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COOPERATIVE EXTENSION SERVICE • MICHIGAN STATE UNIVERSITY

Systems of Runoff Control

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Runoff from open feedlots contains animal manure, spilled feed, and other materials which should not be allowed to enter streams. Runoff control is or soon will be mandatory in most states, and satisfactory methods of runoff control are available for almost every situation. These may be simple or elaborate and can range from relatively low cost to expensive. Almost every system requires individual planning owing to variations in lot size, configuration, topography, soil types, rainfall, and other factors such as lot management and local regulations. However, the basic principles of controlling runoff are very similar throughout the country, and these will be used in this publication to provide guidelines for planning runoff control systems. As nomenclature of system components tends to vary from state to state, more than one name for the same component may be used. A common configuration for runoff control systems is illustrated in Figure 1.

Rainfall and snowmelt are the major causes of runoff; urine and leakage from waterers also causes runoff in some situations. Design flow and storage capacities are usually based on rainfall intensities and amounts (to be discussed in more detail later). Research has shown that it is seldom practical to treat runoff so that it can be discharged to surface waters, so in the systems to be discussed, land application is the only disposal method considered.

Runoff Control System Components
Clean Water Diversion

To minimize the amount of water which must be handled through a runoff control system, unpolluted outside surface water should be prevented from entering the lot. This includes building roof water. This can be done by the use of diversion terraces, channels and roof gutters. Diversion channels and terraces may be either earthen or paved, with earth used most commonly because of its low cost.

Runoff Collection

Lot runoff must be collected and directed to the settling and storage components of the runoff control system. Some lots may have a single outlet point, making collection very simple, while others with slopes in more than one direction and multiple outlet points may require complex collection systems or even more than one complete runoff control system. Curbs, terraces, channels, dikes and pipes are examples of components used to collect lot runoff and direct it to settling facilities and/or storage or disposal.

Settling Basins (Debris Basins)

Settling basins are commonly used to partially treat lot runoff before it enters holding ponds or infiltration areas (vegetative filters). These basins receive runoff from the collection system, allow a portion of the solids to settle and allow the liquid to drain to storage or disposal. Settling basins will remove 50-85% of the manure solids from the lot runoff. This is an important step as the basin prevents solids from reducing storage capacity in the holding ponds or from being deposited in infiltration areas. The solids
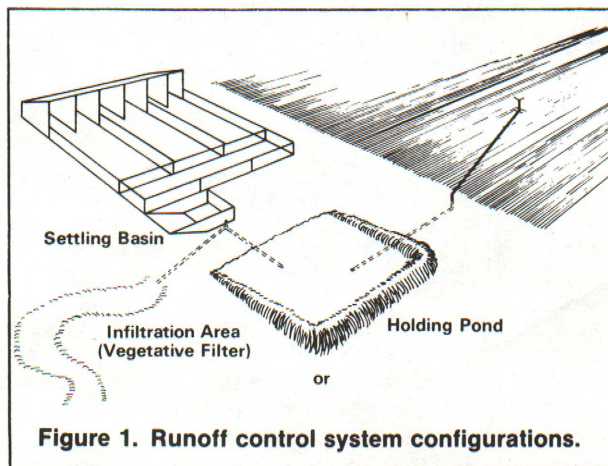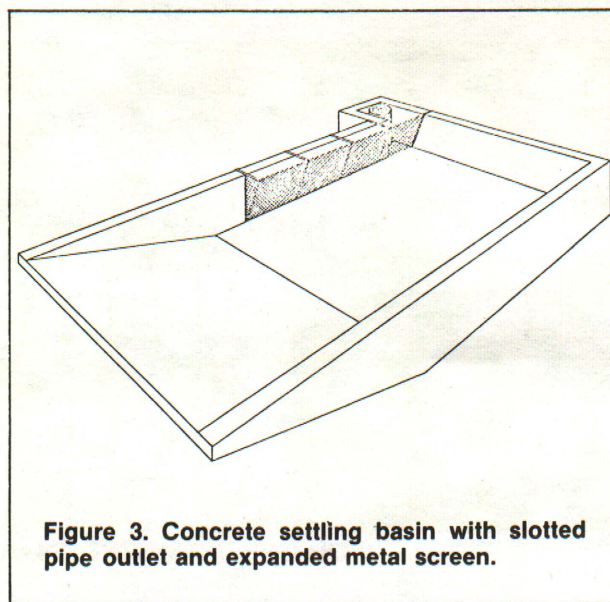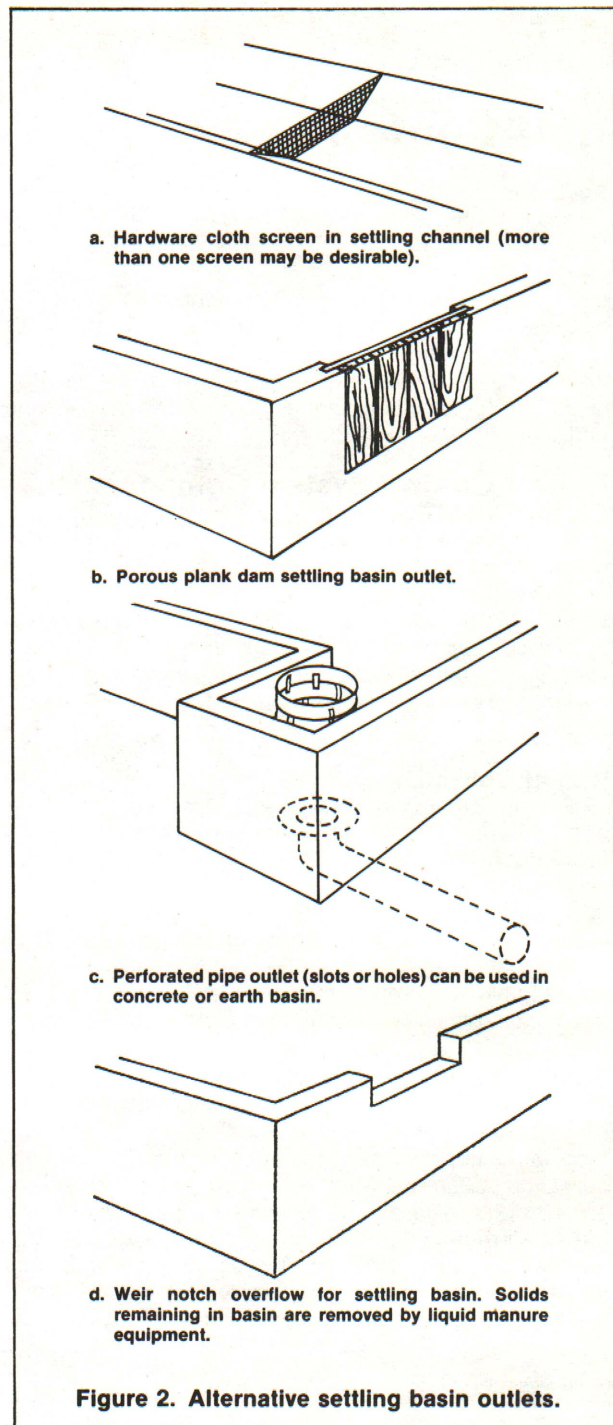

Figure 1. Runoff control system configurations.

Settling Basin

Infiltration Area
(Vegetative Filter)

Holding Pond

or

reduction also helps minimize odors from the holding pond and makes the liquid much easier to pump through small irrigation equipment.

Many types of settling basins can be used, including channels and boxes, earth and concrete. The best basic structure shape is relatively large and shallow, probably less than 3 ft. deep if solids are to be removed from the basin with conventional solid manure handling equipment. In arid areas where the basins dry out readily, earth basins may be satisfactory, and the settled solids can be handled easily with conventional equipment. In humid areas, concrete bottoms or complete concrete basins are necessary so equipment can enter the basin for clean-out. Access ramps to basins should not slope more than 1 in. of fall per foot of horizontal run if front-end loaders will be used to remove the accumulated solids. If liquid manure equipment is available on the farm, it may be easier to

Figure 3. Concrete settling basin with slotted pipe outlet and expanded metal screen.

a. Hardware cloth screen in settling channel (more than one screen may be desirable).

b. Porous plank dam settling basin outlet.

c. Perforated pipe outlet (slots or holes) can be used in concrete or earth basin.

d. Weir notch overflow for settling basin. Solids remaining in basin are removed by liquid manure equipment.

Figure 2. Alternative settling basin outlets.

handle the semi-solids in the basin as a liquid. The frequency of basin cleaning varies a great deal depending on basin size, type of lot surface, amount of manure on the lot surface and storm runoff characteristics. In some instances, cleaning may be necessary after each large storm, but a cleaning frequency of 2 to 4 times per year seems to be adequate in most cases.

Several types of basin outlets can be used, some of which are designed to allow liquid to drain from the full depth of the basin and allow the solids to dry. The perforated or slotted pipe riser and the porous plank dam in Figure 2a, b and c are examples of these. Another alternative is to use a weir notch in the basin sidewall as shown in Figure 2d. With this method, liquid always remains in the basin, and cleaning must be done by liquid manure handling equipment. Overflow liquid from the settling basin may be pumped or may flow by gravity to storage or disposal, either through underground pipe or open surface channels. All types of outlets seem to develop clogging problems periodically which can usually be dealt with by manual cleaning. One outlet modification that has helped some concrete basins is the addition of an expanded metal screen (¾ in., No. 9) to increase the screening area as shown in Figure 3.

Recommended settling basin design criteria vary greatly from state to state. Several states base settling basin capacities upon a desired storage volume of solids plus temporary storage for storm runoff; others, on the basis of a minimum detention time for a given amount of runoff. Recommended capacities are commonly in the range of 5-10 cu. ft. per 100 sq. ft. of feedlot area. Recommended outlet types also vary a great deal. Since these cannot be presented in individual detail and no single method is necessarily better than the others, no attempt will be made here to specify how settling basins should be sized and what their configuration should be. However, research has shown that most of the solids in runoff that will settle, will do so in less than 30 minutes. Therefore a detention time of 30 minutes in the settling basin can be used as a design criterion, where no other design criterion is available. You should check with your local extension agent and the local Soil Conservation Service office for additional information.

Holding Ponds

The purpose of a holding pond is to store runoff temporarily before final disposal on land. It is not meant to be a treatment facility. Almost all holding ponds are of earth

construction. While in a few arid areas evaporation from holding ponds is adequate for dewatering or emptying, in most areas of the country it is necessary to dewater the ponds by other means, usually pumping. Holding ponds tend to seal themselves naturally, so seepage losses are not normally a problem. When ponds are constructed in coarse sands and gravels or near fractured bedrock, sealing by lining with clay or plastic may be necessary.

A certain amount of holding pond management is necessary, primarily timely dewatering. In general, holding ponds should be dewatered whenever land conditions allow application without excessive runoff or damage to growing crops. This is to provide adequate storage capacity to retain lot runoff from the next precipitation. When ponds are sized large enough to provide several months' storage, the added flexibility may allow dewatering to be scheduled to avoid winter periods and to make maximal use of the fertilizer nutrients or the stored water for supplemental irrigation. Required or recommended holding pond sizes vary widely by state and locality. As a minimum in almost every situation, the holding pond capacity should be adequate to contain the runoff from a 25-year frequency, 24-hour duration storm. Many states require larger minimum capacities. For example, in Indiana the recommended minimum capacity is the runoff expected during a 90-day period plus the 25-year, 24-hour storm. This value varies from about 7 in. of depth over the entire lot area for earth lots in northern Indiana to 14 in. for paved lots in southern Indiana. Illinois requires at least 12 in. storage from earth lots and 15 in. from paved lots. In Iowa, minimum storages of 10 in. from earth lots and 12 in. from paved lots are recommended, although smaller capacities may be acceptable in certain situations. These examples should make it clear, however, that anyone planning a runoff control system should first check state and local regulations to insure that the planned system will comply legally as well as perform satisfactorily.

Dewatering Equipment

Disposal of lot runoff stored in holding ponds is normally accomplished by applying it on nearby cropland. While hauling by tank wagon is possible, pumping and irrigating directly to the land is usually the most economical dewatering method. Irrigation systems do not need to be elaborate. The main objective is to empty the pond within a reasonable length of time without exceeding the infiltration capacity of the soil or the nutrient utilization level of the crop in the disposal area.

Standard centrifugal pumps are usually satisfactory for pumping lot runoff from holding ponds through sprinkler systems or gated or perforated pipe. Pumping systems may be simple and low cost or expensive and sophisticated, depending on the size of the operation and operator preference. Whatever the system, pumping to cropland is a simple, efficient means of dewatering holding ponds.

Table 1. Design information for infiltration areas or vegetative filters.

Design basis	Runoff drainage area	Design rainfall event	Basis for runoff receiving capacity	Design area
Infiltration rate	Lot area	24-hr., 25-yr.	Soil infiltration rate, minus rainfall rate, in./hr.	$\dfrac{\text{Lot area} \times \text{Design rainfall}}{\text{Runoff receiving capacity} \times \text{Desired infiltration time*}}$
Water-holding capacity	Lot area	24-hr., 25-yr.	Soil water-holding capacity, minus rainfall, in.	$\dfrac{\text{Lot area} \times \text{Design rainfall}}{\text{Runoff receiving capacity}}$
Hydraulic loading	Lot area	Annual rainfall	Hydraulic loading, in./yr.	$\dfrac{\text{Lot area} \times \text{Design rainfall}}{\text{Runoff receiving capacity}}$

*For example, 12 hours or 24 hours.

Table 2. Approximate infiltration rates and water-holding capacities for various textured soils.

Soil type	Infiltration rate		Water-holding capacity	Hydraulic loading
	cover in./hr.	bare in./hr.	(in./5 ft.)	in./yr.
Sand	1.0+	1.0+	2.5	
Sandy loam	.6	.4	6.5	research underway to develop criteria
Silt loam	.5	.3	11	
Silty clay loam	.4	.25	10	
Clay	.3	.15	9	

Infiltration Areas (Vegetative Filters)

An alternative to the use of holding ponds for runoff detention is the use of infiltration areas or vegetative filter. With this method, runoff flows directly during the rainfall event from the settling basin to a vegetated, usually grassed, field area. The system is designed on the premise that the major portion of the feedlot runoff from storms will infiltrate the soil. In the rare instances when runoff does not totally infiltrate the soil, it will be diluted and treated to such a degree by biological and physical processes during its movement over the vegetated area that it can be discharged. While systems of this type are certainly not adaptable or practical for every situation, early experience indicates that they could provide successful, low-cost runoff control for many smaller swine operations.

The vegetated area may be either a channel similar to a long grassed waterway with a slope of less than 1% or a broad, flat, overland flow area with little or no slope surrounded by berm or dike. All outside surface water should be diverted so the only water on the disposal area is lot runoff and direct precipitation.

Infiltration areas do not need to be elaborate. Management is minimal, consisting primarily of maintaining the vegetative cover in the area. Periodic removal of the vegetation by harvesting is recommended when conditions permit.

Since this is a relatively new concept, research information on which to base design criteria is very limited. Several approaches have been used and are being evaluated. One is simply to estimate the infiltration rate of the soil in the disposal area, calculate the quantity of runoff expected from a given storm or series of storms, and size the vegetated area based on a desired time to infiltrate the entire runoff quantity. A second method is to base the vegetated area size on a desired long-term hydraulic loading rate such as average application of runoff in inches per week or per year. A third approach is to use the estimated water-holding capacity of the soil profile under the vegetated area and size the area so that infiltration from a given storm will not exceed that water-holding capacity. Tables 1 and 2 summarize these design procedures and give some approximate values for design information.

As firm design criteria are not yet established and systems of this type may not be acceptable in some areas, check for local design criteria and compliance with regulations before installing a system of this type.

Table 3. Dimensions of holding ponds.

Useable volume (cu. ft. x 1,000)	Lengths of holding ponds — Total depth 6 ft. Interior width (ft.)					9 ft. Interior width (ft.)					15 ft. Interior width (ft.)				
	50	75	100	150	200	50	75	100	150	200	75	100	125	150	200
3.	34.														
4.	41.	31.													
5.	47.	34.													
6.	53.	37.	31.			50.									
7.	59.	41.	34.			55.									
8.	65.	44.	36.			60.									
9.	71.	48.	39.	31.		65.									
10.	77.	51.	41.	32.		70.	47.								
11.	84.	55.	44.	34.		75.	50.								
12.	90.	58.	46.	35.	30.	80.	52.								
13.	96.	62.	48.	37.	31.	85.	55.								
14.	102.	65.	51.	38.	33.	90.	57.	47.							
15.	108.	69.	53.	40.	34.	95.	60.	48.							
16.	114.	72.	56.	41.	35.	100.	62.	50.							
17.	121.	76.	58.	43.	36.	105.	65.	52.							
18.	127.	79.	61.	44.	37.	110.	67.	53.							
19.	133.	83.	63.	46.	38.	115.	70.	55.							
20.	139.	86.	65.	47.	39.	120.	72.	57.							
22.	151.	93.	70.	50.	41.	130.	77.	60.	46.						
24.	164.	100.	75.	53.	44.	140.	82.	63.	48.		77.				
26.	176.	107.	80.	56.	46.	150.	87.	67.	50.		81.				
28.	188.	114.	85.	59.	48.	160.	92.	70.	52.		85.				
30.	201.	121.	90.	62.	50.	170.	97.	73.	54.	46.	90.				
32.	213.	128.	94.	65.	52.	180.	102.	77.	56.	47.	94.				
34.		135.	99.	68.	54.	190.	107.	80.	58.	49.	98.				
36.		142.	104.	71.	57.	200.	112.	83.	60.	50.	102.	76.			
38.		149.	109.	74.	59.	210.	117.	87.	62.	51.	106.	78.			
40.		156.	114.	77.	61.	220.	122.	90.	64.	53.	110.	81.			
45.		173.	126.	85.	67.		135.	98.	69.	56.	120.	87.			
50.		191.	138.	93.	72.		147.	107.	74.	60.	130.	93.	77.		
55.		208.	150.	100.	77.		160.	115.	79.	64.	141.	99.	81.		
60.		225.	162.	108.	83.		172.	123.	84.	67.	151.	105.	86.	75.	
65.		243.	174.	115.	88.		185.	132.	89.	71.	161.	111.	90.	78.	
70.		260.	187.	123.	94.		197.	140.	94.	74.	171.	117.	94.	82.	
80.		295.	211.	138.	105.		222.	157.	104.	81.	192.	128.	102.	88.	
90.		330.	235.	153.	116.		247.	173.	114.	89.	212.	140.	111.	95.	78.
100.			259.	168.	127.		272.	190.	124.	96.	232.	152.	119.	101.	82.
150.			381.	244.	182.			273.	174.	131.	334.	212.	161.	134.	104.
200.				319.	236.			357.	224.	167.		271.	203.	166.	127.
250.				394.	291.			440.	274.	203.		331.	245.	199.	149.

Notes: 1. Total depths incude a 1 ft. freeboard. 2. The side slope is 2.5 to 1.

Constructing an Infiltration Area

The infiltration channel should not be confused with a waterway. The topsoil in the channel should not be disturbed. In many locations, the channel can be laid out along the natural topography, and a diversion terrace can be built along the channel to prevent outside surface water from entering it. The terrace around the channel need not normally be more than 1 ft. high to contain the feedlot runoff in the channel.

If excavation is necessary, the topsoil should be returned to the channel bed after removing the required amount of subsoil. It is also important that the channel not be heavily compacted during construction.
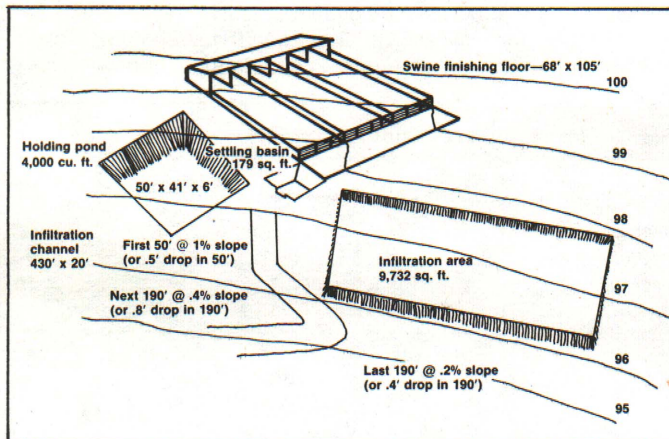
A grass, such as rye grass or fescue, should be sown in the channel as soon after construction as possible. If a drainage tile is needed to control the seasonal high water table, the subsurface drainage tile should be 4 in. in diameter and installed 30-40 in. deep, 10 ft. on either side of the channel.

Before Building . . .

State and local regulations vary, as do recommended runoff control practices for different areas. For this reason, it is advisable to check these with appropriate state agencies and university and Soil Conservation Service personnel before planning and constructing any system. Another excellent source of planning and design information for all types of waste management, including runoff control systems, is the *Livestock Waste Facilities Handbook,* MWPS-18. This publication is available from the Agricultural Engineering departments of most midwestern land-grant universities or from Midwest Plan Service, Iowa State University, Ames, Iowa 50010. It may also be advisable to engage the services of a private consulting engineer for detailed planning work, especially on larger systems. Successful runoff control systems may be simple or complex, cheap or expensive. To insure the success of any system, however, careful forethought and planning is wise.

Runoff Control System Design Worksheet

Example: Design a runoff control system for a paved open feedlot in Lincoln County, Indiana, shown in the illustration. The swine finishing floor is 68 ft. wide x 105 ft. long. The soil type in the area is silty clay loam. The annual rainfall is 36 in. The feedlot and settling basin will be cleaned once a month. An infiltration area or vegetative filter may be used in place of the holding pond if more economical.

Swine finishing floor—68' x 105'
Holding pond 4,000 cu. ft.
Settling basin 179 sq. ft.
50' x 41' x 6'
Infiltration channel 430' x 20'
First 50' @ 1% slope (or .5' drop in 50')
Next 190' @ .4% slope (or .8' drop in 190')
Infiltration area 9,732 sq. ft.
Last 190' @ .2% slope (or .4' drop in 190')

Solution:	Example	Your Situation
I. Settling Basin		
A. Feedlot area		
Width x Length (measured)	68' x 105' = 7,140 sq. ft.	
B. Runoff to settling basin		
Feedlot area x design rainfall (i.e., 1.2" in 1 hour for most of Indiana)	7,140 x (1.2"/hr. ÷ 12"/ft.) = 714 cu. ft./hr.	
C. Basin volume		
1. Design detention time (½ hr.) x runoff to settling basin (B)	½ hr. x 714 cu. ft./hr. = 357 cu. ft.	
D. Settling basin area		
1. Minimum depth (selected by swine producer, usually 2-4')	use 2'	
2. Settling basin area (from C) ÷ depth (2')	357 ÷ 2 = 179 sq. ft.	
E. Settling basin depth		
1. Minimum depth (from D1)	2'	
2. Solid storage (determined by amount of solids in runoff and frequency of cleaning - usually about 1' of depth for each month solids are stored - some states do not recommend additional solids storage besides the minimum depth)	1 month x 1' = 1	
3. Total depth (sum of E1 and E2) (note—excessive depths make cleaning difficult, especially when cleaning is done with tractor loader)	3'	

Solution:	Example	Your Situation

II. Infiltration Area (vegetative filter)
Runoff to infiltration area from feedlot
(24-hr., 25-yr. storm)

Feedlot area (A) x rainfall — $7,140 \times (5.5" \div 12"/ft.)$ = 3,270 cu. ft.
(5.5 in. for most of Indiana) _____

A. Water Holding Capacity Method
 1. Available water receiving capacity

 Water holding capacity (from Table 2) - rainfall (24-hour, 25-year storm) — $10" - 5.5" = 4.5"$ = 0.38' _____

 2. Infiltration area

 Runoff to infiltration area (from II) ÷ available water receiving capacity (from A1) — 3,270 cu. ft. ÷ 0.38' = 8,605 sq. ft. _____

 3. Dimension of infiltration channel
 a. Width (20 ft. maximum) — 20' _____
 b. Length = area ÷ width (if greater than 1,200, use multiple channels) — $8,605 \div 20 = 430'$ _____

 4. Divide channel into sections

 1st 50' @ 1% (since upper end of channel needs more slope) — 50' _____

 ½ remaining length @ .4% — $(430' - 50') \div 2 = 190'$ _____

 remaining length @ .2% — 190' _____

B. Infiltration Rate Method
 1. Infiltration rate (Table 2) — .4 in./hr. _____
 2. Rainfall rate (24 hr., 25-yr. storm, 5.5") — $5.5" \div 24$ hr. = .23 in./hr. _____
 3. Runoff receiving capacity (infiltration rate minus rainfall rate) — 0.4 in./hr. - 0.23 in./hr. = 0.17 in./hr. ÷ 12 in./ft. = .014 ft./hr. _____
 4. Infiltration area
 Runoff to infiltration area (from II) ÷ (runoff receiving capacity x desired infiltration time) — $3,270 \div (0.014$ ft./hr. x 24 hr.) = 9,732 sq. ft. _____
 5. Dimensions of infiltration area— gradually sloping or nearly level field area with surrounding berm or dike — 97 ft. x 100 ft. _____

C. Hydraulic Loading Method
 1. Acceptable hydraulic loading (.5 in./wk. or 26 in./yr. in addition to normal precipitation) (consult with Cooperative Extension Service or Soil Conservation Service for acceptable value for local area)
 2. Yearly rainfall — 36 in./yr. _____
 3. Infiltration area—yearly rainfall x lot area — hydraulic loading — 36 in./yr. x 7,140 sq. ft. ÷ 26 in./yr. = 9,886 sq. ft. _____

 4. Dimensions—select dimensions as desired, either channel or broad field area shape

III. Holding Pond
A. Runoff to be stored in holding pond (Consult Soil Conservation Service) — 5.5", 24-hr., 25-yr. storm _____
B. Holding pond volume
 Feedlot areas x Runoff — $7,140 \times (5.5" \div 12"/ft.)$ = 3,270 cu. ft. _____
C. Holding pond dimension (Table 3) (for 4,000 cu. ft.)
 1. Select depth — 6' _____
 2. Select width — 50' _____
 3. Read length (provides 4,000 cu. ft. storage) — 41' _____

Recommendations: Select among the alternatives which have been presented by using cost comparisons and taking operator preference and special site conditions into consideration.