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AN ANALYSIS OF STRUCTURAL CHANGE IN THE ONTARIO
FEED MILLING SECTOR

by

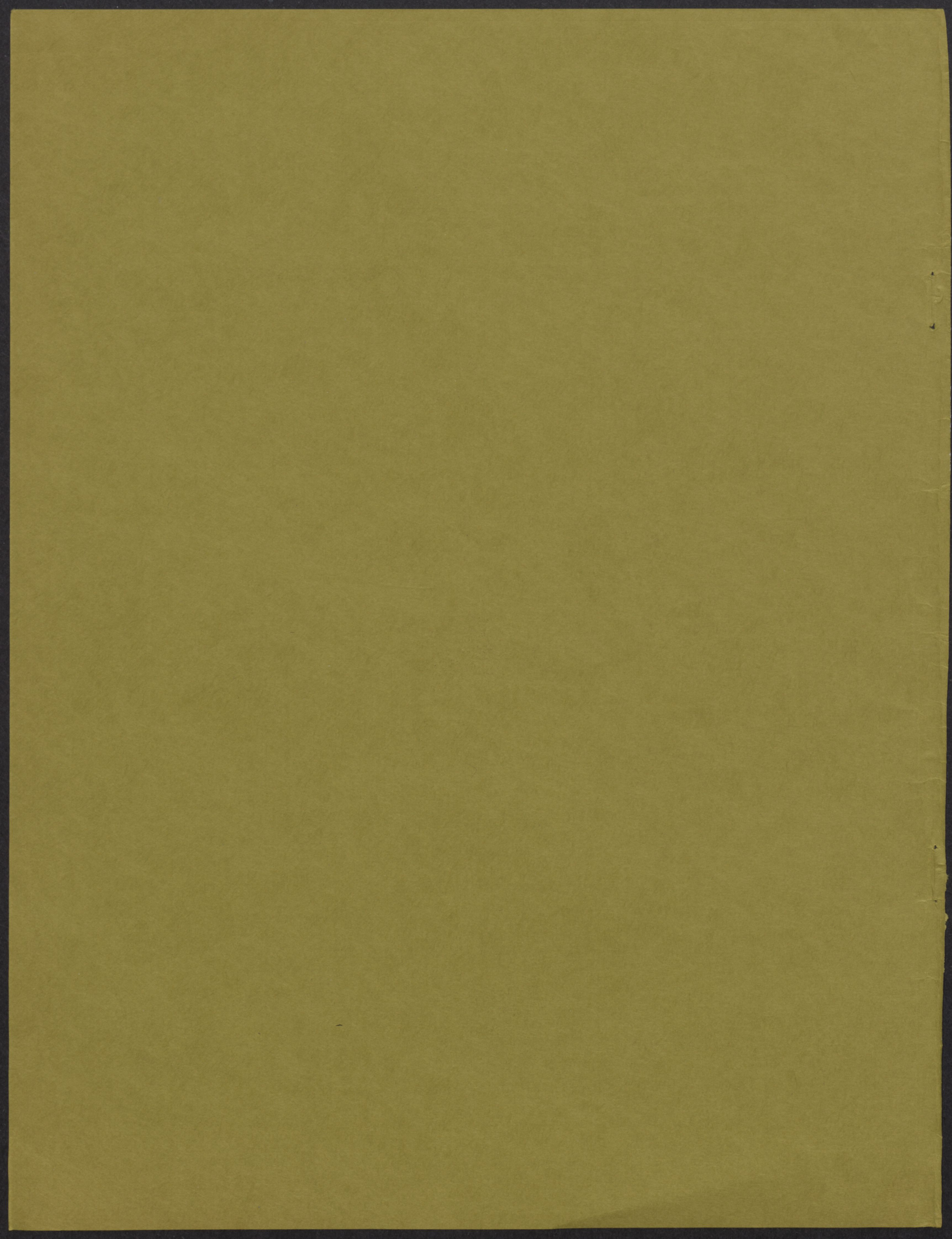
Larry Martin and H. A. Hedley

School of Agricultural Economics and Extension Education
Ontario Agricultural College
University of Guelph



September 1975

AE/75/6



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FOREWORD

This report represents the culmination of a three year research project carried out jointly between the School of Agricultural Economics and Extension Education, University of Guelph, the Canadian Livestock Feed Board and Economics Branch, Ontario Ministry of Agriculture and Food (O.M.A.F.).

In addition to the assistance received from O.M.A.F. and the Canadian Livestock Feed Board on the final phase of the project, the authors are indebted to a number of people and agencies in the feed industry for their help and cooperation. These include the Ontario Grain and Feed Dealers Association, the Ontario Division of the Canadian Feed Manufacturers Association, as well as more than 150 individual firms who took the time to respond to our surveys.

We also thank Prof. T. K. Warley of the University of Guelph and Dr. G. C. Lentz of O.M.A.F. for their helpful comments on an earlier draft of this report, Mr. Gerry Robertson for his assistance in computational problems and Mrs. Debbie Harkies for her usual excellent job of typing. The authors are responsible for any errors of commission or omission in the report.

L. J. Martin
H. A. Hedley
August, 1974

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AN ANALYSIS OF STRUCTURAL CHANGE IN THE ONTARIO

FEED MILLING SECTOR

Larry Martin*

H. A. Hedley**

1.0

INTRODUCTION

In recent years a number of important changes have taken place in Ontario's agriculture which have had a substantial impact on the Province's feed milling sector. These changes include;^{1/} shifts in the level and mix of livestock production among regions of the Province and a change in the nature of demand for feed products to include a larger component of concentrates relative to complete feeds. These changes, in turn, reflect adjustments toward increased sizes of farm operations and an apparent trend toward more on-farm milling of feeds.

As a result of these changes at the farm level, adjustments have taken place in the feed milling sector. These adjustments have had three general characteristics. First, the number of feed milling plants has decreased and the average plant size has increased, thus implying that livestock producers are by-passing small local dealers and secondary mills and purchasing directly from primary manufacturing firms. Second, there is a trend toward regional concentration of feed mills. Third, there has been a change in the mix of products sold by the sector.

These adjustments raise a number of questions for the future of the feed industry. Are the adjustments which have taken place to date the correct ones to best service Ontario's livestock producers? If trends toward increased farm size and on-farm milling continue, what will the long term structure of the feed industry be? Where should feed companies locate their plants to best serve this changing market? How large should plants be, and what mix of products should be produced?

Answers to these questions depend upon a number of interrelated factors. It has already been pointed out that they depend in part upon the demands of livestock producers for the products and services of the feed milling sector. They are also affected by the costs that must be

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^{1/} The adjustments summarized in this and the following paragraph are dealt with in detail in section 2.0.

borne by feed millers in providing their products and services. Such costs include the procurement of ingredients necessary for the manufacture of feeds, the in-plant costs of mixing and milling feeds and the costs of distributing the final product to livestock producers. These costs are, in turn, affected by other factors. Ingredient procurement costs are affected by the distances over which ingredients must be shipped to alternative plant sites. Mixing and milling costs are affected by factors such as economies of size and the number and mix of products which are produced. Distribution costs are affected by the distances over which products must be shipped and the density of feed demand in livestock producing areas.

This publication reports on a study which was undertaken with the general objective of combining these factors in an analysis aimed at providing answers to the questions presented above. In section 2.0 we describe regional changes in livestock production patterns and compound feed demand which have occurred within the Province in the past two decades, and the corresponding adjustments in the structure of the feed milling complex.

In section 3.0 the analytical basis for the analysis of optimum size, number and location of feed milling plants in Ontario is developed and a generalized linear programming model is specified to facilitate the analysis. The individual components of the model are developed in sections 4.0 through 6.0. Section 4.0 contains a description of the 53 market areas and 408 alternative plant sites which are included in the analysis. Section 5.0 presents levels of demand for complete feeds, supplements and pre-mixes in each of the market areas for 1971 and projections to 1980. The parameters of grain procurement, feed manufacturing and feed distribution costs are developed in section 6.0.

The results of the analysis of optimum size, number and location of feed mills are presented in section 7.0. The results are presented in terms of a simulated least-cost structure of the sector for both 1971 and 1980.

2.0

STRUCTURAL CHANGE IN THE FEED MILLING SECTOR

In section 1.0, references were made to structural changes which have at once affected and occurred within the feed milling sector. These structural changes are described below and their possible implications for future adjustments in the sector are discussed. The bulk of the material presented here has been presented in more detail in two earlier reports, [24] and [32]. The major conclusions of these reports are summarized in this section to set the stage for the analysis which follows.

2.1 Implications of Regional Adjustments in Livestock Production

Adjustments in the level and concentration of livestock production can have a number of implications for the feed sector. Most clearly, as livestock numbers increase, we would expect the demand for feed to increase, thereby, providing an incentive for feed millers to increase the number and/or the size of feed plants. But the effects of these adjustments could be much more pervasive. If for example, significant trends in regional specialization of livestock production occur (where regions can be thought of as individual counties or small groups of counties within the Province), those trends could have at least three implications to the feed milling sector. First, interregional adjustments could encourage an expansion of the number or size of plants in intensive livestock producing areas and attendant plant shut downs or over capacity in areas where livestock production is less intensive. Second, intensification of livestock production could encourage an adjustment by the feed sector toward highly specialized milling plants with a narrower range of product lines if such specialization is accompanied by lower in-plant manufacturing costs. Vosloh [42] has shown that substantial economies arise in feed milling plants that are characterized by a relatively small number of product lines. Third, increased specialization of livestock production in a region means that the density of demand for feed will increase. Increased density of demand provides for lower per ton costs of feed distribution to livestock producers, which in turn allows feed millers to take advantage of economies of size in manufacturing. Mikes, et. al. [25] have shown, for example, that substantial economies of size in feed milling can be attained when demand densities increase.

A final implication of adjustments in regional livestock specialization arises from increased size of livestock producing units. If substantial increases in the sizes of producing units occur, there could be an incentive for livestock producers to mix compound feeds at the farm. This circumstance could lead to a change in the nature of demand for feed products. More specifically, it could imply that livestock producers would tend to shift their purchases away from complete feeds toward concentrates - i.e. supplements and premixes. Alternatively, it could provide a very real incentive to the feed industry to provide their products at reduced costs and/or with more services attached - e.g. bulk delivery instead of delivery in bags - in order to respond to the potential competition of on-farm mixing. Two recent studies - one in

Ontario [45] and one in the U.S. [41] have indicated that on-farm mixing can be economical under some conditions for farms which require as little as 70 to 80 tons of feed per year.

2.2 Changes in Regional Livestock Production Patterns in Ontario

It is clear from the foregoing that changes in regional livestock production patterns in Ontario could significantly affect the feed sector. Therefore, an analysis of changes in regional production of major livestock classes (i.e. turkeys, layers and broilers, hogs, beef cows and heifers, beef steers, and dairy cows and heifers) was undertaken to assess changes which took place from 1961 through 1971.

The analysis proceeded by first identifying groups of counties in the Province which had similar trends in livestock inventories^{1/} from 1961 through 1971 (see [24, pp. 3-13]).^{2/} This resulted in thirteen relatively homogeneous groups of counties. Changes in inventories over the 11 year period were then analyzed to assess the degree of specialization in each region and livestock category.

The results of this analysis are presented in Tables 2.1 through 2.3 below. Results are presented in three ways. The first column for each class indicates the absolute percentage change in inventories that occurred in each region from 1961 through 1971. For example, the number of turkeys in region 4 increased by 194.2 percent over this period. The second column shows the percentage that each region represented of total Provincial inventories in 1971. For example, 16.5 percent of all turkeys in the Province were in region 4 in 1971. The third column indicates the percentage change in each region's share of total Provincial inventories from 1961. For example, the share of region 4 increased by 8.8 percent - i.e. from 7.7 percent in 1961 to 16.5 percent in 1971.

A number of conclusions emerge from Tables 2.1 - 2.3. First, substantial interregional adjustments occurred in the poultry classes. While turkey numbers increased by 37.2 percent in the Province as a whole over the 11 year period, they increased in three regions by 194.2, 327.8 and 205.5 percent respectively. There were smaller than average increases in regions 2 and 3 and a decline in all remaining regions. As a result of these adjustments, the Ontario turkey industry has become heavily concentrated in regions 2, 3, 4, 5A and 6, which contain 13 counties in Southwestern Ontario.

Similarly, while the number of chickens in the Province increased by 27.5 percent from 1961-1971, increases in regions 2, 3, 5A,

^{1/} Inventories as reported in [28] are used here as a proxy for annual production.

^{2/} Appendix Table 1 contains a listing of the counties included in each group.

TABLE 2.1: Summary of Regional Trends in Turkey and Chicken Inventories, in Ontario, 1961-1971

Region	Turkeys			Chickens		
	Percentage Change In Inventory	Percentage of Provincial Total 1971	Change in Percentage of Provincial Total	Percentage Change In Inventory	Percentage of Provincial Total 1971	Change in Percentage of Provincial Total
1A	-60.1	3.4	-8.2	-14.6	3.6	-1.7
2	9.8	18.7	-4.7	42.8	9.6	1.0
3	10.8	16.4	-3.9	39.7	21.0	1.8
4	194.2	16.5	8.8	-13.4	4.3	-2.0
5A	327.8	26.3	17.9	90.3	20.0	6.6
6	205.5	6.5	3.6	34.3	8.2	.4
7	-34.9	2.4	-2.7	-9.4	4.0	-1.7
1B	-8.2	5.7	-2.8	-10.7	5.5	-2.4
1C	-76.8	0	-.2	14.2	1.7	-.2
1D	-78.2	.6	-2.9	25.4	2.4	0
5B	-18.1	3.4	-2.3	12.7	12.2	-1.6
8	-92.0	.1	-1.3	-8.6	2.9	-1.2
1E	-100.0	0	-1.3	59.7	4.5	.9
Province	37.2	100	-	27.5	100	-

Source: [24].

and 1E were substantially greater. Changes in the remaining regions were less than the provincial average and, in some cases, there were declines. As a result, over 67 percent of Ontario's chickens were produced in five regions - 2, 3, 5A, 5B, and 1E - in 1971. These regions include six counties in southwestern Ontario, five counties in the Niagara Peninsula, six counties along the north shore of Lake Ontario, and five counties in southeastern Ontario.

Table 2.2 indicates that substantial adjustments have also taken place in hog production. While the number of hogs increased by 26.2 percent over the eleven year period, the numbers in five regions of southern and western Ontario - regions 2, 3, 4, 5A, and 6 - increased by substantially greater percentages, while the remaining regions had either marginal increases or decreases. As a result, by 1971, 62 percent of the hogs produced in the Province were produced in 13 counties.

Table 2.2 also shows that all thirteen regions experienced declines in the number of dairy cattle from 1961 to 1971, but the amount of decline varied around the Provincial total of 18.9 percent. Specifically, two major dairy producing regions - 3 and 1E - had decreases which were much smaller than the Provincial total, while decreases in most other regions were approximately the same or slightly greater than those for the Province as a whole. As a result, there was relatively little interregional adjustment. However, it would appear that regions 3, 5B, 8, and 1E are the major dairy producing areas since the twenty-one counties in these regions represented over 52 percent of the dairy cattle in 1971.

Table 2.3 indicates that while the numbers of beef cows and heifers increased by 37.8 percent in the Province, regions 4, 5A, 1D, 8, and 1E all had greater percentage increases. Five regions had increases which were similar to the Provincial total, while the remaining three regions had either small increases or decreases in numbers. These adjustments imply that there has been a tendency for the production of beef cows and heifers to shift toward central and eastern Ontario, although there is still a substantial amount of production in the southwestern segment of the province (regions 3, 4 and 5A).

Table 2.3 also shows that relatively little interregional adjustment has taken place in steer production. While total numbers increased by 32.4 percent in the Province, the only major relative increase occurred in region 7 (Bruce and Grey counties) which showed an increase of 64.8 percent. Region 7 represented 21.0 percent of total numbers in 1971. In general, the information in Table 2.3 would indicate that there is some tendency for steer production to be concentrated in the nine counties of Western Ontario included in regions 2, 3, 6 and 7. These nine counties represented almost 59 percent of all steers in the Province in 1971.

In summary, this analysis shows that a substantial amount of regional specialization exists in Ontario and that specialization tended to increase from 1961 to 1971. More specifically, we can conclude that much of the relatively intense livestock enterprises such as turkey,

TABLE 2.2: Summary of Regional Trends in Hog and Dairy Cattle Inventories in Ontario, 1961-1971

Region	Hogs			Dairy Cows and Heifers		
	Percentage Change In Inventory	Percentage of Provincial Total 1971	Change in Percentage of Provincial Total	Percentage Change In Inventory	Percentage of Provincial Total 1971	Change in Percentage of Provincial Total
1A	8.2	5.9	- .9	-50.2	1.9	- .7
2	81.9	11.2	3.4	-22.1	5.6	- .2
3	57.0	27.5	5.4	-4.3	12.3	2.2
4	37.7	7.7	.7	-15.1	6.6	.2
5A	64.4	7.4	1.7	-24.5	6.9	- .6
6	60.0	7.8	1.6	-6.7	3.7	.5
7	-4.8	8.4	-2.8	-20.5	7.1	- .3
1B	8.3	5.9	-1.0	-28.3	6.3	- .8
1C	-27.1	1.0	- .8	-18.8	3.0	0
1D	-32.7	.9	- .8	-38.2	6.1	-1.5
5B	-6.8	11.3	-4.0	-20.4	13.9	- .2
8	-17.5	2.9	-1.5	-21.0	14.8	- .4
1E	-14.4	2.2	-1.0	-5.6	11.9	1.9
Province	26.2	100	-	-18.9	100	-

Source: [24].

TABLE 2.3: Summary of Regional Trends in Beef Cattle Inventories in Ontario, 1961-1971

Region	Cows and Heifers				Steers			
	Percentage Change In Inventory	Percentage of Provincial Total 1971	Change in Percentage of Provincial Total		Percentage Change In Inventory	Percentage of Provincial Total 1971	Change in Percentage of Provincial Total	
1A	-26.4	1.6	-1.4		30.2	5.0	-.1	
2	-13.1	9.2	-2.0		33.1	10.9	.1	
3	37.6	11.4	0		33.1	17.8	.1	
4	80.3	3.0	.7		29.6	4.4	-.1	
5A	56.8	2.8	.4		30.2	2.2	0	∞
6	38.9	7.4	0		12.8	9.1	-1.6	
7	38.9	14.9	.2		64.8	21.0	3.1	
1B	30.8	8.2	-.4		43.5	6.1	.5	
1C	6.5	2.2	-.7		13.7	1.7	-.3	
1D	56.6	7.5	.9		-18.3	2.1	-1.3	
5B	22.0	16.8	-2.2		27.6	12.9	-.4	
8	113.5	13.1	4.7		6.7	6.0	-1.5	
1E	81.4	2.7	.6		43.6	.8	0	
Province	37.8	100	-		32.4	100	-	

Source: [24].

chicken, swine and beef steer production has become increasingly concentrated in a fifteen county area in Western Ontario roughly bordered by Lambton county to the West, Bruce and Grey to the North, and Wellington to Niagara to the East. At the same time, the more extensive enterprises, including beef cow and dairy operations have shown some tendency to move toward Central and Eastern Ontario. If these trends continue in the future, they will have important implications for the size and location of the feed industry.

Changes in regional production patterns as well as increased size of livestock enterprises could have important implications for the feed milling sector. In an effort to assess changes in size of enterprises, census data for each region and livestock class were analyzed for 1961, 1966 and 1971.^{1/} Because of the large amount of data involved in this analysis the result of the analysis for only one region (region 2) and one livestock class (hogs) is reported here. This result is representative of trends observed for other regions and livestock classes. Region 2 consists of Lambton and Middlesex counties. In 1961, only 19 of every 100 hogs in these two counties were produced on farms having 122 or more hogs. By 1966, 40 of every 100 hogs were produced on such farms. This trend toward larger farms lends credibility to the suggestion that relatively greater amounts of concentrates and correspondingly smaller amounts of complete feeds would be purchased by livestock producers in the future.

2.3 Structural Change in the Feed Milling Industry

In section 2.2 regional trends in livestock production and changes in the size of livestock enterprises were analyzed. In section 2.1 some implications of these adjustments as they could affect the feed milling sector were listed. In this section, evidence of adjustments in the feed milling sector which occurred through 1971 are presented. These adjustments are shown in terms of: the number of feed mills in Ontario; changes in productive capacity of small, medium and large mills in the Province; and changes in distribution patterns of complete feeds and concentrates.

2.3.1 Number of Feed Mills

The number of mills which mixed and/or manufactured feeds as reported by Statistics Canada [35] from 1957 through 1971 is shown in Table 2.4.^{2/} In addition, Table 2.4 expresses the number of mills each

^{1/} Analysis based on data obtained from [39].

^{2/} There is some discrepancy in the available statistics. The Statistics Canada data appear to understate the number of mills when compared to a listing by the Ontario Grain and Feed Dealers Association (O.G.F.D.A.) [27]. However, O.G.F.D.A. includes some establishments which probably function only as retail outlets. If the Statistics Canada information is understated, the understatement is most likely in terms of smaller mills. The data in Table 2.4 are indicative of the trend in mill numbers.

TABLE 2.4: Number of Feed Mills in Ontario, 1957-1971

Year	Number of Establishments	Percentage of Number in 1957	Percentage Change From Previous Year
		(%)	(%)
1957	509	100	
1958	488	96	-4.10
1959	478	94	-2.05
1960	471	93	-1.40
1961	448	87	-5.52
1962	420	83	-5.62
1963	406	80	-3.33
1964	397	78	-2.22
1965	360	71	-9.32
1966	352	69	-2.22
1967	356	70	+1.14
1968	337	66	-5.34
1969	316	62	-6.23
1970	292	57	-7.59
1971	276	54	-5.48

Source: [35].

year as a percentage of the number of mills in 1957 and the percentage change in number of mills each year. The information in this table shows very clearly that the number of mills has been steadily declining. A reduction occurred in each year except 1967 with the result that only 54 percent of the 1957 total were in existence in 1971.

2.3.2 Changes in Productive Capacity

In an effort to more fully assess the structural change in the feed milling sector, surveys of primary feed manufacturers, premix manufacturers, and local mills were conducted in 1972. Primary manufacturers are defined as those plants which manufacture micro or macro-premixes and mix complete feeds. Premix manufacturers are those plants which only manufacture micro or macro-premixes. Local mills are those plants which only mix premixes or supplements with feedgrains to make complete feeds.

Plants identified in each of the three categories listed above were obtained in consultation with the Canadian Feed Manufacturers Association and the Ontario Grain and Feed Dealers Association. The surveys were conducted by mail with the premix manufacturers and local mills and by on-site interviews with the primary manufacturers. In all, 32 primary manufacturers, 10 premix manufacturers and 345 potential

local mills^{1/} were surveyed. Of these, 23 primary manufacturers, 6 premix manufacturers and 90 local mills returned useable responses. The analysis in this and the following section is based on the responses which were obtained.

Based on the survey response, the concentration of responding primary manufacturers and local mills by region of the Province in 1971 is presented in Table 2.5.^{2/ 3/} The information in Table 2.5 indicates that in 1971 feed manufacturers and local mills tended to be most heavily concentrated in Western and Southern Ontario, while substantially fewer mills were located in the remaining three regions. This would appear to be consistent with our analysis on livestock production trends in section 2.2.

One segment of the surveys addressed the question of changes in productive capacity in the five-year period preceeding the surveys. Each

TABLE 2.5: Location of Responding Primary Manufacturers and Local Mills by Region of Ontario 1971

Region	Primary Manufacturers		Local Mills	
	No.	%	No.	%
South	7	30.5	27	30.0
West	10	43.5	36	40.0
Central	3	13	12	13.3
East	3	13	12	13.3
North	-	0	3	3.4
Province	23	100.0	90	100

Source: [32].

^{1/} As was noted above, O.G.F.D.A. rolls included more establishments than were reported by Statistics Canada. Although the precise number of local mills remains unclear, a number of the 345 potential local mill respondents had, in fact, abandoned operations by 1972 while others operated only as retail dealers.

^{2/} Counties included in South, West, Central, East and North Ontario are based on the regional classification of the Ontario Ministry of Agriculture and Food. The county make up of these regions is contained in Appendix Table 2.

^{3/} Regional concentration of premix manufacturers is not included in Table 2.5 because of the small number of plants.

respondent was asked whether there had been a change in capacity over this period. The responses are summarized according to mill type - i.e. primary or local - and mill capacity in Table 2.6. From Table 2.6, it can be seen that 12 of the 23 responding primary manufacturers (52%) and 46 of the 90 responding local mills (51%) reported increases in capacity over the five year period. Furthermore, the largest number of increases by primary manufacturers were reported by the largest mills - i.e. those with capacity greater than 25,000 tons per year. The largest number of increases by local mills were reported by those in the medium size (2,000-5,000 and 5,000-8,000 tons annually) range. This indicates that while the number of feed mills has been decreasing, many of those remaining in the industry have increased their milling capacity.^{1/}

TABLE 2.6: Distribution of Productive Capacity Increases from 1965-1971 by Responding Primary Manufacturers and Local Mills in Ontario

Annual Output Category (Tons)	Capacity Increases 1965-1971	
	Number Reporting Increases	Percent
Primary Manufacturers:		
0 - 15,000	4	33.3
15,000 - 25,000	3	25.0
25,000 or more	5	41.7
Total	12	100.0
Local Mills:		
0 - 2,000	7	15.3
2,000 - 5,000	14	30.4
5,000 - 8,000	14	30.4
8,000 - 25,000	11	33.9
Total	46	100.0

Source: [32].

2.3.3 Changes in Distribution Patterns

Historically the Ontario feed milling sector has been characterized by a structure which included a relatively small number of primary

^{1/} Respondents were also asked if they planned to expand in the five year period from 1972 to 1977. Again 52 percent of the primary manufacturers and 33 (37%) of the local mills responded positively.

manufacturing firms which often operated two or more large manufacturing plants. The products of these plants were distributed primarily to farmers through a network of retail dealers and local mills, although a substantial amount was also distributed direct to farms by the primary manufacturers. In section 2.3 we pointed out that changes in the basic farm structure could stimulate changes in this structure if larger farms begin to by-pass the local mills to purchase directly from manufacturers. Also, a significant move toward on-farm mixing could be expected to cause a change in the product mix being offered by the primary manufacturers.

Portions of the surveys of the feed milling sector were aimed at assessing the magnitude of these changes, if any, which took place from 1965 to 1971. Results of the survey response from primary manufacturers are presented below in Tables 2.7 and 2.8.

TABLE 2.7: Responding Primary Manufacturers'
Product Mix, 1965-1971

Type of Product	1965		1971		Percentage Change 1965-1971
	Tons	Percent	Tons	Percent	
Complete Feed Equivalents of:		(%)		(%)	(%)
Macro-Premixes	734,330	49.4	1,628,790	59.8	+122.6
Supplements	462,366	31.1	585,199	21.5	+26.6
Complete Feeds	290,200	19.5	510,990	18.7	+76.1
Total	1,486,896	100.0	2,724,979	100.0	+83.2

Source: [32].

In Table 2.7, the product mix of the 23 responding manufacturers for 1965 and 1971 is presented in terms of the total distribution (in complete feed equivalents) of macro-premixes, supplements and complete feeds.^{1/} This information shows, first, that the total complete feed

^{1/} Complete feed equivalents of macro-premixes and supplements are the quantities of complete feeds which would be mixed from the quantities of macro-premixes and supplements actually distributed. The factors used to convert the two concentrates to complete feeds are:

149.4 pounds of macro-premix per ton of complete feed

373.0 pounds of supplement per ton of feed

These factors represent average conversion ratios reported by responding primary manufacturers.

equivalent distribution of the 23 reporting manufacturing plants increased by 83.2 percent over the five year period. Second, by far the greatest increase was in macro-premixes which increased by 122.6 percent, while the distribution of complete feeds and supplements increased by 76.1 percent and 26.6 percent, respectively.

In Table 2.8, distribution (in complete feed equivalents) of the three feed types by the responding primary manufacturers direct-to-farms and through dealers is shown for 1965 and 1971. The information in this table shows, first that a substantially greater amount of primary manufacturers' products were sold direct to farms in 1971 than in 1965. Specifically, only 21.3 percent were sold through this channel in 1965, while by 1971 direct sales represented 45.8 percent of total complete feed equivalents. Second, while the proportions of all three feed types sold direct to farms increased, by far the largest increase was in macro-premixes which represented only 1.4 percent in 1965 and 22.5 percent in 1971.^{1/}

In summary, the information in this section indicates that the feed milling sector appears to have responded to the changing demand it faces. The number of mills has declined, mills are concentrated in the major livestock producing regions of West and South Ontario, many mills remaining in the industry have increased their capacities, primary manufacturers are selling increasing proportions of their products direct to farms, and there has been a change in product mix toward a larger component of concentrates - particularly macro-premixes.

We return now to the questions raised in section 1.0. Is the pattern of adjustment most efficient to serve Ontario's livestock producers? If trends toward regional production specialization, increased farm size, and on-farm mixing continue, what will the long term structure of the feed industry be? Where should feed companies locate plants to best serve this changing market? How large should plants be and what mix of products should be produced? In the remainder of this report, we try to answer these questions.

^{1/} In addition to the sales of macro-premixes by primary manufacturers reported in Tables 2.7 and 2.8, the six reporting premix manufacturers also sold 916,686 tons (in complete feed equivalents) of macro-premix in 1971, of which 322,202 tons (35.2%) were shipped direct to farms and 594,484 tons (64.8%) were shipped to local mills and dealers. Insufficient data were obtained to make a meaningful comparison for 1965.

TABLE 2.8: Distribution of Complete Feed Equivalents of Premixes, Supplements and Complete Feeds by Responding Primary Manufacturers Direct-to-Farms and Through Dealers, 1965-1971

Type of Product and Distribution Channel	<u>1965</u>		<u>1971</u>		Percent Change in Share 1965 - 1971
	Tons	Percent (%)	Tons	Percent (%)	
Direct-to-Farms:					
Complete Feed Equivalents of:					
Macro-Premixes	20,287	1.4	611,358	22.5	+21.1
Supplements	122,046	8.2	267,522	9.8	+1.6
Complete Feeds	175,100	11.8	368,200	13.5	+1.7
Total Direct-to-Farms	317,433	21.3	1,247,080	45.8	+24.5
Through Dealers:					
Complete Feed Equivalents of:					
Macro-Premixes	714,043	48.0	1,017,432	37.3	-10.7
Supplements	340,320	22.9	317,677	11.7	-11.2
Complete Feeds	115,100	7.7	142,790	5.2	-2.5
Total Through Dealers	1,169,463	78.7	1,477,899	54.2	-24.5
Total	1,486,896	100.0	2,724,979	100.0	-

Source: [32].

3.0

THE ANALYTICAL FRAMEWORK

Given the trends and adjustments in the feed milling sector noted in the preceeding sections, our research objective in this study can be summarized as the determination of the optimum size, number and location of plants that will best serve Ontario's livestock producing sector. In this section we first present a brief summary of the theory of plant location. Second, alternative empirical approaches to the analysis of plant location are discussed. Finally, the generalized model employed in this study is developed.^{1/}

3.1 Theoretical Considerations

Development of a theory of processing plant location and size is a problem which economists have been grappling with since the late nineteenth century. Greenhut [12] has outlined several theoretical explanations of the location decision. The most comprehensive of Greenhut's theories, and the one on which this study is based, is known as the maximum profit theory of location. Under this approach, both cost and demand factors affecting the plant are considered, and the location decision is based on the proposition that a processing plant will be located so as to supply the largest possible market area at the lowest possible cost. Specifically, the approach considers three cost components. These are: a) the cost of assembling raw materials at the plant, b) the cost of transforming raw materials into final product, and c) the cost of distributing final product to meet the plant's perceived demand. Then, through the simultaneous minimization of assembly, manufacturing and distribution costs, where manufacturing costs include consideration of economies available through size, and assembly and distribution costs are an increasing function of plant size, optimum plant size and market areas can be determined. Underlying this theory is the assumption that profits are maximized when costs are minimized.

A number of applications of this theory have been made in relation to processing plants in agriculture - e.g. [44], [8] and [25]. These studies have shown that the trade-offs existing between plant size and the size of the plant's market area are equally important in determining plant size and location. More specifically, these studies have shown that while economies of size in processing can, and usually do, exist, these economies are often offset by dis-economies of assembly and/or distribution. These costs depend on the density of final product demands and raw material supplies, and the distances over which products or materials must be shipped. At the extreme, the interrelationships between economies of size in processing and diseconomies in assembly or distribution lead to the conclusion that a processing industry will be characterized by a small number of large plants when the industry faces a situation of dense final product demands and/or a dense concentration

^{1/} The theoretical and methodological underpinnings of this analysis are developed more completely in [14].

of raw material supplies. On the other hand, if raw material supplies and/or final product demands are distributed sparsely over space, then the industry would be characterized by a large number of small plants which are widely distributed throughout the market area.^{1/} Furthermore, when the market has varying densities of demand, as we have seen is the case in Ontario's livestock producing sector, different parts of the market area could have various size and location structures.

3.2 Methodological Considerations

Movement from an abstract theoretical approach to the plant size and location problem to an operational procedure for empirical analysis involves many problems when large spatial areas, many alternative plant sites and other elements of a practical nature are considered. We can list a number of these problems which affect the analysis for feed milling in Ontario. Ontario is a very large area whose livestock producing units are widely distributed in space with varying density. Similarly, raw materials (principally feed grains) are produced or stored over a wide area, also with varying density. Livestock producers purchase three basic types of product - complete feeds, supplements or premixes - some of which they can either buy or produce themselves. Feed milling plants can vary in size and in the product lines they mix or manufacture.

Many studies have been carried out in agricultural processing industries in which attempts were made to incorporate these considerations in operational analyses.^{2/} Most of these studies have employed one of two alternative approaches.^{2/} Stollsteimer [40] developed a three stage minimization procedure which has limited usefulness for the present study since it can include only one of assembly or distribution costs and does not allow for economies of size in manufacturing. Although a number of modifications to the Stollsteimer model have been developed (by Warrack and Fletcher [43], Polopolus [30], Chern and Polopolus [7], and Ladd and Halvorson [20]) they have not been able to substantially overcome the weaknesses mentioned above.

The second empirical approach is through the use of a factor-product spatial equilibrium model which is based on the early work of

^{1/} Clearly these statements are oversimplified in that other factors can also affect industry structure. For example, the relative bulkiness of raw materials and final products, or relative transportation costs, and the nature of competition within the industry can substantially affect plant location.

^{2/} In addition to the two approaches mentioned here, attempts have been made to develop non-linear programming models [10], [33], [19] and [6]. These approaches either do not measurably improve on the procedure used in this study or computer programs are not capable of analyzing problems as large as ours.

Beckmann and Marschak [2] and Lefebvre [21]. Using this procedure, a linear programming model is specified to determine a location pattern which simultaneously minimizes the total costs of assembly, processing and distribution. In their original specification, models of this type were limited in that they could not include economies of size. However, King and Logan [18] and Stammer [34] developed iterative procedures which would allow consideration of size economies.^{1/}

The modified factor-product spatial equilibrium model was developed for the present analysis. In order to provide the reader with an overview of the analysis, the generalized model is presented below in section 3.3.

3.3 The Model

It has been pointed out above that plant sizes and locations in Ontario are affected by many complex factors. In constructing the model to be used in the analysis, we have attempted to include as many of these factors as possible. One of the most important of these factors, which has often been overlooked in previous studies of the feed industry, is the multi-product nature of the industry - i.e. the fact that feed is actually produced as complete feeds, supplements and premixes. We pointed out in section 2.0 that there has been substantial adjustment in the mix of, and marketing channel for these products by many Ontario firms in the past few years. The change in product mix has, in part, been caused by increased on-farm feed mixing. The adjustment in marketing channel has added further pressure for increased firm size and reduced the importance of the small local mill in the marketing system.

It would appear that these considerations will be of continuing importance in the future. Hence we have attempted to include them in the present analysis by including a) separate regional demands for the three types of feed and b) five alternative types of plant which can produce the three types of feed in alternative combinations in the model.

A generalized "picture" of the model developed for the analysis is presented in Figure 3.1. The following four subsections describe the activities included, the constraints imposed and the technical coefficients included in the model, and the iterative procedure used for its solution.

3.3.1 Objective Function and Activities Included

The objective function of the model is to find the combination of plant sizes and locations which minimizes the total cost of grain assembly, feed mixing and feed distribution in Ontario. This is accomplished by including five types of activity in the model. These are: 1) transfers of feedgrains to feed mills, 2) feed manufacturing activities, 3) intra and interplant transfers of supplements and premixes, 4) transfers of feeds to farms, and 5) transfers of feed grains to farms

^{1/} The iterative solution procedure is outlined in section 3.3 as it applies to this study.

FIGURE 3.1: Model of Ontario Feed Manufacturing Industry

Types of Activities Types of Constraints	Grain Assembly To Plants	Feed Manufacturing (Five Plant Types)					Intra-Site Transfers as Inputs			Inter-Site Transfers as Inputs			Distribution of Feed to Farms			Assembly of Grain to Farms	
		CM	SM	PM	CSM	CSPM	ICPLST	ICPLPT	ICPLPT	ICPLPT	ICPLPT	ICPLPT	CD	SD	PD	FGU	
Objective Function	AC																RHS
	A															GTF1	GRS
Supplies of Grain	GT	GUL			GU2	GU3											R
		SUL			SU2	SU3	SEML		SFM2								W
		CTL			CT2	CT3						CDT1					U
			PU1	PU2		PU3		PFM1		PFM2							H
			ST1		ST2	ST3	SFPL		SFP2				SDT1				F
Capacity Constraints				PT1		PT2		PFPL		PFPL					PDT1		D
		CP1	CP2	CP3	CP4	CP5											CPY
Demands for Feeds												CDT2					CFD
														SDT2			SFD
															PDT2		PFD
Transfer Row													GTF4	GTF3	GTF2		B

for on-farm mixing. The individual activities, as shown in Figure 3.1, are outlined below.

1. AC represents 1879 activities for feed grain assembly to the alternative plant sites.
2. CM, SM, PM, CSM and CSPM represent five different types of plant which can be located at each of the 408 plant sites. Plants designated CM are those which produce complete feeds only. Plants designated SM and PM are those which produce supplements or premixes only. Plants designated CSM and CSPM are those which produce a combination of complete feeds and supplements or complete feeds supplements and premixes.^{1/} In total, the segments CM through CSPM include (5 x 408) or 2,040 feed manufacturing activities.
3. Segments labelled IPLST through PTPPT represent 1956 activities for intra or inter-plant transfers of supplements or premixes.
4. CD, SD and PD represent activities for shipping complete feeds, supplements and premixes from plants to farms. Each of these segments include 1,429 separate activities.
5. FGU represents 106 activities for assembly of grain to farms for on-farm mixing with supplements or premix.

In total the foregoing represents 10,268 columns or decision variables which are included in the model.

3.3.2 Constraints on the Model

Four separate types of constraints are included in the model. These include constraints to: 1) ensure sufficient supplies of feed-grains to the feed plants or farms; 2) limit the capacity of feed plants; 3) ensure that demands for complete feeds, supplements and premix by farms are met; and 4) allow the transfer of complete feeds, supplements and premixes between plants and between plants and farms. These are shown in the last column of Figure 3.1 and the individual constraint segments are discussed below.

1. Segment GRS represents 54 constraints indicating the maximum quantity of feedgrain available in each of the 54 grain supply regions.

^{1/} The plant types and their cost functions are described in section 6.0. Plants designated CSM have a product mix consisting of half complete feeds and half supplement. Those designated CSPM produce 66 2/3 percent complete feeds, 25 percent supplements and 8 1/3 percent premix.

2. Constraint segments denoted as R, W, U, H, F, D and B are equality constraints included to allow the transfer of feed grains and feed products within and between plants and between plants and feed consuming regions. In total, these constraints represent 2,501 rows in the model.
3. Segment CPY represents capacity limits which were placed on the alternative plant sites. As specified, the model limits each of the 408 alternative plant sites to have a feed processing capacity no greater than 100,000 tons per year.
4. Segments CFD, SFD and PFD represent constraints which ensure that the demands for complete feeds, supplements and premixes respectively are met in each of the 53 feed consuming regions.

In total, the constraints listed in the foregoing represent 3,123 rows or separate constraints included in the model.

3.3.3 Technical Coefficients in the Model

Linear programming models are constructed to include technical coefficients that relate activities in the objective function to the constraints. This allows the model to ensure that activity levels which exist when the model is solved do not exceed the constraint levels. For example, the present model includes capacity constraints which limit the size of milling plants. Because of these constraints, a set of technical coefficients must be included to ensure that a plant at a particular location (as shown in the objective function) cannot exceed the capacity limit designated in the constraint set.

The interior portion of Figure 3.1 represents the technical coefficients included in the model. In general, there are only two types of technical coefficients. The first type relates milling or production activities in the objective function to feed grain, concentrate, or capacity availabilities. The second type allows transfers to take place - i.e. transfers of feed grains to mills or farms, transfers of premixes or supplements within or between mills, and transfers of premixes, supplements or complete feeds from mills to farms. The individual sets of technical coefficients are explained below.

1. Coefficients denoted by A and GT relate to feed grain assembly to the 408 plant sites - i.e. A is included to allow transfer of feed grains from the supply regions to alternative plant sites while GT is included to transfer grains to alternative plant types at each location.
2. Coefficients in GU1-GU3 indicate the amount of feed grain used per ton of product in each of three types of feed mills. Specifically, mills producing only

complete feeds are assumed to use .8 tons of grain per ton of product, while mills producing a combination of complete feeds and supplements use .4 tons and those producing a combination of complete feeds, supplements and premixes use .5336 tons.

3. Coefficients in SU1-SU3 indicate the amount of supplement used per ton of product in each of three mill types. Specifically, mills producing only complete feeds are assumed to use .2 tons of supplement per ton of product, while mills producing a combination of complete feeds and supplement and those producing complete feeds, supplements and premixes are assumed to use .1 and .1334 tons respectively.
4. Coefficients in PU1-PU3 indicate the amounts of premixes used per ton of product in each of three plant types. Specifically, plants producing only supplement, those producing complete feeds and supplements and those producing complete feeds, supplements and premixes are assumed to use .375, .1875, and .0738 tons of premix per ton of product respectively.
5. Coefficients designated CT, ST or PT are included to transfer complete feeds, supplements and premixes respectively, from sites where they are produced.
6. Coefficients designated by CP1 to CP5 relate the capacity constraints to the quantity of feed produced at each plant site and plant type.
7. Coefficients in SFM1, SFP1, PFM1 and PFP1 allow supplements and premixes which have been manufactured in a particular plant to be mixed with feed grains into complete feeds in the same plant.
8. Coefficients in SFM2, SFP2, PFM2 and PFP2 allow supplements and premixes which have been manufactured at one plant to be transferred for further processing at a second plant.
9. Coefficients in CDT1 and CDT2, SDT1 and SDT2, and PDT1 and PDT2 provide the mechanism for transferring complete feeds, supplements and premixes, respectively from the producing plant to farms in the consuming regions.
10. Coefficients in GTF1, GTF2, GTF3 and GTF4 ensure that grain is available on farms to be mixed with the supplement and premix that is distributed to the farms.

3.3.4 Solution Procedures

The model outlined above is used to determine least cost location patterns for both 1971 and 1980 by employing an iterative solution procedure similar to those developed by King and Logan [18]

and Stammer [34]. The iterative procedure allows the model to incorporate economies of size in feed milling into the solution. The procedure is as follows. First, an initial optimal solution to the model is obtained by setting per ton milling costs for each of the five plant types and 408 plant sites at the cost levels estimated for 80,000 tons annual output (per ton cost functions are presented in section 6.2).^{1/} Second, the initial solution is saved and the per ton milling costs at each plant site are adjusted according to the solution volume. For example in the case of two plants, if plant A has a solution volume of 10,000 tons per year in the initial run and plant B a solution volume of 95,000 tons, then the average manufacturing cost for plant A is increased to the level appropriate for a 10,000 ton plant and the cost for plant B is decreased to the level appropriate for 95,000 tons. These adjustments are made in the initial solution which is saved in the computer program. Then, starting with the saved solution, the model is rerun and a new solution is generated. This procedure of adjusting costs and obtaining the resultant solution is continued until a stable solution is generated by the model. That is, the procedure is halted when the last solution generated by the model is identical to the one before.

This procedure differs in one important aspect from that of King and Logan which has been widely used in other location analyses. In their original application of the factor-product spatial equilibrium model, King and Logan dropped any plant site which had a solution volume of zero from consideration in subsequent iterations by forcing its per unit milling cost to a very high level. For example, if the initial solution resulted in no volume milled at a specific plant, C, the King and Logan procedure would have forced in a very high milling cost for C in the second run and plant C would no longer be considered. Stammer pointed out that this procedure could finally result in an industry solution which is different from the true optimum. Hence, in our procedure, the milling cost for a plant which is driven out of a solution is maintained at the level inserted in the last iteration in which it appeared at a positive value. Thus, for example, if plant C resulted in a production level of zero in the first run, its per ton milling cost is maintained at the same level as that for 80,000 tons in the second iteration. This modification of the King-Logan procedure allows a plant which has been driven out of a particular solution to reenter a subsequent solution as operations are changed at competing plants and results in close approximation of the global optimum industry structure.

This section has presented an overview of the model used in the present analysis and the procedures used in its solution. Sections 4.0 through 6.0 will develop the data needed to apply the model to the Ontario feed milling sector.

^{1/} The model is run using the MPSX linear programming system. Given the size of the model, initial input data are generated onto disc and tape storage as card images using a fortran matrix generator written by Gerry Robertson, School of Agricultural Economics and Extension Education.

4.0

PLANT LOCATIONS AND MARKET AREAS CONSIDERED

The plant location model developed in section 3.3 includes 408 potential plant sites with capacity restrictions, 53 feed consuming regions, and 54 feed grain supply regions. The basis for the plant sites selected, the capacity constraints and specification of the feed consumption and feed grains supply regions is developed in this section.

4.1 Plant Sites and Capacity Restrictions

The 408 potential plant sites included in the model were derived from the Ontario Grain and Feed Dealers Association (OGFDA) Directory [27]. The Directory lists Ontario towns, villages or cities in which OGFDA records indicated feed mills were located in 1973. As was pointed out in section 2.0, there appears to be some discrepancy between OGFDA and Statistics Canada as to the number of mills in Ontario. The Directory apparently includes some sites which function only as retail dealers and some at which local mills operated at one time, but subsequently closed down. However, the 408 sites are included in the analysis because they represent a wide geographical distribution of potential sites.

Each potential site was assigned a location code number that includes the county and town in which the site is located. The sites and their site numbers are shown in Appendix Table 3.

Each plant site was assigned a volume restriction of 100,000 tons in the model (in segment CPY of Figure 3.1). This means that no plant was allowed to produce more than 100,000 tons of feed per year. The 100,000 ton restriction was chosen on the ground that no plant which responded to surveys discussed in section 2.0, reported a volume as high as 100,000 tons in 1971. In fact, only two plants reported volumes in excess of 50,000 tons. Hence, it is assumed that the 100,000 ton capacity represents the limit of any adjustments which may occur over the time horizon analyzed by this study.

Capacity restrictions serve another useful purpose in location models. Since the model's objective function requires minimization of the aggregate costs of raw material assembly, feed manufacturing and product distribution, its solution can be viewed as a monopoly situation. This is despite the competitive assumptions which underlies the model's construction. In other words, when no capacity constraints are considered, the model's solution would provide the set of plant locations and plant sizes which would minimize costs when one firm or agency controlled the entire market. In the reality of the competitive world, decision makers in competing firms make decisions. Their decisions are interdependent. For example, the size of a plant controlled by one firm is often related to the size of a plant controlled by a competitor.

Furthermore, the model implicitly assumes that all plants produce a homogeneous product. That is, there is no product differentiation. In reality, this is not true since the products of many firms are differentiated on the basis of brand name, promotion and services. To the extent that product differentiation is successful, the customer (in this

case, livestock producers) bases his decision to buy a particular firm's product on more than price alone.

Both of these factors are virtually impossible to quantify in the type of analysis attempted here. However, Bobst and Waanenen [3] have suggested that capacity restrictions of the type included in our model provide an indirect, if somewhat crude, method of incorporating them into location analyses. Hence, the 100,000 ton restriction provides a degree of realism in the model both as a limit to the amount of adjustment, as well as an indirect accounting for the interdependence between firms and product differentiation within the industry.

4.2 Delineation of Feed Consumption and Feed Grain Supply Regions

One difficulty with constructing an aggregate industry model such as the one used here is the delineation of marketing regions. On the one hand the size of a region must be small enough to realistically represent the potential market area of a plant, variations in the density of feed grain supply and in the density of feed demand. On the other hand, when large geographical areas, such as the whole of Ontario, are considered, the number of regions must be kept to a minimum or the size of the model becomes entirely unmanageable.

In this study marketing regions are delineated as the fifty-three counties of Ontario. In other words, the Province is divided into fifty-three regions for feed consumption and the quantity of feed products necessary to supply feed for each county's actual or expected livestock numbers is then calculated (see section 5.0). Similarly, feed grain supplies in each county are computed and made available for mixing at the farm, at feed mills located within the county, or for transfer to feed mills located in another county in the model. In addition, a fifty-fourth grain supply region is included to represent shipments of feed grains from areas outside of Ontario. It is assumed that all grains from exporting regions enter Ontario through ports on the Great Lakes.

Marketing regions based on counties are probably not optimal for this analysis. They present two problems. First, they probably result in a slight underestimate of the cost of shipping feeds from plants to farms in the same county (see section 6.0). Second, they present problems in properly specifying feed demands. Counties in Ontario are sufficiently large that substantial variations in livestock mix and density within a county exist. If smaller regions (say townships) were used, it would be possible to better specify feed demands. These two problems could be serious enough to result in a somewhat different solution to the location model if smaller regions were used. It would have been possible to delineate townships as market regions. However, this would have resulted in a model of completely unmanageable size. Hence the larger regions were used on the ground that the marginal costs of going to many smaller regions would have been far greater than the marginal benefits of additional accuracy.

5.0 REGIONAL FEED CONSUMPTION AND FEED GRAIN SUPPLIES

The fifty-three feed consumption and fifty-four feed grain supply regions included in the model were delineated in section 4.0. As indicated previously, the location model was solved for both 1971 and 1980 to determine the number and size of feed mills necessary to satisfy the demands for complete feed, supplements and premixes by Ontario livestock producers for these two years. In this section, the procedures used to estimate these demands and to estimate feed grain supplies in both years is developed.

5.1 Regional Feed Consumption

The estimation of regional feed consumption parameters for the model requires three steps. First, the number of livestock by livestock type actually produced in a county in 1971 or a projected number for 1980 must be obtained. Second, the amount of feed consumed by each livestock type must be obtained and aggregated. Third, since the location model developed for this study assumes that a certain amount of feed will be mixed on farms from home grown grain and purchased premixes or supplements, quantities demanded of complete feeds, supplements and premixes by livestock producers in each county must be calculated. Each of these three steps will be outlined below.

5.1.1 Livestock Numbers

Livestock numbers used to calculate feed consumption for 1971 were obtained from data reported by the Ontario Ministry of Agriculture and Food [28].^{1/} Data are reported for eleven livestock categories: a) hogs over six months, b) hogs under six months, c) dairy heifers, d) dairy cows, e) beef heifers, f) beef cows, g) steers, h) calves, k) hens and pullets for laying, j) broilers, k) turkeys.

To project livestock numbers by county for 1980, simple linear trends were estimated for each county and livestock class and the resulting projections were obtained.^{2/} Varying lengths of time series data and data sources were used to estimate trends for the respective livestock categories. For all cattle categories, data for the period from 1945 to 1971 as reported in [28] were used to estimate the trends. By using a time series of this length it is possible to overcome errors caused by failing to consider cattle cycles in their entirety.

^{1/} These data are reported as the number on farms in each county on June 1 of each year. To obtain the yearly total, it was assumed that the same number were on farms each day of the year. Hence, the June 1 figure is multiplied by 365.

^{2/} The limitations of this procedure and alternatives which could be used are discussed in Martin, Hedley and Stackhouse [24, p. 28].

The length of the time series on which the hog trends were based is shorter than that for cattle. Data from 1955 to 1971 as reported in [28] were used for hogs to allow for changes in production that have resulted from adjustments in demand for pork which have been observed in recent years.^{1/}

It was necessary to use a shorter time series, 1961 to 1971 for layers and turkeys because no continuous time series exists. The series used was developed by combining data from two sources. The number of layers and turkeys on farms is available for all of Ontario on a continuous basis, but not for individual counties in [28]. Layers and turkeys on farms are available by county in census years only in [37]. Therefore, our procedure was to obtain the county-wise data for the census years and then to proportion the totals for intercensal years among the counties on the same basis as was reported in the census years.

Data for broilers are only available by county in the 1971 census. To obtain a time series, we assumed that broiler production is well regulated by the Ontario Broiler Chicken Producers' Marketing Board, and allocated total broiler slaughterings in Ontario per quota period from 1966 through 1972 (as reported in [37]) according to quota allocations by county as reported in [26].

Livestock numbers in 1971 and projections for 1980 are presented for each county in Appendix Table 4. The cattle and hog categories have been aggregated in Appendix Table 4.

5.1.2 Feed Consumption By Type of Livestock

Feed consumption for each livestock category is based on daily rations recommended by the National Academy of Sciences. The daily rations in terms of pounds of concentrate feed (grain plus a supplement or premix) fed per day and nutrient levels required in the ration are presented in Table 5.1.

These rations are based on the assumption that all nutrient requirements for each livestock category are met from concentrate feeds. In reality, many of the nutrients fed to livestock produced in Ontario, particularly cattle, are derived from roughages - i.e. pasture, hay or silage. Therefore, it is necessary to adjust the recommended rations to include roughage. To do this, the following procedures were used. First, it was assumed that 100 percent of the requirements for hogs and poultry are met with concentrate feeds. Thus, the daily consumption figures for these livestock categories are as shown in Table 5.1. Second, daily consumption figures for the cattle categories are adjusted according to the results of an on-going study of the Canadian feed grain

^{1/} Zwart and Martin [46] have noted that per capita pork consumption trended downward during the 1940's and 50's, but increased in the 1960's and early 70's.

TABLE 5.1: Daily Feed and Nutrient Requirements of Livestock

	Weight Fed lbs./day	Protein %	Ether Extract %	Calcium %	Phosphorus %	Metabolizable Energy kcal./lb. of feed
Dairy cows ^{1/}	26.0	12.6	2.0	.41	.30	1,006
Beef cows ^{2/}	18.7	5.3	2.0	.14	.14	740
Dairy heifers ^{3/}	18.4	7.7	2.0	.29	.22	880
Beef heifers ^{4/}	17.9	11.0	2.0	.28	.22	1,090
Calves ^{5/}	5.5	11.0	2.0	.34	.28	1,065
Steers ^{6/}	15.2	11.0	2.0	.33	.24	1,090
Hogs over six months ^{7/}	6.3	14.25	2.0	.60	.40	1,500
Hogs under six months ^{8/}	4.1	15.00	2.0	.63	.61	1,442
Broilers ^{9/}	.150	21.4	7.025	.872	.423	1,424
Laying Hens ^{10/}	.250	15.0	1.0	2.75	.50	1,300
Turkeys ^{11/}	.270	23.25	6.1	.95	.55	1,410

^{1/} Maintenance and milk production for a 1,320 lb. dairy cow. Source: National Academy of Sciences (NAC), Nutrient Requirements of Dairy Cattle, 1971.

^{2/} Dry pregnant mature beef cow weighing 1,100 lbs. Source: NAC, Nutrient Requirements of Beef Cattle, 1970.

^{3/} Growth and maintenance of a 660 lb. dairy heifer. Source: See No. 1.

^{4/} Growth and maintenance of a 660 lb. beef heifer. Source: See No. 2.

^{5/} Nutrients required on an average for growing steers and growing heifers weighing 330 lbs. Source: See No. 1.

^{6/} Growth and maintenance of a 660 lb. steer. Source: See No. 1.

^{7/} A weighted average of rations for bred gilts and sows and of lactating sows (75% and 25% respectively). Source: Nutrient Requirements of Breeding Swine, NAC.

^{8/} A simple average (based on pounds of feed consumed) of each weight class of growing pigs. Source: Nutrient Requirements of Growing and Finishing Swine, NAC.

^{9/} Starting and finishing rations used in the ratio of 3:1 of feed consumption. Source: 1972 Poultry Feed Formulas, Ontario Department of Agriculture, page 72.

^{10/} Simple average of maintenance and egg production for breeding and laying hens. Source: Nutrient Requirements of Poultry, NAC.

^{11/} Average for 12-13 lb. birds. Source: See No. 9, page 90.

economy by the Canadian Department of Agriculture. This study determined that when feed grain and roughage availability in Ontario was confronted with the number of livestock and the nutrient requirements of each, as shown in Table 5.1, 100 percent of the daily requirements of beef cattle is supplied by roughages, 100 percent of the daily requirements of calves is supplied by roughages and milk, 28.87 percent of the daily requirements of dairy cows and heifers is supplied by concentrate feeds, and 0.62 percent of the daily requirements of beef heifers and steers is supplied by concentrate feeds.^{1/} By using these adjustments, daily concentrate feed consumption for each livestock category is as reported in the first column of Table 5.2.

TABLE 5.2: Daily Consumption of Concentrate Feeds by Livestock Category

Livestock Category	Complete Feed	Supplement	Premix
	Lbs/Head/Day	Lbs/Head/Day	Lbs/Head/Day
Dairy cows	8.661	1.732	.65
Beef cows	0.0	0.0	0.0
Dairy heifers	5.312	1.062	0.398
Beef heifers	0.11098	.022	0.008
Calves	0.0	0.0	0.0
Beef steers	0.09424	0.0185	0.007
Hogs over six months	6.3	1.26	0.4725
Hogs under six months	4.1	0.82	0.3075
Broilers	0.15	0.03	0.01125
Laying hens	0.25	0.05	0.01875
Turkeys	0.27	0.054	0.02025

The second and third columns of Table 5.2 show the approximate amounts of supplements or premixes included in the complete feed ration (in the first column) to provide the required protein level for each type of livestock. The factors used to calculate supplement or premix were obtained from the industry surveys discussed in section 2.0. These figures are interfaced with the actual 1971 and projected 1980 livestock numbers from section 5.1.1 to obtain feed requirements for each county. The final step of allocating each county's feed requirements among the three feed types - i.e. complete feed, supplements and premixes - is discussed below.

^{1/} This information was obtained by personal correspondence with personnel of the Economics Branch, Canada Department of Agriculture, Ottawa.

5.1.3 Allocation of Consumption Among Complete Feeds, Supplements and Premixes

Allocation of feed consumption among the three feed types presents a problem since no data exist concerning the extent of on-farm mixing. Because of this problem, a number of assumptions have to be made regarding the extent of on-farm mixing and the breakdown of concentrate demand between supplements and premixes by livestock producers who mix feed at the farm.

Studies by Wrubleski and MacGregor [45] and Trotter and Hoch [41] have indicated that livestock producers can obtain substantial cost savings by mixing their feeds at the farm. But these savings depend, in part, on the volume of feed required.^{1/} That is, because the initial capital outlay for mixing equipment is large, greater benefits, in savings, accrue to producers who can utilize the equipment to mix large volumes of feed. For example, Wrubleski and MacGregor found that a producer must mix more than 82 tons of feed per year before the average cost of on-farm mixing is lower than the cost of purchasing from a feed mill. The findings of Trotter and Hoch were similar. This indicates that the size of a livestock production unit, where size is defined by the number of livestock on the farm, is an important determinant of the type of feed which will be demanded on a farm.

The information contained in the two studies discussed above provided the basis for determining the amount of total feed consumption in each county that would be made up of purchased complete feed and purchased supplement or premix. It was assumed that those farms, based on data from the agricultural census of 1971 (see below), which had livestock enterprises which require 100 tons per year or less of complete feeds would purchase complete feeds. Those farms which had livestock enterprises requiring more than 100 tons per year would purchase supplements or premixes. The 100 ton figure was chosen rather than 80 tons as suggested in the two studies for two reasons. First, since our livestock data are based on June 1 inventories, it was felt that they could be higher than livestock numbers in other months and thus overestimate the demand for supplements or premixes. Second, while 80 tons may represent the point above which on-farm mixing is more economical than purchasing complete feeds, all producers may not adjust to on-farm mixing. The higher figure thus provides a cushion to reflect this lack of adjustment.

Using the above assumption, the next step in this procedure is to calculate the number of livestock in each category which represents an annual feed consumption of 100 tons. This is accomplished by using the feed consumption figures in the first column of Table 5.2. The

^{1/} They also depend upon such factors as the type of equipment, the amount of labor required, whether the producer grows his own feed, and discounts available from feed companies for large volume purchases.

results are summarized in the first column of Table 5.3. These figures were then compared to enterprise size categories in the 1971 census of agriculture^{1/} to determine which census categories bear the closest relationship to the number of livestock required to consume 100 tons. These are reported in the second column of Table 5.3. Thus, the total number of livestock in each county are allocated to two groups based on the 1971 census - those raised on farms which produced a number equal to or less than the number listed in the second column of Table 5.3 and those raised on farms producing more than the number in the second column in Table 5.3. It was then assumed that farms in the first group purchased complete feeds and those in the second group purchase supplements or premixes to mix feed at the farm. These then provide the basis for the estimates of feed consumption in both 1971 and 1980.^{2/}

TABLE 5.3: Livestock Numbers Required to Consume
100 Tons of Complete Feed Per Year

Livestock Category	Number Required To Consume 100 Tons	Corresponding Category in 1971 Census of Agriculture
Total Cattle	31	32
Total Hogs	120	122
Layers	2,192	2,027
Broilers	3,653	5,000
Turkeys	2,029	2,027

The final step in arriving at the estimates of feed consumption involved an assumption concerning the proportion of each county's demand for non-complete feeds which is made up of supplements and premixes. This was accomplished by calculating the actual proportions of complete feed equivalents that were shipped as supplement and premix for each livestock category in 1971 from Statistics Canada data [38]. These proportions, shown in Table 5.4, were then used to determine the amount of supplement and premix required to satisfy the non-complete feed requirements in each county.

^{1/} Obtained from [39].

^{2/} Total cattle and total hogs in Table 5.3 are aggregated from the larger number of categories discussed earlier. Actually there are different values for each category of cattle and hogs and the estimates of consumption are based on these values and the proportion of each livestock category in each county.

TABLE 5.4: Proportions of Non-Complete Feed Shipped
as Supplement and Premix In Ontario, 1971

Livestock Group	Proportion as Supplement	Proportion as Premix
Cattle	.35	.65
Pigs	.13	.87
Layers	.18	.82
Broilers	.18	.82
Turkeys	.18	.82

Source: Statistics Canada, Shipments of Livestock and Poultry Feed,
Catalog 32-004, Ottawa, 1971.

In summary, feed consumption used in the model for each county was obtained in the following steps: 1) actual livestock numbers for each category were obtained for 1971 and projections for 1980 were obtained from linear trend equations; 2) recommended daily rations for each livestock category were derived from National Academy of Sciences reports; 3) the daily rations for the cattle categories were adjusted for roughage availability based on a study by the Canadian Department of Agriculture; 4) by multiplying the number of livestock for 1971 and 1980 (from step 1) by the adjusted daily rations in step 3) and then by 365, total annual feed requirements for each category and county were obtained; 5) the total feed requirements for each category and county were allocated to complete and non-complete feeds according to the number of livestock in each category which were raised on farms which required less than or greater than 100 tons per year respectively, as reported in the 1971 census of agriculture; 6) each county's requirements of non-complete feeds were allocated as supplement or premix based on the proportions of the two feed types shipped in 1971; 7) the requirements of complete feed, supplement and premix for each livestock category were summed to obtain the total requirements of each type of feed per county.

The estimated feed requirements for 1971 and 1980 are presented in Appendix Table 4.

While this procedure for estimating consumption requirements is somewhat complex, it includes many limiting assumptions and is, in many cases, based on questionable data and could, therefore, directly affect the analysis. We have already alluded to the weakness of the livestock projections and they were discussed at some length in an earlier report. The calculations necessary to estimate demand for complete feeds, supplement and premix can be criticized on a number of grounds. Perhaps the most serious is the 100 ton breaking point. This assumption was made because no data exist on which better estimates could be based. The assumption may be particularly crucial to the

estimation of demand for poultry feeds because many poultry producers do not grow their own feed grains. Many purchase much of their feed on a contract basis from feed companies. Hence, the calculations probably over estimate the amount of supplement and complete feed.

Other limiting assumptions can be pointed to in the procedure. The only test of the procedure which we were able to use involved a comparison of the complete feed equivalents estimated for 1971 with the distribution of complete feed equivalents reported by the primary and premix manufacturers which responded to the surveys discussed in section 2.0. This comparison resulted in 18.6 percent more complete feed equivalents estimated for the province as a whole than was reported in the surveys. However, since 4 of the 10 premix manufacturers and 9 of the 32 primary manufacturers did not respond to the survey, the estimated consumption for 1971 is probably very close to the actual.

Given these factors, we conclude that the procedure used here provides the best estimates which could be obtained with the limited data available.

5.2 Regional Feed Grain Supplies

Feed grain supplies can be an important determinant of plant location since their costs of assembly to feed mills are substantial. The procedure and assumptions used to estimate regional feed grain supply levels incorporated in the model are outlined below.

Ontario feed manufacturing plants that responded to the feed industry survey in 1972 indicated that five different grains - corn, winter wheat, mixed grains, barley and oats - are important for use in complete feeds. Production of these five grains is reported annually for each county. A problem with these data is that harvest occurs in the last six months of the year, whereas grain supplies for use in live-stock feed refer to the supply available for the entire calendar year. Despite this, it was assumed that the production in a given year and county is the same as the supply available for feeding during the year.

A second problem arises because each grain has a different level of protein (see Table 5.5). This implies that different amounts of supplements or premixes must be mixed with each grain to attain a given level of protein in complete feed.^{1/} Therefore, for the purposes of this study, feed grains produced in each county are converted to corn equivalents based on the different protein levels and bushel weight for each.

Using these two assumptions, the number of tons of feed grains available in each county are calculated from 1971 data reported in [28]. For feed grain supplies in 1980, a linear trend was estimated for each

^{1/} The factors for converting supplement and premixes to complete feed discussed earlier in this report are for feed produced from corn.

TABLE 5.5: Average Crude Protein Levels in Grain

Grain	Average Level of Crude Protein (%)
Barley	12.7
Corn	9.0
Mixed Grain	12.4
Oats	12.0
Wheat	13.2

Source: [29].

county from data over the period 1957-1971. The trend equations were then used to forecast 1980 supplies. Estimated feed grain supplies for 1971 and 1980 are presented in Appendix Table 5.

As noted earlier, a fifty-fourth supply region is included in the model to account for feed grains obtained outside Ontario. Grain supplies in this region were assumed to be unlimited. In other words, any grain requirements which cannot be satisfied from within the province can be satisfied with imports.

6.0

COST CONSIDERATIONS

The location model developed for this study in section 3.0 includes three cost components. These are: 1) the costs of assembling feed grain supplies from the 54 producing areas or import points to the 408 alternative plant sites, 2) the costs of manufacturing complete feeds, supplements and premixes at each plant site, and 3) the costs of distributing feeds from the plants to the 53 consuming areas. Each of these three components will be developed in this section.

6.1 Grain Assembly Costs

There are two sets of activities in the location model which are concerned with grain transfer. One group represents the assembly of grain to potential plant sites from each county where grain is produced. The second represents assembly of grains to farms for use in feed that is mixed on the farm.

6.1.1 Grain Assembly to Plant Sites

A three step procedure is used to estimate the costs of assembling feed grains to plant sites included in the model. The first step is to estimate the relationship between the unit transfer cost of grain and road mile distance. This was accomplished by asking feed manufacturers in the industry survey to report the charges they paid in 1971 to ship grain to their plants. They also reported locations from which grains were received. Then the distance between the shipping point and the milling plant was measured on a road map. The survey resulted in 22 usable observations of transfer costs and distances. Transfer costs were then regressed on road mile distances to obtain the following transfer cost function,

$$AC_{ij} = 1.85821 + 0.02613 RM_{ij}^{.85} (0.00432)^{1/ij}$$

$$\begin{aligned} R^2 &= .61 \\ S.E.E. &= .477 \\ D.W. &= 1.72 \end{aligned} \quad (1)$$

where,

AC_{ij} = cost of transferring grain from supply point i to plant j in dollars per ton.

RM_{ij} = road map mileage from i to j.

This indicates that the transfer cost per ton increases at a decreasing rate as the distance increases.

The second step is to devise a method by which equation (1) can be used to estimate assembly costs for each of the 408 plant sites and 54

^{1/} Number in parenthesis is the standard deviation of the regression coefficient.

grain supply regions in the model. It is very difficult to measure road mile distances on a map where there is a large number of plants and supply regions. However, it is relatively easy to measure straight line (air mile) distances. In order for the air mile distances to be useful in equation (1), it was necessary to estimate the relationship between air and road miles. This was accomplished by selecting several sets of points at random in each of the five regions of Ontario, as defined by the Ontario Ministry of Agriculture and Food,^{1/} and measuring both the air and road mileages between them. Then the road mileage observations for each region were regressed on air mileages to obtain the relationships shown below in equations (2) through (6).

$$\begin{aligned} RM_S &= 1.9405 + 1.08036 AM_S \\ &\quad (0.01023)^{2/S} \end{aligned} \qquad \begin{aligned} R^2 &= .999 \\ S.E.E. &= 1.4919 \end{aligned} \qquad (2)$$

$$\begin{aligned} RM_W &= 0.89828 + 1.15754 AM_W \\ &\quad (0.02134)^{2/W} \end{aligned} \qquad \begin{aligned} R^2 &= .994 \\ S.E.E. &= 1.635 \end{aligned} \qquad (3)$$

$$\begin{aligned} RM_C &= 1.77963 + 1.33922 AM_C \\ &\quad (0.03348)^{2/C} \end{aligned} \qquad \begin{aligned} R^2 &= .990 \\ S.E.E. &= 2.647 \end{aligned} \qquad (4)$$

$$\begin{aligned} RM_E &= 5.11745 + 1.06048 AM_E \\ &\quad (0.02615)^{2/E} \end{aligned} \qquad \begin{aligned} R^2 &= .990 \\ S.E.E. &= 8.498 \end{aligned} \qquad (5)$$

$$\begin{aligned} RM_N &= -0.81006 + 1.2941 AM_N \\ &\quad (0.05701)^{2/N} \end{aligned} \qquad \begin{aligned} R^2 &= .977 \\ S.E.E. &= 8.883 \end{aligned} \qquad (6)$$

where,

$RM_S, RM_W, RM_C, RM_E, RM_N$ = road miles in Southern, Western, Central, Eastern and Northern Ontario respectively.

$AM_S, AM_W, AM_C, AM_E, AM_N$ = air miles in Southern, Western, Central, Eastern and Northern Ontario respectively.

Equation (2) through (6) were then substituted into equation (1) to estimate the transfer costs for grain assembly to plants located in each of the five regions. This allows assembly costs to be estimated

^{1/} Southern, Western, Central, Eastern and Northern Ontario. The five regions were estimated separately since road patterns vary substantially over the province.

^{2/} Numbers in parentheses are the standard errors of the regression coefficients.

simply by measuring the straight line distance between any grain supply region and any given plant site. Where grain is to be transferred across boundaries of the five regions, the point from which the grain is to be assembled determines which of the equations (2) through (6) is used to estimate transfer costs.

The final step in the procedure includes a set of assumptions used (a) to determine the points at which grain supplies are located, and (b) to limit the number of routes over which grain could be shipped in the model. For (a), it is assumed that the appropriate point in each supply region is the geographic center of the county. Thus, the distance between the center of each county and each plant site is used to estimate cost. It is also assumed that the estimated cost and distance relationships in equations (1) through (6) hold both for grains produced in Ontario as well as those imported. Hence, for imported feed grains, the distance from the nearest Great Lake port to a given plant site is used to estimate the assembly cost for imported grain.

For (b), the possible supply regions from which a given plant site can obtain feed grains in the model is assumed to be limited to (i) the county in which the plant is situated; (ii) the immediately surrounding counties; (iii) the external supply region; and (iv) any county which is highly specialized in grain production which is nearer a plant site than the nearest lake port. These assumptions greatly limit the number of transfer activities included in the model.

6.1.2 Grain Assembly to Farms

Supplement and premix that are distributed to farms by the feed manufacturing industry are mixed with grain at the farm. Activities are included in the model to ensure that enough grain will be available at farms for this purpose. Supplies of grain for the manufacture of complete feed by the feed manufacturing industry are affected by the use of grains on farms. Thus the location of manufacturing plants is influenced by livestock production, not only through demands for feed, but also, through competition for grain supplies.

It is assumed that livestock producers in each feed consuming region can assemble grain from two alternative sources. Grain can be assembled from within the same region or from outside the province. Farms in any region are not permitted to obtain grain from another region within the province. Grain supplies in each other region are maintained to meet grain requirements of livestock producers in that region. Both livestock and grain are usually produced on the same farm. The unit transfer cost of assembling grain within a farm is less than that of assembling grain to a feed manufacturing plant from the region in which the plant is located. It was also assumed that the unit transfer cost of assembling externally produced grain from a lake port to a farm is greater than the unit transfer cost of assembling grain from a lake port to a feed manufacturing plant. The unit transfer cost of assembling grain within the farm was set at one dollar for all regions to ensure that grain would be used on farms rather than selling it to feed manufacturers. Any surpluses

not needed on a farm are available to feed manufacturing plants. The unit transfer cost of assembling externally produced grain to farms from lake ports was set at three dollars. All calculated unit transfer costs of assembly of grain to feed manufacturing plants are in the range of one to three dollars.

6.2 Manufacturing Costs for Feed Plants

As was noted in section 3.0, the location model developed for this analysis includes manufacturing costs for five alternative types of plant. Furthermore, since plant location is theoretically affected by economies of size, the model's solution procedure incorporates the consideration of these economies through the development of long run average manufacturing cost functions.

In order to derive long run average cost functions, both fixed and variable cost data are required. There are two alternative approaches for developing the required data. These are: (i) a cross-sectional survey of the industry, and (ii) economic engineering techniques which enable synthesis of both fixed and variable costs for several sizes of plant. Use of cross-sectional surveys is seriously limited by "the extreme difficulty encountered in locating a sufficient number of firms of the right size that are willing to cooperate to the extent necessary in extracting the required data. Such cost data are normally regarded as highly confidential by most firms" [15, p. 79]. Even when enough cooperating firms can be enlisted, there are further problems with this approach because of differences in accounting procedures, in the levels of technology employed in different plants, in the age of capital equipment, and in the level of capacity utilization among plants. These differences cause difficulty in differentiating between movements along short and long run cost curves.

Plant sizes, technology levels and capacity utilization are predetermined in the economic engineering approach. Cost specifications for each plant are dependent upon the predetermined characteristics. This approach overcomes problems associated with differentiation between long and short run cost curves. On the other hand, the economic engineering approach introduces the potential problem that the costs developed are so idealized that they do not conform to the real costs incurred by firms operating in the industry.

In this study, the economic engineering approach is used for three reasons. First, the experience gained from the initial surveys of the Ontario industry indicated that there would be insurmountable problems in obtaining useful and representative survey data. Second, even if this problem did not exist, the costs involved in carrying out a survey would have been greater than the funds available. Third, as will be noted below, excellent economic engineering data are available for the feed industry from secondary sources.

Data used to derive the long run cost functions are based on studies of feed manufacturing reported by Vosloh [42] and Burbee, et. al.

[4]. Vosloh synthesized the costs of fifty-four model plants using the most technically efficient design and factor costs existing at the time. The fifty-four model plants were a combination of six plant sizes - 20,800; 26,000; 39,000; 52,000; 65,000; and 78,000 tons of feed produced per year - and nine plant types differentiated by varying proportions of bagged to bulk feed and of pelleted to mash feed. Data obtained from the surveys of Ontario feed mills indicated that approximately 52 percent of the feed manufactured in 1971 was in pelleted form and approximately 67 percent was distributed in bulk. Vosloh's plant type specification which is more representative of these characteristics is established as 50 percent pelleted and 50 percent bulk. Hence this specification is used as a basis for estimating costs in the six plant sizes listed above.

Cost data from Vosloh's study were supplemented with data from Burbee, et. al. to estimate costs for plants of 5,434 and 10,868 tons per year. These are included in the model to reflect the large number of small volume plants which exist in Ontario.

The technical specifications and associated costs for these model plants were checked with an engineering consultant^{1/} to determine if they are representative of Ontario plants. The consultant indicated that Vosloh's technical specifications are identical to those of most modern plants in Ontario. Costs for the model plants were modified to Ontario conditions using information obtained from Dr. Herodek along with Ontario - specific cost data relating to utility and wage rates. The average fixed and variable costs as developed for the model plants manufacturing complete feeds only are shown in the upper portion of Table 6.1.

Average cost per ton for four other types of plant with different combinations of output were then developed based on information obtained from the engineering consultant. These other plant types are: (i) supplement only; (ii) premix only; (iii) half supplement and half complete feed, and (iv) two-thirds complete feed, one quarter supplement and one twelfth premix. Average costs for these plant types are summarized in the lower portion of Table 6.1.

The average costs reported in Table 6.1 are calculated for plants operating at full capacity. These costs are plotted in Figure 6.1 to show the estimated cost-volume relationships for each type of plant. Short run average costs were also calculated for plants producing 100 percent complete feed (cost curves A through G). This was done by calculating the average cost per ton of feed for each size of plant at volumes less than full capacity. It can be seen (as would be expected) that as each plant approaches full capacity, manufacturing costs decline. When each plant is at full capacity, the short run average cost is the same as long run average cost. This indicates that the

^{1/} Dr. S. A. Herodek of C. D. Howe Co., Ltd., Toronto.

TABLE 6.1: Manufacturing Costs for Eight Sizes and Five Types of Feed Mills in Ontario

Plant Type	Cost Component	5,434	Volume of Feed Manufactured (Tons per Year)						
			10,686	20,800	26,000	39,000	52,000	65,000	78,000
			(Dollars per Ton)						
<u>Fixed</u>									
100% Complete	Fixed Equipment	\$0.70	\$0.57	\$0.71	\$0.65	\$0.51	\$0.53	\$0.50	\$0.44
	Depreciation								
	Facility Depreciation	0.39	0.29	0.32	0.29	0.23	0.20	0.21	0.44
	Administrative and Supervisory	1.66	1.29	1.15	0.99	0.84	0.77	0.77	0.76
	Taxes	0.20	0.16	0.19	0.17	0.14	0.13	0.13	0.11
	Insurance	0.20	0.16	0.19	0.17	0.14	0.13	0.13	0.11
	Interest	1.01	0.79	0.61	0.53	0.43	0.41	0.40	0.36
<u>Variable</u>									
	Production Labour	2.24	1.81	1.71	1.59	1.47	1.35	1.18	1.02
	Maintenance Labour	0.36	0.27	0.32	0.26	0.23	0.23	0.23	0.22
	Electricity	0.385	0.259	0.186	0.157	0.119	0.109	0.103	0.102
	Fuel Oil	0.28	0.28	0.26	0.23	0.23	0.22	0.19	0.19
	Maintenance and Repairs	1.42	1.10	0.69	0.63	0.51	0.48	0.47	0.44
	Supplies	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Miscellaneous	0.34	0.29	0.25	0.25	0.22	0.19	0.18	0.18
	Total	9.285	7.369	6.686	6.016	5.169	4.849	4.593	4.222
100% Supplement	Total	8.357	6.632	6.021	5.418	4.653	4.365	4.131	3.798
100% Premix	Total	7.892	6.264	5.687	5.117	4.395	4.123	3.902	3.587
50% Complete	Total	10.214	8.106	7.359	6.62	5.687	5.335	5.049	4.642
50% Supplement									
66 2/3% Complete	Total	10.678	8.474	7.694	6.923	5.946	5.578	5.279	4.853
25% Supplement									
8 1/3% Premix									

Sources: Cost Data Developed from:

- (1) [4] for mills of 5,434 and 10,686 ton capacity.
- (2) [42] for mills of greater than 10,686 ton capacity.
- (3) Information obtained through correspondence with Dr. S. A. Herodek, C. D. Howe, Co. Ltd.
- (4) Information obtained from Guelph, Ontario Hydro.
- (5) Information obtained through correspondence with the Canadian Miller's Mutual Fire Insurance Co. Ltd.
- (6) Information obtained from Peter Robinson Insurance Associates, Ltd.

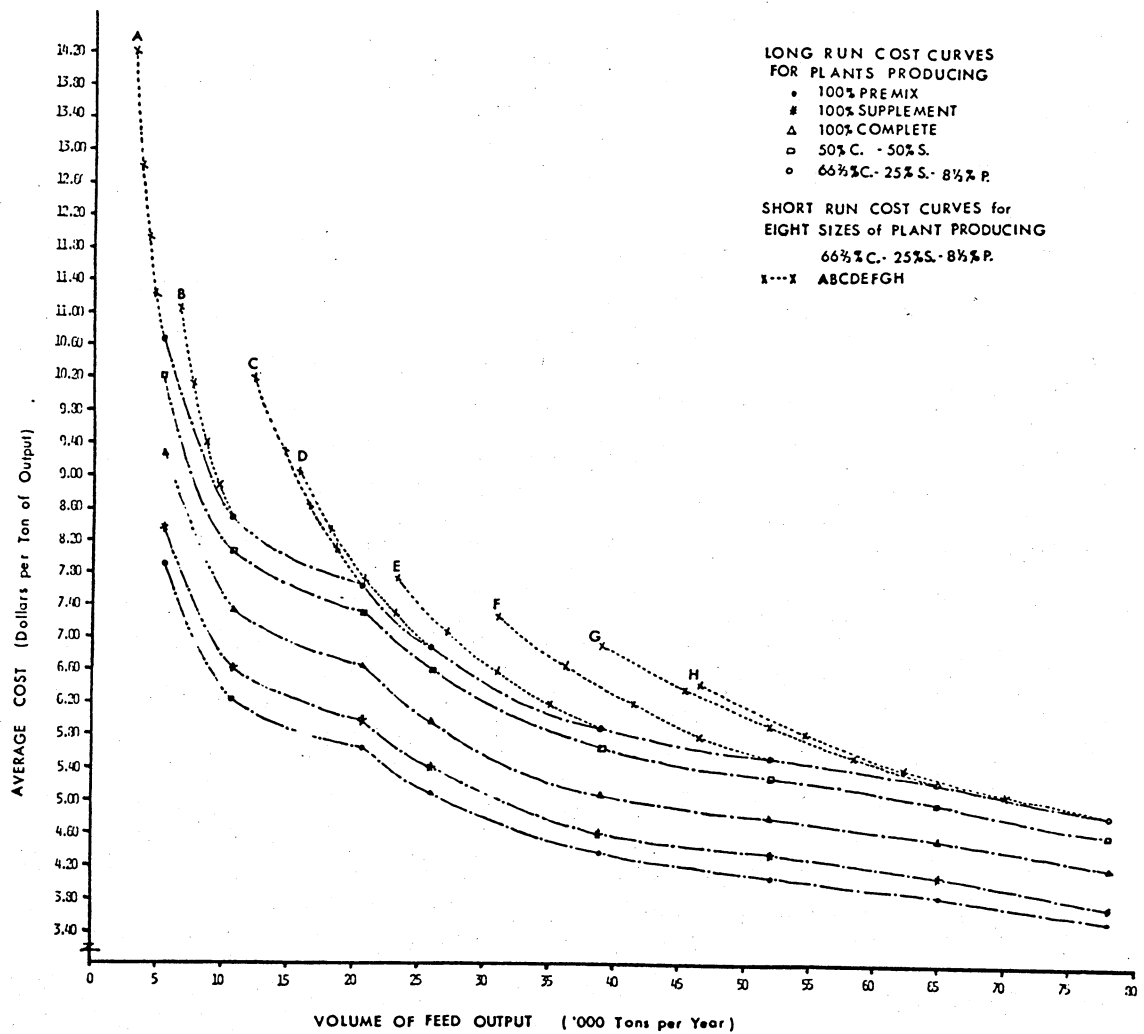


Figure 6.1: Cost Curves for Feed Manufacturing Plants

long run average cost curves represent an envelope function of the individual short run curves.

Using the data in Table 6.1, functional expressions of the long run average cost curves were estimated by fitting logarithmic equations to the data on average cost and volume, using least squares regression. The equations resulting from this analysis are presented in Table 6.2 in both logarithmic and arithmetic form, and in graphical form in Figure 6.2. These equations are used in the location model to determine manufacturing costs for each of the 408 plants.

TABLE 6.2: Long Run Average Cost Curves for Manufacture of Feed
(Standard Errors of the Regression Coefficients are
in Parentheses)

Plant Type	Cost Functions	Variation Explained (%)
100% Complete	(1) $\log AC = 2.0498 - 0.2892 (\log \text{Volume})$ (0.0125)	98.88
	(2) $AC = 112.158 \frac{1}{\text{Volume}^{.2892}}$	
100% Supplement	(3) $\log AC = 2.0041 - 0.2892 (\log \text{Volume})$ (0.0125)	98.88
	(4) $AC = 100.939 \frac{1}{\text{Volume}^{.2892}}$	
100% Premix	(5) $\log AC = 1.9792 - 0.2892 (\log \text{Volume})$ (0.0125)	98.88
	(6) $AC = 95.322 \frac{1}{\text{Volume}^{.2892}}$	
50% Complete 50% Supplement	(7) $\log AC = 2.0913 - 0.2892 (\log \text{Volume})$ (0.0125)	98.89
	(8) $AC = 123.381 \frac{1}{\text{Volume}^{.2892}}$	
66 2/3% Complete 25% Supplement 3 1/3% Premix	(9) $\log AC = 2.11052 - 0.2892 (\log \text{Volume})$ (0.0125)	98.88
	(10) $AC = 128.979 \frac{1}{\text{Volume}^{.2892}}$	

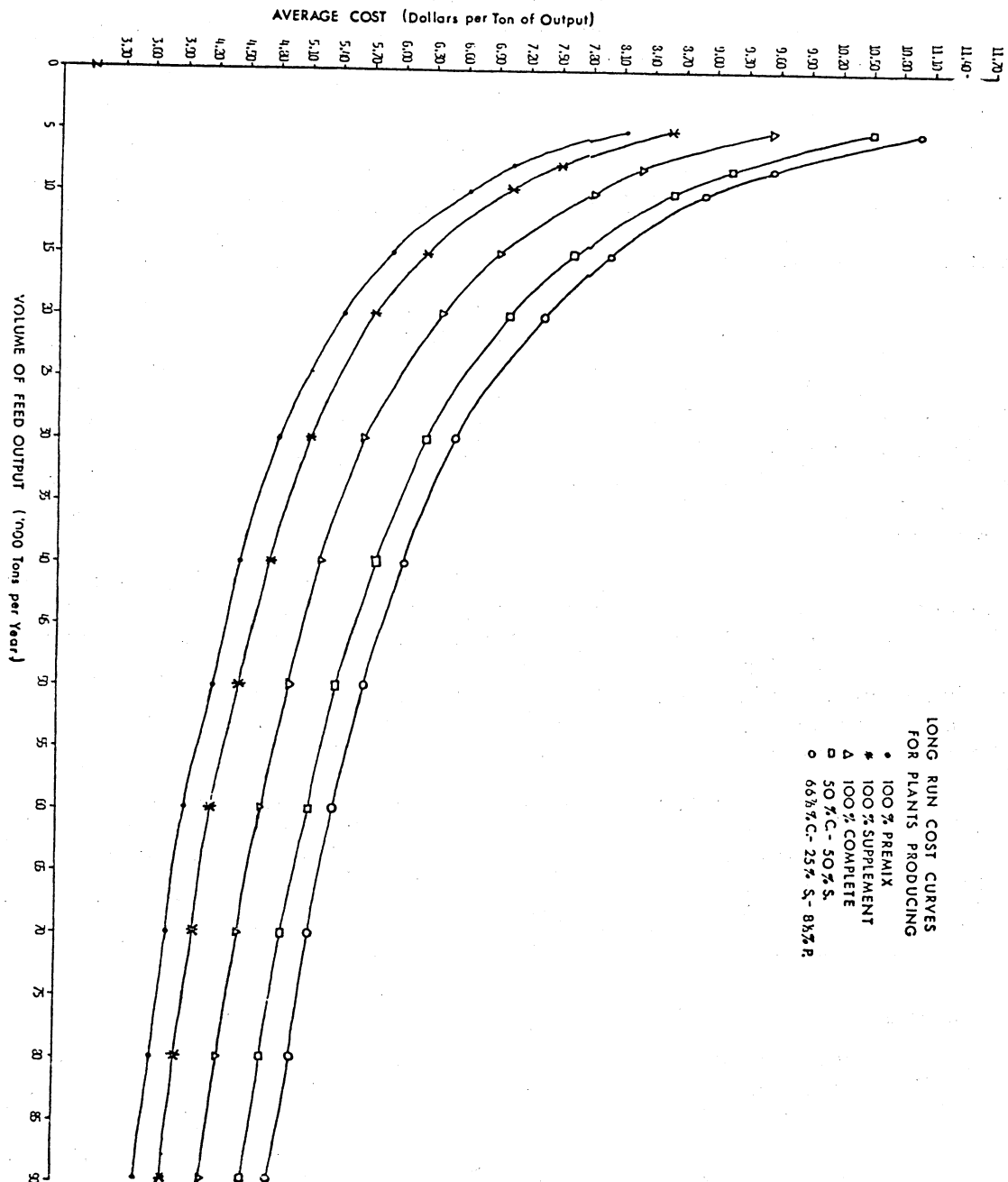


FIGURE 6.2: Estimated Long Run Cost Curves for Manufacture of Feed

6.3 Feed Distribution Costs

Transfer of grain from manufacturing plants involves both the distribution of feed to other plants for further manufacture and to farms for final consumption. In 1971 there were thirty-two feed manufacturing plants and ten premix manufacturing plants which manufactured some combination of complete feeds, supplements and premixes which were distributed to both plants and farms [32]. The remaining plants produced a combination of complete feeds and supplements or only complete feeds for distribution solely to farms. In this study it is assumed initially that complete feed, supplement and premix can be manufactured at each plant site. Supplement and premix manufactured at the thirty-two plant sites mentioned above may be distributed to other plant sites for further manufacture. Supplement and premix manufactured at any of the remaining plant sites may be used in further manufacture only at the site itself.

The unit transfer costs for distribution of feed between plant sites for further manufacture are determined by using the transfer cost equation developed in section 6.1.1. This is done on the assumption that the unit cost of transferring a full truckload of feed between two points is the same as the unit cost of transferring a full truckload of grain between the same two points. We also assume that there is an internal transfer cost of \$0.68 per ton incurred even when supplement and premix are used in further manufacture at the site where they are originally manufactured.^{1/}

Transfer costs from plants to farms is determined from a distribution cost equation. The equation is based on the assumption that each truckload of feed distributed to farms is delivered throughout a feed consuming region, rather than to a single point. Thus a transfer cost equation specific to the distribution of feed is required in order to account for both the density of feed demand in a region and the distance over which feed is distributed.

An equation incorporating these determinants of cost was developed by Burbee, et. al. [4] and refined by Stammer [34] using an economic engineering approach. This equation is adopted and modified for the present study. The equation is:

$$DC_{jk} = \frac{(W + 1.21) (0.568 + 0.0707AS_k + 0.1313AL_k + 0.0221RM_{jk}) + 0.183 RM_{jk}}{AL_k}$$

where,

DC_{jk} = cost per ton of distributing feed from plant site j to consuming region k.

W = wage rate (dollars per hour) paid to labour used to distribute feed.

^{1/} One plant which responded to the industry survey charges 1 5/8 cents per bushel for grain received through simple elevator transfer within the plant. This is equivalent to \$0.68 per ton.

- 1.21 = fixed cost per ton for trucks used to distribute feed, allocated per hour based on a use rate of ten hours per day.
- $(0.568 + 0.0707AS_k + 0.1313AL_k + 0.0221RM_k)$ = the time taken to load, deliver and unload a load^k of feed to region k in hours.
- AS_k = average number of stops per load to distribute a load of feed in region k.
- AL_k = average size of load distributed to region k in tons.
- AS_k and AL_k together reflect the density of livestock production in region k. A low number of stops with large loads indicates a high density of livestock production since the average farm size in k would be large.
- RM_{jk} = the average round trip road mileage from plant site j to consuming region k.
- and 0.183 = variable truck cost - i.e. fuel, oil, maintenance per mile of travel.

A wage rate of \$2.85 per hour is used to calculate the unit costs. Road mileages are estimated by measuring air mile distances in each region and using the equations developed in section 6.1.1 to convert them to road miles.

The average load size distributed to region k (AL_k) is determined by the identity;

$$AL_k = \frac{TFD_k}{(TTL_k)(26)}$$

where,

TFD_k = total tons of all feeds demanded in region k during the year.

TTL_k = total number of truckloads of feed (all types) that must be delivered to region k over a two week period.

It was assumed that the average truck size is twelve tons. Then the number of truckloads required per two week period can be calculated as

$TTL_k = \frac{TFD_k}{(12)(26)}$. It was also assumed that each producer receives enough feed to last two weeks.

The average number of stops per truckload of feed distributed in region k is a measure of density in the region. It is determined by the identity;

$$AS_k = \frac{TS_k}{TTL_k}$$

where,

TS_k = number of farms to which feed must be delivered in a two week period - i.e. the number of stops in region k. This was taken as the lesser of either the number

of census farms or the sum of farms reporting cattle, hogs and poultry in a county.

It was assumed that feed manufacturing firms do not aim to make a profit on the distribution of feed. Thus, the costs generated with the cost equation are inserted in the location model to represent actual delivery charges. To check this assumption, eleven firms were surveyed by telephone to determine their delivery charges. The results of the survey were then compared to costs generated by the equation and were found to vary over a similar range.

As with grain assembly, feed distribution is considered feasible in the location model to farms located in the same county as the plant or to farms in immediately surrounding counties. This assumption again reduces the number of shipment activities which must be included in the model. This assumption appears to be realistic when compared to the market areas reported by Sorflaten and Martin [32] as determined in the industry survey.

The interrelationships between the cost factors developed in this section as they affect plant location were discussed in developing the location model in section 3.0. The next section will present the results generated by the location model for 1971 and 1980.

7.0

RESULTS OF THE LOCATION ANALYSIS

The previous three sections developed the input data necessary for the location model developed in section 3.0. In this section we present the results of the analysis for both the actual 1971 and projected 1980 feed demands.

7.1 Least Cost Structure for 1971

As indicated in section 3.0, the location model was run using an iterative procedure to include consideration of economies of size in feed manufacturing. When feed consumption requirements in each county for 1971 were inserted in the model, the model was run for twenty iterations. Beginning with the sixteenth iteration the solutions were relatively stable, although a few plants with very small volumes manufactured entered and exited the solution from one iteration to the next. The solution which contained the fewest specialized supplement and premix plants is presented below in Table 7.1. With this solution, the total industry cost of grain assembly, feed manufacture and feed distribution, as shown by the model's objective function, is approximately \$16,444,000.

The information in Table 7.1, which shows the locations and annual output volumes of each of the five types of plant in the optimal solution, indicates that 68 plants would have constituted the least cost configuration of the Ontario feed industry in 1971. In addition, it should be noted that many of the specialized premix plants and several of the plants which were denoted as specialized complete feed, supplement and combination supplement and complete feed producing plants have very low annual volumes in the optimal solution. This result was, in most cases obtained because of the rigid specification of the product mix in plants which produce a combination of all three feed types. In other words, the 66 2/3, 25 and 8 1/3 percentage combination of complete feed, supplements and premixes in the latter case meant that small volumes of one type of feed were often forced into production in additional plants of a different type at the same or a nearby location. For example, the optimal solution resulted in a plant which produces 99,009.9 tons of feed in a combination plant at Markdale and a second, specialized premix plant which produces only 990 tons of premix at the same location. The volume in the larger plant represents approximately 66,000 tons of complete feed, 24,750 tons of supplement, and 8,247 tons of premix. Apparently in the model, the large Markdale plant, and others which serve the Grey county market were able to supply all the Grey county market under the existing plant specifications except for 990 tons of premix. As a result, since the model requires that all consumption demands must be met, a smaller plant was forced into Markdale.

This implies that if the model were flexible enough to allow the combination plants to produce the three types of feed in slightly different proportions, there would have been even fewer plants in the optimum solution and the multiproduct plants would have dominated to even a larger degree than they have. Inspection of the solutions in

TABLE 7.1: Plant Locations and Volumes in the Solution by Plant Type for 1971

PLANT TYPE	100% Complete			100% Supplement			100% Premix			50% Complete- 50% Supplement			66 2/3% Complete 25% Supplement 8 1/3% Premix		
	Location	Volume (Tons)		Location	Volume (Tons)		Location	Volume (Tons)		Location	Volume (Tons)		Location	Volume (Tons)	
	3412	11780.41		1601	1634.99		0101	267.24		0904	675.98		0303	80517.09	
	3502	6706.94		3414	38660.51		0303	6893.55		1202	997.70		0401	12806.61	
	3703	68664.83		3703	18421.05		0401	935.76		2702	3411.24		0915	28176.09	
	4302	10209.48		3805	1341.39		1101	1824.11		2815	36646.60		1318	99009.90	
	5106	70391.72		5106	29608.28		1202	871.62		4302	36802.73		1403	100000.00	
	5301	1996.41		5413	10879.13		1318	990.10					1601	14749.60	
	5413	54395.63					1706	208.11					1706	20811.16	
							1816	990.10					1816	99009.90	
							1821	5860.22					2003	54827.72	
							2003	5964.21					2109	70077.34	
							2109	700.77					2302	63799.03	
							2302	5226.35					2610	100000.00	
							2402	960.67					3107	99009.90	
							2502	338.73					3408	100000.00	
							2702	1010.82					3411	100000.00	
							2902	378.33					3904	68205.45	
							3104	6447.42					4203	20429.57	
							3107	990.10					4404	100000.00	
							3303	1063.43					4601	12176.44	
							3414	61339.49					4701	11768.42	
							3803	878.82					5004	58560.68	
							4203	204.30							
							4302	16974.94							
							4601	121.77							
							4701	117.68							
							4702	693.43							
							5004	585.61							
							5209	31096.02							
							5413	4134.07							

Table 7.1 would lead us to say that even a small degree of flexibility in the combination plants would probably remove those plants which produce less than 2,000 tons from the solution.

From Table 7.1 it is possible to determine the percentage of each feed type manufactured by each type of plant. These are presented in Table 7.2. The figures indicate that a high percentage of the complete feeds and supplements are produced in the large multiproduct plants while smaller, more specialized plants satisfy the residual demand for these types of feed. However, for premixes the greater percentage is produced in specialized plants while the residual is produced by the multiproduct plants.

TABLE 7.2: Percentages of Each Feed Type Manufactured by Each Type of Plant - 1971 Optimum Solution, Ontario

Feed Type	Plant Type		
	Specialized	50% Complete 50% Supplement	66 2/3% Complete 25% Supplement 8 1/3% Premix
(Percent)			
Complete Feed	19.6	34	77.0
Supplement	21.5	84	70.1
Premix	60.1	-	39.9

7.1.1 Comparison of Least Cost Structure to Actual 1971 Structure

As was noted in section 2.0, some uncertainty remains concerning the total number of feed mills that existed in 1971 because of the discrepancy between figures reported by Statistics Canada and the Ontario Grain and Feed Dealers Association. However, it seems safe to say that there were in excess of 300 mills that year. Comparison to the least cost structure in 1971, as presented in Table 7.1, indicates that given the costs and demands included in the location model, a smaller number of relatively large plants could have served the Ontario market in 1971. The fact that the smaller number of large plants were included in the model's optimum solution implies that the significant economies of size associated with the larger plants would substantially reduce the costs of supplying feed to livestock producers.

A second comparison that can be made between the least cost structure and the existing 1971 structure relates to the regional location of feed milling capacity. The percentage of feed produced in each of the five O.M.A.F. regions as reported by Sorflaten and Martin and as estimated in the location model are reported in Table 7.3. This table shows that the actual and optimum regional distribution of milling capacity are similar. However, there are differences in the Western and Central parts of

the province. These differences are not significant because the location model resulted in two very large plants being located in the northern part of the southern region (Oxford county, see below) and one in the western part of Central Ontario (Simcoe county) which supply large volumes of feed into Western Ontario.

TABLE 7.3: Actual and Optimum Regional Distribution of Feed Milling Capacity in Ontario - 1971

Region	Actual Percentage of Capacity*	Optimum Percentage of Capacity
South	37.1	40.1
West	40.0	29.7
Central	9.2	15.2
East	12.1	12.8
North	1.6	2.2

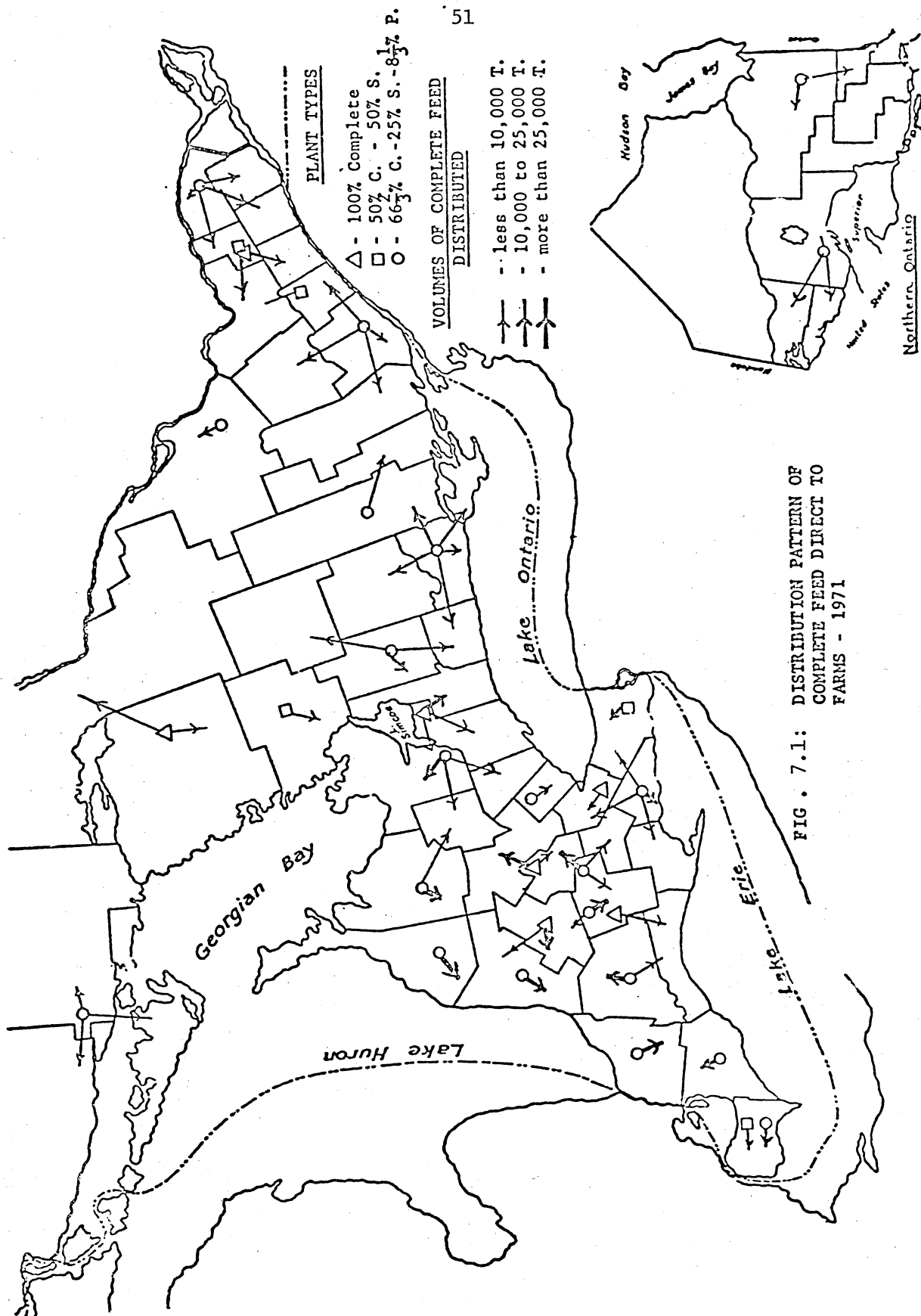
* Source: [22].

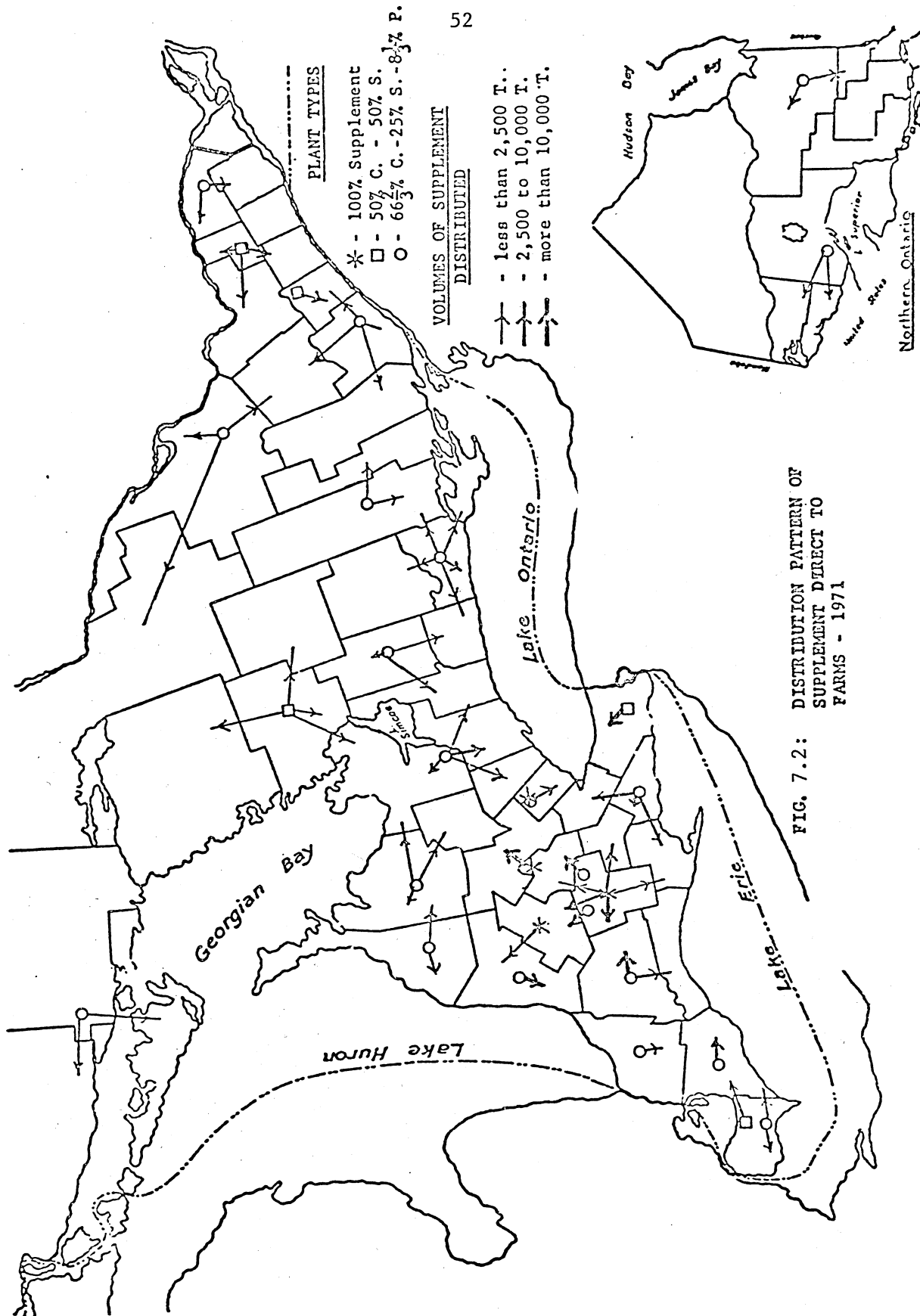
7.1.2 Distribution of Complete Feed to Farms in the Least Cost Structure

Table 7.1 listed the locations of plants which produce complete feeds as determined by the location model. These plants and their direct to farm shipments of complete feeds are mapped in Figure 7.1. This shows that the least cost structure for 1971 would include a number of very large plants in the concentrated livestock producing area of Southern and Western Ontario. These plants would serve a fairly concentrated market area of one to three counties. In those counties of Central and Eastern Ontario, the optimum structure would include a small number of large plants which are centrally located and serve broad geographic market areas. This pattern again suggests that the economies to be gained through increased plant size tend to outweigh the additional costs incurred by distribution of feed over long distances. Plants in Southern and Western Ontario are relatively large and concentrated in a small area because of the density of feed demand in these regions. Demand densities in Central and Eastern Ontario tend to be lower, with the result that it is less costly to have large, centrally located plants distributing over large market areas than to have a large number of smaller plants.

Similar results for the production and distribution of supplements direct to farms are shown in Figure 7.2. This pattern is very similar to that for complete feeds as discussed above.

The plant location and distribution patterns for pre-mixes direct to farms are shown in Figure 7.3. Again the location pattern is similar to that discussed above, with a relatively small number of plants serving large geographic markets. This result would be particularly





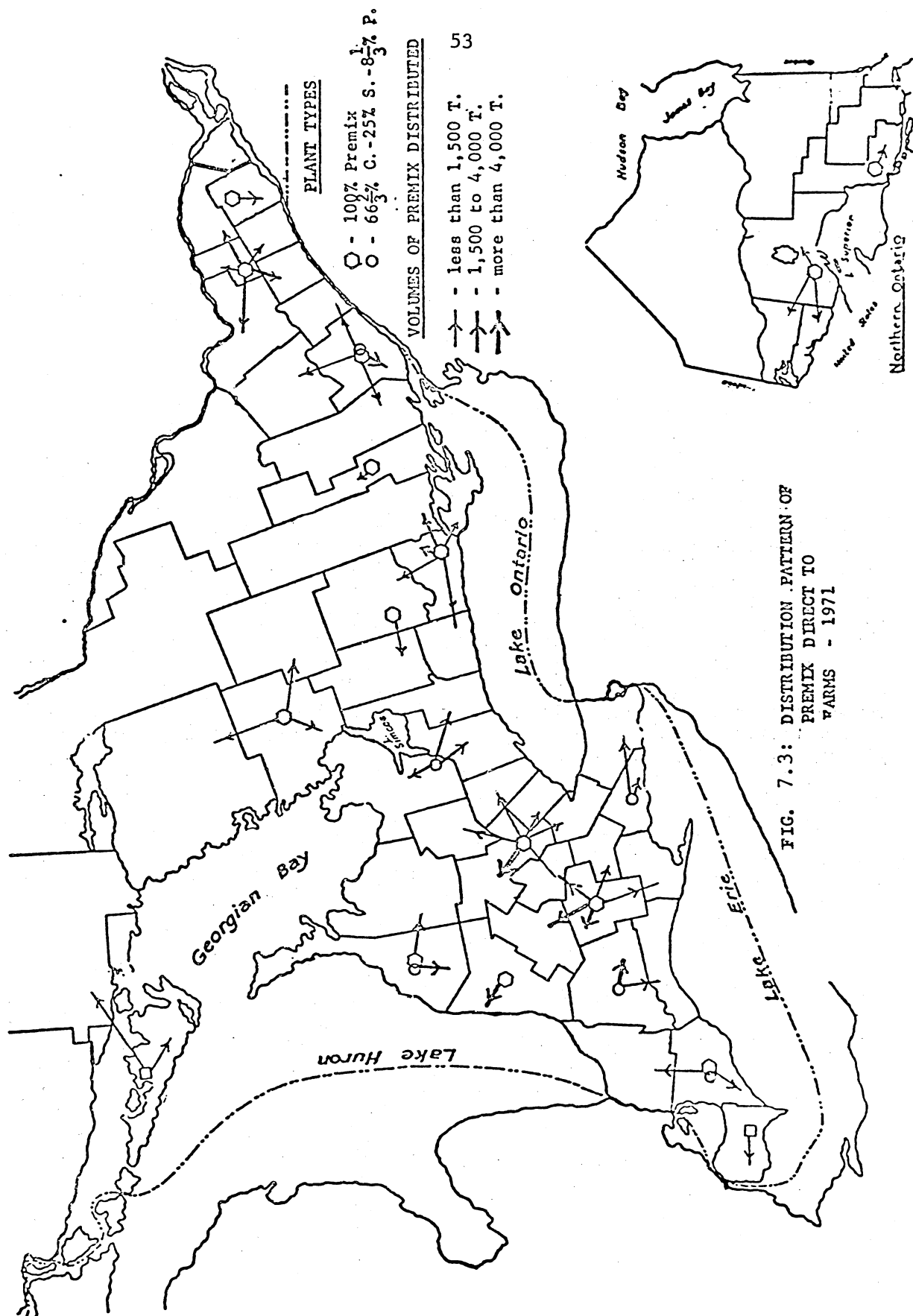


FIG. 7.3: DISTRIBUTION PATTERN OF PREMIX DIRECT TO FARMS - 1971

expected for premix because of the relatively low costs of shipping this high value product.

7.2 Least Cost Structure for 1980

The above discussion demonstrates the existing and optimum structures of the feed industry in 1971. The optimum structure indicates that the existing industry structure should undergo substantial adjustment. However, the question that must be raised is should it adjust toward the 1971 optimum or is there a different optimum for the longer run? To answer this question, the location model was run again using the projected feed grain availabilities and final demands developed in section 5.0 for 1980.

When the model was run using the 1980 situation, a stable solution was reached after eight iterations. The solution included sixty-six plants. The plant locations and their volumes in the optimum solution are shown in Table 7.4. When this solution is compared to the 1971 solution in Table 7.4, it is clear that the two are very similar. There are two fewer plants in the 1980 solution and only a few minor changes in plant size and location. In general, these changes tend to move a larger proportion of total feed milling capacity toward Western Ontario. This occurs because the livestock projections call for a continued high rate of growth in livestock production in that region. As a result, the percentage of total manufacturing volume in the five regions for 1980 is as follows: South, 36.3 percent; West, 36.7 percent; Central, 12.0 percent; East, 13.3 percent; and North, 1.7 percent. The close association of manufacturing volume with livestock production implies that the location decision is heavily dependent upon the costs of distributing feed from the plants to livestock producers.

TABLE 7.4: Plant Locations and Volumes in the Solution for 1980 by Plant Type

PLANT TYPE		100% Supplement		100% Premix		50% Complete- 50% Supplement		66 2/3% Complete 25% Supplement 8 1/3% Premix	
Location	Volume (Tons)	Location	Volume (Tons)	Location	Volume (Tons)	Location	Volume (Tons)	Location	Volume (Tons)
0701	4168.99	0401	175.97	0101	387.79	2815	23550.5	0303	58145.43
2006	25827.17	0906	978.91	0303	10955.68	4302	30564.08	0401	8826.22
2702	843.61	1601	447.38	0401	1078.15			0701	11003.06
3410	19384.95	3414	23530.52	0906	1657.67			1318	99009.90
3703	66947.77	3805	170.23	1101	3096.22			1403	100000.00
4302	10488.74	0915	219.51	1202	767.51			1601	13045.34
5106	74574.72	5106	25425.28	1318	990.10			1816	76163.42
5413	43502.61	5413	8700.52	1404	16696.60			2003	43045.28
				1816	761.63			2109	71737.48
				1821	13140.27			2302	51742.31
				2003	14611.41			2610	100000.00
				2109	717.37			3107	94242.39
				2302	5719.00			3408	100000.00
				2402	1376.04			3411	100000.00
				2614	8105.75			3904	76751.37
				2902	340.21			4003	15209.24
				3104	9386.34			4203	18865.18
				3107	942.42			4404	100000.00
				3205	695.41			4601	9497.16
				3303	955.08			4701	6794.28
				3414	53644.58				
				3805	637.61				
				4203	188.65				
				4302	19984.27				
				4701	67.94				
				4702	1017.66				
				5209	70949.65				
				5413	10019.19				

8.0

SUMMARY AND IMPLICATIONS

This study has been concerned with assessing the adjustments which have taken place in recent years in the Ontario feed milling industry and with projecting the adjustments which should occur in the future.

8.1 Summary

The study has shown that significant adjustments have occurred over the past few years in the regional location of livestock production and in the proportion of livestock feed which is mixed on the farm from home grown feed grains and purchased supplement or premixes. As a result, the feed milling industry has changed in four ways. First, the number of feed mills has decreased while the average size of mills has tended to increase. Second, milling capacity appears to have concentrated in those regions of the Province which have heavy concentrations of livestock production. Third, it would appear that livestock producers have tended to by-pass the traditional small local mill and purchase their feeds from larger plants. This would imply that over-capacity probably exists in the industry in the form of smaller milling plants. Fourth, the product mix, particularly of the larger manufacturing firms, has adjusted to include a larger component of premixes and supplements relative to complete feeds in response to the increased farm demand for these products.

In order to assess the efficiency of the existing industry structure in 1971 and to project the optimum structure for 1980, a linear programming model of the industry was developed. The general objective of the model was to find the industry structure, in terms of the size, number and location of feed plants, which would minimize the total costs to the industry of assembling feed grains, manufacturing feed and distributing it to livestock producers in the Province. The model included 54 grain producing regions, 408 plant sites, each of which could establish one or more of five types of plant and 53 feed consuming regions. The model was used to find the optimum industry structure in 1971 and 1980 by developing from actual 1971 livestock data and projected 1980 data the demands for each of the three types of feed. Then equations used to estimate the costs of assembly and distribution were developed, along with long run manufacturing cost functions to estimate total per ton costs at the alternative plant sites. The long run manufacturing costs were included in the model by using an iterative procedure to incorporate the effects of economies of size.

When the model was run for the 1971 and 1980 situations, it resulted in an optimum structure of sixty-eight and sixty-six plants, respectively. The results for the two years were quite similar, thus suggesting that the optimum industry structure is relatively stable for the foreseeable future.

8.2 Implications of the Analysis

This analysis has a number of implications for the feed industry. First, when the implied least cost structure is compared with the existing

structure in 1971, it can be concluded that considerable inefficiency exists in the industry in the form of many small local mills, many of whom act as middlemen between the livestock producer and larger feed manufacturers. If the present trend toward larger farms continues and livestock producers continue to mix feed at the farm and/or purchase it in bulk form from feed manufacturers, many of the smaller plants will be under continued pressure either to expand or exit.

Second, and perhaps more importantly, when the optimum structure is viewed in light of the adjustments which have occurred in recent years, it can be concluded that the industry has been moving rapidly toward a more optimum structure. The evidence exists in three dimensions. First, the substantial decline in plant numbers and the increase in plant size indicates that the industry is moving toward a more efficient structure. Second, the regional distribution of plant capacity within the province appears to be very similar to the distribution which should exist. Third, the apparent move by many of the larger manufacturing plants to market their products direct to farms instead of through dealers is an indication that the industry is responding to the changing nature of livestock production in the Province.

Third, the analysis implies that there will be a continued tendency for the industry to establish large multiproduct plants which are capable of manufacturing all three types of feed, but that a substantial proportion of premixes will be supplied by a few large premix manufacturers which have relatively large market areas.

Fourth, it implies that in the concentrated livestock producing counties of Southern and Western Ontario, there should be large manufacturing plants in nearly all counties which distribute feed over a relatively small area. In the less concentrated livestock areas of Central and Eastern Ontario, there should be a small number of centrally located plants which distribute feed over relatively larger market areas.

The study has a number of limitations, some of which have been pointed out in the report. These include the inability of an analysis of the type attempted here to directly include all the factors which affect the size and location decisions of the industry such as the preferences that some producers have for particular brands of feed, the assumptions which were used in projecting feed demands, and the inability of the model to include regions smaller than county size. A further limitation of the analysis is the size of the model which limits our ability to use it to draw conclusions about the magnitude of costs which would accrue if a larger number of plants were maintained by the industry or if plants were located at slightly different locations than those which appeared in the optimum solutions. Because of these limitations, the analysis provides, at best, a general indication of the best long run structure of the industry. However, the results reported here do indicate that many existing feed milling firms should examine their present locations and their present sizes very closely to evaluate their long run plans and objectives. The guidelines provided by this analysis could be useful to them as a first step in developing or altering these plans and objectives.

APPENDIX TABLES

APPENDIX TABLE 1: Thirteen Homogeneous County Groupings
for Trends in Livestock Production

Region 1

<u>A</u>	<u>B</u>	<u>C</u>		<u>D</u>	<u>E</u>
Essex	Halton	Peterborough	Muskoka	Haliburton	Grenville
Kent	Peel	Lennox and	Parry Sound	Kenora	Dundas
	Simcoe	Addington	Sudbury	Timiskaming	Russell
			Algoma	Rainy River	Prescott
			Manitoulin	Cochrane	Glengarry
			Nipissing	Thunder Bay	

Region 2

Lambton
Middlesex

Region 3

Elgin
Perth
Waterloo
Wellington

Region 4

Oxford
Brant

Region 5

<u>A</u>			<u>B</u>
Norfolk		Dufferin	Durham
Haldimand		York	Northumberland
Niagara (Lincoln and Welland have been combined)		Ontario	Price Edward
Wentworth		Victoria	Hastings

Region 6

Huron

Region 7

Bruce
Grey

Region 8

Renfrew
Leeds
Frontenac
Carleton
Lanark
Stormont

APPENDIX TABLE 2: Counties in the Regions of Ontario

SOUTHERN ONTARIO	WESTERN ONTARIO	CENTRAL ONTARIO
Brant	Bruce	Durham
Elgin	Dufferin	Haliburton
Essex	Grey	Hastings
Haldimand	Halton	Muskoka
Kent	Huron	Northumberland
Lambton	Peel	Ontario
Middlesex	Perth	Parry Sound
Niagara	Simcoe	Peterborough
Norfolk	Waterloo	Prince Edward
Oxford	Wellington	Victoria
Wentworth		York

EASTERN ONTARIO	NORTHERN ONTARIO
Carleton	Algoma
Dundas	Cochrane
Frontenac	Kenora
Glengarry	Manitoulin
Grenville	Nipissing
Lanark	Rainy River
Leeds	Sudbury
Lennox & Addington	Thunder Bay
Prescott	Timiskaming
Renfrew	
Russell	
Stormont	

APPENDIX TABLE 3: Plant Locations Considered

Site Number	Location	Site Number	Location	Site Number	Location
0101	Sault St. Marie	0807	Springfield	1313	Owen Sound
0201	Brantford	0808	West Lorne	1314	Thornbury
0202	Burford	0901	Amherstburg	1315	Walters Falls
0203	Paris	0902	Belle River	1316	Warton
0204	St. George	0903	Blytheswood	1317	Williamsford
0301	Allenford	0904	Comber	1318	Markdale
0302	Belmore	0905	Cottam	1401	Caledonia
0303	Cargill	0906	Essex	1402	Canboro
0304	Chesley	0907	Harrow	1403	Cayuga
0305	Elmwood	0908	Kingsville	1404	Dunnville
0306	Kincardine	0909	McGregor	1405	Hagersville
0307	Mildmay	0910	Maidstone	1406	Jarvis
0308	Port Elgin	0911	Oldcastle	1407	Nelles Corners
0309	Ripley	0912	Pointe-Aux-Roches	1408	Selkirk
0310	Tara	0913	Ruthven	1601	Acton
0311	Teeswater	0914	St. Claire Beach	1602	Ballinfad
0312	Walkerton	0915	Staples	1603	Burlington
0313	Whitechurch	0916	Tecumseh	1604	Georgetown
0401	Cochrane	0917	Wheatly	1605	Milton
0501	Grand Valley	0918	Windsor	1606	Moffat
0502	Laurel	0101	Kingston	1607	Stewarttown
0503	Orangeville	1002	Sydenham	1608	Oakville
0504	Orton	1101	Alexandria	1701	Bancroft
0505	Shelburne	1102	Dalkeith	1702	Belleville
0601	Brinston	1103	Martintown	1703	Cannifton
0602	Chesterville	1104	Maxville	1704	Deseronto
0603	Inkerman	1105	North Lancaster	1705	Foxboro
0604	Iroquois	1106	Williamstown	1706	Madoc
0605	Morewood	1201	Spencerville	1707	Marmora
0606	South Mountain	1202	Kemptville	1708	Queensboro
0607	Williamsburg	1203	Prescott	1709	Roslin
0608	Winchester	1301	Ayton	1710	Stirling
0701	Blackstock	1302	Chatsworth	1711	Tweed
0702	Bowmanville	1303	Desboro	1801	Belgrave
0703	Campbellcroft	1304	Dromore	1802	Bluevale
0704	Orono	1305	Durham	1803	Blyth
0705	Pontypool	1306	Feversham	1804	Brucefield
0801	Alymer	1307	Flesherton	1805	Brussels
0802	Dutton	1308	Hanover	1806	Centralia
0803	Fingal	1309	Heathcote	1807	Clinton
0804	Port Stanley	1310	Holstein	1808	Dashwood
0805	Rodney	1311	Meaford	1809	Dungannon
0806	St. Thomas	1312	Neustadt	1810	Ethel

APPENDIX TABLE 3 continued

Site Number	Location	Site Number	Location	Site Number	Location
1811	Exeter	2202	Lanark	2808	St. Anns
1812	Fordwich	2203	Pakenham	2809	St. Catherines
1813	Goderich	2204	Perth	2810	Virgil
1814	Hensall	2205	Smith Falls	2811	Stevensville
1815	Kirkton	2301	Addison	2812	Thorold
1816	Londesboro	2302	Athens	2813	Vineland
1817	Molesworth	2303	Brockville	2814	Vineland Station
1818	Seaforth	2304	Gananoque	2815	Welland
1819	Shipka	2305	Lansdowne	2816	Wellandport
1820	Varna	2306	Portland	2817	Grassie
1821	Walton	2307	Seely's Bay	2901	Verner
1822	Wroxeter	2401	Wilton	2902	North Bay
1823	Zurich	2402	Tamworth	2903	Mattawa
1824	Wingham	2403	Newburgh	3001	Courtland
2001	Blenheim	2404	Napanee	3002	Delhi
2002	Bothwell	2501	Manitowaning	3003	Port Rowan
2003	Chatham	2502	Gore Bay	3004	Simcoe
2004	Dresden	2601	Ailsa Craig	3005	Waterford
2005	Ennett	2602	Arva	3101	Brighton
2006	Fletcher	2603	Belmont	3102	Campbellford
2007	Highgate	2604	Dorchester	3103	Cobourg
2008	Kent Bridge	2605	Glanworth	3104	Orland
2009	Louisville	2606	Glencoe	3105	Grafton
2010	Merlin	2607	Hyde Park	3106	Port Hope
2011	Muirkirk	2608	Ilderton	3107	Warkworth
2012	Paincourt	2609	Kerwood	3108	Stockdale
2013	Ridgetown	2610	Komoka	3201	Beaverton
2014	Thamesville	2611	London	3202	Brenchin
2015	Tupperville	2612	Lucan	3203	Brooklin
2016	Wallaceburg	2613	Melborne	3204	Claremont
2101	Alvinston	2614	Mount Brydges	3205	Greenbank
2102	Arkona	2615	Newbury	3206	Oshawa
2103	Brigden	2616	Parkhill	3207	Port Perry
2104	Camlachie	2617	Strathroy	3208	Sunderland
2105	Florence	2618	Thorndale	3209	Uxbridge
2106	Forest	2701	Gravenhurst	3210	Cherrywood
2107	Inwood	2702	Bracebridge	3301	Ashton
2108	Oil Springs	2801	Beamsville	3302	Carp
2109	Petrolia	2802	Campden	3303	Kinburn
2110	Sarnia	2803	Caistorville	3304	Manotick
2111	Thedford	2804	Fenwick	3305	Navan
2112	Wyoming	2805	Niagara Falls	3306	North Gower
2113	Watford	2806	Niagara-on-the-Lake	3307	Ottawa
2201	Almonte	2807	Ridgeway	3308	Sarsfield

APPENDIX TABLE 3 continued

Site Number	Location	Site Number	Location	Site Number	Location
3401	Bright	3902	St. Eugene	5001	Bobcaygeon
3402	Burgessville	3903	Plantagenet	5002	Coboconk
3403	Embro	3904	Vankleek Hill	5003	Dunsford
3404	Hickson	3905	Alfred	5004	Fenelon Falls
3405	Innerkip	4001	Bloomfield	5005	Lindsay
3406	Mount Elgin	4002	Consecon	5006	Oakwood
3407	Norwich	4003	Picton	5007	Woodville
3408	Plattsville	4004	Wellington	5101	Ayr
3409	Princeton	4201	Arnprior	5102	Baden
3410	Springford	4202	Cobden	5103	Preston
3411	Tavistock	4203	Douglas	5104	Conestoga
3412	Thamesford	4204	Eganville	5105	Dorking
3413	Tillsonburg	4205	Pembroke	5106	Elmira
3414	Woodstock	4206	Renfrew	5107	Floradale
3501	Burks Falls	4301	Hammond	5108	Galt
3502	Sunridge	4302	Embrun	5109	Heidelberg
3503	Powassan	4303	Clarence Creek	5110	Kitchener
3601	Bolton	4304	Casselman	5111	Linwood
3602	Brampton	4305	Bourget	5112	New Dundee
3603	Caledon	4401	Alliston	5113	New Hamburg
3604	Caledon East	4402	Barrie	5114	St. Clements
3605	Inglewood	4403	Beeton	5115	Wallenstein
3701	Rostock	4404	Bradford	5116	Wellesley
3702	Atwood	4405	Coldwater	5201	Alma
3703	Brunner	4406	Cookstown	5202	Ariss
3704	Dublin	4407	Creemore	5203	Arthur
3705	Listowel	4408	Elmvale	5204	Clifford
3706	Millbank	4409	Glen Huron	5205	Drayton
3707	Milverton	4410	Hillsdale	5206	Elora
3708	Mitchell	4411	La Fontaine	5207	Erin
3709	Monkton	4412	Midland	5208	Fergus
3710	Newton	4413	Orillia	5209	Guelph
3711	Palmerston	4414	Singhampton	5210	Harriston
3712	Rannoch	4415	Stayner	5211	Kenilworth
3713	St. Marys	4416	Stround	5212	Moorefield
3714	Sebringville	4417	Tottenham	5213	Mount Forest
3715	Shakespeare	4501	Berwick	5214	Rockwood
3716	Stratford	4502	Cornwall	5215	Salem
3801	Fraserville	4503	Crysler	5216	Glen Allan
3802	Hastings	4504	Monkland	5217	Monck
3803	Lakefield	4505	St. Andrews West	5301	Binbrook
3804	Norwood	4601	Massey	5302	Copetown
3805	Peterborough	4701	Thunder Bay	5303	Freelton
3901	St. Isidore	4702	Mokomon	5304	Hamilton
	De Prescott			5305	Sheffield

APPENDIX TABLE 3 continued

Site Number	Location	Site Number	Location	Site Number	Location
5306	Mount Hope	5405	Newmarket	5410	Unionville
5401	Gormley	5406	Nobleton	5411	Toronto
5402	Maple	5407	Queensville	5412	Woodbridge
5403	Mount Albert	5408	Schomberg	5413	Udora
5404	Nashville	5409	Stouffville		

APPENDIX TABLE 4: Number of Livestock (Five Groups) by Region 1971 and 1980

Region	Livestock Groups					- Number of Head -				
	Layers		Turkeys		Cattle		Hogs		Broilers	
	1971	1980	1971	1980	1971	1980	1971	1980	1971	1980
Algoma	50412	76307	504	688	12829	16994	1032	0	177	0
Brant	85805	8439	53613	67961	33474	38549	38380	38640	174027	219629
Bruce	191293	79418	25	0	210869	262883	109582	78478	383408	559202
Cochrane	28456	18889	30	26	10367	12372	1194	0	48	0
Dufferin	71932	0	27027	36674	63785	76948	41619	46555	107100	118278
Dundas	197258	258571	32	0	48980	49668	10445	6375	1335	0
Durham	240898	293748	1007	0	55560	56828	24657	22959	395820	621682
Elgin	213201	181117	118731	144108	55213	64409	73598	55476	286363	299557
Essex	199870	168030	58767	0	16162	17955	27520	34587	105590	97388
Frontenac	79408	105493	42	0	41429	42080	3480	537	7298	0
Glengarry	257938	414708	34	0	42485	44972	8927	7403	33167	0
Grenville	80628	72475	20	0	26298	23521	8266	5749	77100	96911
Grey	192191	43342	90527	4674	179077	222367	96825	79746	264257	532973
Haldimand	180539	182090	26890	0	44628	58520	46001	47223	264508	422930
Haliburton	9199	10179	0	0	1577	1335	217	0	30	0
Halton	117094	68096	77434	112053	22476	26670	23089	19073	472039	733783
Hastings	107467	105921	646	0	62356	50901	20169	9530	50834	21077
Huron	78940	0	246464	337581	199291	245168	204847	156974	1376451	2191970
Kenora	5124	0	41	0	3027	3076	575	118	271	0
Kent	286199	111884	67811	55427	47883	65528	113070	115525	102340	142035
Lambton	759286	990884	393080	264993	92934	104261	134849	137259	157695	195986
Lanark	59606	42371	41	0	55989	45790	10238	8979	595	0
Leeds	263221	393340	93	0	53498	51927	8845	5036	32	0
Lennox & Addington	191571	274732	2	1416	39150	37805	10159	8436	16	0
Manitowlin	6827	0	0	0	25398	29980	3313	5837	137	0
Middlesex	1032240	1410724	311914	283546	150052	178420	150681	134265	162044	468811
Muskoka	8677	4903	20003	0	3985	1884	425	169	365104	0

APPENDIX TABLE 4 continued

	Livestock Groups					
	Layers		Turkeys		Cattle	
	1971	1980	1971	1980	1971	1980
			Hogs		Broilers	
	1971	1980	1971	1980	1971	1980
Niagara	882731	1410579	573412	1035574	34648	38925
Nipissing	7997	0	0	0	15061	15774
Norfolk	93094	12023	340917	506688	20950	17975
Northumberland	252881	259013	1627	597	64672	58871
Ontario	182839	81753	28462	21360	75635	79172
Ottawa-Carleton	164492	186097	427	0	87101	79763
Oxford	41331	258362	567642	797302	123608	143094
Parry Sound	8948	0	239	0	13549	10241
Peel	38053	0	85615	35524	39262	44163
Perth	602161	632613	132017	98756	154620	194566
Peterborough	52491	11799	1310	0	48538	46776
Prescott	377226	638243	5	0	49203	55839
Prince Edward	130079	45771	14	0	29229	30417
Rainy River	12520	256	79	104	21211	26474
Renfrew	53698	0	2428	0	77848	73441
Russell	44193	0	0	0	32834	52440
Simcoe	236788	123278	50743	48776	138199	145356
Stormont	54627	25825	113	0	36364	36778
Sudbury	48942	59992	31	0	8723	6887
Thunder Bay	118783	159226	23	0	12092	13148
Timiskaming	33497	24626	2	0	25807	32804
Victoria	49754	1152	9513	5119	71809	79901
Waterloo	500024	410618	216218	180500	83124	103072
Wellington	406783	239957	151165	179581	141339	173932
Wentworth	265615	336600	49718	0	30205	31695
York	163959	84337	59275	41483	47812	46616
					56349	62395
					2421	0
					27414	30725
					27658	28392
					46524	52662
					15086	1250
					153289	55038
					1612	0
					18027	8368
					222711	230013
					12665	8371
					11174	6661
					10320	5976
					956	0
					10590	12324
					5332	8056
					90102	105132
					11442	12327
					1281	21
					2965	885
					5443	2455
					23270	20002
					149990	223376
					183094	21002
					48886	44000
					51063	68599
					2212802	3833791
					35	0
					493243	725580
					242218	396185
					464255	490992
					3729	0
					412912	686733
					22	0
					49430	0
					1274517	1420515
					240877	416814
					266	0
					149600	304442
					374	0
					1591	0
					50	0
					529716	634028
					1375	0
					15	0
					297	0
					106	0
					95934	168995
					769210	1295847
					1409627	2571805
					1146279	1645538
					741407	903089

APPENDIX TABLE 5: Consumption of Complete Feed, Supplement and Premix
by Region, 1971 and 1980

Region	Complete Feed		Supplement		Premix	
	1971	1980	1971	1980	1971	1980
(Tons)						
Algoma	2604.56	2232.70	524.00	413.67	267.24	387.79
Brant	16538.87	15747.49	3305.28	2040.97	1259.83	2706.38
Bruce	53946.45	38957.44	7707.33	5158.75	3365.20	5725.56
Cochrane	2240.33	1124.84	321.83	266.68	180.17	207.29
Dufferin	22386.63	22019.24	2552.25	1487.88	1057.70	2088.70
Dundas	14582.46	12768.84	3530.90	3144.82	2037.97	2602.41
Durham	16680.27	15538.63	3484.45	2044.95	1217.24	2858.83
Elgin	26622.03	19685.76	5772.20	2252.40	1887.54	3799.35
Essex	19215.97	19786.92	2301.28	978.91	715.27	1657.67
Frontenac	9268.52	5780.51	1629.22	1244.87	991.55	1007.01
Glengarry	11758.80	12767.29	3572.13	2889.89	1824.11	3096.22
Grenville	9925.18	8607.90	1558.70	1046.92	786.48	1014.09
Grey	62709.23	51339.41	6198.02	4250.55	2723.18	4648.67
Haldimand	27477.17	30112.27	4216.38	3379.58	1692.52	3974.05
Haliburton	751.45	467.22	2.79	.05	1.94	.04
Halton	9882.23	8740.38	3404.94	2012.82	999.99	2924.07
Hastings	22084.93	12552.15	2770.79	1434.78	1576.36	1238.14
Huron	71431.68	52040.39	18403.66	9139.61	5860.22	13140.27
Kenora	1182.13	346.15	65.20	35.18	45.29	24.44
Kent	36734.57	34880.59	5630.21	2051.26	1446.10	4791.52
Lambton	46951.82	48064.11	10708.64	4792.61	2844.37	9017.45
Lanark	9488.33	6393.90	1820.99	771.28	1066.58	754.48
Leeds	14063.32	13885.04	3273.04	2650.97	1743.75	2426.00
Lennox & Addington	13943.48	10190.19	1887.12	1401.47	960.67	1376.04
Manitoulin	2572.10	3438.77	291.11	67.60	178.88	116.49
Middlesex	52158.38	51561.04	14199.49	8212.31	4577.56	12306.40
Muskoka	1705.62	367.19	1058.71	.21	210.74	.15

APPENDIX TABLE 5 continued

Region	Complete Feed		Supplement		Premix	
	1971	1980	1971	1980	1971	1980
	(Tons)					
Niagara	24104.45	28854.23	14658.64	10180.67	3228.79	16696.60
Nipissing	3357.62	1857.37	585.22	488.48	378.33	339.29
Norfolk	15229.13	15138.15	4287.91	2459.52	1062.39	3995.67
Northumberland	21350.84	20172.16	3953.67	2309.28	1727.35	2799.23
Ontario	25915.33	26263.70	5109.48	2958.58	2039.03	3768.58
Ottawa-Carleton	14527.23	13001.94	4782.38	3693.95	2823.54	3131.58
Oxford	56692.03	29325.29	15173.04	8993.23	5652.89	10075.34
Parry Sound	3349.32	9.19	228.92	1.33	159.00	.92
Peel	9632.78	5038.95	2353.19	1323.52	1094.09	1165.87
Perth	80399.04	84993.12	18770.22	12547.44	6702.41	16925.59
Peterborough	10910.39	6362.94	2085.37	1063.51	935.33	1301.92
Prescott	14256.63	14577.90	4501.31	4571.03	2312.27	4201.68
Prince Edward	11059.85	8516.52	2161.11	1442.38	991.14	1188.22
Rainy River	1588.73	466.10	298.71	213.67	194.61	148.51
Renfrew	13687.81	10782.30	1639.34	1161.90	1063.43	955.08
Russell	7076.53	10829.22	2215.22	3484.23	1416.44	2546.86
Simcoe	46103.41	49571.72	7315.33	4379.80	2839.12	6064.34
Stormont	12605.69	13249.01	2261.91	2167.57	1392.20	1694.56
Sudbury	2981.69	691.63	359.77	113.59	159.85	163.21
Thunder Bay	5114.28	3739.92	955.85	785.97	454.53	761.30
Timiskaming	6340.10	4788.73	984.71	968.44	627.52	715.73
Victoria	22734.56	11991.04	1867.98	396.57	878.82	695.41
Waterloo	52023.13	70564.00	12046.32	8278.96	3767.83	13845.11
Wellington	62308.43	73881.60	15529.94	10510.34	5094.07	16548.31
Wentworth	20508.96	19808.75	4299.92	3803.81	1473.95	5902.80
York	20984.88	22606.22	5567.52	2878.33	1822.29	4880.07

APPENDIX TABLE 6: Grain Supplies in Corn Equivalents
for 1971 and 1980 by Region

Region	Grain Supply	
	1971 (Tons)	1980 (Tons)
Algoma	8000.51	0
Brant	163717.71	199564.20
Bruce	214894.71	219084.93
Cochrane	6353.29	0
Dufferin	99571.43	96015.86
Dundas	59222.70	49738.24
Durham	94249.59	88644.38
Elgin	304844.41	370426.57
Essex	296824.49	418190.63
Frontenac	24028.46	22156.67
Glengarry	46164.40	32138.47
Grenville	28103.89	28800.74
Grey	183734.67	96402.99
Haldimand	126736.57	180327.00
Haliburton	590.71	0
Halton	56048.69	150237.00
Hastings	60782.17	36737.14
Huron	489674.05	402795.84
Kenora	4774.14	4203.59
Kent	680894.18	943785.05
Lambton	356873.60	531912.62
Lanark	26212.61	11363.63
Leeds	32864.49	29089.52
Lennox & Addington	36180.10	31986.29
Manitoulin	7393.79	2308.04
Middlesex	463427.10	579572.07
Muskoka	1397.66	0
Niagara	89036.86	89289.75
Nipissing	9170.17	0
Norfolk	168341.39	288442.68
Northumberland	86680.73	80439.85
Ontario	132159.49	112668.63
Ottawa-Carleton	87274.58	55455.59
Oxford	364069.98	445498.30
Parry Sound	6371.54	734.80
Peel	74538.03	149963.64
Perth	374871.77	365554.02
Peterborough	40530.37	16009.09
Prescott	60080.10	52737.94
Prince Edward	53675.61	64771.05
Rainy River	7767.95	2155.21

APPENDIX TABLE 6 continued

Region	Grain Supply	
	1971 (Tons)	1980 (Tons)
Renfrew	59449.01	3011 .18
Russell	38126.65	35104.28
Simcoe	239998.91	174778.95
Stormont	34346.19	26100.53
Sudbury	6634.61	334.87
Thunder Bay	8774.42	5700.34
Timiskaming	38958.12	40156.84
Victoria	71339.64	48288.31
Waterloo	198322.94	127445.99
Wellington	283265.28	299833.73
Wentworth	99432.99	127825.17
York	148842.36	126132.98

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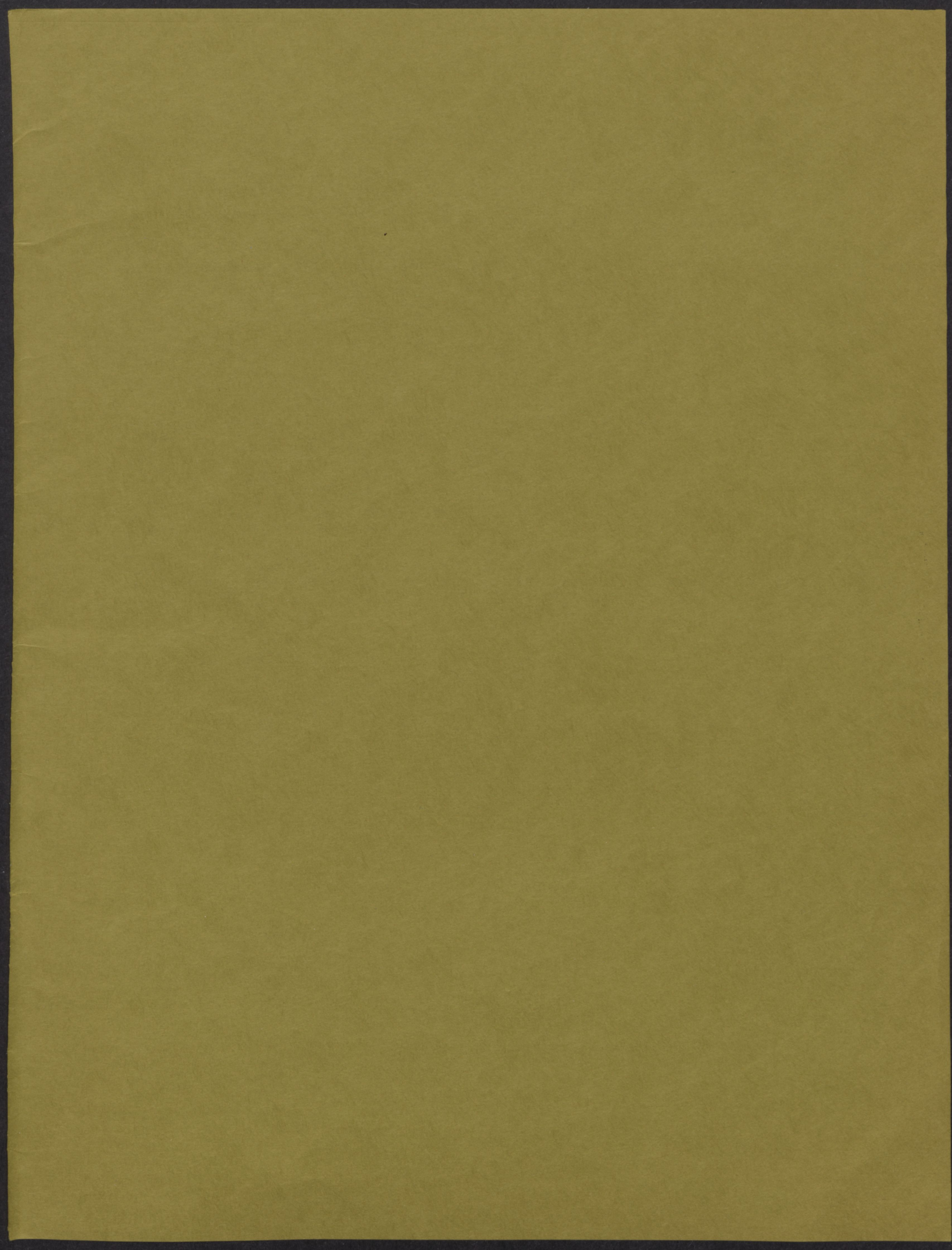
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