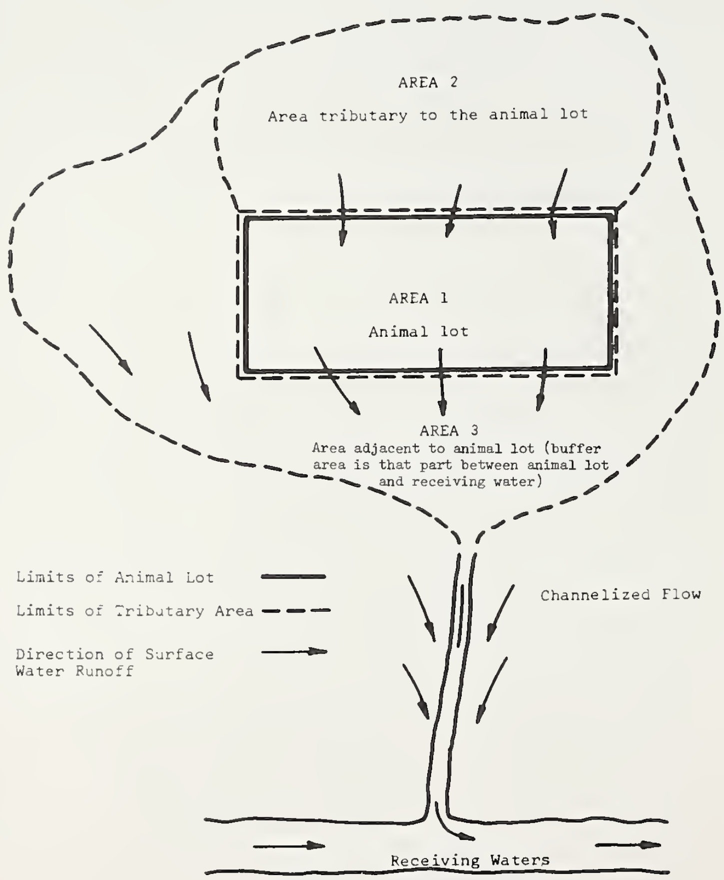

Figure 1.—Local watershed.

The second part (Area 2) refers to tributary areas or the areas from which runoff will drain through the lot or wash across it. This usually includes part of the roof areas of buildings in or adjoining the lot and often includes part of the farmstead. The nonroof portions of the tributary areas may be divided into subareas if there are differences in either soil type or ground cover.

The third part (Area 3) is that portion of the local watershed that contributes runoff to a discharge point but is not included in either the feedlot itself or in the tributary areas. This area is referred to as the adjacent area. That part of Area 3 through which runoff from the feedlot passes before reaching the discharge point is referred to as the buffer area. The buffer-adjacent area may be divided into subareas if there are differences in soil type or ground cover within it.

This discharge point is the point nearest the animal lot at which runoff from the lot becomes channelized and no longer receives effective treatment as it flows over surface vegetation. This discharge point may be a tile inlet, the edge of a drainage ditch or sink hole, or the normal high-water mark of a perennial or intermittent stream, lake, or marsh. It may also be some other point closer to the feedlot at which sheet flow of animal lot runoff ceases; for example, a point where the runoff enters a dry run, a gully, or a large rill. The discharge point can also be the inlet of a grass waterway. However, if the grass waterway is used principally for drainage and treatment of the feedlot runoff, it should be included as part of the buffer area. The discharge point would then be at the outlet of the grass waterway.

Rainfall

After sketching the local watershed, the next step is to determine the design rainfall for which the feedlot is to be evaluated. The runoff volume calculations used to evaluate feedlots for potential pollution can be based on any given design storm. The design rainfall that we selected for use gives a general measure of frequency that runoff from the lot will be allowed to enter the discharge point.

Federal regulations governing animal lots require that, for animal lots having 1,000 animal units or more, no discharge of surface runoff from the animal lot may occur from a 24-hour duration, one in 25-year frequency rainfall. At the present time, federal regulations do not specify any effluent limitations or performance standards for animal lots having less than 1,000 animal units (*43*). The Minnesota Code of Agency Rules of the Pollution Control Agency, however, defines as a potential pollution hazard any feedlot or manure storage area whose construction or operation will allow a discharge of pollutants to surface waters of the State in excess of applicable standards during a rainstorm event of less magnitude than a 25-year, 24-hour event.

For this evaluation system, therefore, even though we are dealing mainly with the potential pollution hazards of feedlots with less than 1,000 animal units, we will use as a design storm the 24-hour duration, 25-year frequency rainfall. Rainfall of any other frequency or duration storm easily can be substituted. Figure 1, Appendix B, shows the estimated rainfall for a 25-year, 24-hour rainfall event in the State of Minnesota (*42*).

The model does not consider pollutants, or nutrients, in precipitation because their contribution would be very small. Measurements of phosphorus in precipitation from several locations in Minnesota indicated that their contribution would probably not exceed 2-1/2 percent of the total phosphorus content of runoff from a vegetated area resulting from a 25-year, 24-hour storm (*5, 47*).

Pollutant Indicators

Runoff from feedlots contains many agents that can be considered potential pollutants, including potential disease carrying organisms, other organic material, nutrients, and suspended inorganic solids. These agents affect receiving waters by increasing the nutrient and suspended solid concentration, decreasing the dissolved oxygen content of the water, and in some cases, even threatening human health. For this model, we selected two parameters to represent the potential pollution hazard of feedlot runoff—chemical oxygen demand (COD) and phosphorus (P).

COD is a measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water and, thus, can be used to indicate the degree of pollution in an effluent; P, an essential element for plant growth, is found in animal manures and mineral deposits and is a major contributor to eutrophication of surface waters. Sufficient data exist on both to develop some general predictive relationships. While feedlots are a source of nitrogen, a potential pollutant of surface waters as well as ground waters, serious difficulties arise in predicting the movement of nitrogen from feedlot surfaces.

COD alone is used for the simplified rating of potential pollution hazard from feedlots because it is a lumped parameter that reasonably appears to be representative of most of the potential pollutants in feedlot runoff. The more detailed information on COD and P is used to design corrective measures and to provide a basis by which the regulatory agency can make judgments on the need for monitoring as well as for pollution-abatement measures.

When dealing with animal wastes, we find that biochemical oxygen demand (BOD) is perhaps a more meaningful parameter than COD, but the analysis for BOD is more complex and time consuming and, as a result, less data are available on BOD concentrations in feedlot runoff. Because animal wastes consist mostly of organic material, however, a number of studies show that, in the case of feedlot runoff, the COD and BOD can be correlated, as can be seen in table 1. These ratios have an average value of 4.57 with a standard deviation of 1.15. Although the ratio will depend on the type of feeding operation and the ration fed for feedlots in the Northern States, a ratio of COD to BOD of approximately 4.5 to 1 appears to be typical and was chosen for use in the model.

Runoff

We used the soil cover complex method, or curve number method, described in the SCS National Engineering Handbook, Section 4, Hydrology, and illustrated in figure 1, Appendix E, to estimate runoff from rainfall for each of the areas included in the local watershed (*39*). For this evaluation, we assumed the curve number method to be accurate. Other more sophisticated runoff models are available, but they would add undue complexity to this procedure.

TABLE 1.—COD/BOD ratios correlated in feedlot runoff

Source	COD/BOD
Wienecke and others (*45*)[1]	4.66
Agricultural Research Council (*1*)	5.31
Midwest Plan Service (*27*)	4.15
Loehr (*19*)	3.20
Madden and Dornbush (*23, 24*)	4.57
Loehr and others (poultry) (*20*)	6.60
Witzel and others (*46*)	3.50

[1] Italic numbers in parentheses refer to Literature Cited, page 10.

In the curve number method, a combination of hydrologic soil group (representing soil) and land use and treatment class (representing vegetative cover) is used to determine the hydrologic soil cover complex. The relationship of the hydrologic soil cover complex to the amount of rainfall that runs off the area is represented by the runoff curve number. These curve numbers, also referred to as soil cover complex numbers, are shown in table 4, Appendix B, which was derived from table 9.1, Section 4, of the National Engineering Handbook (*39*). The values for paved and unpaved feedlots were obtained from previous research results (*28*). We estimated values for the grass waterways to be similar to values from pasture in fair condition. The hydrologic soil groups are found in table 5, Appendix B, which we adapted from table 2.1 of the SCS Hydrology Guide for Minnesota (*41*). When using the model, the soil type involved must be obtained from a soil survey, the SCS, or other source.

Equivalent Animal Units

Because animal species differ in their relative production of various waste constituents or potential pollutant material, equivalent animal units (EAU) are determined from tables and used as a unit of measure to compare differences in the production of COD and P, the two parameters used in the model to measure a pollution hazard. We used these EAU's to determine the potential loading of each parameter in the feedlot discharge. The amount of each potential pollutant produced on a regular basis by a 1,000-pound beef feeder or slaughter steer is used as a standard. Thus, the amount of pollutant produced by a beef animal is represented by a value of one, with the amount produced by all other animals being relative to that. These factors then reflect both the manure production of the various animal species and the concentration of COD and P in that manure. Values used, as shown in table 6, Appendix B, are derived from the American Society of Agricultural Engineers (ASAE D-384) data and from the Midwest Plan Service (MWPS-18) data (*2, 26*).

Animal Unit Density and Percent Manure Pack

The animal unit density (AUD) is equal to the EAU, divided by the area of the feedlot. Because animals differ in the relative proportion of COD and P generated in manure, the values of EAU and AUD for each will be different.

When animal density is high, such as in confined feedlots, almost all of the rainfall and runoff in and from the lot comes in contact with animal wastes before leaving the lot. When animal density is low, however, some of the runoff may escape contact with manure and thus contain no fecal contamination. In a previous study (*36*), the percent coverage was calculated for different densities, assuming completely uniform spreading of cattle manure over a feedlot area, which gives the highest estimate of areal coverage over a given time period.

These figures indicated that one beef animal (1,000 lbs) covered approximately 0.001 acres per day with waste material. Assuming a minimum scraping or removal frequency of 10 days, an animal density of 100 head of beef cattle per acre will result in a 100 percent manure pack. Based on this assumption, we assume that the percent manure pack will vary linearly with AUD up to a value of 100, as shown in figure 2. We emphasized that the percent manure pack factor from this figure reflects the total mass of the pollutant as a product of the total manure produced and the pollutant content of that manure.

Where feedlot systems include partially enclosed areas, or are totally enclosed with some outdoor exercise areas, AUD's must be adjusted on the basis of the average percent of time that the animals spend outside.

Concentration of Runoff at Feedlot Edge

The concentration of various nutrients in runoff from feedlots has been the subject of many different studies (*8, 9, 17, 18, 22, 25, 27, 32, 35, 45, 48*). The average concentration of COD and BOD in feedlot runoff appears to increase from north to south in the United States, probably because of increasing average annual temperatures.

Considering only values from high animal density feedlots in the northern one-half of the United States, typical COD concentrations in runoff from feedlots from 10 different studies are shown in table 2. They averaged 4,462 mg/ℓ with a standard deviation of

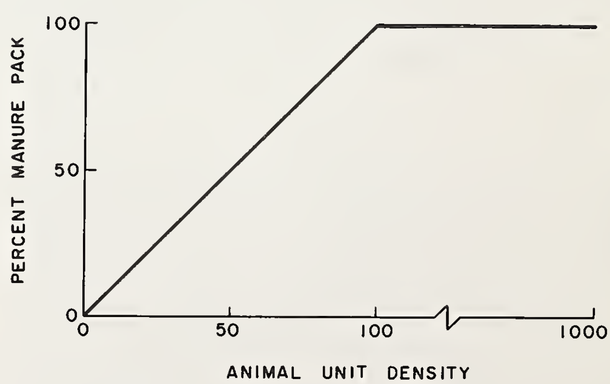

Figure 2.—Percent manure pack versus animal unit density (AUD).

TABLE 2.—Concentration of COD and P in runoff from feedlots

Location and source	COD (mg/ℓ)	P (mg/ℓ)
Minnesota (*48*)[1]	4,000	9
Ontario (*9*)	3,441	72
Utah (*45*)	7,265	32
Kansas (*25*)	7,596	79
Nebraska (*17*)	3,529	300
Kansas (*8*)	5,000	50
South Dakota (*8*)	2,160	47
Nebraska (*22*)	3,100	—
Nebraska (*35*)	2,102	374
Kansas (*16*)	6,111	87
Nebraska (*18*)	4,773	30
Ohio (*15*)	—	14

[1]Italic numbers in parentheses refer to Literature Cited, page 10.

1,888 mg/ℓ. While these values vary around the country, depending upon such factors as species or type of feed, based upon this average, a rounded value of 4,500 mg/ℓ was selected as an average concentration of COD in runoff for feedlots having a 100-percent manure pack. A value of 85 mg/ℓ was selected as an average concentration for P. Concentrations were assumed to decrease linearly with percent manure pack below 100 percent as shown in figure 3. The assumption is made here that with AUD's greater than 100, the pollutant concentration of the runoff from the feedlot itself reaches a maximum level and, thereafter, is independent of the number of animal units in the lot.

If a tributary area (Area 2) generates additional runoff volume passing through the feedlot, the concentration of pollutants in this water must also be taken into consideration. If this volume is small and not channelized, then whatever the pollutant concentration is, as it enters the lot, it will become sufficiently mixed with the runoff water generated within the feedlot to approach the same concentration. If, however, the volume is large, it will not all come in contact with the manure in the lot but will probably channelize as it passes through the lot. In this event, the volume of runoff contributed by Area 2 will have a lower level of concentration of pollutants and will dilute the concentration of the pollutants in the runoff originating in the lot. We estimated this volume at which some dilution will begin to occur as 30 acre-in.

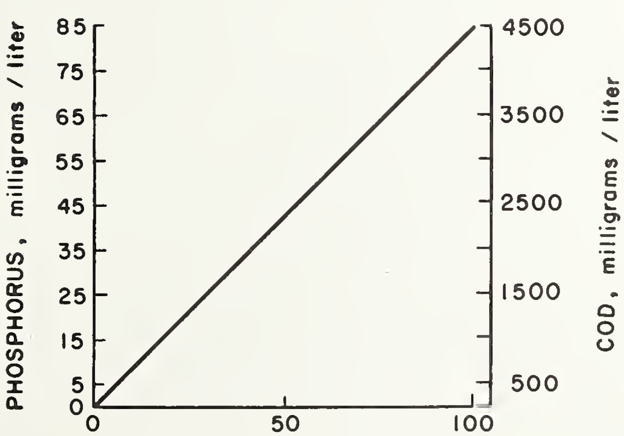

Figure 3.—Concentration of COD and P in feedlot runoff versus percent manure pack.

While the background level of pollutants in runoff from tributary areas will depend on the land use in those areas (table 3), for simplification we used a standard background concentration of 60 mg/ℓ of COD and 2 mg/ℓ of P in runoff water in the model.

Concentration of runoff at the feedlot edge is determined using the general relationship:

$$C_1V_1+C_2V_2=C_FV_F \qquad [1]$$

where C_1 = concentration of runoff in the feedlot, mg/ℓ,
V_1 = volume of runoff from the feedlot itself, acre-in,
C_2 = concentration of runoff from Area 2, mg/ℓ,
V_2 = volume of runoff from Area 2, acre-in,
C_F = concentration of runoff at the feedlot edge, mg/ℓ,
and V_F = volume of runoff at the feedlot edge, acre-in,

Using the assumed background levels, if the volume from tributary Area 2 is less than or equal to 30 acre-in, the concentration at the feedlot edge is calculated by

TABLE 3.—Background concentrations of P and COD from various sources

Source	P (mg/ℓ)	COD (mg/ℓ)
Native prairie (*38*)[1]	0.2	49
Corn (*47*)	.9	
Continuous corn (*5*)	1.1	
Native grass (*10*)	.1	31
Wheat (*31*)	1.4	
Pasture (*31*)	1.0	
Alfalfa (*31*)	2.1	
Corn[2]	.3	
Soybeans[2]	.5	
Small grain[2]	.6	
Cropped watershed[2]	.7	59
Road ditches draining cropped land[2]		144
Forest[2]	.2	78
Soybeans (*21*)	1.5	

[1]Italic numbers in parentheses refer to Literature Cited, page 10.

[2]Young, Robert A. Unpublished data, Morris, Minn.

$$\frac{\text{Percent manure pack}}{100} \times 4500 = \text{mg}/\ell \text{ of COD}, \qquad [2]$$

$$\frac{\text{Percent manure pack}}{100} \times 85.0 = \text{mg}/\ell \text{ of P}. \qquad [3]$$

If the volume of runoff from tributary Area 2 is greater than 30 acre-in, the concentration at the feedlot edge is calculated by

$$[\text{percent manure pack} \times 45 \times (V_1+30)+60(V_2-30)]/(V_1+V_2) = \text{mg}/\ell \text{ of COD}$$

$$[\text{percent manure pack} \times 0.85 \times (V_1+30)+2(V_2-30)]/(V_1+V_2) = \text{mg}/\ell \text{ of P}.$$

where all runoff volumes are expressed in acre-in. Once the concentration of pollutants at the lot edge is determined, then the mass load of pollutants at the lot edge, in pounds, is simply the concentration of the runoff multiplied by the total runoff leaving the lot.

Contact Time

As runoff flows overland across vegetated areas or buffer strips, infiltration, filtration, settling, and adsorption of pollutants all decrease the concentration of pollutants in the runoff water. The rate of reduction in concentration of these pollutants depends on the type of vegetation present in the buffer strip and the length of time the water is in contact with this vegetation. Contact time (T_C) will depend on the effective length of buffer and the velocity of the runoff water, which is a function of land slope and surface roughness resulting from the type of vegetation present. Runoff velocities for various types of vegetation and different slopes are shown in figure 2, Appendix E (from ch. 15 of SCS National Engineering Handbook, Section 4, Hydrology *(39)*). For computing purposes, the following equation may also be used to calculate velocity:

$$\log v = 0.5 \log s - c \qquad [6]$$

where v = flow velocity in ft/sec,
s = slope in percent,
and c = a surface condition constant.

Values of c are shown in table 2, Appendix B, and were calculated from figure 2, Appendix E. However, since flow velocities greater than 2 ft/sec seldom occur in nature for areas of overland flow, if the buffer area is other than a grass waterway, and the calculated value of velocity is greater than 2 ft/sec, a maximum value of 2 should be used. Figure 2, Appendix E, was derived by assuming Manning's flow equation for channels was valid for overland flow *(6)*.

The c value of "1" shown for grass waterways in table 4, Appendix B, is used only as a flag in the calculator program to indicate a different series of calculations. When manually calculating runoff velocity in grass waterways using equation [6], the c value that should be used is -0.18. This value was determined from velocity curves for low retardance channels (n = 0.04) *(6)*.

Once runoff velocity has been estimated, T_C is calculated by dividing the distance (L) from the feedlot edge to the discharge point by the runoff velocity (v):

$$T_C = L/v \qquad [7]$$

Pollutant Reduction from Filtration

Based on several studies, vegetative buffer areas are a relatively effective means of reducing the concentration of potential pollutants from runoff waters (*3, 12, 13, 30, 37, 44, 48*). Based on measured data from these studies, we developed the following equations by simple regression analysis to estimate the percent reduction in pollutant strength of feedlot runoff moving as overland flow as it passes through a vegetative buffer area:

$$D_{C_1} = -27.9 + 42.8 \log T_C \qquad [8]$$

$$D_{P_1} = -49.3 + 50.5 \log T_C \qquad [9]$$

where D_{C_1} = percent reduction in COD concentration (if < 0, $D_{C_1} = 0$),
D_{P_1} = percent reduction in P concentration (if < 0, $D_{P_1} = 0$),
and T_C = contact time in sec.

Equations [8] and [9] do not apply to grass waterways. Channelized flow is not as effective as overland flow in removing potential pollutants (*11, 44*). They require a much greater flow length, or contact time, to achieve the same level of removal as an area of overland flow. For this reason, we developed the following equations for grass waterways as buffer areas *(11, 14)*:[4]

$$D_{C_2} = 15.95 + 0.033\, T_C \qquad [10]$$

$$D_{P_2} = 21.2 + 0.036\, T_C \qquad [11]$$

where D_{C_2} = percent reduction in COD concentration in a grass waterway (if <0, $D_{C_2} = 0$),
D_{P_2} = percent reduction in P concentration in a grass waterway (if <0, $D_{P_2} = 0$),
and T_C = contact time in sec.

Both sets of equations are illustrated in figures 3 and 4, Appendix E. If the buffer area consists of portions of both overland flow and grass waterway, the net reduction in concentration is calculated by

$$C_F \times \left(1 - \frac{D_1}{100}\right) \times \left(1 - \frac{D_2}{100}\right) = C_R. \qquad [12]$$

[4]Swanson, N. P., Mielke, L. N., and Ellis, J. R. Control of feedlot runoff with a waterway. Unpublished report.

where C_F = pollutant concentration at the feedlot edge,
D_1 = percent reduction in pollutant concentration in overland flow,
D_2 = percent reduction in pollutant concentration in grass waterway,
and C_R = reduced pollutant concentration.

If the calculated net reduction equals or exceeds 100 percent, then the buffer strip is sufficient to eliminate any potential pollution hazard posed by the feedlot.

Concentration Reduction from Dilution

In addition to a reduction in pollutant strength from the nature of the vegetated buffer area, a further change in concentration occurs as a result of dilution of the feedlot runoff with the relatively cleaner water running off from the adjacent areas. This change can be calculated by using the following equation:

$$C_R V_F + C_3 V_3 = C_T V_T$$

where C_R = reduced concentration after filtration, mg/ℓ,
V_F = runoff volume at the feedlot edge, acre-in,
C_3 = concentration of runoff from Area 3, mg/ℓ,
V_3 = runoff volume from Area 3, acre-in,
C_T = final concentration at the discharge point, mg/ℓ,
and V_T = total runoff volume at the discharge point, acre-in.

As with runoff from the tributary areas of the feedlot, background levels of COD and P of runoff generated by the buffer area and other adjacent areas are assumed to be 60 mg/ℓ and 2 mg/ℓ, respectively. The product of final concentration times the total runoff volume for the feedlot watershed system is equal to the mass load of pollutants, in pounds, reaching the discharge point.

Determining Whether Pollution Hazard Exists

Once the final concentration of the runoff at the discharge point is estimated, you must determine whether it is a pollution hazard. If it is, then the feedlot can be rated on the basis of its potential to pollute a receiving body of water. We chose COD as the critical parameter on which to judge severity of the potential pollution hazard posed in the feedlot.

The final COD concentration of the runoff at the discharge point is compared with the limits that the State has set for allowable concentrations of COD in all waters of the State. For Minnesota, these limits are set forth in chapters 14 and 15 of the Water Pollution Control Regulations, promulgated in 1973, which state that the limiting concentration for 5-day BOD is 25 mg/ℓ (*29*).

As previously stated, for feedlots in the Northern States, the ratio of COD to BOD is approximately 4.5 to 1. Therefore, a limiting COD concentration of 112 mg/ℓ is approximately equivalent to the limiting BOD concentration of 25 mg/ℓ and is used for comparison with the calculated final concentration of COD in the runoff to determine if the feedlot poses a potential hazard. If the calculated COD exceeds 112 mg/ℓ, the lot is assumed to be a potential hazard and is subjected to a numerical rating procedure. Any other limiting concentration of COD or P could be easily substituted at this point if desired.

Feedlot Rating

The feedlot rating is based only upon the mass load, in pounds of COD, contributed by the feedlot itself and does not include any additional background COD loading contributed by tributary areas above the feedlot or adjacent areas. However, we subtracted any attenuation in loading caused by runoff passing through the buffer from the total at the feedlot edge. The remaining load, in pounds, is first used to determine a factor, F_1, which compresses the range of possible loads onto a logarithmic scale from zero to about 1, as follows:

$$F_1 = \frac{(\log COD_{mass\ load}) - 2}{3} . \qquad [14]$$

A second factor, F_2, is then calculated to slightly modify or weight F_1 on the likelihood of a significant runoff event occurring for that feedlot, considering the location of that feedlot in the State and the ability of its local watershed to intercept and hold runoff. This weighting follows the form:

$$F_2 = 0.8 + 0.1 \log (V_T) \qquad [15]$$

where V_T = total volume of runoff from the local watershed in acre-in for the design storm.

The product of F_1 and F_2, multiplied by 100 and rounded off to the nearest whole number, is equal to the animal lot rating. This numerical rating places a value from zero to approximately 100 on all feedlots whose mass COD load in pounds at the receiving water is from 100 to 100,000 lb and can now be used to assess the relative potential pollution hazard posed by any of the approximately 90,000 feedlots in the State. This rating is **not** a percentile. Estimates show that more than one half of all polluting feedlots in the state would be rated between 40 and 70.

Combining Feedlot Ratings

If the runoff from one or more animal lots at one location does not mix within a single local watershed, animal lot evaluations should be done separately for each feedlot watershed. The ratings of each can then be combined, either manually or using a short computer program, to get a net rating for the system. The computer program for this procedure is found in Appendix D.

Limitations

This feedlot evaluation system has a number of limitations:

(1) The calculations used in determining the concentrations and mass loads of pollutants are based upon the most current research data available but use average values only. Therefore, results and figures are estimates and are not to be regarded as absolute values. Their main purpose is to provide a uniform basis for comparison between feedlots regardless of their location in the State.

(2) If the tributary areas above the feedlot or the adjacent areas below the feedlot are very large, that is, greater than 100 acres, then the runoff calculations become somewhat questionable because of the greater chance for error in determining cover and topographic conditions. Also, the curve number method, upon which all of the runoff calculations are based, was developed primarily from runoff data from relatively small watersheds. Of the approximately 70 watersheds used in developing the curve number system, at least 50 were less than 100 acres (*7*).

In checking the accuracy of the curve number method, using observed versus estimated values of runoff from 25 small, single-crop watersheds (*34*), we obtained the following regression equation:

$$Q_{est} = 1.365 + 0.578\, Q_{obs} \qquad [16]$$

$$r^2 = 0.616$$

where Q_{est} = estimated average annual direct runoff,

Q_{obs} = observed average annual runoff,

and r^2 = coefficient of variation.

This equation indicates that the method underestimates runoff of more than 3-1/4 in while overestimating runoff of less than 3-1/4 in.

(3) The evaluation system gives an indication of the quality of runoff only at the feedlot edge and the defined discharge point; the rating indicates the impact of the discharge on the receiving water at the discharge point. The system does not deal with the value or importance of the receiving water, nor does the rating reflect this factor. The user of the system—county Agricultural Stabilization Conservation Service committee, pollution control official, or others—shall assess the value of the receiving water. This is a local determination and can best be performed by persons familiar with their local waters.

(4) The definition of discharge point, as described earlier, is sometimes difficult to apply in the field (Appendix F).

(5) The potential pollution threat to ground water is treated only lightly in this system. Since ground-water pollution is a matter of serious concern in Minnesota, it deserves additional discussion at this point.

The pollution hazard to ground water has been touched on only superfically in the model because of the difficulty of analyzing the many factors affecting it and because those factors are less subject to generalization than are the factors affecting surface waters. Persons using this system to evaluate feedlots for potential pollution problems, however, should be aware of some considerations that could lead to ground-water pollution, even though their degree of seriousness can only be estimated subjectively, unless an extensive program of site-specific studies is undertaken.

Some significant factors to consider in potential ground-water pollution are the depth to the water table or bedrock, the distance to the nearest well, soil characteristics, the local watershed topography, and the type of vegetation present in the area.

As water passes through the soil profile, many potential contaminants are removed or transformed either by plant roots, soil microorganisms, or other natural processes. Therefore, the farther water must pass through the soil before reaching ground water, the less chance of polluting the ground water. Depth to the water table or bedrock, therefore, plays an obvious role in the potential pollution of ground water. The distance to the nearest well also can be significant in considering potential ground-water pollution because the closer a water well is to a source of pollution, the higher the chance for contaminating that well.

Most of those soil characteristics relating to potential ground-water pollution generally are reflected in the hydrologic soil group. The hydrologic soil group is a classification characterizing the natural drainage of a soil and has values ranging from A to D. Group A is a well-drained soil having high infiltration rates, whereas Group D is a poorly drained soil with very slow infiltration rates under wet conditions. This system of classifying soils takes into consideration soil structure and soil texture and their effects on infiltration, permeability, and hydraulic conductivity. Soils belonging to Group A have a low potential for surface-water pollution but may pose a fairly severe hazard to ground water because of their drainage characteristics, which allow more water to infiltrate and percolate downward. Conversely, while soils of hydrologic Group D may pose a severe hazard to surface-water pollution, their potential for polluting ground water is less because relatively little water infiltrates into the soil. The model considers the effect of the hydrologic soil group on the estimated pollutant load to surface waters only.

Another soil factor, which may play a significant role in affecting the potential for ground-water pollution, is the soil cation exchange capacity (CEC). CEC, simply stated, is the ability of soil colloids to adsorb and store positively charged ions on their surface. Since adsorbed ions are less likely to be leached to ground water, soils having a low CEC will pose a much greater threat to ground water than those having a high CEC. CEC depends primarily on soil texture and organic matter content, but it is also affected by clay type and soil pH. Generally, the finer the soil texture or the greater the organic matter content, or both, the higher the CEC. CEC is measured in millequivalents per 100 g of dry soil and can be estimated by using this equation (*4*):

$$\text{CEC} = (2 \times \text{pct. organic matter}) + (0.5 \times \text{pct. clay}). \quad [17]$$

The topography of a watershed, both macro and micro, affects the pollution potential to ground water because of its effect on the rate at which water is conducted across the watershed to the outlet. The faster the runoff moves across the surface, the less time for infiltration. Macrotopography refers to the land slopes within the watershed. The steeper the slopes, the more rapidly the runoff water is conducted across the watershed, thus allowing less infiltration. Microtopography refers mainly to the soil surface condition or roughness. A rough cloddy surface will decrease runoff and increase the potential for infiltration and ground-water pollution compared to a smooth-tilled surface.

Many practices such as till planting, ridging, contour stripping and terracing, while helping to control soil loss and runoff may, as a result, actually increase the potential for ground-water pollution. The general effects of most of these systems on surface-water pollution are considered in the model in the curve number method of calculating estimated runoff. As with a hydrologic soil group, however, where conditions are beneficial to reducing potential surface-water pollution, generally they will increase the potential for ground-water pollution.

The type of vegetation present downslope from a feedlot is also an important consideration in assessing potential ground-water pollution hazard. As stated in the discussion of surface-water pollution, vegetation affects runoff by increasing the infiltration, filtration, settling, and adsorption of pollutants, all of which reduce the concentration of pollutants in runoff water. These same actions will tend to reduce the potential for ground-water pollution with the possible exception of increasing infiltration. More water infiltrating into the soil can increase the possibility of contaminants reaching the ground water. However, plants take up different amounts of nutrients and different proportions of nutrients from a soil according to their species and to soil conditions (*33*).

Nitrates are the major potential soluble ground-water contaminants. If the vegetation through which the runoff passes has a high capacity for utilizing nitrogen, much of the nitrate in the infiltrating water may be extracted by the plant roots, lessening the chance of nitrate contamination reaching the ground water, thus offsetting any increased infiltration. If a crop is to be planted with the specific purpose of serving as a vegetative filter for feedlot runoff, then such crops as corn, soybeans, or alfalfa, with high-nitrogen requirements, would probably be more suitable for use than crops with lower nitrogen requirements.

A final consideration in potential ground-water pollution is the sink-hole potential. The southeast corner of the State of Minnesota includes a large area of Karst topography, that is, an area of porous limestone containing deep fissures and sink holes and characterized by many underground caves and streams. Feedlot runoff in these areas can provide a severe threat to ground-water quality. As yet, there are no proven means for objectively assessing the seriousness of the problem in the Karst areas. The severity of the threat to ground-water pollution must be subjectively evaluated on a case-by-case basis.

Summary

In conclusion, the evaluation system described in this report was developed through the cooperation of several State and Federal agencies to provide a uniform and objective method of evaluating and rating the pollution potential of the approximately 90,000 animal feedlot operations in the State of Minnesota. The system is simple to use and appears to be quite precise. It provides a generally equitable means of dispersing public funds for pollution abatement, based on the seseverity of the hazard posed by any feedlot operation relative to that of any others. It also helps persons designing feedlot improvements to find the most economical and practical way to abate surface water pollution from any feedlot.

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Appendix A

Feedlot Screening Procedure

The screening procedure is based on the premise that if no allowance is made for dilution with water carrying a low background level of chemical oxygen demand (COD), that is, runoff from Area 2, then the maximum allowable COD concentration in the feedlot runoff is 112 mg/ℓ. Based on the COD or percent manure pack relationship shown in figure 3 (text p. 5), this concentration is equivalent to the COD concentration generated by a feedlot having an animal unit density (AUD) of 2.5 animal units per acre (2.5 × 45 mg/ℓ = 112.5). Therefore, if the distance from the feedlot edge to the discharge point is sufficient to reduce the COD concentration in the runoff to the level that would result from a feedlot having an AUD of 2.5, then the lot would not present a threat to water quality. The screening procedure uses the relationship between contact time(T_c) and percent COD reduction (equation [8], p. 6) to determine this.

The screening formula may be derived as follows:

Given: feedlot area, A
distance from feedlot to discharge point, L
animal type, number, and COD factor,

$$EAU = \Sigma \text{ number of animals} \times \text{COD factor}$$
(for all animal types)

$$AUD = EAU/A$$

$$\text{Percent reduction} = D_c = -27.9 + 42.8 \log T_c = 100\left(\frac{AUD - 2.5}{AUD}\right)$$

or
$$42.8 \log T_c \geq 127.9 - \frac{250}{AUD}$$

$$T_c = L/v$$

where $v \leq 2$ ft/sec.

For the worst case $v = 2$ and $L = 2T_c$,

then
$$\log L = \log 2 + \log T_c.$$

Thus,
$$\log L = \log 2 + 2.99 - \frac{5.84}{AUD} = 3.29 - \frac{5.84}{AUD},$$

and
$$L = 10^{\left(3.29 - \frac{5.84}{AUD}\right)}$$

(If AUD > 100, use 100).

This is the screening formula, and it is used to calculate the minimum value of L that would be required before the feedlot would be considered to pose no pollution hazard. If L, as calculated above, is greater than the value of L reported on the screening form, then the feedlot could present a hazard and should be evaluated further.

Field experience has pointed out the need for a more sensitive screening tool. A preliminary evaluation method, based on a detailed evaluation of the buffer, is presented here to meet this need. This preliminary evaluation can be further refined with certain information from the screening form. It should be noted that this supplementary method is optional and has not been implemented in Minnesota.

The preliminary evaluation must be conducted on the site by the technician. It will result in time savings only if the technician is equipped with a portable programmable calculator so that the preliminary evaluation can be determined immediately at the conclusion of a brief field inspection. If the feedlot is then determined to be a potential pollution hazard, the technician immediately can continue to examine the feedlot and collect the additional data needed for a full evaluation. Instructions for Hewlett-Packard calculators, therefore, are incorporated in the preliminary evaluation form.

The preliminary evaluation formula is based on most of the same assumptions as the screening formula. It is derived simply by substituting the actual T_c, calculated for the buffer in existence on the property, for the estimated T_c ($T_c = L/2$).

Thus
$$42.8 \log T_c = 127.9 - \frac{250}{AUD},$$

and
$$\log T_c = 2.988 - \frac{5.841}{AUD}.$$

In the worst case, AUD = 100, so the required T_c = 851 sec. The preliminary evaluation first checks the calculated T_c using this worst case AUD; if T_c is insufficient, the feedlot is a potential hazard. If the technician believes the AUD is less than 100, information needed for calculating AUD is input, and the actual T_c (from buffer calculations) is compared to the required T_c (from equation above).

If T_c is insufficient—either with or without detailed information on AUD—the feedlot could pose a hazard and should be evaluated further.

Appendix B

Feedlot Evaluation System—Feedlot Screening

Applicant ____________________ Location ____________________
(Section, Township, County)

A. Screening for surface-water pollution hazard:

(1) What are the approximate dimensions, or what is the approximate area of the animal lot?

_________ ft X _________ ft or _________ acres

(2) Approximately how far away from the animal lot is the nearest point where sheet flow ceases or flow becomes channelized? This may be a tile inlet, the edge of a gully, drainage ditch or sink hole, the inlet of a grass waterway or the normal high-water mark of a perennial or intermittent stream, lake, or marsh. _________ ft

(3) What types of animals is the lot intended to support, and what is the maximum number of each? If more than three types, write in margin.

Animal Type

_______________ Number of animals _________

COD factor _________

_______________ Number of animals _________

COD factor _________

_______________ Number of animals _________

COD factor _________

(4) Screening result from programmable calculator
(zero = no hazard, two = evaluation needed) _________

Calculated by (clerk's initials and date) _________

CONTINUE AND COMPLETE ON NEXT PAGE:

TABLE 1.—Ratio of COD produced by various animals to that produced by a 1,000 pound slaughter steer

Animal type	Design weight[1]	COD
	Pounds	
Slaughter steer	1,000	1.00
Young beef	500	.50
Dairy cow	1,400	1.96
Young dairy stock	500	.70
Swine	200	.17
Feeder pig	50	.04
Sheep	100	.18
Turkey	10	.02
Chicken	4	.01
Duck	4	.01
Horse	1,000	.42

[1]Interpolation of values should be based on the maximum weight that the animal would be expected to reach.

B. Screening for ground-water pollution hazard:

(1) How would you describe the soils around your feedlot?

/_/ light /_/ medium /_/ heavy

(2) Estimate the depth to ground water or bedrock:_________ ft.

(3) Is further evaluation of ground-water pollution potential needed?

Clerk's initials and date: __________

/_/ yes
/_/ no

I have received a summary of how the cost-share programs apply to feedlots. I understand that the pollution potential of my feedlot must be evaluated to help set priorities for cost sharing. To assist in the evaluation, I have provided the above information, which is correct to the best of my knowledge.

Signed ______________________________ (Applicant) Date ________________________

Screening instructions

For surface-water pollution hazard -

1. Determine acreage of feedlot from dimensions, if necessary.
2. For each animal type in question 3, insert the appropriate COD factor from Table 1.
3. Calculate the screening using the H-P or Monroe/Compucorp programmable calculator.
4. The screening program will display and print either a zero or a two.

   -- If zero, the animal lot is not a potential surface-water pollution hazard, and no further evaluation is necessary.

   -- If two, the animal lot may be a potential surface-water pollution hazard. It should be evaluated using the Evaluation Data Form and calculated starting with program #2 on either programmable calculator.

For ground-water pollution hazard -

Further evaluation of the ground-water pollution potential is needed if -

	soils are described as:		depth to ground water or bedrock is less than:
	light	and	6 feet
or	medium	and	4 feet
or	heavy	and	2 feet

Feedlot Evaluation System—Preliminary Evaluation Data

Operator ______________________ Location ________________________
(Section, Township, County)

This is a preliminary evaluation of the potential surface-water pollution hazard of runoff from an open animal lot.

Definitions, as used in this preliminary evaluation, are as follows:

Buffer -- That area of land where surface runoff from the lot receives effective treatment as it flows over vegetation, not including any grass waterway. The total length of the buffer is the shortest distance, measured along the line of flow, from any part of the lot to the discharge point.

Discharge Point -- The point where runoff from the lot and the buffer becomes channelized and no longer receives effective treatment as it flows over surface vegetation. The discharge point may be a tile inlet; the edge of a sinkhole, drainage ditch, or grass waterway; the normal high-water mark of a perennial or intermittent stream, lake, or marsh if animal lot runoff drains to such an area; or the point where the runoff enters a dry run, gully, or large rill.

First-level preliminary evaluation

Divide the buffer into one or more sections so that each is fairly uniform in both ground cover and slope. If there is no buffer, proceed with a complete animal lot evaluation.

Survey the slope of each section. If slope is surveyed as zero, record as .01. Refer to table 2 for the surface condition constant c.

	Slope (S)	= __________	Percent
Ground cover __________	(c)	= __________	
	Distance (L)	= __________	
	Slope (S)	= __________	Percent
Ground cover __________	(c)	= __________	
	Distance (L)	= __________	

TABLE 2. — Surface condition constant for various types of cover

Ground cover	Surface condition constant (c)
Fallow	0.22
Row crops:	
Straight rows	.05
Contoured rows	.29
Rotation meadow, small grains, legumes, or woodland	.29
Farmsteads	.01
Forest with heavy litter, permanent meadow	.59
Pasture:[1]	
Poor	.01
Fair	.15
Good	.22

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

Calculate preliminary evaluation on the Hewlett-Packard 67/97.

(1) Turn power switch to "on", set man-trace-norm switch on "norm" and prgm-run switch on "run", and insert program card 6 into calculator (side 1 only). (Feed printed side up.)

(2) Press "A". After flickering briefly, the display will read "6.00".

(3) Enter data on ground cover and slope from previous page. After each complete number entry, press "R/S".

-- CAUTION: Do not depress any key while display is flickering.

-- Note that the spacing of the printed tape matches the format of this form.

-- While only two sets of blanks are provided, note that any number of buffer sections may be entered.

-- When information for all buffer sections has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signaling the calculator that there are no additional buffer sections.

(4) After the display flickers briefly, the calculator will display and print "0.00" or "2.00".

-- If "0.00", the lot is not a potential surface-water pollution hazard. The preliminary evaluation is complete.

-- If "2.00", further information is required to determine whether the lot may be a potential surface-water pollution hazard. Continue with the second level.

Second-level preliminary evaluation

Determine and enter the area of the lot in either of these two ways:

Use the calculator to compute the area of the lot in square feet. When the correct number of square feet shows in the display, press "C" to automatically convert the area to acres; continue with the next step.

Determine the area of the lot:

______ acres

Key this number into the calculator, press "R/S", and continue with the next step.

Enter the number of animals in the lot and the animal-type factor from Table 3 for chemical oxygen demand (COD) as follows:

Animal type

Animal type		
____________	Number of animals	= ____________
	COD factor	= ____________
____________	Number of animals	= ____________
	COD factor	= ____________
____________	Number of animals	= ____________
	COD factor	= ____________

TABLE 3.—Ratio of COD produced by various animals to that produced by a 1,000 pound slaughter steer

Animal type	Design weight[1]	COD
	Pounds	
Slaughter steer	1,000	1.00
Young beef	500	.50
Dairy cow	1,400	1.96
Young dairy stock	500	.70
Swine	200	.17
Feeder pig	50	.04
Sheep	100	.18
Turkey	10	.02
Chicken	4	.01
Duck	4	.01
Horse	1,000	.42

[1]Interpolation of values should be based on the maximum weight that the animal would be expected to reach.

Enter the animal data into the calculator.

-- While only three sets of blanks are provided, note that any number of animal types may be entered.

-- When information for all animal types has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signaling the calculator that there are no additional animal types.

After the display flickers briefly, the calculator will display and print "0.00" or "2.00".

-- If "0.00", the lot is not a potential surface-water pollution hazard. The evaluation is complete.

-- If "2.00", the lot may be a potential surface-water pollution hazard. Proceed with a complete animal lot evaluation.

NOTE: If an error in entering data is made at any point, it is not necessary to reenter card 6. Simply press "A", and proceed to enter data for first-level evaluation after the display reads "6.00". Similarly, to check your work or to conduct a preliminary evaluation of another animal lot, simply press "A" and proceed to enter data.

Operator ______________________ Location ______________________
(Section, Township, County)

This is a system for evaluating the potential pollution hazard of runoff from an open animal lot. It provides numerical ratings for both the surface-water pollution hazard and the ground-water pollution hazard.

Definitions, as used in this system:

Animal lot -- an open lot, or a combination of open lots, intended for the confined feeding, breeding, raising, or holding of animals and specifically designed as a confinement area in which manure may accumulate, or where the concentration of animals is such that a vegetative cover cannot be maintained within the enclosure. This includes poultry ranges, but does not include pastures. "Animal area" is equivalent to "animal lot".

Area 1 -- The animal lot or lots, less any area covered by a roof. (Roof area is considered part of Area 2 if it drains across the lot. Otherwise, it may be part of Area 3 or outside the local watershed entirely.)

Area 2 -- Area tributary to the animal lot, that is, the area from which runoff will drain through the lot or wash across it. Usually includes part of the roof area of buildings adjoining the lot and often includes part of the farmstead.

Area 3 -- That part of the local watershed that contributes runoff to the discharge point but is not included in Area 1 or Area 2. Area 3 includes the entire buffer, plus any other area whose runoff flows over the buffer.

Buffer -- That part of Area 3 in which runoff from the animal lot receives effective treatment as it flows over surface vegetation.

Discharge Point -- The point where runoff from the local watershed becomes channelized and no longer receives effective treatment as it flows over surface vegetation. The discharge point may be a tile inlet, the edge of a sinkhole, drainage ditch or grass waterway,* or the normal high-water mark of a perennial or intermittent stream, lake, or marsh, if animal lot runoff drains to such a point. The discharge point may also be some other point, closer to the animal lot, at which sheet flow of animal lot runoff ceases--for example, a point where the runoff enters a dry run, gully, or large rill.

Local Watershed -- The smallest watershed that includes the animal lot and the buffer. Consists of Areas 1, 2, and 3.

* If an animal lot and its associated Area 2 comprise the majority of the drainage area of a grass waterway, and the waterway is designed principally to treat feedlot runoff, the grass waterway constitutes a buffer and its outlet should be considered the discharge point.

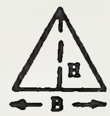
Calculations and notes

Information for Step 4 (next page): 43,560 ft^2 = 1 acre.

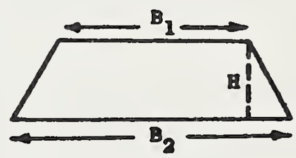
Formulas for calculating areas:

1. Square or Rectangle: $= L \times W$

2. Triangle: $= \frac{B \times H}{2}$



3. Trapezoid: $= \frac{(B_1 + B_2) \times H}{2}$



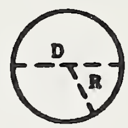
4. Circle:
   a. $A = \pi R^2$

   or

   b. $A = \frac{\pi D^2}{4}$

   or

   c. $A = 0.785\ D^2$



Animal Lot Evaluation Data Operator ____________________

The following steps should be taken to evaluate and rate an animal lot:

Surface-water pollution potential

Step 1. Carefully study the animal lot and the area immediately surrounding it. Briefly describe the discharge point, using the name of the receiving water, if applicable, in the blank on page 29.

Step 2. On the back of this form, sketch the local watershed. For those portions of this watershed outside the animal lot itself, indicate soil types (use the best available soils information) and ground cover (use the categories in table 4). Determine the outside (plan) dimensions of the roofs of barns, feeders, and other buildings. Scale all land dimensions needed for the sketch, using the best available maps and photos, or pace the distances. If the lot is partly paved and partly earthen, estimate the proportion of the total that is paved.

Indicate Areas 1, 2, and 3 on the sketch. Divide Areas 2 and 3 into sub-areas (2a, 2b, 2r; and 3a, 3b, 3c, 3d) if there are differences in soil types or ground cover or if parts are paved or roofed.

Step 3. Determine the design rainfall (R) from rainfall map (fig. 1) for a 25-yr, 24-hour rainfall. R = ______ in (1)

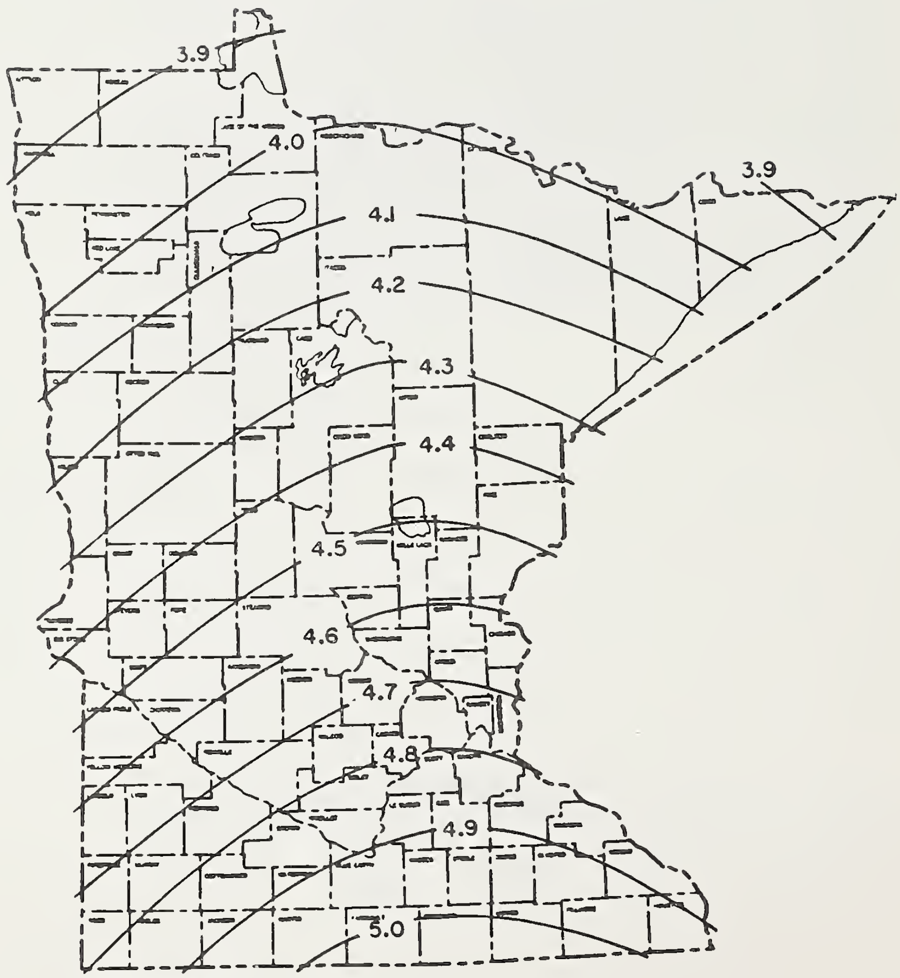
Step 4. Complete all blanks in the following table, inserting "0" in all blanks not otherwise filled. Record the ground cover of each area or subarea as well as their sizes. (Ground cover was indicated on the sketch.) Sizes may be determined from the dimensions on the sketch or, if sketch is drawn to scale, a planimeter or an SCS transparent area scale may be used.

Area 1	Feedlot	______ $ft.^2$	=	______ acre	(2)
Area 2a	____________	______ $ft.^2$	=	______ acre	(3)
Area 2b	____________	______ $ft.^2$	=	______ acre	(4)
Area 2r	Roof Area	______ $ft.^2$	=	______ acre	(5)
Area 3a	____________	______ $ft.^2$	=	______ acre	(6)
Area 3b	____________	______ $ft.^2$	=	______ acre	(7)
Area 3c	____________	______ $ft.^2$	=	______ acre	(8)
Area 3d	____________	______ $ft.^2$	=	______ acre	(9)

Step 5. Enter soil cover complex number (CN) for the animal lot (Area 1) based on the following table:

Percent paved	0-24	25-49	50-74	75-100
CN	91	92	93	94

CN = ________ (10)



SOURCE: USWB TP 40

Figure 1.—25-year, 24-hour rainfall (inches).

TABLE 4.—Surface condition constant and soil cover complex numbers for various cover conditions

Cover	Surface constant (c)	Soil cover complex number			
		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:[1]					
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
Grass waterway	1.00[2]	49	69	79	84
Animal lot:					
Unpaved		91			
Paved		94			
Roof area		100			

[1]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.

[2]Disregard this value when interpolating c values. The "one" for a grass waterway should not be treated as a number. It is merely a code that tells the calculator to use a special formula for computing buffer effectiveness.

Source: Hydrology Guide for Minnesota, USDA-SCS, St. Paul, MN.

 Operator ____________________

Step 6. Complete all blanks in the following table, inserting "0" in blanks not otherwise filled. Soil type was indicated on the sketch. After determining the soil hydrologic group from table 5, find the soil cover complex number from table 4.

	Soil Type	Soil Hydrologic Group		
Area 2_a	____________	________	CN = ________	(11)
Area 2_b	____________	________	CN = ________	(12)
Area 2_r Roof				
Area 3_a	____________	________	CN = ________	(13)
Area 3_b	____________	________	CN = ________	(14)
Area 3_c	____________	________	CN = ________	(15)
Area 3_d	____________	________	CN = ________	(16)

Step 7. Identify the buffer. If there is no buffer, enter zero on line 17 and continue with Step 8.

The total length of the buffer is the shortest distance, measured along the line of flow, from any part of the animal lot to the discharge point. This length may be analyzed as one or more sections so that each is fairly uniform in both ground cover and slope. Note that the calculator will accept any number of buffer sections. If using more than two, write in the margin.

Survey the slope of each section. If slope is surveyed as zero, record as .01. Refer to table 4 for the surface-condition constant (c).

Section a:

Slope (S) = ________% (17)

Ground cover ____________ (c) = ________ (18)

Distance (L) = ________ (19)

TABLE 5.—Soil names and hydrologic classifications

Aastad	B	Brickton	C	Dorset	B	Greenwood	A/D
Aasdahl	B	Brill	B	Dovray	C/D	Grimstad	B
Adolph	B/D	Brodale	C	Downs	B	Grogan	B
Adrian	A/D	Brookings	B	Dubuque	B	Growton	B
Afton	C/D	Brophy	A/D	Duelm	A	Grygla	B/D
Ahmeek	C	Brownton	C/D	Duluth	C	Guckeen	C
Alcester	B	Burkhardt	B	Dunbarton	D	Halder	C
Allendale	B	Burnsville	B	Dundas	B/D	Hamar	A/D
Almena	C	Buse	B	Dunnville	B	Hamel	C
Alstad	B	Calamine	C/D	Dusler	C	Hamerly	C
Alvin	B	Calco	C/D	Eckman	B	Hangaard	A/D
Amery	B	Campia	B	Edison	B	Hanska	C
Ames	C/D	Canisteo	C/D	Edwards	B/D	Hantho	B
Ankeny	B	Carlos	A/D	Egeland	B	Harps	B/D
Anoka	B	Caron	A/D	Elderon	B	Harpster	B/D
Antigo	B	Cashel	C	Eleva	B	Hatfield	B/D
Arcola	C	Cathro	A/D	Ely	B	Hattie	C
Aredale	B	Channahon	D	Embden	B	Haug	B/D
Arenzville	B	Chaseburg	B	Emmert	A	Havana	B
Arland	B	Chaska	B/D	Enloe	D	Hayden	B
Arveson	A/D	Chelsea	A	Enstrom	B	Hayfield	B
Arvilla	B	Chetek	B	Erin	B	Hecla	A
Athelwold	B	Chilgren	C	Estelline	B	Hegne	C/D
Atkinson	B	Clarion	B	Estherville	B	Hesch	B
Auburndale	C/D	Clontarf	B	Etter	B	Heyder	B
Augsburg	B/D	Cloquet	B	Everly	B	Hibbing	C
Automba	B	Clyde	B/D	Eyota	A	Hidewood	C
Badger	C/D	Collinwood	C	Fairhaven	B	Hillet	C/D
Barbert	D	Colo	B/D	Fargo	C	Hiwood	A
Barnes	B	Colvin	C/D	Farrar	B	Hixton	B
Baroda	D	Comfrey	B/D	Faxon	B/D	Holdingford	C
Barrington	B	Conic	C	Fayette	B	Houghton	A/D
Barronett	B/D	Copaston	D	Fedji	A	Hubbard	A
Barrows	B/D	Cordova	C/D	Fieldon	B/D	Huntsville	B
Barto	B/D	Cormant	A/D	Finchford	A	Ihlen	B
Baudette	B	Crippin	B	Flak	C	Indus	D
Bearden	C	Crocker	A	Flaming	A	Insula	D
Beauford	D	Crofton	B	Flandreau	B	Isan	A/D
Becker	B	Cromwell	A	Flom	B/D	Isanti	A/D
Bellechester	A	Curran	C	Floyd	B	Jackson	B
Beltrami	B	Cushing	B	Foldahl	B	Joliet	D
Bena	A	Cutfoot	A	Forada	B/D	Joy	B
Benoit	B/D	Cylinder	B	Fordville	B	Judson	B
Beotia	B	Dakota	B	Forman	B	Kamrar	B
Bergland	D	Dalbo	B	Formdale	B	Kanaranzi	B
Bertrand	B	Darfur	B/D	Fossum	A/D	Karlstad	A
Beseman	A/D	Darnen	B	Foxhome	B	Kasota	C
Billett	B	Dassel	B/D	Fram	B	Kasson	C
Biscay	B/D	Dawson	A/D	Freeon	B	Kato	C
Bixby	B	Deerwood	B/D	Freer	C	Kegonsa	B
Blackhoof	C/D	Derinda	C	Frontenac	B	Kennebec	B
Blomford	B/D	Dickey	A	Fulda	C/D	Kenyon	B
Blooming	B	Dickinson	B	Gale	B	Kilkenny	B
Blue Earth	B/D	Dickman	A	Galva	B	Kingsley	B
Bluffton	C/D	Dinsdale	B	Garnes	B	Kingston	
Bold	B	Divide	B	Garwin	C/D	Kittson	C
Boone	A	Dodgeville	B	Glencoe	B/D	Klinger	B
Boots	A/D	Doland	B	Glyndon	B	Kranzburg	B
Borup	B/D	Donaldson	B	Gonvick	B	Kratka	B/D
Braham	B	Donnan	C	Gotham	A	LaPrairie	B
Brainerd	C	Doran	C	Granby	A/D		
Bremer	C	Dorchester	B	Grays	B		

Lamont	B	Mosomo	A	Rauville	C/D	Swenoda	B
Lamoure	C	Mt. Carroll	B	Readlyn	B	Syrene	B/D
Langhei	B	Muscatine	B	Redby	B	Talcot	B/D
Langola	B	Muskego	A/D	Renova	B	Tallula	B
Lasa	A	Nebish	B	Renshaw	B	Tama	B
Lawler	B	Nemadji	B	Rib	C	Taopi	C
Lawson	B	Nereson	B	Richwood	B	Tara	B
LeSueur	B	Nessel	B	Rifle	A/D	Tawas	A/D
Lemond	B/D	Newfound	C	Rockton	B	Taylor	C
Lerdal	C	Newglarus	B	Rockwell	B/D	Tell	B
Lester	B	Newry	B	Rockwood	C	Terril	B
Letri	B/D	Newson	A/D	Rolfe	C/D	Tilfer	B/D
Lilah	A	Nicollet	B	Roliss	B/D	Timula	B
Linder	B	Nokasippi	D	Rondeau	A/D	Toddville	B
Lindstrom	B	Nokay	C	Ronneby	C	Toivola	A
Lino	B	Nordness	B	Rosemount	B	Tonka	C/D
Lismore	B	Normania	B	Rosendale	B	Torning	B
Litchfield	A	Northcote	C/D	Roseville	B	Towner	B
Lobo	D	Nowen	B/D	Rosholt	B	Trent	B
Lohnes	A	Noyes	C/D	Rothsay	B	Tripoli	B/D
Lomax	B	Nutley	C	Rushmore	B/D	Trosky	B/D
Loxley	A/D	Nymore	A	Ryan	D	Truman	B
Lupton	A/D	Oak Lake	B	Sac	B	Twig	A/D
Lura	C/D	Ocheyedan	B	Salida	A	Udolpho	B/D
Maddock	A	Ogilvie	B/D	Santiago	B	Ulen	B
Madelia	B/D	Okoboji	B/D	Sargeant	D	Upsala	C
Mahtowa	C/D	Oldham	C/D	Sartell	A	Urness	B/D
Malachy	B	Omega	A	Sattre	B	Vallers	C
Marcus	B/D	Onamia	B	Sawmill	B/D	Vasa	B
Markey	A/D	Ontonagon	D	Schapville	C	Ves	B
Marlean	B	Opole	B	Schley	B	Vienna	B
Marna	D	Orion	B	Seaforth	B	Viking	D
Marquette	A	Oronoco	B	Seaton	B	Vlasaty	C
Marshan	B/D	Osakis	B	Seelyeville	A/D	Waccusta	B/D
Marysland	B/D	Oshawa	C/D	Shakopee	C/D	Wadena	B
Mavie	B/D	Ossian	B/D	Shawano	A	Wahpeton	C
Maxcreek	B/D	Ostrander	B	Shible	B	Waldorf	C/D
Maxfield	B/D	Otter	B/D	Shields	C	Warba	B
Mayer	B/D	Otterholt	B	Shocker	C	Warman	B/D
Mazaska	C/D	Paget	C	Shorewood	C	Waskish	A/D
McDonaldsville	C/D	Palms	A/D	Shullsburg	C	Watab	C
McIntosh	B	Palsgrove	B	Sinai	C	Watseka	A
McPaul	B	Parent	B/D	Singsaas	B	Waubay	B
Medary	C	Parnell	C/D	Sioux	A	Waubeek	B
Meehan	A/D	Pelan	B	Skyberg	C	Waucoma	B
Menagha	A	Percy	B/D	Sletten	B/D	Waukee	B
Meridian	B	Perella	B/D	Soderville	A	Waukegan	B
Merton	B	Plainfield	A	Sogn	D	Waukon	B
Merwin	A/D	Poinsett	B	Sparta	A	Webster	B/D
Mesaba	C	Pomroy	B	Spencer	C	Whalan	B
Metogga	A/D	Poppleton	A	Spicer	B/D	Wheatville	B
Milaca	C	Port Byron	B	Spillville	B	Whitewood	C/D
Millerville	A/D	Prebish	C/D	Spooner	C/D	Wildwood	C/D
Millington	B	Primghar	B	Spottswood	B	Wilmonton	B
Minneiska	C	Protvin	C	Storden	B	Winger	B/D
Minneopa	B	Quam	B/D	Strandquist	B/D	Wyndmere	B
Minnetonka	D	Quetico	D	Stronghurst	B	Zell	B
Moland	B	Racine	B	Stuntz	C	Zimmerman	A
Moody	B	Radford	B	Suamico	A/D	Zumbro	A
Moose Lake	A/D	Ransom	B	Svea	B	Zwingle	D
Mora	C	Rasset	B	Sverdrup	B		

Note: Two soil groups, such as B/D, indicate the drained/undrained situation.

Animal Lot Evaluation Data Operator ______________________________

Section b:

	Slope (S)	=	________	(20)
Ground cover ______________	(c)	=	________	(21)
	Distance (L)	=	________	(22)

Step 8. Enter the number of animals in the lot and the animal type factors from table 6 for chemical oxygen demand (COD) and total phosphorus (P).

Animal Type				
____________________	Number of Animals	=	________	(23)
	COD Factor	=	________	(24)
	P Factor	=	________	(25)
____________________	Number of Animals	=	________	(26)
	COD Factor	=	________	(27)
	P Factor	=	________	(28)
____________________	Number of Animals	=	________	(29)
	COD Factor	=	________	(30)
	P Factor	=	________	(31)

** End of data entry **

Ground-water Pollution Potential

Step 9. Consider the first (upper) buffer section.

(A) Note the soil type as shown on the sketch _________________________.

Determine the hydrologic soil group from table 5, and indicate the soil group and soil factor on the table below.

Hydrologic Soil Group	Soil Factor
A	2
B	1
C	0
D	0

(B) Note the minimum depth to ground water or bedrock and indicate source of this information (for example: site inspection or SCS - soils - 5 soil interpretation).

Minimum depth ____________________

According to ____________________

Determine the depth factor and indicate on the table below:

Minimum depth	Depth factor
0 - 2 ft	3
2 - 4 ft	2
4 - 6 ft	1
more than 6 ft	0

(C) Rating value for ground-water pollution:
Soil factor plus depth factor = __________ (32)

TABLE 6.—Ratio of COD and P produced by various animals to that produced by a 1,000 pound slaughter steer

Animal type	Design weight[1]	COD	P
	Pounds		
Slaughter steer .	1,000	1.00	1.00
Young beef	500	.50	.51
Dairy cow	1,400	1.96	.92
Young dairy stock........	500	.70	.33
Swine	200	.17	.27
Feeder pig	50	.04	.07
Sheep	100	.18	.06
Turkey	10	.02	.03
Chicken	4	.01	.01
Duck	4	.01	.01
Horse	1,000	.42	.42

[1]Interpolation of values should be based on the maximum weight animals would be expected to reach.

 Operator ______________________

Step 10. Results of evaluation:

Surface water:

Total volume of runoff at the discharge point __________ acre-in (33)

COD concentration at the discharge point __________ mg/ℓ (34)

Description of discharge point and/or name of receiving water if applicable (from Step 1):

____

____

Animal lot rating for surface-water pollution (0 = no hazard, 100 = very severe hazard) __________ (35)

Ground water: (from line 32) (0 = minor hazard, 5 = very severe hazard). __________ (36)

Additional comments:

____

____

____

Step 10.9. If the feedlot operation includes separate animal lots in immediate proximity to each other that are interdependent in use or management, combine ratings for all such animal lots and enter the results here.

Total volume of runoff from feedlot __________ acre-in

Weighted average COD concentration __________ mg/ℓ

Feedlot rating __________

Prepared by ______________________ Date ______________

Appendix C

Detailed Instructions for Calculations Using the Hewlett-Packard 97 Calculator

Calculating animal lot screening

NOTE -- First follow instructions on back of Screening form.

A. Turn power switch "on".

B. Set man-trace-norm switch on "norm" and prgm-run switch on "run".

C. Insert screening program into calculator. This program is on side 1 of card 1. (Feed printed side up, numbered side leading.)

D. Press "A". After flickering briefly, display will read "1.00".

E. Enter information from the screening form. After each complete number entry, press "R/S".

-- CAUTION - Do not depress any key while display is flashing.

-- Note that the spacing of the printout matches the spacing of the screening form.

F. When information for all animal types has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signaling the calculator that there are no additional entries. After the display flickers briefly, the calculator will display and print the surface water pollution hazard screening result.

G. If an error is made in entering data, or if more than one animal lot is to be screened, it is not necessary to reenter the program card. In either case, simply go back to D above: press "A", etc.

H. An optional feature allows the user to enter the feedlot area from line 1 of the form (E above) in square feet. If this option is selected, the calculator determines and prints the number of acres. To make this automatic conversion, press "C" (instead of "R/S") after keying in the number of square feet.

Calculating animal lot evaluation

A. Turn power switch "on".

B. Set man-trace-norm switch on "norm" and prgm-run switch on "run".

C. Insert program card 2 into calculator (both sides). (Feed printed side up.)

D. Press "A". After flickering briefly, display will read "2.00".

E. Enter data from steps 3 - 6 of the evaluation data form. After each complete number entry, press "R/S".

-- CAUTION - Do not depress any key while display is flickering.

-- Note that the spacing of the printed tape matches the format of the Animal Lot Evaluation Data Form.

-- WARNING - In Step 6, the calculator enters zeroes automatically where required. It "knows" where because of corresponding zeroes entered in Step 4. Watch the paper tape and do not enter any zeroes from keyboard.

F. Enter data from Step 7 of the data form.

-- If there is no buffer, press "R/S" and proceed to enter data from Step 8, as described in G below.

-- While only two sets of blanks are provided, note that any number of buffer sections may be entered.

-- When information for all buffer sections has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signalling the calculator that there are no additional buffer sections.

G. Enter data from Step 8 of the data form.

-- While only three sets of blanks are provided, note that any number of animal types may be entered.

-- When information for all animal types has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signalling the calculator that there are no additional animal types.

H. If an error is made in entering data from the evaluation data form, it is not necessary to reenter card 2. Simply press "A", and proceed with E above after the display reads "2.00".

I. The calculator will display "3.00" after flickering briefly. Insert program card 3 into calculator (both sides). The display will now read "3.".

J. Press "R/S". The calculator will continue flickering and will then print the following information for the animal lot:

-- total runoff volume (acre-inches)

-- COD concentration at discharge point (parts per million, ppm)

-- animal lot rating

The calculator will display "4.00" to indicate that card 4 may now be fed into the calculator if design information is desired.

K. If additional information is desired, insert program card 4 into calculator (both sides). The display will now read "4.".

L. Press "R/S". The calculator will print groups of information on the following factors:

- -- Runoff volume
- -- The rating this lot would have if all runoff from Area 2 was diverted
- -- COD concentrations
- -- COD loadings
- -- P concentrations
- -- P loadings

Details on the format and information are given on the next two pages.

M. To evaluate another animal lot, insert card 2 into calculator and proceed with D above.

N. The following summary of keyboard displays may prove helpful:

2.00 -- awaiting entry of first number (rainfall, step 3) from data form
3.00 -- awaiting insertion of card 3
3. -- card 3 inserted; awaiting the pressing of "R/S"
4.00 -- awaiting insertion of card 4
4. -- card 4 inserted; awaiting the pressing of "R/S"

O. Two optional features provide user convenience in entering data from Step 4 (E above). If not helpful, these should be disregarded.

- -- Press "R/S" to enter zero areas from the display; it is not necessary to press "O" when the display shows zero.
- -- To automatically convert areas from square feet to acres, press "C" (instead of "R/S") after keying in the number of square feet. The calculator will calculate and enter the correct acreage. (Screening does this too.)

Additional information available

If desired, additional information about an animal lot may be obtained after the calculator has printed the rating.

The information relates to:

- -- Runoff volume, acre-inches (A-in);
- -- The rating this animal lot would have if all Area 2 runoff was diverted from the feedlot watershed area (diverted lot);
- -- Concentrations of Chemical Oxygen Demand (COD) in parts per million (ppm);
- -- Loadings of COD in pounds (#);
- -- Concentrations of Phosphorous (P) in ppm; and
- -- Loadings of P in #.

The spacing of the accompanying table matches the spacing of the calculator printout. In interpreting the information, the following comments may be helpful.

-- Runoff from Areas 1+2+3 is the same as the total runoff volume, output previously by the calculator (line 33 on the data form).

-- ppm COD at discharge point is the same as the COD concentration at the discharge point, output previously by the calculator (line 34 on the data form).

-- "at feedlot edge" refers to the lower edge of the animal lot.

-- "buffer effects" include settling, infiltration, adsorption, interception, and other effects. These depend on the time of contact between runoff water and the ground surface.

-- "dilution" refers to the fact that the relatively polluted water from the animal lot, after some cleansing in the buffer, is diluted with runoff from Area 3. Percent reduction due to dilution is positive because dilution reduces concentration of pollutants. Loadings in pounds may be negative because the dilution water contributes additional amounts of pollutants. When calculated pollutant concentrations are less than background levels because the buffer is effective, these percentages are left blank.

-- The animal lot rating is based on COD loadings, but the basis for rating is not included in the information listed here. The model estimates the actual COD and P quality of discharge water.

Number printed	Explanation of printout
A-in	Runoff from Area 1
A-in	Runoff from Area 2
A-in	Runoff from Areas 1 + 2
A-in	Runoff from Area 3
A-in	Runoff from Areas 1 + 2 + 3
A-in	Runoff from diverted lot
ppm	COD at discharge point for diverted lot
rating	for diverted lot
ppm	COD at feedlot edge
%	reduction from buffer effects
%	reduction due to dilution
ppm	COD at discharge point
#	COD at feedlot edge
%	reduction from buffer effects
%	reduction due to dilution
#	COD at discharge point
ppm	P at feedlot edge
%	reduction from buffer effects
%	reduction due to dilution
ppm	P at discharge point
#	P at feedlot edge
%	reduction from buffer effects
%	reduction due to dilution
#	P at discharge point

Combined animal lot rating

If a combined rating is required for more than one animal lot on the farm -

FIRST - evaluate each lot separately, using the evaluation program;
THEN - take the outputs (J above) from each lot and use this program to combine them.

A. Turn power switch "on".

B. Set man-trace-norm switch on "norm" and prgm-run switch on "run".

C. Insert program for combining ratings into calculator. This is program 5, on side 2 of card 1. (Feed printed side up, numbered end leading.)

D. Press "A". After flickering briefly, display will read "5.".

E. For each animal lot included in the total feedlot operation, enter in order:

-- Runoff volume (acre-inches)
-- COD concentration at discharge point (ppm)
-- Animal lot rating*

CAUTION - Do not depress any key while display is flashing.

F. After the information for all animal lots has been entered, the display will show "0.00". Press "R/S" to enter the zero from the display, signalling the calculator that there are no additional entries. After the display flickers briefly, the calculator will combine the information and print:

-- total feedlot runoff volume
-- average COD concentration at discharge point
-- overall feedlot rating

G. If an error is made in entering data, or if more than one set of animal lot ratings is to be combined, it is not necessary to reenter the program card. In either case, simply go back to D above: press "A", etc.

---

* If the rating of any animal lot is zero, the calculator will disregard information on that lot. The information may be entered nonetheless so that the calculator tape will show a complete record.

Detailed Instructions for Calculations Using the Monroe 325 Calculator

PROGRAM OPERATION SHEET

Animal Lot Screening Program	No. 41 Page 1 of 1

OPERATING PROCEDURE

GENERAL	SAMPLE

FIRST: Follow instructions on back of Screening form.

Load Cassette ACP WP-4 3/80.

Rewind; latch Ready on tape drive; press 1 on calculator; press Read From Tape on tape drive. Wait until "1.0000" appears in display. Rewind tape by pressing Stop, Rewind, Stop on tape drive.

Program located at: BLOCK 1
FILE 1

DEPRESS: Jump/Start-Stop/Start-Stop

READ: Program number and location

IDENTIFIER:

1. ENTER approximate area of animal lot (acres)*

2. ENTER approximate distance between animal lot and discharge point.

3. ENTER for first animal type:

   \# of head

   COD factor

   Continue entering:
   Number of head
   COD factor

DEPRESS Start-Stop ONCE when all information has been entered.

. . . .

4. READ surface water pollution hazard screening result

. . . .

Program will return to beginning for screening another animal lot.

* Note--acres = sq. ft. ÷ 43,560.

SAMPLE:

```
•••••••••••
 41 01 01•0
•••••••••••
-1•
       1•00
-2•
       1•00
-3•
       1•00
       1•00
•••••••••••
4•
         0•
•••••••••••

•••••••••••
 41 01 01•0
•••••••••••
-1•
       1•00
-2•
       1•00
-3•
       5•00
       0•70
       2•00
       0•17
•••••••••••
4•
         2•
•••••••••••
```

PROGRAM OPERATION SHEET

Animal Lot Evaluation Program	No. 42 Page 1 of 6

OPERATING PROCEDURE

GENERAL | **SAMPLE**

Load Cassette ACP WP-4 3/80.

Rewind; latch Ready on tape drive; press 2 on calculator; press Read From Tape on tape drive. Wait until two appears in display (may show as "2." or "2.00" or "2.0000").

WARNING: Ready key on tape drive must remain latched! This program automatically continues on Blocks 3 & 4.

Program located at: BLOCK 2
FILE 1

DEPRESS: Jump/Start-Stop/Start-Stop

READ: Program number and location

IDENTIFIER: (Matches step number on left side of data form)

3. ENTER Design Rainfall (inches), line 1 (line numbers are in right margin of data form). (To enter a number, depress the appropriate number keys; then depress Start-Stop once.)

```
• • • • • • • • • • •
 42 01 02•0
• • • • • • • • • • •
-3•
           4•35
```

OBSERVE: The spacing of the printed tape matches the spacing of blanks on the data form.

4. ENTER size of each area or sub-area (acres), lines 2 through 9. Enter zero for lines not used. Note--acres= sq. ft. ÷ 43,560.

```
-4•
           0•95
           0•77
           0•00
           0•14
           0•47
           0•00
           0•00
           0•00
```

5. ENTER Soil Cover Complex Number (CN) for Area 1 (animal lot), line 10.

```
-5•
          91•00
```

WARNING: DO NOT press anything while display is flashing, now or in any subsequent steps!

OPERATING PROCEDURE

GENERAL	SAMPLE
6. ENTER Soil Cover Complex Number (CN) for remaining areas, lines 11 through 16.	-6•
WARNING: The calculator enters zeroes automatically where required. It "knows" where because of corresponding zeroes entered in Step 4. Watch the paper tape and do not enter any zeroes from keyboard.	86•00 0•00 79•00 0•00 0•00 0•00 -7• 1•00 0•29
7. If no buffer, DEPRESS Start-Stop ONCE and proceed to Step 8.	60•00 -8•
If there is any buffer:	300•00
ENTER for first buffer section:	1•00 1•00
Slope (S,%) (line 17)	300•00
Surface Condition Constant (C) (line 18)	0•50 0•51
Distance (L,feet) (line 19)	
Continue Entering: Slope (S) Surface Condition Constant (C) Distance (L)	SAMPLE if there is <u>no</u> buffer: -6• 74•00 0•00
DEPRESS Start-Stop ONCE when all buffer sections have been entered.	74•00 55•00 100•00 0•00
8. ENTER for first animal type;	
# of head (line 23)	-7•
CQD factor (line 24)	-8• 170•00
P factor (line 25)	0•17 0•27
Continue entering: # of head COD factor P factor	10•00 0•50 0•51

OPERATING PROCEDURE

GENERAL	SAMPLE
NOTE: If any errors were made in entering data, DEPRESS Jump/Start-Stop/Start-Stop and start again by entering Design Rainfall (line 1, Step 3)	
After all information has been entered,	
9. DEPRESS Start-Stop ONCE for animal lot rating	
. . . .	
OBSERVE: Tape drive advancing cassette to Block 3	
	•••••••••••
10. READ:	10•
Total runoff volume (acre-inches) (line 33)	7•
COD concentration at discharge point (parts per million, ppm) (line 34)	1516•
	41•
Animal lot rating (line 35)	•••••••••••
. . . .	

AT THIS POINT YOU HAVE TWO OPTIONS.

OPTION 1 - To evaluate another animal lot,

RETURN to the top of Page 1 and read Block 2 from the tape. However, as "2" already appears in the display, it is not necessary to press "2" on the calculator.

OPTION 2 - To obtain additional information, if requested by the technician,

OPERATING PROCEDURE

GENERAL

DEPRESS Start-Stop ONCE

READ:

. . . .

11. *Information on runoff volume

. . . .

OBSERVE: Tape drive advancing cassette to Block 4

12. *Information on the rating this lot would have if all runoff from Area 2 were diverted.

. . . .

13.1 *Information on COD concentrations, ppm

13.2 *Information on COD loadings, pounds

. . . .

14.1 *Information on P concentrations, ppm

14.2 *Information on P loadings, pounds

. . . .

To evaluate another animal lot,

RETURN to the top of Page 1 and read Block 2 from the tape. However, as "2" already appears in the display, it is not necessary to press "2" on the calculator.

*Details of the format and information are given on the next two pages.

SAMPLE

```
...........
11.
           3.19
           2.82
           6.00

           1.06
           7.06
...........
12.
             4.
         1,345.
            32.
...........
13.1
         4,500.

            61.
            14.

         1,516.
13.2
         6,130.

            61.
            -1.

         2,429.
...........
14.1
            85.

            55.
            14.

            33.
14.2
           116.

            55.
            -1.

            52.
...........
```

Additional information available

If desired, additional information about an animal lot may be obtained after the calculator has printed the rating.

The information relates to:

-- Runoff volume, acre-inches (A-in);

-- The rating this animal lot would have if all Area 2 runoff were diverted from the feedlot watershed area (diverted lot);

-- Concentrations of Chemical Oxygen Demand (COD) in parts per million (ppm);

-- Loadings of COD in pounds (#);

-- Concentrations of Phosphorous (P) in ppm; and

-- Loadings of P in #.

The spacing of the accompanying table matches the spacing of the calculator printout. In interpreting the information, the following comments (keyed to the identifiers and line reference letters) may be helpful.

-- Line 11(e) is the same as the total runoff volume, output previously by the calculator (line 33 on the data form).

-- Line 13.1(d) is the same as the COD concentration at the discharge point, output previously by the calculator (line 34 on the data form).

-- "at feedlot edge" refers to the lower edge of the animal lot.

-- "buffer effects" include settling, infiltration, absorption, interception, and other effects. These depend on the time of contact between runoff water and the ground surface.

-- "dilution" refers to the fact that the relatively polluted water from the animal lot, after some cleansing in the buffer, is diluted with runoff from Area 3. Lines 13.1(c) and 14.1(c) are positive because dilution reduces concentration of pollutants. Lines 13.2(c) and 14.2(c) are negative because the dilution water contributes additional amounts of pollutants. When calculated pollutant concentrations are less than background levels because the buffer is effective, these percentages are left blank.

-- The animal lot rating is based on COD loadings, but the basis for rating is not included in the information listed here. The model estimates the actual COD and P quality of discharge water.

Identifier (Monroe & Compucorp only)	Number Printed	Line Reference	Explanation
....			
11			
	A -in		Runoff from Area 1
	A -in		Runoff from Area 2
	A -in		Runoff from Areas 1 + 2
	A -in		Runoff from Area 3
	A -in	(e)	Runoff from Areas 1 + 2 + 3
....			
12			
	A -in		Runoff from diverted lot
	ppm		COD at disch pt. for diverted lot
	rating		for diverted lot
....			
13.1			
	ppm	(a)	COD at feedlot edge
	%	(b)	reduction from buffer effects
	%	(c)	reduction due to dilution
	ppm	(d)	COD at discharge point
13.2			
	#	(a)	COD at feedlot edge
	%	(b)	reduction from buffer effects
	%	(c)	reduction due to dilution
	#	(d)	COD at discharge point
....			
14.1			
	ppm	(a)	P at feedlot edge
	%	(b)	reduction from buffer effects
	%	(c)	reduction due to dilution
	ppm	(d)	P at discharge point
14.2			
	#	(a)	P at feedlot edge
	%	(b)	reduction from buffer effects
	%	(c)	reduction due to dilution
	#	(d)	P at discharge point
....			

PROGRAM OPERATION SHEET

No. 43
Page 1 **of** 2

Combining Animal Lot Ratings

OPERATING PROCEDURE

GENERAL	SAMPLE

If technician requests combined rating for more than one animal lot on the farm-

FIRST evaluate each lot separately, using Program 42 (the evaluation program);
THEN take the outputs (Identifier 10) from each lot and use this program to combine them.

Load Cassette <u>ACP WP-4 3/80</u>

Latch Ready on tape drive; press 5 on calculator; press Read From Tape on tape drive. Wait until five appears in display (may show as "5." or "5.0000"). Rewind tape by pressing Stop, Rewind, Stop on tape drive.

Program located at: BLOCK 5
FILE 1

DEPRESS: Jump/Start-Stop/Start-Stop

READ: Program number and location

ENTER for first animal lot:

	•••••••••••
Runoff Volume (acre-inches) (line 33)	43 01 05•0
	•••••••••••
COD concentration at discharge point (ppm) (line 34)	7•
	1,515•
Animal lot rating (line 35)*	41•
Continue entering:	28•
Runoff volume	805•
COD concentration at discharge point	0•
Animal lot rating*	

CONTINUED ON NEXT PAGE

*If the rating of any animal lot is zero, the calculator will disregard information on that lot. The information may be entered nonetheless so that the calculator tape will show a complete record.

PROGRAM OPERATION SHEET

Combining Animal Lot Ratings

OPERATING PROCEDURE

GENERAL	SAMPLE
DEPRESS: Start-Stop ONCE when all animal lots have been entered.	
. . . .	....
READ:	10•9
	7•
10.9 Total feedlot runoff volume	4515•
Average COD conc. at discharge point	41•
	....
Overall feedlot rating	
. . . .	

Appendix D

Calculator Programs

Program for Hewlett-Packard 67/97/41C Calculator

Screening program
CARD 1

```
001  *LBLA     21 11
002  CLRG      16-53
003  3            03
004  .           -62
005  2            02
006  8            08
007  9            09
008  3            03
009  STOA      35 11
010  5            05
011  .           -62
012  8            08
013  4            04
014  1            01
015  1            01
016  STOB      35 12
017  4            04
018  3            03
019  5            05
020  6            06
021  0            00
022  STOC      35 13
023  1            01
024  SPC       16-11
025  R/S          51
026  *LBLa  21 16 11
027  SPC       16-11
028  SPC       16-11
029  STOD      35 14
030  R/S          51
031  SPC       16-11
032  SPC       16-11
033  STOE      35 15
034  *LBL0     21 00
035  R/S          51
036  X=0?      16-43
037  GTO1      22 01
038  R/S          51
039  x           -35
040  ST+1   35-55 01
041  SPC       16-11
042  0            00
043  GTO0      22 00
044  *LBL1     21 01
045  RCL1      36 01
046  RCLD      36 14
047  ÷           -24
048  EEX         -23
049  2            02
050  X>Y?      16-34
051  X⇄Y         -41
052  RCLB      36 12
053  X⇄Y         -41
054  ÷           -24
055  CHS         -22
056  RCLA      36 11
057  +           -55
058  10^x      16 33
059  RCLE      36 15
060  X≤Y?      16-35
061  GTO2      22 02
062  0            00
063  GTO3      22 03
064  *LBL2     21 02
065  2            02
066  *LBL3     21 03
067  SPC       16-11
068  SPC       16-11
069  PRTX        -14
070  SPC       16-11
071  RTN          24
072  *LBLC     21 13
073  RCLC      36 13
074  ÷           -24
075  PRTX        -14
076  GTOa   22 16 11
077  R/S          51
```

Evaluation program
CARD 2

```
001  *LBLA     21 11
002  CLRG      16-53
003  P⇄S       16-51
004  CLRG      16-53
005  4            04
006  3            03
007  5            05
008  6            06
009  0            00
010  STOB      35 12
011  8            08
012  STOI      35 46
013  2            02
014  SPC       16-11
015  R/S          51
016  STO9      35 09
017  SPC       16-11
018  SPC       16-11
019  *LBL1     21 01
020  R/S          51
021  *LBLa  21 16 11
022  STOi      35 45
023  0            00
024  DSZI   16 25 46
025  GTO1      22 01
026  SPC       16-11
027  SPC       16-11
028  8            08
029  STOI      35 46
030  RCLi      36 45
031  P⇄S       16-51
032  STO5      35 05
033  P⇄S       16-51
034  GSBc   23 16 13
035  SPC       16-11
036  SPC       16-11
037  DSZI   16 25 46
038  GSBb   23 16 12
039  DSZI   16 25 46
040  GSBb   23 16 12
041  DSZI   16 25 46
042  RCL9      36 09
043  STxi   35-35 45
044  DSZI   16 25 46
045  SPC       16-11
046  *LBL2     21 02
047  GSBb   23 16 12
048  DSZI   16 25 46
049  GTO2      22 02
050  RCL4      36 04
051  RCL2      36 02
052  +           -55
053  RCL1      36 01
054  +           -55
055  ST+3   35-55 03
056  RCL7      36 07
057  STO2      35 02
058  RCL6      36 06
059  ST+2   35-55 02
060  RCL5      36 05
061  ST+2   35-55 02
062  RCL8      36 08
063  STO1      35 01
064  RCL2      36 02
065  +           -55
066  RCL3      36 03
067  +           -55
068  STOA      35 11
069  3            03
070  0            00
071  STOB      35 12
072  RCL2      36 02
073  X⇄Y         -41
074  -           -45
075  X<0?      16-45
076  GTO3      22 03
077  STOC      35 13
078  GTO4      22 04
079  *LBLC     21 13
080  RCLB      36 12
081  ÷           -24
082  PRTX        -14
083  GTOa   22 16 11
084  *LBLb  21 16 12
085  RCLi      36 45
086  X≠0?      16-42
087  GTOc   22 16 13
088  PRTX        -14
089  RTN          24
090  *LBLc  21 16 13
091  R/S          51
092  EEX         -23
093  3            03
094  X⇄Y         -41
095  ÷           -24
096  1            01
097  0            00
098  -           -45
099  ENT↑        -21
100  ENT↑        -21
101  .           -62
102  2            02
103  x           -35
104  CHS         -22
```

CARD 2 — Cont.

```
105  RCL9      36 09
106  +           -55
107  X²           53
108  X⇄Y         -41
109  .           -62
110  8            08
111  ×           -35
112  RCL9      36 09
113  +           -55
114  ÷           -24
115  ST×i   35-35 45
116  RTN          24
117  *LBL3     21 03
118  RCL2      36 02
119  STOB      35 12
120  *LBL4     21 04
121  RCLB      36 12
122  RCL1      36 01
123  +           -55
124  STOB      35 12
125  SPC       16-11
126  SPC       16-11
127  P⇄S       16-51
128  0            00
129  R/S          51
130  X≠0?      16-42
131  GTO5      22 05
132  1            01
133  STO0      35 00
134  P⇄S       16-51
135  STO0      35 00
136  0            00
137  STO9      35 09
138  P⇄S       16-51
139  GTO8      22 08
140  *LBL5     21 05
141  R/S          51
142  CHS         -22
143  1            01
144  +           -55
145  X=0?      16-43
146  GTO6      22 06
147  1            01
148  -           -45
149  GSBd   23 16 14
150  2            02
151  X>Y?      16-34
152  X⇄Y         -41
153  R/S          51
154  X⇄Y         -41
155  ÷           -24
156  ST+0   35-55 00
157  GTO7      22 07
158  *LBL6     21 06
159  P⇄S       16-51
160  CLX         -51
161  .           -62
162  1            01
163  8            08
164  GSBd   23 16 14
165  R/S          51
166  X⇄Y         -41
167  ÷           -24
168  ST+0   35-55 00
169  P⇄S       16-51
170  *LBL7     21 07
171  0            00
172  SPC       16-11
173  R/S          51
174  X≠0?      16-42
175  GTO5      22 05
176  *LBL8     21 08
177  SPC       16-11
178  R/S          51
179  X=0?      16-43
180  GTO9      22 09
181  ENT↑        -21
182  ENT↑        -21
183  R/S          51
184  ×           -35
185  ST+3   35-55 03
186  R↓          -31
187  R/S          51
188  ×           -35
189  ST+4   35-55 04
190  0            00
191  GTO8      22 08
192  *LBL9     21 09
193  RCL3      36 03
194  GSBe   23 16 15
195  4            04
196  5            05
197  ×           -35
198  STO3      35 03
199  RCL4      36 04
200  GSBe   23 16 15
201  .           -62
202  8            08
203  5            05
204  ×           -35
205  STO4      35 04
206  P⇄S       16-51
207  3            03
208  RTN          24
209  *LBLd  21 16 14
210  X⇄Y         -41
211  LOG       16 32
212  2            02
213  ÷           -24
214  +           -55
215  10^x      16 33
216  RTN          24
217  *LBLe  21 16 15
218  RCL5      36 05
219  ÷           -24
220  EEX         -23
221  2            02
222  X>Y?      16-34
223  X⇄Y         -41
224  RTN          24
```

Evaluation program
CARD 3

```
001  DSP0      -63 00
002  .           -62
003  2            02
004  2            02
005  7            07
006  STOE      35 15
007  RCL5      36 05
008  X=0?      16-43
009  GTO4      22 04
010  RCL0      36 00
011  X=0?      16-43
012  GTO1      22 01
013  1            01
014  5            05
015  .           -62
016  9            09
017  5            05
018  STO6      35 06
019  .           -62
020  0            00
021  3            03
022  3            03
023  STO7      35 07
024  2            02
025  1            01
026  .           -62
027  2            02
028  CHS         -22
029  STO8      35 08
030  .           -62
031  0            00
032  3            03
033  6            06
034  STO9      35 09
035  RCL0      36 00
036  GSBb   23 16 12
037  GTO2      22 02
038  *LBL1     21 01
039  0            00
040  STO6      35 06
041  STO8      35 08
042  *LBL2     21 02
043  P⇄S       16-51
044  RCL0      36 00
045  X=0?      16-43
046  GTO3      22 03
047  2            02
048  7            07
049  .           -62
050  9            09
051  CHS         -22
052  STO6      35 06
053  4            04
054  2            02
055  .           -62
056  8            08
057  STO7      35 07
058  4            04
059  9            09
060  .           -62
061  3            03
062  CHS         -22
063  STO8      35 08
064  5            05
065  0            00
066  .           -62
067  5            05
068  STO9      35 09
069  RCL0      36 00
070  LOG       16 32
071  GSBb   23 16 12
072  *LBL3     21 03
073  6            06
074  STOI      35 46
075  GSBd   23 16 14
076  P⇄S       16-51
077  STO0      35 00
078  P⇄S       16-51
079  8            08
080  STOI      35 46
081  GSBd   23 16 14
082  STO0      35 00
083  P⇄S       16-51
084  GTO4      22 04
085  *LBLb  21 16 12
086  ENT↑        -21
087  ENT↑        -21
088  RCL9      36 09
089  ×           -35
090  ST+8   35-55 08
091  R↓          -31
092  RCL7      36 07
```

CARD 3 — Cont.

```
093     x       -35
094   RCL6    36 06
095     +       -55
096   GSBc  23 16 13
097   STO6    35 06
098   RCL8    36 08
099   GSBc  23 16 13
100   STO8    35 08
101    RTN       24
102  *LBLc  21 16 13
103   X<0?    16-45
104   GTO9    22 09
105    EEX      -23
106     2        02
107   X>Y?    16-34
108    X⇄Y      -41
109    RTN       24
110  *LBL9    21 09
111     0        00
112    RTN       24
113  *LBLd  21 16 14
114   RCLi    36 45
115   GSBe  23 16 15
116   STOi    35 45
117    P⇄S    16-51
118   RCLi    36 45
119    P⇄S    16-51
120   GSBe  23 16 15
121   RCLi    36 45
122     x       -35
123    RTN       24
124  *LBLe  21 16 15
125    EEX      -23
126     2        02
127     ÷       -24
128     1        01
129     -       -45
130    RTN       24
131  *LBL4    21 04
132    P⇄S    16-51
133   RCL3    36 03
134    P⇄S    16-51
135   STO8    35 08
136     6        06
137     0        00
138   STO9    35 09
139   RCLC    36 13
140     x       -35
141   RCL8    36 08
142   RCLB    36 12
143     x       -35
144     +       -55
145   STO6    35 06
146   RCL0    36 00
147     x       -35
148   RCL3    36 03
149   RCL9    36 09
150     x       -35
151     +       -55
152   RCLA    36 11
153     ÷       -24
154   STO7    35 07
155     1        01
156     1        01
157     2        02
158     .       -62
159     5        05
160   X>Y?    16-34
161   GTO5    22 05
162   RCLB    36 12
163   RCL8    36 08
164     x       -35
165   RCL0    36 00
166     x       -35
167   RCLE    36 15
168     x       -35
169    LOG    16 32
170     2        02
171     -       -45
172   X<0?    16-45
173   GTO5    22 05
174     3        03
175     ÷       -24
176   RCLA    36 11
177    LOG    16 32
178     .       -62
179     1        01
180     x       -35
181     .       -62
182     8        08
183     +       -55
184     x       -35
185    EEX      -23
186     2        02
187     x       -35
188    RND    16 24
189   STOD    35 14
190  *LBL5    21 05
191    SPC    16-11
192   RCLA    36 11
193    RND    16 24
194   PRTX      -14
195    SPC    16-11
196   RCL7    36 07
197   PRTX      -14
198    SPC    16-11
199    SPC    16-11
200   RCLD    36 14
201   PRTX      -14
202   DSP2   -63 02
203     4        04
204    SPC    16-11
205    SPC    16-11
206    R/S       51
```

Additional information
CARD 4

```
001    SPC    16-11
002   DSP2   -63 02
003   RCL1    36 01
004    RND    16 24
005   PRTX      -14
006   RCL2    36 02
007    RND    16 24
008   PRTX      -14
009   RCL1    36 01
010   RCL2    36 02
011     +       -55
012    RND    16 24
013   PRTX      -14
014    SPC    16-11
015   RCL3    36 03
016    RND    16 24
017   PRTX      -14
018   RCLA    36 11
019    RND    16 24
020   PRTX      -14
021    SPC    16-11
022    SPC    16-11
023   DSP0    63 00
024   RCL1    36 01
025   RCL3    36 03
026     +       -55
027    P⇄S    16-51
028   STO1    35 01
029     0        00
030   STO3    35 03
031   RCL4    36 04
032   STO8    35 08
033     2        02
034   STO9    35 09
035   RCLC    36 13
036     x       -35
037   RCL8    36 08
038   RCLB    36 12
039     x       -35
040     +       -55
041   STO6    35 06
042   RCL0    36 00
043     x       -35
044    P⇄S    16-51
045   RCL3    36 03
046    P⇄S    16-51
047   RCL9    36 09
048     x       -35
049     +       -55
050   RCLA    36 11
051     ÷       -24
052   STO7    35 07
053    P⇄S    16-51
054   RCL1    36 01
055   RCL8    36 08
056     x       -35
057   RCL0    36 00
058     x       -35
059    P⇄S    16-51
060   STO4    35 04
061    P⇄S    16-51
062   RCL3    36 03
063   RCL9    36 09
064     x       -35
065    P⇄S    16-51
066     +       -55
067   RCL1    36 01
068     ÷       -24
069   STO2    35 02
070     1        01
071     1        01
072     2        02
073     .       -62
074     5        05
075   X>Y?    16-34
076   GTO1    22 01
077   RCL4    36 04
078   RCLE    36 15
079     x       -35
080    LOG    16 32
081     2        02
082     -       -45
083   X<0?    16-45
084   GTO1    22 01
085     3        03
086     ÷       -24
087   RCL1    36 01
088    LOG    16 32
089     .       -62
090     1        01
091     x       -35
092     .       -62
093     6        06
094     +       -55
095     x       -35
096    EEX      -23
```

CARD 4—Cont.

097	2	02
098	x	-35
099	RND	16 24
100	STO3	35 03
101	*LBL1	21 01
102	SPC	16-11
103	RCL1	36 01
104	RND	16 24
105	PRTX	-14
106	RCL2	36 02
107	RND	16 24
108	PRTX	-14
109	RCL3	36 03
110	PRTX	-14
111	SPC	16-11
112	SPC	16-11
113	P⇄S	16-51
114	GSBE	23 15
115	P⇄S	16-51
116	*LBLE	21 15
117	RCL7	36 07
118	RCL6	36 06
119	RCL0	36 00
120	x	-35
121	X≠0?	16-42
122	÷	-24
123	STO5	35 05
124	SPC	16-11
125	RCL6	36 06
126	RCLB	36 12
127	RCLC	36 13
128	+	-55
129	÷	-24
130	RND	16 24
131	PRTX	-14
132	SPC	16-11
133	RCL0	36 00
134	GSBe	23 16 15
135	RCL5	36 05
136	RCL7	36 07
137	X>Y?	16-34
138	GTO4	22 04
139	SPC	16-11
140	GTO5	22 05
141	*LBL4	21 04
142	RCLB	36 12
143	RCLC	36 13
144	+	-55
145	RCL5	36 05
146	x	-35
147	GSBe	23 16 15
148	*LBL5	21 05
149	SPC	16-11
150	RCL7	36 07
151	RND	16 24
152	PRTX	-14
153	SPC	16-11
154	SPC	16-11
155	RCL6	36 06
156	RCLE	36 15
157	x	-35
158	RND	16 24
159	PRTX	-14
160	SPC	16-11
161	RCL0	36 00
162	GSBe	23 16 15
163	RCL9	36 09
164	RCL7	36 07
165	X>Y?	16-34
166	GTO6	22 06
167	SPC	16-11
168	GTO7	22 07
169	*LBL6	21 06
170	RCLA	36 11
171	RCL5	36 05
172	x	-35
173	GSBe	23 16 15
174	*LBL7	21 07
175	SPC	16-11
176	RCL7	36 07
177	RCLA	36 11
178	x	-35
179	RCLE	36 15
180	x	-35
181	RND	16 24
182	PRTX	-14
183	0	00
184	SPC	16-11
185	SPC	16-11
186	RTN	24
187	*LBLe	21 16 15
188	CHS	-22
189	1	01
190	+	-55
191	EEX	-23
192	2	02
193	x	-35
194	RND	16 24
195	PRTX	-14
196	RTN	24
197	R/S	51

Combining ratings
CARD 5

001	*LBLA	21 11
002	DSP0	-63 00
003	CLRG	16-53
004	.	-62
005	0	00
006	3	03
007	STO1	35 01
008	.	-62
009	1	01
010	STO2	35 02
011	.	-62
012	8	08
013	STO3	35 03
014	5	05
015	SPC	16-11
016	R/S	51
017	*LBL1	21 01
018	X=0?	16-43
019	GTO3	22 03
020	STOA	35 11
021	R/S	51
022	STOB	35 12
023	R/S	51
024	X=0?	16-43
025	GTO2	22 02
026	RCL1	36 01
027	x	-35
028	RCLA	36 11
029	LOG	16 32
030	RCL2	36 02
031	x	-35
032	RCL3	36 03
033	+	-55
034	÷	-24
035	10^x	16 33
036	ST+6	35-55 06
037	RCLA	36 11
038	ST+4	35-55 04
039	RCLB	36 12
040	x	-35
041	ST+5	35-55 05
042	*LBL2	21 02
043	SPC	16-11
044	0	00
045	R/S	51
046	GTO1	22 01
047	*LBL3	21 03
048	SPC	16-11
049	RCL4	36 04
050	PRTX	-14
051	X=0?	16-43
052	GTO4	22 04
053	RCL5	36 05
054	RCL4	36 04
055	÷	-24
056	STO8	35 08
057	RCL4	36 04
058	LOG	16 32
059	RCL2	36 02
060	x	-35
061	RCL3	36 03
062	+	-55
063	RCL6	36 06
064	LOG	16 32
065	RCL1	36 01
066	÷	-24
067	x	-35
068	X<0?	16-45
069	0	00
070	STO9	35 09
071	*LBL4	21 04
072	RCL8	36 08
073	SPC	16-11
074	PRTX	-14
075	SPC	16-11
076	SPC	16-11
077	RCL9	36 09
078	RND	16 24
079	PRTX	-14
080	SPC	16-11
081	SPC	16-11
082	RTN	24
083	R/S	51

Preliminary evaluation
CARD 6

001	*LBLA	21 11
002	CLRG	16-53
003	6	06
004	SPC	16-11
005	R/S	51
006	*LBL1	21 01
007	R/S	51
008	1	01
009	X≠Y?	16-32
010	GTO2	22 02
011	R/S	51
012	GTO3	22 03
013	*LBL2	21 02
014	R↓	-31
015	CHS	-22
016	X⇄Y	-41
017	LOG	16 32
018	2	02
019	÷	-24
020	+	-55
921	10^x	16 33
022	2	02

CARD 6—Cont.

			042	GSBa	23 16 11	062	5	05	082	*LBL0	21 00
023	X>Y?	16-34	043	SPC	16-11	063	.	-62	083	0	00
024	X⇄Y	-41	044	R/S	51	064	8	08	084	GTO5	22 05
025	R/S	51	045	*LBLc	21 16 13	065	4	04	085	*LBLa	21 16 11
026	X⇄Y	-41	046	STO2	35 02	066	1	01	086	2	02
027	÷	-24	047	SPC	16-11	067	1	01	087	*LBL5	21 05
028	ST+1	35-55 01	048	SPC	16-11	068	RCL3	36 03	088	PRTX	-14
029	*LBL3	21 03	049	R/S	51	069	÷	-24	089	SPC	16-11
030	0	00	050	*LBL4	21 04	070	CHS	-22	090	SPC	16-11
031	SPC	16-11	051	R/S	51	071	2	02	091	RTN	24
032	R/S	51	052	×	-35	072	.	-62	092	*LBLC	21 13
033	X≠0?	16-42	053	ST+3	35-55 03	073	9	09	093	4	04
034	GTO1	22 01	054	0	00	074	8	08	094	3	03
035	SPC	16-11	055	SPC	16-11	075	8	08	095	5	05
036	RCL1	36 01	056	R/S	51	076	3	03	096	6	06
037	8	08	057	X≠0?	16-42	077	+	-55	097	0	00
038	5	05	058	GTO4	22 04	078	10^x	16 33	098	÷	-24
039	1	01	059	SPC	16-11	079	RCL1	36 01	099	PRTX	-14
040	X≤Y?	16-35	060	RCL2	36 02	080	X≤Y?	16-35	100	GTOc	22 16 13
041	GTO0	22 00	061	ST÷3	35-24 03	081	GTOa	22 16 11	101	R/S	51

Program for Monroe 325/Compucorp 327 Calculator

Screening program BLOCK 1

•001	001		1
•002	032	I D	
•003	035	P A	
•004	035	P A	
•005	112	D T	
•006	004		4
•007	001		1
•008	015	/	
•009	001		1
•010	015	/	
•011	001		1
•012	012	d	
•013	000		0
•014	015	/	
•015	034	PT	
•016	112	D T	
•017	137	CA	
•018	222	DP	2
•019	001		1
•020	013	S	
•021	032	I D	
•022	034	PT	
•023	033	S S	
•024	034	PT	
•025	300	ST	
•026	000		0
•027	035	P A	
•028	002		2
•029	013	S	
•030	032	I D	
•031	034	PT	
•032	033	S S	
•033	034	PT	
•034	300	ST	
•035	001		1
•036	035	P A	
•037	003		3
•038	013	S	
•039	032	I D	
•040	034	PT	
•041	200	L	0
•042	000		0
•043	033	S S	
•044	354	JC	
•045	001		1
•046	034	PT	
•047	023	×	
•048	033	S S	
•049	034	PT	
•050	020	=	
•051	301	ST+	
•052	002		2
•053	035	P A	
•054	350	J	
•055	000		0
•056	201	L	1
•057	112	D T	
•058	035	P A	
•059	004		4
•060	032	I D	
•061	034	PT	
•062	310	RC	
•063	002		2
•064	024	+	
•065	310	RC	
•066	000		0
•067	020	=	
•068	300	ST	
•069	002		2
•070	022	−	
•071	001		1
•072	000		0
•073	000		0
•074	300	ST	
•075	003		3
•076	020	=	
•077	355	JC	
•078	002		2
•079	310	RC	
•080	002		2
•081	350	J	
•082	003		3

BLOCK 1—Cont.

```
•083  202      L  2
•084  310    RC
•085  003           3
•086  203      L  3
•087  063    ½
•088  023        ×
•089  005           5
•090  012         d
•091  010           8
•092  004           4
•093  001           1
•094  001           1
•095  020        =
•096  013         S
•097  021        +
•098  003           3
•099  012         d
•100  002           2
•101  010           8
•102  011           9
•103  003           3
•104  020        =
•105  161      L-1
•106  022        -
•107  310    RC
•108  001           1
•109  020        =
•110  220  DP     0
•111  355   JC
•112  004           4
•113  000           0
•114  350   J
•115  005           5
•116  204      L  4
•117  002           2
•118  205      L  5
•119  034   PT
•120  035   P  A
•121  112  D  T
•122  035   P  A
•123  222  DP     2
•124  350   J
•125  033     S   S
```

Evaluation program
BLOCK 2

```
•001  002           2
•002  032   I  D
•003  035   P  A
•004  035   P  A
•005  112  D  T
•006  004           4
•007  002           2
•008  015      /
•009  001           1
•010  015      /
•011  002           2
•012  012         d
•013  000           0
•014  015      /
•015  034   PT
•016  112  D  T
•017  137     CA
•018  222  DP     2
•019  003           3
•020  013         S
•021  032   I  D
•022  034   PT
•023  000           0
•024  033     S   S
•025  034   PT
•026  300     ST
•027  000           0
•028  035   P  A
•029  004           4
•030  013         S
•031  032   I  D
•032  034   PT
•033  000           0
•034  033     S   S
•035  034   PT
•036  300     ST
•037  001           1
•038  300     ST
•039  012         d
•040  000           0
•041  033     S   S
•042  034   PT
•043  300     ST
•044  002           2
•045  000           0
•046  033     S   S
•047  034   PT
•048  300     ST
•049  003           3
•050  000           0
•051  033     S   S
•052  034   PT
•053  300     ST
•054  004           4
•055  000           0
•056  033     S   S
•057  034   PT
•058  300     ST
•059  005           5
•060  000           0
•061  033     S   S
•062  034   PT
•063  300     ST
•064  006           6
•065  000           0
•066  033     S   S
•067  034   PT
•068  300     ST
•069  007           7
•070  000           0
•071  033     S   S
•072  034   PT
•073  300     ST
•074  010           8
•075  035   P  A
•076  005           5
•077  013         S
•078  032   I  D
•079  034   PT
•080  310     RC
•081  001           1
•082  360   B
•083  013         S
•084  303     ST×
•085  001           1
•086  035   P  A
•087  006           6
•088  013         S
•089  032   I  D
•090  034   PT
•091  310     RC
•092  002           2
•093  360   B
•094  013         S
•095  303     ST×
•096  002           2
•097  310     RC
•098  003           3
•099  360   B
•100  013         S
•101  303     ST×
•102  003           3
•103  310     RC
•104  000           0
•105  303     ST×
•106  004           4
•107  035   P  A
•108  310     RC
```

BLOCK 2—Cont.

•109	005	5
•110	360	B
•111	013	S
•112	303	ST×
•113	005	5
•114	310	RC
•115	006	6
•116	360	B
•117	013	S
•118	303	ST×
•119	006	6
•120	310	RC
•121	007	7
•122	360	B
•123	013	S
•124	303	ST×
•125	007	7
•126	310	RC
•127	010	8
•128	360	B
•129	013	S
•130	303	ST×
•131	010	8
•132	310	RC
•133	002	2
•134	021	+
•135	310	RC
•136	003	3
•137	021	+
•138	310	RC
•139	004	4
•140	020	=
•141	300	ST
•142	002	2
•143	310	RC
•144	005	5
•145	021	+
•146	310	RC
•147	006	6
•148	021	+
•149	310	RC
•150	007	7
•151	021	+
•152	310	RC
•153	010	8
•154	020	=
•155	300	ST
•156	003	3
•157	310	RC
•158	012	d
•159	300	ST
•160	005	5
•161	000	0
•162	300	ST
•163	006	6
•164	300	ST
•165	007	7
•166	300	ST
•167	010	8
•168	035	P A
•169	007	7
•170	013	S
•171	032	I D
•172	034	PT
•173	000	0
•174	033	S S
•175	300	ST
•176	013	S
•177	300	ST
•178	000	0
•179	351	JC
•180	001	1
•181	001	1
•182	300	ST
•183	012	d
•184	300	ST
•185	013	S
•186	035	P A
•187	350	J
•188	005	5
•189	213	L S
•190	351	JC
•191	000	0
•192	034	PT
•193	030	RT
•194	200	L 0
•195	033	S S
•196	034	PT
•197	063	½
•198	023	×
•199	014	EX
•200	003	3
•201	020	=
•202	022	−
•203	001	1
•204	000	0
•205	020	=
•206	300	ST
•207	013	S
•208	023	×
•209	012	d
•210	002	2
•211	013	S
•212	021	+
•213	310	RC
•214	000	0
•215	020	=
•216	162	SQ
•217	320	XC
•218	013	S
•219	023	×
•220	012	d
•221	010	8
•222	021	+
•223	310	RC
•224	000	0
•225	020	=
•226	063	½
•227	023	×
•228	310	RC
•229	013	S
•230	020	=
•231	030	RT
•232	201	L 1
•233	354	JC
•234	005	5
•235	034	PT
•236	033	S S
•237	034	PT
•238	013	S
•239	300	ST
•240	004	4
•241	021	+
•242	001	1
•243	020	=
•244	354	JC
•245	003	3
•246	360	B
•247	012	d
•248	022	−
•249	002	2
•250	020	=
•251	352	JC
•252	002	2
•253	002	2
•254	300	ST
•255	004	4
•256	202	L 2
•257	310	RC
•258	004	4
•259	033	S S
•260	034	PT
•261	024	÷
•262	310	RC
•263	004	4

BLOCK 2—Cont.

•264	020	=
•265	301	ST+
•266	006	6
•267	350	J
•268	004	4
•269	203	L 3
•270	012	d
•271	001	1
•272	010	8
•273	300	ST
•274	004	4
•275	360	B
•276	012	d
•277	033	S S
•278	034	PT
•279	024	÷
•280	310	RC
•281	004	4
•282	020	=
•283	301	ST+
•284	007	7
•285	204	L 4
•286	000	0
•287	035	P A
•288	033	S S
•289	300	ST
•290	013	S
•291	350	J
•292	001	1
•293	212	L d
•294	310	RC
•295	013	S
•296	061	LG
•297	024	÷
•298	002	2
•299	021	+
•300	310	RC
•301	004	4
•302	020	=
•303	161	L-1
•304	300	ST
•305	004	4
•306	030	RT
•307	205	L 5
•308	010	8
•309	013	S
•310	032	I D
•311	034	PT
•312	206	L 6
•313	033	S S
•314	354	JC
•315	007	7
•316	034	PT
•317	300	ST
•318	004	4
•319	033	S S
•320	034	PT
•321	023	×
•322	310	RC
•323	004	4
•324	020	=
•325	301	ST+
•326	010	8
•327	033	S S
•328	034	PT
•329	023	×
•330	310	RC
•331	004	4
•332	020	=
•333	301	ST+
•334	011	9
•335	000	0
•336	035	P A
•337	350	J
•338	006	6
•339	207	L 7
•340	112	D T
•341	035	P A
•342	310	RC
•343	010	8
•344	360	B
•345	011	9
•346	004	4
•347	005	5
•348	023	×
•349	310	RC
•350	004	4
•351	020	=
•352	300	ST
•353	010	8
•354	310	RC
•355	011	9
•356	360	B
•357	011	9
•358	012	d
•359	010	8
•360	005	5
•361	023	×
•362	310	RC
•363	004	4
•364	020	=
•365	300	ST
•366	011	9
•367	000	0
•368	300	ST
•369	004	4
•370	300	ST
•371	005	5
•372	003	3
•373	041	TR
•374	211	L 9
•375	024	÷
•376	310	RC
•377	005	5
•378	020	=
•379	300	ST
•380	004	4
•381	022	−
•382	014	EX
•383	002	2
•384	020	=
•385	351	JC
•386	010	8
•387	030	RT
•388	210	L 8
•389	014	EX
•390	002	2
•391	300	ST
•392	004	4
•393	030	RT

Evaluation program BLOCK 3

•001	003	3
•002	032	I D
•003	310	RC
•004	000	0
•005	354	JC
•006	002	2
•007	310	RC
•008	007	7
•009	354	JC
•010	000	0
•011	023	×
•012	012	d
•013	000	0
•014	003	3
•015	003	3
•016	021	+
•017	001	1
•018	005	5
•019	012	d
•020	011	9
•021	005	5
•022	020	=
•023	360	B

BLOCK 3—Cont.

•024	012	d
•025	300	ST
•026	004	4
•027	310	RC
•028	007	7
•029	023	×
•030	012	d
•031	000	0
•032	003	3
•033	006	6
•034	022	−
•035	002	2
•036	001	1
•037	012	d
•038	002	2
•039	020	=
•040	360	B
•041	012	d
•042	300	ST
•043	005	5
•044	000	0
•045	300	ST
•046	007	7
•047	200	L 0
•048	310	RC
•049	006	6
•050	354	JC
•051	001	1
•052	061	LG
•053	300	ST
•054	006	6
•055	023	×
•056	005	5
•057	000	0
•058	012	d
•059	005	5
•060	022	−
•061	004	4
•062	011	9
•063	012	d
•064	003	3
•065	020	=
•066	360	B
•067	012	d
•068	300	ST
•069	007	7
•070	310	RC
•071	006	6
•072	023	×
•073	004	4
•074	002	2
•075	012	d
•076	010	8
•077	022	−
•078	002	2
•079	007	7
•080	012	d
•081	011	9
•082	020	=
•083	360	B
•084	012	d
•085	300	ST
•086	006	6
•087	201	L 1
•088	310	RC
•089	004	4
•090	360	B
•091	013	S
•092	300	ST
•093	004	4
•094	310	RC
•095	006	6
•096	360	B
•097	013	S
•098	023	×
•099	310	RC
•100	004	4
•101	020	=
•102	300	ST
•103	012	d
•104	310	RC
•105	005	5
•106	360	B
•107	013	S
•108	300	ST
•109	005	5
•110	310	RC
•111	007	7
•112	360	B
•113	013	S
•114	023	×
•115	310	RC
•116	005	5
•117	020	=
•118	300	ST
•119	013	S
•120	202	L 2
•121	000	0
•122	300	ST
•123	005	5
•124	300	ST
•125	007	7
•126	310	RC
•127	002	2
•128	022	−
•129	003	3
•130	000	0
•131	300	ST
•132	004	4
•133	020	=
•134	351	JC
•135	003	3
•136	310	RC
•137	002	2
•138	300	ST
•139	004	4
•140	350	J
•141	004	4
•142	203	L 3
•143	300	ST
•144	005	5
•145	350	J
•146	004	4
•147	213	L S
•148	024	+
•149	014	EX
•150	002	2
•151	022	−
•152	001	1
•153	020	=
•154	030	RT
•155	212	L d
•156	300	ST
•157	000	0
•158	351	JC
•159	011	9
•160	000	0
•161	030	RT
•162	211	L 9
•163	022	−
•164	014	EX
•165	002	2
•166	020	=
•167	351	JC
•168	010	8
•169	310	RC
•170	000	0
•171	030	RT
•172	210	L 8
•173	014	EX
•174	002	2
•175	030	RT
•176	204	L 4
•177	310	RC
•178	001	1

BLOCK 3—Cont.

•179	301	ST+
•180	004	4
•181	021	+
•182	310	RC
•183	002	2
•184	021	+
•185	310	RC
•186	003	3
•187	020	=
•188	300	ST
•189	000	0
•190	037	CL
•191	026	(
•192	310	RC
•193	004	4
•194	023	×
•195	310	RC
•196	010	8
•197	021	+
•198	026	(
•199	310	RC
•200	005	5
•201	023	×
•202	006	6
•203	000	0
•204	027	)
•205	023	×
•206	310	RC
•207	012	d
•208	027	)
•209	021	+
•210	026	(
•211	310	RC
•212	003	3
•213	023	×
•214	006	6
•215	000	0
•216	027	)
•217	024	÷
•218	310	RC
•219	000	0
•220	020	=
•221	300	ST
•222	006	6
•223	022	−
•224	001	1
•225	001	1
•226	002	2
•227	012	d
•228	005	5
•229	020	=
•230	352	JC
•231	005	5
•232	310	RC
•233	004	4
•234	023	×
•235	310	RC
•236	010	8
•237	023	×
•238	310	RC
•239	012	d
•240	023	×
•241	012	d
•242	002	2
•243	002	2
•244	007	7
•245	020	=
•246	061	LG
•247	022	−
•248	002	2
•249	020	=
•250	352	JC
•251	005	5
•252	024	÷
•253	003	3
•254	023	×
•255	026	(
•256	310	RC
•257	000	0
•258	061	LG
•259	023	×
•260	012	d
•261	001	1
•262	021	+
•263	012	d
•264	010	8
•265	027	)
•266	023	×
•267	014	EX
•268	002	2
•269	020	=
•270	300	ST
•271	007	7
•272	205	L 5
•273	001	1
•274	000	0
•275	032	I D
•276	034	PT
•277	220	DP 0
•278	310	RC
•279	000	0
•280	110	R
•281	034	PT
•282	035	P A
•283	310	RC
•284	006	6
•285	110	R
•286	034	PT
•287	035	P A
•288	035	P A
•289	310	RC
•290	007	7
•291	110	R
•292	034	PT
•293	035	P A
•294	035	P A
•295	112	D T
•296	002	2
•297 —	033 —	S — S
•298	112	D T
•299	001	1
•300	001	1
•301	032	I D
•302	034	PT
•303	222	DP 2
•304	310	RC
•305	001	1
•306	021	+
•307	310	RC
•308	002	2
•309	020	=
•310	300	ST
•311	007	7
•312	310	RC
•313	001	1
•314	110	R
•315	034	PT
•316	310	RC
•317	002	2
•318	110	R
•319	034	PT
•320	310	RC
•321	007	7
•322	110	R
•323	034	PT
•324	035	P A
•325	310	RC
•326	003	3
•327	110	R
•328	034	PT
•329	310	RC
•330	000	0
•331	110	R
•332	034	PT
•333	035	P A
•334	112	D T
•335	001	1
•336	002	2

BLOCK 3—Cont.

```
•337  032  I D
•338  034  PT
•339  220  DP   0
•340  310  RC
•341  001       1
•342  021       +
•343  310  RC
•344  003       3
•345  020       =
•346  300  ST
•347  000       0
•348  000       0
•349  300  ST
•350  007       7
•351  310  RC
•352  001       1
•353  023       ×
•354  310  RC
•355  010       8
•356  023       ×
•357  310  RC
•358  012       d
•359  021       +
•360  026       (
•361  310  RC
•362  003       3
•363  023       ×
•364  006       6
•365  000       0
•366  027       )
•367  024       ÷
•368  310  RC
•369  000       0
•370  020       =
•371  300  ST
•372  006       6
•373  004       4
•374  041  TR
```

Evaluation program
BLOCK 4

```
•001  004       4
•002  032  I D
•003  310  RC
•004  006       6
•005  022       -
•006  001       1
•007  001       1
•008  002       2
•009  012       d
•010  005       5
•011  020       =
•012  352  JC
•013  000       0
•014  310  RC
•015  001       1
•016  023       ×
•017  310  RC
•018  010       8
•019  023       ×
•020  310  RC
•021  012       d
•022  023       ×
•023  012       d
•024  002       2
•025  002       2
•026  007       7
•027  020       =
•028  061  LG
•029  022       -
•030  002       2
•031  020       =
•032  352  JC
•033  000       0
•034  024       ÷
•035  003       3
•036  023       ×
•037  026       (
•038  310  RC
•039  000       0
•040  061  LG
•041  023       ×
•042  012       d
•043  001       1
•044  021       +
•045  012       d
•046  010       8
•047  027       )
•048  023       ×
•049  014  EX
•050  002       2
•051  020       =
•052  300  ST
•053  007       7
•054  200  L    0
•055  310  RC
•056  000       0
•057  110  R
•058  034  PT
•059  310  RC
•060  006       6
•061  110  R
•062  034  PT
•063  310  RC
•064  007       7
•065  110  R
•066  034  PT
•067  035  P A
•068  112  D T
•069  001       1
•070  003       3
•071  012       d
•072  001       1
•073  032  I D
•074  034  PT
•075  310  RC
•076  002       2
•077  301  ST+
•078  000       0
•079  006       6
•080  000       0
•081  300  ST
•082  001       1
•083  360  B
•084  001       1
•085  001       1
•086  003       3
•087  012       d
•088  002       2
•089  032  I D
•090  034  PT
•091  360  B
•092  002       2
•093  001       1
•094  004       4
•095  012       d
•096  001       1
•097  032  I D
•098  034  PT
•099  002       2
•100  300  ST
•101  001       1
•102  310  RC
•103  010       8
•104  320  XC
•105  011       9
•106  300  ST
•107  010       8
•108  310  RC
•109  012       d
•110  320  XC
•111  013       S
•112  300  ST
•113  012       d
•114  360  B
•115  001       1
•116  001       1
•117  004       4
```

BLOCK 4—Cont.

```
•118  012  d
•119  002  2
•120  032  I D
•121  034  PT
•122  360  B
•123  002  2
•124  002  2
•125  033  S S
•126  201  L 1
•127  310  RC
•128  005  5
•129  023  ×
•130  310  RC
•131  001  1
•132  021  +
•133  026  (
•134  310  RC
•135  004  4
•136  023  ×
•137  310  RC
•138  010  8
•139  027  )
•140  020  =
•141  300  ST
•142  006  6
•143  023  ×
•144  310  RC
•145  012  d
•146  021  +
•147  026  (
•148  310  RC
•149  003  3
•150  023  ×
•151  310  RC
•152  001  1
•153  027  )
•154  020  =
•155  024  ÷
•156  310  RC
•157  000  0
•158  020  =
•159  300  ST
•160  007  7
•161  360  B
•162  010  8
•163  352  JC
•164  003  3
•165  310  RC
•166  007  7
•167  024  ÷
•168  026  (
•169  310  RC
•170  006  6
•171  023  ×
•172  310  RC
•173  012  d
•174  027  )
•175  020  =
•176  300  ST
•177  002  2
•178  203  L 3
•179  310  RC
•180  006  6
•181  024  ÷
•182  026  (
•183  310  RC
•184  004  4
•185  021  +
•186  310  RC
•187  005  5
•188  027  )
•189  020  =
•190  110  R
•191  034  PT
•192  035  P A
•193  310  RC
•194  012  d
•195  360  B
•196  011  9
•197  360  B
•198  010  8
•199  352  JC
•200  004  4
•201  310  RC
•202  002  2
•203  023  ×
•204  026  (
•205  310  RC
•206  004  4
•207  021  +
•208  310  RC
•209  005  5
•210  027  )
•211  020  =
•212  360  B
•213  011  9
•214  350  J
•215  005  5
•216  204  L 4
•217  035  P A
•218  205  L 5
•219  035  P A
•220  310  RC
•221  007  7
•222  110  R
•223  034  PT
•224  035  P A
•225  030  RT
•226  202  L 2
•227  310  RC
•228  006  6
•229  023  ×
•230  012  d
•231  002  2
•232  002  2
•233  007  7
•234  020  =
•235  110  R
•236  034  PT
•237  035  P A
•238  310  RC
•239  012  d
•240  360  B
•241  011  9
•242  360  B
•243  010  8
•244  352  JC
•245  006  6
•246  310  RC
•247  002  2
•248  023  ×
•249  310  RC
•250  000  0
•251  020  =
•252  360  B
•253  011  9
•254  350  J
•255  007  7
•256  206  L 6
•257  035  P A
•258  207  L 7
•259  035  P A
•260  310  RC
•261  007  7
•262  023  ×
•263  310  RC
•264  000  0
•265  023  ×
•266  012  d
•267  002  2
•268  002  2
•269  007  7
•270  020  =
•271  110  R
•272  034  PT
•273  035  P A
•274  112  D T
•275  030  RT
```

BLOCK 4—Cont.

•276	210	L 8
•277	310	RC
•278	007	7
•279	022	−
•280	310	RC
•281	001	1
•282	020	=
•283	030	RT
•284	211	L 9
•285	013	S
•286	021	+
•287	001	1
•288	023	×
•289	014	EX
•290	002	2
•291	020	=
•292	110	R
•293	034	PT
•294	030	RT

Combining ratings
BLOCK 5

•001	005	5
•002	032	I D
•003	035	P A
•004	112	D T
•005	004	4
•006	003	3
•007	015	/
•008	001	1
•009	015	/
•010	005	5
•011	012	d
•012	000	0
•013	015	/
•014	034	PT
•015	112	D T
•016	035	P A
•017	137	CA
•018	000	0
•019	220	DP 0
•020	201	L 1
•021	033	S S
•022	354	JC
•023	002	2
•024	300	ST
•025	010	8
•026	034	PT
•027	033	S S
•028	300	ST
•029	011	9
•030	034	PT
•031	033	S S
•032	034	PT
•033	035	P A
•034	354	JC
•035	001	1
•036	023	×
•037	012	d
•038	000	0
•039	003	3
•040	024	÷
•041	026	(
•042	310	RC
•043	010	8
•044	061	LG
•045	023	×
•046	012	d
•047	001	1
•048	021	+
•049	012	d
•050	010	8
•051	027	)
•052	020	=
•053	161	L−1
•054	301	ST+
•055	001	1
•056	310	RC
•057	010	8
•058	301	ST+
•059	002	2
•060	023	×
•061	310	RC
•062	011	9
•063	020	=
•064	301	ST+
•065	003	3
•066	000	0
•067	350	J
•068	001	1
•069	202	L 2
•070	035	P A
•071	112	D T
•072	035	P A
•073	001	1
•074	000	0
•075	012	d
•076	011	9
•077	032	I D
•078	034	PT
•079	310	RC
•080	002	2
•081	110	R
•082	034	PT
•083	035	P A
•084	354	JC
•085	004	4
•086	310	RC
•087	003	3
•088	024	÷
•089	310	RC
•090	002	2
•091	020	=
•092	110	R
•093	300	ST
•094	006	6
•095	310	RC
•096	001	1
•097	061	LG
•098	024	÷
•099	012	d
•100	000	0
•101	003	3
•102	023	×
•103	026	(
•104	310	RC
•105	002	2
•106	061	LG
•107	023	×
•108	012	d
•109	001	1
•110	021	+
•111	012	d
•112	010	8
•113	027	)
•114	020	=
•115	351	JC
•116	003	3
•117	000	0
•118	203	L 3
•119	110	R
•120	300	ST
•121	007	7
•122	204	L 4
•123	310	RC
•124	006	6
•125	034	PT
•126	035	P A
•127	035	P A
•128	310	RC
•129	007	7
•130	034	PT
•131	035	P A
•132	112	D T
•133	035	P A
•134	035	P A
•135	350	J
•136	033	S S

Appendix E

Manual Calculations

The worksheets in this appendix allow evaluation of an animal lot manually--that is, without aid of a programmable calculator. No worksheet is provided for the screening or the preliminary evaluation (see Appendix A for the formulas) nor to combine animal lot ratings. The latter is done by summing total runoff and loading from each animal lot or portion that is a pollution hazard (that is, whose COD concentration exceeds 112.5 ppm) before calculating F_1 and F_2 to obtain the animal lot rating.

This set of worksheets is designed to make it easy for the user to calculate the rating and other outputs of the model.

The algorithms used here are identical to those used by the programmable calculators. This set of worksheets is designed to make it easy for the programmer to modify the programs in Appendix D to fit conditions in other States, and to run on other calculators or on computers.

User-Oriented
Manual Calculation Procedure

Final calculations can also be completed manually by following the remaining steps.

Feedlot Evaluation System. Operator_______________

Step 10. Calculate runoff volumes using Figure 1. Equations [1] and [2] may also be used.

$$S = \frac{1000}{CN} - 10 \quad [1]$$

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad [2]$$

CN = soil cover complex number (from Step 6)

P = design rainfall, inches (from Step 3)

Q = runoff, inches

	CN	: S	: P	: Q	X	Area (from Step 4)	= Vol. (acre-in)		
Area 1	____	____	____	____	X	____	= Total Vol_1	= ______	acre-in*
2_a	____	____	____	____	X	____	= ______		
2_b	____	____	____	____	X	____	= ______		
2_r(roof)	100	0	____	____	X	____	= ______		
							Total Vol_2	= ______	acre-in*
							Total Vol_{1+2}	= ______	acre-in*
3	____	____	____	____	X	____	= ______		
							Total Vol_3	= ______	acre-in*
							Total Vol_{1+2+3}	= ______	acre-in* (33)

*Note: Starred items appear in computer printout of additional information available.

Step. 11. Calculate equivalent animal units (EAU) from information in Step 8.

	Animal type	No. of animals (Step 8)	X	Factor (Table 6)[1]	=	EAU
COD:	________	__________	X	_____	=	____
	________	__________	X	_____	=	____
	________	__________	X	_____	=	____
	________	__________	X	_____	=	____

Total = ______EAU

	Animal type	No. of animals (Step 8)	X	Factor (Table 6)[1]	=	EAU
P:	________	__________	X	_____	=	____
	________	__________	X	_____	=	____
	________	__________	X	_____	=	____
	________	__________	X	_____	=	____

Total = ______EAU

Step 12. Calculate animal unit density (AUD) and % manure pack.

	EAU (Step 11)	÷	Area 1 (Step 4)	=	AUD
COD:	______	÷		=	______
			______		
P:	______	÷		=	______

-- if AUD < 100, % manure pack = AUD

-- if AUD ≥ 100, % manure pack = 100

Manure pack (COD) = ______%

Manure pack (P) = ______%

[1] Appendix B, p. 28.

Feedlot Evaluation System. Operator ____________________

Step 13. Calculate concentration of COD and P in runoff at feedlot edge.

a) if $Vol_2 \leq 30$

	% manure pack (Step 12)	X	Factor	= Concentration
COD:	______________	X	45	= ________mg/ℓ*
P:	______________	X	0.85	= ________mg/ℓ*

b) if $Vol_2 > 30$

[% manure pack (Step 12) x $factor_1$ x (Vol_1+30) + Vol_2-30) x $factor_2$] / Vol_{1+2} = Concentration

COD: [________ X 45 X (____+30) + (____-30) X 60]/_______ = ________mg/ℓ*

P: [________ X 0.85 X (____+30) + (____-30) X 2]/_______ = ________mg/ℓ*

Step 14. Calculate mass load of pollutants in runoff at feedlot edge.

	Concentration	X	Vol_{1+2} (Step 10)	X	Conversion factor [2]	= Mass load
COD:	______________	X				= ________lb*
			__________	X	0.227	
P:	______________	X				= ________lb*

Step 15. Determine velocity through each buffer section using figure 2. Equation [3] may also be used.

$$\log v = 0.5 \log s - c \qquad [3]$$

v = runoff velocity, ft/sec

s = slope, % (Step 7)

c = surface condition constant (from Table 4 or Step 7)[3]

---

[2] $\left(\frac{43{,}560\ ft^2}{A}\right)\left(\frac{ft}{12\ in}\right)\left(\frac{1}{10^6}\right)\left(\frac{62.4\ lb}{ft^3}\right) = 0.227$

[3] Table 4, p. 23 or Step 7, p. 24, Appendix B.

Feedlot Evaluation System. Operator ____________________

Note[1] : If the buffer section is a grass waterway (c from table 4 or Step 7 = 1.0),[3] use a value of c = -0.18 in equation [3].

Note[2] : If the buffer section is overland flow and $v > 2.0$, use $v = 2.0$.

Section a, velocity = ________ft/sec

Section b, velocity = ________ft/sec

velocity = ________ft/sec

Step 16. Calculate the time of contact (T_c) in the buffer. Keep T_c in grass waterways separate from T_c in overland flow.

	Distance, L (Step 7)	÷	Runoff velocity (Step 15)	=	Time of contact, T_c
Section a	__________	÷	__________	=	____________ sec
Section b	__________	÷	__________	=	____________ sec
	__________	÷	__________	=	____________ sec

Total T_c (overland flow) = ________sec

Total T_c (grass waterway) = ________sec

Step 17. Calculate percent reduction in pollutant strength due to buffer effects using figures 3 and 4. Equations [4-7] may also be used.

-- if overland flow

COD: $D_c = -27.9 + 42.8 \log T_c$ [4]

P: $D_p = -49.3 + 50.5 \log T_c$ [5]

-- if grass waterway

COD: $D_c = 15.95 + 0.033\ T_c$ [6]

P: $D_p = -21.2 + 0.036\ T_c$ [7]

D = decrease in pollutant strength, %

T_c = time of contact, sec. (Step 16)

Feedlot Evaluation System. Operator ____________________

Overland flow (OF) COD decrease = _________%

P decrease = _________%

Grass waterway (GW) COD decrease = _________%

P decrease = _________%

Note: If decrease > 100%, use decrease = 100%.

If decrease < 0%, use decrease = 0%.

$$\left[1 - \left(1 - \frac{\%\ \text{decrease (OF)}}{100}\right) \times \left(1 - \frac{\%\ \text{decrease (GW)}}{100}\right)\right] \times 100 = \%\ \text{reduction due to the buffer effects}$$

COD: [1 - ________________ X ________________] X 100 = _________%*

P: [1 - ________________ X ________________] X 100 = _________%*

Step 18. Calculate reduced pollutant strength remaining after infiltration, settling, adsorption, etc., in buffer.

$$\text{Concentration at feedlot edge (Step 13)} \times \left[1 - \frac{\%\ \text{reduction (from Step 17)}}{100}\right] = \text{Reduced concentration}$$

COD: ____________ X ____________________ = _________mg/ℓ

P: ____________ X ____________________ = _________mg/ℓ

Step 19. Calculate reduced pollutant strength due to dilution of feedlot runoff with runoff from the buffer and adjacent areas.

$$\left[\left(\underset{\text{(Step 18)}}{\text{Reduced concentration}} \times \underset{\text{(Step 10)}}{Vol_{1+2}}\right) + \left(\underset{\text{(Step 10)}}{Vol_3} \times \text{factor}\right)\right] \Big/ \underset{\text{(Step 10)}}{Vol_{1+2+3}} = \text{Final concentration}$$

COD: [(__________ X ________) + (_______ X 60)]/ ________ = _________mg/ℓ*(34)

P: [(__________ X ________) + (_______ X 2)]/ ________ = _________mg/ℓ*

Step 20. Calculate the percent reduction in pollutant strength due to dilution.

$$\left[\left(\underset{\text{(Step 18)}}{\text{Reduced concentration}} - \underset{\text{(Step 19)}}{\text{Final concentration}}\right) \Big/ \underset{\text{(Step 18)}}{\text{Reduced concentration}}\right] \times 100 = \%\ \text{reduction due to dilution}$$

COD: [(__________ - __________)/ __________] X 100 = _________%*

P: [(__________ - __________)/ __________] X 100 = _________%*

Feedlot Evaluation System. Operator ____________________

Step 21. Calculate final pollutant load

Final concentration (Step 19) X Vol_{1+2+3} (Step 10) X Conversion factor = Mass load

COD: ________________ X ________ X 0.227 = ________lb*

P: ________________ X = ________lb*

Step 22. Calculate the percent change in pollutant load due to feedlot runoff mixing with runoff from the buffer and adjacent areas.

$$100\left[\text{Load at lot edge} \times \left(1 - \frac{\%\ \text{reduction}}{100}\right) - \text{Final load}\right] \Big/ \left[\text{Load at lot edge} \times \left(1 - \frac{\%\ \text{reduction}}{100}\right)\right] = \%\ \text{change due to mixing}$$

(Step 14) (Step 17) (Step 21) (Step 14) (Step 17)

COD: 100[________ X ____________ - __________]/[________ X ____________] = __________%*

P: 100[________ X ____________ - __________]/[________ X ____________] = __________%*

Step 23. Calculate mass load of COD for rating feedlot by either method a or b.

a) if $Vol_2 \leq 30$

$$\text{Manure pack} \times Vol_{1+2} \times \text{factor}^4 \times \left[1 - \frac{\%\ \text{reduction}}{100}\right] = \text{Mass load}$$

(Step 12) (Step 10) (Step 17)

__________ x ______ x 10.215 x ________________ = _________ lb COD

b) if $Vol_2 > 30$

$$\text{Manure pack} \times (Vol_1 + 30) \times 10.215 \times \left[1 - \frac{\%\ \text{reduction}}{100}\right] = \text{Mass load}$$

(Step 17)

__________ x __________ x 10.215 x ________________ = _______ lb COD

If the final COD concentration ≤ 112.5 mg/ℓ, no further calculation is necessary and the animal lot can be considered to pose no surface water pollution hazard.

If the final COD concentration > 112.5 mg/ℓ, continue calculation to determine a numerical rating of the animal lot as follows:

---

[4] 4500/100 x 0.227 = 10.215.

Step 24. Calculate a rating factor for the animal lot using equation [8].

$$F_1 = \frac{\left[\log COD_{\text{mass load}}\right] - 2}{3} \quad [8]$$

(Step 23)

F_1 = ________

Step 25. Calculate a weighting factor using equation [9].

$$F_2 = 0.8 + 0.1 \log Vol_{1+2+3} \quad [9]$$

(Step 10)

F_2 = ________

Step 26. Calculate final rating for animal lot.

F_1 (Step 24)	x	F_2 (Step 25)	x	100	= Animal lot rating (round off to nearest whole number)	
________	x	________	x	100	= ________	(35)

Results of evaluation.

Surface water:

Total volume of runoff at the discharge point (Step 10) ________acre-in (33)

COD concentration at the discharge point (Step 19) ________mg/ℓ (34)

Description of discharge point and/or name of receiving water if applicable

____

____

Animal lot rating for surface-water pollution
(0 = no hazard, 100 = very severe hazard) (Step 26) ________ (35)

Ground water: (from line 32) (0 = minor hazard, 5 = very severe hazard) (Step 9) ________ (36)

Additional comments:

____

____

____

Prepared by ____ Date ____________

Final calculations can also be completed manually by following the remaining steps.

Step 11. Calculate runoff volumes using figure 1. Equations [1] and [2] may also be used.

$$S = \frac{1000}{CN} - 10 \qquad [1]$$

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad [2]$$

CN = soil cover complex number (Step 6)
P = design rainfall, inches (Step 3)
Q = runoff, inches

Area	CN	S	P	Q	x	Area (Step 4)	= Volume	
1	___	___	___	___	x	___	=	Vol_1 = ___ acre-in
2_a	___	___	"	___	x	___	= ___	
2_b	___	___	"	___	x	___	= ___	
2_r(roof)			"		x	___	= ___	
							Total =	Vol_2 = ___ acre-in
3_a	___	___	"	___	x	___	= ___	
3_b	___	___	"	___	x	___	= ___	
3_c	___	___	"	___	x	___	= ___	
3_d	___	___	"	___	x	___	= ___	
							Total =	Vol_3 = ___ acre-in

Step 12. Calculate time of contact in the buffer. Repeat Steps 12a-12d for each buffer section.

(a) Check the value of c. If c = 1.0, this is a grass waterway. This fact affects the value of c and the maximum velocity.

(b) Determine velocity of flow through buffer using figure 2. Equation [3] may also be used.

$$\log v = 0.5 \log s - c \qquad [3]$$

where v = runoff velocity, ft/sec
s = slope, % (Step 7)
c = surface condition constant (from Table 4 or Step 7,[3] except set c = -0.18 for a grass waterway).

(c) Record velocity below, except that if this is overland flow, and if the calculated velocity exceeds 2.0, use v = 2.0.

(d) Calculate time of contact.

Distance, L (Step 7)	÷	Runoff velocity (Step 12c)	=	Time of contact, T_c
______	÷	______	=	______ min

(e) Add up times of contact in all buffer sections.

Overland flow: Total T_c

_____ + _____ + _____ + _____ + _____ + _____ = _____ min

Grass waterway: Total T_c

_____ + _____ + _____ + _____ + _____ + _____ = _____ min

Step 13. Calculate equivalent animal units (EAU) from information in Step 8.

	Animal type	Number of animals	x	Factor (Table 6)	=	EAU
COD:	______	______	x	______	=	___
	______	______	x	______	=	___
	______	______	x	______	=	___
					Total =	_____ EAU
P:	______	______	x	______	=	___
	______	______	x	______	=	___
	______	______	x	______	=	___
					Total =	_____ EAU

Step 14. Calculate animal unit density (AUD) and % manure pack.

	EAU (Step 13)	÷	Area 1 (Step 4)	= AUD
COD:	______	÷	______	= ___
P:	______	÷		= ___

-- If AUD < 100, % manure pack = AUD.
-- If AUD $\geq$ 100, % manure pack = 100.

Manure pack (COD) = _____

Manure pack (P) = _____

Step 15. Calculate concentration of COD and P in undiluted feedlot runoff.

	Manure Pack (Step 14)	x factor	=	concentration
COD:	________	x 45	=	________ mg/ℓ
P:	________	x 0.85	=	________ mg/ℓ

Step 16. Calculate percent decrease in pollutant strength using figures 3 & 4. Equations [4-7] may also be used.

-- if overland flow,

COD : $D = -27.9 + 42.8 \log T_c$ [4]

P : $D = -49.3 + 50.5 \log T_c$ [5]

-- if grass waterway,

COD : $D = 15.95 + 0.033\ T_c$ [6]

P : $D = -21.2 + 0.036\ T_c$ [7]

D = decrease in pollutant strength, %
T_c = time of contact, seconds (Step 12e)

Overland flow (OF) COD decrease = ________ %

P decrease = ________ %

Grass waterway (GW) COD decrease = ________ %

P decrease = ________ %

Note: If decrease > 100%, use decrease = 100%.
If decrease < 0%, use decrease = 0%.

Step 17. Calculate the proportion of pollutant strength remaining after infiltration, settling, and adsorption in buffer using information from Step 16.

$$\left[1 - \frac{\%\ \text{decrease (GW)}}{100}\right] \times \left[1 - \frac{\%\ \text{decrease (OF)}}{100}\right] = \text{Remaining proportion of strength}$$

COD: (1 - __________/100) x (1 - __________/100) = __________

P: (1 - __________/100) x (1 - __________/100) = __________

(Note: The proportion of strength remaining must be in the range from zero to 1.)

Step 18. Calculate "transformed" volumes, for use in all subsequent calculations, from Volume 1 and Volume 2 (calculated in Step 11). Use <u>either</u> Step 18a <u>or</u> Step 18b, and cross out the part not used.

Transformed Volume 1 (Vol 1T) = volume of runoff from feedlot and Area 2 whose concentration is the same as the concentration of undiluted feedlot runoff (this concentration was determined in Step 15).

Transformed Volume 2 (Vol 2T) = volume of runoff from Area 2, which does not flush pollutants from the feedlot surface but serves to dilute that runoff.

(a) _If_ Volume 2 ≤ 30 acre-in:

Volume 1 + Volume 2 = Vol 1T

________ + ________ = ______ = Vol 1T

Volume 2T equals zero. 0 = Vol 2T

(b) _If_ Volume 2 > 30 acre-in:

Volume 1 + 30 = Vol 1T

________ + 30 = ________ = Vol 1T

Volume 2 - 30 = Vol 2T

________ - 30 = ________ = Vol 2T

Step 19. Calculate other needed volumes.

Volume 1T (Step 18)	+	Volume 2T (Step 18)	=	Volume of runoff from feedlot
____________	+	____________	=	____________

Volume of runoff from feedlot (from line above)	+	Volume 3 (Step 11)	=	Total volume
____________	+	____________	=	__________ (line 33)

Step 20. Calculate amount of pollutants in runoff at feedlot edge.

[Volume 1T (Step 18) x Concentration of undiluted runoff (Step 15)] + [Volume 2T (Step 18) x Background concentration] = Amount

COD: (______ x __________) + (_______ x 60) = ______

P: (______ x __________) + (_______ x 2) = ______

Step 21. Calculate concentration of pollutants in runoff at feedlot edge.[5]

	Amount (Step 20)	÷	Volume of runoff from feedlot (Step 19)	=	Concentration	
COD:	________	÷	________	=	________	ppm
P:	________	÷		=	________	ppm

Step 22. Calculate mass of pollutants in runoff at feedlot edge.

	Amount (Step 20)	x	Conversion factor	=	Mass[6]	
COD:	________	x	0.227	=	____	lb
P:	________	x	0.227	=	____	lb

Step 23. Calculate amount of pollutants from feedlot edge runoff delivered to discharge point.

	Amount (Step 20)	x	Remaining pollutant strength (Step 17)	=	Amount
COD:	________	x	________	=	________
P:	________	x	________	=	________

Step 24. Calculate amount of pollutants from Area 3 delivered to discharge point.

	Volume 3 (Step 11)	x	Background concentration	=	Amount
COD:	________	x	60	=	________
P:		x	2	=	________

---

[5] All the results of Steps 21, 22, 26, 28, and 31 may be printed by the programmable calculator. If such additional information on pollutant loadings is not needed, Steps 21, 22, and 27-31, as well as those portions of Steps 13-17, 20, and 23-26 pertaining to P, may all be omitted.

[6] The conversion factor used to convert amount of a pollutant (units: parts per million x acre-inches) to mass (units: pounds) is derived as follows:

1 acre-inch = 3,630 cubic feet
1 acre-inch water weighs approximately 226,512 pounds
1 part per million (pollutant loading) in an acre-inch water weighs:

$$\frac{226{,}512}{1{,}000{,}000} = 0.227 \text{ pound} = 1 \text{ ppm-acre-inch}$$

Step 25. Calculate total amount of pollutants delivered to discharge point.

	Amount from feedlot edge runoff (Step 23)	+	Amount from Area 3 (Step 24)	=	Total amount
COD:	________	+	________	=	________
P:	________	+	________	=	________

Step 26. Calculate concentration of pollutants delivered to discharge point.

	Amount (Step 25)	÷	Total volume (Step 19)	=	Concentration	
COD:	________	÷	________	=	________	ppm (line 34)
P:	________			=	________	ppm

Step 27. Check for artificially low COD and P levels.[7]

COD: If final COD concentration (Step 26) is less than 60.0, mark out the COD calculations in Steps 29 & 30, and write the word "blank" in the third and fifth lines of Step 31.

P: If final P concentration (Step 26) is less than 2.0, mark out the P calculations in Steps 29 & 30, and write the word "blank" in the fourth and sixth lines of Step 31.

Note: If either value is above the limit (60 or 2, respectively), you have taken no action as a result of performing the check.

Step 28. Calculate mass of pollutants delivered to discharge point.

	Amount (Step 25)	x	Conversion factor	=	Mass	
COD:	________	x	0.227	=	____	lb
P:	________	x	0.227	=	____	lb

Step 29. Calculate proportion of pollutant concentration remaining after considering effect of dilution.

Concentration of pollutants delivered to discharge point (Step 26) ÷ [Concentration of pollutants in runoff at feedlot edge (Step 21) x Remaining pollutant strength (Step 17)] = Proportion remaining

[7] This check has not been incorporated in the calculator programs.

COD: ____________ ÷ (______________ x _________) = __________

P: ____________ ÷ (______________ x _________) = __________

Step 30. Calculate proportion of pollutant mass loading remaining after considering effect of dilution.

Mass of pollutants delivered to discharge point (Step 28)	÷	[Mass of pollutants in runoff at feedlot edge (Step 22)	x	Remaining pollutant strength] (Step 17)	=	Proportion remaining
COD: ________________	÷	(_____________	x	_________)	=	__________
P: ________________	÷	(_____________	x	_________)	=	__________

Step 31. Convert proportion of pollutant remaining (COD and P values from Steps 17, 29, and 30) to percentage reductions in pollutant concentration or loading, using Equation [8]:

% reduction = 100 (1 - proportion remaining) [8]

From Step 17: COD: 100 (1 - ______) = ______%

P: 100 (1 - ______) = ______%

From Step 29: COD: 100 (1 - ______) = ______%

P: 100 (1 - ______) = ______%

(These values cannot be less than zero.)

From Step 30: COD: 100 (1 - ______) = ______%

P: 100 (1 - ______) = ______%

Step 32. Check for compliance with State standards.

If concentration of COD delivered to discharge point (from Step 26) is less than 112.5 ppm, rating is zero, no further calculations are needed, and evaluation of this feedlot is complete. Enter "0" in Step 38.

Step 33. If feedlot is not in compliance with standards, continue with this step and calculate COD mass loading for computation of rating. Use these factors:

Factor a = COD concentration of undiluted feedlot runoff (from Step 15)

Factor b = Proportion of COD remaining after buffer effects (from Step 17)

Factor a (Step 15)	x	Factor b (Step 17)	x	Volume 1T (Step 18)	x	Conversion factor	=	COD mass for rating
_________	x	_________	x	____________	x	0.227	=	________

Step 34. Check for miniscule COD mass.

If COD mass for rating (from Step 33) is less than 101 lbs., rating is zero, no further calculations are needed, and evaluation of this feedlot is complete. Enter "0" in Step 38.

Step 35. If COD mass loading is not miniscule, continue with this step and calculate a COD factor for rating using Equation [9], where the mass for rating was determined in Step 33.

$$F_1 = \frac{\text{Log (mass for rating)} - 2}{3} \qquad [9]$$

F_1 = ________

Step 36. Calculate a weighting factor for rating using Equation [10], where the total volume was determined in Step 19.

$$F_2 = 0.8 + 0.1 \log \text{(total volume)} \qquad [10]$$

F_2 = ________

Step 37. Calculate preliminary rating:

F_1 (Step 35) x F_2 (Step 36) x 100 = Preliminary rating

__________ x __________ x 100 = __________

Step 38. Calculate final rating.

Enter "0" from Step 32 or Step 34, or round the preliminary rating (Step 37) to the nearest whole number and enter here.

Rating

______ (line 35)

Step 39. Calculate rating for a diverted lot.

(a) Vol 1T = Volume 1 (Step 11): Vol 1T = ______

Vol 2T = zero; Vol 2T = 0

(b) Proceed with Steps 19, 20, and 23-26 using the new values of Vol 1T and Vol 2T from Step 39 a. Omit calculations which relate only to P.

(c) Proceed with Steps 32-38, as applicable.

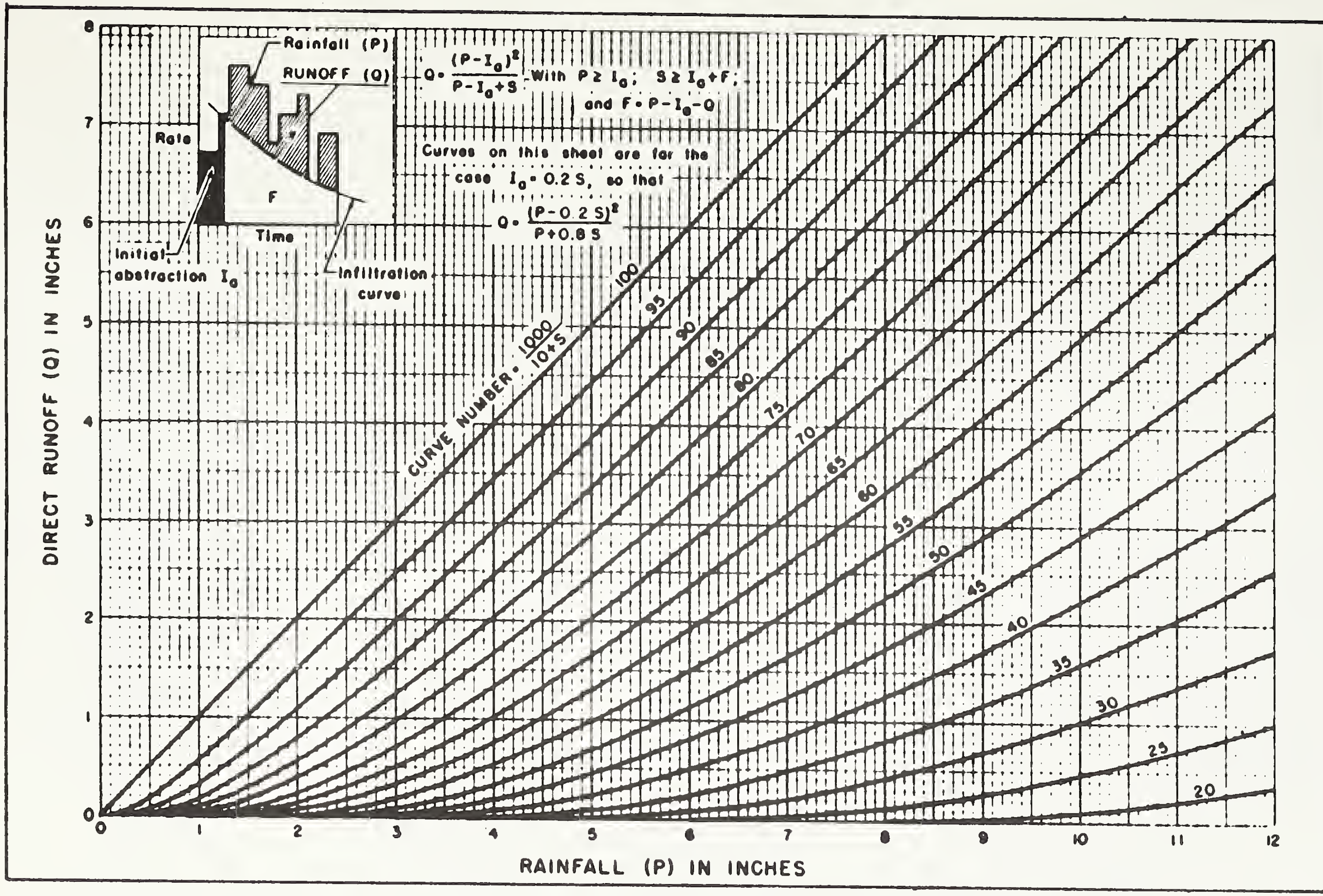


Figure 1.—Soil-cover complex method of estimating direct runoff amounts from storm rainfall.

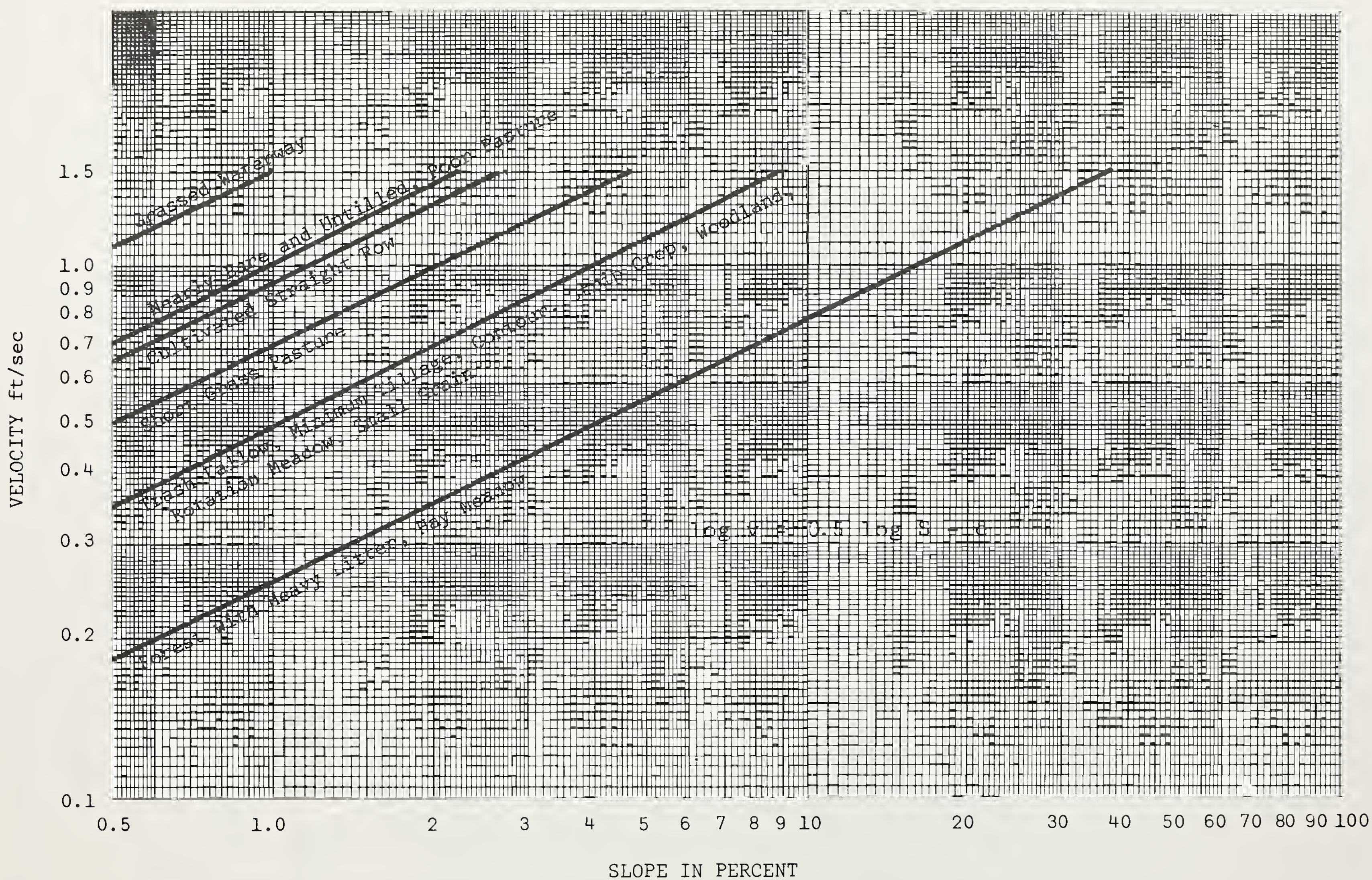


Figure 2.—Runoff velocity versus percent slope for various cover conditions.

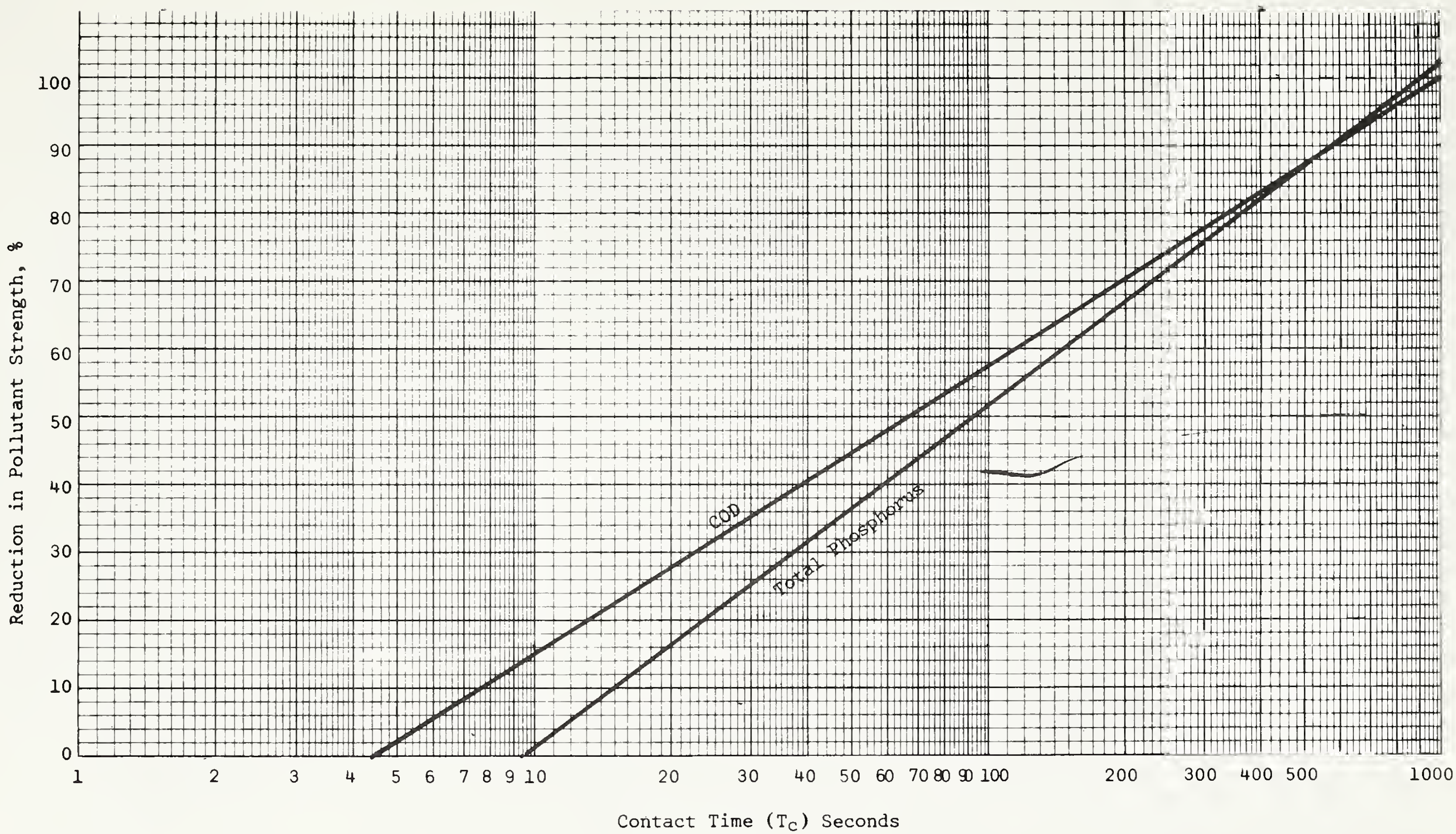


Figure 3.—Reduction in pollutant strength (D) versus contact time (T_c) for vegetated filter areas.

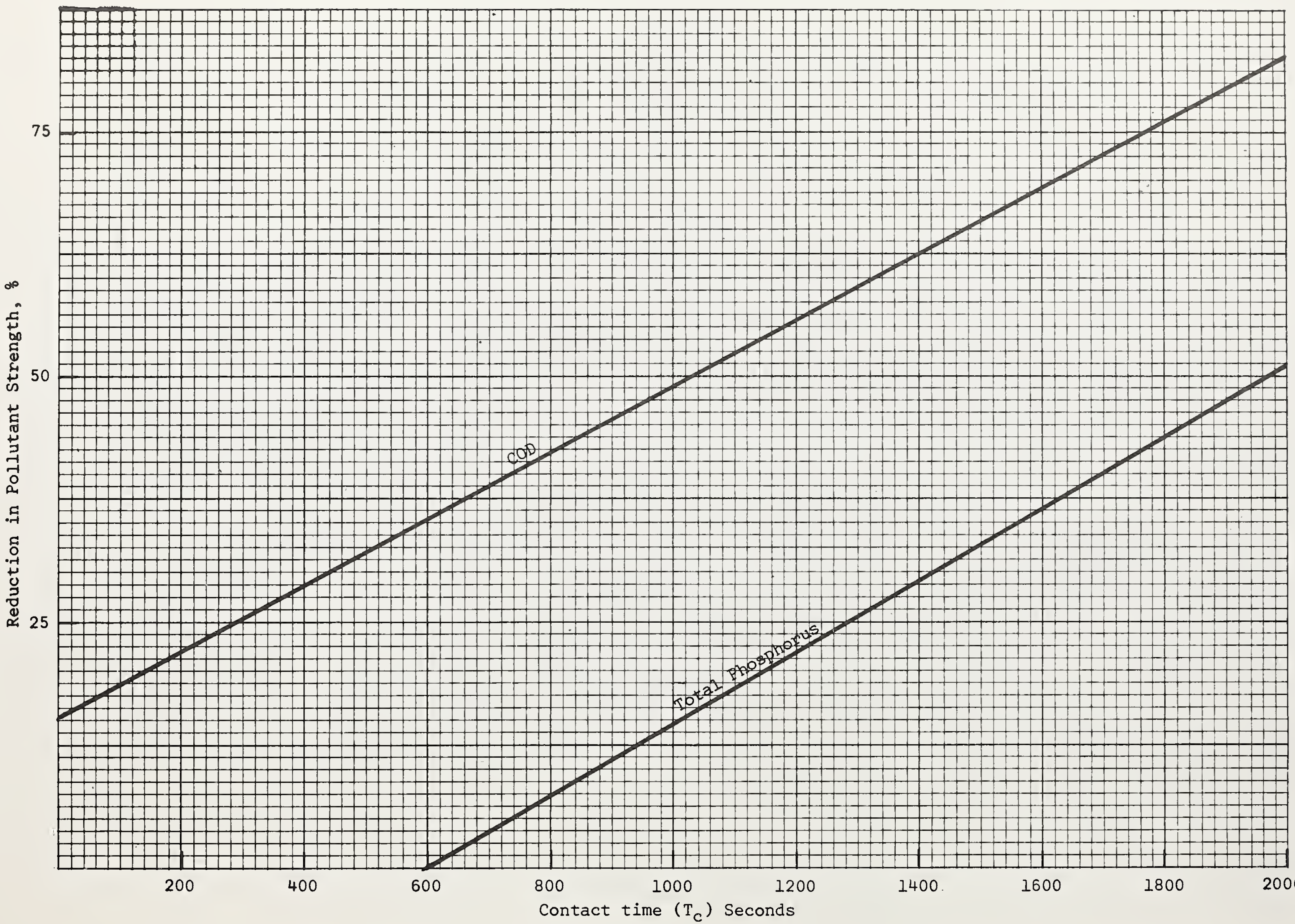


Figure 4.—Reduction in pollutant strength (D) versus contact time (T_c) for grass waterways.

Appendix F

Notes on the Feedlot Evaluation System

Interpreting Animal Lot Ratings

The evaluation system assigns each animal lot a numerical rating for surface-water pollution hazard. These ratings **do not** represent rankings or percentiles. Feedlots will not be evenly spaced in their ratings; more than half of all polluting feedlots are expected to rate between 40 and 70. A rating of zero means the surface-water pollution hazard is negligible or zero. In extreme cases, the rating may exceed 120, but the vast majority of all feedlots will rate less than 90.

A few sample ratings, presented here, are based on the number of animal units (a.u.). An a.u. is one 1,000-lb beef steer or its equivalent in waste generation. Under the recently adopted MPCA rules, the jurisdiction of counties is limited to certain kinds of feedlots with fewer than 1,000 a.u. No Minnesota feedlot smaller than 1,000 a.u. will rate more than 91 under any circumstances. To rate 100, a feedlot would have to be significantly larger than that, at least in Minnesota, where the design (25-year/24-hour) rainfall is moderate. A fictional example of the smallest Minnesota feedlot that could possibly rate 100 would be a feedlot for 1,600 a.u., in Freeborn County, where the design rainfall is 5.05 inches. The same fictional feedlot, if located in Kittson County with a design rainfall of 3.85 inches, would rate 94.

The rating is based on a scientific estimate of the amount of pollution generated by the lot and delivered to a receiving water. However, the rating is a statistical abstraction of this estimate and, like EPA gas mileage estimates for automobiles, is to be used only for comparisons.

The actual rating value may be determined in either of two ways. If the COD concentration at the discharge point is 112 ppm or less, the runoff is considered as probably meeting State standards. (State standards require that BOD not exceed 25 ppm, and COD is approximately 4.48 times as great as BOD for typical feedlot runoff.) If the COD at the discharge point exceeds 112 ppm, the rating is determined by a logarithmic formula, based on the amount of COD delivered from the feedlot to the discharge point.

When a single feedlot operation includes several ani-

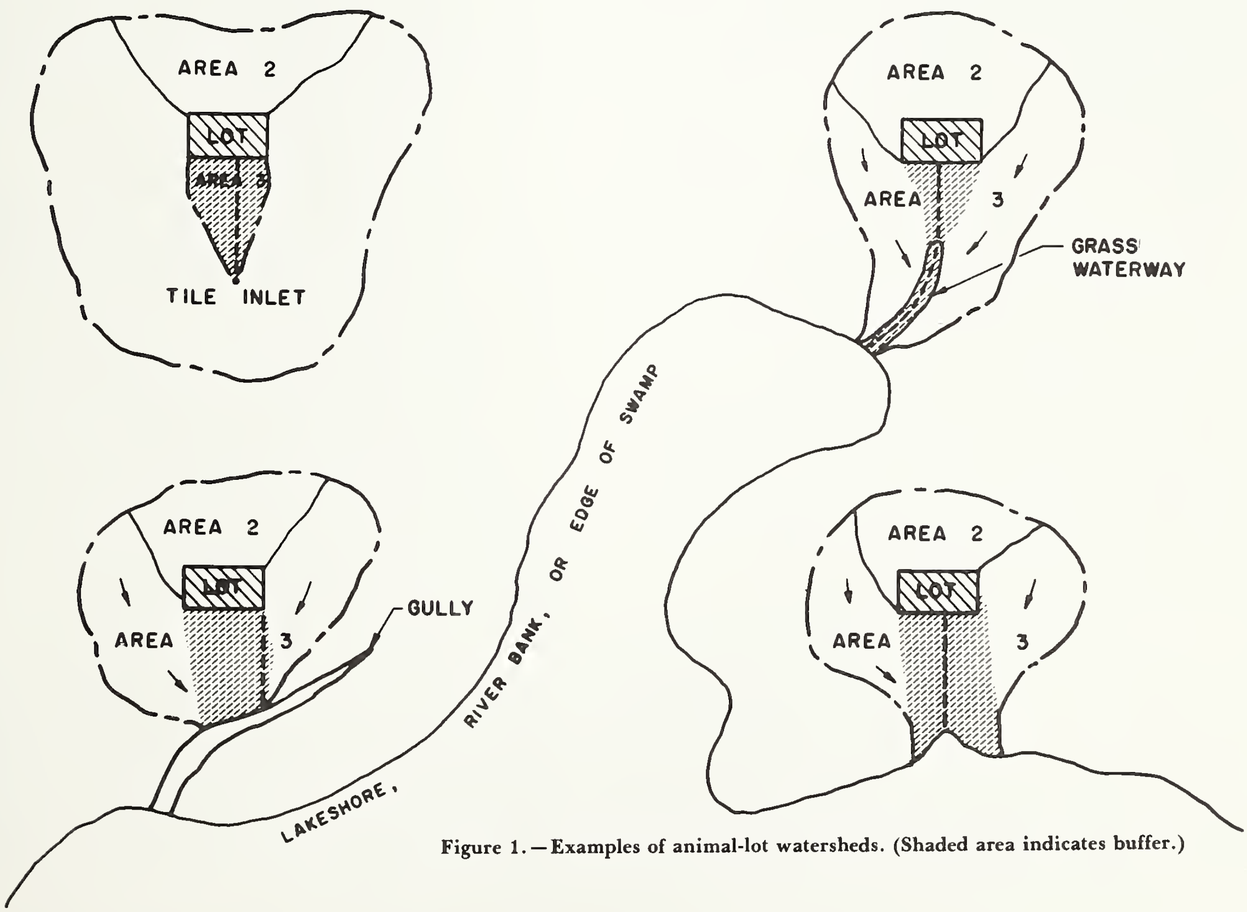


Figure 1.—Examples of animal-lot watersheds. (Shaded area indicates buffer.)

mal lots or animal areas, simple arithmetic **cannot** be used to add the several ratings, except when one of the ratings is zero. A logarithmic method has been provided for this purpose.

Determining Area 3 and the Discharge Point

Area 3 consists of the entire area over which animal lot runoff flows (that is, the buffer), plus any other area whose runoff mixes with that of the buffer.

Runoff from Area 3 mixes with animal lot runoff before it reaches the discharge point. Beyond the discharge point, additional large volumes of water will mix with and dilute it—water from an entire river basin, for example—but this must not be considered as Area 3 (dilution) water.

Another way to look at the situation involves what we might call "flow lines." These are the lines along which a drop of water might flow; they are at all places perpendicular to the contour. Area 3 is bounded above by the animal lot, below by the discharge point or the edge of a water body, and on the sides by flow lines from opposite edges or corners of the animal lot. Defining the local watershed area, therefore, requires two different approaches. Drainage divides are used in defining Area 2, above the animal lot. Below the animal lot, drainage divides do not apply, and flow lines must be used to define Area 3.

A few sketches (fig. 1) may help clarify flow lines and the delineation of Area 3. Arrows indicate the direction of flow in Area 3, and the heavy dashed line indicates the shortest flow line between the animal lot and the discharge point (same as the total length of all buffer sections). These sketches are simplified versions of real situations, and they are intended only to help guide the users professional judgment.

Because of the great variations between actual feedlot sites, we often have difficulty determining the discharge point for a given situation. The key to valid evaluations is, therefore, consistency in identifying the discharge point. Extensive in-the-field training is essential so that **all** personnel evaluating feedlots in any one county or State use consistent criteria.

Buffer Effectiveness

The length, ground cover, and slope of the land between an animal lot and the discharge point determine the effectiveness of a buffer in controlling animal lot pollution. Water in a buffer passes as sheet flow over the land in close contact with the soil and vegetation, facilitating settling, adsorption, interception, and infiltration of the pollutants. Buffer effect depends on the time during which the water is in contact with the buffer surface before entering a channel or flowage. Therefore, length of the buffer has the largest influence on its effectiveness, followed, in turn, by the character of vegetative cover and slope.

Overland flow generally concentrates into a channel within 300 to 500 feet of its origin. If a longer buffer is to be effective, it may be necessary to ensure maintenance of sheet flow by regrading cropland, constructing level spreaders, or other means.

A grass waterway scarcely provides sheet flow and is, therefore, a far less effective buffer (from one-half to one-tenth) as a land surface over which sheet flow occurs. However, a formula reflecting the effectiveness of a grass waterway in reducing animal lot pollution has been incorporated to enable the model to be used for design.

For any buffer other than a grass waterway, a length of about 1,700 feet as sheet flow will invariably be sufficient to reduce the COD concentration to less than 112 ppm, ensuring a zero rating. (As noted above, such a long buffer ordinarily requires measures to ensure the maintenance of sheet flow.) A shorter buffer may suffice if the animals are not packed very densely on the animal lot; the screening formula is based on this fact. While a shorter buffer may also suffice if it is heavily vegetated or relatively flat, these factors were not included in the screening formula because of the expertise required for their determination.

The screening formula cannot be used where a grass waterway serves as a buffer.

Evaluating Manure Stacks

If manure is stacked within an animal lot, no special consideration is necessary. The animal lot should be evaluated just as it would be if the manure was spread over the entire animal lot.

If manure is stacked outside an animal lot, the Animal Lot Evaluation Data Form should be completed, as if the manure stack were an animal lot. The information on Areas 2 and 3, on the buffer section(s), and on the number of animals whose manure is stacked, should all be collected in the usual way. To recognize the fact that it is a manure stack, however, Area 1 should be doubled before entry on the data form. The curve number of the manure stack is 91.

Adjusting for Loafing Areas

When an animal lot is used for a loafing or exercise area and, thus, is not occupied 100 percent of the time, the AUD used in the evaluation should be adjusted. This can be done by multiplying the number of animals by the percent of time the animal lot is occupied and entering this value in Step 8 of the evaluation form.

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