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The Missouri Approach To

Animal Waste Management

Guidelines for Planning and Designing Animal Waste Management Systems in Missouri

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PREFACE

Livestock producers have asked for guidelines on animal waste management that will be feasible and enduring. The Missouri Water Pollution Board has been aware of the need for improvements in methods of handling waste from confined feeding operations and for guidelines for producers.

Chapter 204 of Missouri Statutes, as amended, gives the Water Pollution Board the responsibility and authority to correct and/or prevent "pollution" of "waters of the state." These terms are defined in the law and discussed briefly in the first section.

With these facts in mind, staff engineers of the Water Pollution Board held a series of meetings with staff members of the Extension Division and Department of Agricultural Engineering of the University of Missouri-Columbia to develop guidelines for disposing of waste from confinement feeding operations. This report is a result of their combined efforts.

Others assisting with various phases of development of these guidelines included: School of Engineering, University of Missouri-Columbia; State Department of Health, and the Soil Conservation Service.

Research data and experience in handling livestock wastes have been used to develop the guidelines for planning, design, construction, and management of alternative systems of livestock waste management.

The information and design guidelines herein are intended primarily for the use of personnel in agencies concerned with animal waste management problems.

ACKNOWLEDGMENT

This publication resulted from a request by the Missouri Pollution Board for guidelines on pollution abatement for livestock farms. John Schondelmeyer and James Odendahl, Engineers for the Missouri Water Pollution Board cooperated with the following authors in preparing the publication.

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Missouri Water Pollution Law

In 1957 the Missouri Legislature passed legislation establishing the Water Pollution Board. Its job is to protect the *Waters of the State* from pollution. Waters of state are defined in the state statute as:

*...all rivers, streams, lakes, and other bodies of surface, or subsurface water...not confined and retained completely upon the property of a single individual.**

Programs of the board are administered by an Executive Secretary and his staff. When the Missouri General Assembly passed legislation creating the board, it also *defined water pollution* and adopted *a state water policy.*

What is Water Pollution?

Water Pollution is defined in the law as:

*...the discharge or deposit of sewage, industrial waste or other wastes into the waters of the state in such condition, manner or quantity which causes the waters to be contaminated, unclean, impure, ororous or noxious to such an extent as to be detrimental to public health, to create a public nuisance, to kill or have an unreasonably harmful effect upon fish or other aquatic life, or upon game or other wildlife, or unreasonably detrimental to agriculture, industrial, recreational, or other reasonable uses;**

A useful but non-legal definition is "depositing anything in the water that interferes with its use by others."

State Water Policy

The water policy declares the waters of the state may not be used as a means of disposing of all types of waste:

*...it is declared to be the policy of the state of Missouri to act in the public interest to restore and maintain a reasonable degree of purity in the waters of the state, and to require, where necessary, reasonable treatment of sewage, industrial wastes and other wastes prior to their discharge into the waters of the State.**

The Water Pollution Board, through its Executive Secretary, must initiate programs and establish regulations to carry out this policy.

Composition of the Board

The six-member board is bi-partisan. It is appointed by the Governor subject to approval of the Senate. Membership must include one each from: agriculture, municipal interests, industry, recreation including fish and wildlife, mining, and the public at large. All members of the board serve without compensation except for necessary travel and other expenses incurred in peformance of their duties.

Water Pollution Unlawful

Under present Missouri law it is unlawful for any person to cause pollution as previously defined. Any such act is considered a *public nuisance.*

Nuisance Defined

In its simplest form, a nuisance might be thought of as a use of property which unreasonably interferes with another person's use or enjoyment of his property. This might occur, for example, if a chemical company or a feedlot polluted a stream to the extent that the stream could not be used to water livestock, or to the extent that the stream created undesirable living conditions or a hazard to human health.

It is the responsibility of the board to determine when and where pollution is occurring.

Water Quality Standards for Streams

Water quality standards, have been established for all streams in the state. These vary depending on the type of

*Chapter 204, Missouri Revised Statutes, 1969.

Guidelines for Planning and Designing Animal Waste Management Systems in Missouri

stream and its use.

Included as measures of water quality are pH, dissolved oxygen, temperature, toxic substances, bacteria, taste and odor producing substances, turbidity, color, oil and grease, solids of any kind, radioactive materials, and fluorides. Tolerance for each has been established.

Anyone causing the water quality in a stream to deviate from established standards is considered to be polluting the stream. A copy of the standards adopted by the board for each stream may be obtained upon request to the board.

Basic Concepts in Missouri Approach

Most industrial and municipal waste treatment systems are designed so that there is a single discharge point for effluent into waters of the state. It is required that a professional engineer design these waste treatment systems. A construction permit and an operating permit are required by the Water Pollution Board.

This approach does not fit Missouri agriculture with its thousands of farmer feeders scattered throughout the state. Costs and management associated with municipal-industrial systems with a single discharge point would be unreasonable. The most reasonable alternative for agriculture is to design and manage systems that do not have a planned discharge into water of the state.

The animal waste management approach developed in Missouri includes three basic concepts.

(1) Systems are designed so that there will be no direct discharge into surface or subsurface water as there is in industrial or municipal waste treatment systems.

(2) Systems are designed and managed so that all animal wastes are collected and applied to the land in a controlled manner.

(3) A letter of approval is issued by the Water Pollution Board upon completion of an approved system.

Manure produced from confined feeding operation is a resource that has value if applied to the land. Manure contains nitrogen, phosphorus, potassium and other elements which are needed for crop production. Farmers, unlike most cities or industries, have land which is used for crop production. The objective then is to move the waste from the confined feeding areas to the land at the lowest cost.

Structures and facilities are sized to handle the wastes produced and the maximum runoff 9 years out of 10. The owner has the responsibility, according to the law, that no water pollution will originate from his property. If all the waste is applied to the land in an approved manner, then water pollution does not occur. But any system of waste management designed so there will be no point source of discharge from the property will require attention and proper management from the operator and/or owner.

Another important part of the Missouri approach is the letter of approval issued by the Water Pollution Board. This letter is issued to all individuals who apply and show evidence of having a waste management system that can be managed and operated so that there will be no point source of discharge from their property.

The letter of approval offers incentives to the livestock producer. A record of his waste disposal system is placed on file, indicating that the wastes are being disposed of in an approved manner and are not polluting the water of the state.

How to Obtain Pollution Board Approval

Permits from the Water Pollution Board are required for all waste treatment facilities which have a discharge to waters of the state. Waste facilities that do not discharge to waters of the state are covered by a letter of approval.

Procedures for Approval

Procedures for obtaining a *permit* or *letter of approval* are as follows:

1. Permits

When a discharge is contemplated, two types of permits are required (1) construction and (2) operating. Plans and specifications of proposed facilities must be submitted to the Water Pollution Board along with a completed application for permit. (See attached form W.P.B. 3.33) Such plans should be prepared by a registered professional engineer. Upon a satisfactory review of the plans, a *permit for the construction* of the facilities will be issued. When the facilities are completed, a staff member of the Water Pollution Board will inspect the facilities and if they have been constructed in accordance with the approved plans and specifications, an *operating permit* will be issued.

2. Letter of Approval

To obtain a letter of approval, the plans for the waste management facilities should be submitted to the Water Pollution Board, Box 154, Jefferson City, along with a completed application form (WPB 3.33). The plans will then be reviewed by the Water Pollution Board. Upon a satisfactory review, the applicant will be notified to proceed with construction. When the proposed facilities are completed an inspection may be made by the Board or its representative. If the facilities have been constructed as approved a *letter of approval* for the operation will be issued.

When earthen basins are to be used as part or all of the waste treatment facilities, the Missouri Geological Survey may be contacted by the Water Pollution Board for their comments regarding the geological suitability of the site.

Suggestions for Developing Waste Management System

Following is a list of suggested steps for livestock and poultry feeders to take in developing waste management systems. The agencies to turn to for help at each step also are listed.

What	Who
1. Develop an over-all livestock and/or poultry production facility plan.	Extension and/or SCS.
2. Design the feedlot or confinement feeding waste management system.	Extension and/or SCS.
a. Submit plan to Missouri Water Pollution Board for letter of approval to construct the system. (Anyone may apply for—however, required only for REAP cooperators.)	Plan designer(s).
b. Letter of approval to construct the system sent to the County ASCS Office, to the agency designing the system and to the farmer.	Missouri Water Pollution Board.
c. Provide specifications for individual units or components and give cost estimates to the farmer	Responsibility of plan designer(s).
d. Layout component(s) of system.	Responsibility of plan designer(s).
3. Check construction and submit certification to Missouri Water Pollution Board (SCS has post audit responsibility for REAP in District Counties).	Responsibility of plan designer(s).
4. Issue letter of approval to farmer to operate facility.	Missouri Water Pollution Board.

Flow Charts for Animal Waste Management Systems

Approval

Flow Charts

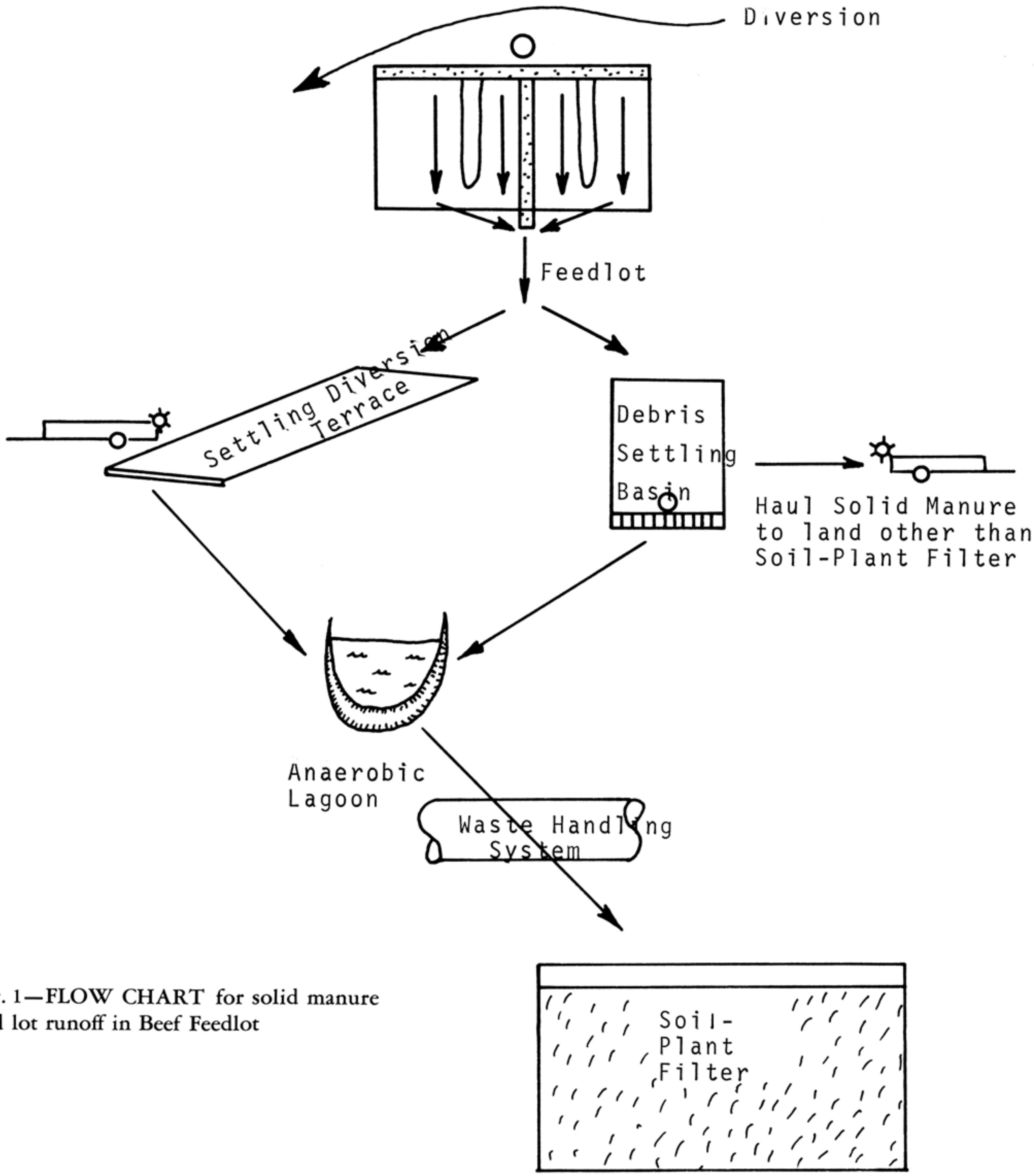


Fig. 1—FLOW CHART for solid manure and lot runoff in Beef Feedlot

Flow charts are a visual representation of the sequence of components in a system. More than one alternative can be shown on one flow chart. Following one complete path will include all the components required for a particular system. The flow charts should include all necessary components required to meet the basic concepts involved in the Missouri approach to animal waste management.

Flow charts associated with livestock facilities having watershed areas will have some common components. The components will be those required to handle manure as a solid or liquid. Additional components will be required to manage the runoff from the watershed area.

Livestock facilities under complete confinement will have the simplest flow charts. These systems will include a method of handling liquid manure, either by spreading directly on land or by lagooning. Many times these two may be combined and gain flexibility when land is not available for spreading.

The following flow charts fit situations having— 1. watershed areas; 2. confinement; 3. dairy facilities. They are not intended to be all inclusive and may be modified within the limits of the basic concepts of one system planning. Other methods not included in these flow charts or manual may be used when conditions justify and water standards can be met.

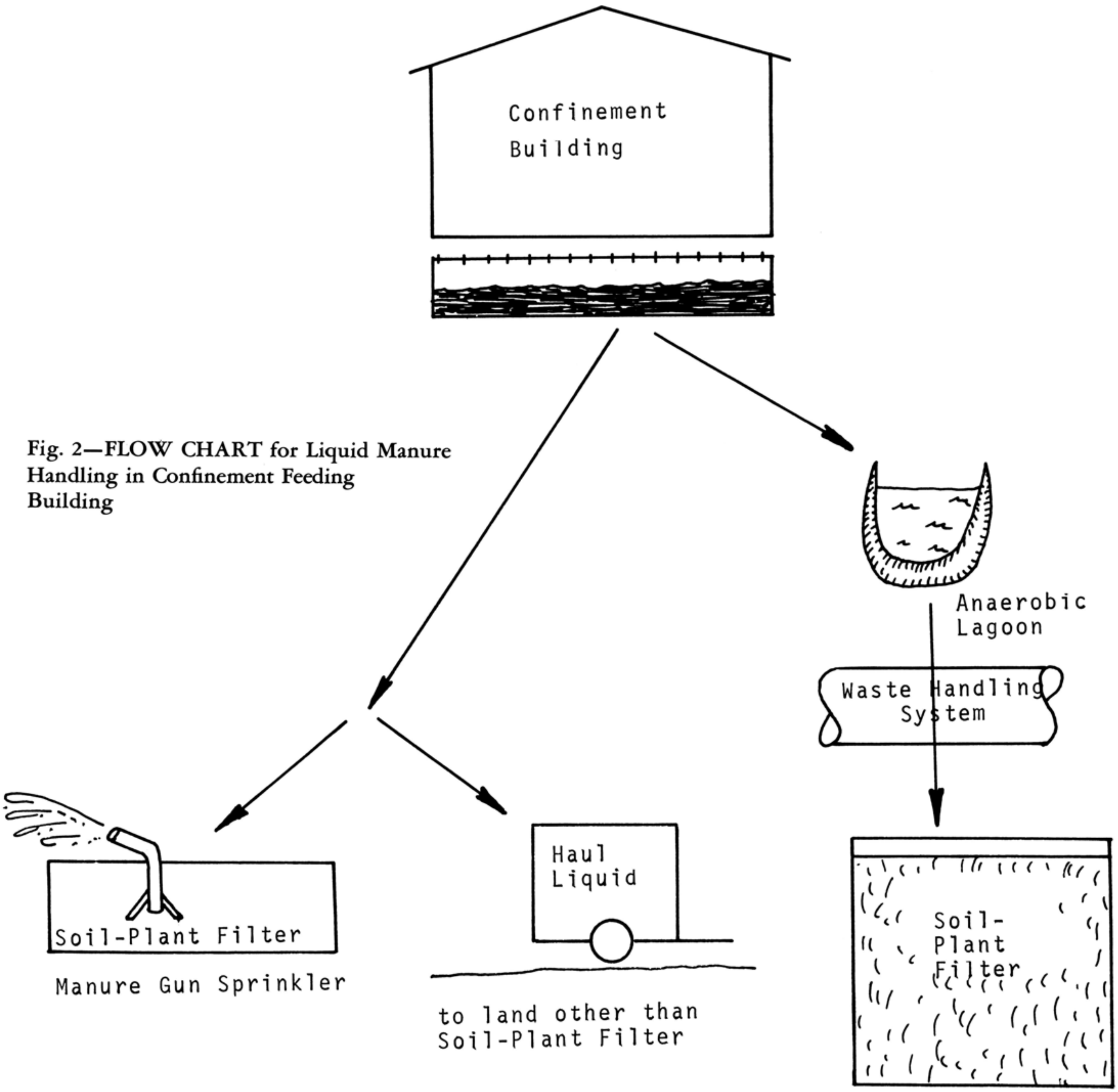


Fig. 2—FLOW CHART for Liquid Manure Handling in Confinement Feeding Building

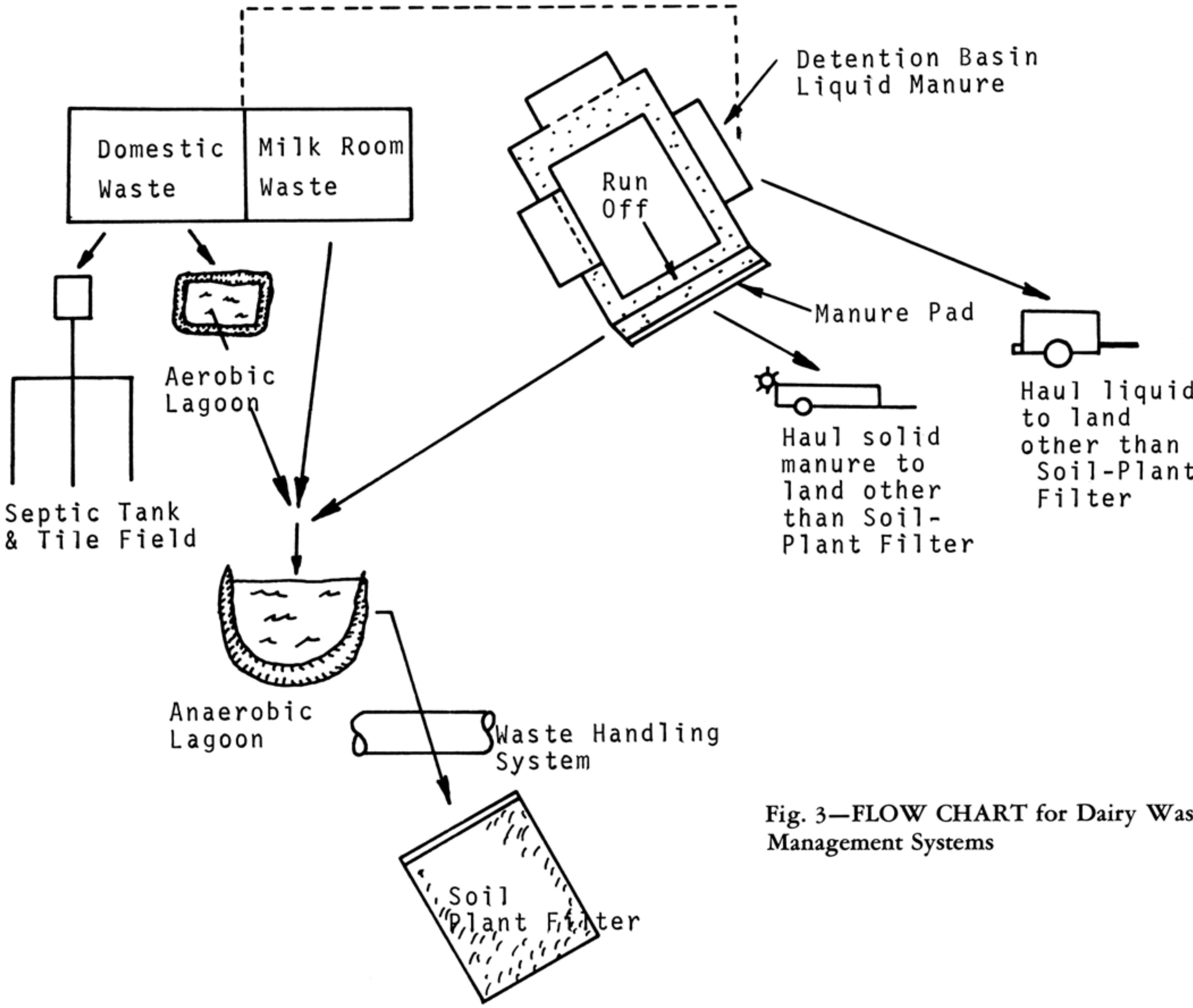


Fig. 3—FLOW CHART for Dairy Waste Management Systems

Components

Settling Basins

Design Considerations

Settling basins are designed to intercept runoff from a feed lot, dairy or other watershed containing livestock. They should be designed in such a manner as to intercept the total runoff, allow some part of the solids to settle, and allow the liquids to be drained into a storage-lagoon system. The system should be managed and designed so that the solids can be removed with conventional front-mounted manure loading equipment at a convenient time during each year. The depth of accumulated solids should be kept less than 1.5 feet.

Design Procedure

Differences in topography will dictate at least two approaches for settling basin design.

a. Settling Diversion Terrace

A settling diversion terrace is a diversion designed to collect some part of the material suspended in the runoff and allow the liquids to drain off. The settling diversion terrace should be designed with a grade of 0.3 percent or greater. The maximum average channel velocity should not exceed 2.5 feet per second. A 0.5 foot free-

Table 1

Peak Rates of Run-off for Settling Diversion Terrace Design

	Percent Slope in Feedlot		
	0-4	4-8	Greater than 8
Peak Rate Runoff cfs/acre	5.0	6.0	7.0

TABLE 2

HEIGHTS (H)* OF DIVERSION RIDGE WITH SPARSE VEGETATION IN CHANNEL

Q, cfs	Bottom Width (B)** feet 6					8					10					Q, cfs
	Velocity	Grade, percent 0.2	0.4	0.6	0.8	Velocity	0.2	0.4	0.6	0.8	Velocity	0.2	0.4	0.6	0.8	
5	1.0	1.3	1.1	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	5
10		1.5	1.3	1.1	1.1		1.3	1.2	1.1	1.0		1.3	1.1	1.0	1.0	10
15	1.5	1.7	1.4	1.3		1.5	1.5	1.3	1.2	1.0		1.4	1.2	1.1	1.0	15
20		1.8	1.5	1.4			1.6	1.4	1.3		1.5	1.5	1.3	1.2		20
25		1.9	1.6				1.7	1.5				1.6	1.4			25
30	2.0	2.0	1.6			2.0	1.8	1.6				1.7	1.5			30
35		2.1					1.9				2.0	1.8				35
40		2.2					2.0					1.9				40
45		2.3					2.1					2.0				45
50	2.5	2.3				2.5	2.2					2.1				50
60											2.5	2.2				60
70																70
80																80
90																90
100																100
120																120
140																140

Q, cfs	Bottom Width (B)** feet 12					16					20					Q, cfs
	Velocity	Grade, percent 0.2	0.4	0.6	0.8	Velocity	0.2	0.4	0.6	0.8	Velocity	0.2	0.4	0.6	0.8	
5	1.0	1.1	1.0	1.0	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0	5
10		1.3	1.1	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	10
15		1.4	1.2	1.0	1.0		1.3	1.1	1.0	1.0		1.2	1.1	1.0	1.0	15
20		1.5	1.3	1.1			1.4	1.2	1.1	1.0		1.3	1.1	1.0	1.0	20
25	1.5	1.6	1.4	1.2		1.5	1.5	1.3	1.1			1.4	1.2	1.1	1.0	25
30		1.7	1.5				1.6	1.3			1.5	1.4	1.3	1.1	1.0	30
35		1.7	1.5				1.6	1.4				1.5	1.3	1.2		35
40	2.0	1.8					1.7	1.4				1.6	1.4			40
45		1.9				2.0	1.7					1.7	1.4			45
50		2.0					1.8				2.0	1.7	1.5			50
60	2.5	2.1					1.9					1.8				60
70						2.5	2.0					1.9				70
80											2.5	1.9				80
90																90
100																100
120																120
140																140
160																160

* Height, feet, required to carry flow with long grass in channel ("D" retardance), including 0.3-foot freeboard measured from the bottom of channel to a point 2 feet off the peak of the ridge. One foot is considered minimum height.

** Bottom width required to give desired velocity with sparse vegetation in channel ("E" retardance).

◯ Velocity, in feet per second, to be expected in channel with short, sparse vegetation ("E" retardance).

Name ____________________________

WORK SHEET-1

DESIGN PROCEDURE FOR SETTLING BASINS

1. Settling Diversion Terrace

Design based on ________acres of feedlot, ________head. Slope of lot________%, and________% of solids expected to be retained in lot and settling diversion terrace. Length of terrace ________ft.

A. Calculations:

1. Calculate solids volume:

   850 $ft.^3/A$ X ________A. = ____________$ft.^3$ solids.

2. Minimum bottom width "b" to store solids 6" deep:

   $$\text{Min. "b"} = \frac{2 \text{ X solids volume}}{\text{length of terrace}} = \frac{2 \text{ X }\_\_\_\_\_\_\_\_}{\quad} = \_\_\_\_\_\_\_\_ \text{ft.}$$

3. From Table 1, determine peak rate of runoff/A :

   Total peak rate runoff, Q, = cfs/A X A.

   ______cfs/A X ______ A = ______ cfs. (Q)

4. Use Table 2, using Q above, select maximum grade, using velocities 2.5 FPS or less, and bottom width greater than that calculated in (2) above. Reconcile these data with economics of construction as determined by slope of land.

   Terrace cross section:

   H__________ + 1 ft. (freeboard + solids) = ________ft.

   Grade = ________%

   b = __________ft.

Name	Address	Position

Signed: ____

____

____

Name ______________________

WORK SHEET-2

DESIGN PROCEDURE FOR SETTLING BASINS

2. DEBRIS SETTLING BASINS:

Design based on _____acres feedlot, or acres per basin:

(A) _____________ (B) _____________ (C) _____________

(D) _____________ (E) _____________ (F) _____________

A. Calculate:

1. From Table 3, select a discharge rate so that the discharge period for design storm is between 3 and 40 hours. From Table 3 use this discharge rate to determine detention storage requirement.

2. Size discharge pipe or weir from Head Loss vs. GPM (CFS) tables and adjust basin volume to fit closest pipe size.

3. Calculate basin area--assume 3 ft. depth. (Minimum area is 1700 sq. ft./a feedlot.)

4. Determine volume of solids storage:

   850 $ft.^3$/A X ______acres = ______$ft.^3$ solids.

NOTE: Economics of construction will usually dictate selecting higher discharge rates and smaller detention basin volumes.

	Detention Storage $ft.^3$				Discharge		
Basin	Liquid	Solids	Total	Area	Rate .	Dia.	Head
A							
B							
C							
D							
E							
F							

Name   Address   Position

Signed: ____

____

____

board should be added. Provide 850 cubic feet of storage for solids for each acre of feedlot area in addition to the cross section area required for peak runoff flow.

The percent of total solids remaining in the lot area or in the settling basin will depend on the slope in the lot and in settling basin areas and the intensity of a particular storm. On relatively flat slopes, 75 percent of solids will be collected in the lot and diversion terrace.

b. Feedlot Debris Settling Basins

Debris settling basins are used where maximum velocities for the settling diversion terrace will be exceeded. Runoff will be impounded in a settling basin created by a dam across the channel of a diversion. A Pipe or weir drain will remove the liquids at a certain controlled rate to allow solids to be settled. The grade in the basin channel should be a minimum of 0.3 percent. The basin shall have capacity to store a 10-year runoff plus accumulated solids, and have a 0.5 foot freeboard.

Provide the required cubic feet of storage per acre of runoff from Table 3, plus 850 cubic feet of solids storage per acre of feedlot area. Maximum depth of solids should not exceed 1.5 feet. A screened, ungated outlet pipe or weir should discharge the storm runoff into a storage-lagoon within a 3 to 40 hour period.

In a debris settling basin, 85 percent of the solids can be assumed to be retained in the lots and the basin. (This is expected regardless of the slope of the lot.)

TABLE 3

Detention Storage Required Per Acre of Feedlot For Given Discharge Rates

Discharge Rate			Detention Storage
CFS/A.[1]	GPM/A.[2]	Hours to Discharge Water From 10-Year Peak Storm	Requirement Cubic Feet/Acre Feedlot. Liquids[3]
0.1	45	40.0	10,500
0.2	90	15.0	8,000
0.3	135	9.0	7,000
0.4	180	6.5	6,200
0.5	225	4.3	5,800
0.6	270	3.2	5,400

(1) $\text{CFS/A} = \frac{\text{Volume (ft.}^3\text{/Acre)}}{\text{Hours x 3600}}$

(2) $\text{GPM/A} = \frac{\text{Volume (ft.}^3\text{/Acre) x .125}}{\text{Hours x 60}}$

(3) Add solids storage at 850 cubic feet/acre feedlot

Detention Basin

Detention basins are a storage device. They may be constructed of concrete or be earthen basins. No treatment of contents is intended.

Detention basins should be sized to hold a minimum of two months production of waste in south Missouri and three months in north Missouri. They will normally be associated with liquid manure handling systems.

It should be noted that one of the major objections to the use of liquid systems is odors created when the waste is spread on land. If odors are a concern, provision should be made in the management of the system to minimize this nuisance.

SIZING MANURE PITS AND DETENTION BASINS

Table 4 provides guidelines that may be used to estimate manure production from different animals. The amount of manure produced is proportional to the live weight of the animals.

TABLE 4

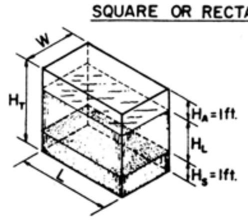
APPROXIMATE DAILY MANURE PRODUCTION

Animal	Cu. Ft./Day Solids & Liquids	Percent Water	Gallons/Day
1000 lb. cow	1 1/2	80-90	11
1000 lb. steer	1	80-90	7 1/2
1000 lb. horse	3/4	65	5 1/2
10 head of hogs			
50 lbs.	2/3	75	5
100 lbs.	1 1/2	75	10
150 lbs.	2 1/4	75	17
200 lbs.	2 3/4	75	20 1/2
250 lbs.	3 1/2	75	26
400 lb. sow	.53		4.0
10 head of sheep	1/2	70	4
1000 5-lb. layers	3	55-75	22 1/2

There are about 34 cu. ft. in a ton of manure.
Storage capacity = number of animals x daily manure production x desired storage time (days) + extra water (including surface runoff, waste from drinking water, and wash water).

FORMULAS FOR DETERMINING VOLUMES OF STRUCTURES FOR LIQUID MANURE STORAGE

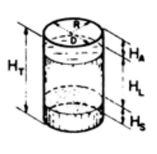
SQUARE OR RECTANGULAR STRUCTURE



W = INSIDE WIDTH IN FEET
L = INSIDE LENGTH IN FEET
H_T = TOTAL INSIDE HEIGHT OF TANK IN FEET
H_A = HEIGHT ALLOWED FOR AIR SPACE
H_L = LIQUID STORAGE DEPTH IN FEET
H_S = HEIGHT ALLOWED FOR LIQUID AND SOLID AT TANK BOTTOM
1 CUBIC FOOT = 7.5 GALLONS

STORAGE CAPACITY OR VOLUME (IN CUBIC FEET) = $W \times L \times H_L$
STORAGE CAPACITY OR VOLUME (IN GALLONS) = $W \times L \times H_L \times 7.5$

ROUND STRUCTURE



$V = \pi R^2 \times H_L$ OR $V = \frac{1}{4} \pi D^2 \times H_L$
R = RADIUS (INSIDE) = ½ D
D = DIAMETER (INSIDE) = 2R
$\pi = 3.1416$

STORAGE CAPACITY OR VOLUME (IN CUBIC FEET) = $3.1416 \times R^2 \times H_L$
STORAGE CAPACITY OR VOLUME (IN CUBIC FEET) = $\frac{1}{4} \times 3.1416 \times D^2 \times H_L$
STORAGE CAPACITY OR VOLUME (IN GALLONS) = $0.7854 \times D^2 \times H_L \times 7.5$
FOR TOTAL INSIDE HEIGHT OF TANK IN FEET = H_T
$H_T = H_A + H_L + H_S$ OR $H_T = 2 \text{ FEET} + H_L$

Earthen Detention Basins

Some existing feedlots are located too close to a stream to allow room for gravity operation into a lagoon system. The alternative solutions might be to either move the feedlot or to construct holding ponds or detention basins within or adjacent to the feedlot and pump from the basin to a lagoon. The following guides may be used in determining the size of the basin and the pumping rate required to empty the basin.

Provide 15,000 cubic feet of storage per acre of feedlot. A pumping rate of 125 gpm per acre of feedlot will empty the basin in 10 hours. This should hold the peak runoff from a storm of maximum severity that occurs once in 10 years. The basin should be pumped into a lagoon within one to three days after the rain. The selection of a pump for this application will depend upon the total head against which it must operate. For low heads, a propeller or centrifugal pump will be adequate. For higher heads, a turbine pump may be required.

TABLE 5 - [1]LIQUID MANURE STORAGE REQUIREMENTS

TOTAL STORAGE REQUIREMENTS FOR VARIOUS NUMBER OF ANIMAL UNITS AND STORAGE PERIODS

TOTAL NO. ANIMAL UNITS	PER DAY		120 DAYS		150 DAYS		180 DAYS	
	CU. FT.	[2]GAL.	CU. FT.	[2]GAL.	CU. FT.	[2]GAL.	CU. FT.	[2]GAL.
100	200	1500	24000	180000	30000	225000	36000	270000
80	160	1200	19200	144000	24000	180000	28800	216000
70	140	1050	16800	126000	21000	157500	25200	189000
60	120	900	14400	108000	18000	135000	21600	162000
50	100	750	12000	90000	15000	112500	18000	135000
40	80	600	9600	72000	12000	90000	14400	108000
30	60	450	7200	54000	9000	67500	10800	81000

[1] BASED ON 2 CUBIC FEET PER COW AND / OR ANIMAL UNIT PER DAY (WHERE 1 COW AND / OR 2 HEIFERS = 1 ANIMAL UNIT)

[2] 1 CUBIC FOOT = 7.48 SAY 7.5 GALLONS

TABLE 6

SIZE OF TANKS FOR VARIOUS STORAGE CAPACITIES AND DEPTHS FOR LIQUID MANURE STORAGE

STORAGE CAPACITY		SHAPE OF STORAGE STRUCTURE & LIQUID STORAGE DEPTH							
		LIQUID STORAGE DEPTH (H_L) = 10 FEET TOTAL TANK DEPTH INSIDE (H_T) = 12 FEET				LIQUID STORAGE DEPTH (H_L) = 12 FEET TOTAL TANK DEPTH INSIDE (H_T) = 14 FEET			
		SQUARE	RECTANGULAR		ROUND	SQUARE	RECTANGULAR		ROUND
CUBIC FEET	GALLONS	W = L	W = 10 FT. L (FEET)	W = 20 FT. L (FEET)	D = DIAMETER	W = L	W = 10 FT. L (FEET)	W = 20 FT. L (FEET)	D = DIAMETER
20000	150000	45'-0"	200	100	50'-6"	41'-0"	166'-6"	83'-6"	46'-0"
18000	135000	42'-6	180	90	48'-0"	38'-6"	150'-0"	75'-0"	44'-0"
16000	120000	40'-0"	160	80	45'-0"	36'-6"	133'-6"	66'-6"	41'-6"
14000	105000	37'-6"	140	70	42'-0"	34'-0"	116'-6"	58'-6"	38'-6"
12000	90000	34'-6"	120	60	39'-0"	31"-6"	100'-0"	50'-0"	35'-6"
10000	75000	31'-6"	100	50	36'-0"	29'-0"	83'-6"	41'-6"	32'-6"
8000	60000	28'-6"	80	40	32'-0"	26'-0"	66'-6"	33'-0"	29'-0"
6000	45000	24'-6"	60	30	27'-6"	22'-6"	50'-0"	25'-0"	25'-6"
4000	30000	20'-0"	40	20	22'-6"	18'-6"	33'-6"	16'-6"	20'-6"

Name ______________________________

WORK SHEET-3

Design Procedure for Detention Basins

1. Concrete Liquid Manure Tanks.

   A. Calculations:

      1. Size: Use table for approximate manure production or Table 4 to determine volume required for 60 days storage in south Missouri and 90 days storage in north Missouri.

      2. Dimensions selected from Table 5 or 6, with following restrictions:
         a. Maximum length of one compartment should be 50 feet, with agitator and removal opening in center. Use 10,000 cu.ft. per opening for each compartment.

Tank	No. Animals	Capacity (ft.^{3})	Dimensions
A.			
B.			
C.			
D.			

	Name	Address	Position
Signed			

Lagoon Systems

The Components included are:

1. **Anaerobic Storage Lagoons**
2. **Mechanically-Aerated Systems**
   a. **Floating aerators**
   b. **Oxidation ditches**
   c. **Other aeration methods**

The use of an anerobic storage lagoon offers a great deal of flexibility to the animal waste management system. The lagoon is sized to collect and store all the expected runoff and waste from a given animal production area for a given time. At a planned time the runoff "storage-volume" of effluent will be distributed on a land area (soil-plant filter) during acceptable weather conditions. A fixed remaining volume will always be in the lagoon and should equal the design volume requirements for the system.

Aerobic lagoons and mechanically aerated systems will offer advantages in controlling odors.

One important point in regard to any of these lagoon systems is that the effluent from them will not meet the water quality standards now in existence in Missouri. Lagoon effluent generally will not meet the BOD, phosphate, or bacterial levels of most stream standards, therefore requiring distribution of the effluent onto land.

1. ANAEROBIC STORAGE LAGOONS

The function on an anerobic-storage lagoon is to collect, store, and liquify manure so that it can be conveyed hydraulically to land at some convenient time.

Advantages of this method of treating manure are its low cost and very high loading rates per volume of lagoon. Disadvantages are that ODORS must be expected, and the effluent must not be discharged into a stream.

Many anaerobic lagoons are operating successfully in Missouri and with a minimum of odors. *Success* depends on correct design and proper management.

Anaerobic Decomposition

Anaerobic decomposition, a complex series of biochemical reactions, is caused by a mixed culture of bacteria. Anaerobic and facultative bacteria, found in animal excreta, will multiply rapidly and turn organic solids to liquid and gas under proper environmental conditions. The process is best described in two steps: (1) the liquefication or acid-forming phase and (2) the gasification or acid-recovery phase.

Acid-Forming Phase

The acid-forming phase involves liquefying of insoluble substances by the hydrolytic enzymes, followed by further metabolism of these materials. Celluloses, hemicelluloses, pectins, lipids, and proteins are partly decomposed by enzyme activity. The hydrogen acceptors for the initial breakdown of complex organics are nitrate and sulfate ions, as well as oxygen combined in organic compounds. Typical reactions during this phase convert organic matter, sulfide, ammonia, and carbon dioxide. The organic intermediates include various nexoses, glucose, mannose, and fructose from the cellulose and hemicelluloses. These hexoses may be further degraded to short-chain organic acids, alcohols, ketones, and aldehydes. Major products resulting from lipid degradation are fatty acids and glycerol. Proteins are successively hydrolyzed into peptides, amino acids, and, finally, to ammonia.

This first step converts most of the insoluble organic wastes to soluble organic intermediates, which include organic acids. If sufficient acid is produced to depress the pH below 6.5, further digestion will be inhibited. Therefore, the acid-forming phase must be accompanied by the acid-recovery phase for digestion to proceed.

Acid-Recovery Phase

In the second step of digestion, methane bacteria convert the short-chain acids and alcohols to methane and carbon dioxide. Thus, methane bacteria are responsible for preventing a build-up of acids. Since methane bacteria are more environment-sensitive than are the acid-forming bacteria, lagoon design and operational parameters should be based on meeting the environment needs of methane bacteria. Methane bacteria are strict anaerobes, are generally non-motile, have low rates of reproduction as compared with the liquefying bacteria, are more sensitive to pH and temperature, and require carbon dioxide for the reduction of volatile acids to methane.

Although liquification with the production of carbon dioxide and organic acids must precede gasification, digestion will stop if the methane bacteria are inhibited by an accumulation of volatile acids, which gives rise to a lowered pH. This produces a sour, septic odor that usually is more offensive than the odor from either the raw or the properly treated waste. Thus, populations of both groups of bacteria must be maintained in balance. Fortunately, optimum conditions for the gasifying bacteria are also satisfactory for the liquifying bacteria.

Anaerobic Lagoon Application

Anaerobic lagooning appeals to some livestock producers, either as a low-cost treatment or as an inexpensive means for temporary, large volume storage of liquid manure. Field-spreading of decomposed wastes from the lagoon may be completed at a later more convenient date.

The basic attraction to the engineer is the ability of the anaerobic process to decompose more organic matter per unit volume than its aerobic counterpart. For this reason alone, the anaerobic processes deserve consideration for the stabilization of strong organic wastes. Depending upon the nature of the waste constituents, organic solids may be reduced from 40 to 100 percent. Carbohydrates are completely converted to methane, carbon dioxide, and water, and certain more resistant materials are reduced 50 percent or less.

Anaerobic lagooning has frequently been adopted as the first or only step in the biological treatment of swine wastes. The high volumetric organic removal rate of the anaerobic process, however, makes it particularly suitable as the first step in a combined anaerobic-aerobic system. Combined systems offer a high degree of treatment more economically than the exclusive use of an aerobic system.

Secondary treatment may also be desired when treated wastewater is to be recirculated to flush raw wastes from swine buildings. Less odor will be introduced into the buildings with aerobically-treated wastewater than with anaerobic lagoon effluent.

Decomposition of organic solids within a lagoon can improve the properties of the liquid manure for application with irrigation equipment if the two-step process is completed to avoid highly offensive odors. Since most of the plant nutrients released from the decomposed wastes are retained in the lagoon, the nutrients can be salvaged at the most convenient and appropriate times for application on cropland if adequate storage volume is provided.

Some Environmental Requirements for Anaerobic Digestion

Temperature:

Anaerobic lagoons are sensitive to temperature changes. Ideally, digester temperatures should be approximately 95°F. and they should be operated the same as municipal heated digesters. A stable temperature is important in maintaining a proper balance between acid forming bacteria and the more delicate methane forming bacteria.

An anaerobic lagoon operates most efficiently and produces minimum odors when these bacterial cultures are in balance.

Sudden temperature changes and "shock loading" upsets the bacterial balance and results in an increase in acid formers, a possible lowering of pH, and increase in offensive odors.

pH:

The desirable combination of bacteria is obtained when, among other conditions, the pH of the lagoon is 6.8-7.4. A pH reading can be made by most extension offices in a soil testing laboratory.

Toxic Materials:

Some ingredients contained in feed, such as copper and antibiotics, may inhibit bacterial action.

Lagoon Design

Size: Loading Rates Vs. Volume

Design of anaerobic lagoons is based on dilution of the manure, diluting a given amount of volatile solids with a given amount of water. Animal waste contains a high percent of volatile solids. Volatile solids are the part of manure that is considered biodegradable and, therefore, a useful parameter for design.

Recommendations from research suggests loading rates of 5 pounds of volatile solids per 100 cubic feet of water for colder climates to 15 pounds of volatile solids per 1000 cubic feet for warmer climates.

Basic recommendations for sizing anaerobic lagoons in central Missouri is 7.5 pounds of volatile solids per 1000 cubic feet of lagoon volume. Proper management of the system is assumed and loading is to be continuous over a 24-hour period. Continuous loading is assumed if the lagoon is loaded at least one time daily. Otherwise, it is intermittent. See footnote (1) of Table 7.

Depth of Lagoon:

Anaerobic lagoons are sized by volume. Maximum depths should be between 8 and 14 feet.

Deeper lagoons offer these advantages.

1. Smaller surface areas provide a more favorable and stable environment for methane bacteria.
2. Encourage more thorough mixing of lagoon contents by rising gas bubbles.
3. Minimize escape of odors.
4. Require less land.
5. Efficient use for mechanical aeration.

Pervious soils should be sealed or lined with plastic. Seepage is not desirable and will result in ground water pollution.

Lagoon Inlets

The inlet should be located near the center or at several locations so the solids will be distributed over the lagoon and not allowed to accumulate near the edge. Both above-surface and below-surface inlets have been used.

TABLE 7

ANAEROBIC LAGOON DESIGN DATA

100% Manure load--continuously loaded.[1]

Livestock	North Missouri	Central Missouri	South Missouri
	Cubic Feet Lagoon Volume Per Lbs. Average Weight Of Animal.[2]		
Beef Cattle, Swine, Dairy[4], Sows[3]	1.5	1.25	1.0
Poultry	3.75	3.0	2.4

[1]Continuous loading is assumed if lagoon is regularly loaded at least one time each 24 hours. A regular loading schedule of 1 time each 6 days or longer is considered intermittent loading. For intermittent loading, multiply continuous loading values above by 1.6. For loading frequencies between 1 time per day and 1 time each 6 days, add 10 percent of the continuous loading rate per day to the continuous loading value for a maximum of 6 days.

[2]Assumes 100% of manure loaded into lagoon. Reduce lagoon volume in direct proportion to percent reduction in total manure loaded into lagoon.

[3]A sow lagoon may be designed as a facultative-aerobic lagoon system that operates as an aerobic lagoon with no odors. Design should always have greater than 200 sq. ft. of surface area per sow and not less than 4.5 ft. average depth. Volume of lagoon in cubic feet per sow: north Missouri-1400, central Missouri-1100, and south Missouri-900.

[4]See also Table 8 for additional data on Dairy.

TABLE 8

Dairy Lagoon Design
(Continuous Loading[1])

	Cubic Feet Lagoon Volume per Cow		
For:	North Missouri	Central Missouri	South Missouri
Manure	2100	1750	1400
Milk Room + Milk Parlor	300	250	200
Lot Runoff	525	440	350
Holding Pens	600	500	400

NOTE: Design data for aerobic lagoons for domestic waste (example, needed when adding toilet): 660 cu. ft. per person at 3-5 ft. depth.

Continuous loading is assumed if lagoon is regularly loaded at least one time each 24 hours. A regular loading schedule of 1 time each 6 days or longer is considered intermittent loading. For intermittent loading, multiply continuous loading values given in the table by 1.6. For loading frequencies between 1 time per day and 1 time each 6 days, add 10% of the continuous loading rate per day to the continuous loading value for a maximum of 6 days.

Above-surface inlets must be provided with a tight stopper or valve at the building to prevent liquids from freezing and the pipe from clogging. During winter, always collect a quantity in a gutter or collection pit and then empty instead of having a constant overflow which could freeze.

Below-surface inlets require water pressure to work well. They seem to discharge the manure more evenly when there is ice cover. The inlet line can plug near the water level within the pipe where the wastes contain large amounts of solids. Provide access to the submerged inlet line so it may be rodded and cleaned.

Use of manure ramps or loading a lagoon by pushing the manure directly into the edge will result in large deposits of manure at the loading point. Bacterial activity and resulting gas bubbles will eventually distribute manure into the lagoon.

Discharge From Lagoon

Overflow from anaerobic lagoons is not permitted to enter the natural water courses of the state. When the lagoon is full, some of its contents must be applied to a soil plant filter area to prevent overflow when new wastes are added.

Lagoon Shape and Construction

A circular lagoon will best facilitate mixing. Rectangular lagoons may be used, provided they have a length to width ratio of 3 to 1 or less. Avoid narrow appendages isolated from the main body of water; they contribute little water volume and may be a source of nuisance conditions. Earthen dikes and banks should be sloped to 3:1 or less to facilitate easier establishment of vegetative cover and safer mowing of vegetation.

Dikes, diversion ditches, and surface grading should be used to prevent unwanted surface runoff from entering the lagoon. Some runoff may be beneficial to fill the lagoon initially and to maintain the desired water volume, but uncontrolled entrance of surface runoff will reduce waste detention time in the lagoon and cause unnecessary effluent discharge.

All lagoons should be fenced to exclude children and domestic animals. The fence should be located so that it will not interfere with mowing, dike maintenance, or sludge removal equipment.

Major Limitations of Anaerobic Lagoons:

Occasional release of objectionable odors is the greatest deterrent to the widespread adoption of anaerobic lagoons. A lagoon will freeze over during a portion of the year, odor production is more objectionable during several weeks after ice melts than later in the year when the water temperature is higher. Also, odorous gases become more concentrated and are more easily detected when conditions of high humidity, temperature inversion, and low wind velocity retard normal gas dispersion.

The necessity of maintaining an adequate volume of dilution water in the lagoon and of minimizing ground-water pollution means that the lagoon location must be restricted to fairly impervious soils, through which seepage losses will be negligible, or the pervious soils must be sealed or lined with plastic.

What it Takes to Make Lagoons Work:

1. Anaerobic lagoons must be properly designed and constructed.
2. Good management practices must be used for most efficient operation.

Management of Anaerobic Lagoon Systems:

Fill a new lagoon with surface runoff, roof runoff or water from a well. After a lagoon is filled, divert runoff. Add water any time lagoon is below a design level.

Start a lagoon at the beginning of warm weather. Take samples from lagoon and measure pH frequently. If pH is below 6.7 add hydrated lime or caustic soda (lye) one pound per 1000 square feet daily until pH is neutral (pH = 7.0).

Load lagoon continuously. This means manure is put into lagoon at least one time per 24 hours. "Slug loading" or large amounts of manure at long intervals will cause rapid increase in volatile acids and lowering of pH. Methane bacteria are sensitive to pH below 6.7 and die. The lagoon then will not function efficiently and will produce excessive odors.

If slug loading is unavoidable, design for this condition and add required quantities of hydrated lime or caustic soda with manure to eliminate changes in pH.

Do not exceed designed loading rates.

Experience has shown that lagoons about two years old will establish an equilibrium and operate in a consistent manner. Odors are normally more prevalent during a period of time during warm-up in the spring. These odors can be minimized by checking pH and adding lime during this period.

A normal pH of 6.7-7.2 can exist and the lagoon have excessive volatile acids concentration and resulting odors.

Rainfall plus animal waste accumulation will exceed evaporation, even on confinement hog lagoon systems, in a normal year. The lagoon therefore will have to be pumped each normal year. However, in excessively dry years, evaporation can exceed the accumulating volume and pumping may not be required unless extra water were to be added. A reason for annual pumping is to maintain a diluted state of chemicals (N,P,K) and toxic materials to a desirable minimum level.

Always keep not less than 12 inches of freeboard on each lagoon. For large feedlots, more freeboard is required. Multiply acres in feedlot times 3 inches to determine freeboard needed. For example, a 5 acre feedlot times 3 inches equals 15 inches of freeboard. Pump within 20 days if water reaches that height.

2. MECHANICALLY AERATED SYSTEMS

Floating Aerators for Odor Control

The floating aerator is an electric water pump that floats on the surface of a lagoon. Liquid intake is about 24 inches below the surface. The liquid is sprayed upward and outward above the surface of the lagoon, thereby mixing air with it. Oxygen is added to the liquid at the approximate rate of 3.2 pounds oxygen per hour, per horsepower of the aerator.

Purdue University has run numerous tests on aerators to see how effective they are in controlling anaerobic lagoon odors. These tests indicate that anaerobic lagoons that previously had a serious odor problem are converted to lagoons that are mostly aerobic with little odor by the installation and operation of a proper sized aerator.

The following formula gives the size aerator for a hog lagoon.

$$\text{Horsepower of Aerator} = \frac{\text{Total lbs. animal wt. x lbs. } BOD_5 \text{ x C}}{\text{24 hrs./day x 3.2 lbs. oxygen/hp.}}$$

TABLE 9 - C VALUES FOR AERATOR HORSEPOWER

Design Condition	Values for C.
1. Acceptable odor control	1.0
2. Good odor control + aerobic digestion.	1.5
3. Complete Aerobic treatment	2.0

TABLE 10 - BOD_5 VALUES FOR AERATOR HORSEPOWER

Livestock Unit	Wt./Unit	BOD_5--lbs./unit
Boar	350	.40
Gestating sow	275	.40
Sow + litter	375	.75
Nursery pig	35	.07
Growing pig	65	.13
Finish pig	150	.30

Mechanically Aerated System Oxidation Ditch

The Midwest Plan Publication AED-14 "Oxidation Ditch for Treating Hog Wastes" is included as a part of this report. The design concepts may be applied to cattle waste and other wastes by using appropriate BOD values. The management requirements are similar for all waste products.

OXIDATION DITCH FOR TREATING HOG WASTES
AED-14

Oxidation ditches are a low-odor refinement to liquid waste storage and disposal. They can greatly reduce offensive odors in a building with stored liquid wastes and during field disposal of those wastes.

The oxidation ditch is a continuous open channel which holds the liquid waste (Fig. 1). An aeration rotor churns the liquid wastes, mixing in air which supplies the necessary oxygen for the aerobic bacteria. The action of the rotor also keeps the wastes circulating so that the solids are kept in suspension. The rotor is normally operated continuously.

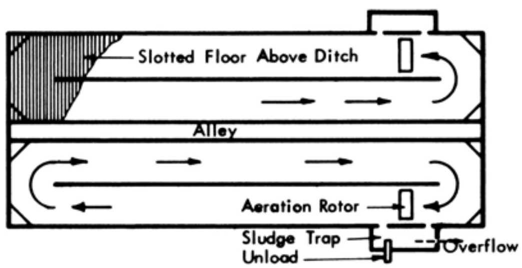


Figure 4. Schematic diagram of typical oxidation ditch installation.

Aerobic bacteria use the organic matter in the wastes as food, reducing the biologically degradable organic matter to stable minerals, with carbon dioxide and water as byproducts. In time, nondegradable organic solids and salts may build up in the ditch to the point where they will interfere with the biological process. Solids can be diluted by emptying part of the ditch and refilling with water, or the solids can be settled out in a settling tank and disposed of separately. The overflow from the ditch may flow into a lagoon or be spread on crop land; it is not treated adequately for discharge into a natural watercourse.

Advantages include:

- Objectionable odors will be reduced in the building and during transport and field spreading.
- Total waste volume to be hauled will be reduced through digestion and through evaporation in the building and from the surface of the lagoon.
- Rodent and insect pests will not infest the liquid.
- Minimum continuous winter ventilation rates may be reduced below those commonly recommended for odor control.
- Regular operation and maintenance of the ditch and equipment are fairly simple.

Disadvantages include:

- Cost of facilities and operation are higher than some other disposal systems.
- Extra attention is required after even a relatively short (1 day) period with the rotor not working (power or equipment failure or equipment maintenance).
- Foaming problems may be severe if there is a system failure or the building is overloaded with more animals than the system can service.
- Few buildings can be adapted to the system without major construction.

DESIGN

Shape

The most common shape of an oxidation ditch is a racetrack as shown. Other shapes could be used if a continuous loop is maintained and the curvature at the end of the ditch is not too sharp. Where sharp corners exist, install deflectors in the corners to help maintain uniform flow and reduce settling.

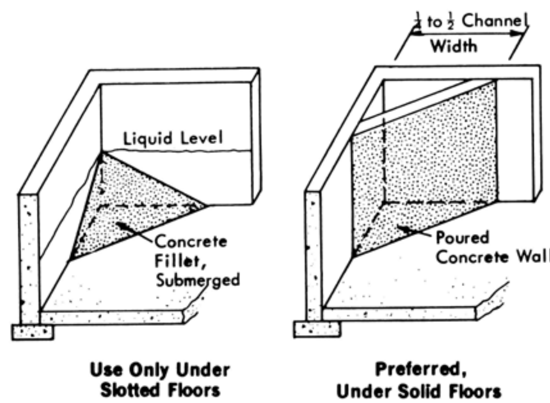


Figure 5. Corner deflector.

Ditch Capacity

Recommended capacity is specified in Table 1 and described in the example, page **4** . The recommendations allow for about 50 days of detention time. The ditch should be designed for the maximum pounds of pigs per building, and not just the average weight.

Experience has shown that a high percentage of slotted floor is needed, especially for finishing hogs, to get the required ditch volume and desirable shallow depth.

Developed from American Society of Agricultural Engineers' Paper 69-924 by D.L. Day et al, University of Illinois, and from AEng-878 by A.J. Muehling, University of Illinois.

Rotor Capacity

A major role of the aeration rotor is to mix air into the liquid wastes as a means of adding oxygen. The recommended oxygen that must be supplied equals 2 times the 5-day biological oxygen demand (BOD_5) of swine wastes, or about 0.6 lb of oxygen per 150 lb of liveweight (Table 1).

Rotors must be calibrated in water at the immersion depth at which they will operate to determine their oxygenation capacity. Capacities have been measured in clear water from 1.3 lb of oxygen per hour-foot of rotor at 6″ immersion and 100 rpm, to 5.65 lb of oxygen per hour-foot of rotor at 12″ immersion and 100 rpm. A general guide for good treatment is: one foot of rotor length for 40 to 45 150-lb hogs with a 6″ immersion and turning at 100 rpm.

Depth of Rotor Immersion and Liquid Depth

Increasing the depth of rotor immersion increases the rate of oxygenation, rate of liquid flow, size of motor required, and power consumption. Increasing the liquid depth in the channel increases detention time, depth of immersion, and the rate of rotor rotation needed to keep the solids in suspension. The simplest method of operation for a constant rotor immersion is to keep a constant liquid level in the ditch by using an overflow that discharges into a holding tank or lagoon. Slight variations in the liquid depth may be desirable to achieve the most efficient rotor immersion depth.

For finishing hogs, rotor immersion is equal to about one-third the liquid depth in the ditch to prevent settling of the solids. A 6″ immersion is about maximum to avoid rotor operation problems. Recommended liquid depth is, then, between 1′ and 2′. Greater depths at 6″ immersion may result in excess settling of solids. Provide a ditch 12″ or more deeper than the maximum liquid level to allow for some foaming without obstructing liquid circulation.

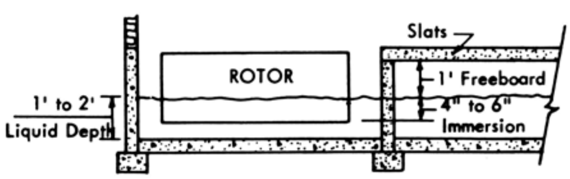


Figure 6. Typical cross section dimensions.

Rate of Liquid Flow

The aeration rotor must circulate the liquid wastes fast enough to keep the solid particles in suspension. Liquid transport can be the limiting factor in the design of a rotor even when adequate oxygen is being added. The liquid velocity required depends on the weight and size of waste particles in suspension circulating in the ditch. Normally, a minimum velocity of about 1.25 ft/sec of the liquid is recommended. At this velocity, the liquid should not travel over about 350′ without passing another rotor, since air should be added to the wastes about every 5 minutes for most efficient treatment.

OPERATION

Start-up

Fill the channel with water and start the rotor at the designed blade immersion. Start **before** adding manure to the ditch. Add wastes gradually at first to minimize foaming. A slight ammonia odor may be noticed during start-up. If initial foaming is a problem, it can be controlled with antifoam agents such as vegetable or fuel oil. Once an adequate microflora is established in the ditch, the start-up foaming should subside. This can take up to 3 weeks. The start-up period can be reduced by initially "seeding" the ditch with activated sludge from a satisfactorily operating ditch or from a municipal sewage plant. Don't drain the ditch completely unless absolutely necessary. Leave at least one-third the volume for enough sludge to provide a "seed" when the ditch is refilled with water.

Problems

The major operating problems have been foaming and incomplete treatment. If aerobic conditions are not maintained, anaerobic bacteria will predominate, causing odors and foam. There are other causes of foaming, including sudden temperature changes and sudden increases in waste quantities added to the ditch. The solution is more dissolved oxygen, reduced waste loading rate, or both. Temporary solutions include removing some wastes and refilling with water, or removing some livestock from the building. Increase rotor speed or depth of immersion for regular operation.

Symptoms of Inadequate Operation

Changes in appearance of the liquid or the foam may indicate imminent foaming problems. Clinging odors indicate an improperly operating ditch, while an earthy smell generally means a properly operating ditch. A greenish-black liquid color indicates anaerobic action and that more oxygen is needed, while a dark rich brown indicates a properly operating ditch.

The dissolved oxygen concentration indicates how the ditch is operating, but requires special equipment for measurements. A reading of 3 to 5 ppm of dissolved oxygen about 15′ downstream from the rotor is common. The oxygen level in the last one-fourth of the ditch normally falls below 0.5 ppm, showing that aerobic bacteria have been active.

CAUTION: Open up the house and turn on maximum ventilation before starting a rotor which has not been operating for over one day. Pigs have been killed by gases released when a rotor was started after having been turned off for some time, allowing the ditch contents to become septic. If the rotor has been off more than 2 or 3 days, drain part of the wastes and refill with tap water before restarting.

Regular maintenance is required. Rotor bearings must be lubricated regularly and occasionally replaced so they should be located for easy service and replacement. Belt drives seem to operate better than chain drives.

Sludge Removal

After a ditch has been in operation for several months, remove some sludge to reduce the amount of solids in the ditch. A properly operating ditch should stabilize the sludge so it can be handled without causing objectionable odors.

A sludge trap is not normally recommended, but if desired, one can be provided as in Fig. 1. Since the rotor creates an inch or so of hydraulic head, the inlet to the trap can be placed in the ditch just after the flow passes the rotor. If the outlet is placed just behind the rotor, flow will be opposite the direction of flow in the ditch (see Fig. 1). As the flow enters the tank, the velocity drops and solids are deposited in the trap. The sludge trap will need to be cleaned out periodically; pump onto drying beds or haul directly to the fields for fertilizer.

If no sludge trap is available, the solids content can be lowered occasionally by removing several inches of liquid from the ditch and diluting the remainder with tap water.

Final Disposal

The liquids from the oxidation ditch cannot be released into a natural watercourse. For operator convenience, allow overflow to discharge into a lagoon with a fluctuating depth. Irrigate from the lagoon if surplus water is a problem.

If it is not desirable or possible to have a lagoon, build a storage tank outside the building to store the overflow from the ditch. Empty the storage tank with a tank wagon for spreading on fields or distribute with an irrigation system.

Costs

The costs for an oxidation ditch will include first costs and operating costs. The cost of the rotor is about $300 per horsepower, so a 5 hp rotor costs about $1,500 including motor. Operating costs are estimated in Table 2. Additional costs will include maintenance, effluent disposal, and sludge removal.

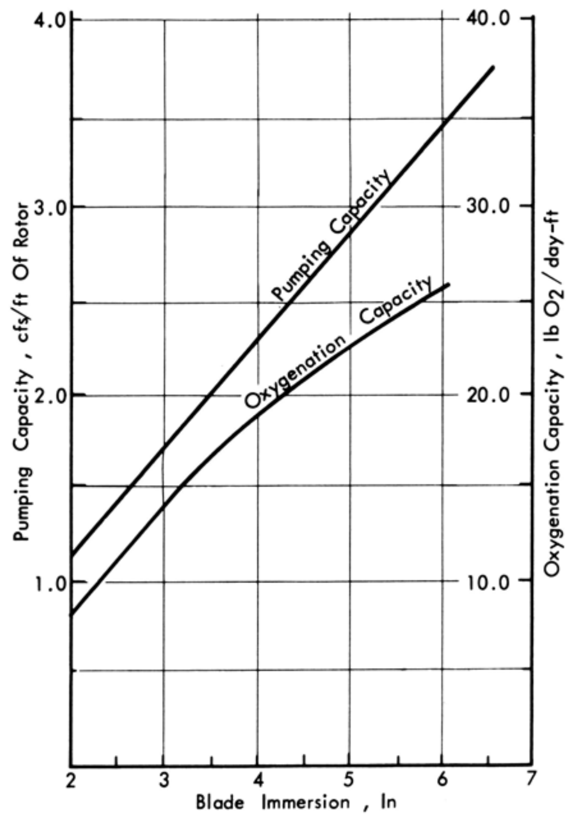


Figure 7. Performance data for a typical type of rotor.

Table 11. Design Recommendations for in-The-Building Oxidation Ditches.

Unit	Weight (lb/unit)	Ditch volume (cu ft/unit)1	Daily BOD_5 (lb/unit)	Daily required oxygenation cap. (lb/unit)2	Ditch area at 18" liq. depth, (sq ft/unit)
Boar	350 lb	12.0 cu ft	.40 lb	.80 lb	8.0 sq ft
Gestating sow	275	12.0	.40	.80	8.0
Sow with litter	375	22.5	.75	1.50	15.0
Nursery pig	35	2.1	.07	.14	1.4
Growing pig	65	3.9	.13	.26	2.6
Finishing pig	150	9.0	.30	.60	6.0

[1] Ditch volume based on approximately 30 cu ft/lb of daily BOD_3 produced.
[2] Oxygenation capacity to be supplied is twice the daily BOD_5 produced.

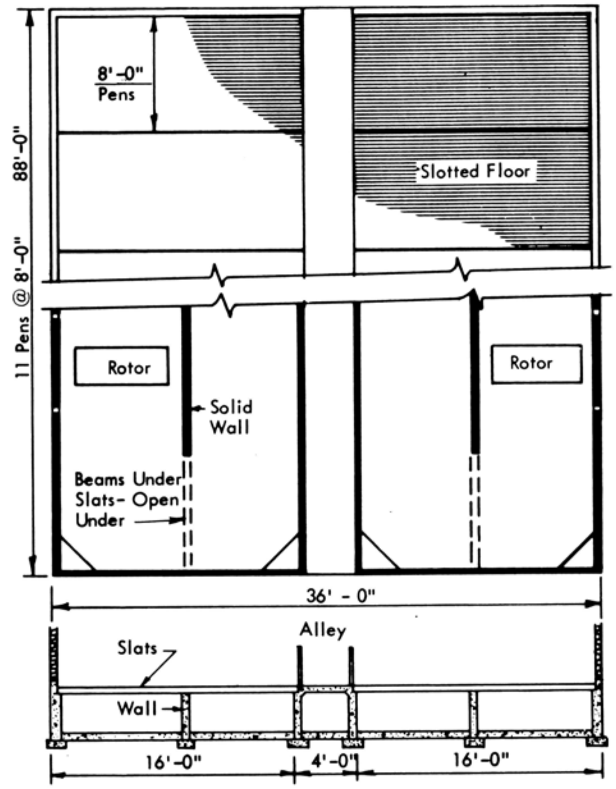
Table 12. Approximate Power Requirement and Daily Cost of Oxidation Ditches.

Unit	Daily power requirement (KWH/unit)	Daily cost, (¢/unit)1
Boar	.42 KWH	.84 ¢
Gestating sow	.42	.84
Sow with litter	.79	1.58
Nursery pig	.07	.14
Growing pig	.14	.28
Finishing pig	.32	.64

[1] Daily operating cost is based on 2¢/KWH.

EXAMPLE: OXIDATION DITCH FOR SWINE FINISHING UNIT.

(Note: refer to manufacturer for performance and specifications for the actual rotor to be installed.)



Given:

A building with slotted floors to house 500 finishing pigs with maximum average weight of 150 lb. Specify an in-the-building oxidation ditch to treat the waste and eliminate objectionable odors. Assume the ditch is operated at a constant liquid depth by using an overflow.

Solution:

Use a floor area of 6 sq ft per finishing pig. A 36′ wide building with 22-8′x16′ pens in 2 rows will provide one extra pen: total building length is 88′.

Step 1. **Find the required ditch liquid volume.**
From Table 1, liquid volume = 9 cu ft per hog x 500 hogs = 4,500 cu ft.

Step 2. **Find the required ditch liquid depth.**
Assume two ditches, one on each side of the building. Total ditch length = 4 x 88′ = 352′. The surface area of the ditch circuit will be 352′x 7.5′ = 2,640 sq ft. The ditch depth = 4,500 cu ft/2,640 sq ft = 1.7′, or about 21″.

Step 3. **Find the oxygen capacity that must be supplied by the rotor.**
From Table 1, oxygen required = 0.6 lb O_2 hog-day x 500 hogs = 300 lb O_2/day.

Step 4. **Find the rotor depth required for oxygenation.**
Assume two rotors, each 7′ wide. Thus the oxygenation rate = (300 lb O_2/day) ÷ (2 x 7′ rotor) = 21.4 lb O_2 day per foot of rotor length. From Fig. 4 a rotor blade immersion of 4.8″ should be used for oxygenation. To keep solids completely in suspension, the ratio of liquid depth to rotor blade immersion depth should be no more than 4:1, preferably 3:1. Therefore, for 21″ ditch depth, immersion should be 5¼″-7″. Use 5½″.

The maximum distance between rotors should be about 350′—one rotor in each 176′ ditch is acceptable.

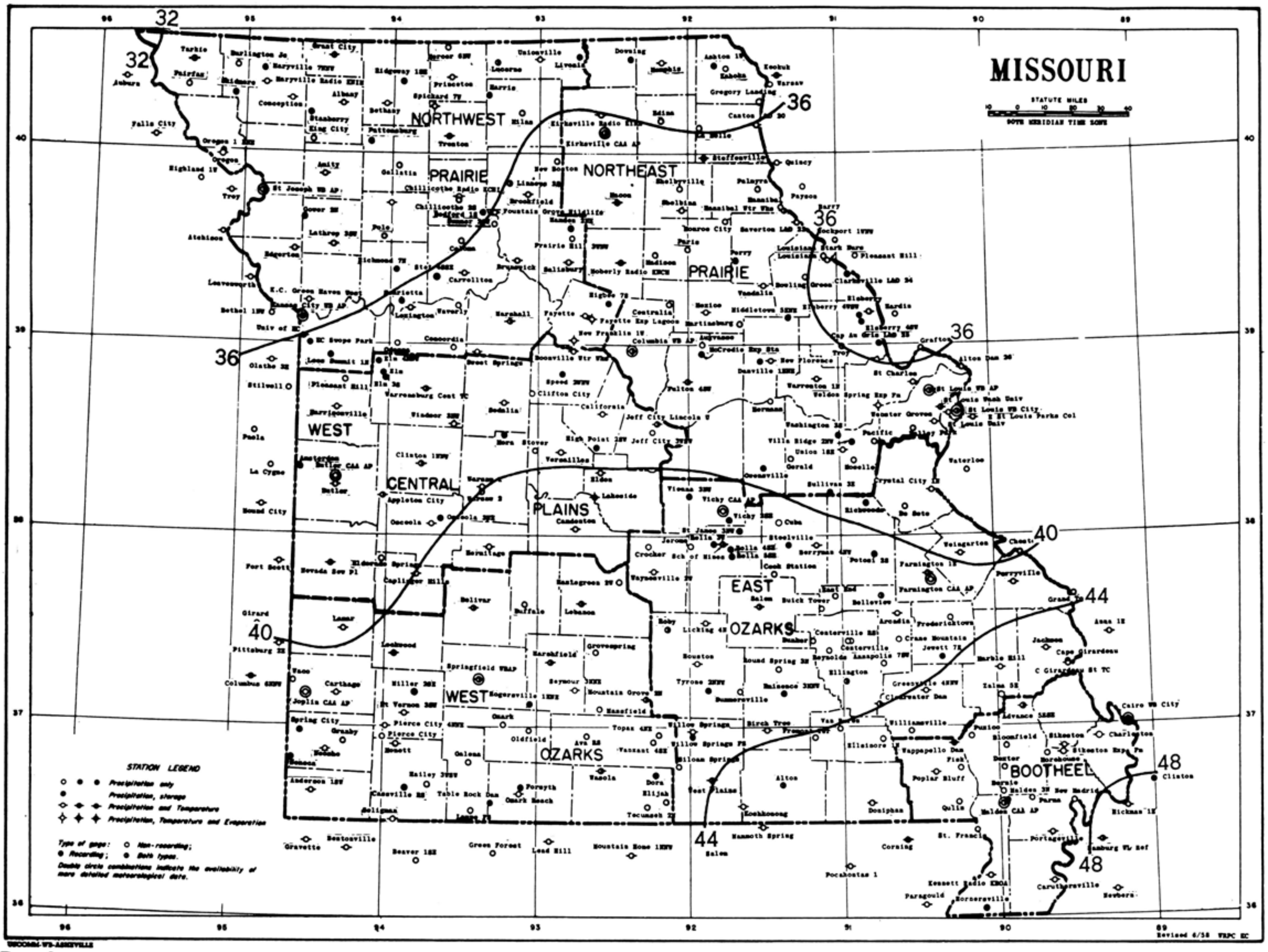
Step 5. **Check the rotor depth required for pumping capacity.**
The ditch liquid cross sectional area is 1.7′ x 7.5′ = 12.75 sq ft. A minimum flow rate of about 1.25 ft/sec should be maintained. Thus the rotor pumping rate = 1.25 ft/sec x 12.75 sq ft = 17 cu ft/sec. The required pumping capacity = 17 cu ft/sec ÷ 7 ft = 2.45 cu ft/sec per foot of rotor. From Fig. 4, a rotor depth of 4.2″ will give the required pumping capacity—therefore the 5½″ depth selected for oxygenation is adequate.

Step 6. **Check the rotor operating cost.**
From Table 2, the approximate operating power cost is 0.6¢/hog x 500 hogs = $3.00/day.

Step 7. **Select a method of ultimate disposal of the mixed liquor overflow.**
Assume the mixed liquor effluent will flow by gravity to a non-overflow, naturally aerobic lagoon. The daily BOD_5 loading of the lagoon may be assumed at 10% of the daily ditch loading, due to a typical 90% BOD_5 reduction in the ditch. A lagoon loading rate of 45 lb of daily BOD_5 per surface acre can be used in the central latitudes of the United States. The surface area required for a 4′ depth is (0.03 lb BOD_5/hog-day x 500 hogs) ÷ (45 lb daily BOD_5/acre) = 1/3 acre. The lagoon depth may fluctuate; remove surplus water and sludge as required.

3/70

Mean Annual Precipitation, Inches



Based on period 1931-55 U.S. Department of Commerce—Environmental Science Service Administration

Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas.

DESIGN PROCEDURE FOR STORAGE LAGOON SYSTEMS

The storage lagoon will be designed to accumulate runoff, manure, and rainfall minus evaporation for selected time periods. The storage volume will be pumped onto land at selected intervals. A fixed volume will always be retained in the lagoon and will equal the design lagoon volume.

Worksheet 4 provides a sequence of steps and references with which the required data can be calculated for these systems.

Name ______________________________

WORK SHEET-4

DESIGN PROCEDURE FOR STORAGE-LAGOON SYSTEMS

(Swine and Beef)

SIZING LAGOON AND STORAGE CAPACITY. Design based on _______acres, or sq.ft. of feedlot area, _______head at _______lbs.

1. MANURE STORAGE VOLUME:
   _______cu.ft./animal (Table 4) x _______days x
   _______animals x _______% into lagoon
2. RUNOFF FROM LOT AREAS:
   _______acres x 43,500 x _______ft. run-off (Table 13, col. 3) _______$ft.^3$
3. STORAGE REQUIRED FOR SELECTED PERIOD:
   $\frac{\text{Total} = (1) + (2)}{\text{No. times pumped}}$ + _______ = (3) $\boxed{\quad ft.^3}$
4. LAGOON DESIGN VOLUME:
   _______lbs./animal x _______No. animals x
   _______cu.ft./lb. (Table 7) x _______% in
   lagoon = (4) $\boxed{\quad ft.^3}$
5. DETERMINED REQUIRED SURFACE AREA FROM CHART I -
   for volume (3) + (4) _______$ft.^3$ for maximum
   depth expected minus 2 ft. = _______$ft.^2$
6. RAINFALL - EVAPORATION VOLUME:
   _______$ft.^2$ surface (5) x _______ft. (R-E) (Table 13, col. 14) = _______$ft.^3$
7. RUNOFF FROM DAM AREA:
   _______lineal ft. dam x _______ft. (center of
   dam to water line) x _______ft. .9 (maximum rain)
   (Table 13, col. 4) = _______$ft.^3$
8. $\frac{\text{TOTAL (6) + (7)}}{\text{No. times pumped}}$ = (8) $\boxed{\quad ft.^3}$
9. TOTAL LAGOON AND STORAGE REQUIREMENT =
   (3) + (4) + (8) = (9) $\boxed{\quad ft.^3}$

Sample—Supplies of work sheets available at County Extension Centers and from Missouri Water Pollution Board.

WORK SHEET-4 (Continued)

10. TOTAL STORAGE VOLUME (9) ________ $ft.^3$

11. LAGOON DESIGN VOLUME (4) ________ $ft.^3$

12. VOLUME APPLIED TO SOIL PLANT FILTER (10) - (11) ________ $ft.^3$

13. FEET PUMP-DOWN = $\frac{(10)\_\_\_\_\_\_\_ ft.^3}{(5) \qquad ft.^2}$

Note: Determine and mark permanently the depth in the constructed lagoon representing the design volume. Do not pump below this level. Add dilution water when required in exceptionally dry years.

Name	Address	Position

Signed: ____________________

WORK SHEET-5

DESIGN PROCEDURE FOR DAIRY STORAGE LAGOON SYSTEMS

Size of lagoon is based upon _______square feet of paved lot area, including roofs of buildings; and _______ square feet of earth area adjacent to lot that drain into lagoon; a herd size of _______cows averaging 1330 pounds body weight and assuming that they will be confined in lot _______days and on pasture _______days during the year. Manure from feeding and loafing area will be hauled and spread on _______days not on pasture. Further, the lagoon will be pumped or drained down to its designed volume requirement level _______times annually.

ITEM 1. LAGOON DESIGN VOLUME REQUIREMENT. Calculate days during year when each facility will be used. Using volume for your region of state calculate cubic feet of volume per cow for each facility or area of the facility. For example: Parlor will probably be used 365 days; holding pen will probably be used 365 days however, count only those days when the manure produced will ultimately go into lagoon or exclude days when spread on fields; count lot surface runoff for 365 days or all days when cattle have access to a confined lot; manure from feeding and loafing areas should be counted for those days when manure produced in lot and loafing area is put into lagoon.

	Select Appropriate Region								
	North	Central	South		% of Time (1)		If Manure Hauled (2)		
	cu.ft./cow								
Milking Parlor	240	200	160	x	_______	x	1.00	=	_______cu.ft./cow
Holding Pen	600	500	400	x	_______	x	.25	=	_______cu.ft./cow
Lot Runoff	480	400	320	x	_______	x	1.00	=	_______cu.ft./cow
Manure-Feeding & Loafing Areas	1080	900	720	x	_______	x	.25	=	_______cu.ft./cow

_______No. cows x cu.ft./cow _______ = (1) $\boxed{\quad ft.^3}$ Lagoon Design Volume

(1) % of time = No. days use/365

(2) Use factor of 1.00, if manure not hauled.

ITEM 2. MANURE STORAGE VOLUME: Calculate days during year when each facility or area contributes waste to lagoon. Figure days as in Item 1.

	cu./ft./Cow Per Day		(1)		If Manure Hauled		
Milking Parlor	0.2	x	_______days	x	1.00	=	_______cu.ft./cow/yr.
Holding Pen	0.5	x	_______days	x	.25	=	_______cu.ft./cow/yr.
Lot Runoff	0.4	x	_______days	x	1.00	=	_______cu.ft./cow/yr.
Manure-Feeding & Loafing Areas	0.9	x	_______days	x	.25	=	_______cu.ft./cow/yr.

_______No. cows x cu.ft./cow yr._______ = $\boxed{\quad ft.^3}$ Manure Storage Volume

(1) Days same as Item 1.

ITEM 3. STORAGE FOR RAINFALL RUNOFF FROM LOTS:

$$(0.9)\left(\begin{array}{l}\text{Square ft. area of concrete \&}\\ \text{roof surface draining into}\\ \text{lagoon}\end{array}\right) \times \frac{\text{Maximum Rainfall Table 13, col.2}}{12}\Bigg) + \left(\begin{array}{l}\text{sq. ft. area of earth}\\ \text{Surface draining into}\\ \text{lagoon}\end{array}\right) \times \frac{\text{Runoff Table 13, col. 3}}{12}\Bigg) = \text{cut. ft. runoff from lots}$$

ITEM 4. OTHER SOURCES OF WATER INTO LAGOON, (including volume of water where parlor or holding pen is flushed drainage from other areas. Explain briefly. _______cu. ft.

ITEM 5. TOTAL STORAGE REQUIRED FOR MANURE WASTES AND WATER.

Sum of Items 2, 3, and 4 = ________cu.ft.

ITEM 6. TOTAL STORAGE REQUIRED FOR MANURE WASTES AND WATER DIVIDED BY TIMES LAGOON IS TO BE PUMPED DOWN ANNUALLY.

$\frac{\text{Item 5}}{\text{No. times pumped}}$ = Item 6 = ________cu.ft.

ITEM 7. LAGOON DESIGN VOLUME PLUS STORAGE NEEDED.

Item 1 + Item 6 = Item 7 = (7) ________cu.ft.

ITEM 8. DETERMINE SURFACE AREA OF LAGOON (Chart I) for volume in Item 7 and for maximum depth attainable at site of lagoon less 2 feet allowance for rainfall minus evaporation.

Maximum depth - 2 = __________ft. of depth of lagoon.

__________sq. ft. surface area from Chart I, Page

ITEM 9. RAINFALL MINUS EVAPORATION ON LAGOON AREA PLUS RAINFALL ON PORTION OF DAM AND SHORE SLOPING INTO LAGOON.

(a) Surface area of lagoon Item 8 x $\frac{\text{Maximum Rainfall-Evaporation in inches (Table 13, col. 4)}}{12}$ =

Volume needed for excess rainfall on lagoon surface ________cu. ft.

(b) (Feet of perimeter of lagoon (surface, bank & shore (sloping into lagoon x Feet Average width of the perimeter x

$\frac{\text{Runoff Table 13, col. 3)}}{12}$ = Volume needed for runoff into lagoon ________cu.ft.

(c) Subtotal 9(a) + 9(b) = $\frac{\text{\_\_\_\_\_\_\_\_cu. ft.}}{\text{No. times pumped down annually}}$ = (9) ________cu.ft. Added to lagoon by rainfall

ITEM 10. TOTAL STORAGE (Sum of Items 1,6, and 9) of (7) + (9) = ___________cu. ft.

ITEM 11. MAXIMUM DEPTH OBTAINED FROM CHART I, using total storage in Item 10 and surface area in Item 8. ___________ft. of depth

ITEM 12. (a) Total Storage (Item 10) ___________cu. ft.

(b) Lagoon Design Volume, (Item 1) ___________cu. ft.

(c) Volume to be removed each time lagoon is pumped down (Item 10 minus Item 1) ___________cu. ft.

(d) Depth of water when pumped down __________ times annual (Item 12c ÷ Item 8 = Depth of pump down in ft.) ___________ft.

TABLE 13

RAINFALL, RUNOFF AND ANNUAL RAINFALL MINUS EVAPORATION

Data for Missouri (1918-1954)

(1) Average Annual Rainfall (Inches/Year)	(2) Maximum Rainfall 1 Year Out of 10 (Inches/Year)[1]	(3) Maximum Lot Run Off Expected 1 Year Out of 10 (Inches/Year)[2]	(4) Maximum Rainfall Minus Evaporation Expected[3] 1 Year Out of 10 (Inches/Year)
30	39.0	16.5	4.6
32	41.5	18.0	8.0
34	44.0	20.0	11.0
36	47.0	22.0	14.0
38	49.5	24.5	16.0
40	52.0	26.5	19.0
42	54.5	29.5	21.5
44	57.0	32.0	24.5
46	60.0	33.5	27.5
48	62.5	36.0	30.0
50	65.0	38.2	33.0

(1) Maximum rainfall equal to or less than 9 years out of 10 = 1.3 x Average Annual Rainfall (Inches/Year)

(2) $Y = .037\ X^{1.665}$ Y = Inches per year lot runoff
X = Inches rainfall per year (use maximum 1 year out of 10)

(3) From University of Missouri-Columbia, College of Agriculture, Research Report 974, Saxton and Whitaker

Soil-Plant Filter

Design Considerations

A soil-plant filter area is a fixed area selected to be used for the disposal of liquefied waste such as effluent from a lagoon system by means of some conventional irrigation method.

The topography and quantity of effluent will dictate the type of irrigation method to be used, and the ultimate cost of the system. The size of the area will be determined by the elements contained in the original waste and the quantities expected to be applied to the crop on the soil-plant filter. The soil-plant filter concept assumes that the elements contained in the lagoon effluent applied to the land will be removed by the plants, and the plants will be removed from the land. This concept results in no accumulation of toxic or detrimental levels of elements in the soil.

Ideally, the distribution pattern offered by sprinkler systems would be most desirable. A gravity distribution system is cheaper to install but crops will be lowered by the heavier discharge at the upper end of the field. Over a period of years, the improved production from the more even distribution of a sprinkling system may pay for its installation. Judgment, experience and personal preference on the part of the designer and operator will have to be used in selecting the system.

Management of the soil-plant filter will be required to obtain the benefits assumed in the basic concepts. It is assumed that the system can be so managed that the effluent can be applied and be absorbed into the soil with no runoff nine years out of 10. Management will be required in planning the time and frequency of applying the effluent to the soil-plant filter. Harvesting and removal of the crop will be required. Soil tests will be required to determine the balance of major and minor elements in the soil. A record of the accumulation of toxic elements, such as salts, should be made.

TABLE 14 - SIZE OF SOIL-PLANT FILTER AREA FOR 100% MANURE DISPOSAL

	Pasture[1]	Cultivated or Corn
	Number of Animals/Acre[2]	
Hogs - Average Weight, 150#	30	40
Beef Cattle Average Weight 900#	20	27
Dairy	8	12
Poultry		

[1]Effluent may be applied in three separate applications and minimize lost time in returning livestock to grass.

[2]This area is allocated assuming one animal space is occupied for one year. If only a part of the manure is loaded into the lagoon or animals occupy the space for a part of the year, animals/acre may be estimated by calculating "% time used" or "% of total load" expected to be applied through the lagoon system. EXAMPLE: A feed lot where it is assumed that 75% of the manure is collected in the lot and the settling basin area, leaving 25% to go through the lagoon and onto the soil-plant filter area used as pasture.

Then:

$$\text{Cattle/A} = \frac{\text{20 head/acre}}{.25} \text{ (100\% pasture)}$$

$$= \text{80 head/acre}$$

Design Procedure

The size of the soil-plant filter area will be determined by the chemicals contained in the lagoon effluent. This in turn is determined by the number of animals producing the manure. Because of the variation in the moisture content of fresh manure, manure production is corrected to a 20 percent moisture (w.b.) to equate the chemical values in the manure from various animals.

Basic guides in sizing the soil-plant filter area for hogs, beef cattle, and dairy animals will be 30 tons/acre on pasture and 40 tons/acre on cultivated land or corn. Poultry waste will be applied at the rate of 3 tons/acre on pasture and 4½ tons/acre on cultivated or corn land.

TABLE 15 - SOIL-PLANT FILTER DATA FOR DAIRY

I. Minimum Land Required for 100% Disposal of Manure:

8 Cows Per Acre - Pasture (1)
12 Cows Per Acre - Corn or Cultivated Land

II. Combinations of Itemized Loading Conditions:

Conditional Loading of Lagoon	Pasture	Cultivated or Corn
	Cows/A.	
A - Milk Room + Milk Parlor	65	100
B - Milk Room + Milk Parlor + Holding Pens	23	33
C - Milk Room + Milk Parlor + Holding Pens + Lot Runof	14	21
D - (A) + (B) + (C) + Remaining Manure	8	12

III. Itemized Loading Conditions as 9% if Total Lagoon Load

Condition	% Total Load
Lot Runoff	21.1
Milk Room + Milk Parlor	12.1
Holding Pen	24.2
Remaining Total Manure	42.5

(1) Effluent should be applied to pasture in a minimum of th three applications. Allow 3 days before pasturing.

To determine Soil-Plant Filter areas for combinations not shown, add the "% total load" and divide into "cows/acre for 100%." i.e., combining lot runoff and holding pens = 21.1 + 24.2 = 45.4%. For Soil-Plant Filter area on pasture--cows/acre = 8/.454 = 18 cows/Acre.

Name ______________________

WORK SHEET-6

DESIGN PROCEDURE FOR SOIL-PLANT FILTER AREA

1. Area Requirements:

   Design based on _______ head (hogs, cattle, dairy, poultry), ________% manure load, crop = pasture, cultivated crop.

   A. Calculate % manure load:
      Hogs _______%, Beef _______%, Dairy _______% (1), Poultry _______%

____

(1) The % load for dairy may be taken or calculated from the dairy work sheet "Design Procedure for Storage-Lagoon Systems."

   B. Acres soil-plant filter required:

$$\text{Animals/acre SPF} = \frac{\text{Animals/A (100\% manure load)}}{\text{Manure load as decimal (A, above)}}$$

$$= \underline{\hspace{3cm}} = \underline{\hspace{3cm}} \text{ Animal/A.}$$

$$\text{ACRES SPF} = \frac{\text{Total No. Animals}}{\text{Animals/acre spf}} = \underline{\hspace{3cm}} = \underline{\hspace{3cm}}\text{A.}$$

	Name	Address	Position
Signed:			

Waste Handling Systems

Methods of transporting manure or lagoon effluent are the conventional systems available today. Liquid tanks, and manure spreaders will continue to be used. Where lagoons are used, the manure will be liquified and kept in suspension by the lagoon activity so that all this material will easily be handled through ordinary irrigation systems. Liquid manure collected in detention basins will require special manure gun irrigation systems and some dilution before distribution to land.

Knowing the size of soil-plant-filter, the volume of water produced in one year, proximity of neighbors, and the labor available, a disposal system may now be selected. Two or more alternatives, such as a liquid manure tank-wagon, a hand carry sprinkler system, and a traveling gun sprinkler system may be considered for cost, labor, etc.

Liquid Handling Systems

Liquid handling systems will have the following basic components:

a. Collection method
b. Storage
c. Agitation and removal with liquid manure tank
d. Safety aspects

Emphasis should be given to each of the components in planning liquid handling systems to be able to operate the systems efficiently and not have management bottlenecks that might contribute to water or air pollution.

The collection method might be termed "self loading" in cases of confinement using slatted floors. In other cases the manure will be scraped from areas into one or more liquid pits or detention basins for storage. Attention should be given to the location and number of basins with regard to distances manure has to be scraped and the traffic pattern required to move tractors and equipment in loading and unloading the tanks.

The size, number and shape of storage tanks are directly related to the success of the system.

The total storage requirement will be dictated by the length of storage required to have access to fields and not have pollution potential present. The storage tanks must be of sufficient size to hold the total accumulated solids for this storage period. Minimum storage period recommended for Missouri conditions would be 60 days storage in south Missouri and 90 days storage in north Missouri.

An ideal size per agitation and removal opening is 10,000 cubic feet or a 20 x 50 x 10 feet deep tank with the agitation and removal opening at the center of the tank. The maximum length of rectangular tanks should be limited by end walls or dividing walls to increments of 50 feet. Agitation and removal of wastes is most critical. The maximum distances from the point of agitation to a wall should be 25 feet or less. Chopper-pumps are the most satisfactory methods for agitation of dairy and beef wastes. Swine and poultry wastes are more easily mixed, and pumping back into the pit from a vacuum tank is usually satisfactory.

Safety precautions should be observed in keeping liquid tanks covered to keep humans and animals out of the tank. Adequate liquid tank ventilation is essential when tanks or pits are located inside buildings during the agitation and removal operations. The tops and covers of liquid tanks should be reinforced to carry the weight of a tractor and loaded spreader. Walls must be reinforced to withstand pressures from both inside and outside. Covered tanks offer protection from fly breeding. All tanks should be of water-tight construction.

Management and planning are critical if liquid systems are to be operated practically and conditions avoided that would lead to water and air pollution.

a. The length of the storage period should be selected so that land is available in a condition to receive waste without polluting waters of the state.
b. Odors associated with liquid manure storage and spreading are highly offensive and are legally a nuisance to other people.

Refer to Figure 14. Determine the number of trips required per year to dispose of the given amount of liquid waste. Estimate time required to haul wastes from Figure 14. Initial costs and plans for expansion will also affect the selection of equipment. Liquid manure tank wagons have the flexibility of hauling to distant fields without purchasing additional pipe.

Odors

Animal manure, when stored or accumulated in pits, is subjected to bacterial decomposition resulting in intense concentrations of odorous gases. These gases are released when manure is agitated or loaded into liquid spreading equipment. The odors are persistent for two or three days after spreading, depending on weather conditions.

The production of odorous gases is one of the by-products of the acid-forming phase of the anaerobic digestion process. The pH of the material is acid and will usually be 6.7 and lower.

Odors released from manure spread on farm land constitute a nuisance to any person in the vicinity. Such odor problems are an open door to *legal actions.*

There are some possibilities in controlling odors created by field spreading of liquid manure.

The greatest reduction in odors will result when liquid manure is plowed under at the time of application. Much of the conversation today about spreading manure *on* land is being changed to spreading manure *into* the land.

A possible second best method is to spread on crop land and then disk immediately.

The greatest odor reduction will be obtained when liquid manure is *mixed into* and *covered* with soil.

In many cases, advantages can be gained in the selection of the field for spreading with respect to wind direction, neighbors, or towns.

As farm business expands and livestock production takes on greater proportions, the waste disposal problem increases in volume. As livestock production is increased, available land for spreading manure is reduced. To meet this dilemma many farmers are combining lagooning with field spreading. This combination offers flexibility in selecting the time and place for field spreading. The total volume of manure returned to land is reduced with this combination.

Odors can be a problem with anaerobic lagoons. Proper design, management, and the use of mechanical aeration will eliminate these odors.

Liquid manure that has been aerated for periods of 30 to 60 days will not have odors when spread.

Some other methods of controlling odors using disposal systems other than field spreading might be listed:

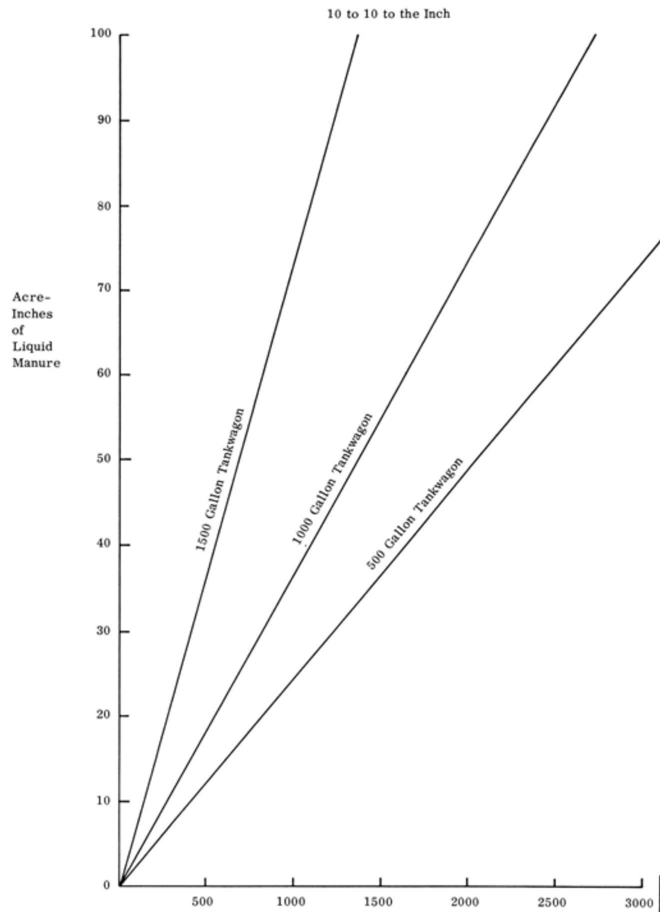


Fig. 14—Number of Trips with Liquid Manure Tankwagon.

1. Total lagooning using mechanical aeration for odor control. It should be noted that with this system the effluent from the lagoon *can not* be discharged into public waters.
2. Oxidation ditch treating. This system is more costly than others, but has advantages. A major advantage, when operating properly, is NO ODORS. However, the effluent from the oxidation ditch will have to be treated by a soil-plant filter system, the same as a lagoon system.
3. Chemical masking agents. Because of costs, masking agents will probably be used on small areas such as buildings and lots when required and when other methods are not available.

Solid Manure Handling Systems

The components required for solid handling systems include:

a. Tractor and mounted scoop and blade.
b. Manure spreader.
c. Concrete manure pad for spreading.

Solid manure can be scraped from concrete areas and loaded directly onto a spreader, when field conditions are acceptable for field spreading. Under adverse field conditions, the manure should be stored on a concrete manure pad with three retaining walls and one open side.

The pad should be located so it can be easily loaded and unloaded. The pad floor should be sloped 3 to 4 percent for drainage of liquids into the lagoon system. Loading can be facilitated on ground level pads by loading against the retaining walls. If topography is convenient, a manure loading ramp is desirable. Storage volume should be provided at 1 cubic foot per day per head of beef cattle and 1.5 cubic foot per day per head of dairy cattle.

Often a producer will choose a combination of liquid and dry handling equipment. Although additional equipment is needed, this allows a producer to keep his lots in better condition, and is usually necessary to clean debris basins. The combination of debris basins and storage lagoons reduces anaerobic loading and keeps solids from plugging irrigation equipment.

Irrigation for Waste Handling

Design Considerations

Advantages. For relatively large amounts of livestock, waste effluent irrigation systems are economical and labor saving. One acre-foot of liquid waste = 325,000 gallons = 216 trips with a 1500 gallon honey-wagon or 12 hours of pumping with an average size big gun sprinkler.

The system can also be used for irrigating crops.

Runoff water and livestock wastes are returned to the land.

Effluent from lagoons, which cannot be discharged directly into streams, can be readily pumped through irrigation systems.

Disadvantages. This approach often requires a significant initial investment in addition to operating costs.

Good management is essential.

Some labor is required and not the most desirable type of labor. This varies greatly from one system to another.

The odor problem may be increased or decreased, depending on management.

System Capacity

Refer to Table 16 or 17. Select a system with capacity to dispose of the quantity of wastes in a week to 10 days.

TABLE 16. SIZING PUMPING CAPACITY FOR LAGOONS USED WITH CONFINEMENT HOG SYSTEMS

Expected No. of Days Pumping	Probability Level 5 yrs. in 10	Probability Level 9 yrs. in 10
	Pump Capacity GPM/100 Head (10 Hr/Day)	
2	58.0	95.0
3	39.0	63.0
4	29.0	47.0
5	24.0	38.0
6	19.5	31.5
7	16.5	27.0
8	14.5	23.5
9	13.0	21.0
10	12.0	19.0

TABLE 17 - Number of Days (10 hours/day) Required to Dispose of a Given Quantity of Liquid Wastes

Gal. Per Min.	Acre In. Per Hour	Acres-Inches of Waste 6	12	24	36	48	60	120	240
25	.05	12.0	24.0	48					
50	.11	5.5	10.9	21.8	32.8	43.6	54.6		
100	.22	2.7	5.5	10.9	16.4	21.8	27.3	54.5	
200	.44	1.4	2.7	5.5	8.2	10.9	13.6	27.3	54.5
300	.66		1.8	3.6	5.5	7.3	9.1	18.2	36.4
400	.88			2.7	4.0	5.5	6.8	13.6	27.4
500	1.10			2.2	3.2	4.4	5.5	10.9	21.8
600	1.32			1.8	2.6	3.6	4.6	9.1	18.1
800	1.77				2.0	2.7	3.4	6.8	13.6
1000	2.21					2.2	2.7	5.4	10.8

Units

1 acre-inch = 27,154 gallons = 3,621 cu.ft.

1 acre-foot = 12 acre-inches = 325,848 gallons = 43,560 cu.ft.

1 acre-inch/hour = 450 gallons/minute = 1 cubic foot/second.

A system with a small capacity would require more labor and disposal time than a larger, more expensive system. A 400 gpm hand-carry sprinkler system costs less but requires more labor than a 200 gpm traveling gun. One or more farmers may lease or purchase together a labor saving system. Design the piping or ditch system to cover the entire soil-plant-filter area.

Choice of Disposal System

In general, the disposal system is designed to be able to handle a particular consistency of waste effluent.

Fluid wastes containing less than 5 percent solids can be handled by almost all irrigation systems: gated pipe, ditches with spile tubes, hand-carry sprinkler systems, traveling gun systems, central pivot sprinklers, side-roll sprinkler systems. These fluid wastes are typical of feedlot runoff, or effluent from a lagoon system. Generally, it is desirable to handle solids and liquids separately to minimize handling equipment problems.

Semi-liquid wastes may have up to 15 percent solids, and can be handled by only one system, the manure gun sprinkler. Semi-liquid wastes are typical of the wastes collected in a liquid pit or detention basin. Special pumping equipment is required for handling semi-liquid slurries.

Select a surface or springler irrigation system that is well adapted to the particular topography, soil, and crop grown on the soil-plant-filter. A properly designed system should enable management of the system without runoff or erosion.

WASTE DISPOSAL SYSTEM SELECTION CHART

	TYPE OF SYSTEM										
	Tank Wagon	Sprinkler								Gravity	
Factor Considered	Honey Wagon	Hand-Carry Sprinkler	Traveling Gun	Towline	Manure Gun	Solid Set	Side Roll	Boom	Center Pivot	Gated Pipe	Open Ditch
Soil Type	Suitable for use on soils with a wide range of intake rates								Moderate to high intake soils	Soils with moderate to low intake rates	
Surface Topography	Adaptable to a wide range of surface topography						Limited to moderately undulating topography			Limited to moderate to flat slopes	
Labor Required	Very High on large operations	High	Low	Moderately low	High on large operations	Very low	Moderate		Very low	High	Very high
Management required 1)	Low	Moderately Low		Moderately low						High	Very high
Flexibility for Expansion	Inflexible 3)	Moderate	Inflexible 3)	Moderate		Inflexible 3)		Inflexible 3)	Inflexible 3)	Very flexible	
Initial Investment	Low to Moderate		Moderate	Low to Moderate		Highest	Low to Moderate		High	Low to Moderate	Lowest
Operating Costs 2)	Moderate to High		High	Moderate to High						Low	
Crop Suitability	All except tall growing crops	All	All with Adaptations				All except tall growing crops	All		All	
Size of Operation	Small to Medium Size		All Sizes		Small to medium size	All Sizes			Large	All sizes; depends on topography	
Type of Effluent	Liquids to semi-liquid slurries	Liquids only	Liquids to semi-liquid slurries	Liquids only	Liquids to semi-liquid slurries	Liquids only			Well filtered liquids	Liquids only	

Note: 1) Management refers to the skill required, or the ability to set the system and go off and leave it.

2) Operating costs are a small factor in selecting a waste disposal system.

3) Of course another system may be purchased.

Planning Irrigation Waste Disposal System

Sprinkler Irrigation Design Criteria.

Sprinkler systems allow waste disposal on rolling and irregular land that would be uneconomical to surface irrigate. Although initial and operating costs are generally higher for sprinklers, labor requirements are sometimes reduced, and some systems may be automated. The uniformity of application is also improved. For all sprinkler systems, select sprinklers and spacings that will not cause runoff on the particular soil type, topography, crop, and time of application. Clean water should be flushed through the system after each application. Washing wastes off of plant foliage is not possible with traveling sprinkler systems.

Hand-carry Portable Sprinkler Systems. Hand-carry sprinkler systems, quite popular in the past, have become less popular because of the advent of more labor saving sprinkler systems. Their ability to irrigate small acreages, adaptability to diverse topography, and the availability of used systems offer advantages.

Manure Gun Sprinkler Systems. One system adapts to handling relatively heavy slurries (up to 15 percent solids) —the manure gun sprinkler. These large sprinklers generally have a capacity of 100 to 400 gallons per minute, and can cover from ½ to 2 acres at a setting. The large nozzle can usually pass ¾″ diameter solids, and requires special high pressure pumping equipment. Some models have rubber nozzles. This system adapts well to either confinement feeding systems, where wastes are collected in a pit, or to handling lagoon effluent.

Traveling Sprinkler Systems. The traveling sprinkler consists of a single large sprinkler mounted on a four-wheel trailer. Power for travel is a small auxiliary engine, a water turbine, or a water cylinder. The auxiliary engine units probably travel at a more nearly uniform speed, but they have a higher initial cost.

These traveling units range in capacity from 100 to 1500 gallons per minute.

A cable, mounted on a winch on the machine is extend 1320 feet (¼ mile) across the field and anchored at the far end. As the power source drives the cable winch, the unit is pulled across the field, irrigating as it travels.

As the self-propelled unit passes adjacent to the water supply outlet (usually portable aluminum pipe) the hose forms an elongated "U" behind the unit. As the self-propelled unit proceeds along its travel path the hose is extended full length in the opposite direction from its original layout. The utilization in this way allows for continuous movement of twice the length of the hose, or 1,320 feet. Thus, one pass through a 40-acre field can be attained without stopping.

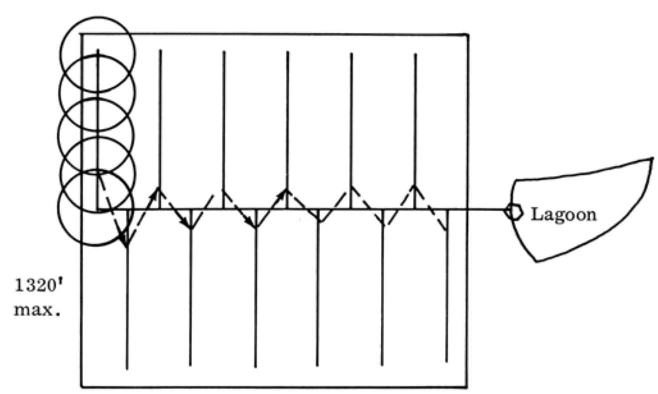
Speed of movement can be varied from ½ to 8 feet per minute, applying from 0.3 to 3.5 inches per application. Application rate is generally between 0.3 and 0.7 inches per hour.

Many of the units were designed to pull the hose around a "capstan" when changing positions but more recently a "hose reel" has been added which offers versatility in storing hose and changing positions; however, the cost of the reel is extra.

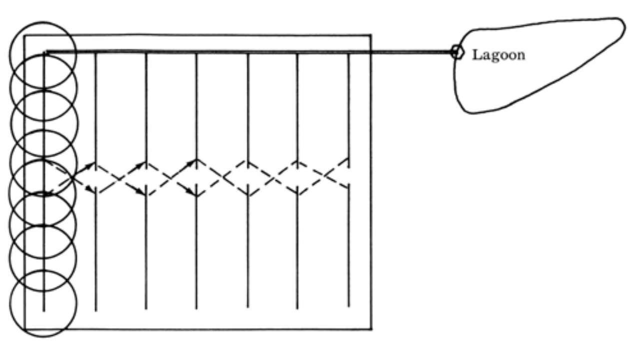
When possible, travel distances of not more than 1320 feet (¼ mile) should be selected so as to require a hose not greater than 660 feet. The traveling guns are adapted to irregular shaped fields and rough terrain. They cross a terrace best directly perpendicular to it. When row crops are to be irrigated, most units will require that 2 or 3 rows be left out of production (or mowed if rows are not straight) to provide lanes for the traveling unit.

Towline Sprinkler System (End-Tow Lateral). The towline system saves labor by enabling the towline to be towed from one set to another by a tractor. These systems generally have a lower initial cost and operating cost than traveling sprinkler systems. For corn, travel lanes and turn space are required, amounting to about 10 percent of the land area. Underground mainline pipe may be used, the mainline pipe may be disconnected for each move, or the mainline may be laid in a shallow V-ditch. The latter enables the operator to cross the mainline pipe, and is quite popular. A short (10-15′) flexible hose is used to connect the lateral to the mainline.

Towline systems are often designed for laterals spaced 60 feet apart, with sprinklers spaced 40 feet apart on the lateral. An 80′ x 60′ spacing is also used. The towline has special merit over hand carry systems for waste disposal because of the relative ease of moving the lateral line with little increase in cost. The following diagrams indicate possible towline layouts:



Mainline Pipe in Center of Field



Mainline Pipe at End of Field, Two Laterals Needed

Side-roll lateral, Boom, and Solid Set Sprinkler Systems. These systems have all been used for waste disposal systems, and adapt well if properly designed. Sprinkler spacing, pressure, nozzle diameters, and pipe diameters can all be sized similarly to hand-carry, portable sprinkler systems.

Side-roll lateral sprinkler systems adapt best to close-growing crops, and rectangular fields. The aluminum supply line is the axle for the lateral line. Boom sprinklers, somewhat obsolete for irrigation because of the labor involved, cover from 1¼ to 4 acres at a setting, and used systems may be available at a reasonable price.

Center-pivot Sprinkler Systems. The center pivot sprinkler system consists of a self-propelled sprinkler lateral pivoting around a central point. Although its high initial cost usually limits its applicability in livestock waste disposal systems, they can be used if the effluent is properly screened.

Surface Irrigation Design Considerations

Four types of surface irrigation are suited to disposal of liquid wastes: border irrigation, furrow irrigation, corrugations, and wild flooding.

Waste water can be supplied to the disposal field by gated pipe, lay-flat irrigation tubing, open ditches with spile tubes, open ditches with siphon tubes, or open ditches with turnout gates. Gated pipe or open ditches with turnout gates are recommended because of their ease of cleaning.*

Gated pipe is 4″ to 12″ diameter aluminum or plastic pipe, with openings or gates every 30 to 80 inches. This pipe is portable, giving flexibility to the system. The cost of gated pipe is greater than spile or siphon tubes, but less than sprinkler systems. Also, less labor is required, and the desired flow can be more easily managed.

Spile tubes are ¾″ to 3″ diameter tubes with stoppers installed in the bank of an open ditch. Construct a ditch pad approximately 9 inches wide and then form the ditch with a ditcher or blade. Control the flow with canvas, concrete, or metal check dams. Open ditches with spile tubes require a low investment, but labor and maintenance required may be quite high.

Waste water should not be applied to the disposal area unless the field is dry enough to travel over, and preferably drier. The border, furrow, or corrugation stream should be shut off before the waste water reaches the other end of the field to eliminate runoff. This should be done when the water is ⅔ to ¾ of the way to the end. Catching the runoff from the field in a basin and returning it to the irrigation system is another alternative.

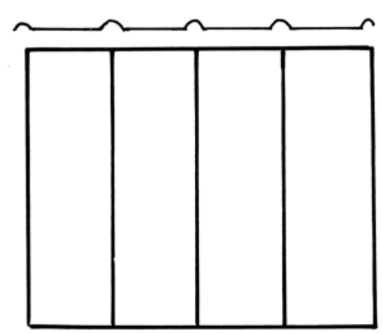
Although surface irrigation is not generally recommended on slopes steeper than 1 percent for furrow irrigation and 2 to 3 percent for border irrigation of close growing crops, steeper slopes may be used for waste disposal if the following conditions exist: a short run, a good grass cover, and small flow rates. The following table may be used as a guide:

TABLE 16 - MAXIMUM RECOMMENDED FLOW RATES THROUGH GATED PIPE, 30 to 40" Spacing

Q, gpm	40	25	16	12	10	5	2
Slope, %	0.2	0.4	0.6	0.8	1	2	5

Border Irrigation

Border irrigation consists of low parallel soil berms constructed in the direction of the maximum slope of the field. The berms or borders, are spaced from 30 feet to 100 feet apart. Forages, pasture, and other close growing crops can be irrigated with a border system.



Uniform water distribution depends on a sheet of water passing down through the border, with a depth of from 3 to 5 inches. Consequently, the fall between berms should not exceed .2 feet. Because of this limitation, border irrigation requires an even, gently sloping field, either naturally or through land grading. Berms may be spaced close together with a border maker, a road maintainer, or a rear blade behind a tractor.

Furrow Irrigation. Irrigation with furrows provides relatively uniform distribution of waste waters for row crops. Furrow irrigation is geneally not recommended on fields steeper than 1 percent. However, steeper slopes may

*The extra labor required of most surface irrigation systems may be desirable when disposing of liquid manure, changing gates, checking distance of flow, etc. A more expensive sprinkler system may be preferred for this reason.

Irrigation

be irrigated for short distances, Slopes up to 10 percent can be irrigated with contour furrows. Often some land grading is required for good water distribution.

The row crop may be planted on ridges, or the furrows may be constructed with disc or middlebuster furrow openers. Furrow flow rates should not exceed the carrying capacity of the furrow nor cause erosion. The following guide lines may be used:

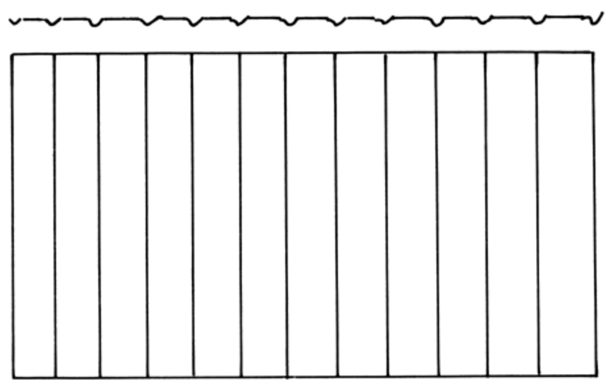
Corrugation Irrigation. Corrugations provide a means of irrigating relatively steep, irregular land by surface irrigation. Adapting best to close growing crops, the corrugations (V notches) are constructed by pulling a tool bar implement over the ground.

Pump Selection

Select a pump that has the capabilities to do the particular job. It is desirable to stir up the liquid wastes before pumping. This will minimize the amount of solids to be handled separately. A rotor aerator, a mechanical agitator, or a bypass can accomplish this. Increase the size of the power unit on a waste disposal pump by 10 percent to account for increased friction losses and specific gravity of livestock wastes.

Several different types of pumps are available for pumping liquid manure. Some of these have a chopper attachment for chopping the manure into finer particles, or a bypass for agitation by recirculation. Select a pump and power unit that will be able to handle a particular consistency of effluent for the required flow rate and pressure.

These V notches are generally spaced 30 to 40 inches apart. The guide lines for furrow flow rates may be used for corrugations, unless this exceeds the corrugation carrying capacity.



Controlled Flooding. Wild flooding generally refers to applying waste water to land with no control structures other than the distribution pipe or ditch. This method has a low initial cost, adapts to a wide range of irrigation flows, and can be used on close growing crops, rolling land and shallow soils. However, wild flooding often subdivides the field, has a high labor requirement, and uneven water distribution. An alternative system with a higher initial cost may be more economical in the long run.

One possible approach to wild flooding on rolling topography is to lay gated pipe on a terrace, and surface irrigate a close growing crop, such as a grass-legume mixture. Shut off the flow when the water nearly reaches the next terrace channel. This requires a great deal of labor, especially if the topography is fairly steep. If the field is not terraced, gated pipe may be laid out on an approximate contour line. Because the water will tend to concentrate, the water should be shut off, and the pipe relaid higher on the hill, about two terrace spacings. This system requires good management and considerable labor.

Vacuum pumps are generally mounted on a liquid manure tank wagon. A vacuum is created in the tank wagon which sucks the thick manure slurry from the pit. The pump is then reversed, building up pressure in the tank, and discharging its contents.

Other pumps that are suitable for pumping heavy slurries against low lifts include auger, diaphragm, submerged centrifugal, propeller, and self-priming centrifugal pumps. Submerged centrifugal pumps are pumps in which the centrifugal impellor is submerged in the liquid. Some centrifugal pumps, called self-priming, are located above the water level and are specially designed to eliminate priming.

Three types of pumps adapt to pumping heavy slurries against high pressures, such as through a manure gun sprinkler system: piston, worm, and submerged centrifugal pumps. These pumps do not require priming, and therefore can be adapted to automation relatively easily. Although all of these three pumps will handle thick slurries, their performance will be improved if dilution water is added. This extra volume is usually not a problem, especially if the system can handle large volumes easily, such as in an irrigation system.

Most irrigation pumps (vertical turbine pumps and centrifugal pumps) will handle livestock waste effluent that contains few solids, such as from a lagoon or detention basin. Open or semi-open impellors are desirable to minimize plugging. Maximum suction lifts of centrifugal pumps is generally 15 to 20 feet. Propeller pumps are specially suited to pumping large volumes of water against low heads. Liquids may be pumped off the top of a settling basin by locating the pump inlet on a float near the surface. Some centrifugal pumps designed to float on the surface also will accomplish this.

Waste disposal pumps may be powered by any power source: electric, gasoline, LP gas, diesel, or a tractor pto. Electric motors are most easily automated and generally require a minimum of maintenance. However, a service line may have to be constructed to the pumping location. Also, single phase service is generally restricted to 7½ to 10 horsepower.

Use of a farm tractor on a waste disposal pump decreases initial cost of the system. A set of safety cut-off switches should be installed on all pumping units for protection of the power unit.

Intake Screen

The selection and design of the intake screen on the suction side of the pump is very important. The largest size opening should never be larger than the smallest sprinkler, spile tube, or gate and all material should readily pass through the pump. The screen area should be as large as possible to minimize velocities into the screen and to eliminate plugging.

A trash guard with a 5 to 15 foot radius encircling the screen is often beneficial. The guard can be constructed with small diameter woven or meshed wire. A floating square of 2″ x 4″s around the intake would also be useful.

Name ______________________

WORK SHEET-7

Waste Disposal Irrigation System

1. Secure site information and make a sketch of soil plant filter area. Obtain all dimensions, locate buildings, boundaries, obstructions, elevations, and soil type.

   Soil-plant-filter, acres ________________

   Soil type ____________________________

   From Appendix Table 2, maximum application rate, inches/hour __________

2. Select the type of system that the operator prefers and size the distribution system to fit the capacity desired.

   Type of system __________________

   From system capacity (Table 16, 17) __________________

   a) For a hand-carry, end tow, or side-roll sprinkler system, select a sprinkler size, spacing, operating pressure, and lateral length and diameter that will cover the soil-plant-filter area in a reasonable number of moves. (Equipment costs would be excessive if two moves would cover the area. Similarly, labor would be excessive if 40 moves would be required to cover the acreage. Lateral lines should be sized so that lateral friction loss will not exceed 20 per cent of total operating pressure. For a shortcut method, refer to Appendix Table 19, "Pre-Engineered Sprinkler Lateral Lines."

   Sprinkler spacing _________ GPM/sprinkler _________

   Lateral operating pressure, psi _________ Lateral length _________

   Application rate, in./hr. _________ Total GPM _________

   Lateral diameter, in. _________ Number of moves/total area _________

   Acres per set _________

   b) For a traveling sprinkler system, select a sprinkler from Appendix Table 4, including type of nozzle, nozzle diameter, and operating pressure. Keep pressures fairly low to reduce horsepower demand.

   Nozzle type __________________ Nozzle diameter, inches ________

   Operating pressure, psi _______.

   Refer to Appendix Table 8. Determine the optimum lateral spacing. (70 to 75%) is commonly used). Quarter-mile runs require the least amount of labor. Divide the total area into rectangles with the dimensions of (lane spacing) times (2 hose lengths). Some fields may not require the full 660' of hose. Refer to Appendix Table 16. Determine hose diameter.

   Lane spacing, ft. _____________ Hose length, ft. ____________

   Number of sets/total area _________ Hose diameter, inches _______

c) The sprinkler main line for any of the systems above should be sized so that the friction loss in the main line should not exceed 15% of the total pump operating pressure. Psi and ft. of head are two units of measuring pressure. 1 psi = 2.31 ft. of head.

Refer to Appendix Table 12. Select a main line pipe size that has a friction loss no greater than 2.31 ft. of head (1 psi) per 100 ft. of pipe. This results in a maximum of 30 GPM for 2" main line, 85 GPM for main line, 180 GPM for 4" main line, 320 GPM for 5" main line, 550 GPM for 6" main line, 750 GPM for 7" main line, and 1000 GPM for 8" main line.

Main line pipe size, in. ________

From the sketch, determine length of main line needed __________ft.

From Appendix Table 12, determine total friction loss in main line ____________ft. of head

Add lateral operating pressure (X 2.31) ____________ft. of head

Add maximum elevation from lagoon to high point in field. (If lagoon is higher than the field, this can be a minus value) ____ft. of head.

If a traveling sprinkler system, add sprinkler operating pressure (X 2.31) = ___________ft. of head

Add flexible hose friction loss (X 2.31) = ___________ft. of head

Add 6' for elbows, fittings, etc. = ___________ft. of head

If a traveling gun sprinkler system add 10 to 14 ft. of head loss through machine ___________ft. of head

Total operating pressure___________ft. of head

Check to see that main line friction loss does not exceed 15% of total ft. of head. If not, adjust accordingly. To obtain total operating pressure in psi, divide above figure by 2.31.

d) For a gated pipe system, refer to Appendix Tables 12 and 15. Select a pipe diameter that has a friction loss less than 2.31 ft. of head (1 psi) 100 ft. of pipe. Pipe diameter, in. ___________

Total dynamic head (ft. of head) = friction loss in closed pipe + friction loss in pipe with open gates + elevation.

Closed pipe friction loss = (length of pipe without open gates) X (ft. of head loss/100 ft. of pipe) = _____ft.

Open gated pipe friction loss = (length of pipe with open gates) X (ft. of head loss/100 ft. of pipe) X (F value for the number of open gates, Appendix Table 18) = _____ft.

Elevation from water level at source to point where gates are open = _____ft.

TOTAL ________ft. of head

Note: The pumping condition usually limiting is when gates are opened on the far end of the pipeline. If the elevation at the far end of the gated pipeline is much lower than the gated pipe nearer the pump, check to see if the pressure requirement is greater for that pumping condition.

Note: If lagoon is higher than field, divide available ft. of head (elevation of lagoon surface above high point of field) by the length of pipe. The resulting figure is pipe friction loss per 100 ft. of pipe. Refer to Tables 12 and 15 to determine corresponding flow rate for a given pipe size.

3. Determine horsepower requirements.

$$\text{Brake horsepower} = \frac{\text{total ft. of head X gpm}}{\text{3960 X drive efficiency X pump efficiency}} = \underline{\qquad}\text{bhp.}$$

Brake horsepower is the horsepower demand of the pump on a continuous basis. Assume a pumping efficiency of 75% for new units of existing pumps in good adjustment. Drive efficiency for belts and gear heads is approximately 95%. Electric motors are rated on continuous brake horsepower for field conditions.

If a farm tractor will be used, the horsepower required by the pump should not exceed 75 per cent of the maximum belt or pto horsepower output. This maximum of 75 per cent would apply only when the tractor is in new or excellent condition. A lower percentage should be used for older tractors, perhaps dropping to 50 per cent or lower for tractor engines in only fair mechanical condition. See UMC Guide 1658, "Tractor Power For Irrigation Pumping."

$$\text{Size of tractor needed} = \frac{\text{brake hp}}{.75} = \underline{\qquad\quad}\text{ hp tractor.}$$

Internal combustion engine horsepower ratings are based on short power tests run under cool, sea level, conditions with no accessories on the engine. To correct for this, divide brake hp by the following factors:

Horsepower Rating Adjustment Of An Engine Considered For Irrigation Pumping

Conditions	Divide horsepower required to the pump (bhp) by:
Engine Accessories	.85
Maximum air temperature (degrees)	
110	.95
100	.96
90	.97
Elevation above sea level (feet)	
250	.99
500	.98
1000	.97
2000	.94
Continuous Service	.80

For example,

Internal combustion engine hp = $\frac{\text{brake hp}}{(.85)(.96)(.97)(.80)}$ ________engine hp.

4. Estimate approximate costs. Refer to Appendix Table 20.

Pipe _______ ft. of _____" diam @ $ 1 ft.	$___________
Sprinklers ________ at $ ________ each	$ ___________
Pump	$ ___________
Power Unit	$ ___________
Other	$ ___________
TOTAL	$ ___________

5. System Management.

Refer to Appendix Tables 10 and 11. Determine amount that can be applied without runoff. Assume 50% available moisture. _____inches/application.

Total application, inches = application rate in./hr. X hours of operation.

Hours of operation to apply 1" = $\frac{\text{(acres/set)(453)}}{\text{(system, capacity, gpm)}}$ _____hours/set.

Name Address Position

Signed ____

____

____

Irrigation Examples

Example 1.

A farmer has 250 head of finishing hogs and 30 sows in his buildings at one time. Each time the lagoon is to be pumped down 13 acre-inches, to go on 6 acres of soil plant filter. The soil plant filter is in corn, and can be surface irrigated. Its dimensions are 330' x 800', with the slope 800' long.

The lagoon lies 10' above some bottomland, and would require 1000' of pipe to irrigate the 6 acres by surface irrigation. Available footage of head is therefore 10/10, or 1 ft. of head for each 100 ft. of pipe. (Refer to Table 12.) Four-inch aluminum pipe would produce a flow of 120 gpm without a pump; 5 inch aluminum pipe will produce a flow of 190 gpm.

Although the slope is less than .3 percent in the field, allowing large furrow flow rates, 5 gpm furrow flow rates are chosen, allowing more acreage for settling. Distribution in the furrow is less desirable, but acceptable for waste disposal.

Assuming 5 gpm/furrow and a total flowrate of 120 gpm, 40 gates would be opened. From Table 21, 40 rows, 40 inches wide, 330 feet long, make a one acre set. This soil plant filter can be covered in 6 sets. From No. 5 in Work Sheet 6,

$$\text{Hours of operation to apply } 1'' = \frac{(1 \text{ acre/set})\ (453)}{(120 \text{ gpm})} = 3\ 3/4 \text{ hours per set.}$$

Thus, six, 7 1/2 hour sets would dispose of the 13 acre-inches on 6 acres of soil plant filter.

1000' of 4" gated pipe @ 33¢/ft. =	$330.00
Tube and valve in lagoon	$100.00
	$430.00

<u>Note</u>: As the velocity becomes quite low on the end of the gated pipe, it is desirable to strain out solids in the lagoon, and to flush the system.

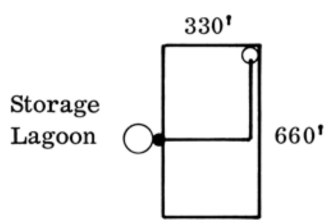
<u>Note</u>: 4" diameter gated pipe is generally not available, although used pipe could be converted. 4 1/4" diameter lay-flat irrigation tubing would cost about 35¢/ft., and would reduce the flow rate only by 20 gpm.

Example 2.

A farmer has 5 acres of soil plant filter, a silt loam soil in grass. Labor is no problem, and he wants the least cost system possible. The lowest cost pumps are often available through farm supply departments of large department stores. Pumps are available (roller or centrifugal) that will deliver 20 gpm at 100 psi. We will thus design the system for this pump.

Assume that the effluent is fairly thick, and therefore one single-nozzle sprinkler is most desirable. Refer to Table 10, Example 6a. This 5/16" single nozzle sprinkler would produce 20.0 gpm at 50 psi, would be moved 60' down the length of the lateral, and the lateral would be moved 90' along the mainline.

Assume the 5-acre soil plant filter is rectangular, located beside the lagoon:



As this sprinkler covers 125 acres per set, 5/.25 = 40 sets to cover the total area. Six hundred feet of main line pipe is required.

Table 14 shows 1 1/2" plastic pipe has a friction loss of 2.6'/100' of pipe.

2.6 x 6 = 15.6' of head.	Main friction loss	15.6' of head
Assume 8' of elevation from the lagoon to the high point in the field.	elevation	8.0'
Sprinkler operating pressure = 50 psi X 2.3 = 115'		115' of head
		138.6' of head

138.6/2.31 = 60 psi operating pressure.

Refer to Design Work Sheet.

Assume belt drive on a small internal combustion enginer (95% eff.)

$$\text{brake hp} = \frac{20\ (138.6)}{3960\ (.95)\ (.75)} = .98 \text{ brake hp}$$

Thus a 1 hp electric motor could power this pump.

$$\text{Internal combustion engine hp} = \frac{.98}{(.85)\ (.95)\ (.97)\ (.80)} = 1.5 \text{ hp}$$

Estimate costs. Refer to Table 20.

600' of 1 1/2" plastic pipe @ $.22/ft. =	$132
Fittings	$ 20
1 sprinkler and riser	$ 20
Pump	$ 80
	$252

Note: Before purchasing the 1 1/2" and 2" black plastic pipe, consider (a) the difficulty in moving the pipe without quick couplings such as in aluminum pipe, (b) the relative cost of aluminum pipe of the same diameter, and (c) the maximum allowable pressure of the black plastic pipe.

Example 3.

A large feedlot: a total of 10 acre-feet of liquids to be emptied onto 20 acres of soil plant filter.
10 acre-feet x 12"/foot = 120 acre-inches.
120 acre-inches ÷ 4 times emptying per year = 30 acre-inches.
30 acre-inches on 20 acres = a 1 1/2 inch application.

Assume a deep silt loam soil. From Table 2, maximum intake rate on 0 - 5% slope with cover is 0.5"/hr.

A traveling gun sprinkler system is being used.

From the table on system capacity, a 250 gpm system will pump out the 120 acres-inches in 218 hours of pumping, or 22 ten-hour days. Refer to Table 4. A 1.18" ring nozzle gun sprinkler will yield 245 gpm at 70 psi, with a wetted diameter of 330 ft.

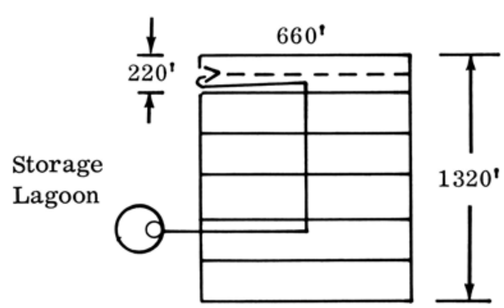
Refer to Table 6. The application rate of this 23° gun is approximately .34"/hr., which is acceptable if this soil has cover.

Refer to Table 8. Select a lane spacing of 70 percent of the wetted diameter or 230 feet. 220 feet is chosen because it enables the operator to cover the field in exactly 6 passes.

From Table 17, a 3" diameter flexible hose is required. A 330' length of flexible hose is chosen to reduce the initial investment. Approximately 45 hours of labor would be required to operate this system per year. The labor would be reduced by about 1/2 if a 660' length of hose is purchased. This would increase the initial cost of the system by $1000.00.

From Table 12, a pipe size with no greater friction loss than 1 psi/100 ft. of pipe for 250 gpm would be a 5" main line; with 1.63'/100 ft. of pipe.

From the sketch below, 1300' of 5" main line is required.



20 acres of soil plant filter

Main line friction loss = 1300 X 1.63'/100'	=	21.2' of head
Elevation from lagoon to high point of field	=	25' of head
From Table 17, hose friction loss, (330' of 3'' hose) = 11.9 psi X 2.31 ft./1 psi	=	27.5' of head
Sprinkler operating pressure = 70 psi X 2.31	=	161.6' of head
Add 6' for elbows, etc.	=	6'
Add 12' for friction loss through sprinkler machine	=	12'
Total Operating Pressure		253.3' of head

(253.3/2.31 = 110 psi)

Check to see that main line friction loss does not exceed 15% of total operating pressure. (.15) (253.3) = 38' of head, which is more than the main line loss.

Determine horsepower requirements. Assume pto, v-belt drive from tractor (95% efficiency), and 75% pump efficiency.

$$\text{Brake hp} = \frac{(253.3 \text{ ft. of head})\ (245 \text{ gpm})}{(3960)\ (.95)\ (.75)} = \underline{22 \text{ bhp}}$$

An electric motor of this size would be adequate.

$$\text{Size of tractor needed} = \frac{22}{.75} = \underline{29.4 \text{ hp tractor}}$$

Assuming 100°F maximum air temperature, and 1000' elevation,

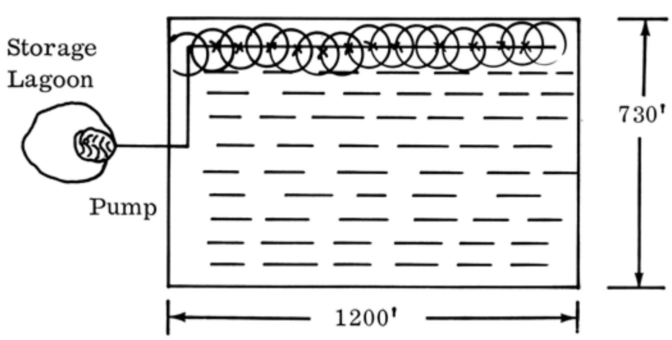
$$\text{Internal combustion engine hp} = \frac{22}{(.85)\ (.96)\ (.97)\ (.80)} = \underline{34.8 \text{ hp}}$$

To estimate costs, refer to Table 20.

Sprinkler system	$1600
330' of 3'' hose @ $3.50/ft.	$1150
1300' of 5'' Al. pipe @ $.85/ft.	$1100
Pump	$ 450
Total Cost	$4300

Example 4.

Same feedlot as Example 3, 300 gpm on 20 acres; hand carry sprinkler system, 50' x 90', 9 moves. See Table 19, Pre-Engineered Lateral Sprinkler Lines. Estimated labor required 70 hours per season.

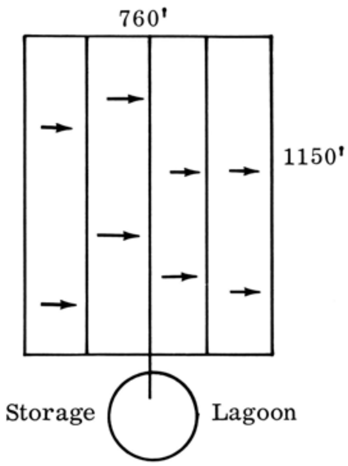


PTO Pump	$ 450.00
1700' of 5'' Al. pipe with couplers	1450.00
20 Sprinklers with risers @ $20 each	$ 400.00
	$2300.00

Note: A single gun hand carry system would cost about the same. This system would have less labor, a higher application rate, higher pressure and horsepower requirement.

Example 5.

Same feedlot, 300 gpm on 20 acres. Gated Pipe System, laid out on non-terraced rolling land, irrigating a grass-legume mix. Assume 6% slope. The maximum recommended pipe spacing is double the normal terrace spacing, or about 200 feet.



1600 of 5" gated pipe (450' of which has no gates) @ 85¢/ft.	=	\$1360.00
PTO Pump		\$ 200.00
		\$1560.00

Note: Although in this particular case pipe would have to be moved 4 times, the labor of changing gates would be similar to that for a hand carry sprinkler system. Good management is required. Also, if this field was terraces, the labor would about double, and the other systems would generally be more suited.

Example 6.

Manure Gun Sprinkler, 150 gpm, to dispose of waste on 6 to 8 acres, one acre/setting.

PTO Pump and Sprinkler	\$ 900.00
700' of 4" Aluminum Pipe @ 65¢/ft.	\$ 455.00
	\$1355.00

Example 7.

Hand carry sprinkler system, 140 gpm. Five 29 gpm sprinklers; one acre per setting will irrigate 6 to 8 acres with this amount of pipe.

PTO Pump	\$ 450.00
Sprinklers	\$ 185.00
700' of Aluminum Pipe	\$ 420.00
	\$1055.00

Example 8.

Traveling Small Gun Sprinkler System, 50 gpm.

Note: Components must be purchased separately and assembled. 1 1/2 acre/pass, 108' X 660'.

330' of 2 1/2" Hose	\$ 660.00
Sprinkler	\$ 35.00
800' of 2" Aluminum Pipe	\$ 224.00
Cable and Parts	\$ 80.00
Pump	\$ 200.00
	\$1199.00

APPENDIX

TABLE 1. UNITS OF MEASUREMENT

One gallon	=	231 cubic inches 8.3 lbs. 3.78 liters
One cubic foot	=	7.5 gallons 62.4 lbs.
One acre	=	43,560 sq. ft.
One acre-foot	=	43,560 cu. ft. 325,848 gallons
One acre-inch	=	3,621 cu. ft. 27,154 gallons 133 tons
One acre-inch per hour	=	450 gal. per minute 1 cubic foot per second
One pound per square inch	=	2.31 ft. of head 2.04 inches of mercury
One ft. of head	=	.433 psi
Atmosphere pressure	=	14.7 psi 33.9 ft. of head 29.92 inches of mercury

TABLE 2. SUGGESTED MAXIMUM WATER APPLICATION RATES FOR SPRINKLER SYSTEMS, INCHES PER HOUR

	0 - 5% Slope	
	w/cover	bare
1. Clay soils throughout; very poorly drained (Alligator, Carlow, Sharkey, Wabash).	.3"/hr.	.15"/hr.
2. Silty surface; poorly drained clay and claypan subsoils (Calhoun, Chariton, Edina, Gerald, Mexico, Putnam Mexico).	.4"/hr.	.25 hr.
3. Medium textured surface soils; moderate to imperfectly drained profile (Bates, Baxter, Eldon Fullerton, Nixa, Bates, Dundee, Grundy, Lindley, Pershing, Seymour).	.5"/hr.	.30"/hr.
4. Silt loams, loams and very fine sandy loams, well to moderately well drained (Knox, Marshall, Newtonia, Huntington, Nodaway, Sharon).	.6"/hr.	. 4"/hr.
5. Loamy sands, sandy loams, or peat soils, well drained (Bertrand, Cass, Dexter, Sarpy).	.9"/hr.	.6"/hr.

Note: Reduce precipitation rates on sloping ground:

Slope	Precipitation Rate Reduction
0 - 5% grade	0%
6 - 8% grade	20%
9 - 12% grade	40%
13 - 20% grade	60%
Over 20%	75%

Note: Design Application Rate should not exceed rates suggested above. Soils will usually absorb water at a faster rate than mentioned above if applied in light applications (3/4" to 1 1/2") when soil is dry.

TABLE 3

NOZZLE DISCHARGE-GPM AT 100% EFFICIENCY

	NOZZLE DIAMETER IN INCHES												
P.S.I.	1/16"	5/64"	3/32"	7/64"	1/8"	9/64"	5/32"	11/64"	3/16"	13/64"	7/32"	1/4"	9/32"
20	0.52	0.81	1.17	1.59	2.09	2.65	3.26	3.92	4.69	5.51	6.37	8.35	10.5
25	0.58	0.90	1.31	1.78	2.34	2.96	3.64	4.38	5.25	6 18	7.13	9.34	11.8
30	0.64	1.00	1.44	1.96	2.56	3.26	4.01	4.83	5.75	6.80	7.85	10.2	13.0
35	0.69	1.08	1.55	2.11	2.77	3.50	4.31	5.18	6.21	7.30	8.43	11.1	13.9
40	0.74	1.15	1.66	2.25	2.96	3.74	4.61	5.54	6.64	7.80	9.02	11.8	14.9
45	0.78	1.22	1.76	2.40	3.13	3.99	4.91	5.91	7.03	8.30	9.60	12.5	15.9
50	0.83	1.29	1.85	2.52	3.30	4.18	5.15	6.19	7.41	8.71	10.10	13.2	16.6
55	0.87	1.36	1.94	2.63	3.48	4.37	5.39	6.48	7.77	9.12	10.50	13.8	17.4
60	0.90	1.40	2.03	2.76	3.62	4.50	5.65	6.80	8.12	9.56	11.05	14.5	18.3
65	0.94	1.47	2.11	2.86	3.77	4.76	5.87	7.06	8.45	9.92	11.45	15.1	19.0
70	0.98	1.53	2.19	2.98	3.91	4.96	6.10	7.34	8.78	10.32	11.95	15.7	19.8
75	1.01	1.58	2.27	3.08	4.05	5.12	6.30	7.58	9.08	10.66	12.32	16.2	20.4
80	1.05	1.64	2.35	3.18	4.18	5.29	6.52	7.84	9.39	11.02	12.74	16.7	21.1
85	1.08	1.68	2.42	3.28	4.31	5.45	6.71	8.07	9.87	11.35	13.11	17.3	21.7
90	1.11	1.73	2.49	3.38	4.43	5.61	6.91	8.31	9.95	11.69	13.51	17.7	22.3
95	1.14	1.78	2.56	3.46	4.56	5.76	7.09	8.53	10.2	11.99	13.86	18.2	22.9
100	1.17	1.83	2.63	3.56	4.67	5.91	7.29	8.76	10.5	12.32	14.23	18.7	23.5

TABLE 4

PERFORMANCE OF LARGE GUN SPRINKLERS

TAPER BORE NOZZLE		TAPER BORE NOZZLE, 23°													
		NOZZLE .7"		NOZZLE .8"		NOZZLE .9"		NOZZLE 1.0"		NOZZLE 1.1"		NOZZLE 1.2"		NOZZLE 1.3"	
	P.S.I.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.
--Greatest Stream Integrity	60	110	265	143	285	182	305	225	325	275	345	330	365	385	380
	70	120	280	155	300	197	320	245	340	295	360	355	380	415	395
--Longest Distance Of Throw	80	128	290	165	310	210	335	260	355	315	375	380	395	445	410
	90	136	200	175	320	223	345	275	365	335	390	405	410	475	425
	100	141	310	185	330	235	355	280	375	355	400	425	420	500	440
--Minimum Wind Distortion	110	150	320	195	340	247	365	305	385	370	410	445	430	525	450
	120	157	330	204	350	258	375	320	395	385	420	465	440	545	460

		RING NOZZLE, 23°													
		RING .86"		RING .97"		RING 1.08"		RING 1.18"		RING 1.26"		RING 1.34"		RING 1.41"	
RING NOZZLE	P.S.I.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.
--Better Stream Break Up For Delicate Crops and Lower Pressure Operation	60	110	260	143	280	182	300	225	315	275	335	330	350	385	365
	70	120	270	155	290	197	310	245	330	295	350	355	365	415	380
	80	128	280	165	300	210	320	260	340	315	360	380	380	445	395
	90	135	290	175	310	223	330	275	350	335	370	405	390	475	405
--Flexibility In Nozzle Sizes	100	143	300	185	320	235	340	290	360	355	380	425	400	500	415
	110	150	310	195	330	247	350	305	370	370	390	445	410	525	425
	120	157	315	204	335	258	360	320	380	385	400	465	420	545	435

TABLE 5
APPLICATION RATES, INCHES PER HOUR

TABLE OF APPLICATION RATES, INCHES PER HOUR

SPACING FEET	GALLONS PER MINUTE FROM EACH SPRINKLER																			
	.5	.75	1	2	3	4	5	6	8	10	12	15	18	20	25	30	35	40	45	50
10 x 10	.48	.72	.96	1.93																
10 x 15	.32	.48	.64	1.28	1.93															
20 x 20	.12	.18	.24	.48	.72	.96	1.20	1.44	1.92											
20 x 30	.08	.12	.16	.32	.48	.64	.80	.96	1.28	1.60	1.93									
20 x 40	.06	.09	.12	.24	.36	.48	.60	.72	.96	1.20	1.45	1.81	2.17							
20 x 50	.05	.07	.10	.19	.29	.39	.48	.58	.77	.96	1.15	1.45	1.73	1.93						
20 x 60	.04	.06	.08	.16	.24	.32	.40	.48	.64	.80	.96	1.20	1.44	1.60	2.00					
25 x 25		.08	.11	.31	.46	.62	.77	.92	1.23	1.54	1.85	2.31								
30 x 30			.08	.21	.32	.43	.54	.64	.86	1.07	1.28	1.61	1.93	2.14						
30 x 40				.16	.24	.32	.40	.48	.64	.80	.96	1.20	1.45	1.61	2.01	2.40				
30 x 50				.13	.19	.26	.32	.38	.51	.64	.76	.96	1.15	1.28	1.60	1.92				
30 x 60				.11	.16	.21	.27	.32	.43	.53	.64	.80	.96	1.07	1.54	1.61	1.87	2.14		
40 x 40				.12	.18	.24	.30	.36	.48	.60	.72	.90	1.08	1.20	1.50	1.80	2.10	2.40		
40 x 50				.10	.14	.19	.24	.29	.38	.48	.58	.72	.86	.96	1.20	1.44	1.68	1.92	2.16	
40 x 60					.12	.16	.20	.24	.32	.40	.48	.60	.72	.80	1.00	1.20	1.40	1.60	1.80	2.00
40 x 70					.10	.14	.17	.21	.28	.34	.41	.52	.62	.69	.86	1.03	1.20	1.38	1.55	1.72
40 x 80					.09	.12	.15	.18	.24	.30	.36	.45	.54	.60	.75	.90	1.05	1.20	1.35	1.50
50 x 50					.12	.15	.19	.23	.31	.39	.46	.58	.69	.77	.96	1.15	1.35	1.54	1.73	1.92
50 x 60					.10	.13	.16	.19	.26	.32	.39	.48	.58	.64	.80	.96	1.12	1.28	1.44	1.60
50 x 70						.11	.14	.17	.22	.28	.33	.41	.49	.55	.69	.82	.96	1.10	1.24	1.37
60 x 60						.11	.13	.16	.21	.27	.32	.40	.48	.53	.67	.80	.93	1.07	1.20	1.34
60 x 70							.11	.14	.18	.23	.27	.34	.41	.46	.57	.69	.80	.92	1.03	1.15
60 x 80							.10	.12	.16	.20	.24	.30	.36	.40	.50	.60	.70	.80	.90	1.00
70 x 70							.10	.12	.16	.20	.24	.29	.35	.39	.49	.59	.69	.79	.88	.98
70 x 80								.10	.14	.19	.21	.26	.31	.34	.43	.52	.60	.69	.77	.86
70 x 90									.12	.15	.18	.23	.28	.30	.38	.46	.54	.61	.69	.76
80 x 80									.12	.15	.18	.23	.27	.30	.38	.45	.53	.60	.68	.75
80 x 90									.11	.13	.16	.20	.24	.27	.33	.40	.47	.53	.60	.67
80 x 100									.10	.12	.14	.18	.22	.24	.30	.36	.42	.48	.54	.60
100 x 100										.10	.12	.14	.17	.19	.24	.29	.34	.39	.43	.48

Formula:

$$\text{Application rate In/Hr.} = \frac{96.3 \times \text{Sprinkler G.P.M.}}{\text{Net area covered by sprinkler (ft}^2\text{)}}$$

The indicated diameters in this catalog are obtainable when operating without wind and with: 6" riser pipe for discharges up to 10 GPM, 9" riser pipe for discharges from 10 GPM to 26 GPM, 12" riser pipe for discharges from 26 GPM to 50 GPM and 18" riser pipe for discharges above 50 GPM.

Total Depth of Application = Application Rate, in./hr. x Hours of Operation

TABLE 6
AVERAGE APPLICATION RATES OF FULL CIRCLE GUN SPRINKLERS

Ring Nozzles			Taper Bore Nozzles		
Nozzle Size In.	Trajectory Angle Degrees	Appl. Rate In./Hr.	Nozzle Size In.	Trajectory Angle Degrees	Appl. Rate In./Hr.
1 1/4	27	0.30	1.05	27	0.28
	21	0.33		21	0.31
1 3/8	27	0.33	1.2	27	0.32
	21	0.37		21	0.35
1 1/2	27	0.36	1.3	27	0.34
	21	0.39		21	0.375
1 5/8	27	0.38	1.4	27	0.35
	21	0.42		21	0.40
1 3/4	27	0.40	1.5	27	0.37
	21	0.44		21	0.41
1 7/8	27	0.43	1.6	27	0.38
	21	0.47		21	0.43
2	27	0.47	1.75	27	0.41
	21	0.52		21	0.46

Formula: $$\text{Application Rate In./Hr.} = \frac{110.0 \times \text{Sprinkler GPM}}{\text{Area of Wetted Circle, Sq. Ft.}}$$

Note: The application rate of Sprinklers is independent of operating pressure when within the range in Table 4.

TABLE 7

SPRINKLER SPACING GUIDES
Hand Carry, Towline, Solid Set, and Side Roll Systems

Square Spacing, Maximum Distance

- 60% of Wetted Diameter With Winds Up to 4 Mph
- 50% of Wetted Diameter With Winds Up to 8 Mph

Rectangular Spacing, Maximum Distance

- For Winds Up to 8 mph
- Spacing of Sprinklers on Lateral = 45% of Wetted Diameter
- Spacing of Laterals on Main Line = 65% of Wetted Diameter

TABLE 8
MAXIMUM TRAVEL LANE SPACING (FEET) FOR TRAVELING SPRINKLER SYSTEMS

Sprinkler Wetted Diameter Feet	Percent of Wetted Diameter						
	50	55	60	65	70	75	80
	Wind Over 10 MPH		Wind Up To 10 MPH		Wind Up To 5 MPH		No Wind
200	100	110	120	130	140	150	160
250	125	137	150	162	175	187	200
300	150	165	180	195	210	225	240
350	175	192	210	227	245	262	280
400	200	220	240	260	280	300	320
450	225	248	270	292	315	338	360
500	250	275	300	325	350	375	400
550	275	302	330	358	385	412	440
600	300	330	360	390	420	—	—

TABLE 9

TRAVELING SPRINKLER SYSTEM FORMULAS

$$\text{Application Rate, In./hr.} = \frac{110.0 \times \text{Sprinkler GPM}}{\text{Area of Wetted Circle, Sq.Ft.}}$$

$$\text{Acres Irrigated Per Hour} = \frac{\text{Travel Speed, Ft./Min.} \times \text{Spacing Between Runs, Ft.}}{726}$$

$$\text{Acres Irrigated Per 1/4 Mile Travel} = \frac{\text{Lane Spacing, Ft.}}{33}$$

$$\text{Hours Required Per 1/4 Mile Travel} = \frac{22}{\text{Travel Speed, ft./min.}}$$

$$\text{Average Water Depth Applied, Inches} = \frac{1.605 \times \text{Sprinkler GPM}}{\text{Lane Spacing, Ft.} \times \text{Travel Speed, Ft./Min.}}$$

TABLE 10

FEEL AND APPEARANCE GUIDE FOR DETERMINING SOIL MOISTURE

Moisture Condition	Percent of available moisture remaining in soil	SOIL TEXTURE		
		Sands - Sandy Loams	Loams - Silt Loams	Clay Loams - Clay
Dry	0% Wilting Point	Dry, loose, flows through fingers.	Powdery, sometimes slightly crusted but easily broken down into powdery condition.	Hard, baked, cracked; difficult to break down into powdery condition.
Low	50% or less	Loose, can't feel moistness.	Will form a weak ball when squeezed but won't stick to tools.	Pliable, but not slick, will ball under pressure - sticks to tools.
		TIME TO IRRIGATE		
Fair	50 to 75%	Tends to ball under pressure but seldom will hold together when bounced in the hand.	Forms a ball somewhat plastic, will slick slightly with pressure. Doesn't stick to tools.	Forms a ball, will ribbon out between thumb and forefinger, has a slick feeling.
Good	75 to 100%	Forms a weak ball, breaks easily when bounced in the hand, can feel moistness in soil.	Forms a ball, very pliable, slicks readily, clings slightly to tools.	Easily ribbons out between thumb and forefinger, has a slick feeling, very sticky.
Ideal	Field Capacity 100%	Soil mass will cling together. Upon squeezing, outline of ball is left on hand.	Wet outline of ball is left on hand when soil is squeezed. Sticks to tools.	Wet outline of ball is left on hand when soil is squeezed. Sticky enough to cling to fingers.

TABLE 11

AMOUNT OF MOISTURE TO APPLY TO VARIOUS SOILS UNDER DIFFERENT MOISTURE RETENTION CONDITIONS

Soil Type	Root Zone Depth	Available Moisture Plant Use	Net Inches to Apply Per Irrigation With Various Percents Available Moisture Retained in the Soil at Irrigation		
	Feet	Inches	67%	50%	33%
Light Sandy	1	1.00	0.33	0.50	0.67
	1½	1.50	0.50	0.75	1.00
	2	2.00	0.56	1.00	1.33
	2½	2.50	0.83	1.25	1.67
	3	3.00	0.99	1.50	2.00
Medium	1	1.69	0.57	0.85	1.13
	1½	2.53	0.84	1.26	1.70
	2	3.38	1.11	1.69	2.26
	2½	4.21	1.39	2.11	2.82
	3	5.06	1.67	2.53	3.38
Heavy	1	2.39	0.79	1.20	1.59
	1½	3.58	1.18	1.79	2.38
	2	4.78	1.58	2.39	3.25
	2½	5.97	1.97	2.98	3.97
	3	7.17	2.36	3.58	4.77

TABLE 12

FRICTION LOSS IN FEET OF HEAD FOR 100 FEET OF PIPE–ALUMINUM PIPE WITH COUPLERS

Gallons Per Minute	1" O.D.	2" O.D.	3" O.D.	4" O.D.	5" O.D.	6" O.D.	7" O.D.	8" O.D.	10" O.D.	12" O.D.
2	.44									
4	1.58									
6	3.32									
8	6.12	.18								
10	9.12	.27								
12	13.28	.38								
16	22.96	.66								
20		1.02	.14							
30		2.19	.30							
40		3.82	.53							
50		5.82	.80							
60		8.22	1.14							
70		11.01	1.51							
80		14.19	1.94							
90		17.68	2.42							
100				0.81	0.28					
200				3.01	1.02	0.42				
300				6.61	2.24	0.92	0.42			
400				10.21	3.69	1.50	0.72	0.37		
500				15.3	5.20	2.19	0.99	0.55	0.18	
600				21.8	7.60	3.19	1.48	0.79	0.25	
700					10.52	4.13	1.89	1.04	0.35	0.14
800					12.5	5.29	2.40	1.27	0.42	0.18
900					15.7	6.59	3.05	1.57	0.53	0.22
1000					19.1	7.95	3.69	1.89	0.65	0.28
1200					26.9	11.52	5.41	2.72	0.95	0.39
1400						14.7	7.30	3.79	1.25	0.53
1600						18.8	9.28	4.90	1.60	0.67
1800						23.6	11.01	6.01	2.01	0.83
2000							13.7	7.30	2.35	0.99
2500									3.91	1.59
3000										2.23

TABLE 13

FRICTION LOSS IN FEET OF HEAD FOR 100 FEET OF PIPE

PLASTIC PIPE

Gallons Per Minute	4"	5"	6"	7"	8"	10"	12"
100	0.55	0.18					
200	1.98	0.64	0.28	0.14			
300	4.19	1.38	0.58	0.28	0.14		
400	7.14	2.42	0.99	0.46	0.23		
500	11.0	3.68	1.52	0.71	0.37	0.12	
600		5.13	2.12	1.01	0.48	0.18	
700		6.90	2.83	1.34	0.69	0.23	
800		8.93	3.64	1.69	0.90	0.299	0.12
900		11.15	4.60	2.15	1.10	0.27	0.14
1000			5.50	2.56	1.36	0.46	0.18
1200			7.78	3.66	1.91	0.65	0.25
1400			9.74	4.84	2.50	0.83	0.35
1600				6.21	3.24	1.08	0.46
1800				7.80	4.09	1.36	0.55
2000				9.49	5.01	1.68	0.69
2500					8.60	2.8	1.0
3000					10.2	3.2	1.5

TABLE 14

FRICTION LOSS IN FEET OF HEAD FOR 100 FEET OF PIPE

PLASTIC PIPE

Gallons Per Minute	PIPE SIZE								
	1/2"	3/4"	1"	1¼"	1½"	2"	2½"	3"	4"
2	3.7	1.0							
5	21.0	5.0	1.7	0.5	0.2				
10	73.5	19.0	5.9	1.6	0.7	0.3	0.1		
15		40.0	12.5	3.3	1.5	0.6	0.2	0.1	
20		68.0	21.0	5.6	2.6	0.9	0.3	0.2	
30			44.5	11.5	5.5	1.9	0.7	0.3	
40			76.0	20.0	9.4	3.3	1.1	0.5	0.1
50				30.0	14.2	5.0	1.7	0.7	0.2
75				64.5	30.0	10.5	3.6	1.5	0.4
100					51.0	17.9	6.0	2.5	0.6

TABLE 15

FRICTION LOSS IN FEET OF HEAD FOR 100 FEET OF PIPE

LAY-FLAT IRRIGATION TUBING

Gallons Per Minute	Pressure Units	4"	6"	8"	10"	12"	14"	16"
100	Ft.	1.06	.13					
200	Ft.	3.60	.48					
300	Ft.		1.07	.11				
400	Ft.		1.82	.25	.14			
500	Ft.		2.90	.68	.22			
600	Ft.		4.10	.95	.32	.12		
700	Ft.			1.20	.40	.15		
800	Ft.			1.67	.54	.21		
900	Ft.			2.05	.67	.27	.12	
1000	Ft.			2.55	.83	.33	.15	
1200	Ft.			3.50	1.12	.45	.21	.10
1400	Ft.				1.53	.61	.28	.14
1600	Ft.				2.00	.80	.37	.19
1800	Ft.				2.50	1.00	.46	.23
2000	Ft.				3.10	1.22	.56	.28
2500	Ft.					1.90	.87	.43
3000	Ft.					2.70	1.21	.62

TABLE 16a

FRICTION LOSS IN FEET OF HEAD FOR 100 FEET OF PIPE
AVERAGE STEEL PIPE

Gallons Per Minute	Pressure Units	PIPE SIZE							
		1/2"	3/4"	1"	1¼"	1½"	2"	2½"	3"
2	Ft.	7.4	1.9						
5	Ft.	42.0	10.0	3.3	0.9	0.4			
10	Ft.	147.0	38.0	11.7	3.1	1.4	0.5	0.2	0.1
15	Ft.		80.0	25.0	6.5	3.0	1.1	0.4	0.2
20	Ft.		136.0	42.0	11.1	5.2	1.8	0.6	0.3
30	Ft.			89.0	23.0	11.0	3.8	1.3	0.5
40	Ft.			151.0	40.0	18.8	6.6	2.2	0.9
50	Ft.				60.0	28.4	9.9	3.3	1.4
75	Ft.				129.0	60.0	20.9	7.1	3.0
100	Ft.					102.0	35.8	12.0	5.0

TABLE 16b

FRICTION LOSS IN FEET PER 100 FEET IN MAIN LINES OF WELDED STEEL PIPE 15 YEARS OLD

Flow Gallons Per Minute	4-inch[1]			5-inch[1]		6-inch[1]		7-inch[1]		8-inch[1]		10-inch[1]	
	16-Gage	14-Gage	12-Gage	14-Gage	12-Gage	14-Gage	12-Gage	14-Gage	12-Gage	14-Gage	12-Gage	14-Gage	12-Gage
40	0.150	0.155	0.169	0.048	0.052								
50	.218	.227	.246	.074	.080								
60	.300	.312	.339	.106	.113								
70	.393	.411	.444	.142	.151								
80	.558	.579	.628	.182	.193	0.074	0.079						
90	.677	.709	.768	.228	.242	.091	.096						
100	.810	.848	.920	.279	.296	.109	.115	0.052	0.054				
125	1.28	1.34	1.45	.425	.452	.172	.181	.079	.082				
150	1.76	1.83	1.99	.602	.640	.235	.249	.111	.116				
175	2.42	2.52	2.73	.807	.857	.323	.341	.148	.155	0.075	0.080		
200	3.04	3.17	3.44	1.04	1.10	.407	.429	.191	.200	.096	.100		
250	4.79	5.01	5.43	1.59	1.69	.643	.678	.292	.306	.152	.159	0.050	0.052
300	6.74	7.04	7.63	2.25	2.39	.903	.953	.414	.432	.215	.223	.070	.072
350	8.99	9.41	10.2	3.01	3.23	1.21	1.27	.555	.579	.287	.297	.095	.097
400	11.5	12.1	13.1	3.88	4.12	1.55	1.63	.714	.746	.369	.381	.120	.124
450	14.4	15.3	16.2	4.85	5.16	1.94	2.04	.894	.934	.458	.476	.150	.155
500	17.6	18.6	19.9	5.93	6.30	2.36	2.49	1.09	1.14	.559	.580	.183	.189
600				8.38	8.91	3.39	3.57	1.54	1.61	.801	.834	.263	.271
700				11.2	11.9	4.51	4.76	2.07	2.16	1.07	1.11	.352	.361
800				14.5	15.4	5.79	6.10	2.67	2.79	1.37	1.42	.450	.464
900						7.28	7.68	3.34	3.48	1.73	1.79	.573	.584
1000						8.90	9.38	4.08	4.26	2.11	2.18	.694	.712
1200						12.5	13.2	5.76	6.02	3.04	3.07	.977	1.00
1400								7.73	8.07	3.98	4.14	1.30	1.35
1600								9.96	10.4	5.13	5.33	1.68	1.74
1800										6.43	6.66	2.12	2.17
2000										7.86	8.18	2.62	2.65
2500										12.0	12.5	3.97	4.05
3000												5.52	5.74

[1]Outside Diameters.

TABLE 17

ESTIMATED PRESSURE LOSS IN P.S.I. FOR HIGH PRESSURE
FLEXIBLE HOSE WHEN OPERATING AT ABOUT 100 P.S.I

	Nominal Inside Diameter, Inches							
	2½ (0-150 GPM)		3 (150-250 GPM)		4 (300-500 GPM)		5 (550-1000 GPM)	
GPM	Per 100 Ft.	Per 660 Ft. Length	Per 100 Ft.	Per 660 Ft. Length	Per 100 Ft.	Per 660 Ft. Length	Per 100 Ft.	Per 660 Ft. Length
100	1.6	10.6	--	--	--	--	--	--
150	3.4	22.4	1.4	9.3	--	--	--	--
200	5.6	37.0	2.4	15.8	--	--	--	--
250	--	--	3.6	23.8	0.95	6.3	--	--
300	--	--	5.1	33.6	1.35	8.9	--	--
400	--	--	--	--	2.3	15.2	--	--
500	--	--	--	--	3.5	23.1	1.1	7.3
600	--	--	--	--	4.9	32.4	1.6	10.6
700	--	--	--	--	--	--	2.1	13.9
800	--	--	--	--	--	--	2.7	17.8
900	--	--	--	--	--	--	3.4	22.4
1000	--	--	--	--	--	--	4.2	27.7

TABLE 18
"F" VALUES BY WHICH THE FRICTION LOSS IN PIPE MUST BE MULTIPLIED TO OBTAIN THE ACTUAL LOSS IN A SPRINKLER OR GATED PIPE LATERAL

NUMBER OF SPRINKLERS	"F"
1	1.0
2	0.625
3	0.518
4	0.469
5	0.440
6	0.421
7	0.408
8	0.398
9	0.391
10	0.385
12	0.376
14	0.370
16	0.365
18	0.361
20	0.359
22	0.357
24	0.355
26	0.353
28	0.351
30	0.350
35	0.347
40	0.345
50	0.343
100	0.338
00	0.333

TABLE 19
PRE-ENGINEERED SPRINKLER LATERAL LINES

1) 40'x60' Spacing,* Rainbird 40BW or Equivalent,*** 5/32" Nozzle Diameter, 40 psi, 4.45 GPM, 93' Wetted Diameter, 18"/hour Application Rate

Length of Lateral	140	180	220	260	300	340	380	460	540	620	700	780	860	940	1020	1100	1180	1260	1300	1380
No. Of Sprink-lers	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30	32	33	35
Acres Per Set	.23	.28	.33	.39	.44	.50	.55	.61	.77	.88	.99	1.10	1.21	1.32	1.43	1.54	1.65	1.76	1.82	1.93
Total GPM	17.8	22.2	26.7	31.2	35.6	40.0	44.5	53.4	62.2	71.1	80.0	89.0	97.9	101	106	125	133	142	147	156
Tubing Size**	1½" Al. or Plas.	1½" Al. or Plas.	1½" Al. or Plas.	1½" Al. or Plas.	1½" Al. or Plas.	2" Al.	2" Al.	3" Al.	3" Al.	3" Al.	3"	3"	3"	3"	4"	4"	4"	4"	4"	4"
Lateral Opera-ting Pres-sure, Psi	41	42	43	45	42	44	45	41	41	42	43	44	45	46	42	42	43	43	43	44

*40'x60' Spacing Indicated 40' Sprinkler Spacings on Lateral; Laterals Spaced 60' Apart on Mainline.

**Tubing Size is for Aluminum Unless Otherwise Specified.

***Minimum Riser Height, 6"

Note:Endorsement of any companies equipment is not intended. Mentioning the specific model number assists in identifying the desired sprinkler characteristics.

Note:Design #1 is especially adapted to low capacity, low pressure systems, using small pipe. The larger spacings generally cost more, have a higher horsepower requirement, but require less moves per acre.

Note:Friction loss in lateral pipe line should not exceed 20% of total operating pressure.

Note:A 40'x60' spacing indicated sprinklers are 40' apart on the lateral, laterals are spaced 60' apart on the main line.

Note:Proper screening is more critical on small nozzles.

TABLE 19 (Continued)

2) 40'x60' Spacing, Rainbird 30WS or Equivalent,* 3/16" Nozzle Diameter, 50 psi, 7.18 GPM, 100' Wetted Diameter, .29"/hour.

Length of Lateral	100	140	180	220	260	300	340	380	460	540	620	700	780	860	940	1020	1100	1180	1260	1300	1380
No. of Sprinklers	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30	32	33	35
Acres Per Set	.18	.23	.28	.33	.39	.44	.50	.55	.61	.77	.88	.99	1.10	1.21	1.32	1.43	1.54	1.65	1.76	1.82	1.93
Total GPM	21.5	28.7	35.8	43.1	50.2	57.4	65.5	71.7	86.0	10.0	11.5	12.9	14.3	15.8	17.2	18.6	20.0	21.5	22.9	23.6	25.1
Tubing Size	1½" Plas. or Al.	1½" Plas. or Al.	2" Al.	2" Al.	2"	2"	3"	3"	3"	3"	3"	4"	4"	4"	4"	4"	4"	4"	4"	4"	4"
Lateral Operating Pressure, psi	51	51	52	53	54	56	51	51	52	54	55	57	52	53	54	54	55	56	58	58	60

imum Riser Height, 6"

3) 60'X60' Spacing, Rainbird 14600 W-TNT or Equivalent,* 3/16" Nozzle Diameter, 60 psi, 7.82 GPM, 111' Wetted Diameter, .21"/hour Application Rate.

Length of Lateral	120	150	210	270	330	390	450	510	570	630	690	750	810	870	930	990	1050	1110	1170	1290	1350	1410
No. of Sprinklers	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	24
Total GPM	15.6	23.4	31.3	39.1	46.9	54.7	62.5	70.4	78.2	86.0	93.9	102	109	117	125	133	141	149	156	172	180	188
Acres Per Set	.17	.25	.33	.41	.50	.58	.67	.74	.83	.91	.99	1.08	1.16	1.24	1.32	1.41	1.49	1.57	1.65	1.82	1.90	1.97
Tubing Size	1½" Al. or Plas.	1½" Al. or Plas.	1½" Al. or Plas.	2"	2"	2"	3"	3"	3"	3"	3"	3"	3"	3"	4"	4"	4"	4"	4"	4"	4"	4"
Lateral Operating Pressure, psi	62	64	66	66	63	65	67	61	62	64	65	66	67	62	62	63	63	63	64	65	65	66

*Minimum Riser Height, 6".

TABLE 19 (Continued)

4) 60'x90' Spacing, Rainbird 70EW or Equivalent,* 1/4" Nozzle Diameter, 65 psi, 14.8 GPM, 142' Diameter, .26"/hour Application Rate.

Length of Lateral	0	90	150	210	270	330	390	450	510	570	630	690	750	810	870	930	990	1050	1110	1170	1290	1350
No. of Sprinklers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24
Acres Per Set	.12	.24	.37	.50	.62	.74	.87	.99	1.11	1.24	1.36	1.48	1.61	1.73	1.85	1.98	2.10	2.22	2.35	2.48	2.72	2.97
Total GPM	14.8	29.6	44.4	59.1	74.0	88.9	103.7	118.5	133.2	148.0	163.0	177.6	192.3	207.8	222.0	236.4	251.8	266.2	281.5	296.0	326.0	355.0
Tubing Size	Main Line Size	1½" Al. or Plas.	2"	2"	3"	3"	3"	3"	3"	3"	4"	4"	4"	4"	4"	4"	5"	5"	5"	5"	5"	5"
Lateral Operating Pressure, psi	65	73	69	72	67	67	68	69	71	73	67	68	69	70	71	72	68	68	69	69	70	70

*Minimum riser height, 9"

5) 80'x120' Spacing, Rainbird 80EW or Equivalent* 7/16" Nozzle Diameter, 75 psi, 46.8 GPM, 184' Wetted Diameter, .47"/hr. Application Rate.

Length Of Lateral	0	120	200	280	360	440	520	600	680	760	840	920	1000	1080	1160	1240	1320	1400
No. of Sprinklers	1	2	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Acres Per Set	.22	.44	.66	.88	1.10	1.32	1.54	1.76	1.98	2.20	2.42	2.64	2.86	3.08	3.30	3.52	3.74	3.96
Total GPM	46.8	93.5	140	187	234	281	328	374	421	468	515	561	607	655	701	748	795	841
Tubing Size	Main Line Size	3"	3"	4"	4"	4"	4"	5"	5"	5"	6"	6"	6"	6"	7"	7"	8"	8"
Lateral Operating Pressure Psi	75	78	81	77	79	81	83	79	80	82	79	80	82	83	80	81	79	80

*Minimum riser height 12"

TABLE 19 (Continued)

6) SMALL, SINGLE NOZZLE SYSTEMS

To reduce pipe and pipe size, small single nozzle systems may be designed, using a single nozzle and moving it many times. The sprinkler sizes, operating pressures, and spacing between moves mentioned above are applicable. Consider all pipe line out to the sprinkler as mainline and design it as described in the design worksheet.

Additional possibilities for single nozzle sprinklers are:

a. 20.0 gpm, Rainbird 70EW or equivalent, 5/16" single nozzle, 50 psi, 140' wetted diameter, 60'x90' spacing .35"/hr. application rate, .125 acres set.

b. 26.2 gpm, Rainbird 70EW or equivalent, 22/32" single nozzle, 60 psi, 156' wetted diameter, 36"/hr, 70'x100' spacing, .16 acres/set.

c. Same sprinkler as above; increase to 65 psi for 80'x90' spacing.

d. 84 gpm, Rainbird 90-TNT or equivalent, 1/2"x5/16" nozzles, 70 psi, 210' wetted diameter, 100'x120' or 90'x120' spacing. Approximate application rate, .35"/hr.

7) MANURE GUN SYSTEM

Refer to Tables 4 and 7.

a. 180'x180' spacing, .7" nozzle diameter, 60 psi, 110 GPM, 250' wetted diameter, .36"/hr. application rate, .82 acre/setting.

b. 240'x240' spacing, .9" nozzle diameter, 80 psi, 220 GPM, 340' wetted diameter, 41"z/hr. application rate, 1.32 acres/ setting.

<u>Note</u>: Either large gun sprinklers or specially designed manure gun sprinklers may be used. The latter should be used when pumping effluent of fairly thick consistency.

TABLE 20. APPROXIMATE NEW COSTS OF IRRIGATION SYSTEMS FOR WASTE DISPOSAL

<u>Surface Irrigation</u>

Lay-flat Irrigation Tubing with Outlets	4" : $ .35/ft.
	6" : $ .40/ft.
	8" : $ .50/ft.
	4" : $1.15/ft.
Aluminum Gated Pipe with Gates	6" : $1.15/ft.
	8" : $1.40/ft.

Cont'd.

TABLE 20 (Cont'd.)

Sprinkler Irrigation

Plastic Pipe (black)	1 1/2"	$ .22/ft.
	2"	$ .35/ft.
Aluminum Pipe with Coupler, High Pressure	2"	$ .28/ft.
	3"	$ .45/ft.
	4"	$ .65/ft.
	5"	$ .85/ft.
	6"	$1.20/ft.
	7"	$1.35/ft.
	8"	$1.80/ft.

Sprinklers with Risers	5-9 GPM Capacity	$7-13 each
	15 GPM Capacity	$20 each
	50 GPM Capacity	$35 each
	Manure Gun	$200 each
High-pressure Flexible Hose	2 1/2" Diameter	$3.00/ft.
	3" Diameter	$3.50/ft.
	4" Diameter	$4.40/ft.
	5" Diameter	$6.50/ft.
Traveling Sprinkling Systems	150 GPM Capacity	$1200
	250 GPM Capacity	$1600
	350 GPM Capacity	$2000
	500 GPM Capacity	$2600

Pumps (without power units)

1) 240 GPM @ 25 psi (for surface irrigation system) (needs 5 brake hp)	$ 60.00
2) 25 GPM @ 50 psi (for small sprinkler system) (needs 1 1/2 brake hp)	$ 80.00
3) 140 GPM @ 120 psi	$230.00
4) 300 GPM @ 90 psi	$330.00
5) 450 GPM @ 85 psi	$650.00
6) 800 GPM @ 15 psi	$750.00
7) 450 GPM @ 120 psi	$800.00

Note: Irrigation equipment costs vary widely throughout the state. The figures on this table may be considerably higher or lower than one particular situation.
Used equipment can often be purchased quite reasonably, and do a fine job.

TABLE 21

ACRES IRRIGATED PER SET

Length of Run in Feet	Number of Rows Per Set (40-inch Rows)											
	10	20	30	40	60	80	100	120	140	160	180	200
100	.076	.15	.23	.31	.46	.61	.76	.92	1.07	1.22	1.38	1.53
200	.15	.30	.46	.61	.92	1.22	1.52	1.84	2.14	2.44	2.76	3.06
300	.23	.46	.69	.72	1.38	1.83	2.28	2.76	3.21	3.66	4.14	4.59
400	.31	.61	.92	1.22	1.84	2.44	3.04	3.68	4.28	4.88	5.52	6.12
500	.38	.76	1.15	1.53	2.30	3.05	3.80	4.60	5.35	6.10	6.90	7.65
660	.50	1.0	1.51	2.0	3.0	4.0	5.0	6.1	7.1	8.1	9.1	10.1
800	.61	1.2	1.83	2.4	3.7	4.9	6.1	7.3	8.6	9.8	11.0	12.2
1000	.75	1.5	2.25	3.1	4.6	6.1	7.6	9.2	10.7	12.2	13.8	15.3
1200	.92	1.8	2.76	3.7	5.5	7.3	9.2	11.0	12.9	14.7	16.5	18.4
1400	1.07	2.1	3.21	4.3	6.4	8.6	10.7	12.9	15.0	17.1	19.3	21.4

Note: For 30 inch rows, multiply the acres irrigated per set by 30/40.

Note: For border irrigation of close growing crops, No. of gates open = $\frac{\text{Total gpm}}{\text{gpm/gate}}$. Refer to the above table for the acres/set with a given number of open gates. Adjust for gate spacing.

Sizes of ditches required for different irrigation streams.

GRADE 0.05 FOOT PER 100 FEET

Stream size (Cubic feet per second)	Stream	Size of ditch [1]	
		Base width	Water depth
	Gallons per minute	*Inches*	*Inches*
0.5	225	12	8
1.0	450	18	9
2.0	900	24	11
4.0	1,800	36	13
8.0	3,600	48	17
GRADE 0.1 FOOT PER 100 FEET			
0.5	225	12	6
1.0	450	15	9
2.0	900	18	10
4.0	1,800	24	13
8.0	3,600	36	16
GRADE 0.2 FOOT PER 100 FEET			
0.5	225	12	5
1.0	450	15	5
2.0	900	18	9
4.0	1,800	18	12
8.0	3,600	24	15
GRADE 0.5 FOOT PER 100 FEET			
0.5	225	12	4
1.0	450	12	6
2.0	900	18	7
4.0	1,800	18	10
8.0	3,600	24	13

[1] Side slopes 1.5 to 1.

CHART 1

LAGOON DESIGN DATA

Surface Area Vs. Volume For Given Depth

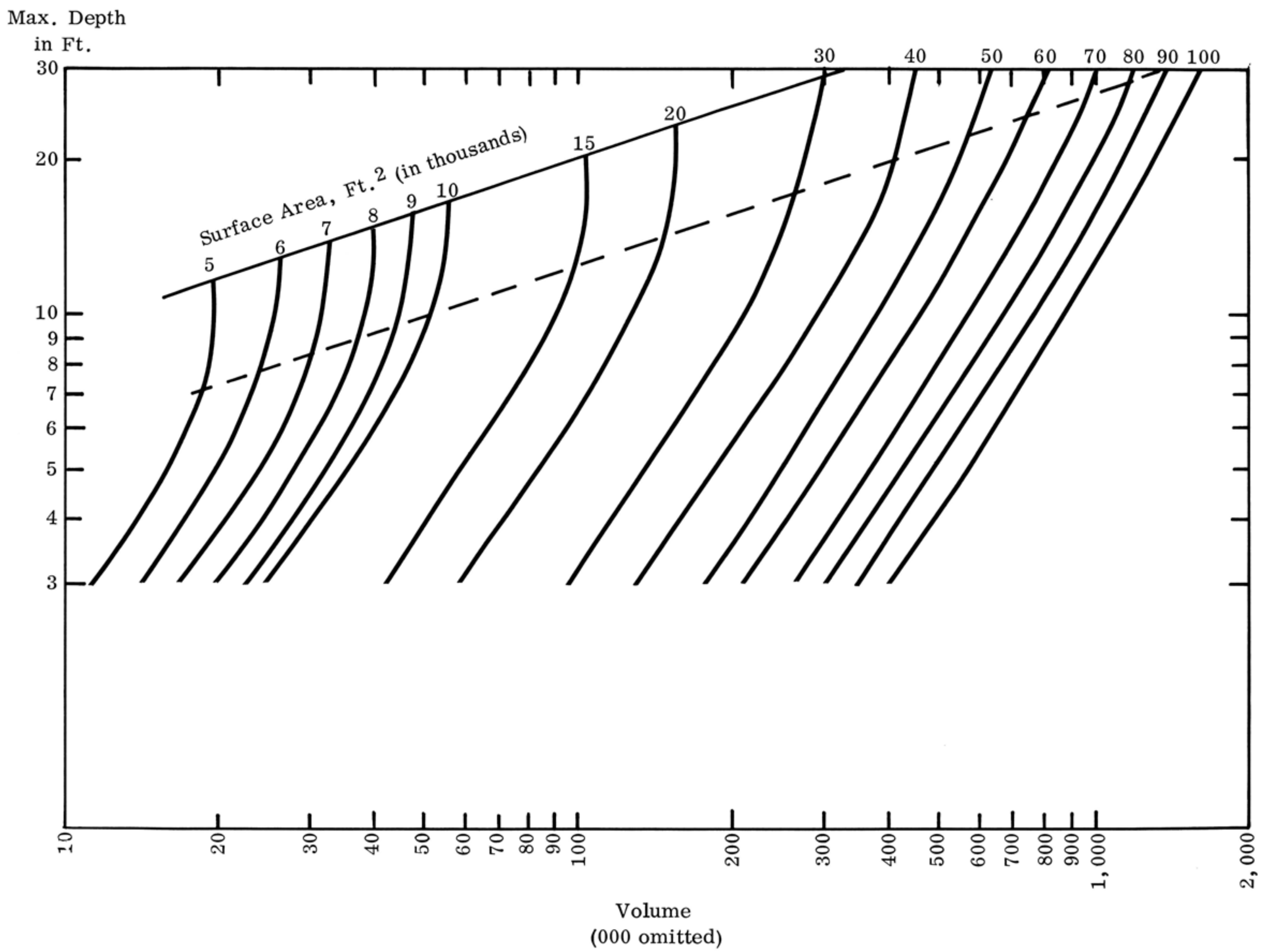
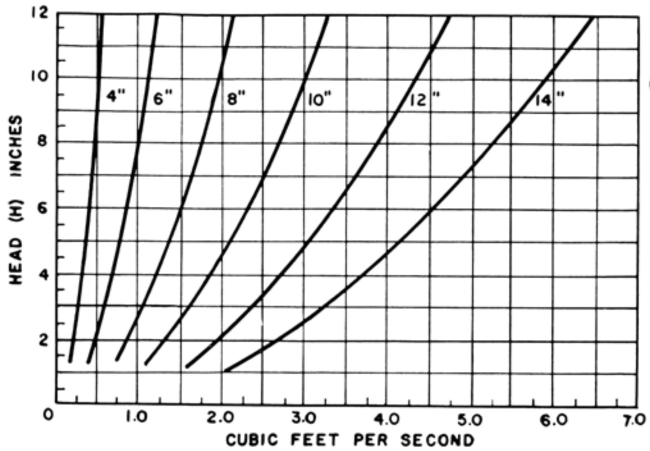


CHART 2

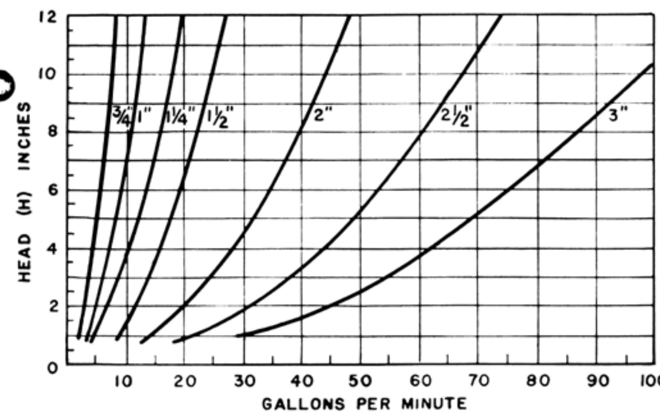
SIPHON TUBE RATE OF FLOW

Rate of flow through large pipe

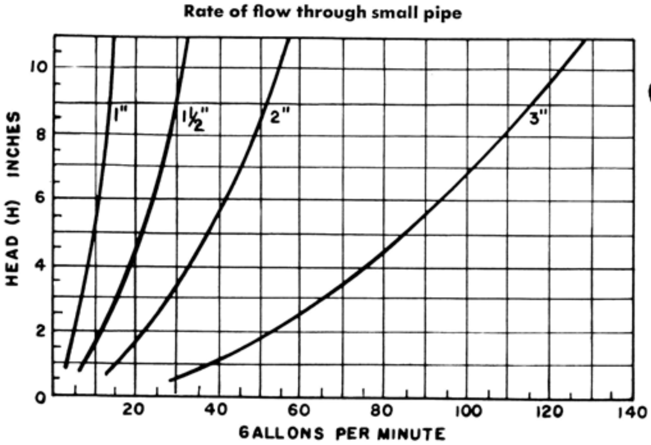


To determine rate of flow start at left, move horizontally from point of measured head to the size of pipe (or siphon), then vertically down to find rate of flow in cubic feet per second.

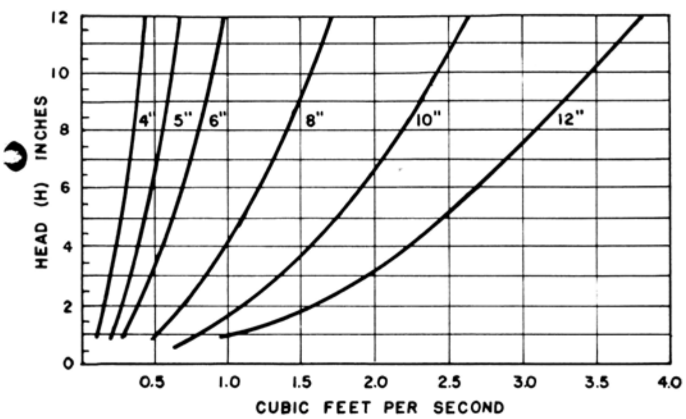
Rate of flow through small siphons

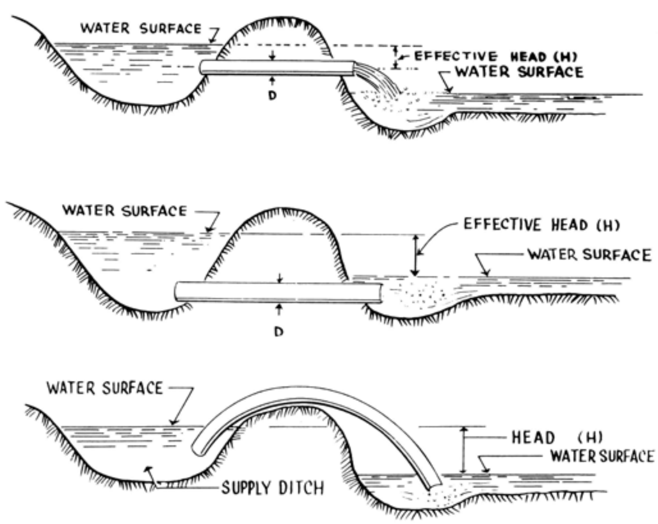


Rate of flow through small pipe



Rate of flow through large siphons





Measuring head on spiles and siphons. For free-flowing spiles (top) measure head as difference in elevation between water in the ditch and the center of the downstream end of the spile. For submerged spiles or siphons (center and bottom) measure difference in elevation of water in ditch and water in field.

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