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POTENTIAL IMPACT OF ENVIRONMENTAL POLLUTION ABATEMENT ALTERNATIVES ON THE MICHIGAN DAIRY FARMING INDUSTRY

By

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ABSTRACT

POTENTIAL IMPACT OF ENVIRONMENTAL POLLUTION ABATEMENT ALTERNATIVES ON THE MICHIGAN DAIRY FARMING INDUSTRY

By

Darrel Good

Concern is being expressed by the public, industry groups, and researchers over the contamination and pollution of the environment. Pollution originating from all sources, whether it be municipal, industrial or agricultural, is receiving attention from local, state and federal agencies charged with maintaining or enhancing environmental quality.

Over time, the problems surrounding the management of animal waste in such a manner as to prevent environmental contamination have been compounded because of the increased concentration of livestock production into larger and more confined facilities and the increasing numbers of nonfarm residents in traditional farming areas. Although various federal and state statutes have been enacted or proposed to curb environmental pollution arising from animal wastes, more persuasive controls in

the form of direct regulation may be expected to originate from state legislatures.

The economic impact upon Michigan dairy farms of compliance with specific legal constraints for animal waste management was evaluated. Impacts of legal constraints upon cost of milk production were first analyzed within a theoretical framework. A linear programming model was established to analyze the impact of specific control measures on "representative" farms in terms of labor requirements, costs of production and returns to the operator's labor and management. Capital requirements of compliance with the control measures were also determined. Synthesized dairy firms were developed; organized around specified herd size and housing and waste handling systems. These synthesized firms were incorporated into the linear programming model and analyzed under three environmental pollution abatement alternatives:

1. Mandatory retention and disposal of surface runoff at the production site,
2. Prohibition of winter land disposal of wastes, and
3. Mandatory subsurface disposal of wastes.

Compliance with these pollution abatement alternatives requires additional investment in dairy waste handling facilities. The magnitude of these investment requirements vary according to production technology utilized. The warm enclosed housing systems utilizing outside waste storage facilities have the lowest additional investment requirements per cow. The stanchion housing systems require the largest additional investment per cow.

Investment economies accrue to the larger herd sizes. The magnitude of these economies varies by production technology utilized. Depending on production technology utilized, investments per cow are 4 to 15 percent lower for the larger herd sizes than for the smaller herds.

Policy compliance increases total milk production costs, at the present level of output, for all production technology-herd size combinations studied. Variable costs of production are reduced only for the stanchion and cold covered housing systems. Total milk production costs are increased the least for the cold covered housing systems, and the most for the stanchion housing systems and the 80-cow open lot system.

Returns to operator's labor are reduced by only five percent for 160-cow cold covered housing systems, but are reduced by 37 percent for 40-cow stanchion housing systems. This implies that operators of smaller dairy herds, especially those with stanchion housing systems, may be economically disadvantaged by pollution abatement policies, of the nature considered in this study, to the extent that they will discontinue milk production.

ACKNOWLEDGMENTS

This thesis represents the efforts of several individuals, and the author wishes to express sincere appreciation to those individuals who contributed to its development. Dr. Larry Connor, who served as the author's major professor and thesis adviser, provided invaluable assistance in initiating and completing this thesis. His patience, guidance and friendship during the past three years are deeply appreciated.

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Last, but certainly not least, I wish to express appreciation to my wife, Nancy, and sons, Kevin and Keith for their encouragement and sacrifices throughout my graduate program.

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CHAPTER I

INTRODUCTION

Concern is being expressed by the public, industry groups, and researchers over the contamination and pollution of the environment. Pollution originating from all sources, whether it be municipal, industrial or agricultural, is receiving attention from local, state and federal agencies charged with maintaining or enhancing environmental quality.

Several types of farm wastes have been identified as potential or existing sources of environmental pollutants. These sources include: (1) accumulation of sediment from soil erosion, (2) fertilizers applied to soils, (3) pesticide residues and (4) animal wastes.

Animal wastes may contribute to air, surface water, ground water and/or soil contamination. Over time the problems surrounding the disposal of animal waste in such a manner as to prevent environmental contamination have been compounded because of: (1) increased concentration of livestock production into larger and more confined facilities, (2) availability of relatively inexpensive commercial fertilizers which sharply diminishes the value of animal manure as a source of plant nutrients, (3) reduction in the availability of farm labor which forces many livestock producers to seek labor-saving technology in handling animal wastes and (4) increasing numbers of nonfarm residents in traditional farming areas. In recent years various federal and state statutes have been enacted or proposed to curb environmental pollution arising from animal wastes. Thus, some livestock producers are now faced with large volumes of wastes that are low in economic values; moreover, the management and physical disposition of these low-value wastes are legally restricted to assure pollution control.

The Problem

This investigation is to determine the economic impact on Michigan dairy farms of potential environmental quality controls on animal waste management. The impact of environmental quality controls will depend on: (1) the extent to which livestock wastes on Michigan dairy farms are actually contributing to environmental pollution, (2) the nature of this pollution (i.e., water or air pollution) and (3) the requirements necessary to abate pollution. The requirements necessary to abate pollution, in turn, depend upon the type of legal control measures enacted.

For purposes of this study, three potential legal control measures, specific to livestock production, are examined. These measures include: (1) mandatory retention and disposal of barnyard and/or feedlot waste runoff, (2) prohibition of "winter" land disposal of wastes and (3) mandatory odor control of wastes by means of subsurface disposal.

The impact of these alternative legal controls are appraised from the standpoint of adjustments required on Michigan dairy farms to be in compliance with these controls. The effect of the required adjustments are analyzed in terms of capital requirements, operating costs, labor requirements and return to the operator's labor, management and risk bearing.

Research Objectives

The specific objectives of this study include:

1. To determine the present legal restraints within which Michigan dairy farmers must function in the management of animal wastes.
2. To identify those Michigan dairy operations which are potentially most affected by legal environmental quality controls.
3. To evaluate the effects upon representative dairy farms of adjusting existing waste

management systems to be in compliance with applicable environmental quality controls.

The achievement of these objectives will provide information on the economic impact of implementing alternative legal pollution control measures to individual dairymen and public policy decision-makers.

Method of Procedure

The objectives of this study are met in three steps. The first step assembles data relevant to identifying actual or potential livestock waste management problems on Michigan dairy farms. Data assembled are taken from several secondary sources and Michigan dairy farm surveys conducted by the Michigan State University Department of Agricultural Economics.[1] The data collected includes: trends in number of dairymen selling milk in Michigan, trends in number of milk cows on Michigan farms, number and percentage distribution of Michigan dairy farms and milk cows by size of herd, geographic distribution of dairy farms and cows, number and percentage distribution of dairy housing systems by size of herd, relationship of size of herd to waste handling system used on Michigan dairy farms, survey results of dairymen's estimates of neighbor's objections to manure odors, and survey results indicating distance from dairy production unit to nonfarm and farm homes, and survey results indicating distance from dairy production unit to lakes and streams.

In the second step, the present legal restraints within which Michigan dairy farmers must function in the management of animal wastes are identified. The results of a survey of state legal statutes in the North Central Region which pertain to animal waste management[2] and selected cases of private litigation involving livestock waste management problems are used as a basis for defining present legal restraints. Two additional sources of information are utilized in an attempt to predict various future legal restraints on animal waste management in Michigan. These sources are: (1) actions recently taken by the Michigan Water Resources Commission and the Air Pollution Control Division of the Michigan Department of Health in correcting individual pollution problems on Michigan farms and (2) actual and/or proposed legal restraints applicable to livestock production in other states.

The third step is an evaluation of the economic impact upon Michigan dairy farms of compliance with legal constraints for animal waste management. Impacts of legal restraints upon cost of milk production are first analyzed within a theoretical framework. Then, a linear programming model is established to analyze the impact of specific control measures on "representative" farms in terms of labor requirements, costs of production, and returns to the operator's labor and management. Capital requirements are handled external to the model. Synthesized firms are developed, organized around specified herd size and housing and waste handling systems. These synthesized firms are incorporated into the linear programming model and analyzed under the three alternative legal control measures previously enumerated.

Subsequent chapters present the analysis, as completed in these three steps. Chapter II describes the structure of Michigan dairy farming; Chapter III discusses the legal pollution constraints within Michigan and in other states; Chapter IV is a theoretic presentation of the economic impact of pollution abatement on individual firms; Chapter V describes the linear programming model; Chapter VI provides the estimates used therein; Chapter VII presents empirical results of the analysis; and Chapter VIII summarizes the analysis and presents implications for dairymen and public decision-makers.

Chapter I Footnotes

[1]1964 Census of Agriculture, U.S. Department of Commerce, Bureau of the Census, Vol. II, Chapter 2; Dairy Statistics 1960-1967, U.S.D.A., ERS, Statistical Bulletin No. 430, pp. 47-48; C. R. Hoglund, "The Dairy Farm Enterprise: Project 80+5. The Michigan Dairy Industry of 1985," Michigan Agricultural Experiment Station, Research Report (in process of print); C. R. Hoglund and G. McBride, Michigan's Changing Dairy Farming, Research Report 96, Michigan State University, Agricultural Experiment Station, January, 1970, p. 7; C. R. Hoglund, J. S., Boyd, L. J. Connor and J. B. Johnson, "Waste Management Practices and Systems on Michigan Dairy Farms," Agricultural Economics Report, Report No. 208, Michigan State University, January, 1972.

[2]L. J. Connor, J. B. Johnson, C. R. Hoglund, "A Summary of State Regulations Pertaining to Animal Waste Management in the North Central Region of the United States," Agricultural Economics Report, No. 193, Department of Agricultural Economics, Michigan State University, May, 1971.

CHAPTER II

APPRAISAL OF WASTE HANDLING AND DISPOSAL PROBLEMS ON MICHIGAN DAIRY FARMS

Introduction

The problems encountered by dairy farmers in the collection, storage and disposal of waste are a function of several variables. These variables include: the amount of manure produced (i.e., number of cows); the type of housing facility (open lot, stanchion, cold covered, or warm enclosed); the type of waste handling system being used (liquid or conventional); the nearness of the production unit and land disposal area to neighbors and waterways. This chapter examines some of these variables with respect to Michigan dairy farms to provide an appraisal of the type and magnitude of waste handling problems on these farms.

Dairy Farms, Milk Cows and Milk Production

Number of Dairymen Selling Milk

There has been a consistent downward trend in the number of Michigan dairymen selling milk over the past 15 years. A high percentage of those dairymen discontinuing milk production had herds of less than 30 cows, with the number of dairymen with herds larger than 30 cows actually increasing for some periods. The trends in the number of dairymen selling milk for the period 1956 to 1970 and projected[1] for 1985 are shown in Figure 1. The number of dairymen selling milk decreased from more than 57,000 in 1956 to approximately 13,800 in 1972. The decrease is expected to continue in the future, resulting in an estimated 4,800 dairymen by 1985. Figure 1 also indicates that Grade B dairy farms are expected to cease to exist in Michigan after 1980.

Number of Milk Cows

The trends in the number of milk cows on Michigan dairy farms for the period 1955 to 1972 and projected for 1985 are given in Figure 2. The number of milk cows decrease from 817,000 in 1956 to an estimated 466,000 in 1972. The rate of decrease in the number of dairy cows was quite drastic from 1955 to 1959 and again from 1964 to 1970. Between 1959 and 1964 the total number of dairy cows only decreased by approximately five percent, from 650,000 to 620,000. Census data indicate that during this same time period, the number of cows on farms with herd sizes of 30 cows or more increased by slightly more than 66 percent. The number of cows on farms with herds of less

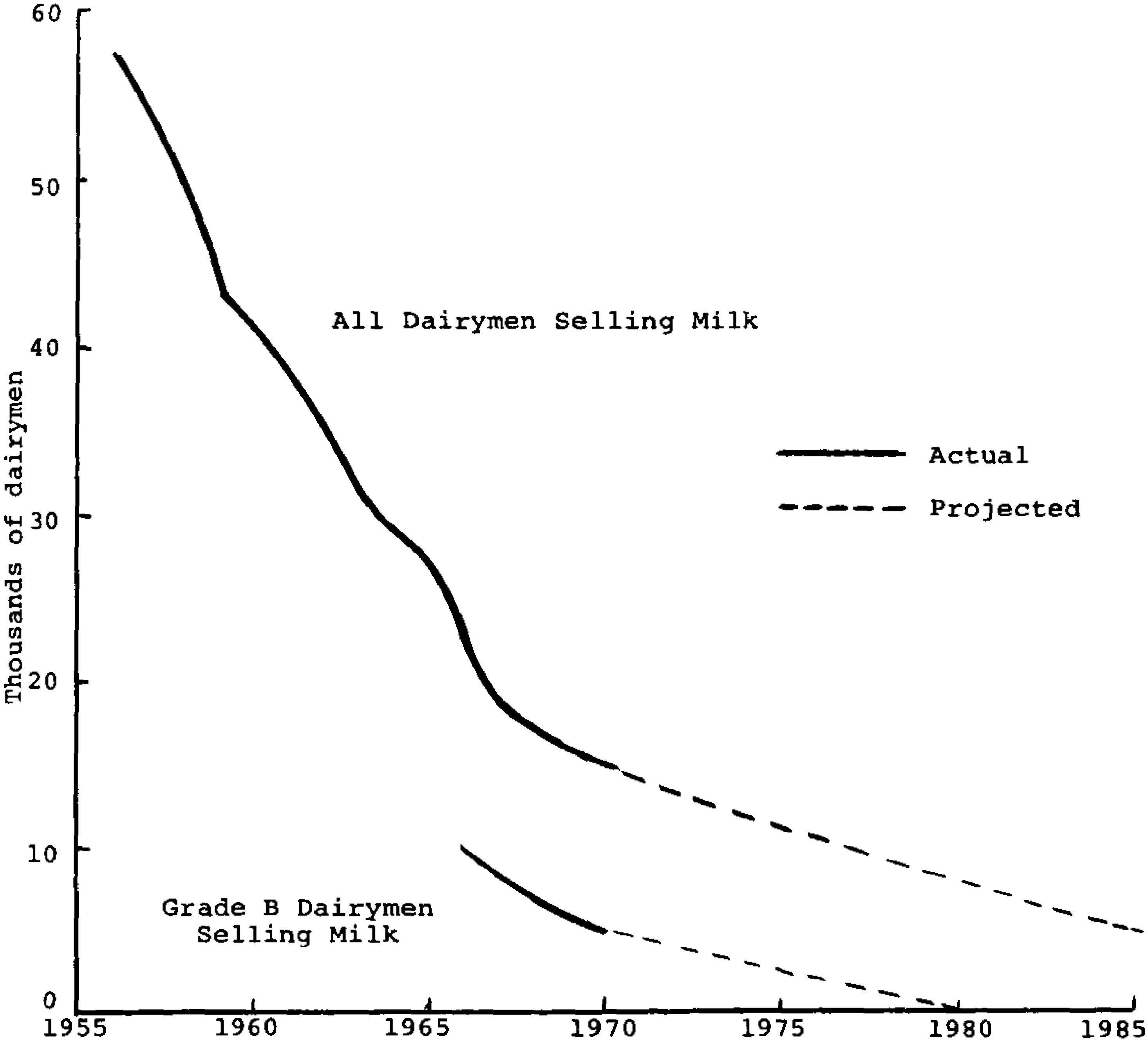
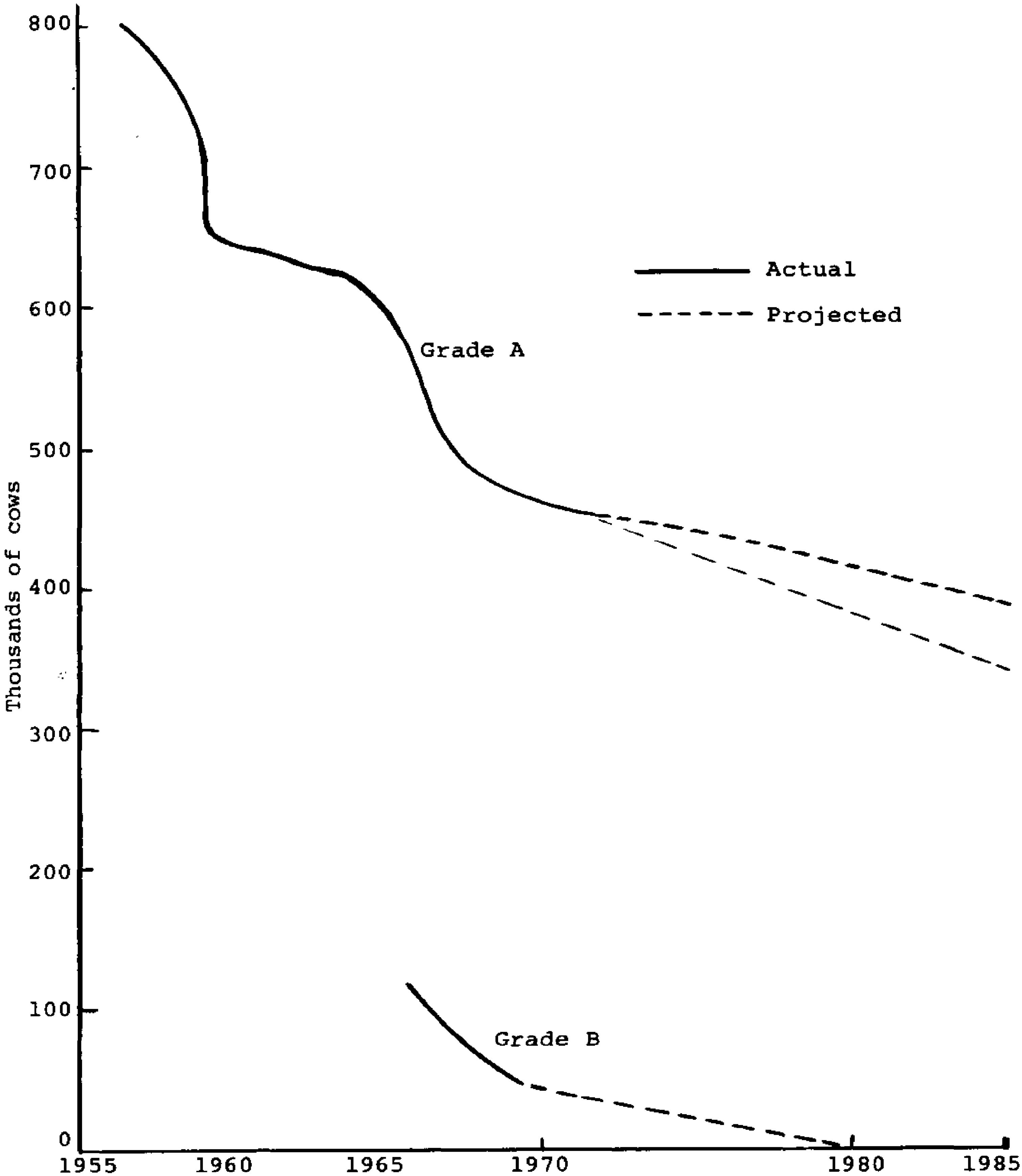


Figure 1. Trends in total number of dairymen selling milk in Michigan, 1955-1970, and projected for 1985.

Source: 1955-1972: Animal Health Division, Michigan Department of Agriculture, BRY periodic reports. 1985: Ray Hoglund, "The Dairy Farm Enterprise: Project 80+5. The Michigan Dairy Industry of 1985," Michigan Agricultural Experiment Station, Research Report (in process of print).

Figure 2. Trends in number of milk cows on Michigan Farms, 1955-1970, projected 1985.

Source: 1955-1969: Milk Production, Disposition and Income, U.S.D.A., Statistical Reporting Service, DA 1-2.
1970: Karl Wright, Dairy Changes in Michigan and the Top Five Dairy States, Agricultural Economics Report, Report No. 209, Michigan State University, September, 1971, p. 35.
1985: Ray Hoglund, Project 80+5 Report.


800
700
600
500
400
300
200
100
0
Thousands of cows
Actual
Projected
Grade A
Grade B
1955
1960
1965
1970
1980
1985

than thirty cows decreased by approximately 35 percent. U.S.D.A. statistics indicate that the number of dairy farms with herd sizes of 30 or more cows increased by nearly 52 percent during the period 1959 to 1964.[2]

For 1966, Grade A milk production accounted for 53 percent of the herds and 75 percent of the cows on Michigan dairy farms. By 1971 these percentages had increased to 70 and 88 percent, respectively. As indicated above, it is estimated that by 1980 all milk production in Michigan will be Grade A.

Size Distribution of Michigan Dairy Herds

The number and percentage distribution of dairy farms and milk cows by size of herd for 1959, 1964, 1970 and projected for 1985 are given in Table 1. However, data for 1959 and 1964 are not completely comparable to the 1970 data. The data for number of herds for 1959 and 1964 are actually "number of farms reporting dairy cows," based on U.S.D.A. statistics. Data for 1970 are "number of dairymen selling milk," based on unpublished data obtained from Ray Hoglund, Department of Agricultural Economics, Michigan State University. It is expected that the "number of farms reporting dairy cows" would be overstated relative to "number of dairymen selling milk" for those herds with less than 30 cows. Data for the

Table 1. Number and percentage distribution of dairy farms and milk cows by herd size for Michigan, 1959, 1964, 1970 and projected 1985.

	Cows Per Farm				
	<30	30-49	50-99	>100	Totals
Number of Herds					
1959[a]	47,701	3,388	634	51	51,774
1964[a]	26,980	4,679	1,371	146	33,176
1970	9,140	3,900	1,650	410	15,100
1985	400	1,100	1,400	1,100	4,000
Percent of Herds					
1959[a]	92.1	6.6	1.2	0.1	100.0
1964[a]	81.3	14.1	4.1	0.5	100.0
1970	60.6	25.8	10.9	2.7	100.0
1985	10.0	27.5	35.0	27.5	100.0
Number of Cows					
1959[a]	462.639	120,091	38,441	6,873	628,044
1964[a]	300,795	170,057	89,447	16,246	576,545
1970	142,000	150,000	116,000	57,000	465,000
1985	10,000	45,000	105,000	200,000	360,000
Percent of Cows					
1959[a]	73.7	19.1	6.1	1.1	100.0
1964[a]	52.2	29.5	15.5	2.8	100.0
1970	30.5	32.3	25.0	12.2	100.0
1985	2.8	12.5	29.2	55.5	100.0

[a]Totals for 1959 and 1964 are not the same as indicated in Figures 1 and 2 because of different sources of data.

Sources: 1959, 1964: Number of Cows--1964 Census of Agriculture, U.S. Department of Commerce, Bureau of the Census, Vol. II, Chapter 2. Number of Herds--Dairy Statistics 1960-67, U.S.D.A., E.R.S., Statistical Bulletin No. 430, pp. 47-48.
1970, 1985: Ray Hoglund, "The Dairy Farm Enterprise: Project 80+5. The Michigan Dairy Industry of 1985," Michigan Agricultural Experiment Station, Research Report (in process of print).

other herd sizes should be relatively comparable, particularly percentage distribution data.

Data for number of cows for 1959 and 1964 are 1964 Census of Agriculture data. The total number of cows in Michigan for 1970 is based on data in Wright's publication (Karl Wright, Dairy Changes in Michigan and the Top Five Dairy States, Agricultural Economics Report, Report No. 209, Michigan State University, September, 1971, p. 35) with the herd size breakdown based on data from the Project 80+5 report. These data are expected to be comparable. However, the figures for total number of cows in 1959 and 1964 are substantially smaller than those provided by U.S.D.A. statistics (upon which Wright's publication is based). Therefore, the percentage distribution of dairy cows for 1959, 1964 and 1970 should be comparable although the distribution by number may not be comparable.

Table 1 indicates that between 1959 and 1970 there was a definite trend towards fewer and larger dairy farms. There was a drastic reduction in the number of herds of less than 30 cows, with a substantial increase in the number of herds of more than 50 cows. This trend is expected to continue, resulting in only ten percent of the herds having less than 30 cows and more than 60 percent of the herds having more than 50 cows by 1985.

The same type of trend has occurred with regard to the number of dairy cows. There has been a substantial reduction in the number of cows on farms with less than 30 cows, relatively little change on farms with 30-49 cows, a considerable increase for herd sizes of 50-99, and a relatively large increase for herds with more than 100 cows. The 1985 estimates indicate that the greatest reduction in the number of cows in the future will come from herds with fewer than 50 cows. The number of cows on farms with more than 100 cows is expected to increase substantially, accounting for 55 percent of all dairy cows by 1985.

Geographic Adjustment

The number of dairy farms and milk cows are shown for seven production areas for Michigan for 1960 and 1970 and projected for 1985 in Table 2. In absolute figures, both number of dairymen and cows were reduced in all areas; however, percentagewise, there were slight reductions in the importance of dairying from 1960 to 1970 in the Upper Peninsula, Northern and Southeastern areas and slight gains occurring in the Western, Southern and Thumb areas. These trends are expected to continue in the future, with the Southern area gaining the most and the urbanized Southeastern area losing the most in both number of dairymen selling milk and number of dairy cows.

The average size of dairy herds for all production areas doubled from 1960 to 1970 and are projected to increase by two and one-half times from 1970 to 1985. Herd

Table 2. Number and percentage distribution of dairymen selling milk and number of cows for seven production areas and state, 1960 and 1970 and projected for 1985.

	Dairymen Selling Milk			Milk Cows			Cows Per Farm		
	1960	1970	1985[a]	1960	1970	1985[a]	1960	1970	1985
				Number					
1. Upper Peninsula	3,186	1,141	270	39,100	25,650	17,350	12	23	64
2. Northern	4,766	1,431	350	60,250	34,500	25,050	13	24	71
3. Western	6,962	2,569	720	101,280	79,200	66,600	15	31	92
4. Central	5,249	1,963	490	68,590	49,450	37,700	13	25	77
5. Thumb	6,804	2.836	820	104,480	83,900	71,200	15	30	87
6. Southern	8,717	3,200	975	151,280	115,900	100,750	17	36	103
7. Southeastern	5,978	1,940	375	116,020	77,400	41,350	19	40	110
State	41,662	15,100	4,000	641,000	466,000	360,000	15	31	90
				Percent					
1. Upper Peninsula	7.7	7.6	6.7	6.1	5.5	4.8			
2. Northern	11.4	9.5	8.9	9.4	7.4	7.0			
3. Western	16.7	17.0	18.0	15.8	17.0	18.5			
4. Central	12.6	13.0	12.2	10.7	10.6	10.5			
5. Thumb	16.4	18.8	20.4	16.3	18.0	19.8			
6. Southern	20.9	21.3	24.2	23.6	24.9	28.0			
7. Southeastern	14.3	12.8	9.6	18.1	16.6	11.4			
State	100.0	100.0	100.0	100.0	100.0	100.0			

[a]Medium projection.

Source: Ray Hoglund, "The Dairy Farm Enterprise: Project 80+5. The Michigan Dairy Industry of 1985," Michigan Agricultural Experiment Station, Research Report (in process of print).

size is the smallest in the Upper Peninsula, Northern and Central areas and the largest in the Southern and Southeastern areas. For the state, average herd size is projected to increase by 59 cows or to 90 cows by 1985.

Total Milk Production

Total milk production during the ten-year period, 1955-1965, was relatively stable compared to the downward trend in number of milk cows (Figure 3). Total milk supply actually increased during the period 1959 to 1964. This corresponds to the period when the number of milk cows on farms was almost constant. There was a sharp reduction in both milk cow numbers and milk production from 1965 to 1968 and a leveling off of both since 1968. It is estimated that by 1985 total milk production in Michigan will be from 4.7 to 5.2 billion pounds annually.

Milk Production Per Cow

Figure 4 indicates that milk production per cow increased steadily from 1955 to 1965, stabilized from 1965 through 1967 and increased again from 1967 to 1970. Over this 16-year period, production per cow increased by nearly 50 percent, or from 6,670 pounds per cow annually to 9,903 pounds per cow annually. Telfarm data at Michigan State University indicates that milk production per cow does not vary substantially with the size of the herd. Production

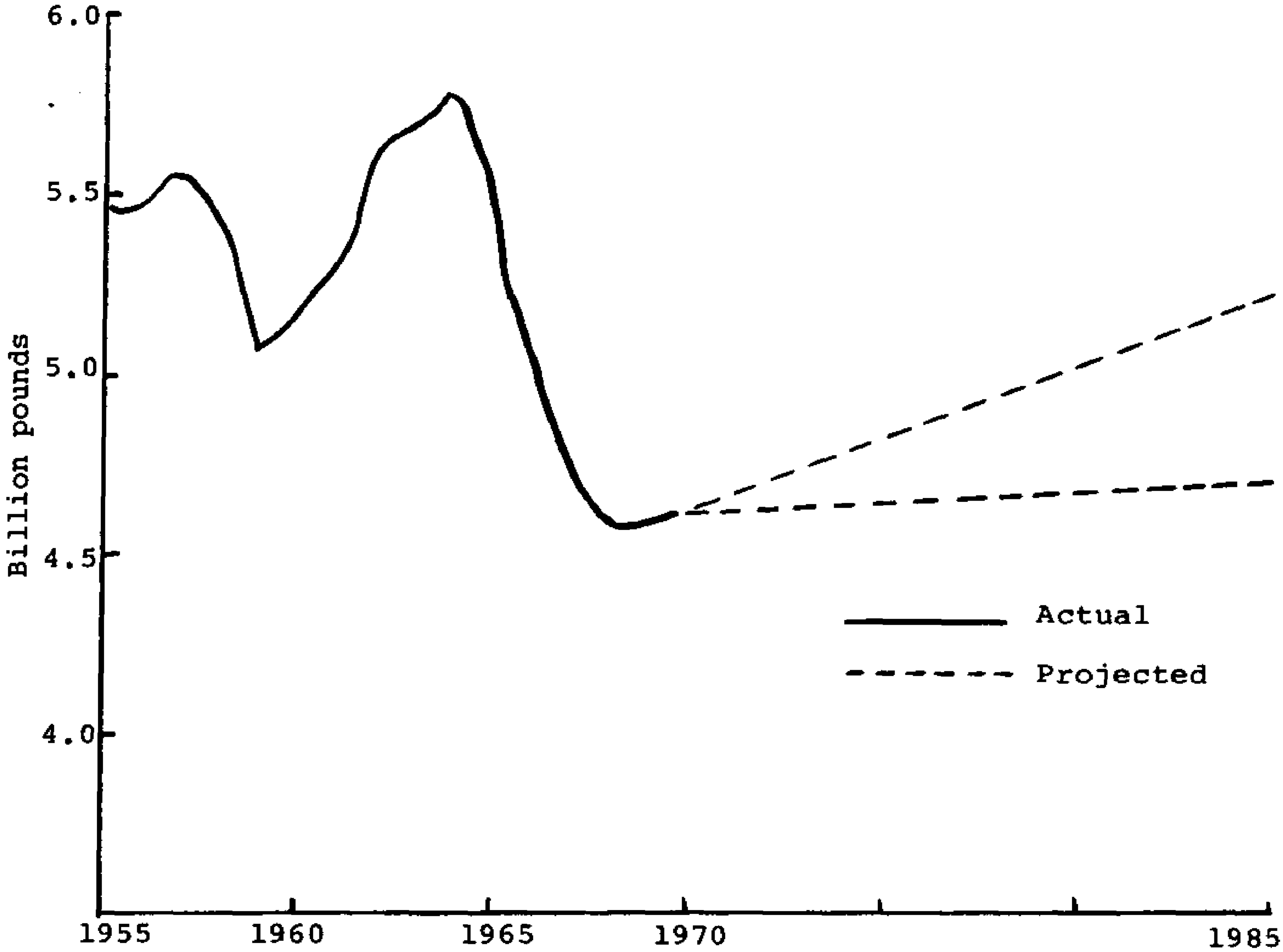


Figure 3. Trend in total milk production in Michigan, 1955-1970, projected for 1985.

Sources: 1955-1970--Milk Production Disposition and Income, U.S.D.A., Statistical Reporting Service, DA 1-2. 1985--Ray Hoglund, "The Dairy Farm Industry: Project 80+5, The Michigan Dairy Industry of 1985," Michigan Agricultural Experiment Station, Research Report (in process of print).

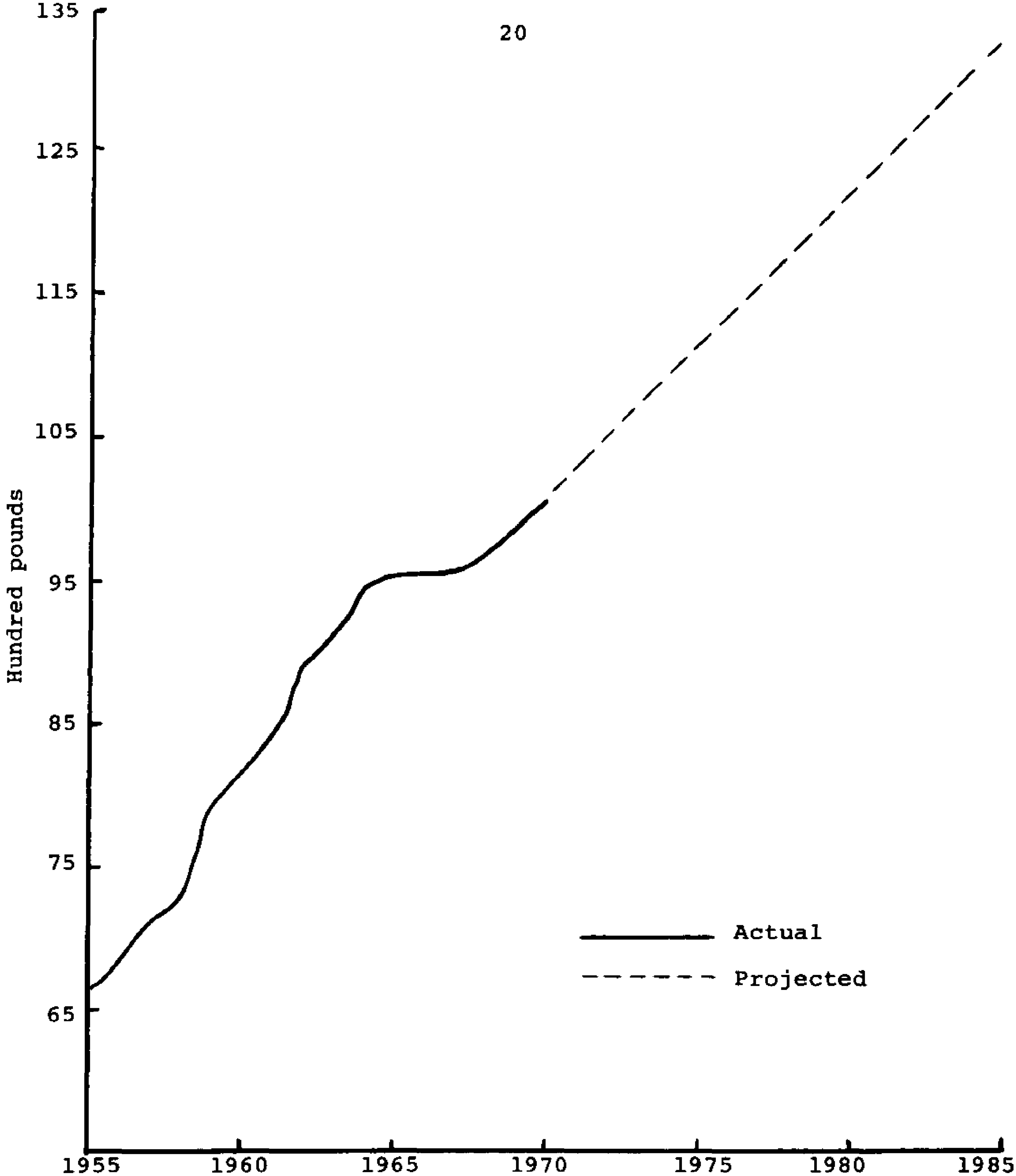


Figure 4. Milk production per cow, 1955-1970 and projected 1985.

Source: 1955-1970--Milk Production, Disposition and Income, USDA Statistical Reporting Service, DA 1-2. 1985--Ray Hoglund, "The Dairy Farm Enterprise, Project 80+5. The Michigan Dairy Industry of 1985," Michigan Agricultural Experiment Station, Research Report (in process of print).

per cow is slightly lower for herds with less than 30 cows, but is essentially equal for other herd size categories. It is estimated that by 1985 milk production per cow will be at a 13,000 pound average.

Housing and Waste Handling Systems

Dairy Housing Systems

The number and percentage distribution of dairy housing systems, by size of herd, on Michigan Grade A dairy farms for 1970 and projected for 1985 are given in Table 3. The predominant type of housing system in Michigan is presently the stanchion barn. However, these systems are concentrated in the smaller herd sizes, with the open lot free stall and cold covered free stall systems being more prevalent for larger herd sizes. Because the trend of small producers discontinuing production is expected to continue, the open lot free stall and the cold covered free stall systems are expected to dominate by 1985. The number of farms with warm enclosed free stall housing systems in 1985 is expected to be more than double the number of present systems.

Although similar figures on distribution of dairy housing systems by size of herd are not available for earlier time periods, some indication of the past trends in dairy housing are given by Hoglund, Boyd and Speicher.[3]

Table 3. Number and percentage distribution of dairy housing systems by size of herd on Michigan Grade A dairy farms, 1970 and projected for 1985.

Type of Housing	Cows Per Farm									
	Under 30		30-49		50-99		100 or More		Totals	
	1970	1985	1970	1985	1970	1985	1970	1985	1970	1985
Number of Farms										
Stanchion	3,460	280	2,090	530	390	170	14	10	5,954	990
Stanchion-switch	250	45	270	110	130	85	4	10	654	250
Open lot loose housing	420	20	510	110	300	80	31	30	1,260	240
Open lot free stall	90	55	435	300	490	525	186	250	1,201	1,130
Cold covered free stall	--	--	35	40	255	420	130	600	420	1,060
Warm enclosed free stall	--	--	10	10	85	120	45	200	140	330
Totals	4,220	400	3,350	1,100	1,650	1,400	410	1,100	9,630	4,000
Percent of Farms										
Stanchion	82.0	70.0	62.4	48.2	23.6	12.1	3.4	0.9	61.7	24.8
Stanchion-switch	5.9	11.2	8.1	10.0	8.0	6.1	1.0	0.9	6.8	6.2
Open lot loose housing	10.0	6.0	15.2	10.0	18.0	5.7	7.6	2.7	13.1	6.0
Open lot free stall	2.1	13.8	13.0	27.3	29.7	37.5	45.4	22.7	12.5	28.2
Cold covered free stall	--	--	1.0	3.6	15.5	30.0	31.7	54.6	4.4	26.5
Warm enclosed free stall	--	--	0.3	0.9	6.2	8.6	10.9	18.2	1.5	8.3
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Ray Hoglund, "The Dairy Farm Enterprise; Project 80+5, The Michigan Dairy Industry of 1985," Michigan Agricultural Experiment Station, Research Report (in process of print).

In the early 1960's, approximately 85 percent of the dairy cows in Michigan were housed in stanchion barns. This was down to 65 percent in 1968 and is expected to be less than 20 percent by 1980. Free stall housing is of recent origin in Michigan with the first system constructed in 1961. By early 1963 there were less than 20 in operation. A study of Grade A farms indicated the number of free stall systems had increased to more than 1,000 by the end of 1968, representing 11 percent of the herds and 19 percent of the cows on Grade A farms. As Table 3 shows, free stall housing represented slightly more than 18 percent of the Grade A herds in 1970.

The first covered free stall housing systems in Michigan were built in 1965. The previously cited study indicates that dairymen had built at least 40 completely new cold covered and 10 new warm enclosed systems by the end of 1968. In addition, at least 25 dairymen had constructed a partial cold covered system which included the free stall barn and usually a feed bunk located within the barn. As indicated by Table 3, free stall housing, open lot, and covered housing systems are becoming more prevalent and are expected to predominate by 1985.

Waste Handling Systems

Detailed historical data on the type of waste handling systems used on Michigan dairy farms is not available. However, some data is available on recent trends in the type of systems in use. Tables 4 and 5 show the relationship between size of dairy herd and type of housing systems to the type of waste handling systems used on Michigan Grade A dairy farms in 1968. These tables indicate that all farms with less than 30 cows and all farms using either a stanchion or stanchion-switch housing system used the conventional waste handling system. Liquid waste systems were more predominant on the large farms (100 or more dairy cows) and on dairy farms using a covered housing system. In total, there were only 74 liquid waste systems in operation on Michigan Grade A dairy farms in

Table 4. Relationship of size of herd to waste handling system used, Michigan Grade A dairy farm survey, 1968.

Waste Handling System Used	Cows Per Farm				
	30	30-49	50-99	100 and Over	All Farms
<u>Number of Farms</u>					
Conventional	5,284	3,705	1,357	170	10,516
Liquid	--	12	30	32	74
<u>Percent of Farms</u>					
Conventional	100.0	99.7	97.9	84.7	93.3
Liquid	--	.3	2.1	15.3	.7

Source: C. R. Hoglund and G. McBride. <u>Michigan's Changing Dairy Farming</u>, Research Report 96, Michigan State University, Agricultural Experiment Station, January, 1970, p. 7.

Table 5. Relationship of type of housing to waste handling system used, Michigan Grade A dairy farm survey, 1968.

Waste Handling System Used	Type of Dairy Housing					
	Stan-chion	Stan-chion Switch	Open Lot Loose Housing	Open Lot Free Stall	Cold Covered	Warm en-closed
Number of Herds						
Conventional	7,212	593	1,595	1,036	79	1
Liquid	0	0	4	44	17	9
Percent of Herds						
Conventional	100.0	100.0	99.7	95.9	81.8	10.0
Liquid	0	0	.3	4.1	18.2	90.0

Source: C. R. Hoglund and G. McBride, Michigan's Changing Dairy Farming, Research Report 96, Michigan State University, Agricultural Experiment Station, January, 1970, p. 7.

1968, representing only .7 percent of all Grade A producers. Table 6 shows the distribution of dairy farms by type of housing, waste handling system and size of herd for those farms included in a 1971 survey of Southern Michigan dairy farmers.[4] The scraper-loader-spreader system was the most important method of handling and hauling dairy waste for all herd sizes. Liquid waste handling systems were used on 16.4 percent of those dairy farms with 100 or more cows. Six of the 25 farms with liquid systems utilized an open lot system of housing, a system not well adapted to liquid storage and handling. As the trend towards

Table 6. Number of dairy farms by type of housing and waste handling systems and size of herd, 1971 survey of Southern Michigan dairy farms.

Housing and Waste Handling System[a]	Cows Per Farm				
	30-49	50-74	75-99	100 & Over	All Farms
Stanchion					
Stanchion	20	13	--	--	33
Stanchion switch	14	12	5	3	34
Open Lot					
Bedded area:					
Scraper-loader-spreader	14	9	3	4	30
Free stall:					
Scraper-loader-spreader	31	42	38	41	152
Liquid system	--	--	3	3	6
Covered Housing--Free Stalls					
Scraper-loader-spreader	6	7	14	13	40
Liquid system	--	6	4	9	19
Totals	85	89	67	73	314[b]

[a]Farms with less than 30 dairy cows were not included in the survey. The farms with less than 30 cows utilize a common system of handling dairy wastes: wastes are either hand loaded or mechanically loaded into a spreader with a gutter cleaner and distributed on cropland on every suitable day.

[b]Total of 340 survey schedules returned from 550 mailed out. Twenty-six survey schedules not sufficiently filled in to use in analysis.

Source: C. R. Hoglund, J. S. Boyd, L. J. Connor and J. B. Johnson, "Waste Management Practices and Systems on Michigan Dairy Farms," Agricultural Economics Report, Report No. 208, Michigan State University, January, 1972.

larger dairy herds and more covered housing systems continue, the number of liquid waste handling systems will likely increase.

Environmental Considerations

Odors

In a recent survey of Southern Michigan dairy farmers,[5] respondents were asked about their neighbors' reactions to manure odors from their dairy operations. They were asked to indicate whether the neighbors objected very strongly, only moderately or not at all to dairy-related odors. Of 314 respondents, 236 or 84 percent indicated no objections had been raised by their neighbors. For the dairymen with covered housing-liquid manure systems, 31 percent indicated moderate objections and 6 percent indicated very strong objections to manure odors had been reported by neighbors (Table 7).

Nearness to Neighbors

The urban sprawl in many areas of Michigan has resulted in a mixture of rural nonfarm residents and dairy farmers in areas which had historically been inhabited only by farmers. In the above-mentioned survey, approximately one-half of the dairymen stated that they had nonfarm neighbors within one-half mile of their barnyard (Table 7). A smaller percentage of the dairymen with

Table 7. Dairymen's estimate of neighbors' objections to manure odors and distance to nearest nonfarm and farm home and lake or stream.

Item		Housing and Manure Handling System			
		Open Lot Housing		Covered Housing	
	Stanchion Housing	Bedded Area	Free Stalls	Scraper-Loader System	Liquid System
			Percent		
Objections of neighbors to manure odors:					
Very strongly	--	--	1.3	--	6.3
Moderately	9.1	13.3	16.5	7.2	31.2
Not at all	90.9	86.7	82.2	92.5	62.5
Distance from barnyard to nearest:					
Nonfarm home--					
<1/2 mile	54.5	56.7	50.0	47.5	43.8
1/2 - 1 mile	27.3	30.0	29.6	32.5	37.5
>1 mile	18.2	13.3	20.4	20.0	18.7
Farm neighbor--					
<1/2 mile	66.6	66.6	63.1	65.0	50.0
1/2 - 1 mile	27.4	27.6	31.6	32.5	50.0
>1 mile	6.0	5.8	5.3	2.5	0.0
Lake or stream--					
<1/2 mile	30.3	40.0	36.2	37.5	43.8
1/2 - 1 mile	18.2	36.7	30.2	30.0	31.2
>1 mile	51.5	23.3	33.6	32.5	25.0
Distance from fields covered with manure to nearest:					
Nonfarm home--					
<1/2 mile	66.7	73.3	63.8	55.0	68.8
1/2 - 1 mile	15.1	16.6	21.1	30.0	25.0
>1 mile	18.2	10.1	15.1	15.0	6.2
Farm neighbor--					
<1/2 mile	75.7	80.0	73.7	82.5	68.8
1/2 - 1 mile	18.2	16.7	22.4	15.0	31.2
>1 mile	6.1	3.3	3.3	2.5	--
Stream or lake--					
<1/2 mile	33.3	50.0	50.0	45.0	56.1
1/2 - 1 mile	21.2	20.0	20.4	17.5	25.1
>1 mile	45.5	30.0	29.6	37.5	18.8

Source: C. R. Hoglund, J. S. Boyd, L. J. Connor and J. B. Johnson, "Waste Management Practices and Systems on Michigan Dairy Farms," Agricultural Economics Report, Report No. 208, Michigan State University, 1972.

larger herd sizes, especially those with covered housing systems, indicated a nonfarm neighbor this close to their barnyard. Approximately 64 percent of the dairymen reported a farm neighbor within one-half mile of their barnyard. Sixty-five percent of the dairymen reported nonfarm neighbors within one-half mile from fields which were used for manure disposal. Seventy-five percent of the respondents had farm neighbors within one-half mile of fields being covered with manure.

Nearness to Lakes and Streams

Approximately 35 percent of the survey respondents indicated the location of a lake or stream within one-half mile of their dairy barns and yards. Forty-five percent of the respondents indicated the location of a stream or lake within one-half mile of the fields on which manure was spread.

Summary

The data presented in this chapter indicate several trends which have created actual or potential environmental pollution problems resulting from animal wastes produced on Michigan dairy farms. The trend towards larger producing units had resulted in larger amounts of manure being produced at any one site. Actual and potential problems are created in disposing of the dairy wastes without polluting the environment because of the increased volume of manure to be handled.

The trend towards confinement housing systems and liquid waste handling systems has resulted in the practice of providing two or more months of waste storage capacity. Consequently, for these systems, larger amounts of dairy wastes must be disposed of at one time. This situation may increase the possibility of surface water pollution from field runoff. Furthermore, surface runoff may become a problem for those firms using an open lot housing system.

The concentration of milk production in the southern portion of the state corresponds to the state's human population concentration. As urban sprawl continues, the probability of a farm-nonfarm interface increases. Odor from livestock wastes will become a definite problem for dairy farmers operating in these interfaces.

Surface water pollution from livestock wastes, originating from either the production site or the disposal site, is a constant threat. Because of the large number of lakes and streams in Michigan, many dairy farms are located within one-half mile of a body of water.

Chapter III discusses present legal control measures, both in Michigan and in other states, which are applicable to problems of environmental pollution resulting from animal wastes.

Chapter II Footnotes

[1]Ray Hoglund, "The Dairy Farm Enterprise: Project 80+5, The Michigan Dairy Industry of 1985," Michigan Agricultural Experiment Station, Research Report, (in process of print).

[2]Dairy Statistics, 1960-67, U.S.D.A., E.R.S., Statistical Bulletin, No. 430, pp. 47-48.

[3]C. R. Hoglund, J. S. Boyd, and J. A. Speicher, "Economics of Open Lot Versus Covered Free Stall Dairy Housing Systems," Farm Science, Research Report 91, Michigan State University, Agricultural Experiment Station, June 1970.

[4]C. R. Hoglund, L. J. Connor, J. B. Johnson and J. S. Boyd, "Waste Management Practices and Systems on Michigan Dairy Farms," Agricultural Economics Report No. 208, Department of Agricultural Economics, Michigan State University, January, 1972.

[5]Ibid.

CHAPTER III

PRESENT AND POTENTIAL ENVIRONMENTAL QUALITY CONTROLS RELEVANT TO MICHIGAN DAIRY FARMS

Introduction

This chapter examines in some detail the present legal restraints within which Michigan dairy farmers must function in the management of animal wastes. Federal and State statutory controls and codes are examined; cases of private litigation are reviewed. In addition, predictions of probable directions of future environmental controls on Michigan livestock producers are presented. The basis for these predictions include: (1) actions taken by the Michigan Water Resources Commission and the Michigan Air Pollution Control Division of the Michigan Public Health Department in correcting individual pollution problems on Michigan farms and (2) actual and/or proposed environmental quality controls in other states. The economic impact of implementing each of these potential legal controls on Michigan dairy farmers is analyzed in Chapter VII.

Present Control Measures

Federal Regulation

The Federal Water Quality Act of 1965 (Public Law 89-234) provides that the states may, prior to June 30, 1967, and after public hearing, adopt water quality criteria applicable to interstate waters or portions thereof within the State.[1] Upon U.S. Environmental Protection Agency's approval of such State criteria, these criteria will become applicable quality standards. The discharge of matter from any source, including livestock operations, into such waters which reduces water quality below standard specification is subject to prosecution by the Attorney General of the United States. Michigan water quality standards, adopted June 28, 1967, were approved by the U.S. Government on April 17, 1968. These approved standards are enforceable by the Federal government and the State of Michigan.

The U.S. Army Corps of Engineers, under authorization provided in the Refuse Act of 1899, has jurisdiction over some animal waste pollution problems through its approval or denial of applications for permits to discharge wastes to navigable waters and their tributaries. The approval of the Michigan Water Resources Commission and the United States Environmental Protection Agency for water quality considerations is a prerequisite to issuance of the permit by the Corps of Engineers.[2] Under administrative codes developed to implement provisions of the Refuse Act, confined feeding operations need to apply and obtain a permit if two criteria are met: (1) if the maximum size of their operation at any one time in the preceding year exceeded 1,000 animals units <u>and</u> (2) if there was a direct discharge of waste to the receiving waters. Specifically, a statement of the code concerning applicability says that:

> Confined livestock and poultry operations are subject to the permit program if the given feedlot or facility contain 1,000 or more animal units (1,000 beef animals, 700 dairy cows, 290,000 broilers, 180,000 laying hens, 55,000 turkeys, 4,500 hogs for the slaughter market, 35,000 feeder pigs, 12,000 sheep and lambs, or 145,000 ducks) at any time during the calendar year preceding the filing of the application; <u>AND</u>, (1) the livestock or poultry facility utilizes a man-made drainage, flushing or collecting system (waste pits, ditches, detention ponds, lagoons, waste pipes, or the like) from which measurable waterborn wastes are regularly discharged irrespective of rains or melting snow, into a navigable stream or its tributary, or (2) a regularly flowing stream into which wastes are directly placed traverses the feedlot or facility, or (3) there is a frequent overflow from a containment or retention facility.[3]

Runoff from confined livestock and poultry operations due only to natural causes is not considered a "discharge" at this time, within the meaning of the term as applied to permits required under the Refuse Act of 1899.[4] If an operator has confined livestock operations at different locations or a feedlot which naturally drains in separate directions the 1,000 animal unit criterion applies to each separate operating unit.

Michigan dairymen can obtain application forms for a discharge permit from the U.S. Army Engineer, Detroit District Office. Information provided by the dairyman indicates the details of the dairy operation including size of operation, quantities of feed and water used, waste handling practices, nature of the water discharged, and a drawing to identify the location of confined feeding areas, adjacent streams, ditches, ravines, containment ponds, land disposal areas and other appropriate facilities.

The Michigan Water Resources Commission must provide in a certification or other written communication a statement that there is a reasonable assurance that the applicant will conduct his dairy operation in a manner which will not violate applicable water quality standards. The U.S. Environmental Protection Agency will evaluate the application to assure that (1) applicable State water quality standards have been correctly applied, (2) the applicant's affluent is given at least secondary treatment or its equivalent where the standard required this, and (3) there is strict adherence to the Environmental Protection Agency's policy that high quality waters do not suffer degradation. After approval of the application by the Michigan Water Resources Commission and the U.S.

Environmental Protection Agency, the Corps of Army Engineers can issue a permit.

State Regulations

In Michigan, authority for pollution control is vested in the Water Resources Commission and the Air Pollution Control Commission. To date, neither of these Commissions have established regulations relating specifically to livestock production. Both Commissions have dealt with environmental problems accruing from livestock operations on an individual farm basis. Complaints are referred directly to these Commissions, who in turn review the individual case and prescribe the necessary actions.

The water Resources Commission feels this method of dealing with potential pollution problems is superior to specific regulations requiring minimum abatement facilities for all livestock production. Commission personnel have stated that to be effective in controlling pollution, such a regulation would have to be tailored to handle the worst possible situation. As a result, the regulation would require over-investment in pollution abatement facilities on many farms. If the regulation were not designed to handle the worst possible situation, the case could arise in which an individual producer fully complied with the regulation, but continued to contribute to water pollution. Personnel with the Water

Resources Commission indicate that they would favor the issuance of guidelines to be followed by livestock producers in order to minimize water pollution problems.[5]

The responsibilities and authority of the Water Resources Commission and the Air Pollution Control Commission are discussed separately. In addition, the major provisions of the Michigan Environmental Protection Act and an example of its application are discussed.

Water Resources Commission[6]

The Water Resources Commission is responsible for establishing water quality standards for the various waters of the state in relation to current or future public use as it shall deem necessary (Act 245, Public Acts of 1929, as amended). State waters include both underground and surface waters. The Commission has the authority to make regulations and orders restricting the polluting content of any waste material or polluting substance discharged or sought to be discharged into any state waters. It has the authority to take all appropriate steps to prevent any pollution it feels is unreasonable and against public interest in view of the existing conditions of any state waters. The Commission, or any duly appointed agent, has the right to enter at all reasonable times, in or upon, any private or public property for the purpose of inspecting and investigating conditions relating to the pollution of any water. Any person requiring a new or substantial increase over the present use now made of the waters of the state for sewage or waste disposal is required to file a written statement with the Commission detailing: (1) the nature of the enterprise contemplated, (2) the amount of water required, (3) source of the water, (4) the proposed point of discharge of the wastes into state waters, (5) the estimated amount discharged, and (6) a fair statement setting forth the expected or known characteristics of the waste.

Most incidents of actual or potential water pollution involving established livestock producers are brought to the attention of the Water Resources Commission on a complaint basis. Some incidents, however, are discovered by Water Resources Commission field agents. When the Water Resources Commission receives a complaint of actual or possible water pollution, it makes an immediate investigation of the situation. The prime concern of the Water Resources Commission is the levels of BOD, suspended solids, nutrients and bacteria (Clostridium) of waters which are receiving livestock effluent. If the Water Resources Commission makes a finding of unlawful pollution, it issues a notice of the finding to the involved party. The notice includes orders for abating the pollution; included in the orders are a time table for (1) the submission of abatement plans by the livestock producer to the Water Resources Commission for approval, (2) the initiation of construction activities for abating pollution and (3) the completion of the abatement facility. Provisions for a public hearing regarding the alleged pollution, if so desired, are also specified in the orders. If a hearing is held, and the findings of the Water Resources Commission are upheld, the time table as perscribed must be followed. Following is a brief description of the cases of livestock waste management in which the Water Resources Commission has been involved.[7]

The first involvement of the Water Resources Commission in livestock waste management concerned a party establishing a new beef feeding-slaughter plant operation in Southern Michigan. The feedlot was designed to annually feed approximately 20,000 cattle. As required by law, the party proposing the operations came to the Water Resources Commission with a plan for handling waste produced by the operation. The Water Resources Commission reviewed the plans and made recommendations. The final plans for handling the feedlot wastes consisted of runoff retention facilities, storage lagoons and a spray irrigation system. Wells were also located around the feedlot and disposal area as a means of monitoring ground water characteristics.

The Water Resources Commission has since been involved in two incidents of stream pollution from beef cattle feedlot runoff. The first incident involved a cattle feeding operation which was constructed on an existing farm. The feedlot itself was a new operation, designed to feed 2,000 cattle. The owners failed to file with the Water Resource Commission. The Water Resources Commission notified the owners of the requirements to file a written statement for approval of the waste control facilities. The owners took no immediate action and in the spring of the following year, investigation by the Water Resources Commission determined that runoff from the feedlot had substantially increased the level of suspended solids, nutrients, BOD and clostridium bacteria in a stream located near the feedlot. The owners were then required to devise some method (subject to approval by the Water Resources Commission) to collect and dispose of the runoff. As a result, the feedlot was graded and a waterway constructed to channel runoff into a lagoon for storage. Stored wastes were then applied through spray irrigation onto the owner's land.

The second incident of water pollution due to feedlot runoff involved a feedlot consisting of four ten-acre plots designed to facilitate 2,000 cattle. At the time of investigation by the Water Resources Commission, there were approximately 2,500 cattle on these four lots. Runoff from these lots resulted in a high level of organic material, oxygen depletion and a "substantial" fish kill in a nearby stream. As a result, the feedlot owner was required to construct a retention facility to collect the runoff. The waste was collected in a lagoon and disposed of via a spray irrigation system. Wells were also constructed around the feedlot in order to monitor the ground water characteristics. In addition, the feedlot owner reduced the number of cattle in the feedlots.

The Water Resources Commission also became involved in an incident involving a cattleman who allowed his pastured cattle to graze into a river which bordered the pasture. As a result, the banks of the river became eroded, creating a soil runoff and sediment problem. The Water Resources Commission investigated and made a finding of unlawful pollution. Before the Commission completed its process of making recommendations for correction of the problem, the owner moved the cattle to a different location. The Commission indicated that their recommendation would have required the construction of a fence to prohibit the cattle access to the banks of the river.

In addition to the above incidents, personnel of the Commission indicated that they have handled some "minor cases" of water pollution from livestock wastes. These incidents were handled on an ad hoc basis by Water Resources Commission field agents. Recommendations for corrective actions required only minor adjustments by the livestock producers and were followed voluntarily and immediately.

Air Pollution Control Commission[8]

The Michigan Air Pollution Control Commission is responsible for establishing rules and regulations for controlling or prohibiting air pollution and controlling and abating air pollution in accordance with any rule or regulation which it may promulgate under existing legislation (Act 348, Public Acts of 1965, as amended). The Commission has the right to enter and inspect any property at reasonable times or places pursuant to reasonable notice for the purpose of investigating either an actual or suspected source of air pollution or ascertaining compliance or noncompliance with any rule or regulation. This Commission also has other powers such as to receive and initiate complaints of air pollution in alleged violation of any rule or regulation which may be promulgated under the Air Pollution Act.

As part of the general rules of the Air Pollution Control Commission, a person planning to construct, install, reconstruct or alter any process or control equipment which may be a source of air pollution must submit plans and specifications to the Commission for approval prior to the initiation of any construction, installation or alteration. The plans and specifications should include such information as the expected composition of the air stream, expected physical characteristics of particles and type of air cleaning device (if any). A permit to install is granted when the Commission determines that the plans and specifications are in accordance with the rules and regulations pertaining to air pollution control. After the completion of any construction for which an application, plans and specifications were approved, the Commission shall issue a permit to operate the facility, provided its actual operation does comply with air pollution control rules and regulations.

The Air Pollution Control Division of the Michigan Department of Health has responsibility for investigating complaints concerning air pollution in Michigan. If the complaint is found to be substantive, the Air Pollution Control Division makes recommendations for abating the pollution, and can legally enforce these recommendations if the party involved is in violation of any Air Pollution Control Commission regulations. Following is a brief discussion of some of the complaints, specific to livestock operations, which the Air Pollution Control Division has received and acted upon.[9]

Dairy.--The Air Pollution Control Division has investigated only one dairy operation for alleged air pollution. A number of residents located near a dairy operation complained of foul odors emanating from the manure as it was being spread on the operator's land. The dairy operation in question was a 110-cow operation using a liquid manure system. The complaint was investigated and found to be substantive. The operator agreed to the Air Pollution Control Division's recommendation that he use a chemical treatment in the liquid storage tanks to reduce odors. The treatment has been effective in controlling odor within the tolerance limits of the neighbors. If the chemical treatment had not been effective, the Air Pollution Control Division would have then recommended subsurface disposal of the liquid manure.

Poultry.--The Air Pollution Control Division has received complaints concerning 16 different poultry facilities. All complaints received were concerning odors from caged layer-egg production units. The sources of these odors were determined to be primarily from the bird housing unit, manure disposal methods and improper incineration or disposal of dead birds.

The investigation of these complaints showed that three facilities were considered to be in compliance; 11 were considered to be in violation of the Michigan Air Pollution Control Act (Act 348, P.A., 1965) and corrective action was requested; two require further evaluation to determine compliance. Of the 11 facilities requiring corrective action, four have successfully completed control programs and seven have yet to submit control programs or additional evaluation of the effectiveness of the program is necessary.

The air pollution control staff recommended that improved housekeeping techniques, improved techniques for manure disposal (eq., plowing under manure the same day it is spread), and proper dead bird disposal methods (use of adequate pathological incinerator or burial methods) be included in odor control programs.

Swine.--Complaints have been received concerning seven different swine facilities. The complaints were of odors from the housing unit and/or from the spreading of the wastes on the land. Investigations revealed that two facilities were considered to be in compliance and another operator improved his housekeeping techniques, resolving the problem before the investigation was completed; two facilities require further evaluation; the other two facilities have resolved odor problems, one by ceasing operation and the other by using ground injection of the liquid manure.

Beef Cattle.--Complaints have been received concerning three different beef cattle facilities. All of these complaints were of odors from manure accumulation on the feedlots. The results of Air Pollution Control Division investigation indicated that one operator removed the cattle from the lot before the investigation was complete; one operator reached an agreement with the complainants to limit the number of cattle on the lot and one operation was following generally good sanitation methods when it closed.

Environmental Protection
Act of 1970[10]

This Act provides that

> . . . the Attorney General, any citizen, corporation, organization, governmental unit or other legal entity may bring an action in the circuit courts of the state against any other citizen . . . entity for declaratory and equitable relief for the purpose of protecting the air, water and other natural resources of the state from pollution, impairment, or destruction.

Before this Act became Michigan law, an individual had to demonstrate some personal injury or damage before bringing suit. This Act provides individuals the opportunity to bring action directly against governmental agencies as well as against private concerns or nongovernmental entities, without having been personally damaged, in order to protect the public's interest in the State's natural resources. This is true even though the defendant may have previously complied with requirements of the Air Pollution Control Commission or the Water Resources Commission, or both.

The first court case relating to a livestock farm under the Environmental Protection Act came to trial in October, 1971, and was decided in February, 1972, (Clinton

County Circuit Court File No. 844). The plaintiffs based their action on two counts. In Count I plaintiffs claimed that a swine finishing barn constructed by defendants in 1965 constituted a private nuisance because noxious odors and toxic gases emanating from defendants' barn were carried to plaintiffs' property by reason of prevailing winds from the southwest and exhaust fans in the barn. In Count II plaintiffs cited Act 127, P.A. 1970, M.S.A. 14.528, effective October 1, 1970, known as the Thomas J. Anderson, Gordon Rockwell Environmental Protection Act of 1970 and on the basis of the factual allegations of Count I claimed a violation of this Act. Under both counts, plaintiffs sought injunctive relief.

The defendant was operating a swine confinement finishing barn in an area zoned agricultural. The barn was constructed according to plans and specifications prepared by the Michigan State University Department of Agricultural Engineering. The excrement was collected in a pit below the floor of the barn and was periodically emptied by means of a vacuum tank wagon and spread on defendant's land.

The plaintiffs' complaints were investigated by the Air Pollution Control Section of the Michigan Department of Health. In seven visits, the Air Pollution Control Section was unable to substantiate the complaints. Furthermore, the Air Pollution Control Section has, for its purpose, the enforcement of standards regulating pollution set by the Air Pollution Control Commission. Since no standards or regulations relative to pollution control of agriculture have been promulgated by the Commission, any action to abate would have to be by persuasion rather than by enforcement of regulations.

There was no question that the swine operation was producing disagreeable odors. The court was not convinced, however, that the plaintiffs proved diminished property values or any health hazard from the odors. Furthermore, the court found that the defendant was using good farming practices, producing neither insect and rodent problems nor water pollution problems. In addition, it was estimated that the defendant would suffer a cost of $20,000 if he were forced to relocate his barn, without assurance that other neighbors would not be subjected to the same odors. The court found that on balance the equities were in favor of the defendant and the appeal for injunctive relief on the basis of nuisance was denied. Due to the lack of standards by the Air Pollution Control Commission, the court also found that the Environmental Protection Act, as it now stands, could not serve as a basis for relief to the plaintiffs.

In reaching this decision, the court made the following statements which may have significance in future cases:

> There is no question but what the Environmental Protection Act is broad in scope and does not exclude agricultural pursuits from its operation. However, as the Court interprets Sec. 3 of the Act, the legislature is in effect saying that some balance has to be maintained between absolutely no pollution and the carrying on of activities necessary to human existence. The raising of livestock to provide meat for human consumption is a lawful and necessary occupation that of necessity will result in the production of animal waste and in turn odor. It would be the opinion of the Court that if the livestock operation is carried on in an area zoned for that purpose in a generally accepted manner, and that the operation is carefully carried on so that waste products are handled with reasonable efficiency and dispatch so that the odor entering the atmosphere is held to a practical minimum, it could very well be said that a defendant has established an affirmative defense "that there is no feasible and prudent alternative to defendants" conduct and that such conduct is consistent with the promotion of the public health, safety and welfare. This is not to say that the raising of livestock is free from all restraint so far as the Environmental Control Act, as it now stands. Unless there are definite standards set there would appear to be a balancing of interests on a case by case basis required with the livestock raiser having the burden of affirmative defense.

<u>Privaetly Initiated Court Action</u>

Regulation of pollution may occur through common law provisions such as nuisance, trespass and water rights. Nuisance actions have been used more often and more successfully than the other two.[11]

What constitutes a "nuisance" may vary substantially from state to state. In general, however, the existence of a "nuisance" is based on the premise that all persons have the basic right that they are not to be interfered with in the reasonable enjoyment of their property.[12] With regards to livestock and poultry operations, "the following might be 'nuisances' if they interfere with the free movement on or use of property, decrease the value of or profits from property, offend the sense of smell, hearing and sight, or cause inconvenience, bodily discomfort, mental distress or injury to health: manure solids or other waste-derived pollutants in surface water or underground water; offensive or otherwise objectionable odors, dust, smoke, feathers and other wind-transported materials; objectionable noises or excessive flies, rodents and other pests."[13]

Plaintiffs have essentially three alternative courses of action in a nuisance suit: (1) seek an injunction, (2) seek damages (actual and/or punitive) or (3) seek an injunction and damages. If the suit is for an injunction, a "balancing-of-interests" (balancing of equities) approach is used by many courts. Under this approach the court is actually weighing the interests of the parties involved in the suit. The party judged to have the greatest interest will win the lawsuit. If the interests of the plaintiff is judged to be superior, there is a trend to require modification of the livestock operation to reduce or eliminate pollution rather than to require the livestock producer to cease production.

Cases dealing with requests for injunctive relief may be accompanied by spearate counts requesting "actual" and/or "punitive" damages.[14] The primary legal issue in actual damages is whether the polluter caused the damages allegedly suffered by the plaintiff. It is not necessary to determine whether negligence was involved in order to establish liability; proof of causation is sufficient. Punitive damages may be granted if there was malicious intent related to the conduct which injured another person or his property.

The following actual cases (not in Michigan) are presented to illustrate recent nuisance cases involving the awarding of actual damages, punitive damages and injunctive relief.

Case 1

In this case, a cattle feeder had contracted to feed 7,500 head of cattle for a major packer.[15] Soon after the feedlot began operating, a heavy rain "flushed out" the feedlot into a nearby creek. The contaminated water from the creek seeped into the well of a dairy farmer located downstream. After drinking from the well water, his cattle became ill and several died. The dairyman incurred substantial veterinary expenses, was forced to haul water from other sources and eventually had no other choice but to discontinue dairying. At trial, the jury decided this was legally a nuisance and the dairy farmer was reimbursed for his actual damages. No punitive damages were awarded because the cattle feeder's actions were judged to be neither malicious nor intentional.

Case 2

This case was a civil action to recover damages and seek an injunction because of a private nuisance.[16] The defendant had purchased a 139-acre tract of land and constructed facilities for the production of hog breeding stock. Facilities included eleven totally enclosed and mechanically ventilated buildings with capacity of about 3,800 head of hogs, 30 acres of open lots for hog confinement, and eight anaerobic lagoons with a combined surface area of five acres and capacity to store three to four years' manure production. The plaintiffs (owning property adjacent to the defendant) indicated that (1) lagoon overflow or release of lagoon contents flowed across their property and on one occasion, a dislodged plug on one lagoon drainpipe permitted a large volume of lagoon contents to flow across the property of one of the plaintiffs, through his stock watering pond and into a creek; (2) runoff from about 12 acres of hog lots drained across the plaintiffs' property and into ponds; and (3) obnoxious odors from the defendant's property affected the uses and values of their properties. The court awarded $46,200 in actual damages and $90,000 in punitive damages to the plaintiffs. The presiding judge had excluded an injunction as a possible choice.

Case 3

This case involves a request for injunction on two counts: (1) that the use of the defendant's property as a cattle feedlot was unlawful since it was contrary to the zoning ordinance, and (2) that the cattle feedlot was both a public and private nuisance because of odors, flies, other insects, bacteria in the air, and nitrates in the groundwater.[17]

The defendant purchased a 24-acre plot of land in an area that had been classified as an "agricultural district" in 1942 and proceeded to construct a commercial feedlot designed to confine about 2,800 cattle (the previous owner had finished as many as 400 cattle at one time on this property). The intention was to construct a circular, funnel-shaped feedlot (covering four acres), divided into 12 pie-shaped pens, with all pen surfaces sloping toward the center of the circle. Manure was to be drained into an earthen pit and then trucked to a Wisconsin-based composting operation. Fourteen hundred cattle were being fed on the partially finished feedlot.

The court found that the defendant was operating a commercial cattle feedlot in an Agricultural Use District. The court ruled that the feedlot did not constitute a stock farm, a domestic animal-breeding operation, or a use commonly classed as agricultural, but was found to be a stockyard or a use substantially similar to that of a stockyard as defined under Industrial Zoning. Therefore, the defendant was found in violation of the zoning ordinance. The decree further found the feedlot to be a public and private nuisance because of the imminent danger of contaminating groundwater, of actual pollution of surface water which escaped to nearby properties, of the existence of offensive odors with no effective means to control or abate the odors and substantially contributing to the fly population. The defendant was permanently enjoined from using the premises as a cattle feedlot after March 1, 1970.

Controls in Other States

The predominant provisions provided by specific legislation and administrative codes in other states are livestock operation registry and/or permit provisions. These registration and permit requirements are of two general types.[18] The first type requires the registration and/or a permit for the continued operation of a livestock production facility. The second type, usually established from general state water quality statute provisions, most frequently requires the approval and issuance of a permit for the construction and continued operation of a waste abatement facility and/or waste discharge point.

Criteria used to determine whether a livestock facility is eligible for registration or for the approval of an operating permit for initiating or continuing production vary among states. Several states require only that the livestock operation be in compliance with waste discharge requirements, with the means of achieving compliance being the decision of the operator, who may choose among various alternatives and seek the approval of the water pollution control agency for that alternative which is optimally suited to his overall resource position. Other states, however, specify minimum facilities which must be constructed prior to the registration or issuance of a permit.

In Iowa, the minimum water pollution control facilities for uncovered confined beef feeding operations include terraces and retention ponds capable of containing three inches of surface runoff from the feedlot, waste storage, and other contributing areas. Similar minimum water pollution control facilities are required in Kansas. In Arizona and Oklahoma feedlots are required to have at all times mechanical means for scraping, cleaning, and grading feedlots.[19] Criteria such as these imply a required set of abatement technology for all firms, irrespective of the uniqueness of the resource position of a particular firm.

In general, those required to register are new and/or expanding firms, firms which have or are contemplating discharges directly into streams, and livestock firms over a given minimum size or over a minimum level of waste production. States now having a registration and/or permit system include Connecticut, Maine, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island, Minnesota, Indiana, Iowa, Kansas, Nebraska, Oklahoma, Texas, Arizona and Florida.

In Massachusetts a statute requires that there be no cattle or other animals housed or otherwise confined within fifty feet of the high water mark of water supply sources. In Minnesota new animal lots are prohibited within shoreland, within a floodway, within 1,000 feet of the boundary of a public park, in sinkholes or areas draining into sinkholes or within one-half mile of the nearest point of a concentration of ten or more residences at the time of construction.

The states of Maine and Illinois have considered or are considering legislation which would limit the timing of manure application to the land to limit the drainage therefrom to inland or tidal waters.

Most state controls on livestock operations are derived from general state water and/or air quality statutes. However, several states are considering the introduction of legislation specific to livestock operations. These states include New Jersey, Pennsylvania, Illinois, Missouri, North Dakota and South Dakota.

Potential Environmental Controls Specific to Michigan Livestock Production

Based upon the information presented in this chapter, three potential control measures, specific to Michigan livestock producers, are identified for analysis in Chapter VII. These regulations will be analyzed to determine their impact upon Michigan dairy farmers in terms of capital requirements, labor requirements, costs of production and net returns to the farm operator.

Two of the control measures selected for analysis are primarily measures for reducing potential water pollution from livestock wastes. These are the mandatory control of runoff from open lots and prohibition of winter spreading of dairy wastes. The first control measure will presumably apply largely to those dairymen who have open lot facilities. It implies that some type of retention and holding facility must be installed to collect surface runoff from the lot. The second control measure would apply to all milk producers and would imply that satisfactory manure storage facilities be constructed.

The capacity of this storage facility would have to be sufficient to store manure production for six months.

A third control measure which is analyzed consists of measures designed to reduce odors resulting from livestock wastes. This measure would specify subsurface disposal of manure through the use of a soil injector in the case of liquid manure, or the plow-down method with regards to solid wastes. Although aerated lagoons represent an alternative for odor control, they are not analyzed in this study. The specific requirements of compliance with these control measures will be detailed in Chapter VII. To provide a basis for the empirical analysis of these control measures, a theoretical discussion of the economic impact of pollution abatement is presented in the next chapter.

Chapter III Footnotes

[1]L. J. Connor, R. L. Maddex and L. L. Leighty. "For Michigan Livestock Producers: Environmental Quality Legal Considerations," Extension Bulletin E-732, Farm Science Series, Cooperative Extension Service, Michigan State University, December, 1971.

[2]*Federal Register*, 36:67 (April 7, 1971), 6564-6570).

[3]Correspondence, U.S. Environmental Protection Agency, Chicago Office, November, 1971.

[4]*Ibid*.

[5]Personal interview with Mr. Robert Courchaine, Michigan Water Resources Commission, March 12, 1972.

[6]L. J. Connor, R. L. Maddex and L. L. Leighty. "For Michigan Livestock Producers: Environmental Quality Legal Considerations," Extension Bulletin E-732, Farm Science Series, Cooperative Extension Service, Michigan State University, December, 1971, pp. 4-5.

[7]Based on interview with Mr. Robert Courchaine, Michigan Water Resources Commission, March 12, 1972.

[8]L. J. Connor, R. L. Maddex and L. L. Leighty. "For Michigan Livestock Producers: Environmental Quality Legal Considerations," Extension Bulletin E-732, Farm Science Series, Cooperative Extension Service, Michigan State University, December, 1971, p. 5.

[9]Based upon telephone conversation and subsequent letter dated April 10, 1972, from Mr. Paul Shutt, Division of Air Pollution Control, Michigan Department of Public Health.

[10]L. J. Connor, R. L. Maddex and L. L. Leighty. "For Michigan Livestock Producers: Environmental Quality Legal Considerations," Extension Bulletin E-732, Farm Science Series, Cooperative Extension Service, Michigan State University, December, 1971, p. 5.

[11]Donald R. Levi and Dale Colyer, "Economic Implications of Some Citizen-Initiated Legal Mechanisms for Solving Environmental Quality Problems," American Journal of Agricultural Economics, 53:5 (December, 1968).

[12]L. J. Connor, R. L. Maddex and L. L. Leighty, "For Michigan Livestock Producers: Environmental Qulaity Legal Considerations," Extension Bulletin E-732, Farm Science Series, Cooperative Extension Service, Michigan State University, December, 1971, p. 6.

[13]T. L. Willrich and J. R. Miner, "Litigation Experience of Five Livestock and Poultry Producers," ASAE International Symposium on Livestock Wastes, held at The Ohio State University, April, 1971.

[14]L. J. Connor, R. L. Maddex and L. L. Leighty, "For Michigan Livestock Producers: Environmental Quality Legal Considerations," Extension Bulletin E-732, Farm Science Series, Cooperative Extension Service, Michigan State University, December, 1971, p. 6.

[15]Ibid.

[16]T. L. Willrich and J. R. Miner, "Litigation Experience of Five Livestock and Poultry Producers," ASAE International Symposium on Livestock Wastes, held at The Ohio State University, April, 1971.

[17]Ibid.

[18]J. B. Johnson, L. J. Connor, C. R. Hoglund and J. Roy Black, "Implications of State Environmental Legislation on Livestock Waste Management," paper prepared for the 1972 Cornell Agricultural Waste Management Conference.

[19]L. J. Connor, J. B. Johnson and C. R. Hoglund, "A Summary of State Regulations Pertaining to Animal Waste Management in the North Central Region of the United States," Agricultural Economics Report, No. 193, Department of Agricultural Economics, Michigan State University, May, 1971.

CHAPTER IV

THEORETICAL ECONOMIC IMPACT OF POLLUTION ABATEMENT

Externalities

The fact of environmental pollution from livestock wastes is essentially one of technological externalities.[1] Externalities exist because the property rights for such goods as water and air are not adequately defined. For example, the water of "navigable" waterways is nominally recognized as belonging to all of the people of a state, but ownership of the water is not vested in any one agent who could act as trustee for the people. This lack of clarity of property rights inhibits trading. This situation differs from the case of most other inputs, such as land and labor, where ownership is precisely defined and services must be purchased. As a result, livestock producers may view waste disposal into the waterways (and atmosphere) as a free resource which contributes to production. However, the livestock producers' disposal activities may have a direct (negative) effect on other users of the water. Consequently, other users of the natural resources may incur additional costs due to the pollution which they can't avoid by purchase.

In the absence of fully defined property rights for goods such as water and air, the livestock producers' use of these resources for waste disposal is not counted as a cost of production. Consequently, the supply and demand mechanism of the market does not make its adjustments nor allocate resources with complete knowledge of all costs that are incurred. Therefore, in the absence of adequately defined property rights, environmental quality controls developed by mechanisms external to the market system are thought necessary to provide a more socially acceptable balance between levels of economic activity (i.e., livestock production) and environmental pollution.

Alternative Solutions

It is implied in much of the recent literature that the solutions to the problems of pollution require the establishment of environmental quality standards. A number of possibilities by which these standards of quality may be established have been discussed in the literature. The alternatives may be classified as: (1) voluntary action, (2) legal actions initiated either by those personally damaged or by individuals not personally damaged and (3) collective action initiated by local, state or federal government.[2]

Voluntary actions per se are unlikely to be effective unless there is some type of economic incentive for a polluter to reduce the level of pollution. This incentive may take the form of bribes by those affected; i.e., individuals suffering damage may pay a polluter to reduce pollution. The affected party will continue to pay for reduction of pollution until this payment becomes equal to the cost of suffering the pollution. The effectiveness of bribes are limited because of imperfections in some bargaining situations and because of the public good's nature of pollution. (That is, affected party A may not offer a bribe in the belief that someone else will; and he will reap the benefits and not suffer any costs.)

Another possibility of voluntary action is for the polluter and damaged party to merge into one unit (internalize the externality). This solution may not be desirable if there are a large number of parties involved or if these parties are not firms, but individuals.

Johnson and Connor[3] point out that voluntary action on the part of a firm to reduce pollution may be limited by the size of the firm. If uniform voluntary adoption of some abatement technology were expected by all members of an industry group, smaller individual firms could become economically disadvantaged.

The second possibility of establishing environmental quality standards to control agricultural pollution is that of individual legal action. Walker[4] has pointed out the ineffectiveness of this alternative due to: (1) the difficulties encountered in pleading and proof of an agricultural pollution claim, (2) the failure of the courts to approach the agricultural pollution problems with an enlightened attitude and (3) the fact that court action is too unpredictable to serve as a basis for reliable pollution control.

This leaves as the third, and most frequently discussed alternative, collective action by a governmental unit. Within the realm of collective action there are several means by which environmental standards could be achieved. These include prohibition, directive, regulation, zoning, taxes and subsidies or payments.

Prohibition as a means of achieving a quality standard overlooks the fundamental point that optimality does not require that externalities be eliminated, but rather optimality requires that externalities be present in the "right amount." It should be recognized that most receiving resources possess some natural capacity for self-cleansing. Prohibition would mean that this natural capacity would go unused.

Solution by directive implies that some governmental unit could decide the "right amount" of pollution and issue a directive limiting pollution to this amount. The "right amount" of pollution may be defined as that quantity of pollution which equates the marginal benefit (to the polluter) of pollution to the marginal cost of those suffering from the pollution. However, the benefits and costs associated with pollution are conditioned upon the manner in which property rights are defined. Any redefinition of property rights for resources such as air and water could result in a different "right amount" of pollution. Therefore, there may be as many "right amounts" of pollution as there are ways in which property rights are defined. The directives should be adjusted so that the marginal effectiveness of the last dollar spent for processing of wastes would be equated for all polluters.[5] The measurement and administrative problems and costs would undoubtedly be substantial.

Government regulation to control pollution has tended to imply uniform requirements imposed on the productive process of all firms. The regulation would apply to all producers without allowing for differences in size and location of producers and the amount of actual damage resulting from each producer. That is, the effects of pollution by various producers are different, but regulations would require them all to follow uniform practices. Macaulay[6] shows that regulation leads to long run forces that will result in an overdemand for stream quality. That is, within given property rights, regulation result is less waste discharge than that quantity which equates marginal benefits to marginal costs of the discharge.

Zoning has been used to prevent mixtures of conflicting land uses. However, zoning may have come too late in many cases.[7] Zoning usually applies only to the establishment of new firms in an area. Provisions for nonconforming uses do not allow for the remedy of already conflicting uses.

Government payment for the installation of pollution abatement devices which the firm would not otherwise purchase because of the magnitude of the capital outlay required or because the investment is not profitable represents another possible method of achieving environmental quality standards. A variant of the payment scheme is to provide incentive payments to the firm for pollution abatement. Payment schemes seem to have some merit if the firm is allowed some flexibility in its selection of the technique used in abating the pollution.

The last category of collective action considered consists of tax and subsidy schemes. That is, a firm could be taxed for any external diseconomy it created and paid a subsidy for any external economy it creates. Most of the concern seems to be with external diseconomies. The theory of the tax scheme is that a firm would use those methods required to reduce pollution until the cost of abatement increased to equal the tax it is charged per unit of pollution. The tax rate would be set so that these two costs become equal at the "right amount" of pollution. Macaulay[8] presents an interesting argument on who should be charged, the polluter for the damage he causes or the affected party who demands clean water. He contends that if people want clean water they should pay for it. That is, their demand for clean water is just as much an externality on the polluting firm as pollution is to them. He further points out that subsidies may result in overdemand for stream quality in the long run, but charges do not.

Knetsch[9] provides an interesting footnote to the discussion of charges versus subsidies. He notes that efficiency is served by either subsidizing polluters not to pollute or charging polluters for the right to pollute, but that policy prescription differs with equity considerations and the way in which we interpret property rights. That is, subsidization or charges result in the same amount of pollution abatement per dollar expended, but different people bear the costs of the abatement.

Theory of Firm Adjustment to Environmental Controls

The solutions to agricultural pollution problems arising from animal wastes are restricted to a large degree by the production technology involved. For example, in milk production milk and manure are actually joint products. The proportion of milk to manure can be altered to some degree by changing the feed ration, changing the amount of feed fed, or by milking a different breed of cattle. Within the present technology, however, the proportion cannot be altered sufficiently to allow substantial milk production with little or no manure production. [Furthermore, the "price" of manure is normally negative. That is, the cost of disposing of manure (usually on land) is greater than the nutrient value of the manure in crop production.] As a result, the milk producer is faced with substantial amounts of a waste material that must be disposed of or utilized in some effective manner.

Since the amount of manure associated with milk production cannot be reduced substantially, the remaining methods of reducing pollution originating from animal wastes are (1) reduction in the number of animals, (2) alteration of the collecting, handling, processing and/or disposing phase of the waste system or (3) some combination of these two. It is expected that in cases where animal wastes are posing a severe water pollution problem, the alteration of the waste handling system will involve investment in "durable" abatement facilities. This expectation has been substantiated in cases involving beef production in Michigan.[10]

Investments in durable assets for waste handling and/or pollution abatement are reflected in the "fixed" cost curves of the firm. That is, once the investment has been made, the costs associated with that asset do not change as the level of milk production changes. The added waste handling and/or pollution abatement facilities *per se* are assumed to be neutral to the milk production process; that is, these additional durable assets do not affect the efficiency of feed use in the production of milk. Variable costs of production may be affected, however, if the added waste handling and/or abatement facility also requires the use of other resources (e.g., labor). For instance, the same level of milk production would require a larger input of labor, or conversely the same labor input would yield a lower output of milk. This type of an effect would be reflected by a shift to a new production function resulting in a different firm cost structure. Variable costs may be reduced in instances where the abatement facility substitutes for some previously performed services (i.e., stacking and hauling of manure) which were previously reflected in total variable costs.

The economic impact of environmental controls affecting animal waste management, in terms of cost of production, are expected to be substantially different from the case of restricted pesticide use. In the case of restrictions on pesticide usage, the input is a variable factor of production and the impact is on variable costs of production rather than "fixed" costs.[11]

Within the population of Michigan milk producers, the economic impact of environmental controls can be expected to vary substantially between individual firms. Whenever environmental quality controls are implemented, each producer must identify the form, investment outlay required, and cost of abatement technology that best suits his existing resource situation. The type and magnitude of costs associated with the abatement system can be expected to differ among milk producers depending upon (1) the current cost structure of the producer (determined by type of dairy housing system, number of cows, feeding and milking arrangements and type of waste handling system being used), (2) the form of the legal restraint (i.e., directive, regulation, etc.) and the phase of the waste handling system which is affected (i.e., collection, storage or disposal) and (3) locational differences of milk producers.

An illustration of the differential effects of alternative forms of legal restraints is the government regulation versus a directive. For example, a government regulation requiring compulsory adoption of a particular pollution abatement facility would be expected to have different consequences than a directive specifying the maximum nutrient load of a stream and allowing each Michigan milk producer to make the decision of which abatement technology to employ to be in compliance with directive requirements. Economic analysis indicates that the costs of livestock production attributable to abatement facilities and practices are minimized when the operator is allowed to choose that abatement facility which most efficiently uses his existing resources.[12]

Locational differences may arise because streams carry different use-class standards, which in turn carry different water quality discharge requirements. Since it is unlawful for a livestock operator to discharge wastes into a waterway if the discharge will reduce the quality of the receiving waterway below its specific use-class standards, the milk producer discharging into the higher use-class stream may incur more abatement costs than will the operator discharging into the lower use-class stream.

Because of the variety of factors which affect the economic impact of environmental controls on animal waste management, responses by individual producers are expected to differ. Therefore, four different alternative initial impacts of environmental controls are analyzed to determine the possible effects on individual operators.

Assumptions

For the purposes of this theoretical analysis, four basic assumptions are made. First,

it is assumed that the production of milk is given by:

$$Y = F(X_1 \ldots X_d / X_{d+1} \ldots X_g // X_{g+1} \ldots X_n)$$

where: Y = output of milk

$X_1 \ldots X_d$ = variable factors of production

$X_{d+1} \ldots X_g$ = factors which are fixed for the firm but variable between enterprises

$X_{g+1} \ldots X_n$ = factors which are fixed for the firm and for the production of milk.

The factors $X_1 \ldots X_d$ are combined in their least cost combination and are used to the point where $\frac{MVP_{x_i}}{P_{x_i}} = 1$ for i = 1 ... d. In terms of milk production, this vector of inputs may consist of feed, hired labor, off-farm services and any other inputs which have an expected earning power greater than the cost of the input. The factors $X_{d+1} \ldots X_g$ are fixed for the farm because the value of these factors in production is less than acquisition price, but greater than salvage price ($\infty > P_{x_i}$ acq $> MVP_{x_i} > P_{x_i}$ sal $\overline{>} 0$, for i = d+1 ... g). These factors are variable between enterprises, however, and are expected to be allocated between enterprises to obtain equal marginal returns ($MVP_{x_i y_j}$ are identical, for i = d+1 ... g, and for all j). This input vector may include such factors as buildings, tractors, land and family labor. Some of these factors may become variable (upward or downward) in the event that a change in product prices, input price or productivity of the factors which is sufficient to change the relationship of MVP's with respect to acquisition and salvage prices.

The factors $X_{g+1} \ldots X_n$ are fixed on the firm for the same reason as the $X_{d+1} \ldots X_g$ factors (i.e., $\infty > P_{x_i}$ acq $> MVP_{x_i} > P_{x_i}$ sal $\overline{>} 0$), but are not variable between enterprises. This input category may include such factors as the milking parlor and associated equipment, specialized buildings, waste handling equipment and the dairy cows. Again, these factors may become variable in the event that the relationship of MVP's to prices of the factors is altered.

The production function for milk may be represented as in Figure 5.

The basic assumption concerning the nature of the production function, specifically the nature of fixed

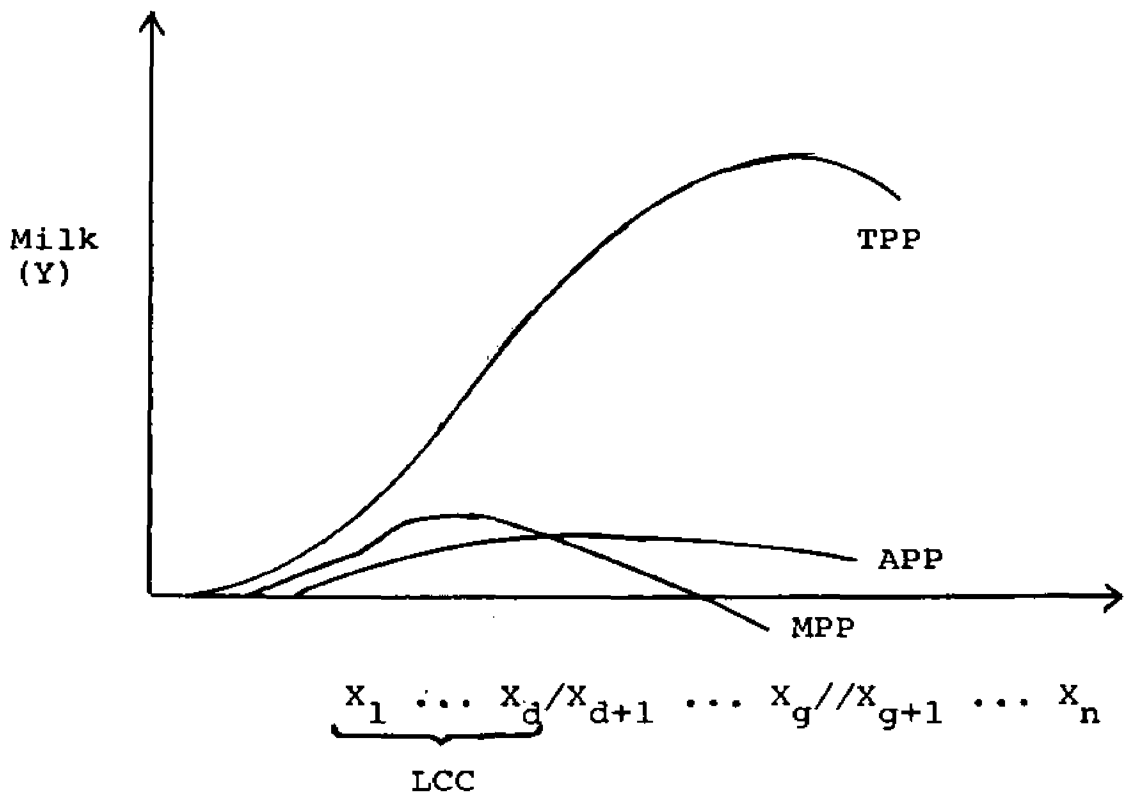


Figure 5. Firm production function for milk.

factors of production, implies that the general form of cost functions associated with milk production are those illustrated in Figure 6.

Figure 6 illustrates two average fixed cost and two average total cost curves. These result from valuing fixed factors of production at two price levels, acquisition and salvage. The salvage value of the fixed factors are included in the analysis to represent opportunity cost of these factors of production. It is expected that in some instances, compliance with environmental controls may reduce the profitability of milk production sufficiently that some factors which are presently fixed may be withdrawn

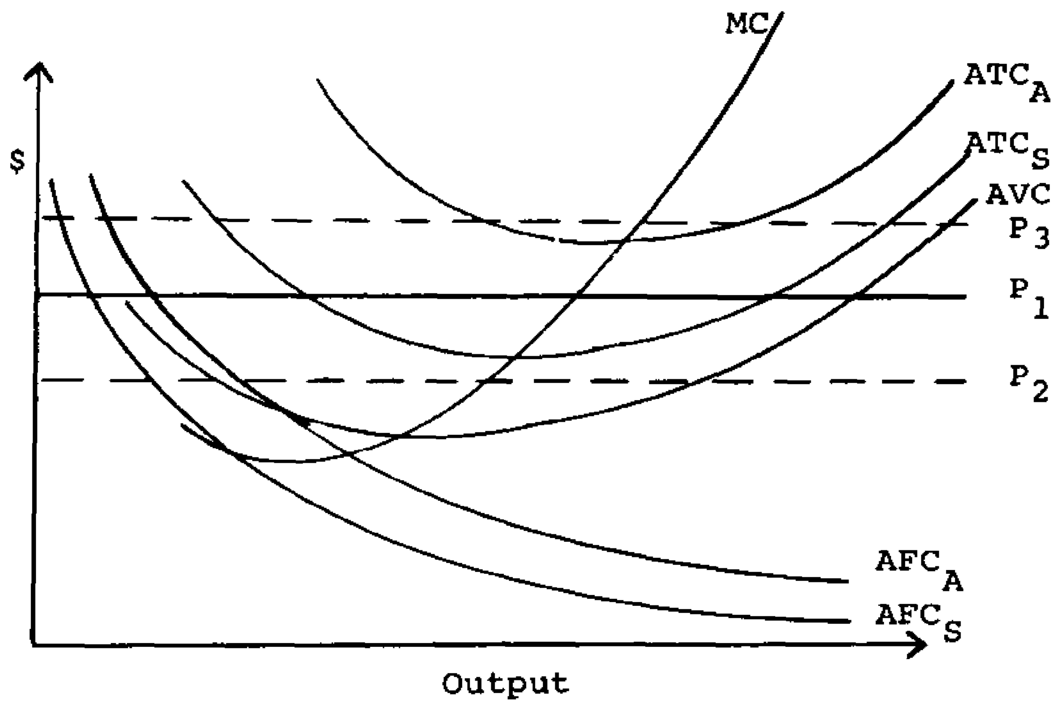


Figure 6. Firm cost functions for milk production.

from milk production. For example, it may become more profitable to use buildings or family labor in other livestock enterprises. In the case of low profit margins, the opportunity cost of the dairy herd itself may exceed its value in milk production and, therefore, be sold.

Secondly, it is assumed in the analysis that input prices as well as the price of milk remain constant. This assumption is made because presumably current prices are relevant when the operator makes the decision of whether or not to comply with environmental controls. It is recognized that due to reorganization of some firms the supply and, therefore, price of milk may be affected. However, there is no method of saying a priori in which direction and by what magnitude prices for milk will move.

Thirdly, as a starting point in subsequent analysis, milk price is assumed to be within the vertical interval bounded by minimum ATC_A and minimum ATC_S (P_1 in Figure 6). This assumption is consistent with the definition of fixed factors of production employed in this analysis. If price of milk was below min ATC_S (P_2 in Figure 6), some of the fixed factors would be diverted to other enterprises or sold off the farm. Conversely, if the price of milk was above min ATC_A (P_3 in Figure 6), more of the "fixed" assets would be purchased or diverted from other enterprises into milk production. If price of milk was not in the ATC_S - ATC_A interval, the milk producer would reorganize production so that this was the case.

The fourth assumption is that milk producers are profit maximizers and will, therefore, produce at that output level where the marginal cost of milk production equals the marginal revenue of milk production. This is assumed to be in stage II of production, i.e., a positively sloped marginal cost curve.

Analysis

With these assumptions specified, it is possible to theoretically analyze the possible economic impacts and resulting milk producer adjustments resulting from compliance with environmental controls specific to livestock waste management. Four (4) basic impacts will be analyzed in terms of their possible effects on the individual milk producer. These impacts include environmental controls for which compliance results in (1) increased fixed costs of production, (2) increased fixed costs of production and increased variable costs of production, (3) only increased variable costs of production and (4) increased fixed costs of production but decreased variable costs of production. The possible effects of these initial impacts are analyzed in terms of changes in usage levels of variable and "fixed" factors of production, changes in the level of milk output and changes in per unit as well as total returns.

Increased Fixed Costs of Production

Environmental quality controls may necessitate only an investment in a new durable asset which would not affect the production function of milk. That is, it is conceivable that some type of abatement system could be adopted that is completely neutral to milk production.

This type of facility would affect the milk production costs, however, by increasing "fixed" costs. This effect is represented in Figure 7, where such an increase is shown in the shift of AFC_S, AFC_A, ATC_S and ATC_A curves.[13]

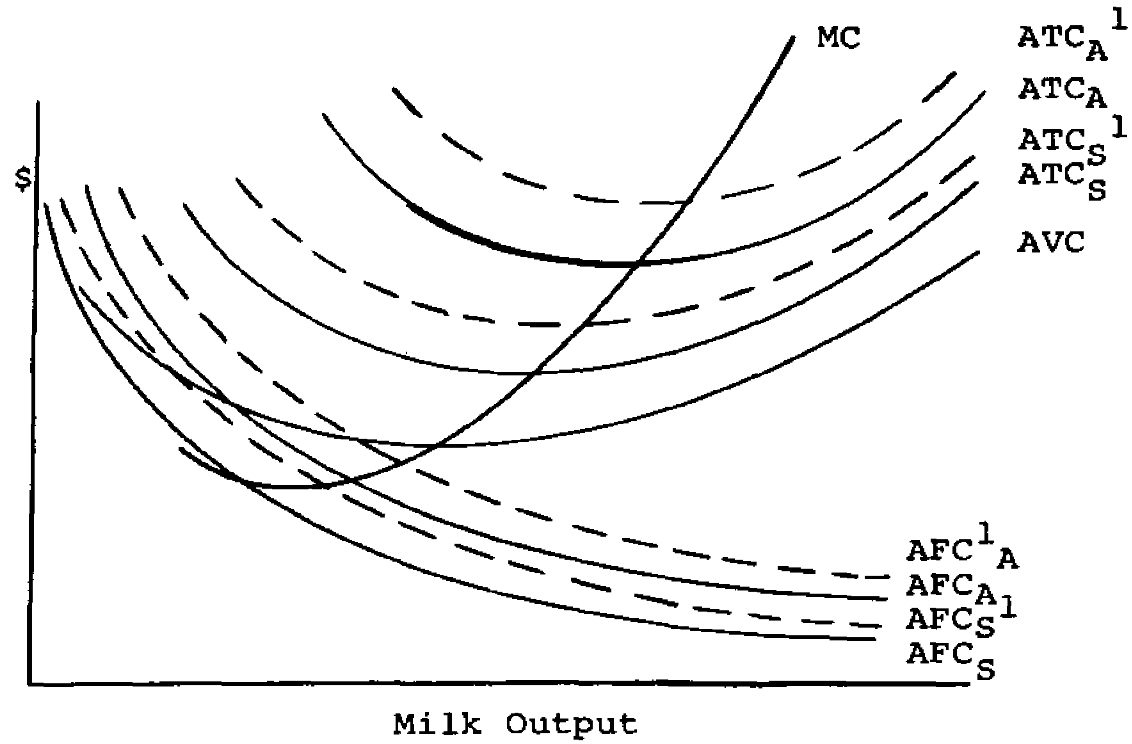


Figure 7. Increased fixed costs associated with abatement facility.

It could be argued that the salvage value of some pollution abatement facilities is zero or even negative (i.e., incur a cost of removal). However, if the "fixed" factors are considered in aggregate (i.e., the farmstead) the addition of a pollution abatement facility is expected to increase AFC_S and ATC_S.

The decision to make this type of investment depends on the magnitude of the increase in ATC_S relative to the price of milk. The investment would be justified if the resulting ATC_S^1 curve (at its minimum) does not exceed the price of milk.

The level of milk production will remain at the same level, but the returns above ATC_S are reduced. If the investment in pollution abatement facilities would result in an ATC_S curve which exceeds the price of milk, the optimal adjustment for the individual operator would be to either discontinue milk production or reorganize by selling some of the previously "fixed" assets. Depending on the technology being used, the optimal adjustment may involve replacing the present housing-milking-manure handling system and expanding herd size in order to attain a lower cost operation. This type of adjustment is made possible by the fact that previously "fixed" assets have become variable.

Increased Fixed and Variable Costs of Production

A second possibility is that compliance with environmental quality controls implies an investment in a pollution abatement facility or modification of present facilities, which, in turn, affects the productivity of other factors in the milk production function. For example, abatement technology which requires the use of labor implies that to attain the previous level of output of milk more labor is required. Conversely, maintaining the present level of labor input, less milk production is possible. In effect, the addition of the abatement facility results in a new production function for milk. The shape of the new production function is actually not known for the general case. All that can be said, in general, is that the resulting output after adjustment will likely be less than the original output levels at corresponding levels of input usage.

Compliance with an environmental control having this type of impact, will result in a new set of cost curves for the firm. Again, the exact shape of the new cost curves is not known; but, in general, they will exceed the original curves because of the reduced productivity of some inputs. Figure 8 illustrates that all cost curves would be expected to shift.

Figure 8 illustrates that AVC^1, ATC^1_S and ATC^1_A each reach a minimum at lower output levels than achieved on corresponding curves prior to the adoption and operation of the abatement facilities. This is due to the fact that production is lower at all levels of input of the variable factors.

The individual milk producer will make the necessary adjustments to his existing facilities if ATC^1_S, at

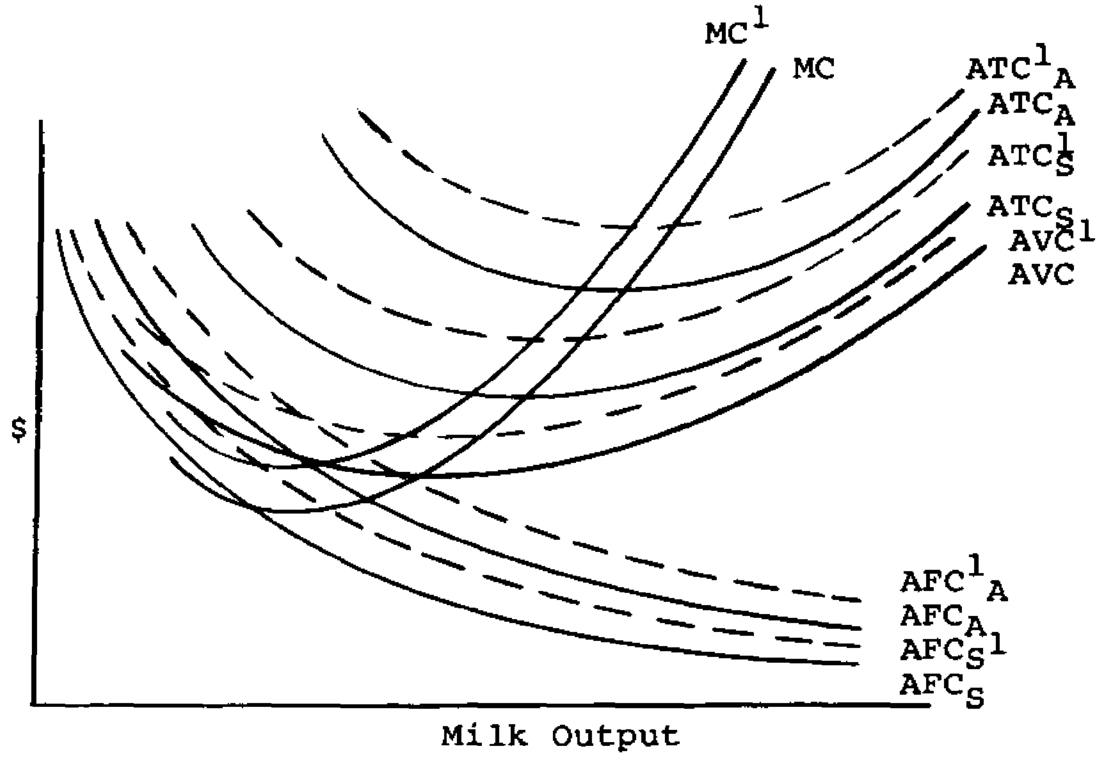


Figure 8. Increased fixed and variable costs of production associated with abatement facility.

its minimum point, does not exceed the price of milk. Assuming that this is the case, output of milk will be reduced because the MC curve will shift upward and to the left, due to reduced efficiency of some inputs. Total returns over ATC_S as well as returns per unit of milk produced will be reduced.

If compliance with environmental controls resulted in an ATC_S curve which exceeded the price of milk, the optimal adjustment for the firm would be to discontinue milk production or to reorganize the production process by selling some of the previously fixed assets ("selling" includes transfer of the use of some assets out of milk production into other on-farm enterprises). Again, depending on the present technology being used, the optimal adjustment may be to replace the housing-milking-manure handling system with a lower (per unit) cost operation.

Increased Variable
Costs of Production

Compliance with environmental controls may necessitate only the reorganization or timing of use of presently used inputs. If this is the case, the production function for milk is again altered. Presumably, the new production function for milk will lie below the original function at all levels of inputs. That is, the new combination of inputs is expected to be less efficient than the original. Again, the exact shape of the new production function with respect to the original function is unknown. However, if no additional inputs are used, fixed costs will remain the same; but variable and marginal costs are expected to increase. Figure 9 illustrates the nature of the new cost structure relative to the original costs of production.

The individual milk producer will comply with environmental controls which have this type of an effect on the costs of production as long as the ATC^1_S curve, at its minimum, does not exceed the price of milk. The

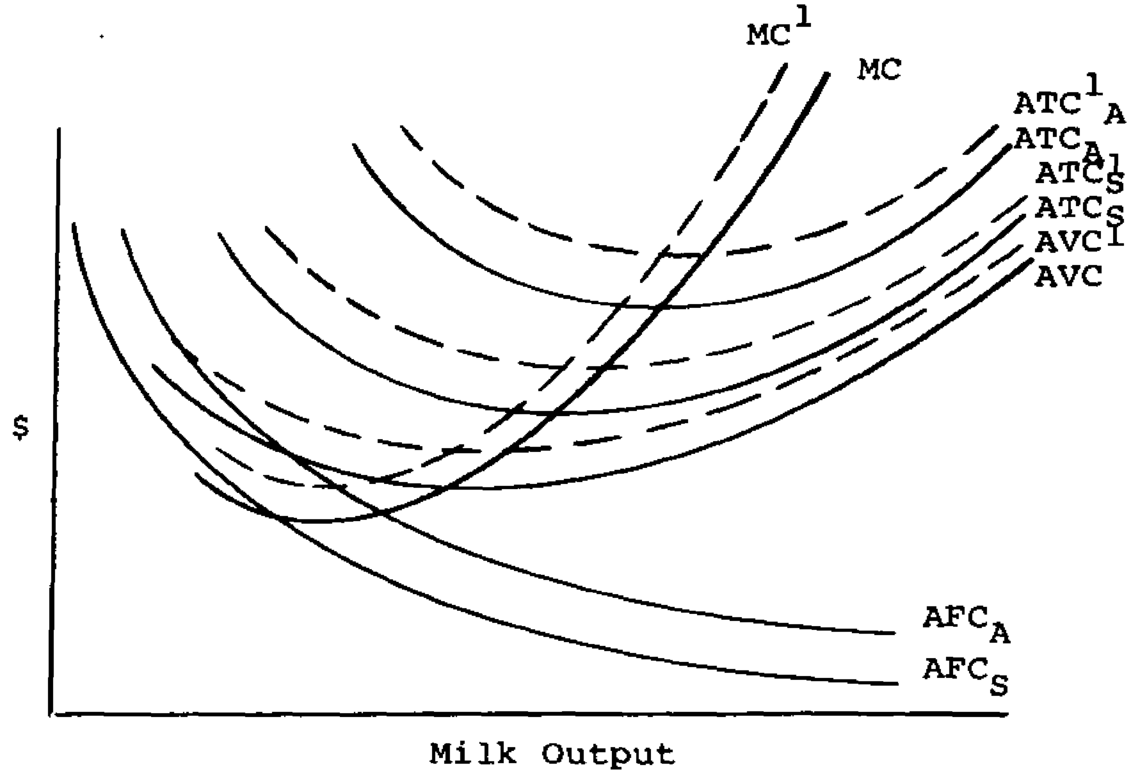


Figure 9. Increased variable costs of production due to reordering of the use of variable inputs of production.

production of milk will be reduced as a result of the marginal cost curve shifting upwards and to the left. Per unit, as well as total returns over ATC_S, will be reduced.

If compliance resulted in an ATC_S curve which exceeded the price of milk, the optimal adjustment for the milk producer would be to either discontinue milk production or reorganize his production system.

Increased Fixed Costs and Decreased Variable Costs of Production

Compliance with environmental controls may result in an increase in "fixed" costs of production but a reduction in the variable costs of production. As indicated above, such a situation could occur if the installation and use of a pollution abatement facility substituted for some previously performed services which were relfected in the total variable cost functions. As a result of this type of substitution effect, a new production function becomes relevant. However, in this instance the new function will exceed the original production function. Therefore, although fixed costs increase, total costs may increase, decrease or remain unchanged.

Figure 10 illustrates the new cost structure relative to the old in the case of increased fixed costs, and reduced variable costs sufficient to reduce total costs.

The individual operator will comply with the environmental controls without reorganizing his operation if price of milk does not exceed ATC^{1}_{A}. However, the level of output will be increased because the MC curve has shifted downward and to the right, due to increased efficiency of some inputs. Per unit as well as total returns above ATC_{S}^{1} will be increased.

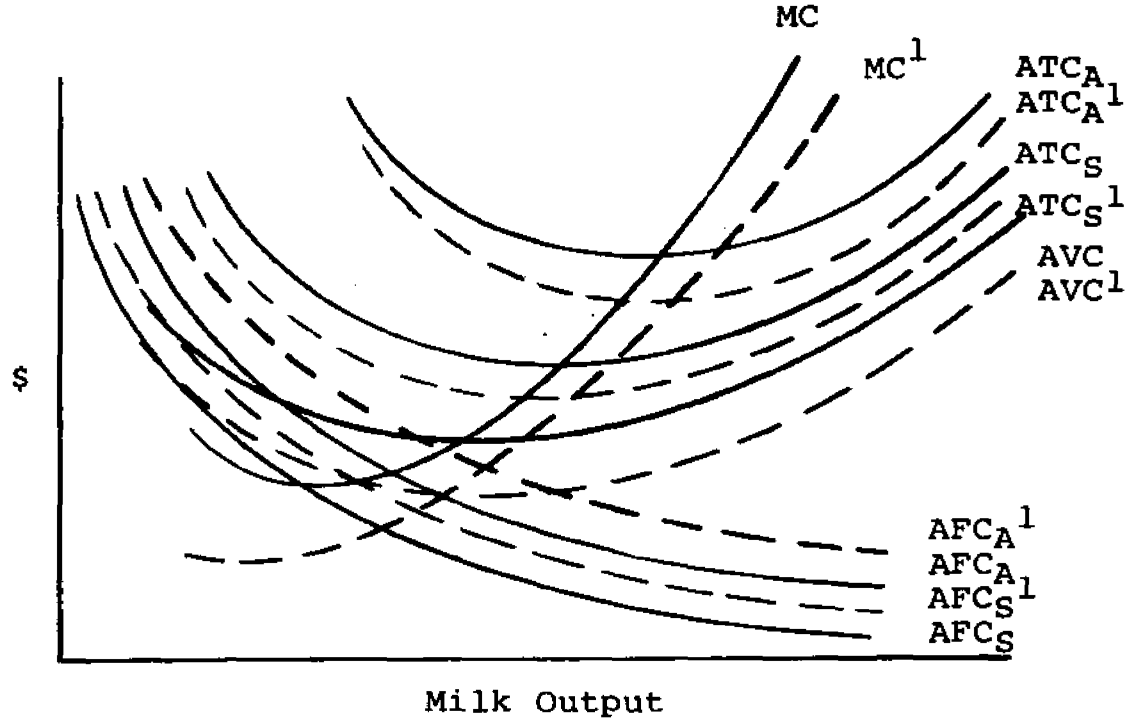


Figure 10. Increased fixed costs, reduced variable costs and reduced total costs due to addition of abatement facilities and the reordering of the use of variable production inputs.

If compliance with the environmental controls within the present structural framework resulted in an ATC_A^1 curve lying below the price of milk, the optimal adjustment for the firm would be to reorganize his operation by purchasing more of the previously "fixed" assets.

Figure 11 illustrates the new cost structure relative to the original curves in the case that variable costs are reduced but fixed costs increase sufficiently that total costs increase.

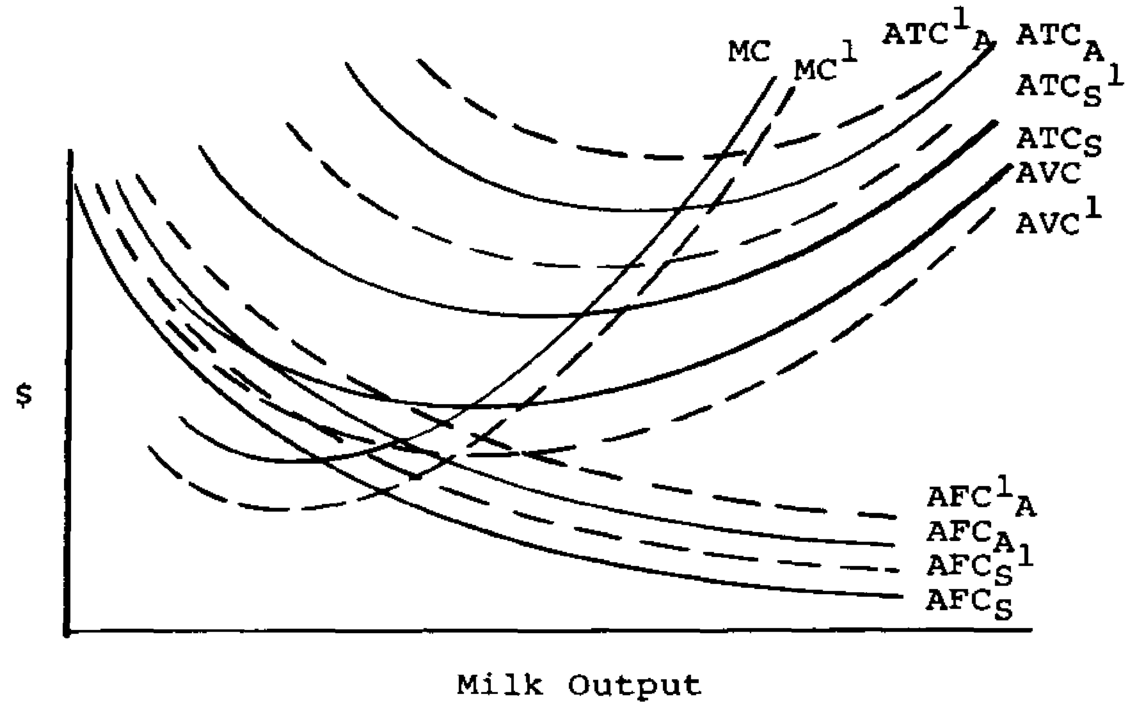


Figure 11. Increased fixed costs, reduced variable costs, increased total costs due to addition of pollution abatement facility and the reordering of the use of variable production inputs.

The individual operator will comply with environmental controls within his present structure as long as ATC_S^{1} (at its minimum) does not exceed the price of milk. The level of milk production will be increased because of the shift of the MC curve. Per unit returns above ATC_S will be reduced, although total returns may be increased or decreased depending on the magnitude of increased output relative to the decrease in per unit returns.

If compliance resulted in an ATC_S^{1} curve which exceeded the price of milk, the optimal adjustment for the firm would be to reorganize by selling some of the previously "fixed" factors of production.

Figure 12 illustrates the new cost structure relative to the original cost curves in the case where fixed costs are increased, but are exactly offset by reduced variable costs such that total costs remain unchanged.

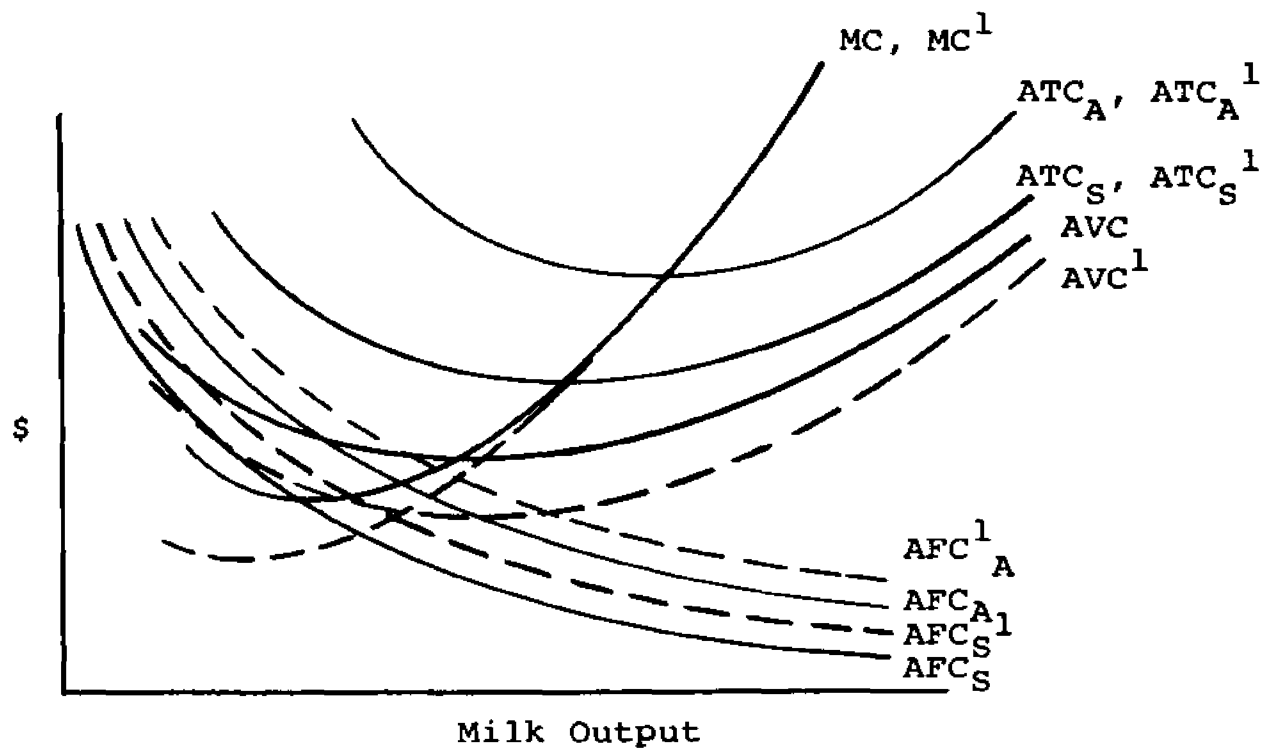


Figure 12. Increased fixed costs, reduced variable costs, unchanged total costs, due to the addition of pollution abatement facilities and the reordering of the use of variable production inputs.

The producer will comply with an environmental control of this type, with no effect on output or returns.

It should be noted that the economic impacts which have been analyzed do not exhaust all the possible impacts. It has been assumed in this analysis that the impact on costs of production was the same at all levels of output. For example, when average fixed costs, average variable costs and average total costs increased, it was assumed that they increased at all levels of production. It is quite possible that compliance with environmental controls may affect the production function such that total costs have the relationship illustrated in Figure 13.

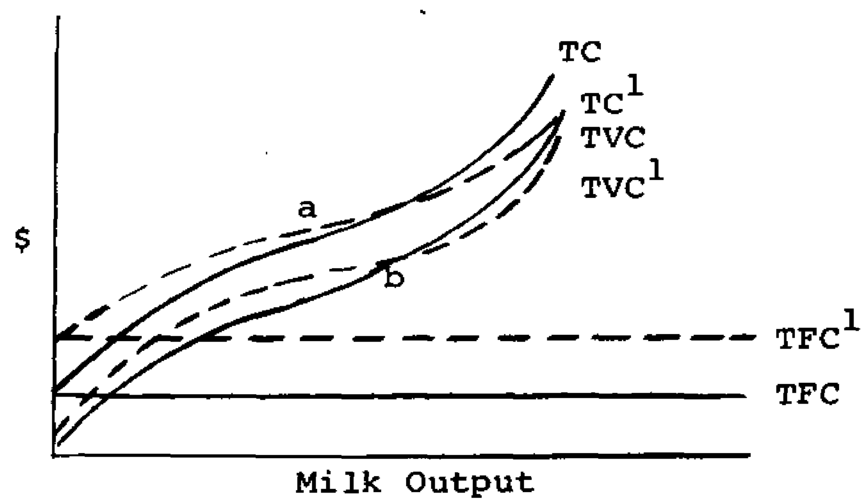


Figure 13. Increased fixed costs, increased variable and total costs for low levels of output, reduced variable and total costs for high levels of output, due to addition of pollution abatement facility and reordering of the use of variable production inputs--total cost curves.

If this type of impact is relevant, the optimal adjustment for the firm will depend on the level of output at which points a and b exist in Figure 13 relative to the present level of output. That is, an impact such as that illustrated in Figure 13 will result in new average and marginal cost curves that will intersect the original cost curves. It is this type of shift in cost structure that may lead to expansions in output within the present structure or through purchase of more of the previously "fixed" assets. Figure 14 illustrates this alternative.

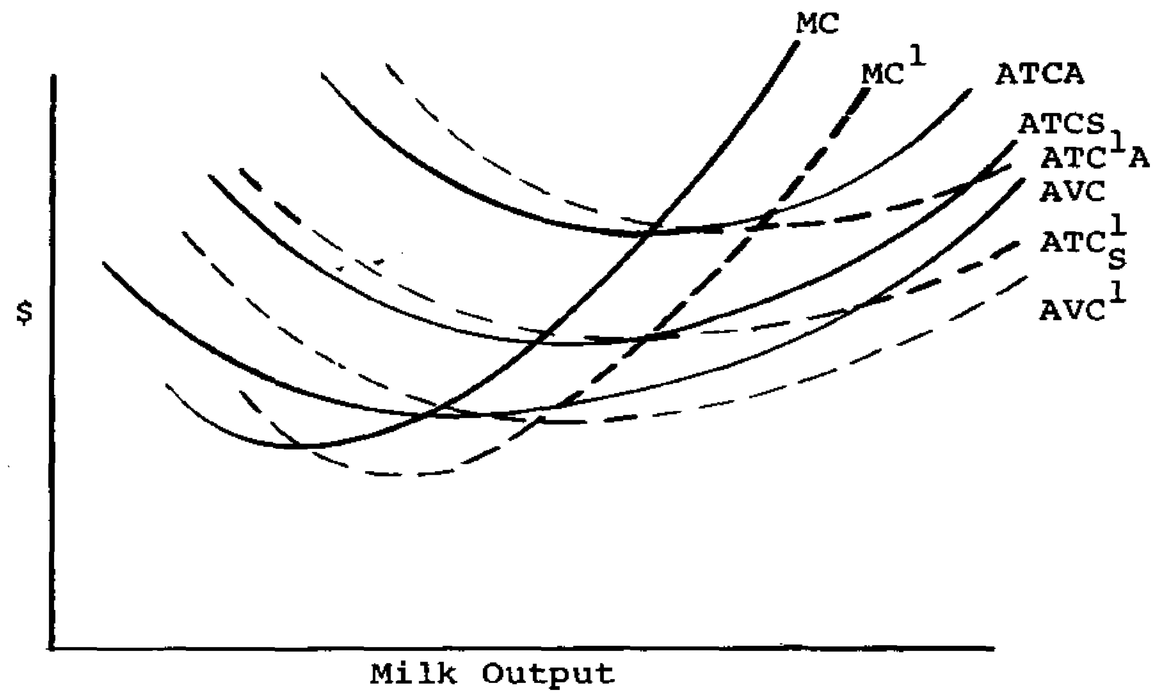


Figure 14. Increased fixed costs, increased variable and total costs for low levels of output, reduced variable and total costs for high levels of output, due to addition of pollution abatement facility and reordering of the use of variable production inputs--average cost curves.

Essentially, what this type of shift in cost structure indicates is economies to size in the pollution abatement equipment. As a result, milk production will be expanded with the addition of the pollution abatement system. If the minimum point of ATC_A^1 is below the price of milk, the firm will reorganize by purchasing more of the previously "fixed" assets. The possibility also exists in this situation for the firm to change completely the milk production technology in use (e.g., from a stanchion housing system to a confinement system).

Figure 14 presents only one possible relationship of the new cost curves, relative to the original cost structure, in the set of impacts which have different effects at different levels of output. There are a large number of possible effects, depending on where the new cost curves intersect the original curves. The true relationship is an emperical question, but is expected to vary among firms depending on existing technology and the form of environmental control.

Constraints on Compliance With Environmental Controls

The previous analysis indicates, theoretically, the optimal adjustment of individual milk producers to environmental controls designed to reduce pollution originating from animal wastes. However, there are several factors which may act as constraints, which are not incorporated in the above analysis. These constraints may prohibit individual operators from adjusting in the manner indicated by the analysis. Following is a brief discussion of some of the major constraints which may affect some milk producers.[14]

Financial Consideration

Economic feasibility of adoption of pollution abatement facilities is a necessary but not a sufficient condition for obtaining pollution abatement. In instances where a substantial investment is required in order to comply with environmental controls, milk producers must have or be able to get the funds needed to make the investment. The ability of a farmer to obtain credit from the usual sources (commercial banks, PCA, FHA, Federal Land Banks, life insurance companies) depends to a large extent on prospects for repayment within a reasonable length of time. The purpose for which a farmer uses the credit would not ordinarily be an important restruction. Thus, credit to construct animal waste abatement facilities would be generally available if the farmer's repayment capacity was satisfactory.

Although pollution abatement is an eligible purpose for most lenders, some concern exists about the possibility of farmers being able to get financing for such facilities if they do not add to earning capacity.[15] This may be more serious for marginal operators, but even qualified operators may be reluctant to borrow for investments that would not increase income and, therefore, require repayment from the present level of earnings.

Another relevant consideration that both farmers and lenders face is the possibility of rapid obsolescence of equipment and facilities due to changing technology and environmental standards. Furthermore, it is conceivable that credit requirements for pollution abatement would preclude credit availability for regular farm production purposes.

Experience to date (Farm Credit Administration) indicates that initially some problems may arise in lending for waste disposal systems. Underestimation of construction costs and disruption of business have led to over indebtedness and repayment difficulties. Relocation of the farm or facility, because of waste control requirements, has in instances brought unanticipated problems of high cost, lost income and additional debt.

There are presently a few programs available which may be used by individual producers to defer some of the investment requirements for pollution abatement facilities, although limited in scope. The Rural Environmental Assistance Program provides "cost" sharing assistance to farmers. Examples pertaining to animal waste management include: (1) construction of lagoons, pits, trenches, diversions and other management systems. Cost sharing cannot be used to build a new slotted-floor barn, but can be used for the collecting pit under the slotted floor, and (2) vegetated filter strips which provide a barrier between the farm and any nearby stream.

Tax incentives are provided through rapid amortization and investment tax credit. Amortization over a 60-month period may be elected for certified pollution control facilities added to or used in connection with a plant in existence before 1969 and placed in service before 1975. The amortization deduction is available only for the portion of the property's basis attributable to the first fifteen years of its useful life. The investment credit is not allowed in the case of pollution control facilities for which the taxpayer elects the rapid amortization provision except to the cost attributable to the useful life in excess of fifteen years.

Uncertainty and Lack of Knowledge

Milk producers are confronted with two basic problems related to proper management of livestock wastes in order to reduce pollution. First, the effectiveness of various control measures is sometimes unknown. Second, great uncertainty exists regarding the degree of environmental quality that will eventually be demanded by society and the control measures that will be needed to achieve that quality. The cost of installing facilities that may not satisfy regulations yet to be specified has placed many livestock producers in a wait-and-see position, since most could not afford to do the job twice.

Old Age and Tenancy

The operation of farms is affected by the age and consequent planning horizon of the persons in control of the resources involved. As people pass middle age, they become less interested in making long-term investments, discounting future returns at a higher rate. Security and immediate income become relatively more important, reducing the incentive to make long-term investments. This situation may be more acute for those owners who do not plan to transfer the farm enterprise to other family members.

The situation is further aggravated by tenure status of some farm operators. Any permanent improvements, livestock waste management systems included, to be installed on rented land are largely the responsibility of the landlord since all but portable equipment becomes part of the land. Thus, many tenants cannot take action to abate pollution or add any other permanent facility unless they do so at their own expense and risk of non-recovery of the investment.

Lack of Technical Assistance

Livestock farms exist in an almost unlimited combination of circumstances with respect to size, combination of enterprises, type of soil, slope of the land, distance from residential areas and proximity to water sources of different usage. They are, therefore, confronted with a multitude of different problems associated with livestock waste management. It is unlikely that farmers have the knowledge to successfully abate pollution themselves.

Programs of technical assistance to help producers solve livestock waste management problems are currently available through the U.S. Soil Conservation Service, the Federal Extension Service, the U.S. Environmental Protection Agency and, to a lesser extent, through some state agencies. However, in many instances, the demand for technical assistance exceeds the available supply. This problem could become more acute as producers attempt to comply with future environmental controls.

Ability to Escape Enforcement

Depending upon the enforcement mechanisms associated with environmental controls, some livestock farmers may choose not to comply. They may be willing to pay the costs of noncompliance (if any) or they may be able to avoid detection.

Chapter IV Footnotes

[1]A technological externality is defined here to be a direct effect, that is not priced, which one decision unit might impose on another.

[2]J. B. Johnson, L. J. Connor, "Origin and Implications of Environmental Quality Standards for Animal Production Firms," Proceedings of International Symposium on Livestock Wastes, ASAE (April, 1971), 102-107.

[3]Ibid.

[4]William R. Walker, "Legal Restraints on Agricultural Pollution," Paper presented at Cornell Agricultural Waste Management Conference, Rochester, New York, January 19-21, 1970.

[5]Otto A. Davis, Morton I. Kamien, "Externalities, Information and Alternative Collective Action," The Analysis and Evaluation of Public Expenditures: The PPB System, A compendium of papers submitted to the subcommittee on Economy in Government of the Joint Economic Committee, Congress of the U.S., 91st Congress, 1st Session, pp. 67-86.

[6]Hugh H. Macaulay, Uses of Taxes, Subsidies and Regulations for Pollution Abatement, Report No. 16, Water Resources Research Institute, Clemson University, Clemson, South Carolina, June, 1970.

[7]J. B. Johnson, L. J. Connor, "Origin and Implications of Environmental Quality Standards for Animal Production Firms," Proceedings of International Symposium on Livestock Wastes, ASAE (April, 1971), 102-107.

[8]Hugh H. Macaulay, Uses of Taxes, Subsidies and Regulations for Pollution Abatement, Report No. 16, Water Resources Research Institute, Clemson University, Clemson, South Carolina, June, 1970.

[9]Jack L. Knetsch, "Economic Aspects of Environmental Pollution," Journal of Farm Economics, 48:5 (December, 1966), 1257-1266.

[10]Conversation with Mr. Robert Courchaine, Michigan Water Resources Commission.

[11]Austin S. Fox, "Economic Consequences of Restrictions or Banning the Use of Pesticides," paper published in Economic Research on Pesticides for Policy Decisionmaking, proceedings of a symposium in Washington, D.C., April 27-29, 1970.

[12]Roy N. Van Arsdall, James B. Johnson, "Economic Implications of Water Pollution Abatement in Family Farm Livestock Production," material for discussion before President's Water Pollution Control Board, Peoria, Illinois, January 24, 1972.

[13]AFC, AVC, ATC, MC are used to represent the initial cost curves: AFC', AVC', ATC', MC' are used to represent the cost curves after adjustment. The subscripts S and A are used to represent cost curves evaluated at salvage and acquisition prices.

[14]Roy N. Van Arsdall, James B. Johnson, "Economic Implications of Water Pollution Abatement in Family Farm Livestock Production," material for discussion before President's Water Pollution Control Board, Peoria, Illinois, January 24, 1972.

[15]However, a lending institution may have a vested interest in keeping the farmer in operation if former debt repayment depends on continued production.

CHAPTER V

THE ANALYTICAL MODEL

Introduction

It is hypothesized that environmental quality controls specific to livestock production will increase the cost of milk production on Michigan dairy farms. Further, it is assumed that the magnitude of the impact will depend upon the present structure of the dairy farm in terms of type of housing used, type of manure handling facility used and size of the dairy herd. An economic model of the firm was developed in the previous chapter to determine the theoretical immediate or "short-run" impact of compliance with environmental quality controls for the firm with different production technologies, explicitly recognizing the fixity of certain firm assets.

This chapter presents an analytical model designed to quantify the theoretical relationships expressed previously and to test the null hypothesis expressed above. Three alternative control measures are analyzed in terms of their impact on (1) labor requirements, (2) capital requirements, (3) cost of milk production, and (4) net returns to the operator for dairy farms organized around alternative milk production technologies.

The model is a profit maximizing algorithm cast in a setting of perfect competition. Firm size, measured in terms of cow number and operators' labor, is fixed in any specific problem.

Also, the milking facilities, feed storage and handling facilities, basic machinery complement and feed ration are assumed fixed. However, acres of land, capital needs and hours of labor are considered variable, with the magnitude of these items determined relative to the various technologies used, both before and after compliance with environmental controls.

The Technique

A profit maximizing linear programming modeling technique is used to analyze the impact of environmental controls on Michigan dairy farms. This computerized technique is employed rather than conventional budgeting techniques becuase of the large number of alternatives being considered in the analysis.

The synthetic-firm technique is used to evaluate labor requirements, costs of milk production and return to operators labor for firms as they are presently organized. The effect of environmental quality controls on the input-output coefficients is incorporated into the model to determine the impact of these controls on dairy farms using alternative technologies. Synthetic firms are developed on the basis of data which the researcher determined most realistically reflected the present structure of Michigan dairy farms. Assumptions underlying linear programming do not restrict use of the model or make it less realistic. As noted above, this analysis determines the impact of complying with environmental quality controls <u>within</u> the present resource organization of the firm (i.e., constant herd size and milk production technology). This implies a "short-run" analysis; consequently, the assumption of constant factor and product prices is valid.

Another assumption basic to linear programming is that the firms' input-output, output-output and input-input relations are all linear. There is no apparent reason to assume otherwise for most relationships in this study. Where empirical evidence indicates a nonlinear relationship, the relationship is assumed to be discontinuous, having different linear relationships over specified ranges of the variable. Nonlinearity in the above-specified relations is taken into consideration by using a specific linear program for a specific size of firm.

The linear programming technique further assumes the existence of resource constraints that influence the decisions. In this analysis, constraints in the form of operator labor, milk production technology and herd size are assumed. Since real-world firms operate with constraints of one type or another, this analytical model is not restricted by this assumption.

The Firm

The main consideration of this study is the impact of changes in waste handling facilities and/or practices on the level of returns to the operator for his labor, management and rish bearing. To facilitate the analysis of this aspect of the dairy operation, assumptions are made relative to other aspects of the operation in order to hold them constant. A breif discussion of the assumptions made relative to these other aspects of the dairy operation is presented.[1] These assumptions are made for all firms, regardless of milk production technology used.

The Manager

The farm operator is assumed to have the ability to manage the particular size of operation and technology being studied. The level of management assumed, in terms of milk production per cow, crop yields and labor usage are estimated to represent the upper quartile of present Michigan dairy farm managers. However, this level of management is expected to be the average or "typical" level by 1980. Since this study is oriented toward future adjustments, this level of management is reflected in the analysis.

The size of the dairy herd and production technology (except for waste handling equipment) are assumed to remain constant. Therefore, it is assumed that the manager's goal is profit maximization <u>within</u> the specific technological organization being studied.

Location

The "synthetic" farms developed for analysis are assumed to be located in Southern Michigan. As indicated in Chapter II, Southern Michigan has the greatest concentration of milk production and is expected to retain this position in the future.

Land

The hypothetical farms are assumed to be capable of acquiring enough land to produce all of the feed requirements for the particular herd size being studied. As long as the cost of ownership can be paid, the amount of land required is only limited to the specific herd size being studied. The land is also assumed to be in Land Capability Classes I or II.

Capital

In this analysis, capital is also treated as a variable input. That is, capital is assumed to be available in amounts large enough to make investments in additional waste handling equipment and/or pollution abatement equipment to be in compliance with environmental quality controls. This assumption was made for two reasons. One, to indicate to farm operators the magnitude of capital required for compliance, and secondly, to indicate the impact of the investment in waste handling facilities on net returns. Even though increased investment in waste handling facilities is not revenue increasing, or necessarily cost reducing, such investments are assumed to be made in order for the firm to remain in operation.

Labor

The regular labor force of the hypothetical firms is assumed to consist of one operator. However, it is also assumed that qualified labor is available for hire as needed. This assumption is made to give an indication of total labor requirements before and after compliance with a specific environmental quality control. In addition, monthly labor requirements are determined as a means of appraising the impact of environmental quality controls on the distribution of labor requirements.

Enterprises

The hypothetical firms are assumed to be specialized dairy farms. However, replacement stock and all feed requirements are assumed to be farm produced.

The size of the dairy operation is considered to be fixed at four different levels: 40, 60, 80, and 160 cows plus replacement stock. The cows, regardless of herd size, are assumed to produce 13,000 pounds of milk annually. The 13,000 milk production level is based on Telfarm[2] account data indicating average milk production levels on Southern Michigan dairy farms.

It is assumed that the feed ration on all farms consists of corn silage, haylage, corn grain, soybean oil meal and urea. In addition, it is assumed that the forage ration consists of 50 percent corn silage and 50 percent alfalfa haylage. Both corn silage and haylage are assumed stored in concrete tower silos and mechanically fed. Corn grain is assumed to be fed as corn and cob meal.

As mentioned above, it is assumed that all forage and corn grain requirments are produced on the farm. However, it is assumed that farms with 40, 60, or 80 dairy cows would custom hire the harvesting of corn grain. Because of the relatively low acreage requirements for corn grain on these size farms, ownership of corn harvesting equipment is not a common practice.

Alternative Technologies

Types of dairy production firms included in this analysis were selected on two basic criteria. The first criterion was to include those milk production systems which presently represent the majority of milk production in Michigan. Secondly, those systems which are expected to increase in popularity in the future were included. As a result, twelve alternative milk production technologies are identified for initial analysis. Synthetic firms are developed to represent each of these production technologies as they presently exist.

The technologies selected are differentiated on the basis of herd size, type of housing, and type of manure handling system (Table 8). Two synthetic firms are developed to represent milk production with stanchion housing facilities; one for a 40-cow herd and one for a 60-cow herd. Both systems are assumed to have gutter cleaners in the housing facility with wastes hauled and spread daily.

For firms with open lot housing facilities, the initial assumption is that alleyways and outside lots would be scraped daily with a tractor-scraper, and the wastes hauled and spread daily. Again, two synthetic firms are developed, one for an 80-cow herd, and one for a 160-cow herd.

Firms with cold covered housing systems are also assumed to scrape, load, and haul manure daily. Both an 80-cow herd and a 160-cow herd are synthesized.

Table 8. Type of housing and manure handling systems adapted to Michigan.

Herd Size	Stanchion	Open Lot-Free Stall	Cold Covered-Free Stall	Warm Enclosed-Free Stall
40	Gutter cleaner-spreader Daily hauling			
60	Gutter cleaner-spreader Daily hauling			
80		Tractor scraper-loader-spreader, Daily hauling	Tractor scraper-loader-spreader, Daily hauling	Tractor scraper-liquid storage-agitator-pump-liquid spreader. Mechanical scraper-liquid storage-agitator-pump-liquid spreader. Slotted floors-liquid storage-agitator-pump-liquid spreader.
160		Tractor scraper-loader-spreader.	Tractor scraper-loader-spreader	Tractor scraper-liquid storage-agitator-pump-liquid spreader. Mechanical scraper-liquid storage-agitator-pump-liquid spreader. Slotted floors-liquid storage-agitator-pump-liquid spreader.

For the warm enclosed housing systems two herd sizes and three alternative manure handling systems are synthesized. All three systems assumed three-months storage of manure in the liquid state. The only difference in the three systems is the waste collection method. A synthetic firm is developed to represent each of the three collection methods: (1) use of a tractor to scrape waste into storage tanks, (2) use of a mechanical scraper, and (3) use of slotted floors with no scraping.

Detailed descriptions of these synthetic firms, in terms of costs of milk production, labor requirements, investment requirements and returns to the operator's labor are presented in Chapter VI. Using twelve alternative milk production technologies as the starting point, the impact of alternative pollution abatement policies is analyzed.

The Model Description

Only one linear programming model is used to analyze all of the situations of concern in this study. By making changes in the values reflecting labor requirements and costs of the milk production activity, alternative milk production technologies and alternative firm sizes are analyzed. Since capital (or credit) is assumed not to be limiting, investment requirements of the alternative milk production systems are analyzed separately from the linear programming model.

Following is a formal description of the linear programming model which is used to analyze all alternatives.

The Objective Function

The solution to a specific problem maximizes the "objective value" (Zo) within the constraints and activities available. In this study, the objective value is the return to the operator's labor and a basic machinery complement. After determination of the objective value, the cost of the machinery complement is deducted to give a "residual" return to the operator for his labor, management, and risk bearing.

The objective function of the model used is:

$$(1)\quad Zo = C_1X_1 - C_2X_2 - C_3X_3 - C_4X_4 - C_5X_5 - \sum_{j=6}^{17} C_jX_j$$

Where: Zo is the objective value, C_1X_1 is the total returns from selling milk. C_1 is the price of milk after hauling. X_1 is the cost of milk sold.

C_2X_2 is the total cost of producing milk from ten cows plus replacements, less returns from culls and calves. This cost figure included operating and ownership costs of milking, caring for the dairy, waste handling, feeding and housing the dairy herd; with the exclusion of all labor costs and the ownership cost of the basic machinery complement. X_2 is the number of ten cow units in production.

C_3X_3 is the total cost of producing corn grain. C_3 is the cost of producing an acre of corn grain, including land costs. X_3 is the number of acres of corn grain produced.

C_4X_4 is the total cost of producing corn silage. C_4 is the cost of producing an acre of corn grain, including land costs. X_4 is the number of acres of corn silage produced.

C_5X_5 is the total cost of producing alfalfa haylage. C_5 is the cost of producing an acre of alfalfa haylage, including land costs. X_5 is the number of acres of alfalfa haylage produced.

$\sum_{j=6}^{17} C_jX_j$ is the total cost of hiring labor during the twelve months of the year. C_j, j=6 ... 17, is the acquisition price of labor. X_j, j=6 ... 17, is the number of hours of labor hired.

The Constraints

The objective function (equation 1) is maximized subject to the following resource restrictions:

$\sum_{j=1}^{17} A_{1,j}X_j \leq L_1$	L_1 is the labor resource available in period 1 (January).
(2)	L_2 . . . L_{12} are the labor resources available in the remaining 11 months. Several of the $A_{1,j}$'s will be 0 due to no labor required in that period for a particular activity.
$\sum_{j=1}^{17} A_{12,j}X_j \leq L_{12}$	$A_{1,6}$, $A_{2,7}$, $A_{3,8}$ . . . $A_{12,17}$ will all have a -1 value because they are labor hiring activities which add to the labor resources.
(3) $A_{14,2}\ X_2 - A_{14,1}\ X_1 = 0$	This is the transfer of milk produced to milk sales. It says that the milk sold must equal that produced.
(4) $A_{15,2}\ X_2 - A_{15,3}\ X_3 = 0$	This is the corn grain transfer. It says that the amount produced must equal the amount required by the herd.
(5) $A_{16,2}\ X_2 - A_{16,4}\ X_4 = 0$	This is the corn silage transfer.
(6) $A_{17,2}\ X_2 - A_{17,5}\ X_5 = 0$	This is the alfalfa haylage transfer.

(7) $A_{18,1}\ X_1 = c$ This constraint sets the herd size. C = 4, 6, 8, 16 for a 40, 60, 80, and 160 cow herd, respectively.

The last constraint, herd size, is the limiting constraint, with the model determining the amount of land and hired labor required for each of the herd sizes. In this manner, the model actually "simulates" the dairy production unit as it presently exists.

The initial model is run once for each of the twelve production systems to deterime (1) the amount of hired labor required in each month, (2) the amount of crop land required, and (3) the return to the operator's labor and management for each of the twelve systems.

After the twelve initial runs, three alternative pollution abatement policies are examined to determine (1) which producers are affected, (2) how they are affected, and (3) the magnitude of the impact on affected producers, assuming policy compliance.

The first policy alternative is the control of runoff from the production site. As earlier determined, only open lot systems would be affected. Therefore, relevant $A_{i,j}$'s and C_j are adjusted for this policy; and the model is run for the two open lot systems.

Next, a policy prohibiting winter spreading of manure, in addition to runoff control at the production site, is examined. Compliance with this policy will affect all producers, regardless of production technology. Therefore, the relevant $A_{i,j}$'s and C_j are adjusted and the model run for each of the twelve production systems. However, more than one alternative method of complying with this policy is analyzed for some of the producers, necessitating a total of 22 runs of the model.

Thirdly, a policy requiring subsurface disposal of manure, in addition to the above two policies, is examined. As earlier determined, only those producers with liquid manure systems would be affected. Again, the relevant $A_{i,j}$'s and C_j are adjusted and the model run for those systems handling manure as a liquid. Since firms with liquid systems were provided with more than one alternative method of compliance with the policy of no winter spreading, the impact of subsurface disposal has to be run for each of those alternatives, necessitating sixteen runs of the model.

In total then, there are 52 runs of the model:

a) Twelve runs to "simulate" the production units as they presently operate,

b) Two runs to determine the impact of runoff controls,

c) Twenty-two runs to determine the possible impacts of no winter spreading, and

d) Sixteen runs to illustrate the additional impact of subsurface disposal of manure when handled as a liquid.

Within the model, the impact of these three pollution alternative policies; in terms of (1) the total labor requirement and the monthly labor requirement, (2) costs of milk production and (3) returns to the operator's labor is determined. In addition, the investment requirements of each of these policy alternatives are identified.

Chapter V Footnotes

[1]For a more complete discussion and rationale for these assumptions, see: Allen E. Shapley, "Alternatives in Dairy Farm Technology with Special Emphasis on Labor," (Unpublished Ph.D. dissertation, Michigan State University, 1968).

[2]Telefarm is a computerized farm record keeping system maintained by the Department of Agricultural Economics at Michigan State University.

CHAPTER VI

THE SYNTHETIC FIRMS

Introduction

In order to determine the impact of pollution abatement policies on dairy farmers, synthetic firms are developed to simulate milk production on farms with alternative production technology-herd size combinations. These synthetic firms are designed to be "representative" of dairy farms within alternative production technology-herd size categories. They are "representative" in the sense that they display the same internal and external characteristics. That is, a given synthetic firm represents a population of dairy farms which have essentially the same set of productive facilities, the same input-output relationships, and have similar input and product market situations.

Since a linear programming model is employed, the construction of synthetic firms involves the estimation of prices of inputs and outputs, the estimation of the level of constraining resources, and the estimation of the input-output relationships. In addition, estimates are made of the magnitude of capital investments required for each of the synthetic firms.

The Estimates

The estimates required to develop the synthetic firms were derived by examining data from a number of sources and making judgments based on these data. In some instances it was necessary to make estimates on the basis of very limited research results. However, the estimates were examined by specialists in the field to check for relevancy and consistency.

Prices

The prices of most inputs in the milk production and crop production activities require very little discussion. For example, prices of purchased feed, seed and fertilizer are relatively standardized and are referenced as presented. Some prices, however, are subject to more variability and require further discussion. Following is a brief discussion of the price estimates used for some of the more crucial factors involved in milk production.

Milk

The price estimate of $6.00 per cwt. for milk is based on the average blend price of milk expected to prevail, after deductions of $.50 per cwt. for handling charges, in five to six years in Michigan. The average blend price for milk in Michigan, before deductions for handling charges, was $6.07 per cwt. for the first six months of 1972. It is asknowledged that the use of a different price would have a significant impact on the results, in terms of return to operator's labor, management and risk bearing. However, of most interest in this study is the relationship of returns among the different production technologies. This relationship is exemplified regardless of the assumptions made about price, given that all producers receive the same price.

Land

As indicated in the preceding chapter, all crop producing land is assumed to be in Land Capability Class I or II. An "average" price of $500 per acre is assumed. An annual charge of $40.00 or 8 percent of the price of land is assumed as a charge for interest and real property taxes.

Labor

Although some of the producers represented by the synthetic firms normally have full-time hired help and/or additional family labor, the assumption made relative to this study is that labor required beyond that available from the operator would be hired on an hourly basis. For the larger firms, this may be full-time labor. It is assumed that labor could be hired as needed, at a wage of $3.00/hour. This wage was selected as representing an equivalent salary of full-time hired labor.

Constraints

The only resource assumed to have a limited availability for purpose of this study is operator labor. It is assumed that the operator works fifty hours per week for fifty weeks, or 2,500 hours per year. Although survey information indicates that Michigan dairy farmers work close to sixty hours per week, ten hours are deducted to reflect time required for miscellaneous chores such as sick cows, repairs and up-keep of equipment and buildings. The two weeks not otherwise accounted for is considered to be vacation time to be taken in August.

Total operator labor availability, by month, is indicated in Table 9.

In addition to the limits placed on the availability of the operator labor, restrictions are placed on the number of cows in the dairy herd. That is, for each synthetic firm the size of the herd is predetermined and forced to be at that level. This constraint, in turn, is the crucial factor in determining total labor, land, and capital requirements.

Table 9. Restrictions on operator labor availability

Month	Hours of Labor	Month	Hours of Labor
January	220.7	July	220.7
February	199.4	August	122.0
March	220.7	September	213.6
April	213.6	October	220.7
May	220.7	November	213.6
June	213.6	December	220.7
TOTAL			2,500.0

Coefficients

There are four production activities specified for each of the synthetic firms. These include the "milk production" activity, the "corn grain production" activity, the "corn silage production" activity and the "alfalfa haylage production" activity. The remaining thirteen activities specified for the firms consist of twelve "labor-hiring activities" and one "milk-selling" activity. These activities require no estimates other than the prices which are discussed above.

The "milk production" activity included the inputs required to milk, feed and house the cows and the inputs required to collect and dispose of dairy wastes.

The alternative technologies studied influence the coefficient values for waste handling and feed storage operations. Therefore, twelve sets of coefficients for the milk production activity are necessary to reflect each of the milk production systems. The analysis of these twelve sets of coefficients were handled by one program, the only difference between runs being the set of coefficients used in the "milk production activity."

The "corn grain production" activity, the "corn silage production" activity and the "alfalfa haylage production" activity consist of those inputs required to grow and harvest an acre of crop, with the exception of the ownership costs of the fixed machinery complement. Following is a discussion of the labor requirements and operating and ownership costs of the four production activities for each of the twelve production systems analyzed. Following this presentation is a discussion of the investment requirements for each of the twelve systems.

Labor Requirements and Costs of Milk Production

Labor Requirements

The estimated labor requirements for the "milk production activity," by month, for the twelve production systems being analyzed are presented in Table 10. This

Table 10. Estimated labor requirements per cow for the milk production activity--alternative housing systems, herd sizes and manure handling systems.[a,b]

Labor Period	Stanchion Housing		Open Lot Housing		Cold Covered Housing		Warm Enclosed Housing: Tractor-Scraper		Warm Enclosed Housing: Mechanical-Scraper		Warm Enclosed Housing: Slotted Floor	
	40 cows	60 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows
	hours per cow plus replacement											
January	5.9	5.4	3.9	3.7	4.0	3.8	3.5	3.3	3.2	3.0	3.2	3.0
February	5.3	4.9	3.5	3.3	3.6	3.4	3.2	3.0	2.9	2.7	2.9	2.7
March	5.9	5.4	3.9	3.7	4.0	3.8	3.9	3.7	3.6	3.4	3.6	3.4
April	5.8	5.3	3.7	3.5	3.8	3.6	3.4	3.2	3.1	2.9	3.1	2.9
May	5.9	5.4	3.9	3.7	4.0	3.8	3.5	3.3	3.2	3.0	3.2	3.0
June	5.8	5.3	3.7	3.5	3.8	3.6	3.8	3.6	3.5	3.3	3.5	3.3
July	5.9	5.4	3.9	3.7	4.0	3.8	3.5	3.3	3.2	3.0	3.2	3.0
August	5.9	5.4	3.9	3.7	4.0	3.8	3.5	3.3	3.2	3.0	3.2	3.0
September	5.8	5.3	3.7	3.5	3.8	3.6	3.8	3.6	3.5	3.3	3.5	3.3
October	5.9	5.4	3.9	3.7	4.0	3.8	3.5	3.3	3.2	3.0	3.2	3.0
November	5.8	5.3	3.7	3.5	3.8	3.6	3.4	3.2	3.1	2.9	3.1	2.9
December	5.9	5.4	3.9	3.7	4.6	3.8	3.8	3.9	3.6	3.4	3.6	3.4
Total Hrs/ cow/year	69.8	63.9	45.6	43.2	46.8	44.4	42.9	40.5	39.3	36.9	39.3	36.9

[a]Includes collection of cows, preparation of equipment, milking, cleaning equipment, feeding forage and grain, bedding and complete manure handling.

[b]Source: C. R. Hoglund, "Labor Requirements, Investments and Annual Costs--Alternative Manure Handling Systems," unpublished data, Dept. of Ag. Econ., Mich. State Univ.; John A. Speicher, D. Lynall MacLachlan, C. R. Hoglund and James S. Boyd, "Labor Efficiency in Open Lot and Covered Free Stall Dairy Housing," Farm Science, Research Report 107, Michigan Agricultural Experiment Station, March, 1970; I. F. Fellows, "Economic Affect of Alternative Methods of Housing and Milking Dairy Cows," Connecticut Agricultural Experimental Station Bulletin 398, 1966; D. Lynall MacLachlan, "A Study of Dairy Chore Labor Under Different Systems of Free Stall Housing," unpublished M.S. Thesis, Michigan State University, 1967.

estimate includes the time required for milking, including time to collect cows, and prepare and clean equipment; the time required to feed both forage and grain; and time required for the complete waste handling activity, including bedding.

In all cases, except for stanchion housing, a double-four herring bone milking parlor is assumed. For the stanchion housing, cows are assumed milked in the same building using a pipeline to the bulk tank.

It is assumed, for all systems, that all feed is stored in concrete tower silos equipped with mechanical unloaders. For the open lot and covered housing systems, the feed is unloaded directly into the feed bunks. For the stanchion housing system, however, a feed cart is required to distribute the feed from the unloader to the cows.

Wastes are assumed to be handled as a solid for the stanchion, open lot and cold covered housing systems. Furthermore, for each of these systems, it was assumed that wastes are collected, hauled, and spread daily. In the case of the stanchion housing system, a mechanical gutter cleaner is utilized to transport manure and bedding into the spreader. For the open lot and cold covered housing systems, a tractor equipped with a front end loader and scraper blade is utilized to collect and load the manure.

Manure is assumed to be handled as a liquid for the warm enclosed housing systems. For all systems, the manure is assumed to be stored in underground tanks for a three-month period. The tanks, therefore, require emptying four times per year--March, June, September and December. The only difference in the warm enclosed housing systems is the method in which wastes are collected. One system utilizes a tractor-scraper to scrape waste into the storage pits; another utilizes a mechanical scraper; and the third utilizes a slotted floor system, requiring no scraping.

Table 10 indicates that there is a substantial difference in annual labor requirements per cow plus replacement among the alternative production systems. The labor requirements range from a high of 69.8 hours/cow/year for the 40-cow stanchion housing system to a low of 36.9 hours/cow/year for both the mechanically scraped and slotted floor warm enclosed housing systems.

Variations in labor requirements among the alternative milk production systems is attributable to differences in the milking, feeding, and waste handling operations of respective systems. Table 11 presents separate estimates of the labor requirements for the milking and feeding, and the waste handling operations.

Table 11 indicates that the labor requirements for the milking, feeding, and waste handling operations

Table 11. Estimated annual labor requirements per cow for the milking and feeding activities and the manure handling operations--alternative housing systems, herd sizes and manure handling systems.

Production System	Milking and Feeding	Manure Handling and Bedding	Total Labor Req/Cow + R/Year
	hours/cow + R/year		
Stanchion Housing			
40 cows	53.5	16.3	69.8
60 cows	50.2	13.7	63.9
Open Lot Housing			
80 cows	34.5	11.2	45.7
160 cows	32.6	10.7	43.3
Cold Covered Housing			
80 cows	34.2	12.6	46.8
160 cows	32.3	12.1	44.4
Warm Enclosed Housing			
Tractor-Scraper			
80 cows	34.2	8.7	42.9
160 cows	32.3	6.3	40.5
Mech.-Scraper			
80 cows	34.2	5.1	39.3
160 cows	32.3	4.6	36.9
Slotted Floors			
80 cows	34.2	5.1	39.3
160 cows	32.3	4.6	36.9

are relatively high for the stanchion housing system. Labor requirements for the feeding operation are increased due to hand distribution of feed from the silo unloader. Labor requirements for the milking activity are relatively high due to the necessity of moving the milker from cow to cow throughout the barn. Time required for the manure handling activity is increased due to the necessity of at least partially bedding each stall daily.

Since all covered housing systems are assumed to have the same milking and feeding systems, the labor requirements are identical. The time required for the milking operation is somewhat higher for the open lot system due to the fact that it takes longer to collect the cows for milking.

The labor requirement for the waste handling activities is slightly less for the open lot system than for the cold covered system. The liquid waste handling systems require less time due to the increased efficiency of hauling and spreading only four times per year. The mechanical scraper and slotted floor systems require the least labor for waste handling due to the elimination of the human agent in the scraping operation.

Costs of Milk Production

The costs discussed in this section include the cash or operating costs and the ownership costs of buildings, machinery and equipment, excluding the costs associated with ownership of the fixed machinery complement. These latter costs are discussed separately in the "Investment Requirements" section of this chapter.

Several costs associated with the milk production activity are assumed constant (per cow) regardless of the milk production system being used or the size of the herd under consideration. These cost estimates are listed in Table 12. The annual cost of $36.00 for each cow and replacement represents an 8 percent interest charge on the capital invested in the dairy herd. It is assumed that the market price in Michigan of dairy cows capable of producing 13,000 pounds of milk is $350. The average value of a replacement animal is assumed to be equal to $100, so that the total value of a cow and replacement is $450.

Livestock receipts are based on the assumption that each year 25 percent of the cows would be sold as culls for an average price of $160 each, and 75 percent of the heifers are sold as young calves at an average price of $40 each. Assuming a 50-50 bull-heifer ratio and a ten percent calf mortality rate, the livestock receipts add to $85.00 per cow plus replacement.

The remaining cost estimates associated with the milk production activity are not the same for all production systems or herd sizes. These cost estimates are presented in Table 13. Although the source of data

Table 12. Estimated costs and receipts per cow plus replacement of items unaffected by production technology or herd size.

Item	Dollars/Cow + R/Year
Cash Costs	
Breeding	8.00[a]
Supplies	13.00[b]
Taxes	18.00[b]
Spray	10.00[b]
SBOM	15.00[c]
UREA	7.20[d]
Insurance	10.00[b]
Vet	14.50
Capital Costs	
Cows and Replacement	36.00[e]
Total Cost/Cow + R/Year	131.70
Livestock Sales	85.00[f]

[a]Source: MABC rates for 1972.

[b]Source: MSU Telefarm System.

[c]Assumes 250/lb./cow/year @ $120/T.

[d]Assumes 120/lb./cow/year @ $120/T.

[e]Eight percent of market price.

[f]Includes cull calves, bull calves and excess heifer calves.

Table 13. Estimated costs per cow plus replacement of items affected by production technology or herd size.

	Stanchion Housing		Open Lot Housing		Cold Covered Housing		Warm Enclosed Housing: Tractor-Scraper		Warm Enclosed Housing: Mechanical-Scraper		Warm Enclosed Housing: Slotted Floors	
	40 cows	60 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows
	Dollars/Cow + R/Year											
Cash Costs												
Bedding[a]	20.00	20.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Repairs & Main.[b]	14.00	14.00	14.00	13.00	16.00	15.00	16.00	15.00	16.00	15.00	16.00	15.00
Utilities[c]	15.00	15.00	15.00	15.00	16.50	15.70	16.50	15.70	17.65	16.84	16.50	15.70
Tractor Power[d]	8.80	10.00	12.40	14.00	15.50	16.00	7.00	7.76	3.00	3.35	3.00	3.35
Misc.	10.00	10.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Capital Costs												
Gutter Cleaner[d,h]	12.50	10.75	--	--	--	--	--	--	--	--	--	--
Manure Spreader[d,i]	8.25	6.87	5.50	4.54	5.50	4.54	2.00	1.65	2.00	1.69	2.00	1.65
Scraper & Loader[d,j]	--	--	5.50	4.54	5.50	4.54	2.00	1.12	1.40	1.12	1.40	1.12
Mech. Scraper[d,h]	--	--	--	--	--	--	--	--	5.00	4.40	--	--
Pump & Agitator[d,k]	--	--	--	--	--	--	3.13	3.00	3.13	3.00	3.13	3.00
Manure Storage[d,l]	--	--	--	--	--	--	15.00	12.48	15.00	12.48	15.00	12.48
Liquid Spreader[d,h]	--	--	--	--	--	--	3.60	3.12	3.60	3.12	3.60	3.12
Housing & Milking Parlor[e,l]	60.75	60.00	60.50	60.50	67.00	62.75	77.00	72.75	77.00	72.50	83.75	79.37
Silage Storage & Equipment[f]	48.50	45.00	38.40	28.20	38.40	28.20	38.40	28.20	38.40	28.20	38.40	28.20
Grain Storage & Handling[g,m]	32.80	32.80	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60
Total Cost/Cow + R/Year	230.60	224.42	195.77	184.09	208.87	191.04	226.63	207.27	228.78	208.51	229.38	209.54

[a]Assumes 1T/Cow + R/Year for stanchion housing and 1/2T/Cow + R/Year for other housing systems.

[b]Source: MSU Telefarm data.

[c]Source: MSU Telefarm data modified by C. R. Hoglund, "Labor Requirements, Investments and annual costs--Alternative Manure Handling Systems," unpublished data, Dept. of Ag. Econ., MSU.

[d]Source: C. R. Hoglund, "Labor Requirements, Investments and Annual Costs--Alternative Manure Handling Systems," unpublished data, Dept. of Ag. Econ., MSU.

[e]C. R. Hoglund, "Dairy Farming Today and Tomorrow--Trends, New Developments, and Costs and Returns," prepared for Agriculture in Action program, Jan. & Feb., 1972.

[f]Source: Richard L. Trimble, Larry Connor, John R. Brake, "Michigan Farm Management Handbook--1971," Agriculture Economics Report, Report No. 181, Dept. of Ag. Econ., MSU, May, 1971.

[g]C. R. Hoglund, "Economics of Grain Silage Systems," paper presented at Ontario Silage Conference, Rexdale, Ontario, Canada, December, 1971.

[h]Assumes an annual charge of 20 percent of investment.

[i]Assumes an annual charge of 22 percent of investment.

[j]Assumes an annual charge of 15 percent of investment.

[k]Assumes an annual charge of 25 percent of investment.

[l]Assumes an annual charge of 10 percent of investment.

[m]Includes depreciation and interest on silo unloading equipment, plastic covers, extra field losses and storage losses and grinding charges.

used in determining the estimates are given below the Table, several of the capital cost estimates require additional discussion.

The annual capital cost associated with the ownership of a conventional manure spreader illustrates some economics of size in the new price of spreaders. For these systems handling wastes as a solid the annual charge for the spreader was 22 percent of the new price of the spreader. The cost of a spreader is assumed to be $1,500 for the 40-cow herd, $1,875 for the 60-cow herd and $2,000 for the 80-cow herds. For those systems handling wastes as a liquid, the ownership of an inexpensive, older spreader is assumed for hauling solid manure for the dry cow and heifer barns. It is estimated that the cost of this type of spreader is $1,000 for the 80-cow herd and $1,200 for the 160-cow herd. Because of the nature of these spreaders, the annual charge is assumed to be only fifteen percent of the price.

The same type of relationship is assumed in the case of the ownership of a manure scraper and loader. The price of a scraper and loader is estimated to be $1,800 for the 80-cow herd and $2,400 for the 160-cow herd, except for the liquid systems. Again, the ownership of an old scraper and loader is assumed for those systems handling waste as a liquid, valued at $1,000 for the 80-cow herd and $1,200 for the 160-cow herd.

For those systems handling waste as liquid, three months storage capacity is assumed. Furthermore, the assumption is made that 1,500 gallons of storage capacity would be required for each cow per three months. Construction costs are estimated to be $.10 per gallon of capacity for the 80-cow herd and $.083 per gallon of capacity for the 160-cow herd. Assessing an annual charge of ten percent of the new cost results in an estimated annual cost of $15 per cow for the 80-cow herd and $12.48 per cow for the 160-cow herd.

The investment requirements for the housing and milking parlor, including bulk tank and related equipment, are listed in Table 14. All systems have a double four-herringbone milking parlor, except for the stanchion housing system. The investment requirements per cow for the milking parlor are estimated to be $265 for the open lot systems; $295 for the 80-cow covered systems; and $272.50 for the 160-cow covered systems.

The required investments, per cow, for the dairy barns are estimated to be $265 for the open lot housing system; $300 for the 80-cow cold covered housing system; $280 for the 160-cow cold covered housing system; $400 for the 80-cow warm enclosed housing system; and $380 for the 160-cow warm enclosed housing system. The slotted floor housing system requires an additional investment of $67.50 per cow for the 80-cow herd and

Table 14. Estimated investment requirements for housing facilities and milking parlor.[a]

System	Dollars/Cow + R
Stanchion	
40 cows	607.50
60 cows	600.00
Open Lot	
80 cows	605.00[b]
160 cows	605.00[b]
Cold Covered	
80 cows	670.00
160 cows	627.75
Warm Enclosed	
Tractor Scraper	
80 cows	770.00
160 cows	727.50
Mechanical Scraper	
80 cows	770.00
160 cows	727.50
Slotted Floors	
80 cows	837.50
160 cows	793.70

[a]Source: C. R. Hoglund, "Dairy Farming Today and Tomorrow, Trends, New Developments and Costs and Returns," Paper prepared for Agriculture in Action Programs, January and February, 1972, and I. F. Fellows and G. S. Sanford, "Economic Evaluation of Combining a Milking Center with a Stanchion Barn," Connecticut Agricultural Experiment Station Bulletin 398, 1966.

[b]Includes paved lots.

$67.20 per cow for the 160-cow herd. In addition, an investment of $75 per cow is estimated to be required to house replacement stock and calves.

The annual capital cost associated with silage storage and related equipment are taken to be ten percent of the new cost of concrete tower silos of sufficient capacity to meet the feed storage requirements. The size of silos assumed are one 20' X 70' and one 24' X 50' for the 40-cow herd; one 24' X 60' and one 24' X 70' for the 60-cow herd; one 26' X 70' and one 30' X 60' for the 80-cow herd and two 36' X 70' silos for the 160-cow herd.

The cost estimates associated with grain storage include not only a charge for the storage facility, but also the cost associated with grinding the corn and a charge for storage loss. The total of these costs are estimated to be $.40 per bushel for the 40- and 60-cow herds and $.30 per bushel for the 80- and 160-cow herds.

Summary of Milk Production Activity

The labor requirements, costs and receipts for the milk production activity are summarized in Table 15. The estimates included in this table are merely transfers from other tables already discussed in this chapter. Data in Table 15 indicate that the 160-cow, open lot housing system has the lowest milk production cost per cow and that the 40-cow stanchion housing system has

Table 15. Labor requirements, costs and receipts per cow plus replacement for producing milk under alternative housing systems, waste handling systems and herd sizes.

							Warm Enclosed Housing					
	Stanchion Housing		Open Lot Housing		Cold Covered Housing		Tractor-Scraper		Mechanical-Scraper		Slotted Floors	
	40 Cows	60 Cows	80 Cows	160 Cows	80 Cows	160 Cows	80 Cows	160 Cows	80 Cows	160 Cows	80 Cows	160 Cows
Annual Labor Requirements	69.8	63.9	45.6	43.2	46.8	44.4	42.9	40.5	39.3	36.9	39.3	36.9
Costs												
General[a]	131.70	131.70	131.70	131.70	131.70	131.70	131.70	131.70	131.70	131.70	131.70	131.70
Cash Costs[b]	67.80	69.00	63.40	64.00	70.00	68.70	61.50	60.35	58.65	57.19	57.50	56.05
Capital Costs												
Manure Handling[c]	20.75	17.62	8.87	6.79	8.87	6.79	25.13	21.37	30.13	25.77	25.13	21.37
Housing and Milk Parlor	60.75	60.00	60.50	60.50	67.00	62.75	77.00	72.75	77.00	72.75	83.75	79.37
Feed Storage[c]	81.30	77.80	63.00	52.80	63.00	52.80	63.00	52.80	63.00	52.80	63.00	52.80
Livestock Receipts	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00
Net Cost[d]	277.30	271.12	242.47	230.79	255.57	237.74	273.33	253.97	275.40	255.21	276.08	256.29

[a]From Table 11.

[b]Sum of cash costs of Table 12.

[c]From Table 13.

[d]Excluding hired labor costs and costs of feed production.

the highest milk production cost per cow. However, these cost estimates do not include hired labor charges. The addition of labor charges will change the relationship of production costs among these systems. Under the assumptions within which estimates were developed for this study, there exists only relatively small differences in the total cost of milk production as shown in Table 15.

Labor Requirements and Costs of Crop Production Activities

Three crop production activities are defined for each dairy production system considered. Corn for grain, corn silage and alfalfa haylage needed to fulfill the requirements of the dairy herd are produced; none are produced for sale.

The per acre labor requirements and costs to produce these three crops are given in Table 16. These requirements are assumed to be the same for 40-, 60- and 80-cow herds but somewhat less for the 160-cow herds because of a different machinery complement. It is assumed that only those firms with 160 cows would do their own corn grain harvesting. Other firms are assumed to custom hire this operation. No machinery or equipment charges are included in Table 16 as these are included in the charge for the machinery complement.

Table 16. Estimated labor requirements and costs of corn grain, corn silage and alfalfa haylage production.

Item	Corn Grain		Corn Silage		Alfalfa Haylage	
	40, 60 or 80 cows	160 cows	40, 60 or 80 cows	160 cows	40, 60 or 80 cows	160 cows
			Hours Per Acre			
Labor Requirements[a]						
March	.25	.2	-	-	-	-
April	.5	.4	.5	.4	.12	.1
May	.62	1.5	.62	.5	1.3	1.1
June	.5	.4	.5	.4	1.2	1.0
July	.12	.1	.12	.1	2.5	2.0
August	.12	.1	.12	.1	.63	.5
September	-	1.0	2.5	2.0	1.8	1.5
October	.25	1.2	2.5	2.0	-	-
November	.37	.3	.25	.2	-	-
Total Labor/Year	2.73	4.2	7.11	5.7	7.55	6.2
			Dollars Per Acre			
Cash Costs						
Seed[b]	4.80	4.80	4.80	4.80	5.50	5.50
Fertilizer[b]	19.00	19.00	19.00	19.00	9.00	9.00
Spray[b]	5.00	5.00	6.50	6.50	1.00	1.00
Fuel and Repairs[a]	3.20	6.00	7.00	7.00	7.50	7.50
Custom Hire[b]	6.50					
Capital Costs						
Land[c]	40.00	40.00	40.00	40.00	40.00	40.00
Total Cost/Acre[d]	78.50	74.80	77.30	77.30	63.00	63.00

[a]Source: Allen E. Shapley, "Alternatives in Dairy Farm Technology with Special Emphasis on Labor," unpublished Ph.D. Dissertation, Michigan State University, 1968, modified by Richard L. Trimble, Larry J. Connor, John R. Brake, "Michigan Farm Management Handbook, 1971," Agricultural Economics Report, Report No. 191, Department of Agricultural Economics, Michigan State University, May, 1971.

[b]Source: Richard L. Trimble, Larry J. Connor, John R. Brake, "Michigan Farm Management Handbook, 1971," Agricultural Economics Report, Report No. 191, Department of Agricultural Economics, Michigan State University, May, 1971.

[c]Source: C. R. Hoglund, C. D. Schwab and M. B. Tesar, "Economics of Growing and Feeding Alfalfa and Corn Silage for Dairy Cattle," Farm Science, Research Report 154, Michigan Agricultural Experiment Station, March, 1972.

[d]Excluding labor costs.

Net crop yields considered for this study are: 92 bushels per acre for corn grain, 15 tons per acre of corn silage and 4.2 tons per acre (hay equivalent) for alfalfa haylage.[1] These figures are on a "preserved for feeding" basis, allowing for some harvesting and storage loss. The annual feed requirements per cow plus replacement were assumed to be 82 bushels of corn, 12 tons of corn silage and 4.3 tons of hay equivalent.[2]

Basic Machinery Complement

The linear programming algorithm employed in this study yields an objective function value which is a composite return to the operator's labor, management, and to the basic machinery complement. Costs associated with the ownership of the basic machinery complement are deducted from the objective value to determine the return to the operator for his labor and management.

Machinery ownership costs are deducted from the objective value rather than specifying machinery costs for each production activity. As several pieces of machinery are used for more than one production activity, this procedure eliminated the need to arbitrarily spread the fixed costs of the machinery complement among its joint uses.

The investment and annual ownership costs associated with the basic machinery complements, one for the 40-, 60- and 80-cow herds and one for the 160-cow herds, are specified in Table 17.

Investment Requirements

Presented in Table 18 are estimates of investment requirements for housing and milking parlors, for feed storage and handling, for waste handling equipment, for the dairy cows and replacement stock, for the machinery complement and for cropland for alternative production systems and herd sizes. The 40-cow stanchion housing system requires the highest investment per cow, due largely to two factors: (1) the assumption of identical machinery complements for the 40-, 60- and 80-cow herds results in a large investment per cow for machinery for the 40-cow herd; and (2) substantial economies of size in feed storage facilities result in large per cow investments for the small herds.

The 80-cow warm enclosed systems rank second in investment requirements per cow. Although the 80-cow systems enjoy some economies of size in feed storage and machinery, the investments for housing and waste storage are substantial. The mechanical scraper and slotted floor systems require a higher investment than the tractor scraper system.

The 60-cow stanchion housing system has a relatively high investment requirement, again due to the

Table 17. Estimated costs of basic machinery complement.

Item	Spec.	New Price[c] Herd Size ≤80	160	Annual Ownership Costs[a] Herd Size ≤80	160
Tractor (Used)[b]	50 H.P.	1,400	1,400	84	84
Tractor	38 H.P.	4,200	4,200	567	567
Tractor	53 H.P.	5,600	5,600	757	757
Tractor	70 H.P.	7,400	--	1,000	--
Tractor	90 H.P.	--	10,000	--	1,351
Plow	3-16"	1,600	1,600	252	252
Plow	4-16"	2,000	--	315	--
Plow	5-16"	--	2,350	--	370
Disc	12'	1,300	--	176	--
Disc	16'	--	1,600	--	216
Corn Planter	4-Row	1,500	--	236	--
Corn Planter	6-Row	--	2,100	--	331
Spray Attachment	4-Row	300	--	40	--
Spray Attachment	6-Row	--	450	--	47
Seeder[b]		900	900	120	120
Field Chopper	2-R PTO	3,900	--	615	--
Field Chopper	2-R PTO	--	10,000	--	1,200
Corn Harvester	2-R Mounted	--	4,900	--	662
Sprayer	32'	1,000	1,000	150	150
Silage Wagons	S.U.	3,400	5,100	460	690
Grain Wagon		--	575	--	78
Forage Head		800	--	120	--
Forage Head		--	1,000	--	150
Corn Head	2-Row	600	--	120	--
Corn Head	2-Row	--	1,000	--	150
Harrow	16'	450	450	47	47
Cultivator	4-Row	850	--	115	--
Cultivator	6-Row	--	1,200	--	162
Feed Grinder	PTO	650	--	130	--
Feed Grinder	PTO	--	1,000	--	200
Windrower	9' PTO	2,700	--	527	--
Windrower	11' S.P.	--	4,800	--	756
Silage Blower	60'	900	--	122	--
Silage Blower	70'	--	1,000	--	150
Truck	3/4 T.	2,500	--	500	--
Truck	1 1/2 T.	--	4,500	--	900
Total Cost		43,950	66,725	6,453	9,390

[a]Unless specified, the estimates were taken from Richard L. Trimble, Larry J. Connor and John R. Brake, "Michigan Farm Management Handbook, 1971," Agricultural Economics Report, Report No. 191, Department of Agricultural Economics, Michigan State University, May, 1971.

[b]Source: Allen E. Shapley, "Alternatives in Dairy Farm Technology with Special Emphasis on Labor," unpublished Ph.D. dissertation, Michigan State University, 1968.

Table 18. Estimated total investment requirements--alternative housing systems, manure handling systems and herd sizes.

Item	Stanchion Housing		Open Lot Housing	
	40 cows	60 cows	80 cows	160 cows
Housing and Milking Parlor[a]	24,300	36,000	48,400	96,800
Silage Storage[b]	19,400	27,000	30,050	45,000
Grain Storage[c]	5,400	7,600	9,200	15,000
Manure Handling[d]				
Gutter Cleaner	2,500	3,050	--	--
Manure Spreader	1,500	1,875	2,000	3,300
Liquid Storage	--	--	--	--
Scraper and Loader	--	--	1,800	2,400
Mechanical Scraper	--	--	--	--
Pump and Agitator	--	--	--	--
Liquid Spreader	--	--	--	--
Total Manure Handling	4,000	5,925	3,800	5,700
Machinery Complement[e]	43,950	43,950	43,950	66,725
Land[f]	54,300	81,450	108,600	217,200
Cows and Replacement[g]	18,000	27,000	36,000	72,000
Total Investment	169,350	227,925	180,000	518,425
Total Investment/Cow	4,233.75	3,798.75	3,800.00	3,240.16

[a]Source: C. R. Hoglund, "Dairy Farming Today and Tomorrow--Trends, New Developments, and Costs and Returns," paper prepared for Agriculture in Action Programs, January and February, 1972.

[b]Source: Richard L. Trimble, Larry J. Connor, John R. Brake, "Michigan Farm Management Handbook, 1971," Agricultural Economics Report, Report No. 191, Department of Agricultural Economics, Michigan State University, May, 1971.

[c]Source: C. R. Hoglund, "Economics of Grain Silage Systems," paper presented at Ontario Silage Conference, Rexdale, Ontario, Canada, December 15, 1971.

[d]Source: C. R. Hoglund, "Labor Requirements, Investments and Annual Costs--Alternative Manure Handling Systems," unpublished data, Department of Agricultural Economics, Michigan State University.

		Warm Enclosed Housing					
Cold Covered Housing		Tractor Scraper		Mechanical Scraper		Slotted Floors	
80 cows	160 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows
53,600	100,400	61,600	116,400	61,600	116,400	67,000	127,000
30,050	45,000	30,050	45,000	30,050	45,000	30,050	45,000
9,200	15,000	9,200	15,000	9,200	15,000	9,200	15,000
--	--	--	--	--	--	--	--
3,000	3,300	1,000	1,200	1,000	1,200	1,000	1,200
--	--	12,000	20,000	12,000	20,000	12,000	20,000
1,800	2,400	1,000	1,200	1,000	1,200	1,000	1,200
--	--	--	--	2,000	3,500	--	--
--	--	1,000	1,900	1,000	1,900	1,000	1,900
--	--	1,500	2,500	1,500	2,500	1,500	2,500
4,800	5,700	16,500	26,800	18,500	30,300	16,500	26,800
43,950	66,725	43,950	66,725	43,950	66,725	43,950	66,725
108,600	217,200	108,600	217,200	108,600	217,200	108,600	217,200
36,000	72,000	36,000	72,000	36,000	72,000	36,000	72,000
286,200	522,025	305,900	559,225	307,900	562,625	311,300	568,525
3,577.50	3,262.66	3,823.75	3,495.16	3,848.75	3,516,40	3,891.25	3,554.33

[e]Source: Allen E. Shapley, "Alternatives in Dairy Farm Technology with Special Emphasis on Labor," unpublished Ph.D. dissertation, Michigan State University, 1968, modified by Richard L. Trimble, Larry J. Connor, John R. Brake, "Michigan Farm Management Handbook, 1971," Agricultural Economics Report, Report No. 191, Department of Agricultural Economics, Michigan State University, May, 1971.

[f]Number of acres determined by the linear programming model described in the next section.

[g]Assumes a value of $450 per cow + R.

diseconomies of feed storage and machinery for the smaller herd sizes. The 80-cow cold covered system requires a higher investment than the 80-cow open lot system due almost entirely to the more expensive dairy barn required for the cold covered system.

The 160-cow herds require the least investment per cow due largely to economies of size in feed storage facilities and the machinery complement. The open lot system requires no waste storage facilities and utilizes a less expensive dairy barn than the other systems, resulting in the lowest investment requirement per cow of all systems.

Hired Labor and Return to Operator's Labor

Using the estimates derived in previous sections and the model outlined in Chapter V, the amount of hired labor and the return to the operator's labor, and management are determined for each of the twelve synthetic firms (Table 19).

All firms hire substantial amounts of labor from March through October. This period represents the increased labor requirements of the cropping activities. Firms utilizing liquid waste handling systems require additional hired labor to empty manure tanks during the months of March, June, September and December.

Table 19. Hired labor, return to fixed factors and return to operator--alternative housing systems, waste handling systems and herd sizes.

	Stanchion Housing		Open Lot Housing		Cold Covered Housing	
	40 cows	60 cows	80 cows	160 cows	80 cows	160 cows
			hours			
Hired Labor[a]						
January	15.3	103.3	91.3	371.3	99.3	387.3
February	12.6	94.6	80.6	328.6	88.6	344.6
March	24.2	116.7	109.1	399.8	117.1	415.8
April	57.1	162.5	159.9	471.0	167.9	487.0
May	110.5	246.1	281.7	686.8	289.7	702.8
June	101.3	228.8	248.3	618.4	256.3	634.5
July	125.8	269.0	342.3	726.0	320.3	742.0
August	147.8	252.7	257.7	578.8	265.7	594.8
September	172.1	334.9	389.8	990.7	397.8	1,006.7
October	104.2	236.7	269.1	798.4	277.1	814.4
November	39.6	136.2	124.8	414.7	132.8	430.8
December	15.3	103.3	91.3	371.3	99.3	387.3
Total Hired Labor	925.8	2,284.8	2,415.9	6,755.8	2,511.9	6,948.0
Total Hired Labor/Cow	23.1	38.1	30.2	42.2	31.4	43.4
Return to Fixed Factors (Obj. Value)	9,477.88	11,899.47	20,049.86	36,723.84	18,713.86	35,035.84
Machinery Charge	6,453.00	6,453.00	6,453.00	9,390.00	6,453.00	9,390.00
Return to Operator	3,024.88	5,446.47	13,596.86	27,333.84	12,260.86	25,645.84
Return/Hour of Operator Labor	1.21	2.18	5.44	10.93	4.90	10.26

[a]Determined by the Linear Programming model as described in the next section.

Warm Enclosed Housing					
Tractor Scraper		Mechanical Scraper		Slotted Floors	
80 cows	160 cows	80 cows	160 cows	80 cows	160 cows
		hours			
59.3	307.3	35.3	259.3	35.3	259.3
56.6	280.6	32.6	232.6	32.6	232.6
109.1	399.8	85.1	351.8	85.1	351.8
135.9	423.0	111.9	375.0	111.9	375.0
249.7	622.8	225.7	574.8	225.7	574.8
256.3	634.5	232.3	586.5	232.3	586.5
280.3	662.0	256.3	614.0	256.3	614.0
225.7	514.9	201.7	466.9	201.7	466.9
397.8	1,006.7	373.8	958.7	373.8	958.7
237.1	734.4	213.1	686.4	213.1	686.4
100.8	366.8	76.8	318.8	76.8	318.8
91.3	371.3	67.3	323.3	67.3	323.3
2,199.9	6,324.1	1,911.9	5,748.1	1,911.9	5,748.1
27.5	39.5	23.9	35.3	23.9	35.3
18,229.06	34,311.04	18,921.06	35,840.64	18,873.06	35,667.84
6,453.00	9,390.00	6,453.00	9,390.00	6,453.00	9,390.00
11,776.06	24,921.04	12,468.06	26,450.64	12,420.06	26,277.84
4.71	9.97	4.99	10.58	4.96	10.49

The 160-cow cold covered housing system requires the greatest amount of hired labor due to the higher waste handling labor requirements.

Even though the 40-cow stanchion housing system is the most labor intensive system analyzed, hired labor requirements are the least due to the small size of operation.

The returns to the operator for his labor and management range from $10.93 per hour of labor for the 160-cow open lot housing system to $1.21 per hour for the 40-cow stanchion housing system. Among the 80-cow herds, returns to the operator ranged from $5.44 per hour for the open lot system to $4.71 per hour for the warm enclosed housing system utilizing a tractor scraper for manure collection.

Variation in returns to the operator among the alternative systems of the same herd size is not very great. This results largely from the fact that the capital intensive systems require less hired labor and the labor intensive systems have a lower capital cost component. Therefore, the total cost of milk production and, thus, total returns are very similar for these systems.

Summary of Synthetic Firms

The labor requirements, investment requirements, acres of cropland, annual costs and returns of the twelve synthetic firms are summarized in Table 20. The information provided in this table, along with the distribution of hired labor given in Table 18, completely describes the synthetic firms developed for this study. In Chapter VII these synthetic firms are used to analyze the impact of three alternative pollution abatement policies on Michigan dairy producers. Not all of the synthetic firms are affected by each of the policies considered. But, for those firms which are affected, the analysis consists of the determination of the impact on policy compliance with respect to: (1) the total labor requirements of the firm, (2) the monthly distribution of labor requirements, (3) the investment requirements of the firm, (4) the costs of milk production, and (5) the returns to the operator's labor, management and risk bearing.

Table 20. Labor requirements, investment requirements, crop acreage, annual costs and returns of milk production--alternative housing systems, manure handling systems and herd sizes.

	Stanchion Housing		Open Lot Housing		Cold Covered Housing	
	40 cows	60 cows	80 cows	160 cows	80 cows	160 cows
Labor Hours/Year[a]	3,425.8	4,784.8	4,915.9	9,255.8	5,011.9	9,448.0
Acres of Crops	108.6	162.9	217.2	434.4	217.2	434.4
			Dollars			
Investments						
Housing & Parlor	24,300.00	36,000.00	48,400.00	96,800.00	53,600.00	100,400.00
Feed Storage	24,800.00	34,600.00	39,250.00	60,000.00	39,250.00	60,000.00
Manure Handling	4,000.00	5,925.00	3,800.00	5,700.00	4,800.00	5,700.00
Machinery	43,950.00	43,950.00	43,950.00	66,725.00	43,950.00	66,725.00
Land	54,300.00	81,450.00	108,600.00	217,200.00	108,600.00	217,200.00
Cows + R	18,000.00	27,000.00	36,000.00	72,000.00	36,000.00	72,000.00
Total Investment	169,350.00	227,925.00	280,000.00	518,425.00	286,200.00	522,025.00
Investments/Cow + R	4,233.75	3,798.75	3,500.00	3,240.16	3,577.50	3,262.66
Annual Costs						
Milk Production[b]	11,092.00	16,267.20	19,397.60	36,926.40	20,445.60	38,038.40
Crop Production	7,852.72	11,778.95	15,704.84	30,882.36	15,704.84	30,882.36
Machinery	6,453.00	6,453.00	6,453.00	9,390.00	6,453.00	9,390.00
Hired Labor	2,777.40	6,854.40	7,247.70	20,267.40	7,535.70	20,843.40
Total Annual Costs	28,175.12	41,353.55	48,803.14	97,466.16	50,139.14	99,154.16
Total Returns[c]	31,200.00	46,800.00	62,400.00	124,800.00	62,400.00	124,800.00
Net Returns	3,024.88	5,446.47	13,596.86	27,333.84	12,260.86	25,645.84
Net Returns/Cow	75.62	90.77	169.96	170.84	153.26	160.29

[a]Includes 2,500 hours of operator labor.

[b]Includes a deduction of $85.00/cow for sale of cull cows and calves, but does not include crop production or labor costs.

[c]Total milk sales.

Warm Enclosed Housing					
Tractor Scraper		Mechanical Scraper		Slotted Floors	
80 cows	160 cows	80 cows	160 cows	80 cows	160 cows
4,699.9	8,824.1	4,411.9	8,248.1	4,411.9	8,248.1
217.2	434.4	217.2	434.4	217.2	434.4
61,600.00	116,400.00	61,600.00	116,400.00	67,000.00	127,000.00
39,250.00	60,000.00	39,250.00	60,000.00	39,250.00	60,000.00
16,500.00	26,800.00	18,500.00	30,300.00	16,500.00	26,800.00
43,950.00	66,725.00	43,950.00	66,725.00	43,950.00	66,725.00
108,600.00	217,200.00	108,600.00	217,200.00	108,600.00	217,200.00
36,000.00	72,000.00	36,000.00	72,000.00	36,000.00	72,000.00
305,900.00	559,225.00	307,900.00	562,625.00	311,300.00	568,525.00
3,823.75	3,495.16	3,848.75	3,516.40	3,891.25	3,554.33
21,866.40	40,635.20	22,038.40	40,833.60	22,086.40	41,006.40
15,704.84	30,882.36	15,704.84	30,882.36	15,704.84	30,882.36
6,453.00	9,390.00	6,453.00	9,390.00	6,453.00	9,390.00
6,599.70	18,971.40	5,735.70	17,243.40	5,735.70	17,243.40
50,623.94	99,878.96	49,931.94	98,349.36	49,979.94	98,522.16
62,400.00	124,800.00	62,400.00	124,800.00	62,400.00	124,800.00
11,776.06	24,921.04	12,468.06	26,450.64	12,420.06	26,277.84
147.20	155.76	155.85	165.32	155.25	164.24

CHAPTER VII

IMPACTS OF ALTERNATIVE POLLUTION ABATEMENT POLICIES

Introduction

The purpose of this chapter is to examine the physical and economic impacts of compliance with pollution abatement policies on the twelve synthetic firms. Assuming production remains at the same level of output after compliance, the impact on the costs of production is related to the theoretical, economic models developed in Chapter IV. The theoretical models presented in Chapter IV assume the cost structure of the firm is known for all levels of output and that acquisition and salvage prices are known for all "fixed" inputs. The synthetic firms developed for this study only describe one point on the firm cost curves, however. Furthermore, only the acquisition prices of inputs are presented. As a result, no definitive statements can be made concerning whether or not a given firm would comply with the pollution abatement policy, or whether output (number of cows) would remain at the same level. However, implications can be identified from the nature of the impact on the synthetic firm.

The policy alternatives to be examined in this chapter include: (1) mandatory control of runoff from open lots, (2) prohibition of winter spreading of wastes, and (3) mandatory subsurface disposal of dairy wastes. The impact of these alternative policies are examined.

Impact of Runoff Control Policy

Under the assumptions made for this study, a policy requiring control of waste runoff from the production site is only applicable to the open lot housing system. Although stanchion housing systems may have open lot areas, cows are generally confined during the winter. Because of the exposed nature of the feeding and exercise area associated with the open lot systems, wastes are susceptible to "flushing" with storm events. This runoff is created not only by the precipitation which falls on the lot itself, but also by water from outside the lot flowing across the lot.

The amount of waste which enters a waterway from runoff is dependent upon many variables. Among the primary variables to be considered are the location of the feedlot, the physical characteristics of the feedlot facilities, the feedlot management of wastes and, perhaps most important, the intensity of each incidence of precipitation. Depending on the mix of these variables, some firms may have no runoff problems; others may have severe problems.

Facility Requirements

For those open lot systems which do create runoff, a policy requiring control of this runoff is assumed. The methods and requirements for control of runoff can be expected to differ from one farm situation to another. In general, however, this type of policy implies the construction of facilities to (1) divert precipitation which falls upon areas outside the lot but tends to flow across the lot, (2) collect the mixture of water and wastes which flows from the lot with each rainfall, and (3) periodically empty the collection facilities.

Again, the size and nature of diversion facilities and amount of excavation required for the detention pond depends upon the physical characteristics of the production site. Specifically, the location of the production site in relationship to existing waterways and the nature of the terrain in the area of pond construction are crucial factors in determining the type and cost of diversion and retention facilities required. For purposes of this study, the following assumptions are made relative to the physical requirements of runoff control for the "typical" or representative open lot system.[1]

For the diversion facility, it is assumed that the construction of an earth embankment or dike would be required on two sides of the production site in order to divert water away from the open lot. The production site includes the dairy barn, the open lot, the feed storage facilities and related equipment. This embankment shall be constructed to specifications allowing the diversion of rainfall equivalent to the maximum ten-year, 24-hour storm level.

The size of diversion required to encompass the two high sides of the production site depends on the layout of the open lot and related buildings and equipment. For purposes of this study, it was assumed that the size of the open lot is 50' X 160' for the 80-cow herd and 80' X 200' for the 160-cow herd. Making allowances for the dairy barn and feed storage facilities, the size of diversion required was estimated to be 140' X 310' for the 80-cow system and 175' X 375' for the 160-cow operation. This results in watersheds of approximately one acre and one and a half acres for the 80-cow and 160-cow operations, respectively.

A detention pond would be constructed adjacent to the watershed to collect the runnoff from the watershed. Because of the physical nature of dairy cow wastes, the use of a settling basin in conjunction with the detention pond is not required. The detention pond is assumed to be constructed to Soil Conservation Service specifications. These specifications require:[2]

1. One foot of freeboard above the design storage level of the pond;
2. An earth spillway with minimum depth of one foot;
3. An elevation difference of at least two and one-half feet between maximum design pond level and the top of the embankment around the basin;
4. An emergency spillway at least ten feet wide and at least one foot above the maximum design pool level;
5. That the pond have a sealed botton, not susceptible to filling by groundwater; and
6. That the pond be constructed at least 1,000 feet from the home of persons other than the owner.

In addition, the embankments, spillways and diversions must be vegetated and the detention facilities must be fenced.

The size of the detention pond required is estimated by assuming that the facility would be designed to retain six months' runoff from the watershed. Due to the assumption of paved lots and to the impervious nature of the production site, it was assumed that all precipitation in the watershed would require detention. Using an estimate of eighteen inches of rainfall in a six-month period, the capacity of the detention ponds was determined to be 2,400 cubic yards and 3,600 cubic yards for the 80- and 160-cow operations, respectively.

The detention ponds are assumed to be emptied twice a year by means of a pump and irrigation system. Under the assumption that wastes are scraped from the lots daily, and given the composition of dairy cow manure, it is assumed that with minimal agitation all of the contents of the detention pond can be emptied by means of irrigation.

An SCS restriction allows a maximum irrigation load of two inches per acre at any one time. This restriction implies a land requirement of nine acres for the 80-cow herd and 13.5 acres for the 160-cow operation, for irrigation purposes, assuming that the pond is emptied in one pumping. It is assumed that cropland is available within pumping distance of the detention pond.

Economic Impact

The estimated investment requirements and annual costs associated with controlling runoff are presented in Table 21. The estimated investment outlays required

Table 21. Estimated investment requirements and annual costs of runoff control for two open lot housing systems.

Item	Size of Operation: 80 cows	Size of Operation: 160 cows
Investment Requirements		
Diversion[a]	$ 225.00	$ 275.00
Detention Pond[b]		
Excavation	1,800.00	2,700.00
Bottom Surfacing	200.00	350.00
Vegetation and Fencing	150.00	200.00
Irrigation Equipment[c]	1,500.00	2,000.00
Total Investment	$3,875.00	$5,525.00
Annual Capital Costs/Cow[d]		
Diversion	$ .25	$ .16
Detention Pond	2.43	1.90
Vegetation and Fencing	.17	.12
Irrigation Equipment	1.70	1.12
Annual Cash Costs/Cow		
Maintenance[e]	.50	.35
Irrigation[f]	3.40	2.50
Total Annual Costs/Cow[g]	$ 8.45	$ 6.15

[a]Source: Cost estimate of $.50/foot provided by Paul Koch of SCS.

[b]Source: Cost estimate of $.50-$1.00/cubic yard suggested by Paul Koch of SCS.

[c]Source: Cost suggested by Ray Hoglund, Professor of Agricultural Economics, Michigan State University.

[d]Annual costs of 10 percent of investment.

[e]Annual cost of one percent of investment.

[f]Cost of operating the irrigation pump.

[g]No additional costs are attributed to taking of land for detention facilities.

for construction of a diversion embankment are based on a per unit construction charge of fifty cents per linear foot of embankment. The combined per unit construction charge of the detention pond, freeboard, and spillway is estimated to be seventy-five cents per cubic yard of excavation. This cost can be altered substantially, depending upon the terrain of the excavation site and the amount of labor provided by the operator. The cost of excavation presented in Table 21 approaches the maximum that would be required. The cost for surfacing the bottom of the pond assumes approximately eighteen inches of clay will be required to seal the pond to prevent filling by groundwater. It is assumed that second-hand irrigation equipment, including pump, pipe and sprinkler heads, of adequate quality can be purchased.

The annual cost of controlling runoff includes a ten percent charge on investment, a maintenance charge of one percent of investment, and the cost of operating the irrigation system. In addition, labor requirements are increased by the necessity of setting up, moving, and disassembling the irrigation equipment. It is assumed that the detention pond will be emptied twice a year, once during April and May and once in October. Each emptying of the pond is estimated to require sixteen hours of labor for the 80-cow herd and thirty-two hours for the 160-cow herd.

Table 22 presents a comparison of investment requirements, costs of production, hired labor requirements and returns to the operator's labor before and after compliance with the runoff control policy. Compliance with the runoff control policy approximately doubles the investment requirements for waste handling facilities. At the same time, total investment is only increased by about one percent.

The annual costs of milk production are increased by only 1.6 percent and 1.2 percent for the 80- and 160-cow herds, respectively; but net returns are reduced by 5.7 percent and 4.3 percent, respectively. In essence, a runoff control policy will require the operator to make an increased investment in the milk production system ($3,875.00 and $5,525.00 for the 80- and 160-cow systems, respectively) but suffer a decrease in net returns on his total investment ($772.00 and $1,176.00 for the 80- and 160-cow systems, respectively). The reduction in returns is equivalent to $.075 per hundredweight of milk produced for the 80-cow herd and $.057 per hundredweight for the 160-cow herd.

Summary

Runoff control policies, primarily affecting beef feedlots, are in effect in certain states. In Michigan the Water Resources Commission has required

Table 22. Impact of runoff control on two open lot housing systems.

Item	Before Policy		After Policy		Difference		Percentage Difference	
	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows
				Dollars				
Total Investment	280,000.00	518,425.00	283,875.00	523,950.00	+3,875.00	+5,525.00	1.4	+ 1.1
Investment/Cow	3,500.00	3,240.16	3,548.45	3,274.69	+ 48.45	+ 34.53	+ 1.4	+ 1.1
Investment in Waste Handling Facilities	3,800.00	5,700.00	7,675.00	11,225.00	+3,875.00	+5,525.00	+102.0	+97.0
Investment in Waste Handling Facilities/Cow	47.50	35.63	95.95	70.16	+ 48.45	+ 34.53	102.0	97.0
Cost of Milk Production[a]	48,803.14	97,466.16	49,575.14	98,642.16	+ 772.00	+1,176.00	+ 1.6	+ 1.2
Cost of Milk Production/Cow	610.04	609.06	619.69	616.41	+ 9.65	+ 7.35	+ 1.6	+ 1.2
Net Returns to Operator	13,596.86	27,333.84	12,824.86	26,157.86	- 772.00	-1,176.00	- 5.7	- 4.3
Net Returns/Hour of Operator Labor	5.44	10.93	5.13	10.46	- .31	- .47	- 5.7	- 4.3
Net Returns/Cow	169.96	170.84	160.31	163.49	- 9.65	- 7.35	- 5.7	- 4.3
Hired Labor (Hours)	2,415.9	6,755.8	2,447.9	6,819.9	+ 32[b]	+ 64[c]	+ 1.3	+ .9

[a]Also includes feed production, hired labor and machinery ownership.

[b]An additional 8 hours in April and May and 16 hours in October.

[c]An additional 16 hours in April and May and 32 hours in October.

runoff detention in several instances as a means of reducing water pollution. It is not unrealistic to expect dairy producers with open lot housing systems to become subjected to similar controls, through authorized actions for existing legislation or through new legislation.

If this type of runoff control were to take the form of a state regulation imposing uniform requirements on all producers, some 2,500 Michigan Grade A milk producers could be affected. If runoff control is imposed through private litigation or as authorized by existing state legislation, via the Michigan Water Resources Commission, expectations are that substantially fewer than 2,500 firms would be affected.

For those firms which may be required to control runoff, the above analysis indicates that investments in waste handling facilities could double from the present level. In addition, returns to operators' labor may be expected to decrease by approximately five percent. Required investments range from approximately $4,000 to $5,500; however, annual returns to operators' labor are reduced by $800 to $1,200.

Impact of No Winter Disposal Policy

Two states have or are considering legislation which would prohibit the spreading of wastes during the winter months when the ground is frozen. Such considerations have arisen from the concern about waste runoff from the land disposal sites, namely croplands. As previously noted, the majority of Michigan milk producers currently employ waste handling systems which require daily waste hauling and spreading. For Michigan climatic conditions, this necessitates the spreading of wastes on frozen or snow-covered land during winter months. Wastes spread during these months are susceptible to runoff during the periodic thawing of the snow, and susceptible to flushing from frozen surfaces during winter rains. With the prevelance of waterways in many Michigan dairy areas, the potential of field runoff of wastes resulting in water pollution does exist.

The degree of water pollution arising from winter spread dairy wastes depends on the nature of the disposal area--the slope, vegetation, soil type, and nearness to waterways. Until measures of these variables for all Michigan dairies are taken, the extent of water pollution originating from winter spreading of dairy wastes will not be known. However, given Michigan's general climatic and topographical conditions, the problem is potentially serious and is being given research consideration.

Depending on the means of implementing a policy prohibiting winter spreading of dairy wastes, a large majority of Michigan dairy producers could be affected.

Presently, few producers, other than those utilizing a liquid waste system, have waste storage facilities. Those with liquid systems generally have storage capacities for only three months. A policy prohibiting waste spreading from October 15 to April 15 would require the construction of new facilities or the addition to existing facilities on most Michigan dairies to provide waste storage capacity for this six-month period.

A six-month storage period for dairy wastes alters the pattern of labor usage and changes milk production costs and returns. The magnitude of these changes are analyzed separately for those systems handling wastes as a solid, assuming no initial storage facilities; systems handling wastes as a liquid are also analyzed, assuming an initial storage facility with capacity for wastes produced in three months.

Impact on Solid Manure Systems

Facility Requirements

For the stanchion, open lot and cold covered housing systems, a policy of no winter spreading requires the construction of new storage facilities with six months' capacity. The storage facility used in conjunction with the stanchion and open lot system is expected to resemble a bunker silo with paved floors and walls, on three sides, constructed of concrete blocks, wooden planks, tilt-up concrete slabs or poured concrete. These systems require the use of a stacker to transport the wastes into the storage facility. The stacker is attached directly to the gutter cleaner when used with stanchion housing. In conjunction with the open lot system, the stacker is located adjacent to the storage facility and the wastes are scraped from the lot for loading.

The storage facility expected to be used with the cold covered housing system is substantially different from the facilities previously described. Typically, the storage facilities will consist of a roofed structure located at one end of the barn or somewhat removed from the barn if required by sanitation regulations. Wastes are scraped directly into storage from the concrete alleys.

In all cases, a front-end loader and spreader will be used to empty the storage facilities. Therefore, an existing stanchion housing system is required to purchase a front-end loader and scraper.

Economic Impact

The estimated investment requirements, changes in annual costs, and changes in labor requirements resulting from a policy prohibiting winter spreading of wastes are presented in Table 23 for systems handling wastes as a

Table 23. Estimated investment requirements and changes in annual costs and labor requirements per cow resulting from a no winter disposal policy--alternative housing systems and herd sizes.

Item	Stanchion Housing		Open Lot Housing		Cold Covered Housing	
Investment Requirements[a]	40 cows	60 cows	80 cows	160 cows	80 cows	160 cows
			Dollars			
Stacker	1,900.00	2,200.00	2,500.00	3,500.00	--	--
Storage	4,800.00	7,000.00	7,100.00	13,800.00	9,300.00	17,800.00
Scraper and Loader	1,800.00	1,800.00	--	--	--	--
Total Investments	8,500.00	11,000.00	9,600.00	17,300.00	9,300.00	17,800.00
Annual Capital Costs/Cow						
Stacker[b]	9.50	7.33	6.25	4.37	--	--
Storage[c]	12.00	11.67	8.88	8.62	11.63	11.13
Scraper and Loader[d]	6.75	4.50	--	--	--	--
Changes in Annual Cash Costs/Cow						
Tractor Power[a]	-.50	-.83	-1.06	-1.12	-1.50	-1.61
Utilities[a]	.38	.38	.38	.38	--	--
Maintenance	2.00	2.00	2.00	2.00	2.00	2.00
Net Change in Annual Costs/Cow[e]	30.13	25.05	16.45	14.25	12.13	11.52
			Hours			
Changes in Labor Requirements/Cow[a]						
January	-.4	-.4	-.4	-.4	-.4	-.4

February	-.4	-.4	-.4	-.4	-.4	-.4
March	-.4	-.4	-.4	-.4	-.4	-.4
April	.7	.6	.7	.6	.7	.6
May	.7	.6	.7	.6	.7	.6
June	-.4	-.4	-.4	-.4	-.4	-.4
July	-.4	-.4	-.4	-.4	-.4	-.4
August	-.4	-.4	-.4	-.4	-.4	-.4
September	-.4	-.4	-.4	-.4	-.4	-.4
October	1.4	1.2	1.4	1.2	1.4	1.2
November	-.4	-.4	-.4	-.4	-.4	-.4
December	-.4	-.4	-.4	-.4	-.4	-.4
Total	-.8	-1.2	-.8	-1.2	-.8	-1.2

[a]Source: Ray Hoglund, "Labor Requirements, Investments and Annual Costs--Alternative Manure Handling Systems," unpublished paper, Department of Agricultural Economics, Michigan State University.

[b]Assumes an annual charge of 20 percent of investment.

[c]Assumes an annual charge of 10 percent of investment.

[d]Assumes an annual charge of 15 percent of investment.

[e]Excludes hired labor costs.

solid. Substantial additional investment in waste handling facilities is required; ranging from $8,500 for the 40-cow stanchion system to $17,800 for the 160-cow cold covered system. Associated with these investment outlays are changes in the level of cash costs. The cost of hauling wastes, reflected in the charge for tractor power, is reduced because of the efficiency of hauling wastes twice annually rather than daily. However, utility costs are increased for the stanchion and open lot housing systems due to electrical requirements of the stacker.

Annual costs of milk production increase substantially for all systems when winter storage of dairy wastes is required. Excluding changes in labor costs, these increases range from $30.13 per cow for the 40-cow stanchion system to $11.52 for the 160-cow cold covered system. These increased costs are offset only slightly by reductions in labor requirements. The reduced labor requirements accrue because of increased labor efficiency due to hauling wastes only twice annually rather than daily. However, labor requirements are increased during April, May and October, the months in which the storage facilities are emptied.

To illustrate the overall impact of a policy prohibiting winter spreading of manure, Table 24 presents changes in investment requirements, annual costs, annual returns, and hired labor requirements, for firms complying

Table 24. Estimated changes in investments, costs, returns and hired labor resulting from a no winter disposal policy--alternative housing systems and herd sizes.

Item	Stanchion Housing				Open Lot Housing				Cold Covered Housing			
	40 cows		60 cows		80 cows		160 cows		80 cows		160 cows	
	Change	%	Change	%	Change	%	Change	%	Change	%	Change	%
	Dollars		Dollars		Dollars		Dollars		Dollars		Dollars	
Total Investment	8,500.00	5.	11,000.00	4.8	9,600.00	3.4	17,300.00	3.3	9,300.00	3.2	17,800.00	3.4
Investment/ Cow	212.25	5.	183.33	4.8	120.00	3.4	108.13	3.3	116.25	3.2	111.25	3.4
Investment in Manure Handling Facilities	8,500.00	212.25	11,000.00	185.65	9,600.00	252.6	17,300.00	303.5	9,300.00	193.8	17,800.00	312.3
Investment/ Cow in Manure Handling Facilities	212.25	212.25	183.33	185.65	120.00	252.6	108.13	303.5	116.25	193.8	111.25	312.3
Cost of Milk Production[a]	1,113.40	3.9	1,287.00	3.1	1,124.00	2.3	1,702.40	1.7	778.40	1.6	1,267.20	1.3
Cost of Milk Production/ Cow[a]	27.84	3.9	21.45	3.1	14.05	2.3	10.64	1.7	9.73	1.6	7.92	1.3
Net Returns to Operator	-1,113.40	-37.2	-1,287.00	-23.6	-1,124.00	-8.3	-1,702.40	-6.2	-778.40	-6.3	-1,267.20	-4.9
Net Returns/ Hour of Operator Labor	-.44	-37.2	-.51	-23.6	-.45	-8.3	-.68	-6.2	-.31	-6.3	-.51	-4.9
Net Returns/ Cow	-27.84	-37.2	-21.45	-23.6	-14.05	-8.3	-10.64	-6.2	-9.73	-6.3	-7.92	-4.9
Hired Labor (Hours)[b]	-30.6	-3.3	-72.	-3.1	-64.	-2.6	-192.	-2.8	-64.	-2.5	-192.	-2.8

[a]Also includes feed production, hired labor and machinery ownership.

[b]Increased hired labor requirements in April, May and October, decreased requirements for the remainder of the year.

with the policy. Investment requirements for the total dairy production process are only increased slightly (3.4-5 percent) through policy compliance. However, added investments are for waste handling facilities, representing increased investments in waste handling facilities of 185 percent to 212 percent.

Costs of milk production are increased by a low of 1.3 percent for the 160-cow cold covered systems and a high of 3.9 percent for the 40-cow stanchion systems. As a consequence, reductions in net returns range from 4.9 percent to 37.2 percent.

Summary

Analysis results presented in Table 24 indicate the differential impacts of a policy prohibiting winter waste disposal. Investment requirements are similar for open lot and cold covered housing systesm ($108-$120 per cow). However, due to greater ownership and operating costs associated with open lot facilities, net returns are reduced by approximately $350-$400 more than for the cold covered system. Net returns are reduced five to six percent for cold covered systems and six to eight percent for the open lot systems; returns are reduced proportionately greater for 80-cow herds.

Impacts on stanchion housing systems are substantially more severe than for open lot and cold covered systems. Investment requirements are increased by approximately $200 per cow. This investment, while increasing costs of production by 3-4 percent, induces a deduction in returns to operators' labor of 24 percent and 37 percent for the 60- and 40-cow herds, respectively. As a result, the 40-cow herd is estimated to return only $.77 per hour to the operator for his labor and management and $1.67 per hour to operators with 60 cows.

Assuming capital or credit is available to make the necessary investments, storing dairy wastes during the winter months increases milk production costs by only $.061-$.075 per hundredweight for cold covered housing systems and $.081-$.108 per hundredweight for the open lot systems. However, costs of milk production for stanchion housing are increased by $.165 per hundredweight for 60-cow herds and $.215 per hundredweight for 40-cow herds.

Impact on Liquid Manure Systems

Facility Requirements

For the warm enclosed housing system, a policy prohibiting winter disposal of wastes require the construction of additional storage facilities. For purposes of this study, two alternative methods of meeting this additional waste storage requirement are considered.

The first method supplements existing storage facilities with additional underground, liquid manure tanks. The second alternative requires construction of an outside storage pond. With this method, wastes would be pumped underground from existing storage facilities to the pond. For each alternative, facility requirements are assumed to be identical for the tractor-scraper, mechanical-scraper and slotted floor systems.

Further analysis of the tractor-scraper system is conducted to determine the impact of installing a mechanical scraper in conjunction with increasing waste storage capacity. As a result, four alternatives are analyzed for the tractor-scraper system: additional tank storage, retain tractor scraper; additional tank storage, install mechanical scraper; outside storage, retain tractor scraper; and outside storage, install mechanical scraper (Figure 15)

<u>Tractor-Scraper System</u>

1. Additional tank storage
   a. Retain tractor scraper
   b. Install mechanical scraper
2. Outside storate
   a. Retain tractor scraper
   b. Install mechanical scraper

<u>Mechanical-Scraper System</u>

1. Additional tank storage
2. Outside storage

<u>Slotted Floor System</u>

1. Additional tank storage
2. Outside storage

Figure 15. Alternative adjustments to required winter storage of wastes for warm enclosed housing systems.

Economic Impact

Investment requirements, cost changes, and changes in labor requirements for milk production for each storage alternative are presented in Table 25. Supplementary waste storage capacity with additional tank storage requires an investment of 3.0 to 3.5 times greater than associated with an outside storage pond. Even with higher operating costs, addition of outside storage systems is economically superior to adding more tank storage.

Adding a mechanical scraper to a tractor-scraper system increases investment requirements; however, operating and labor costs are sufficiently reduced to make mechanical scraping more economically desirable than tractor scraping. Given the assumptions concerning the cost of labor and the availability of capital which have been made in this study, savings in annual costs associated with the mechanical scraper almost offset the increased annual costs of additional storage associated with adding an outside storage pond.

Although outside storage is the more economical means for supplementing existing storage, physical considerations could preclude the use of storage ponds. Therefore, both tank and outside storage facilities are considered alternatives to the initial situation; these alternatives are compared with respect to investments,

Table 25. Estimated investment requirements and changes in annual costs and labor requirements per cow resulting from a no winter disposal policy for those systems handling wastes as a liquid.

Item	Additional Tank Storage[a]		Outside Storage[a]		Additional Tank Storage[b]		Outside Storage[b]	
	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows
	Dollars							
Investments[c]								
Storage	13,200.00	24,000.00	2,800.00	4,000.00	13,200.00	24,000.00	2,800.00	4,000.00
Underground Pump	--	--	2,000.00	3,000.00	--	--	2,000.00	4,000.00
Mechanical Scraper	--	--	--	--	2,000.00	3,500.00	2,000.00	3,500.00
Total Investment	13,200.00	24,000.00	4,800.00	7,000.00	15,200.00	27,500.00	6,800.00	11,500.00
Annual Capital Costs/Cow								
Storage[a]	16.50	15.00	5.25	3.75	16.50	15.00	5.25	3.75
Pump[e]	--	--	5.00	3.75	--	--	5.00	3.75
Mechanical Scraper[e]	--	--	--	--	5.00	4.38	5.00	4.38
Annual Cash Costs/Cow								
Tractor Power[c]	--	--	--	--	-4.25	-4.25	-4.25	-4.25
Utilities[c]	--	--	1.25	1.25	2.40	2.40	2.40	2.40
Maintenance	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Total Annual Costs/ Cow*	18.50	17.00	13.50	10.75	21.65	19.53	15.40	12.03
Change in Labor Requirements/Cow[f]								
January	0	-.4						
February	0	-.4						

March	-.5	-.8
April	+.4	+.2
May	+.4	+.2
June	-.5	-.8
July	0	-.4
August	0	-.4
September	-.5	-.8
October	+.8	+.4
November	0	-.4
December	-.5	-.8
Total	-.4	-4.0

*Excluding hired labor costs.

[a]For mechanical-scraper, slotted floor and tractor-scraper systems.

[b]For conversion of tractor scraper to mechanical scraper.

[c]Source: Ray Hoglund, "Labor Requirements, Investments and Annual Costs--Alternative Manure Handling Systems," unpublished data, Department of Agricultural Economics, Michigan State University.

[d]Assumes an annual charge of 10 percent of investment.

[e]Assumes an annual charge of 20 percent of investment.

[f]First figure is for all three systems and both herd sizes. Second figure is for conversion of tractor scraper to mechanical scraper, both herd sizes.

costs, returns, and hired labor requirements (Tables 26 and 27). Two additional alternatives are considered for the tractor-scraper system; one assumes retention of the tractor and scraper method of collecting wastes; the other assumes conversion to a mechanical scraper.

If underground tanks are used to provide additional storage, total investments are increased by four to five percent, as contrasted with one to two percent for outside storage. This represents an added investment per cow of $150 to $190 for tank storage and $43 to $85 for outside storage.

Additional storage increases costs of milk production by $5 to $6 more per cow than if supplementary storage capacity is provided by an outside storage pond. Costs of milk production are increased approximately 2.5 to 2.8 percent when tank storage is used as compared to 1.5 to 2.0 percent with outside storage. When the tractor-scraper system is converted to a mechanical-scraper system in conjunction with the outside storage pond, costs of milk production are increased by only $.03 per cow, for the 160-cow herd.

The impact on returns to the operator of storing manure during the winter is dependent upon herd size and storage alternatives selected. For 80-cow herds, net returns are reduced approximately 11 to 11.5 percent with the addition of tank storage as compared to 7.9 to 8.4

Table 26. Estimated changes in investments, costs, returns and hired labor resulting from supplementing existing storage facilities with additional tank storage--warm enclosed housing.

Item	80 Cows				160 Cows				80 Cows		160 Cows	
	Change	%[a]	%[b]	%[c]	Change	%[a]	%[b]	%[c]	Change	%[d]	Change	%[d]
	Dollars				Dollars				Dollars		Dollars	
Total Investment	13,200.00	4.3	4.3	4.2	24,000.00	4.3	4.3	4.2	15,200.00	5.0	27,500.00	4.9
Investment/Cow	165.00	4.3	4.3	4.2	150.00	4.3	4.3	4.2	190.00	5.0	171.90	4.9
Investment in Manure Handling Facilities	13,200.00	80.0	71.4	80.0	24,000.00	89.6	79.2	89.6	15,200.00	92.1	27,500.00	102.6
Investment/Cow in Manure Handling Facilities	165.00	80.0	71.4	80.0	150.00	89.6	79.2	89.6	190.00	92.1	171.90	102.6
Cost of Milk Production	1,384.00	2.7	2.8	2.8	2,528.00	2.5	2.6	2.6	772.00	1.5	1,204.50	1.2
Cost of Milk Production/ Cow	17.30	2.7	2.8	2.8	15.80	2.5	2.6	2.6	9.65	1.5	7.53	1.2
Net Returns to Operator	-1,384.00	-11.6	-11.1	-11.1	-2,528.00	-10.1	-9.6	-9.6	-772.00	-6.5	-1,204.50	-4.8
Net Returns/Hour of Operator Labor	-.55	-11.6	-11.0	-11.4	-1.01	-10.1	-9.5	-9.6	-.31	-6.6	-.48	-4.8
Net Returns/Cow	-17.30	-11.6	-11.0	-11.1	-15.80	-10.1	-9.5	-9.6	-9.65	-6.6	-7.58	-4.8
Hired Labor (Hours)	-32.	-1.5	-1.7	-1.7	-64.	-1.0	-1.0	-1.1	-320.	-14.5	-640.	-10.1

[a]Tractor-scraper system, retaining tractor scraper.

[b]Mechanical-scraper system.

[c]Slotted floor system.

[d]Conversion of tractor scraper to mechanical scraper.

Table 27. Estimated changes in investments, costs, returns, and hired labor resulting from supplementing existing storage facilities with outside storage--warm enclosed housing.

Item	80 Cows				160 Cows				80 Cows		160 Cows	
	Change	%[a]	%[b]	%[c]	Change	%[a]	%[b]	%[c]	Change	%[d]	Change	%[e]
	Dollars				Dollars				Dollars		Dollars	
Total Investment	4,800.00	1.6	1.6	1.5	7,000.00	1.3	1.2	1.2	6,800.00	2.2	10,500.00	1.9
Investment/Cow	60.00	1.6	1.6	1.5	43.75	1.3	1.2	1.2	85.00	2.2	65.63	1.9
Investment in Manure Handling Facilities	4,800.00	29.1	25.9	29.1	7,000.00	26.1	23.1	26.1	6,800.00	41.2	10,500.00	39.2
Investment/Cow in Manure Handling Facilities	60.00	29.1	25.9	29.1	43.75	26.1	23.1	26.1	85.00	41.2	65.63	39.2
Cost of Milk Production	984.00	1.9	2.0	2.0	1,528.00	1.5	1.5	1.5	272.00	.5	4.80	--
Cost of Milk Production/ Cow	12.30	1.9	2.0	2.0	9.55	1.5	1.5	1.5	3.40	.5	.03	--
Net Returns to Operator	-984.00	-8.4	-7.9	-7.9	-1,528.00	-6.1	-5.8	-5.8	-272.00	-2.3	-4.80	-.02
Net Returns/Hour of Operator Labor	-.39	-8.3	-7.8	-7.9	-.61	-6.1	-5.8	-5.8	-.11	-2.3	-.002	-.02
Net Returns/Cow	-12.30	-8.3	-7.8	-7.9	-9.55	-6.1	-5.8	-5.8	-3.40	-2.3	-.03	-.02
Hired Labor (Hours)	-32.	-1.5	-1.7	-1.7	-64.	-1.0	-1.1	-1.1	-320.	-14.5	-640.	-10.1

[a]Tractor-scraper system, retaining tractor scraper.

[b]Mechanical-scraper system.

[c]Slotted floor system.

[d]Conversion of tractor scraper to mechanical scraper.

percent with outside storage. The reductions are approximately ten and six percent, respectively, for the 160-cow herds. Although the absolute reduction in net returns is identical for all systems, the tractor-scraper system has the largest percentage decrease in net returns.

If the tractor-scraper system is converted to a mechanically scraped system, however, the decrease in net returns is not as severe. Specifically, net returns are reduced by 2.3 percent for the 80-cow herd and by .02 percent for the 160-cow herd if the outside storage alternative is selected.

Under the assumption that each cow produces 13,000 pounds of milk annually, the impact of storing manure for the winter months can be expressed in terms of increased cost per hundredweight of milk produced. If supplementary storage capacity is in the form of underground tank storage, milk production costs are increased by \$.13 per hundredweight for the 80-cow herd and \$.12 per hundredweight for the 160-cow herd. With the outside storage alternative, these costs are \$.095 per hundredweight and \$.073 per hundredweight for the 80- and 160-cow herds, respectively. Converting the tractor-scraper system to a mechanically scraped system in conjunction with additional tank storage increases milk production costs by only \$.074 per hundredweight of milk produced for the 80-cow herd and \$.058 per hundredweight for the 160-cow herd. With the outside storage option, costs are increased by $.026 per hundredweight for the 80-cow herd, but remain approximately unchanged for the 160-cow herd.

Impact of Subsurface Disposal Policy

As previously cited, the Air Pollution Control Division of the Michigan Department of Public Health has received complaints of odors associated with the disposal of livestock wastes. It is expected that if prohibition on winter spreading became a reality, the odor associated with waste disposal will increase. The increased odor may be attributed to two factors: (1) the increased quantity of wastes being spread at one time and (2) the partial anaerobic decomposition of the wastes during storage. Furthermore, as previously indicated, it is not uncommon for farm and nonfarm residences to be located within one-half mile of fields used for waste disposal. If the trend of increasing numbers of nonfarm, rural residents continues, the problem of air pollution attributed to livestock wastes could become acute.

One method of reducing the odors associated with land disposal of wastes is subsurface disposal. Although subsurface disposal does not control odors as wastes are taken from storage, this method appears adequate for controlling odors during field disposal.

Facility Requirements

For subsurface waste disposal to effectively control manure odors at the disposal site, winter storage facilities are necessary, the impacts of which are discussed in the previous section. In addition, a soil injector must be added to systems handling dairy wastes as a liquid.

The type of injector analyzed is one which can be readily attached to existing liquid manure spreaders. The injector consists of "knives" mounted on the rear of the spreader. The "knives" are drawn through the soil and serve as the line to contain the flow of slurry from the tank to the soil. The injector is pivot mounted so that it can be raised during transport to and from the disposal site.

For those systems handling manure as a solid, subsurface disposal implies immediate plow-down of wastes at time of spreading. This analysis assumes wastes are spread and plowed down twice annually, once in April and May before corn planting and once in October following the corn silage harvest.

Economic Impact

Although subsurface disposal of solid wastes may require a change of timing in the plowing operation, costs of production are not expected to increase. It is assumed that land in corn production must be plowed, either in the fall or spring, regardless of waste disposal activities. It is further assumed that the cost of plowing is the same in the fall of the year as in the spring. The impact of plowing down manure as it is spread is, at most, to require fall plowing that may have been delayed until spring. Therefore, it is assumed that subsurface disposal of manure will have no direct impact on the cost of production for those systems handling manure as a solid.[3]

Subsurface disposal of liquid manure, however, requires an investment in a soil injector, resulting in an increase in annual costs of production (Table 28). Subsurface disposal requires an investment of $700 and increases labor requirements[4] by eight hours for an 80-cow herd and by 14 hours for a 160-cow herd. As a result, annual costs of milk production are increased by $208 and $288.80 for the 80- and 160-cow herds, respectively. This represents an increase in costs of less than one percent and a reduction in net returns of less than two percent. The cost of milk production is increased by $.02 per hundredweight of milk produced for the 80-cow herd and $.014 per hundred weight for the 160-cow herd.

Table 28. Estimated investment requirements and changes in annual costs and labor requirements per cow resulting from subsurface disposal of manure--two herd sizes.

Item	80 Cows	160 Cows
	Dollars	
Investment		
Soil Injector[a]	700.00	700.00
Annual Capital Costs/Cow		
Soil Injector[b]	1.75	.88
Annual Cash Costs/Cow		
Tractor Power[a]	.55	.60
Total Annual Costs/Cow*	2.30	1.48
Changes in Labor Requirements		
January	0	0
February	0	0
March	0	0
April	2	3.5
May	2	3.5
June	0	0
July	0	0
August	0	0
September	0	0
October	4	7
November	0	0
December	0	0
Total	8	14

*F :luding hired labor costs.

[a]Source: Ray Hoglund, "Labor Requirements, Investments and Annual Costs--Alternative Manure Handling Systems," unpublished data, Department of Agricultural Economics, Michigan State University.

[b]Assumes an annual cost of 20 percent of investment.

Impact of Three Pollution Abatement Policies

The above analysis has considered, separately, the impact of three alternative pollution abatement policies. Those production systems affected by each policy are identified; the physical requirements of compliance are described; the economic impacts on the synthetic firms are examined. This section examines the combined economic impact of the three policies.

The pollution abatement policies, as previously outlined, would require: (1) all dairy producers to have a minimum of six months' waste storage capacity; (2) the open lot systems to provide facilities to collect runoff from the production site; and (3) subsurface disposal of all dairy wastes. The combined impact of these three policies on investments, annual costs and returns, and monthly labor requirements for twelve synthetic firms is presented in Table 29. For the warm enclosed housing systems, the impact of two alternative methods of supplementing existing storage capacity are presented.

Additional investment requirements resulting from pollution abatement controls are least for the warm enclosed housing systems using outside manure storage ($5,500 for the 80-cow herd and $7,700 for the 160-cow herd); additional investments required are highest for warm enclosed housing systems using additional tank

Table 29. Estimated impact of three pollution abatement policies--alternative housing systems, waste handling systems and herd sizes.

Item	Stanchion Housing		Open Lot Housing		Cold Covered Housing	
	40 cows	60 cows	80 cows	160 cows	80 cows	160 cows
			Dollars			
Investment	8,500.00	11,000.00	13,475.00	22,825.00	9,300.00	17,800.00
Percentage Increase in investments	5.0	4.8	4.8	4.4	3.2	3.4
Total Annual Costs	1,113.40	1,287.00	1,896.00	2,880.00	778.40	1,267.20
Percent Increase in Annual Costs	4.0	3.1	3.9	3.0	1.6	1.3
Cost/Cwt. of Milk Produced	.214	.165	.183	.138	.075	.061
Return/Hour of Operators' Labor	-.445	-.515	-.758	-1.15	-.311	-.507
Percent Decrease in Returns to Operators' Labor	36.8	28.6	13.9	10.5	6.3	4.9
			Hours			
Hired Labor						
January	-15.3	-24.0	-32.0	-64.0	-32.0	-64.0
February	-16.0	-24.0	-32.0	-64.0	-32.0	-64.0
March	-16.0	-24.0	-32.0	-64.0	-32.0	-64.0
April	+28.0	+36.0	+60.0	+104.0	+56.0	+96.0
May	+28.0	+36.0	+60.0	+104.0	+56.0	+96.0
June	-16.0	-24.0	-32.0	-64.0	-32.0	-64.0
July	-16.0	-24.0	-32.0	-64.0	-32.0	-64.0
August	-16.0	-24.0	-32.0	-64.0	-32.0	-64.0
September	-16.0	-24.0	-32.0	-64.0	-32.0	-64.0
October	+56.0	+72.0	+120.0	+208.0	+112.0	+192.0
November	-16.0	-24.0	-32.0	-64.0	-32.0	-64.0
December	-15.3	-24.0	-32.0	-64.0	-32.0	-64.0
Total	-30.6	-72.0	-48.0	-160.0	-64.0	-192.0

[a]First figure applicable to outside storage. Second figure applicable to tank storage.

Warm Enclosed Housing					
Tractor Scraper		Mechanical Scraper		Slotted Floors	
80 cows[a]	160 cows[a]	80 cows[a]	160 cows[a]	80 cows[a]	160 cows[a]
Dollars					
5,500., 13,900.	7,700., 24,700.	5,500., 13,900.	7,700., 24,700.	5,500., 13,900.	7,700., 24,700.
1.8, 4.5	1.4, 4.4	1.8, 4.5	1.4, 4.4	1.8,4.5	1.3,4.3
1,192., 1,592.	1,816.00, 2,876.00	1,192., 1,592.	1,816.00 2,876.00	1,192., 1,592.	1,816.00, 2,876.00
2.3, 3.0	1.7, 2.7	2.3, 3.1	1.8, 2.8	2.3, 3.1	1.7, 2.8
.115, .153	.087, .134	.115, .153	.087, .134	.115, .153	.087, .134
-.46, -.62	-.69, -1.09	-.46, -.62	-.69, -1.09	-.46, -.62	-.69, -1.09
9.8, 13.2	6.9, 10.9	9.2, 12.4	6.5, 10.3	9.3, 12.5	6.6, 10.4
Hours					
0	0	0	0	0	0
0	0	0	0	0	0
-40	--80	-40	-80	-40	-80
+32	+64	+32	+64	+32	+64
+32	+64	+32	+64	+32	+64
-40	-80	-40	-80	-40	-80
0	0	0	0	0	0
0	0	0	0	0	0
-40	-80	-40	-80	-40	-80
+64	+128	+64	+128	+64	+128
0	0	0	0	0	0
-40	-80	-40	-80	-40	-80
-32	-64	-32	-64	-32	-64

storage ($13,900 for the 80-cow herd and $24,700 for the 160-cow herd) and the open lot housing system ($13,475 and $22,825 for the 80- and 160-cow herds, respectively). In percentage terms, the stanchion housing and 80-cow, open lot systems incur the largest investment increases.

Increases in total annual costs range from $778.40 for an 80-cow cold covered system to $2,880 for a 160-cow open lot system. Percentagewise, annual costs are increased the least for cold covered housing systems and warm enclosed housing systems using the outside storage alternative. The greatest percentage increases in costs are incurred by the 40-cow stanchion and 80-cow open lot systems.

Annual costs per hundredweight of milk produced resulting from pollution abatement range from $.061 for a 160-cow cold covered system to $.215 for the 40-cow stanchion housing system.[5] Returns per hour of operators' labor are reduced only $.31 for the 80-cow cold covered system as a result of compliance with the pollution abatement policies.[6] However, compliance for the 160-cow open lot system results in a reduction of $1.15 per hour of operator's labor.

A reduction of only $.44 per hour for the operator of a 40-cow stanchion system represents a 36.8 percentage decrease in hourly returns. Again, the cold covered housing system has the smallest percentage decrease in returns to operator's labor.

Hired labor requirements are increased for all production systems during the months of April, May, and October--the months in which waste storage facilities are emptied. Requirements are diminished or remain constant for the remainder of the months, resulting in a net decrease in total hired labor requirements for all production systems.

Relationship to Economic Theory

This empirical analysis of alternative pollution abatement policies requires a relatively rigid set of assumptions concerning the input-output relationships of milk production, the prices of inputs and outputs, and the type of production facilities used by Michigan dairy farmers. However, the synthetic firms which are developed approximate actual production conditions for a large number of Michigan milk producers. Those methods of compliance with pollution abatement policies, as described in this chapter, are methods which would be required for those firms which are actually contributing to air and/or water pollution from open lot runoff, winter disposal of wastes, and/or surface disposal of dairy waste.

This empirical analysis gives some insight into the discussion of the theoretical impact of pollution abatement (Chapter III) on the economic cost structure of the firm. Specifically, some empirical evidence is provided as a basis for answering the questions of: Which cost functions will change? In what direction will these functions move? What is the effect of pollution abatement on returns? Will the firm comply with pollution abatement policies? Although, the assumptions of the empirical analysis are somewnat restrictive, as herd size, and, therefore, milk production, are not allowed to change in order to avoid compliance or as a result of compliance, the following observations can be made.

At the time the decision is made to comply or not to comply with a pollution abatement policy, the cost of investing in additional waste handling facilities is a variable cost. However, if the decision is made to comply with the policy and the investment is made, this cost becomes a "fixed" cost. That is, once an investment is made, the cost of that investment does not change with the level of milk production.[7] Viewed in this manner, compliance with those policies discussed in this chapter imply an increase in "fixed" costs for all firms analyzed.

Each of the three policies analyzed has an impact on the variable costs of production. The control of run-off from open lot systems requires an increase in variable costs in the form of hired labor and the operation and maintenance of the irrigation system. These costs are regarded as "variable" in the sense that the magnitude of these costs are a function of the level of milk production (i.e., number of cows). In contrast to investment costs, these costs can be eliminated by discontinuing milk production.

A policy requiring winter storage of dairy wastes increases some variable costs of production (maintenance, utilities) and decreases others (tractor power, labor). For those systems handling dairy wastes as a solid, total variable costs are <u>reduced</u>, at the same level of output. For those systems handling manure as a liquid, total variable costs are <u>increased</u>, at the same level of output. In both instances, however, total costs of production are increased. (That is, for systems handling wastes in solid form, the magnitude of the decrease in variable costs is less than the magnitude of increase in fixed costs. For systems handling wastes as a solid, both fixed and variable components increase; therefore, total costs are increased.)

For those systems handling waste as a liquid, compliance with a policy of subsurface disposal increases both "fixed" costs, as defined above, and variable costs of production. Compliance for those systems handling manure as a solid resulted in no change in the costs of production, under the assumptions of the analysis. (This theoretical case is not discussed in Chapter III.)

The overall impact of compliance with the pollution abatement policies is to increase the total costs of milk production, and reduce the level of returns for all firms at original levels of output. However, two other important observations can be made. One observation provides more insight into question of whether or not a firm will discontinue production rather than comply with a pollution abatement policy. The other observation concerns the question of reorganizing the production process to some degree as a result of pollution abatement policies.

It will be recalled, from Chapter III, that economic theory indicates that some "fixed" factors of production will be withdrawn from production if they have a higher earning value in other activities (i.e., MVP becomes less than salvage value). In the case of the stanchion housing system, the returns to operators' labor (a "fixed" input) is reduced substantially; to $.77 per hour for the 40-cow herd and $1.67 per hour for the 60-cow herd. Although returns to operators' labor were relatively low for these systems before compliance, the reduced returns may be incentive enough for these systems to discontinue milk production rather than comply with pollution abatement policies.

The last observation to be made concerns the analysis of the impact of conversion of the tractor-scraper system to a mechanical-scraper system. Under the assumptions of this study, the increased cost associated with the mechanical scraper and additional waste storage in the form of an outside pond, are almost offset by reduced labor costs. As a result, returns to operator's labor are decreased very little. Obviously, the conversion from a tractor-scraper method of collecting wastes to a mechanical scraper is profitable in the absence of any pollution abatement policies. However, the increased cost of pollution abatement provides an additional incentive to make the investment in the mechanical scraper. A relatively small investment which may not have been made in order to increase returns, may be made in order to offset, or at least reduce, the amount by which returns are decreased, due to compliance with legal pollution abatement controls.

Summary and Conclusions

In this chapter, the impact of three pollution abatement objectives is analyzed for twelve synthetic firms. These firms represent alternative milk production technologies and herd sizes. The objectives examined are designed to reduce (1) water pollution from waste runoff at the production site, (2) water pollution from runoff at the disposal site, and (3) air pollution, in the form of disagreeable odors, at the disposal site.

Achievement of these three objectives increases the investment requirements for all production systems. Additional investment requirements vary by production technology presently being used, by herd size and by waste storage alternatives selected. A 160-cow, warm enclosed housing system, selecting additional tank storage, requires $24,700 additional investment. An 80-cow, warm enclosed housing system, using the outside storage alternative, requires only $5,500 additional investment. Percentagewise, the stanchion and the 80-cow, open lot systems require the largest additional investments.

Achievement of the pollution abatement objectives increase costs of milk production by $.215 per hundredweight of milk produced for a 40-cow, stanchion housing system and by $.061 per hundredweight for a 160-cow, cold covered housing system. "Fixed" costs are increased for all production systems. Variable costs of production are actually decreased for the stanchion and cold covered housing systems.

Open lot systems designed for 160-cows incur the largest decrease in returns per hour of operator's labor; $1.15. However, compliance with the policies only reduces returns to operator's labor by $.31 per hour for 80-cow cold covered systems. Returns are reduced sufficiently for the 40-cow stanchion housing system to raise doubts as to whether or not these systems would discontinue production rather than comply with the pollution abatement policies.

Because of the increased efficiency of disposing of manure only twice annually, hired labor requirements are reduced for all production systems.

Chapter VII Footnotes

[1]Assumptions are based on a personal interview with Mr. Paul Koch of the Soil Conservation Service, East Lansing, Michigan.

[2]Source: Philip Christensen, "Soil Conservation Assistance in Animal Waste Management," paper prepared for The Livestock Waste Management Conference, March 1-2, 1972, Champaign, Illinois. Soil Conservation Service, "Farm Waste Disposal System," Michigan Engineering Standard, Technical Guide, Section IV-G.

[3]Costs of production may be indirectly affected in terms of differing opportunity costs of labor at different times of the year and differing yields and management practices associated with fall and spring plowed land. This possibility is recognized but not treated in this study.

[4]Spreading operation is slower with a soil injector than without.

[5]Based on the assumption of 13,000 pounds of milk produced per cow.

[6]Assumes 2,500 hours of operator labor per year.

[7]Furthermore, these inputs (detention ponds, diversion embankments, storage facilities, irrigation equipment and soil injectors) are "fixed" according to the definition used in Chapter III. Once these inputs are purchased and pollution is abated, it isn't profitable to buy more of them and conversely as long as price and production relationships remain the same as at the time the decision was made, there is no economic incentive to sell these inputs or to divert them to other uses.

CHAPTER VIII

CONCLUSIONS

Summary of Analytical Models

The purpose of this study was to determine the economic impact of potential pollution abatement policies on the Michigan dairy farming industry. Specifically, the objectives of the study were:

1. To determine the present and potential legal restraints within which Michigan dairy farmers must function in the management of animal wastes.
2. To identify those Michigan dairy operations which are potentially most affected by legal environmental quality controls.
3. To evaluate the effects upon representative dairy farms of adjusting existing dairy waste management systems for compliance with applicable environmental quality controls.

Pollution Control Constraints

Two criteria were used in identifying potential environmental quality controls on Michigan dairy farms.

These criteria were: (1) actual or potential livestock waste management problems on Michigan dairy farms which may result in environmental pollution; and (2) the present and/or proposed legal constraints on livestock waste management in Michigan and in other states.

The legal constraints examined were: actual or proposed legal statutes in Michigan and other states, selected cases of private litigation involving livestock waste management problems, and actions taken by the Michigan Water Resources Commission and the Air Pollution Control Division of the Michigan Department of Health in correcting individual pollution problems on Michigan livestock farms.

Based on these two criteria, three hypothetical control measures specific to Michigan livestock producers were identified for analysis. These measures included:

1. Mandatory control of runoff from open lots.
2. Prohibition of winter spreading of dairy wastes, and
3. Subsurface disposal of dairy wastes.

Theoretical Considerations

To develop a theoretical basis for analyzing these three pollution abatement measures, the economic impacts of pollution abatement on the firm cost structure were deduced from the economic theory of the firm with explicit emphasis given to the consequences of asset fixity. Economic impacts were deduced relative to productive input usage, product output levels, and returns to fixed factors of production.

Synthetic Firm Analysis

Empirical analysis of the hypothetical pollution control measures was facilitated by developing synthesized dairy firms, considering an array of specified production technologies and dairy herd size combinations. Linear programming techniques were employed to determine returns to fixed factors and amount of hired labor required for each synthetic firm, before implementation of pollution abatement policies. Investment requirements were identified for each firm. The coefficients of the linear programming tableau were then adjusted to reflect compliance with the pollution abatement policies to determine the impact of compliance on each of the synthetic firms. Specifically, effects of compliance on milk production costs, hired labor requirements, investment requirements and returns to operator's labor and management were determined.

Industry Effects

Aggregate estimates were derived from the synthetic firm analysis (Appendix B). Estimates of the economic impact of compliance with the three pollution abatement policies were made. Considered were aggregate total investment requirements of all Michigan Grade A dairy farmers necessary for pollution policy compliance and the resulting effects on the average cost of Grade A milk production in Michigan.

Empirical Findings

Limitations of Analytical Procedures

Recognition of the following limitations of this study is required for proper interpretation of the empirical findings:

1. Synthetic firms were not developed to represent all Michigan milk producing firms. Only twelve synthetic firms were developed to represent the more prevelant production technology--herd size combinations currently in existence in Michigan. The results of the synthetic firm analysis were assumed to be applicable to those production technology--herd size combinations not explicitly included in the analysis.
2. Synthetic firms constructed for empirical analysis were designed to be "typical" and,

therefore, do not reflect all variations in actual production situations.

3. Assumptions concerning the availability of capital and labor may be unrealistic for some Michigan milk producers. It was assumed that capital or credit was available in quantities sufficient to make the investments required for policy compliance. As indicated in Chapter IV, this may not be true for all producers. It was further assumed that the "fixed" labor component for each of the synthetic firms consisted of one operator; additional labor was assumed hired on an hourly basis as required. For some milk producers, additional family labor or full-time hired labor is available. This labor may be considered as part of the fixed component, reducing the amount of hourly hired labor requirements.

4. The empirical analysis of pollution abatement policies assumed that herd size and housing technology remain unchanged upon compliance. This type of analysis indicated the impact of policy compliance on milk production costs and returns within the present set of fixed assets of the firm. As a result, some indication was given of the differentiable impact

of policy compliance on alternative production technology--herd size combinations, and the combinations which were more severely disadvantaged were identified. However, this type of analysis does not identify those firms that will or will not comply with pollution abatement policies or does it identify to what extent, if any, production technologies or herd sizes will be altered in response to these policies.

Major Findings

Under the assumptions specified, the empirical analysis of synthetic firms yielded the following major findings:

1. Runoff control from production facilities (applicable only to open lot housing systems) had the following economic effects:
    a. Investment economies accrued to larger herd sizes; that is, $48.45 additional investments per cow were required for 80-cow herds and $34.50 were required for 160-cow herds.
    b. Slight increases in hired labor were required for both herd sizes.

c. Total costs of milk production were increased by \$.057 per hundredweight of milk produced for the 160-cow herd and by \$.075 per hundredweight for the 80-cow herd.

d. Returns to operator's labor were reduced by \$.31 per hour for 80-cow herds and by \$.47 per hour for the 160-cow herd.

2. A control policy requiring six months' storage capacity had the following economic effects on systems handling wastes as a solid:

   a. Additional investment requirements, per cow, by housing type and herd size were: stanchion housing--\$212 for 40-cow herds and \$185 for 60-cow herds; open lot housing--\$120 for 80-cow herds and \$108 for 160-cow herds; cold covered housing--\$116 for 80-cow herds and \$111 for 160-cow herds.

   b. Hired labor requirements were reduced by approximately three percent for all three housing types.

   c. Increased milk production cost, per hundredweight of milk by housing type and herd size were: stanchion housing--\$.214 for 40-cow herds and \$.165 for 60-cow herds;

lot housing--$.108 for 80-cow herds and $.081 for 160-cow herds; cold covered housing--$.075 for 80-cow herds and $.061 for 160-cow herds.

d. Reductions in returns to operators' labor, per hour, by type of housing and herd size were: stanchion housing--$.44 for 40-cow herds and $.51 for 60-cow herds; open lot housing--$.45 for 80-cow herds and $.68 for 160-cow herds; cold covered housing--$.31 for 80-cow herds and $.51 for 160 cow herds.

3. Compliance with a control policy requiring six months' storage capacity for dairy wastes had the following economic effects on systems handling wastes as a liquid:

   a. Additional investment requirements, per cow, by type of storage facility and herd size were: additional tank storage--$165 for 80-cow herds and $150 for 160-cow herds; outside storage--$60 for 80-cow herds and $43.75 for 160-cow herds.

   b. Hired labor requirements were reduced by one to two percent.

   c. Increased milk production costs, per hundredweight of milk produced, by storage facility and herd size were: additional tank storage--$.13 for 80-cow herd and $.12 for 160-cow herd; outside storage--$.095 for 80-cow herds and $.073 for 160-cow herds.

d. Reductions in returns to operator's labor, per hour, by type of storage facility and herd size were: additional tank storage--$.55 for 80-cow herds and $1.01 for 160-cow herds; outside storage--$.39 for 80-cow herds and $.61 for 160-cow herds.

4. Compliance with a policy requiring subsurface disposal of dairy wastes had the following economic effect:

   a. No economic impact on those firms handling wastes as a solid.

   b. Additional investments of $700 per <u>firm</u> for firms handling wastes as a liquid.

   c. Very slight increases in hired labor requirements for firms handling wastes as a liquid.

   d. Increased milk production costs of $.02 per hundredweight for 80-cow herds and $.014 per hundredweight for 160-cow herds handling wastes as a liquid.

e. Reduction in returns to operators labor of $.08 per hour for 80-cow herds and $.12 per hour for 160-cow herds handling wastes as a liquid.

5. If the three pollution abatement policies are implemented as <u>state regulations</u> (Appendix B), the resulting aggregate economic impacts were:

a. Michigan Grade A dairy farmers would be required to invest $65.5 million in additional waste handling facilities if all Grade A producers remained in production and $48.5 million if all Grade A producers with less than 30 cows ceased production and those with 30 or more cows remained in production at the current size.

b. Total labor requirements on Michigan Grade A dairy farms would be reduced by 270,000 hours annually if all producers remained in production and by 220,000 hours on those farms with thirty or more cows.

c. The total cost of Grade A milk production would be increased by .175 per hundredweight of milk produced if all producers remained in production and by $.166 per hundredweight if those firms with less than thirty cows ceased production.

d. Total Grade A milk supply would be reduced by approximately twenty percent if all Grade A firms with less than thirty cows ceased production and the remaining firms did not change herd size.

Implications

The theoretical economic impacts deduced from firm theory and the empirical measures of these impacts have implications for dairymen, policymakers and other researchers.

Dairymen

The effects of compliance with the three pollution abatement policies analyzed in this study have several implications for Michigan dairymen:

1. Policy compliance requires additional investment in dairy waste handling facilities. The magnitude of these investment requirements vary according to production technology. The warm enclosed housing systems utilizing outside storage facilities have the lowest additional investment requirements per cow. The cold covered housing system has the second

lowest investment requirement followed by the open lot housing system and the warm enclosed systems utilizing additional tank storage. The stanchion housing systems require the largest additional investment per cow.

2. Investment economies accrue to larger herd sizes. The magnitude of these economies varies by production technology: stanchion housing--investments per cow are thirteen percent lower for the 60-cow herd than for the 40-cow herd; open lot housing--investments per cow are fifteen percent lower for the 160-cow herd than for the 80-cow herd; cold covered housing--investments per cow are four percent lower for the 160-cow herd than for the 80-cow herd; warm enclosed housing--investments per cow are thirty percent lower for the 160-cow herd than for the 80-cow herd with the outside storage option and eleven percent lower with the tank storage option.

3. Policy compliance increases total milk production costs, at the present level of output, for all production technology-herd size combinations. Variable costs of production are reduced only for the stanchion and cold

covered housing systems. Total milk production costs are increased the least for the cold covered housing systems, and the most for the stanchion housing systems and the 80-cow open lot systems.

4. Policy compliance reduces returns to operator's labor by only five percent for 160-cow cold covered housing systems, but reduces returns to operator's labor by thirty-seven percent for 40-cow stanchion housing systems. This implies that operators of smaller dairy herds, especially those with stanchion housing systems, may be economically disadvantaged by pollution abatement policies to the extent that they will discontinue milk production.

5. In order to minimize the investment requirements and production costs associated with pollution abatement, Michigan dairymen planning to expand or construct new dairy facilities should consider:

    a. Covered housing systems as a means of minimizing runoff from the production site.

    b. Liquid manure systems utilizing an outside storage pond.

    c. Waste storage facilities with six months' capacity; investment requirements are higher when existing facilities must be modified than if six months' capacity is provided initially.

d. Labor saving devices, such as mechanical scrapers.

6. All dairymen should be aware of the pollution potential of animal wastes and follow those waste management practices which minimize potential environmental problems and/or pollution control measures. Producers planning to enlarge the size of their operations or planning to develop new operations are, in some instances, required to check with the Water Resources and Air Pollution Control Commissions. Dairymen should also be aware that federal funds are available, through the Agricultural Stabilization and Conservation Service, to offset some of the investment requirements for approved waste handling facilities.

Policymakers

1. Policymakers should be aware that pollution control policies require substantial investments by milk producers and increase total milk production costs. Furthermore, some

producers may find that milk production costs are increased sufficiently to force them to discontinue milk production.

2. Information on the economic impact of pollution abatement policies, of the nature presented in this study, should be combined with information on the social benefit of abatement of environmental pollution from dairy wastes to fully evaluate the policies. That is, the incremental social benefit associated with pollution abatement should be greater or equal the incremental cost of abating pollution.

3. Policymakers should be aware of the differentiable impacts and tradeoffs associated with alternative methods of implementing pollution abatement policies. As indicated by personnel of the Michigan Water Resources Commission, regulations requiring a given set of pollution abatement facilities for all milk producers are easier and less costly to administer than directives which establish and provide for enforcement of environmental quality standards. However, economic analysis indicates that the costs of livestock production attributable to abatement facilities and practices are

minimized when the operator is allowed to choose that abatement facility which most efficiently uses his existing resources. These types of tradeoffs, between costs of administration and enforcement and costs of abatement, should be considered in evaluating pollution abatement policies.

Further Research

Subsequent research to more fully identify the economic impacts of pollution control policies on the structure of the Michigan dairy farming industry is needed. Researchable questions derived from the theoretical and emperical findings of this analysis are:

1. To what extent will Michigan dairymen adjust herd size in response to pollution abatement policies?
2. What are the economics of changing production technologies to comply with pollution abatement policies? Specifically, is it economically preferable to convert an open lot housing system to a covered housing system rather than control runoff from the open lot?
3. What is the availability of capital and/or credit for investment in cost increasing waste handling facilities?

4. What are the implications of alternative methods of implementing pollution abatement policies? Specifically, what are the costs and benefits associated with alternative means (regulations, directives, taxes, subsidies) of implementing pollution abatement policies.

Not an economic question, but one that needs to be addressed is:

5. To what extent are alternative pollution abatement policies effective in reducing or eliminating environmental pollution from dairy wastes?

APPENDICES

APPENDIX A

COEFFICIENTS FOR THE "MILK PRODUCTION ACTIVITY" USED IN THE VARIOUS RUNS OF THE MODEL AND BASIC LINEAR PROGRAMMING TABLEAU

Table A1. Coefficients for milk production activity reflecting twelve combinations of housing systems, manure handling systems and herd sizes for synthetic dairy firms.

Item	Unit	Stanchion Housing		Open Lot Housing	
		40 cows	60 cows	80 cows	160 cows
Cost Per Unit	Dollars	2,773.00	2,711.20	2,424.70	2,307.90
January Labor	Hours	59.0	54.0	39.0	37.0
February Labor	Hours	53.0	49.0	35.0	33.0
March Labor	Hours	59.0	54.0	39.0	37.0
April Labor	Hours	58.0	53.0	37.0	35.0
May Labor	Hours	59.0	54.0	39.0	37.0
June Labor	Hours	58.0	53.0	37.0	35.0
July Labor	Hours	59.0	54.0	39.0	37.0
August Labor	Hours	59.0	54.0	39.0	37.0
September Labor	Hours	58.0	53.0	37.0	35.0
October Labor	Hours	59.0	54.0	39.0	37.0
November Labor	Hours	58.0	53.0	37.0	35.0
December Labor	Hours	59.0	54.0	39.0	37.0
Cropland	Acres				
Milk Transfer	Cwt.	-1,300	-1,300	-1,300	-1,300
Corn Transfer	Bu.	820	820	820	820
Corn Silage Transfer	T.	120	120	120	120
Haylage Transfer	T.	43	43	43	43
Cow Limit	10 cows	1	1	1	1

Cold Covered Housing		Warm Enclosed Housing					
		Tractor Scraper		Mechanical Scraper		Slotted Floors	
80 cows	160 cows	80 cows	160 cows	80 cows	160 cows	80 cows	160 cows
2,555.70	2,377.40	2,733.30	2,539.70	2,754.80	2,552.10	2,760.80	2,562.90
40.0	38.0	35.0	33.0	32.0	30.0	32.0	30.0
36.0	34.0	32.0	30.0	29.0	27.0	29.0	27.0
40.0	38.0	39.0	37.0	36.0	34.0	36.0	34.0
38.0	36.0	34.0	32.0	31.0	29.0	31.0	29.0
40.0	38.0	35.0	33.0	32.0	30.0	32.0	30.0
38.0	36.0	38.0	36.0	35.0	33.0	35.0	33.0
40.0	38.0	35.0	33.0	32.0	30.0	32.0	30.0
40.0	38.0	35.0	33.0	32.0	30.0	32.0	30.0
38.0	36.0	38.0	36.0	35.0	33.0	35.0	33.0
40.0	38.0	35.0	33.0	32.0	30.0	32.0	30.0
38.0	36.0	34.0	32.0	31.0	29.0	31.0	29.0
40.0	38.0	39.0	37.0	36.0	34.0	36.0	34.0
-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300
820	820	820	820	820	820	820	820
120	120	120	120	120	120	120	120
43	43	43	43	43	43	43	43
1	1	1	1	1	1	1	1

Table A2. Coefficients for milk production activity reflecting runoff control on the open lot housing system--two herd sizes.

Item	Unit	80 Cows	160 Cows
Cost Per Unit	Dollars	2,509.20	2,364.70
January Labor	Hours	39.0	37.0
February Labor	Hours	35.0	33.0
March Labor	Hours	39.0	37.0
April Labor	Hours	38.0	36.0
May Labor	Hours	40.0	38.0
June Labor	Hours	37.0	35.0
July Labor	Hours	39.0	37.0
August Labor	Hours	39.0	37.0
September Labor	Hours	37.0	35.0
October Labor	Hours	41.0	39.0
November Labor	Hours	37.0	35.0
December Labor	Hours	39.0	37.0
Cropland	Acres		
Milk Transfer	Cwt.	-1,300	-1,300
Corn Grain Transfer	Bu.	820	820
Corn Silage Transfer	T.	120	120
Haylage Transfer	T.	43	43
Cow Limit	10 Cows	1	1

Table A3. Coefficients for milk production activity reflecting winter storage and runoff control-alternative housing systems and herd sizes.

Item	Unit	Stanchion Housing		Open Lot Housing		Cold Covered Housing		Warm Enclosed Housing											
								Tractor Scraper				Mechanical Scraper				Slotted Floors			
		40 cows	60 cows	80 cows	160 cows	80 cows	160 cows	80 cows	80 cows	160 cows	160 cows	80 cows	80 cows	160 cows	160 cows	80 cows	80 cows	160 cows	160 cows
Cost Per Unit	dols.	3,074.30	2,961.77	2,673.70	2,507.20	2,677.00	2,492.60	2,918.80	2,868.80	2,709.70	2,657.20	2,934.80	2,889.80	2,722.10	2,659.60	2,945.80	2,894.80	2,732.90	2,670.70
January Labor	hrs.	55.0	50.0	35.0	33.0	36.0	34.0	35.0	35.0	33.0	33.0	32.0	32.0	30.0	30.0	32.0	32.0	30.0	30.0
February Labor	hrs.	49.0	45.0	31.0	29.0	32.0	30.0	32.0	32.0	30.0	30.0	29.0	29.0	27.0	27.0	29.0	29.0	27.0	27.0
March Labor	hrs.	55.0	60.0	35.0	33.0	36.0	34.0	34.0	34.0	32.0	32.0	31.0	31.0	29.0	29.0	31.0	31.0	29.0	29.0
April Labor	hrs.	65.0	59.0	45.0	42.0	45.0	42.0	38.0	38.0	36.0	36.0	35.0	35.0	33.0	33.0	35.0	35.0	33.0	33.0
May Labor	hrs.	65.0	60.0	47.0	44.0	47.0	44.0	39.0	39.0	37.0	37.0	36.0	36.0	34.0	34.0	36.0	36.0	34.0	34.0
June Labor	hrs.	54.0	49.0	33.0	31.0	34.0	32.0	33.0	33.0	31.0	31.0	30.0	30.0	28.0	28.0	30.0	30.0	28.0	28.0
July Labor	hrs.	55.0	50.0	35.0	33.0	36.0	34.0	35.0	35.0	33.0	33.0	32.0	32.0	30.0	30.0	32.0	32.0	30.0	30.0
August Labor	hrs.	55.0	50.0	35.0	33.0	36.0	34.0	35.0	35.0	33.0	33.0	32.0	32.0	30.0	30.0	32.0	32.0	30.0	30.0
Sept. Labor	hrs.	54.0	49.0	33.0	31.0	34.0	32.0	33.0	33.0	31.0	31.0	30.0	30.0	28.0	28.0	30.0	30.0	28.0	28.0
October Labor	hrs.	72.0	66.0	55.0	51.0	54.0	50.0	43.0	43.0	41.0	41.0	40.0	40.0	38.0	38.0	40.0	40.0	38.0	38.0
Nov. Labor	hrs.	54.0	49.0	33.0	31.0	34.0	32.0	34.0	34.0	32.0	32.0	31.1	31.0	29.0	29.0	31.0	32.0	29.0	29.0
Dec. Labor	hrs.	55.0	50.0	35.0	33.0	36.0	34.0	35.0	35.0	33.0	33.0	31.0	31.0	29.0	29.0	31.0	31.0	29.0	29.0
Crop Land	acres																		
Milk Transfer	cwt.	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300
Corn Grain Transfer	bu.	820	820	820	820	820	820	820	820	820	820	820	820	820	820	820	820	820	820
Corn Silage Transfer	T.	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Haylage Transfer	T.	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Cow Limit	10 cows	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

[a]First listing for each herd size is applicable to additional tank storage, the second for outside storage.

Table A4. Coefficients for the milk production activity reflecting winter storage and subsurface disposal of manure--liquid manure handling systems.[a]

Item	Unit	Tractor Scraper			
		80 Cows	80 Cows	160 Cows	160 Cows
Cost Per Unit	Dollars	2,941.80	2,891.80	2,724.50	2,662.00
January Labor	Hours	35.0	35.0	33.0	33.0
February Labor	Hours	32.0	32.0	30.0	30.0
March Labor	Hours	34.0	34.0	32.0	32.0
April Labor	Hours	38.25	38.25	36.22	36.22
May Labor	Hours	39.25	39.25	37.22	37.22
June Labor	Hours	33.0	33.0	31.0	31.0
July Labor	Hours	35.0	35.0	33.0	33.0
August Labor	Hours	35.0	35.0	33.0	33.0
September Labor	Hours	33.0	33.0	31.0	31.0
October Labor	Hours	43.5	43.5	41.44	41.44
November Labor	Hours	34.0	34.0	32.0	32.0
December Labor	Hours	35.0	35.0	33.0	33.0
Cropland	Acres				
Milk Transfer	Cwt.	-1,300	-1,300	-1,300	-1,300
Corn Grain Transfer	Bu.	820	820	820	820
Corn Silage Transfer	T.	120	120	120	120
Haylage Transfer	T.	43	43	43	43
Cow Limit	10 Cows	1	1	1	1

[a]First listing for each herd size is applicable to additional tank storage, the second for outside storage.

Mechanical Scraper				Slotted Floors			
80 Cows	80 Cows	160 Cows	160 Cows	80 Cows	80 Cows	160 Cows	160 Cows
2,962.80	2,912.80	2,736.90	2,674.40	2,968.80	2,918.80	2,747.70	2,658.50
32.0	32.0	30.0	30.0	32.0	32.0	30.0	30.0
29.0	29.0	27.0	27.0	29.0	29.0	27.0	27.0
31.0	31.0	29.0	29.0	32.0	31.0	29.0	29.0
35.25	35.25	33.22	33.22	35.25	35.25	33.22	33.22
36.25	36.25	34.22	34.22	36.25	36.25	34.22	34.22
30.0	30.0	28.0	28.0	30.0	30.0	28.0	28.0
32.0	32.0	30.0	30.0	32.0	32.0	30.0	30.0
32.0	32.0	30.0	30.0	32.0	32.0	30.0	30.0
30.0	30.0	28.0	28.0	30.0	30.0	28.0	28.0
40.5	40.5	38.44	38.44	40.5	40.5	38.44	38.44
31.0	31.0	29.0	29.0	31.0	31.0	29.0	29.0
31.0	31.0	29.0	29.0	31.0	31.0	29.0	29.0
-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300	-1,300
820	820	820	820	820	820	820	820
120	120	120	120	120	120	120	120
43	43	43	43	43	43	43	43
1	1	1	1	1	1	1	1

Table A5. Basic linear programming tableau for synthetic dairy firms in southern Michigan.

Item	Unit	b Value	Milk Prod. (10 Cows + R)	Prod. Corn Grain (Acre)	Prod. Corn Silage (Acre)	Prod. Haylage (Acre)
Cost Per Unit	Dollars		[b]	-78.50; -74.80[c]	-77.30	-63.00
January Labor	Hours	220.7				
February Labor	Hours	199.4				
March Labor	Hours	220.7		.25, .20		
April Labor	Hours	213.6		.50, .40	.50, .40	.12, .10
May Labor	Hours	220.7		.62, .50	.62, .50	1.3, 1.1
June Labor	Hours	122.0		.50, .40	.50, .40	1.2, 1.0
July Labor	Hours	213.6		.12, .10	.12, .10	2.5, 2.0
August Labor	Hours	220.7		.12, .10	.12, .10	.63, .50
September Labor	Hours	213.6		1.0	2.5, 2.0	1.8, 1.5
October Labor	Hours	220.7		.25, 1.2	2.5, 2.0	
November Labor	Hours	213.6		.37, .30	.25, .20	
December Labor	Hours	220.7				
Cropland	Acres	0		-1	-1	-1
Milk Transfer	Cwt.	0	-1,300			
Corn Grain Transfer	Bu.	0	820	-92		
Corn Silage Transfer	T.	0	120		-15	
Haylage Transfer	T.	0	43			-4.2
Cow Limit	10 Cows	[a]	1			

[a]b values were 4, 6, 8 and 16 for the 40-, 60-, 80- and 160-cow herds, respectively.

[b]The coefficients for the milk production activity varied according to herd size, housing system and pollution abatement policy. These coefficients are listed in Tables A1-A4.

[c]The first coefficient listed is applicable to the 40-, 60- and 80-cow herds; the second figure is applicable to the 160-cow herd.

Table A5. Continued

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sell Milk (Cwt.)
-3.00	-3.00	-3.00	-3.00	-3.00	-3.00	-3.00	-3.00	-3.00	-3.00	-3.00	-3.00	6.00
-1												
	-1											
		-1										
			-1									
				-1								
					-1							
						-1						
							-1					
								-1				
									-1			
										-1		
											-1	
												1

APPENDIX B

A DETAILED DISCUSSION OF THE AGGREGATE IMPLICATIONS OF THE POLLUTION ABATEMENT POLICIES ANALYZED IN THIS STUDY

Industry Effects

This analysis is directed primarily at firm level questions of adjustment through use of a "synthetic firm" technique. Synthetic firms are developed for herd sizes of 40, 60, 80 and 160 cows. The question approached here is, "What are the aggregate implications of this analysis for the Michigan dairy farming industry?" Aggregation of the synthetic firm data are used to address this question.

Limitations of Method

Basically, aggregation is accomplished by weighting the impact of pollution abatement policies on each synthetic firm by the number of firms represented by a particular synthetic firm. The limitations of these methods of aggregation are made explicit for the reader's consideration:

1. Synthetic firms have not been developed to represent all Michigan dairy producing firms. Those dairy farms with less than thirty cows have not been considered. Furthermore, not all farms with more than thirty cows are included in the population defined by the synthetic firms (e.g., 40-cow, open lot housing system).

2. Data describing the distribution of dairy farms by size of herd and type of housing (which are needed for weighting) are only available for Grade A milk producers.
3. The price of milk and milk production per cow assumed for analytical purposes do not necessarily reflect Grade B milk production.
4. Estimates reflecting crop yields, milk production and labor requirements assume good to excellent management.
5. The synthetic firm analysis does not allow the synthetic firms to change production technology or dairy herd size (i.e., stanchion to cold confinement).
6. The cost of pollution abatement facilities is assumed to be the same for all firms within a particular production technology--herd size combination.

To the extent that the above restrictions limit aggregation, the results of this aggregation of empirical synthetic firm findings will not fully approach real world effects.

Assumptions

The following assumptions are made to facilitate the aggregation of empirical findings of synthetic firm analyses:

1. Pollution abatement policies are in the form of state regulations, requiring all firms to utilize similar facilities to abate pollution.
2. Only Grade A herds are considered.
3. Firms do not change milk production technology (i.e., housing system) or herd size as a result of pollution abatement policies.
4. Empirical estimates of the characteristics of the previously presented are representative of Grade A dairy firms. Specifically: (a) the empirical analysis of the synthetic farm representative of 40-cow stanchion housing system is assumed representative of all stanchion housing systems with one to fifty cows, (b) the 60-cow stanchion housing system is assumed representative of all stanchion housing systems with fifty or more cows, (c) the 80-cow open lot housing system is assumed representative of all open lot systems with less than 100 cows, (d) the 160-cow open lot housing system is assumed representative of all open lot systems with more than 100 cows, (e) the 80-cow covered housing system (cold covered and warm enclosed) is assumed representative of all covered systems with 30-99 cows, (f) the 160-cow covered

housing system (cold covered and warm enclosed) is assumed representative of all covered systems with more than 100 cows.

Two sets of aggregate estimates are presented. One set of estimates assumes all Grade A herds comply with the pollution abatement policies. The second set of estimates assumes all Grade A herds with less than thirty cows discontinue production, rather than comply with the pollution abatement policies.

The second set of aggregative estimates is made for fwo reasons: (1) data in Chapter II indicates that the number of dairy farms with less than thirty cows have been declining rapidly in recent years; and (2) empirical findings of the synthetic firm analysis indicate pollution abatement policies, may hasten the decline in number of small herds utilizing stanchion housing systems. (Approximately 88 percent of those Grade A herds with less than thirty cows utilized a stanchion housing system in 1970).

Grade B herds are not included in the synthetic firm analysis or in the aggregate analysis. Grade B milk production accounted for approximately 43 percent of the dairy herds and 22 percent of the dairy cows in Michigan in 1970. However, by 1980, all milk production in Michigan is expected to be Grade A.

Aggregate Implications

To facilitate the estimation of the industry effects of pollution abatement policies, it is necessary to estimate the number of dairy cattle in each herd size--housing system stratum. Information on the size distribution of dairy farms and milk cows in 1970 (Table 1, page 14) and information on the distribution of Grade A herds (1970) by herd size and housing system (Table 3, page 22) are combined to provide the necessary estimate for each herd size--housing system stratum. The estimated number of Grade A dairy cows, by herd size and housing system, employed for aggregating the empirical findings of the synthetic firm analysis are presented in Table B1.

Table B1. Estimated distribution of Grade A dairy cows by size of herd and type of housing.

Type of Housing	Cows Per Farm				
	Under 30	30-49	50-99	100 or More	Totals
Stanchion	61,321	79,815	39,083	2,563	182,782
Open Lot	8,441	31,975	59,389	31,262	131,067
Cold Covered	--	1,179	19,167	18,695	39,041
Warm Enclosed	--	419	6,361	6,480	13,260
Total	69,762	113,388	124,000	69,000	366.150

This estimated distribution of dairy cows is used to weight the empirical findings of the synthetic firm analysis to provide estimates of the aggregate impact of pollution abatement policies on: (1) total investment requirements, (2) labor requirements and (3) cost of milk production. These aggregate estimates are presented in Tables B2 and B3.

Aggregate estimates in Table B2 assume all Grade A herds will comply with the pollution abatement policies. Aggregate estimates presented in Table B3 assume all Grade A firms with less than thirty cows will discontinue milk production.

Estimates in Table B2 indicate regulatory runoff controls would require an additional investment of $5.5 million on Michigan dairy farms and increase the cost of milk production by an average of $.071 per hundredweight for open lot housing systems, and by an average of $.025 per hundredweight for all milk produced. Labor requirements are increased by approximately 52,000 hours annually.

Winter storage of manure would require an estimated additional investment of $58.2 to $59.6 million by Michigan milk producers and increase the cost of milk production by an estimated $.148 to $.150 per hundredweight of milk produced. However, labor requirements for the

Table B2. Estimated aggregate effect of pollution abatement policies on the Michigan dairy farming industry--all Grade A dairy herds.

Item	Unit	Stanchion Housing		Open Lot Housing		Cold Covered Housing		Warm Enclosed Housing		Total/ Ave.
		1-49 Cows	50 or More Cows	1-99 Cows	160 or More Cows	30-99 Cows	100 or More Cows	30-99 Cows	100 or More Cows	
Runoff Control										
Investment/Cow	Dollars			48.45	34.53					45.12[a] 16.16[b]
Total Investments	Million Dollars			4.8	1.1					5.9
Labor/Cow	Hours			.4	.4					.4
Total Labor	Hours			39,922	12,505					52,427
Annual Cost/Cwt. of Milk	Dollars			.075	.057					.071[a]
Ave. Annual Cost/Cwt.	Dollars									.025[b]
No Winter Disposal										
Investment/Cow	Dollars	212.25	183.33	120.00	108.12	116.25	111.25	60-165.00	43.75-150.00	158.62-162.42
Total Investment	Million Dollars	30.1	7.6	12.0	3.4	2.3	2.1	.4-1.1	.3-1.0	58.2-59.6
Labor/Cow	Hours	-.8	-1.2	-.8	-1.2	-.8	-1.2	-.4	-.4	-189
Total Labor	Hours	-112,909	-49,975	-79,844	-37,514	-16,277	-22,434	-2,712	-2,593	-324,258

Annual Cost/ Cwt. of Milk	Dollars	.215	.165	.108	.081	.075	.061	.095-.13	.073-.12	.148-.15
Ave. Annual Cost/Cwt.	Dollars									.148-.15
Subsurface Disposal										
Investment/Cow	Dollars							8.75	4.37	6.61[a] .24[b]
Total Investment	Million Dollars							.06	.03	.09
Labor/Cow	Hours							.1	.088	.09
Total Labor	Hours							678	570	1,248
Annual Cost/ Cwt. of Milk	Dollars							.02	.014	.0.7[a]
Ave. Annual Cost/Cwt.	Dollars	.385	.116	.273	.085	.056	.051	.018	.018	.0006[b]
All Three Policies										
Investment/Cow	Dollars	212.25	183.33	168.45	142.66	116.25	111.25	68.75-173.75	48.12-154.37	175.02-178.82[b]
Total Investment	Million Dollars	30.1	7.6	16.8	4.5	2.3	2.1	.46-1.06	.33-1.03	64.2-65.5
Labor/Cow	Hours	-.8	-1.2	-.4	-.8	-.8	-1.2	-.3	-.312	-.76[a]
Total Labor	Hours	-112,909	-49,975	-39,922	-25,009	-16,277	-22,434	-2,034	-2,023	-270,583
Annual Cost/ Cwt. of Milk	Dollars	.215	.165	.183	.138	.075	.061	.115-.15	.087-.134	.174-.176 .174-.176

[a]Average of those herds affected by the policy.

[b]Average of all herds.

Table B3. Estimated aggregate effect of pollution abatement policies on the Michigan dairy farming industry--Grade A dairy herds with thirty or more cows.

Item	Unit	Stanchion Housing		Open Lot Housing		Cold Covered Housing		Warm Enclosed Housing		Total/ Ave.
		30-49 Cows	50 or More Cows	30-99 Cows	100 or More Cows	30-99 Cows	100 or More Cows	30-99 Cows	100 or More Cows	
Runoff Control										
Investment/Cow	Dollars			48.45	34.53					44.90[a] 18.55[b]
Total Investment	Million Dollars			4.4	1.1					5.5
Labor/Cow	Hours			.4	.4					.4[a]
Total Labor	Hours			36,546	12,505					49.051
Annual Cost/ Cwt. of Milk	Dollars			.075	.057					.07[a]
Ave. Annual Cost/Cwt.	Dollars									.029[b]
No Winter Disposal										
Investment/Cow	Dollars	212.25	183.33	120.00	108.13	116.25	111.25	60-165.00	43.75-150.00	118.66-153,41
Total Investment	Million Dollars	16.9	7.6	11.0	3.4	2.3	2.1	.4-1.1	.3-1.0	44.0-45.4
Labor/Cow	Hours	-.8	-1.2	-.8	-1.2	-.8	-1.2	-.4	-.4	-.91
Total Labor	Hours	-63,852	-49,975	-73,091	-37,514	-16,277	-22,434	-2,712	-2,593	-268,448
Annual Cost/ Cwt. of Milk	Dollars	215	.165	.108	.081	.075	.061	.095-.13	.073-.12	.136-.138[a]

Annual Cost/ Cwt. of Milk	Dollars	215	.165	.108	.081	.075	.061	.095-.13	.073-.12	.136-.138
Ave. Annual Cost/Cwt.	Dollars									.136-.138[b]
Subsurface Disposal										
Investment/Cow	Dollars							8.75	4.37	6.61[a] .30[b]
Total Investment	Million Dollars							.06	.03	.09
Labor/Cow	Hours							-.1	.088	.09
Total Labor	Hours							678	570	1,248
Annual Cost/ Cwt. of Milk	Dollars							.02	.014	.017[a]
Ave. Annual Cost/Cwt.	Dollars									.0008[b]
All Three Policies										
Investment/Cow	Dollars	212.25	183.33	168.45	142.66	116.25	111.25	68.75-173.75	48.12-1,561.37	167.50-172.26[b]
Total Investment	Million Dollars	16.9	7.6	15.4	3.5	2.3	2.1	.4-1.1	.3-1.0	48.5-49.9
Labor/Cow	Hours	-.8	-1.2	-.4	-.8	-.8	-1.2	-.3	.312	-.74
Total Labor	Hours	-63,852	-49,975	-36,545	-25,009	-16,277	-22,434	-2,034	-2,023	-218, 149
Annual Cost/ Cwt. of Milk	Dollars	.215	.165	.183	.138	.075	.061	.115-.15	-.087-.134	.166-.167
Ave. Annual Cost/Cwt.	Dollars									.166-.167

[a]Average of those herds affected by the policy.

[b]Average of all herds.

handling of wastes are estimated to be reduced by approximately 325,000 hours annually.

As indicated in Table B2, subsurface disposal of manure would require an estimated additional investment of $90,000 by Michigan dairy farmers. The cost of milk production would increase by an estimated $.017 per hundredweight for those systems handling wastes as a liquid and by an average of only $.0006 per hundredweight for all milk produced.

Compliance with all three policies would require an estimated additional investment of $64.2 to $65.5 million by Michigan Grade A milk producers. Labor requirements on Michigan dairy farms would be reduced by an estimated 270,000 hours annually. The cost of Grade A milk production would increase by an estimated $.174 to $.176 per hundredweight of milk. Under the assumptions employed in obtaining the aggregate estimates, total Grade A milk supply would be unchanged.

Aggregate estimates presented in Table B3 indicate that if Grade A herds of less than thirty cows discontinued production, compliance with the three pollution abatement policies would require an estimated investment of $48.5 to $49.9 million by Michigan Grade A milk producers. Labor requirements would be reduced by approximately 220,000 hours annually for those farms remaining in production. The annual cost of Grade A milk production would increase by an estimated $.166 to $.167 per hundredweight of milk produced. At the same time, approximately forty percent of the Michigan Grade A milk producers would discontinue production, resulting initially in an estimated twenty percent reduction in the total Grade A milk supply.

It should be noted that some of the facilities described in this study are eligible for subsidization through the federal cost-share arrangements of the Rural Environmental Assistance Program (REAP) administered by the Agricultural Stabilization and Conservation Service.[1] Specifically, the cost-share arrangement is authorized for animal waste storage facilities, including: lagoons, liquid manure tanks, holding pits or ponds, collection basins, settling basins, diversions, channels, waterways, outlets piping, land shaping, fencing and vegetation needed to protect the system, leveling and filling, and permanently installed equipment needed as an integral part of the system.

To be eligible, land owners must obtain one of the following items from the Water Resources Commission:

1. A letter indicating that his proposed system does not require the filing of a statement of new or increased use of the waters of the State for waste disposal purposes; or

2. An Order of Determination setting forth the various requirements of his waste disposal system.

Cost-sharing is not authorized for (1) measures primarily for the prevention or abatement of air pollution unless the measures also have soil and water conserving benefits, or (2) pumps, pumping equipment or other portable equipment; buildings or modification of buildings; or for spreading animal wastes on the land.

Cost-sharing is limited to fifty percent of the cost of facilities, not exceeding a maximum of $2,500 per person. However, cost-sharing for low income farmers may be authorized up to eighty percent of the cost of each practice in the county program.

For Michigan, $131,100 was authorized under REAP for construction of ninety-four animal waste handling structures in 1970. In 1971, $186,928 was authorized for the construction of 132 structures.[2]

Conclusions

This aggregate analysis of impacts of pollution abatement controls is conducted under a set of quite restrictive assumptions. The estimates provided by this analysis represent an estimated "upper bound" on the impact of pollution abatement policies on the Michigan dairy farming industry.

If the pollution abatement policies were implemented by directives (in a manner similar to which the Michigan Water Resources Commission currently requires dairy farm action to remedy waste management problems) rather than by regulation, as assumed in this aggregate analysis, the total impact would be expected to be substantially less than the aggregates estimated, as explained by the following judgments: (1) It is doubtful that all Michigan milk producers are contributing to environmental pollution. Therefore, some firms would not be required to consider additional pollution abatement facilities to be in compliance with legal pollution controls. (2) For firms contributing to environmental pollution, abatement may not require investment in facilities assumed in this analysis. Some firms may find an improvement in management, or "housekeeping," practices sufficient to fulfill requirements of legal pollution controls.

It should be emphasized, however, that feedlot runoff controls have been expressed in regulation form in other states. Furthermore, policies requiring winter storage of livestock wastes have been considered in some states; such requirements could be expressed as a regulation, requiring waste storage facilities for all milk producers. Implementation of such regulations in Michigan would require additional investments totaling $48 to $65 million. Under such regulations, costs of milk production would be increased by an estimated \$.166 to \$.176 per hundredweight of milk produced with a concurrent twenty percent reduction in the Michigan milk supply.

It could be expected that the increased cost of milk production combined with a decrease in total milk supply would increase the price of milk. Aggregate estimates indicate runoff control for open lot housing systems would not be expected to have a significant impact on the cost of milk production or the total supply of milk. This policy would increase the average cost of total milk production by an estimated \$.025 to \$.03 per hundredweight. Under the assumption that producers with less than thirty cows would discontinue milk production, the effect of this policy would be an estimated two to three percent reduction in total milk supply. Requirements for winter storage of dairy wastes, however, are estimated to have a substantial impact on the cost of milk production and total milk supply.

Interpretation of these aggregate estimates should be tempered by the restrictive assumptions necessary to facilitate computations. Little information is provided to indicate the extent to which dairy producers may change production technology, herd size, or discontinue milk production.

Appendix B Footnotes

[1] See United States Department of Agriculture, *State Program Handbook, Rural Environmental Assistance Program*, ASCS, Short Reference I-MI(RE), Revision 1, November 22, 1971.

[2] Source: Mr. Bob Payne, Michigan Agricultural Stabilization and Conservation Service, East Lansing, Michigan.

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