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Hydrologic Aspects of Feedlot Waste Control

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HYDROLOGIC ASPECTS OF FEEDLOT WASTE CONTROL

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Table 1. Fed Cattle Marketings from the Leading Cattle Producing States (1967).

State	Number of Cattle Marketed
7 Leading States	
Iowa	4,057,000
Nebraska	3,066,000
California	2,049,000
Texas	1,654,000
Colorado	1,330,000
Kansas	1,321,000
Illinois	1,279,000
Total	14,756,000
12 Leading Midwestern States	
Iowa	4,057,000
Nebraska	3,066,000
Kansas	1,321,000
Illinois	1,279,000
Minnesota	869,000
Missouri	690,000
S. Dakota	618,000
Indiana	496,000
Ohio	442,000
Michigan	240,000
Wisconsin	206,000
N. Dakota	139,000
Total	13,423,000

1, 000 head or more are increasing at a rate of about 16 per cent per year[1]. The national trend is toward the feeding of larger numbers of animals on fewer feedlots.

Feedlot Wastes

Cattle wastes consist primarily of feces and urine from the animals, but also includes feed spillages on the surface of the feedlot. Several researchers have published data on the characteristics of cattle wastes[2, 3, 4]. Taiganides and Hazen presented guide values for the characteristics of cattle manure[2]. These data are presented in Tables 2 and 3. Witzel et al. published data on the physical, chemical, and bacteriological properties of bovine animal wastes[3].

Miner et al. published data on the characteristics of cattle feedlot runoff[4]. The data were collected from experimental feedlots located at Kansas State University. Each lot had an area of 0. 05 acre, a slope of two per cent, and contained ten head of cattle. Rainfall was simulated by means of irrigation sprinklers. For an unsurfaced lot, suspended solids concentrations ranged from 1, 100 to 7, 000 mg/l. The solids averaged 39 per cent volatile. Chemical oxygen demand (COD) ranged from 1, 900 to 8, 900 mg/l. The median COD to 5-day BOD ratio was 8. 8. It was found that the strength of the runoff increased with increasing temperature, increasing moisture on the lot, and decreasing rainfall rates[4].

Population Equivalent

The term "population equivalent" (PE) was coined for the purpose of providing a basis for comparing industrial wastes with domestic wastes. For cattle feedlot wastes, it is incorrect to calculate PE values on the basis of the total raw waste defecated by the animal. Domestic wastes are delivered to streams or treatment plants on a

Table 2. Characteristics of Cattle Wastes.
[From Taiganides and Hazen[2]]

Item	Units	Cattle (1000 lb.)
Wet Manure	lb./day	64.0
Total Solids	% Wet Basis	16.0
Volatile Solids	% Dry Basis	80.0
Nitrogen	% Dry Basis	3.7
Phosphorus (P_2O_5)	% Dry Basis	1.1
Potassium (K_2O)	% Dry Basis	3.0
BOD	1/ lb./day/100 lb.	0.13
COD	1/ lb./day/100 lb.	1.05

1/ Values are per 100 lb. live weight.

Table 3. Quantities of Major Fertizing Elements from Cattle Wastes. 1/
[From Taiganides and Hazen[2]]

Item	Cattle lb./day	Cattle lb./yr.
Nitrogen (N)	0.38	138
Phosphorus (P_2O_5)	0.11	41
Potassium (K_2O)	0.31	112

1/ Values are based on 1000 lb. of live animal weight.

nearly continuous basis. The transport of wastes from a cattle feedlot to surface waters is intermittent, occurring as the result of rainfall and runoff. Also, of the total waste defecated by an animal on a feedlot a large portion will often remain on the feedlot surface as a manure accumulation.

The frequency at which feedlot runoff may be delivered to streams can be determined from an analysis of precipation data. Figure 1 indicates the number of days during a year when rainfall in eastern Iowa can be expected to equal or exceed accumulations up to two inches. Rainfalls equaling or exceeding 0.25 in. can be expected to occur on about 33 days per year at any point in eastern Iowa. Rainfalls equaling or exceeding 1.0 in. will occur on about 7 days per year. Thus, cattle feedlot wastes may be delivered to streams in eastern Iowa on only about 10 per cent of the days. In addition, rainfall occurrences tend to be more numerous in the spring months when stream flows are higher (Figure 2).

The intermittent nature of the delivery of feedlot wastes to streams has both advantages and disadvantages. The advantage is that not all of the feedlot waste actually enters the stream. The disadvantage is that when rainfall and runoff occurs, wastes are washed to the stream on a slug basis. This tends to "shock load" the receiving stream, the extent of the shock depending on the strength and volume of the runoff and the nature of the receiving stream.

The domestic population that would be required to deliver a shock load equal to that exerted by feedlot runoff is of interest. Figure 3 indicates the PE that might be exerted in a stream by one inch of runoff resulting from various rainfall rates. As shown, the actual PE is affected significantly by the animal density on the feedlot. The curves in Figure 3 were developed from the relation-

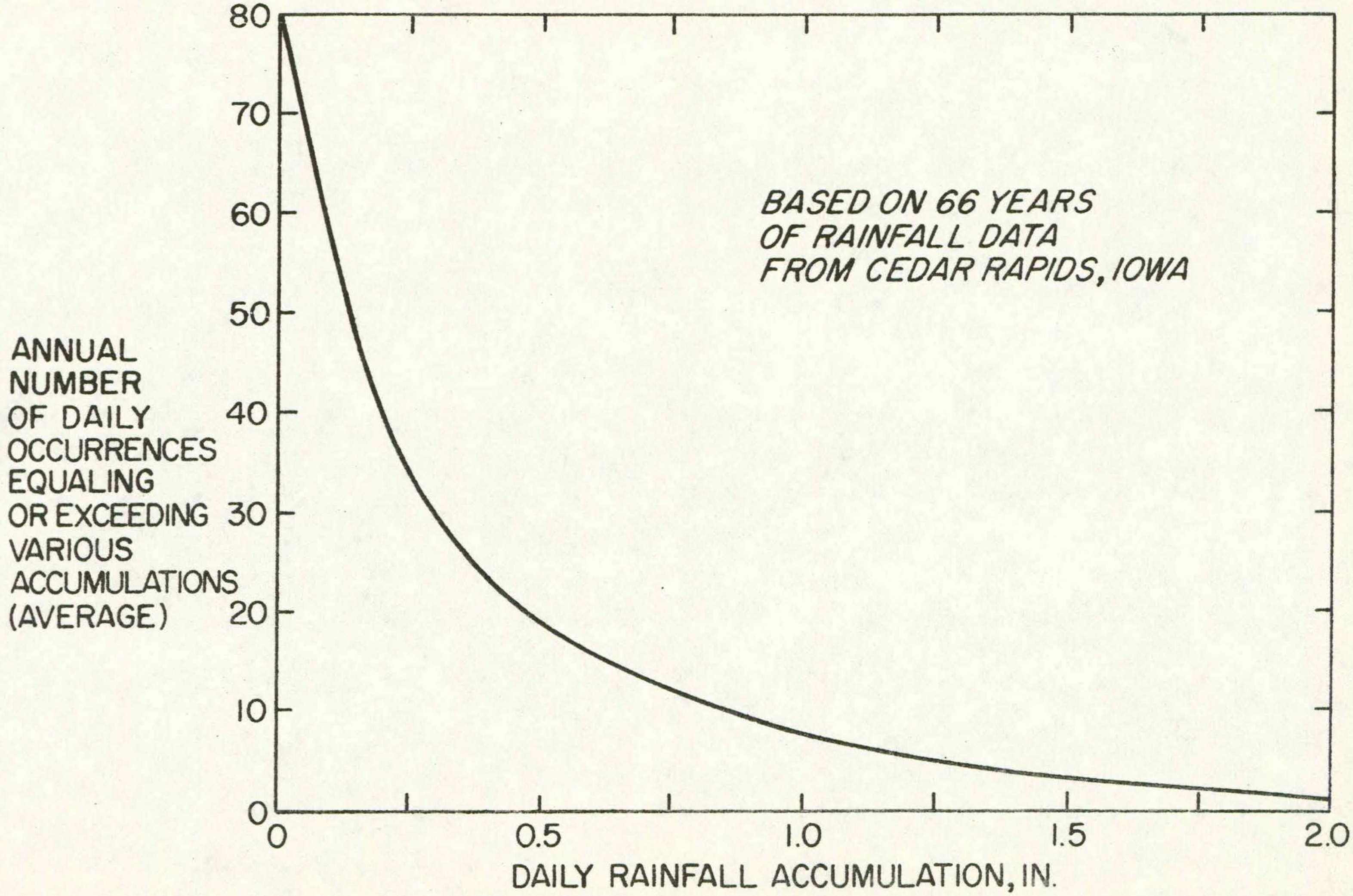

Fig. 1. The Number of Rainfall Events Decreases With Increasing Daily Accumulations.

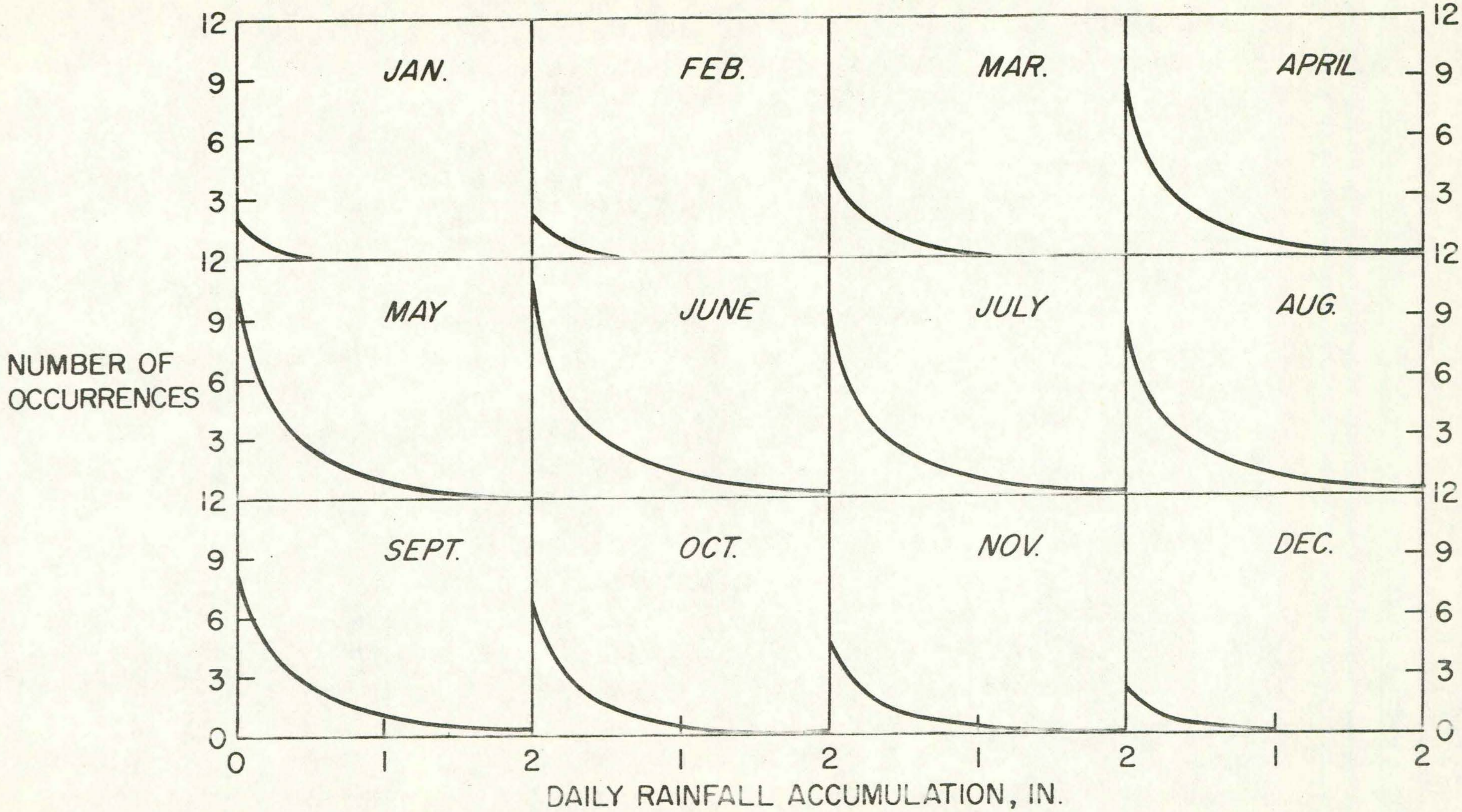

Fig. 2. The Average Number of Rainfall Events Varies for Different Months [Based on 66 years of data, Cedar Rapids, Iowa].

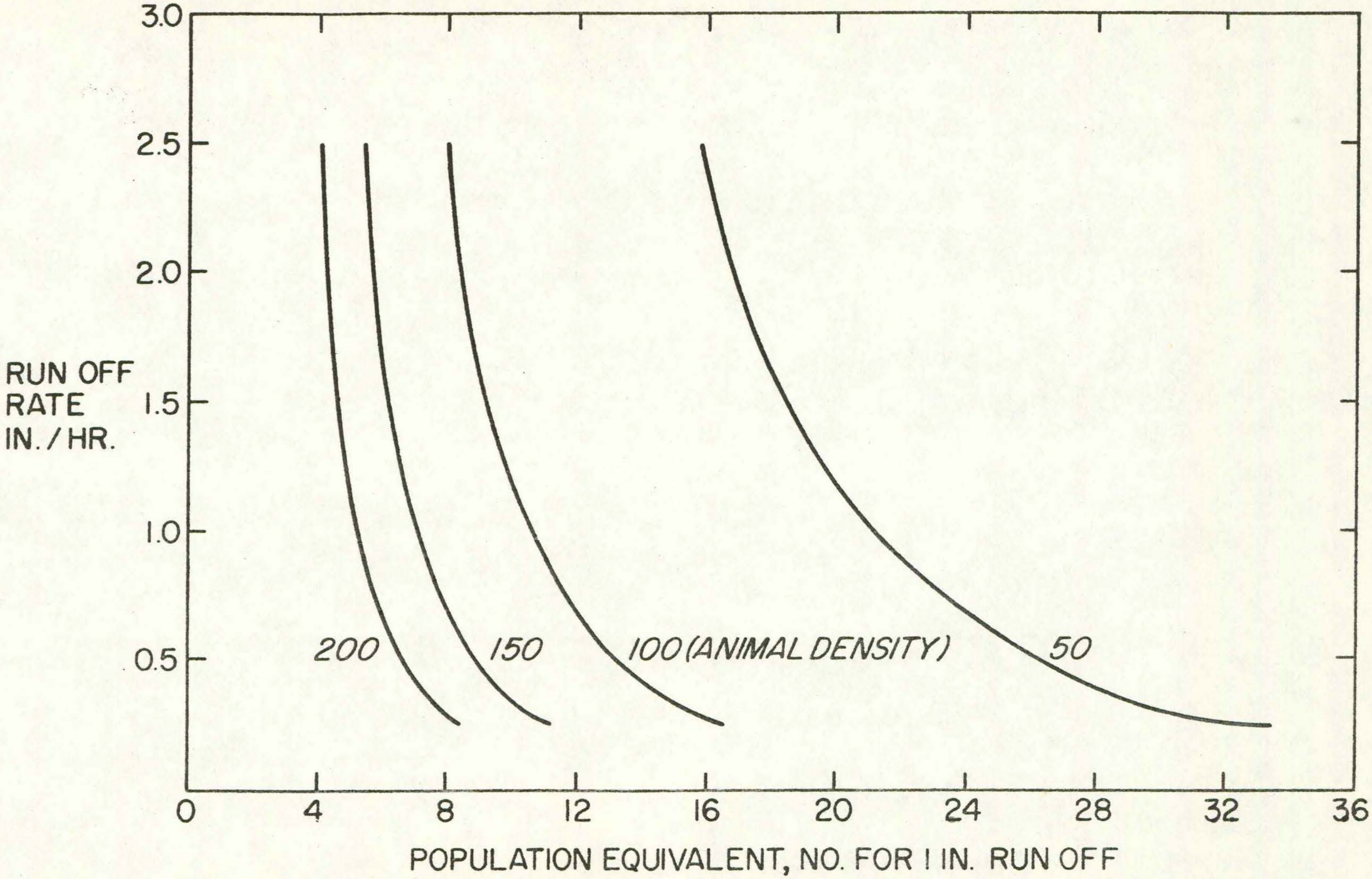

Fig. 3. The Population Equivalent Decreases with Increasing Rainfall Intensity and Cattle Density.

∝

ship between BOD in feedlot runoff and rainfall rate given by Miner et al.[4] In developing the curves, temperature and moisture conditions on the lot were assumed to be the most adverse, i.e., a wet lot surface at a high temperature.

Figure 3 demonstrates, for the experimental feedlots at Kansas State University, that PE values on a BOD basis may range from a high of 34, at a rainfall rate of 0.25 in/hr and cattle density of 50 per acre, to a low of 4, at a rainfall rate of 2.5 in/hr and a cattle density of 200 per acre. Although this PE is not exerted continuously, the short-term shock load can do great damage to the aquatic life in a stream.

Cattle Waste Control

Cattle feedlot waste is an industrial waste. As such, it is subject to the same fundamental analyses routinely applied by engineers in solving industrial waste problems.

The questions that should be answered in seeking a solution to an industrial waste problem are:

1. Can the waste volume and/or strength be reduced at its source?
2. Can the physical, chemical, and biological characteristics of the waste be improved at the source?
3. Is it possible and feasible to recover by-products from the waste?
4. What systems will most economically accomplish the necessary degree of waste control or treatment?

The source of cattle waste is the feedlot surface. From this source, two wastes with different characteristics arise. One is the semi-solid manure accumulation on the lot surface. The other is the liquid runoff resulting from rainfall.

The key to gaining a reduction in the volume and strength of the waste and to improving the characteristics of the waste at the source is retention on the lot surface. Here the organic matter will undergo biological decomposition and drying. The efficiency of organic removal will be equal to that achieved by biological treatment on a "formal" basis. By preventing manure transport from the lot in runoff, a reduction in the pollutional potential of the manure and the strength of the runoff can be accomplished. Also, reductions in the weight and volume of the manure by natural drying is enhanced.

Methods employed to retain manure and runoff on the feedlot surface will vary. One method is the use of terraces. A variety of terracing schemes are possible, but the goal of each is to retain the liquid and reduce the transport of solids from the feedlot. Whatever method is used, it should not create undesirable environmental conditions for the animals.

A significant reduction in the volume of runoff can be accomplished by reducing the area of the feedlot. For a given total number of cattle, this practice will increase the animal density on the lot. Whether or not such an increase in cattle density is feasible must be determined for each individual case.

Runoff can be completely eliminated by the placement of a roof over the feedlot. An example of such a facility is that of the Western Consumers Industries, Inc., Ontario, California (Figure 4). This firm feeds 9,600 cattle in 7 acres of roofed feedlot. The animals are fed on slotted floors with the manure being collected in pits below the floor. The manure is moved mechanically to a dehydrator where the moisture content is reduced from 85 to 10 per cent. The dried manure is sold as a soil conditioner.

Once all feasible methods of reducing the volume and strength of the waste, of improving the characteristics of the waste, and of by-product recovery have been investigated, the next step is the

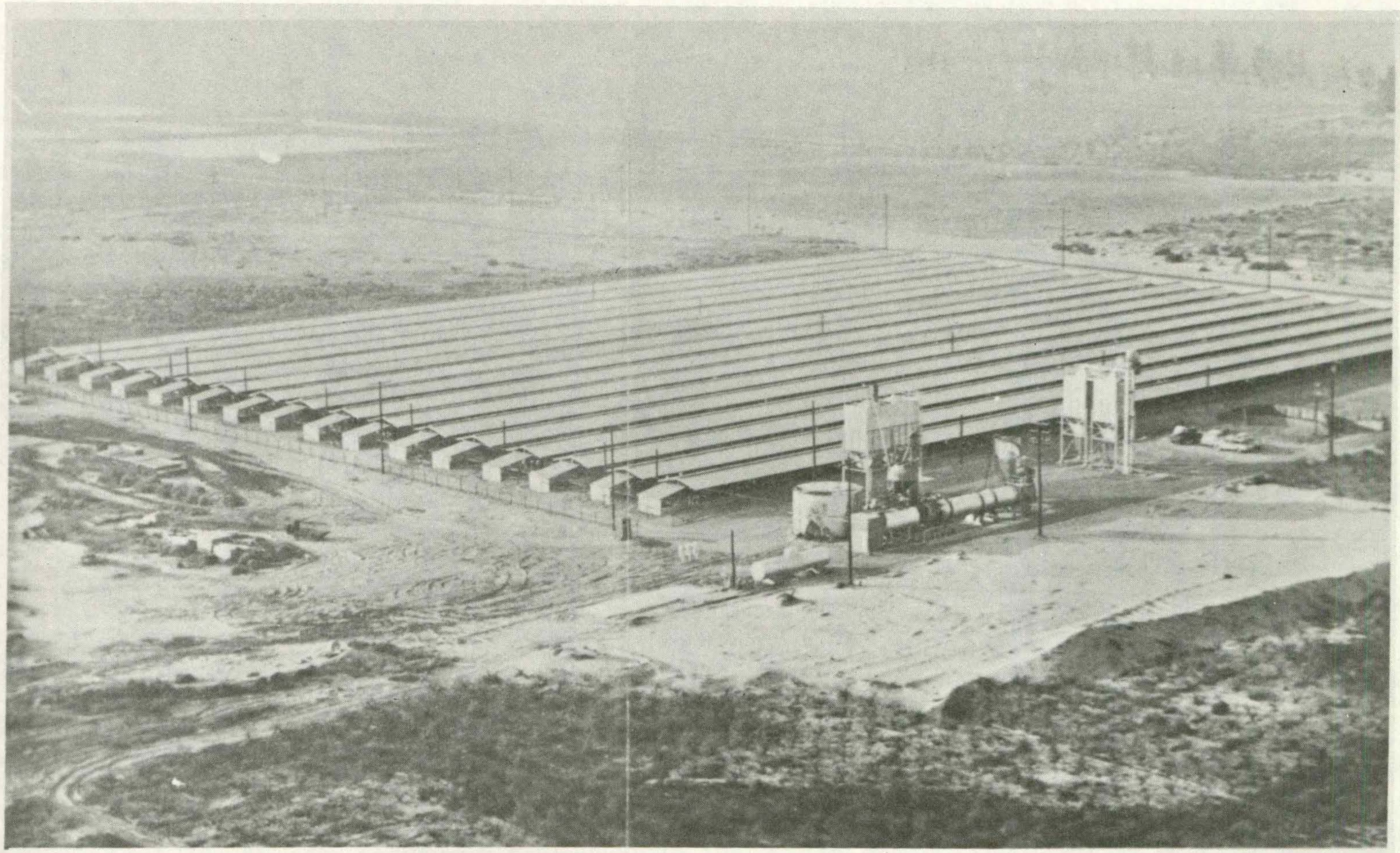

Fig. 4. The Seven Acre Feedlot is Covered with a Roof and Contains 9,600 Cattle. (Courtesy Western Consumers Industries, Inc., Ontario, Calif.)

selection of systems to control the remaining waste.

FUNDAMENTAL ANALYSES

Fundamental hydrologic and water quality concepts can be applied to determine the size of runoff control facilities for cattle feedlots on any river basin. These concepts will be demonstrated using the Iowa River basin as a model.

The Iowa River rises in north-central Iowa and flows south-, easterly to the Mississippi River (Figure 5). The basin area above its confluence with the Cedar River is 4,770 sq mi. The Iowa River basin is rather typical of Iowa with land use devoted heavily to agriculture. The Coralville Reservoir, used for flood control and recreational purposes, is located about five miles upstream from Iowa City.

Feedlot Runoff

To determine the quantity and time distribution of point precipitation on the Iowa River basin, 66 years of data from the U.S. Weather Bureau gaging station at Cedar Rapids, Iowa, were analyzed. The data were analyzed to determine both the probable annual and probable monthly precipitation. The annual data are plotted on a recurrence interval basis in Figure 6.

To determine the time distribution of the annual precipitation, the data were analyzed to determine the average percentage of the annual precipitation occurring during each month. The results are shown in Table 4. These data provide the depth and time distribution of the 10-year recurrence interval precipitation and provide the basis for a mass diagram of waste inflow to the control structure. In this analysis, the feedlot runoff was assumed to be equal to the precipitation.

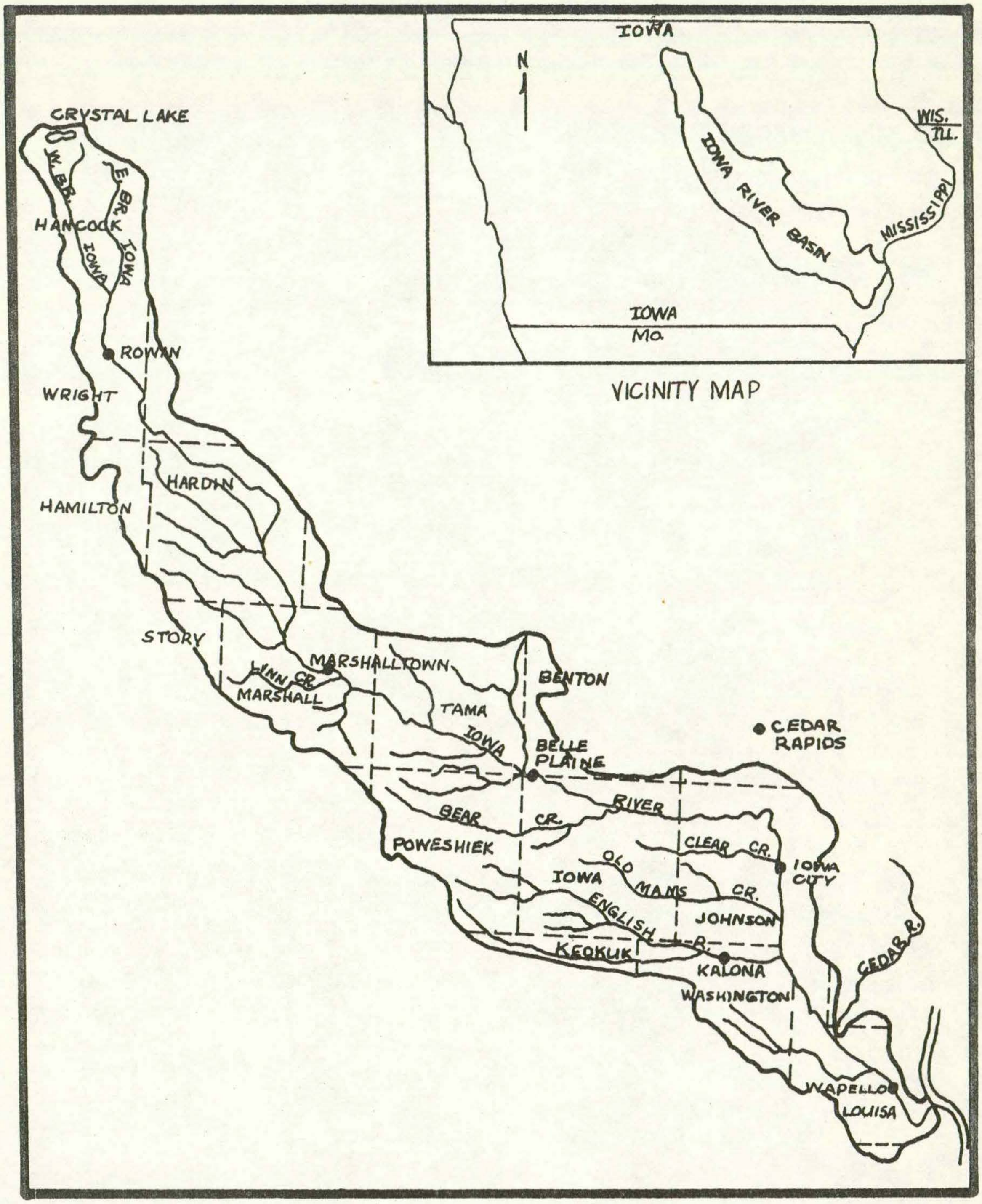

Fig. 5 . Iowa River Basin.

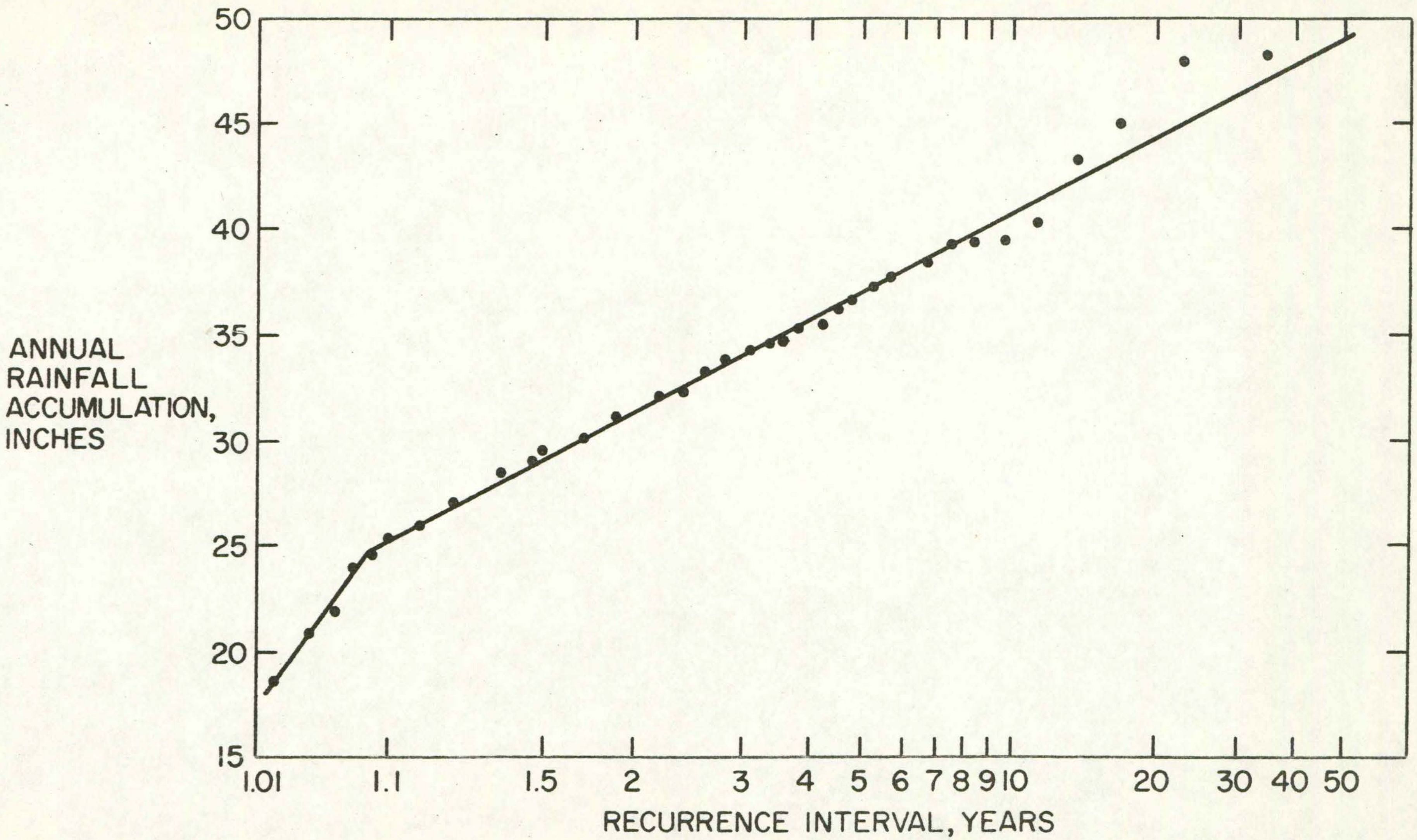

Fig. 6 . The Annual Rainfall Accumulation Increases with Increasing Recurrence Interval [Based on 66 years of data, Cedar Rapids, Iowa].

Table 4 . Monthly Precipitation Distribution.

(10-Year Reccurrence Interval)[1/]

Month	Percent of Annual	Precipitation inches	Summation inches
Jan	3.8	1.56	1.56
Feb	3.5	1.43	2.99
Mar	6.4	2.62	5.61
Apr	9.0	3.69	9.30
May	11.9	4.88	14.18
June	13.8	5.66	19.84
July	11.8	4.84	24.68
Aug	11.2	4.60	29.28
Sept	12.3	5.04	34.32
Oct	7.0	2.87	37.19
Nov	5.5	2.25	39.44
Dec	3.8	1.56	41.00

[1/] Values equaled or exceeded once in 10 years

Stream Flow

To determine the allowable rate of release of feedlot runoff to the stream, it is necessary to determine the magnitude and variations in stream flow. Therefore, 49 years of Iowa River flow data from the U.S. Geological Survey gaging station at Marshalltown were analyzed. The data were analyzed on a monthly basis and flow-recurrence interval plots developed for each month. A typical curve is shown in Figure 7.

Iowa River Water Quality

The ultimate receiving stream for feedlot runoff is the Iowa River. Iowa water quality standards to protect aquatic life in a warm water stream apply. These standards require that dissolved oxygen (DO) concentrations be not less than 4 mg/l at any time and not less than 5 mg/l for 16 hours each day.

The quantity of feedlot runoff, or other waste, that might be released to the stream during any given time period is dependent upon the existing DO, BOD, and temperature in the stream at the point of discharge. As with precipitation and stream flow, the quality data are variable throughout the year.

Water quality data from the Iowa River has been collected for the past four years. This work is directed by Dr. D.B. McDonald, Dept. of Civil Engineering, University of Iowa. The DO and BOD data for the month of April, plotted on a probability basis, are shown in Figures 8 and 9, respectively. Similar plots were developed for each month of the year. The average water temperature and the 50 percentile DO and 5-day BOD values for each month are summarized in Table 5.

Required Dilution Factors

One method of disposal for feedlot runoff is controlled release to

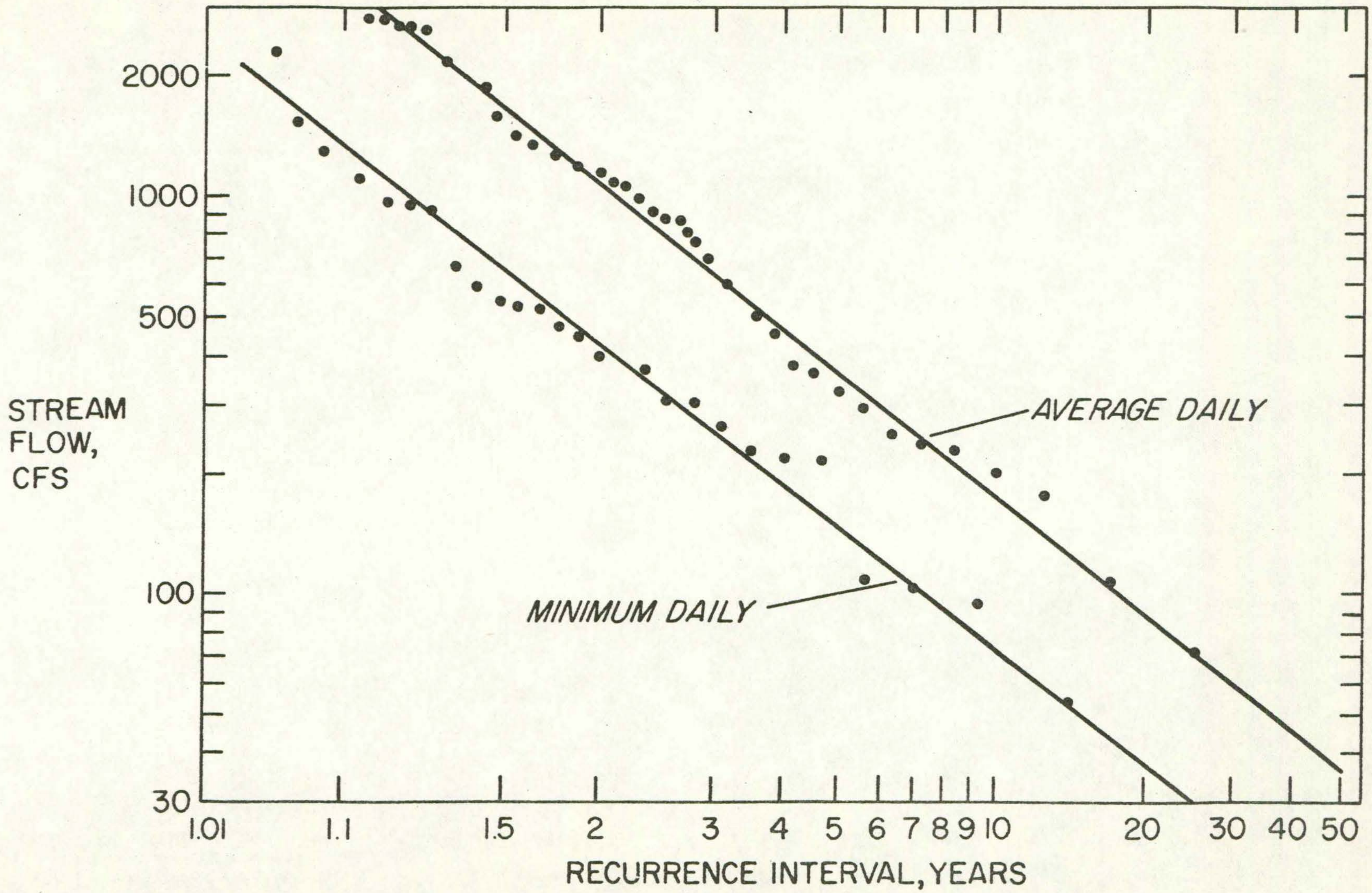

Fig. 7 . Minimum Daily and Average Daily Flow, Iowa River at Marshalltown, Month of June [49 years of flow data, U.S.G.S.].

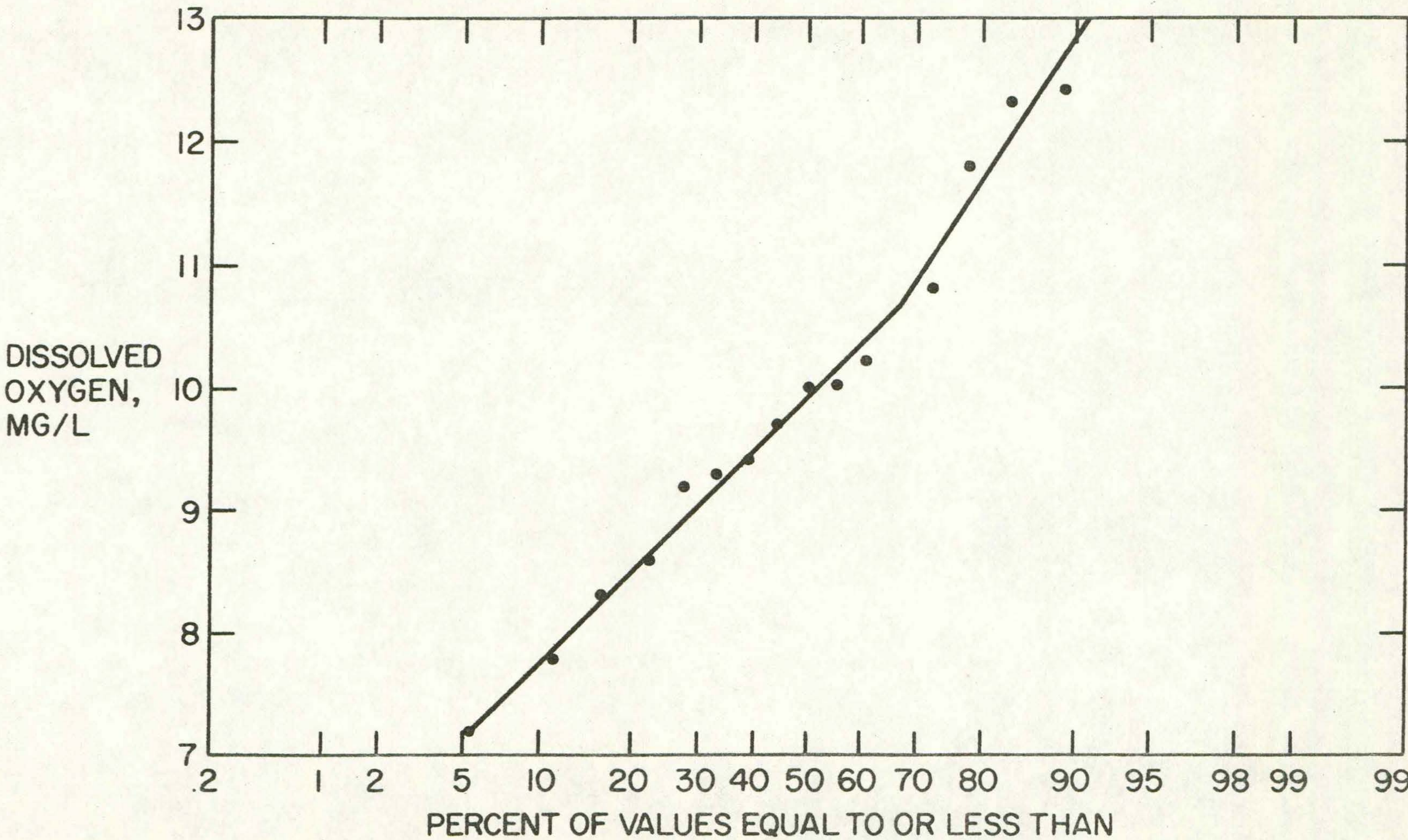

Fig. 8. Probability Distribution for Dissolved Oxygen in the Iowa River Immediately Upstream from the Coralville Reservoir, Month of April [Data from D. B. McDonald].

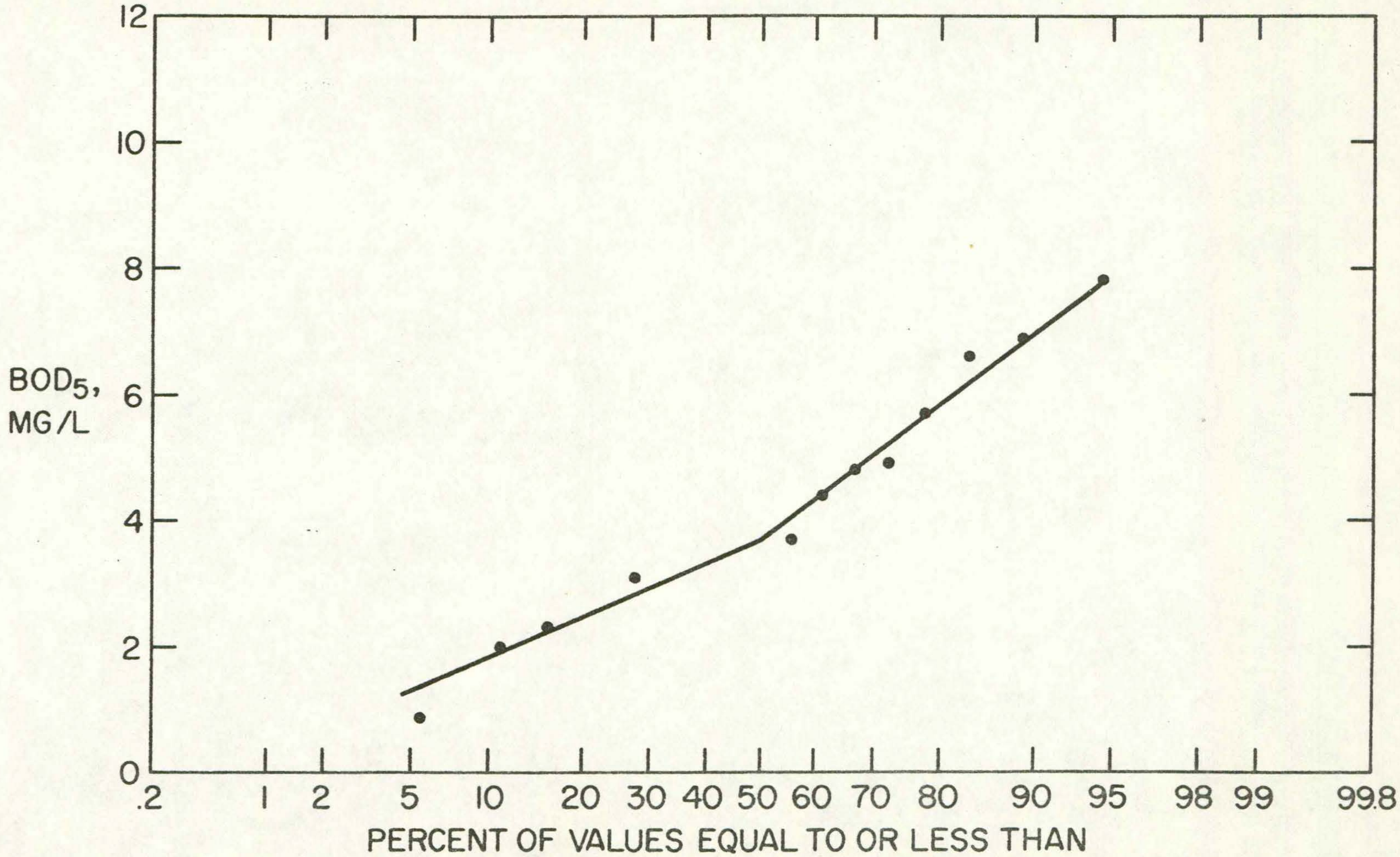

Fig. 9. Probability Distribution for 5-Day BOD in the Iowa River Immediately Upstream from the Coralville Reservoir, Month of April [Data from D. B. McDonald].

Table 5. Iowa River Water Quality[1].

Month	Temperature °C (Average)	Dissolved[2] Oxygen mg/l	BOD_5[2] mg/l
Jan	1	8.9	3.0
Feb	1	9.8	4.5
Mar	6	10.1	8.0
Apr	11	9.9	3.7
May	15	9.3	5.5
June	23	7.1	2.7
July	27	7.2	4.7
Aug	24	8.3	5.0
Sept	18	7.6	3.8
Oct	12	10.1	3.5
Nov	6	11.4	3.4
Dec	2	11.7	2.9

1/ Immediately upstream from Coralville Reservoir.

2/ 50 percentile value.

the stream. The question is: When and at what rates can the waste be released? This question must be answered for each basin. In this example it was considered reasonable not to allow discharges to the stream during the winter months (Dec., Jan., Feb.) and the summer months (June, July, Aug.). The reason for prohibiting feedlot runoff discharges during these months are: 1) ice cover during the winter, and 2) recreational use of the Coralville Reservoir during the summer.

Allowable runoff release rates were determined using the Streeter-Phelps relationship for BOD exertion and reaeration in a stream[5]. In this analysis it was necessary to determine the allowable ultimate BOD in the stream such that a minimum DO criterion was not violated at any point in the stream.

The maximum rate at which waste can be released to a stream without violating established minimum DO requirements depend on several factors. These factors include:

1. The flow in the stream,
2. The self purification factor, f = r/k, for the stream, where r is the reaeration constant and k is the deoxygenation constant,
3. The initial DO and ultimate BOD in the stream,
4. The minimum DO, or critical deficit, to be allowed at any point in the stream.

It was assumed that the minimum DO in the stream was to be 7.0 mg/l. Although this is higher than the permissible minimum DO allowed by Iowa water quality standards, it was thought to be a reasonable allocation of the oxygen resource to the feedlot runoff waste source. The 5-day BOD of the stream and of the effluent from the runoff retention pond were converted to ultimate BOD using 20°C BOD exertion rate constants (K) of 0.089 for the feedlot runoff[3] and 0.10 for the stream[6]. Using these constants along with the known water quality during each month (Table 5), it is possible to calculate the allowable ultimate BOD in the stream for each month of the year. The procedure for making this calculation is described in the text book by Fair, Geyer, and Okun[7]. In this analysis, a stream purification factor (f) of 2.0, at 20°C, was used and corrected for temperature[7]. Also, the critical deficit was set at the difference between the saturation DO for each month and 7.0 mg/l. The results of these calculations are presented in Table 6.

The relationship between flow and ultimate BOD in the stream and the flow and ultimate BOD released from the retention pond is:

$$L_a (Q_s + Q_p) = L_s Q_s + L_p Q_p \qquad (1)$$

or

$$\frac{Q_s}{Q_p} = \frac{L_p - L_a}{L_a - L_s} \qquad (1\text{-}1)$$

where

L_a = Allowable ultimate BOD in the stream,
L_s = Existing ultimate BOD of the stream,
L_p = Ultimate BOD of pond effluent,
Q_s = Flow in stream,
Q_p = Retention pond discharge.

Using Equation 1-1, it is possible to calculate the dilution factor, Q_s/Q_p, required to meet the established minimum DO value. These dilution factors, and the factors used in their calculation, are shown in Table 7. In calculating the required dilution factors, the 5-day BOD of the retention pond effluent was assumed to be 720 mg/l which, using a BOD exertion rate constant of 0.089, gives an ultimate BOD of 1,120 mg/l. Of course, this value must be determined for each design situation. It is felt that the ultimate BOD of settled feedlot

Table 6. Allowable Ultimate BOD in the Stream.

Month	D.O. Saturation mg/l	Initial Deficit D_a mg/l	Critical Deficit D_c mg/l	Allowable Ultimate BOD L_a mg/l
Jan	14.3	5.4	7.3	30.7
Feb	14.3	4.5	7.3	32.8
Mar	12.5	2.4	5.5	24.2
Apr	11.0	1.1	4.0	17.2
May	10.0	0.7	3.0	12.3
June	8.5	1.4	1.5	3.7
July	7.9	0.7	0.9	2.3
Aug	8.3	0.0	1.3	4.9
Sept	9.4	1.8	2.4	7.7
Oct	10.8	0.7	3.8	16.7
Nov	12.5	1.1	5.5	26.4
Dec	13.9	2.2	6.9	33.8

Table 7. Required Dilution Factors.

Month	L_a mg/l	L_s mg/l	L_p mg/l	Dilution Factor Q_s/Q_p
Jan	30.7	4.4	1120	1/
Feb	32.8	6.6	1120	1/
Mar	24.2	11.7	1120	88
Apr	17.2	5.4	1120	93
May	12.3	8.1	1120	264
June	3.7	4.0	1120	2/
July	2.3	6.9	1120	2/
Aug	4.9	7.3	1120	2/
Sept	7.7	5.6	1120	530
Oct	16.7	5.1	1120	95
Nov	26.4	5.0	1120	51
Dec	33.8	4.2	1120	37

1/ No pond discharge due to ice cover in stream.

2/ No pond discharge due to water quality in stream.

runoff will seldom exceed the value used herein.

Allowable Pond Discharge

With a knowledge of the required dilution factors for each time period and the flow in the receiving stream, the allowable retention pond discharge rates can be calculated. Since a feedlot might be located at any point in a basin, it is necessary to determine the probable receiving stream flow at any location in the basin. This can be done by converting the probable stream flow, expressed in cfs, to basin yield, expressed in cfs/sq mi. Then, knowing the contributing basin area, it is possible to calculate the receiving stream flow at any feedlot location. Of course, to make the conversion from flow in the principal receiving stream to basin yield it must be determined that the basin is reasonably homogenous from the standpoint of runoff contribution per unit area. In this study, it was found that the yield of basins tributary to the Iowa River did not vary by more than plus or minus ten percent from the yield of the entire basin upstream from the gaging station at Marshalltown. Thus, it was possible to convert the stream flow values to a yield basis. The results of this conversion are shown in Table 8.

Knowing the required dilution factors (Table 7) and basin yields (Table 8), it is possible to calculate the allowable retention pond discharge rates in cfs per square mile of contributing drainage area. The results of such calculations for various recurrence intervals of the low and average daily stream flow are shown in Table 9.

TYPICAL DESIGN

To demonstrate the application of the analysis presented herein, it will be assumed that a ten-acre cattle feedlot is located on the Iowa

Table 8 . Stream Flow and Basin Yield.

Month	Most Probable Low Daily Flow		Most Probable Average Daily Flow	
	cfs[1]	cfs/sq mi[2]	cfs[1]	cfs/sq mi[2]
Jan	93	0.0594	250	0.1598
Feb	128	0.0818	600	0.3836
Mar	420	0.2685	1850	1.1828
Apr	630	0.4028	1130	0.7225
May	520	0.3324	1170	0.7480
June	580	0.3708	1700	1.0869
July	300	0.1919	660	0.4219
Aug	147	0.0939	302	0.1930
Sept	135	0.0863	370	0.2365
Oct	190	0.1214	345	0.2205
Nov	150	0.0959	325	0.2078
Dec	115	0.0735	232	0.1488

1/ Iowa River at Marshalltown.

2/ Drainage basin area upstream from Marshalltown is 1564 sq. mi.

Table 9 . Allowable Retention Pond Discharge Rates in CFS per Square Mile of Contributing Basin Area.

Month[1]		Recurrence Interval, Years 1.575 (Most Probable)	2	5	10
Mar	Low	0.0030	0.0017	0.0007	0.0004
	Ave	0.0134	0.0087	0.0032	0.0017
Apr	Low	0.0043	0.0031	0.0010	0.0007
	Ave	0.0078	0.0061	0.0029	0.0017
May	Low	0.0012	0.0009	0.0003	0.0002
	Ave	0.0028	0.0020	0.0007	0.0004
Sept	Low	0.0001	0.0001	0	0
	Ave	0.0004	0.0003	0.0001	0.0001
Oct	Low	0.0013	0.0008	0.0004	0.0002
	Ave	0.0023	0.0014	0.0005	0.0004
Nov	Low	0.0019	0.0012	0.0008	0.0005
	Ave	0.0041	0.0026	0.0012	0.0008
Dec	Low	0.0020	0.0015	0.0008	0.0006
	Ave	0.0040	0.0029	0.0010	0.0008

[1] No pond discharge during months of Jan, Feb, June, July, and Aug.

River basin at a point where the drainage area contributing to the receiving stream is only 75 sq mi. Such a feedlot might reasonably be expected to contain 1,500 cattle.

Allowable Pond Discharge Rate

Using the data in Table 9, it is possible to calculate the allowable retention pond discharge rate for a feedlot located at a point where the contributing drainage area is 75 sq mi. The results of this calculation, based on the most probable low daily flow in the stream, are shown in Table 10. The values in Table 10 are the maximum rates and monthly volumes of retention pond effluent that could be released to the receiving stream.

Basic Runoff Control Procedures

There are four basic procedures that might be followed in disposing of retention pond effluent. These are:

1. Controlled release to the stream,
2. Controlled release to the land,
3. Combination; controlled release to the land and stream,
4. Controlled release to a treatment system.

The retention pond volume required for the ten-acre feedlot will vary depending on which of these procedures is used to control the runoff.

Release to Stream

The retention pond volume to enable controlled release of feedlot runoff to the stream can be determined from the inflow-outflow mass diagram. Such a diagram is shown in Figure 10. The inflow mass diagram is based on the expected monthly distribution of the ten-year recurrence interval precipitation (Table 4). The outflow diagram is based on the allowable times and rates of waste release.

From Figure 10 it can be seen that the required retention pond volume is 15.3 in per acre of feedlot. Thus, for the 10-acre feedlot,

Table 10. Allowable Retention Pond Discharge Rate.[1/]

Month	Discharge Days	Discharge Rate cfs	Discharge Rate acre-in./day	Discharge Volume acre-in.
Jan	0	0	0	0
Feb	0	0	0	0
Mar	31	0.229	5.45	169
Apr	30	0.325	7.73	232
May	31	0.094	2.24	69
June	0	0	0	0
July	0	0	0	0
Aug	0	0	0	0
Sept	30	0.012	0.28	8
Oct	31	0.096	2.28	71
Nov	30	0.141	3.35	100
Dec	15	0.149	3.54	53

[1/] Based on the most probable low daily flow in the stream for a contributing drainage area of 75 sq mi.

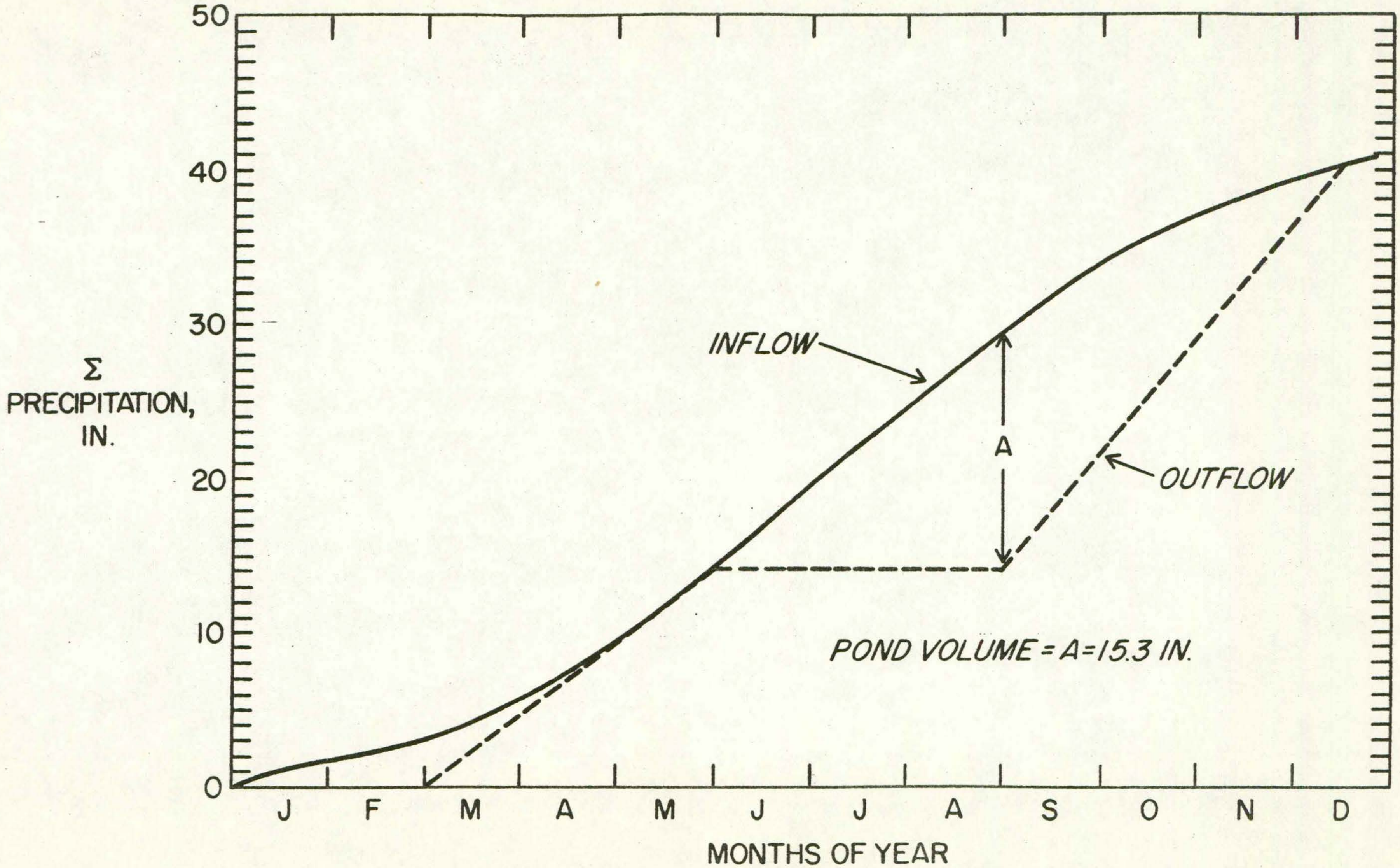

Fig. 10 . The Pond Volume is Determined from the Inflow-Outflow Mass Diagram [For controlled release to stream].

153 acre-in of pond storage would be required. This quantity of storage would enable holding all feedlot runoff during the months of January, February, and the last 15 days of December, and during the summer months of June, July, and August. The maximum rate of release from the pond would be 0.25 acre-in/day during the period from September 1st to December 15th. If the cattle stocking rate is 150 head per acre and the 5-day BOD of the pond effluent is 720 mg/l, the population equivalent of the waste from each animal would be about 0.16. As can be seen from Figure 3, the potential slug-load population equivalent of the feedlot is about 11 per animal. Thus, this relatively simple runoff control procedure would accomplish a 99 per cent reduction in the slug-load effect on the stream.

Release to Land

Another possible method for disposing of feedlot runoff is controlled release to the land. Of course, to practice this procedure suitable land must be available. The advantage of this method is that no waste enters the stream. Also, the wastewater may be used as irrigation water and as a source of nutrients for growing crops.

In Iowa, the ground is frozen most of the time during the months of January, February, March, and December. Therefore, wastewater could not be released to the land during this period. The inflow-outflow mass diagram for controlled release to the land is shown in Figure 11.

From Figure 11, it can be seen that the required pond volume is 7.2 in per acre of feedlot or a total of 72 acre-in for the 10 acre feedlot. Also, the required rate of waste release is about 1.2 acre-in per week. If the land can accept 1.0 acre-in of wastewater per week, the total land area required for disposal of runoff from the 10 acre feedlot would be 12 acres.

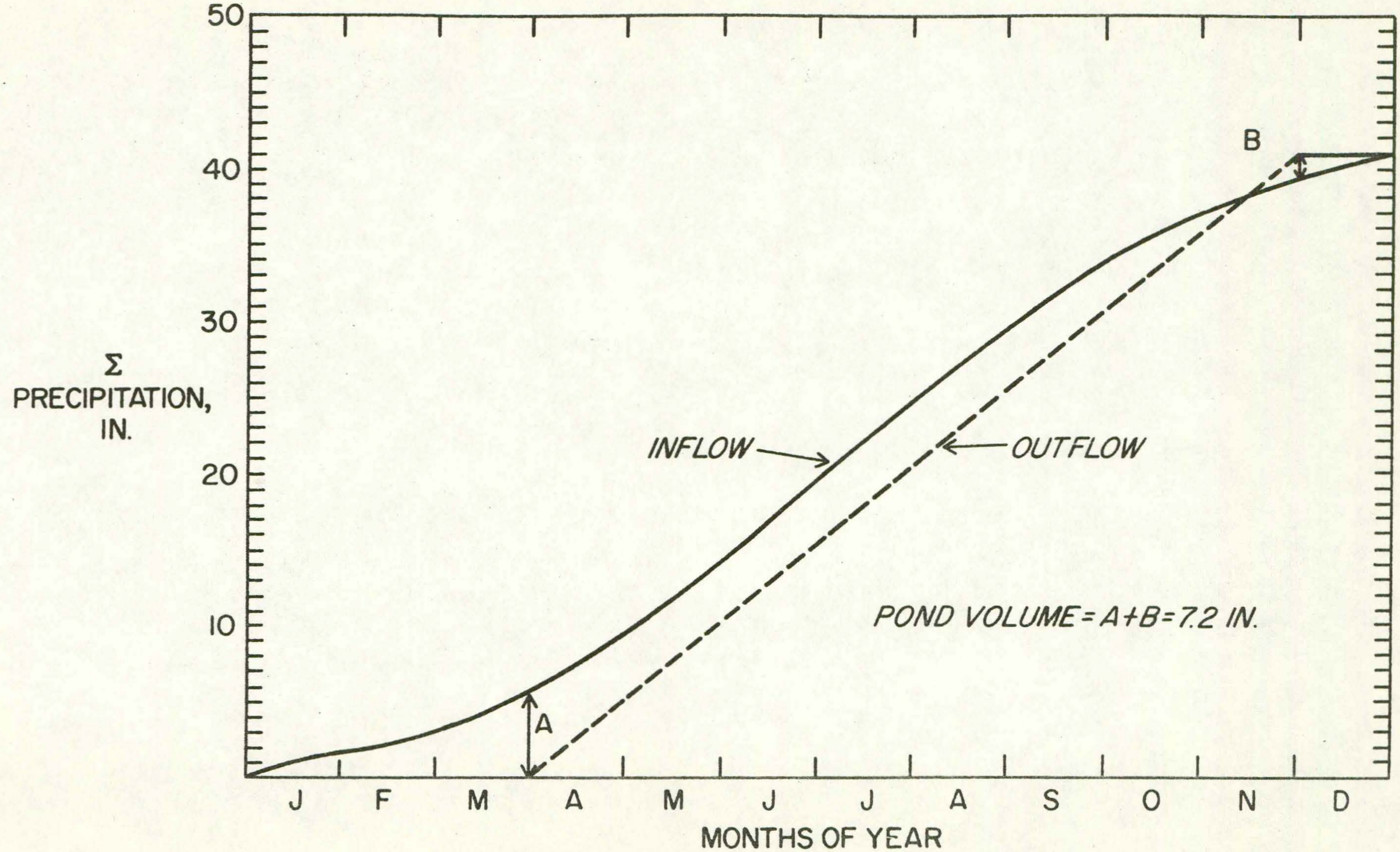

Fig. 11. The Pond Volume is Determined from the Inflow-Outflow Mass Diagram [For controlled release to land].

Release to Land and Stream

The required volume of retention pond can be minimized by employing a combination of release to the stream and release to the land. With this plan, wastewater would be released to the stream during March and December. For the months of April through November wastewater would be released to land. During January and February, no wastewater would be released. For these conditions, the required pond volume is 3.0 in per acre of feedlot (Figure 12).

Release to a Treatment System

Another possible procedure for controlling feedlot runoff is release to a treatment system. The treatment system might be a biological process such as an aerated lagoon, oxidation pond, or both. In any event, it is desirable to feed the treatment system at a reasonably uniform rate. If it is desired to release retention pond effluent at a uniform rate throughout the year, the retention pond volume in this example would be 7.5 in per acre of feedlot (Figure 13.).

The maximum slope of the inflow mass diagram (Figure 13) is about 0.5 in/day. Therefore, the minimum detention time in the retention pond would be 15 days. The pond discharge rate would be the slope of the outflow mass diagram, or about 0.115 in/day. Thus, if it was desired to treat the retention pond effluent in a lagoon having a detention time of 30 days, the volume of the lagoon would be about 3.5 acre-in per acre of feedlot area. For the 10-acre feedlot, this would be 35 acre-in, or about three acre-ft. The mass diagram is a convenient tool for use in determining not only retention pond volume but also for determining the required size of any subsequent treatment systems.

CONCLUSIONS

A significant reduction in water pollution from cattle feedlot run-

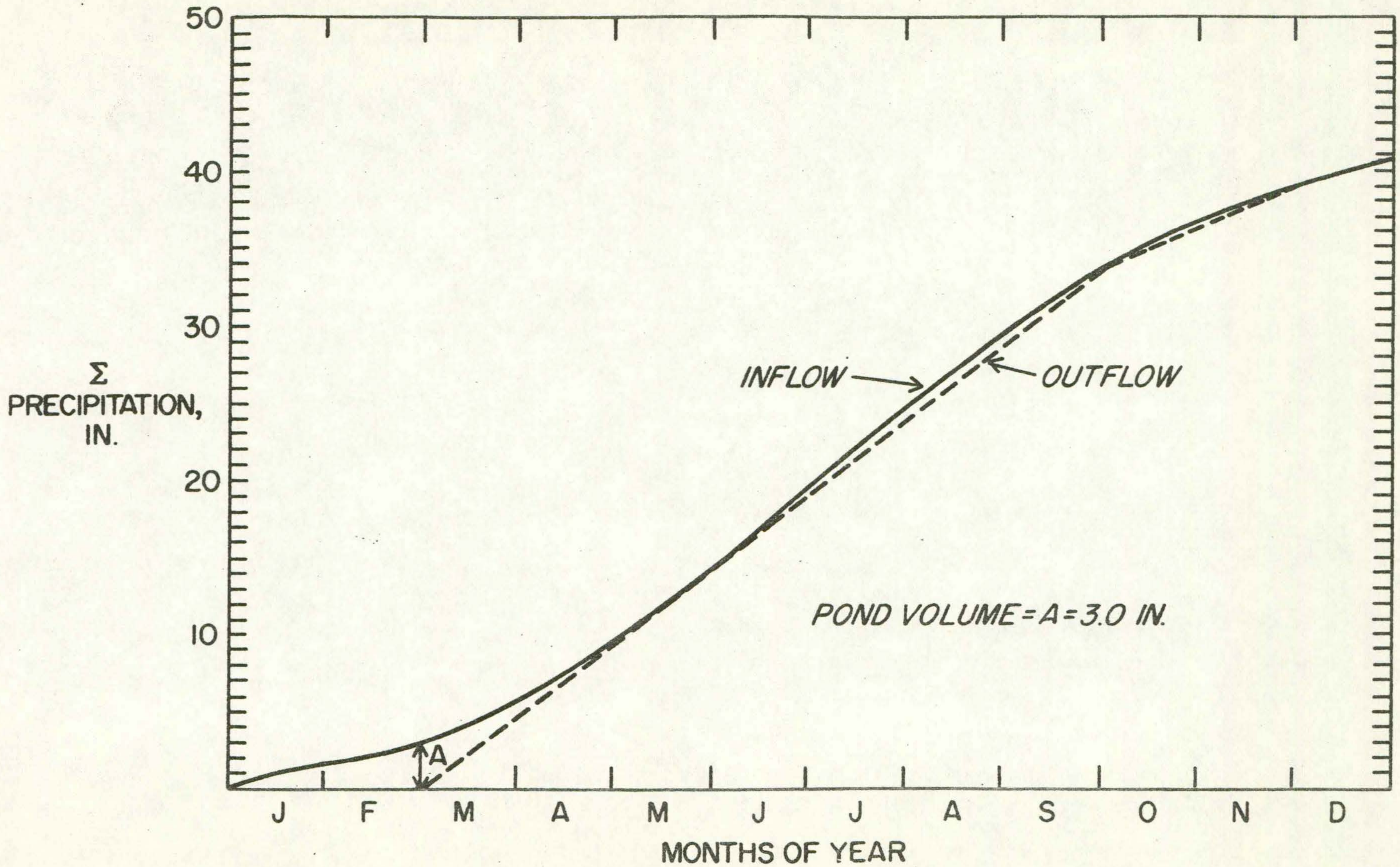

Fig. 12. The Pond Volume is Determined from the Inflow-Outflow Mass Diagram [For controlled release to land and stream].

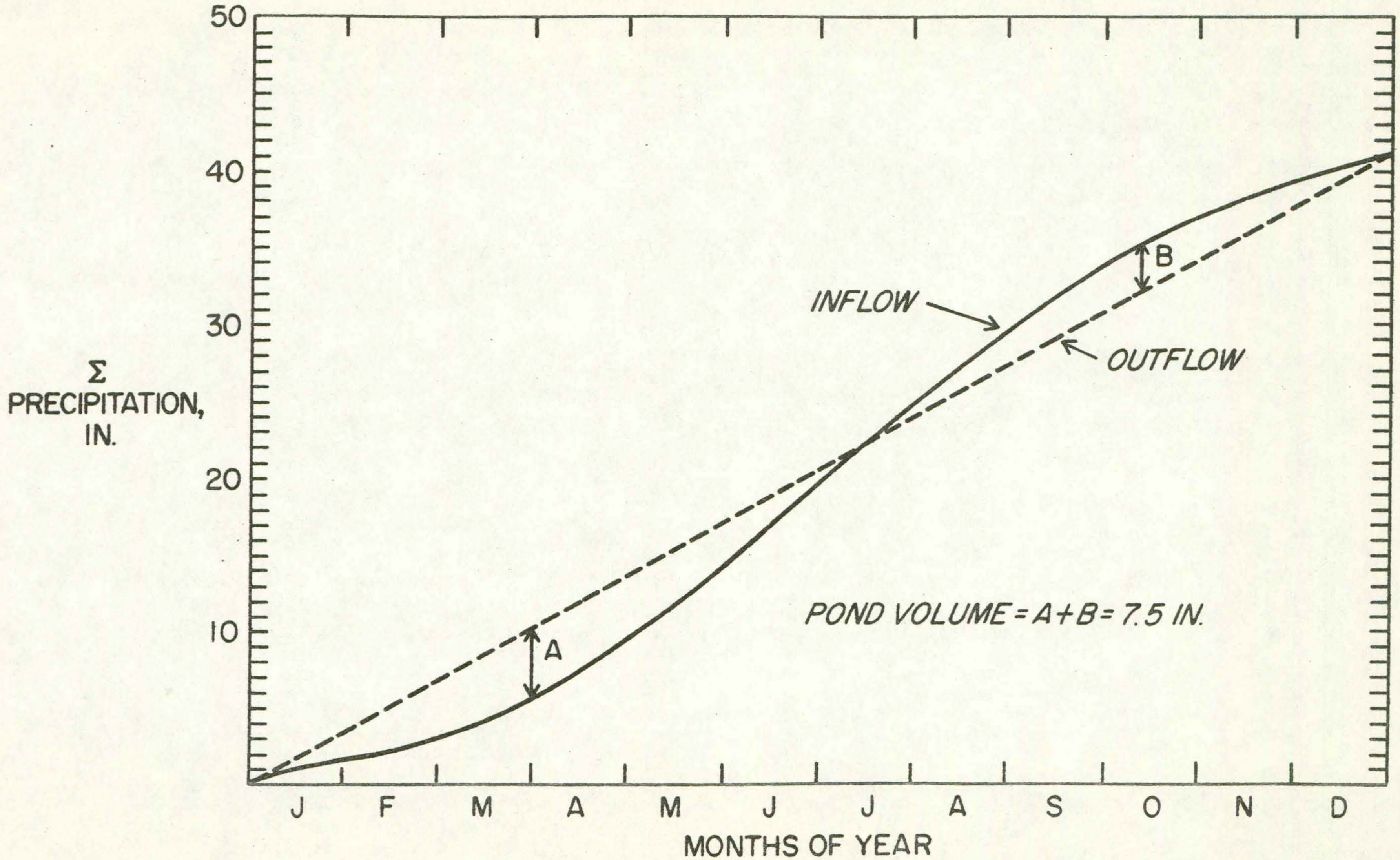

Fig. 13. The Pond Volume is Determined from the Inflow-Outflow Mass Diagram [For controlled release to a treatment system].

off can be accomplished by employing relatively simple and inexpensive runoff control facilities. The size of such facilities can be determined using established techniques for hydrologic and water quality analyses.

Using procedures similar to those described herein, it would be possible for control agencies to establish the minimum size of runoff control facilities for each region or major stream basin for each of several possible ultimate runoff disposal practices.

Caution should be exercised in applying the term "population equivalent" to cattle feedlot wastes. Any use of the term must consider the fact that the fraction of the total waste that enters water is extremely variable from one location to another and is heavily dependent upon the quantity and time variation in precipitation, the cattle density on the feedlot, and the topographic characteristics of the lot.

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