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Signed by the final examining committee:

Will Candler, chairman

John E. Kadlec

James R. Foster

Robert A. Meyer

Ludwig Eisgruber

Approved by the head of school or department:

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W. V. Candler
Professor ~~in~~ charge of the thesis

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ABSTRACT

Strom, Jay Loren, Ph.D., Purdue University, May, 1973, Simulation of a Swine Breeding Herd. Major Professor: W. V. Candler.

While very important to Indiana farmers, swine production is a complex and uncertain economic and technical enterprise. Uncertainty complicates farmers' management decisions, yet computer models for extension have largely ignored the stochastic nature of production. An objective of this study was to provide a model to aid in analysis of swine management decisions which involve stochastic outcomes.

Swine producers are faced with stochastic outcomes for survival, estrus, conception, litter size and growth rates which affect the scheduling of the herd for breeding, culling, and sales as well as for the use of buildings and equipment.

Stochastic and integer elements in swine planning models either cannot be incorporated in traditional modeling techniques or expand them beyond the capacity of currently existing computing technology.

A Markov type model was developed and demonstrated by implementing a small scale monthly example model of a swine herd. The full scale research model was implemented as a computer program (simulation). Central emphasis of the model is the problem of scheduling the herd through buildings. Control variables include farrowing, breeding, culling, and sales dates and criteria along with the parameters

which define the random variables of production and survival. A six farrowings per year system was modeled.

An input-output form is used to facilitate use of the model by research workers and to define those control parameters which are optional to the user of the computer program.

The primary disadvantages to the modeling procedures chosen were those of implementation which resulted in a relatively large and complex computer program requiring long run times. The simulator, despite its high cost of operation,may be both a cheaper and faster method than experimentation with live animals.

Illustrative examples of the output of computer runs are presented. The program will be most useful when used to test the feasibility of swine management strategies or to generate production outcomes as in an experimental setting.

CHAPTER 1

INTRODUCTION AND THESIS GUIDE

Swine production is one of the most important livestock industries. In Indiana, farmers consistently market 6.5 to 7.0 million head of hogs annually, contributing over 300 million dollars to annual cash farm income. During the period 1965-1970, swine production accounted for 45% of all livestock sales and over 24% of sales from all commodities marketed from Indiana farms.[1/]

While very important to Indiana farmers, swine production is a complex and uncertain economic and technical enterprise. The complexity is due in part to the uncertainty involved in the production process, where uncertainty reveals itself in the stochastic nature of conception, litter size, survival, growth, etc. The complexity of technical production is evident when breeding, farrowing, weaning, culling, and sales must be scheduled. Both technical complexity and uncertainty complicate economic decision making.

Knowledge about the outcomes of management decisions can be gained by experimenting with real herds. This method of learning is, however, a slow and tedious process, and involves a relatively high cost. Experiments which require the sacrifice of a large number of animals can be prohibitive, yet the importance of the swine enterprise indicates the need for knowledgeable decisions on the part of the swine producer.

1/ Based on United States Department of Agriculture Statistics for the years 1965-1970 [38].

Computer modeling has been used as an alternative to experimenting with real herds. Previous computer models have abstracted from the risk and uncertainty involved in swine production even though this aspect is central to the swine producers planning problem. Extension models for swine production decision making have assumed non-stochastic performance rates without giving attention to stochastic elements operating in the swine herd. These models are most appropriate for finishing, the least uncertain and most routine aspect of the production process.

Given the stochastic nature of the problem, can computer models be used to help researchers in their analysis? Can they be used in extension work with farmers? Is it technically possible to build an appropriate computer program and is such a computer program even economical for use in research or extension? These questions motivated development of a research model appropriate to at least some of the most important planning problems of the swine producer. This model may ultimately lead to further development of research and extension models for analysis of swine producers problems.

1.1 Modeling Swine Production

This section first presents a discussion of the terminology revolving around the use of the words "model" and "simulation" as used in this study. The nature of the production problem is then presented, followed by a discussion of the management practices used in a swine breeding herd.

1.1.1 Definitions

A model is an abstract representation of the real world. The art of model building is built upon the appropriate degree of abstraction. For example, abstraction which may be legitimate for extension purposes may be quite inappropriate for research purposes. A model includes important elements so that it can provide a useful representation without containing the great many details of the real world.

A Conceptual model ideally defines all the significant relationships of a system in a logical and concise manner. Its purpose is to define and clarify (conceptualize) the relationships of the system under investigation. A researcher may be able to express a set of mathematical equations which define all the important relationships of a simple system, but more often he must turn to summarization and abstraction by making only the more important relationships explicit in abstract graphical, narrative or mathematical expressions.

A mathematical programming model at once connotates both the well known structural framework of the programming procedure (model) and the solution procedures (algorithms) of that type of mathematical problem, if they are known.[1/]

An algorithm is a computational method for deriving numerical solutions to a model [40, p.80]. In particular for this study, an algorithm is the solution procedures and techniques organized in computer program form.

1/ Linear Programming, for example, defines a mathematical programming problem (accepted structure and assumptions) for which the Simplex method is one of the solution techniques (algorithms).

A research model contains the essential structure and those variables chosen as necessary to adequately represent the problem being modeled, yet permit implementation as a computer program to permit experimentation with the model.

An extension model as opposed to a research model, must permit routine use by farmers or extension personnel. A notable characteristic is the importance of computer efficiency and Input-Output forms.

Simulation is use of a computer program (simulator) to study a quantitative model. Given an objective function it may, or may not, involve procedures aimed at finding a "good" solution to the model. Obviously, if there is no objective function, as in this study, such procedures are irrelevant. It is assumed the model being studied is stochastic.

An experiment consists of repeated runs of the simulation (where a run refers to one pass through the simulation from input to output) with given parameter values of interest. Repeated runs are required because outcomes are stochastic. An experiment allows evaluation of if ... then statements, i.e., if the parameters are at level X then we can expect an outcome with an associated Mean, Range, and Variance.

1.1.2 Nature of the Production Problem

If a producer has decided to produce hogs with a breeding herd, has a given herd inventory, has a set of facilities and labor committed to swine production, then his problem is to economically schedule those committed resources and carry out his production plan.

The results from given production plans are subject to major uncertainties. Physical uncertainty is recognized by the producer in expecting disease to strike sometime, in recognizing that a whole group of sows may be relatively infertile, and that virtually a whole farrowing of pigs may be lost if an epidemic baby pig disease should strike.

Other uncertainties are less drastic to the execution of a management plan. Most of these involve risk in the traditional sense that a statistical mean and probability distribution can be estimated which may be useful in a decision model. For example, the length of the estrus cycle, the likelihood of pregnancy if serviced, the likelihood of farrowing if in gestation, and the number of pigs farrowed are all stochastic variables which are often explicitly modeled as non-stochastic variables, possibly at their mean values, for planning purposes. This simplifies the modeling process but ignores important questions in the breeding and scheduling of the herd for given facilities.

Stochastic and integer elements in swine production need to be incorporated into decision models to increase their usefulness.[1/] These elements either cannot be incorporated into traditional modeling techniques, and/or expand the traditional models beyond the capacity of currently existing algorithms and computing technology. Linear programming cannot be used to handle uncertain or integer aspects of the swine production problem. Therefore, application of other modeling methods seems appropriate.

1/ Section 1.1.3 discusses management practices which lead to the need for recognizing integer aspects of the problem. Objectives of the study appear in section 1.2. Section 2.1 includes a discussion of the stochastic nature of swine production. Section 2.3 is a review of previous studies. See section 1.3 for a guide to the thesis.

1.1.3 Management Practices

The manager's major scheduling decisions revolve around conflicting goals. His problem is a dynamic one, characterized by the changing structure of the herd, and imperfect knowledge as to outcomes of his production plans. The production manager's job involves a large number of scheduling decisions; number of animals and dates must be chosen for breeding, farrowing, moving animals, culling, and selling.

Popular management practices aimed at controlling the incidence of disease, require emptying and cleaning farrowing buildings after periodic farrowing. In addition, producers can tightly group farrowing dates with the goal of a uniform group of baby pigs which can be grown to sale weights in relatively uniform pen lots. Weaning dates also can be adjusted to make sows available for breeding for tightly grouped target farrowing dates, but this competes with the nursing requirements of the baby pig.

The swine herd is usually housed in several specialized buildings. A sow maintenance, breeding, and handling area or building is one such facility. Farrowing and nursery buildings or some combination comprise a second major category with finishing facilities constituting a third.

Reduction of the number of sows maintained, and hence reduction of feed, housing, and labor cost, is an objective in conflict with the requirement of a large pool of sows available for breeding to fill facilities on target farrowing dates.

Culling practices reflect a conflict between revenue from and productivity of butcher hogs, gilts, and sows. A large number of gilts and sows in the breeding herd delays recovery of their market value as well as resulting in high maintenance costs. Income tax considerations, especially the possibility of capital gains for the sale of sows may also influence culling policy.

Disruptions of the social order among animals in any one pen is avoided by starting animals of similar size and age together; then further intermixing is avoided when possible. Few animals in any one pen, and hence better pig performance, is an objective in conflict with the goal of maximum utilization of available facilities. Housing few animals in each building as a precaution against disease, conflicts with the need for efficient labor and building utilization.

In addition, the manager must decide on ration composition, feeding rates, health care, genetic improvement, investment in facilities, etc. As the above discussion has shown, production scheduling is a vital part of over-all swine management decision making.

1.2 Objectives of the Study

The objective of this study was to explore the feasibility of modeling the stochastic and integer elements of swine production in a way which would be helpful for the study of at least one swine production system. Emphasis was on the scheduling problems of a swine breeding and finishing herd as opposed to an operation involved exclusively in finishing purchased feeder pigs.

The Specific Objectives of this study were:

1. To identify stochastic, uncertain, and integer elements which are of importance in modeling swine production,

2. To search for an appropriate approximating[1/] model,
3. To implement that model in the form of an operational computer program for use by research workers, and
4. To demonstrate solutions to the approximating model.

1.2.1 Discussion of the Objectives

Identification of stochastic, uncertain, and integer elements is a process which continued throughout the study. These elements were hypothesized and included as attributes of the model, however, their relative importance in modeling the swine breeding herd cannot be answered until some experience is gained from use of the model as an experimental tool.

The results of the search for modeling alternatives are discussed in Chapters 2 and 3.

The third objective involved the construction of a research model,[2/] and its implementation by simulation. The model constructed was a non-adaptive management system simulator which tested the feasibility of scheduled mating strategies, estrus control and the like.

1/ Approximating in the sense that modeling approximates by excluding variables to permit analysis. For a discussion of variables required and those excluded from this model, see section 2.1 of the following Chapter.

2/ The term "research model" places emphasis upon structural flexibility and the ability to experiment with the model as opposed to the requirements of a model which is for routine use by extension personnel. Computer software, as well as modeling objectives, may be quite distinct for an extension model as compared to a research model. See Candler, Boehlje, and Saathoff [6, pp. 71-80].

1.3 Thesis Guide

In accordance with the second objective listed above, Chapter 2 explores alternative model types which could be used, and reviews previous studies.

Chapter 3 reports the work which led up to the research model. A conceptual model was constructed and then demonstrated by making it operational in small scale examples. Shortcomings of the demonstration models led to Chapter 4 which shifts attention to the full scale research model by presenting a statement of the model, and its implementation as a computer program.

Chapter 5 demonstrates use of the model by presenting illustrative results.

Over-all summary, limitations and implications are given in Chapter 6.

The Appendices contain FORTRAN IV coded listings of the model, and a copy of the Input-Output forms.

CHAPTER 2

MODELING ALTERNATIVES AND PREVIOUS STUDIES

Chapter 2 first presents a discussion of the variables required in a model of a swine breeding herd. Attention is then turned to the modeling alternatives available for handling these variables and finally presents a review of some previous studies of swine production.

2.1 Variables Required in the Model

A swine production scheduling model must be able to handle the time dimension of swine production, perhaps in discrete time intervals of hours, days, weeks or months. In addition, the uncertain nature of swine production dictates that the model include stochastic variables. This is discussed further in section 2.1.2.

The need to clean out facilities completely, for disease control, dictates integer variables in the model: either the facility is cleaned out, or it is not. From the disease control viewpoint, a half cleaned out building, is still dirty.

The following management practices were incorporated in the model: (a) periodic building emptying and cleaning, (b) grouping of animals for housing assignment, (c) planning of breeding, culling and replacement for target farrowings, and (d) movement of animals from building to building.

Ideally, this thesis would have produced an adaptive research model [1/] in which management strategies would be defined for all possible outcomes. At the present stage of our knowledge of swine herd scheduling, this was felt to be too ambitious an objective. Accordingly, a non-adaptive model was developed.[2/] In the present model, animals survive and space is either exceeded or is not, there are sufficient sows in the herd for breeding the target number of litters for each farrowing or there are not, and so on. A non-adaptive model carries out a management plan and notes the results. In particular, it notes the types of infeasibilities that occurred and their frequency. It does not consider the wide range of alternative management strategies open to a farmer who perceives the danger of infeasibility.[3/]

Control variables permitted experimenting with management

1/ An adaptive model is defined for the purposes of this study to mean a model which adapts by choosing among classes of strategies, the action to be taken in response to improved information. For example, an adaptive model would determine sow replacements by first making an inventory of those expected to be available for breeding, and comparing this with the expected number required, to determine the number of gilts selected for replacement. The non-adaptive model developed here selects a predetermined number of replacements without regard to the condition of the breeding herd.

2/ The computer program implementing the model did, however, permit inclusion of simple adaptive techniques. These included restricted weaning and moving of pigs when buildings became full, and altered conception rates when boars were found to be in short supply. For a discussion of these and other features of the research model implemented in the form of a computer program, see Chapters 4 and 5.

3/ At worst, the farmer can usually sell stock to correct building overflow, albeit at a discount.

policies,[1/] these are discussed in the following section.

2.1.1 Control Variables

Control variables are necessary to allow the researcher to perform experiments with the model and to define management policies. The more important control variables for a swine management policy might be defined as:

1. Gilt and boar selection for the breeding herd
   - 1.1 Number to select,
   - 1.2 Time at which new gilts and boars are brought into the herd, and
   - 1.3 Criteria for selection.
2. Farrowings and their target dates
   - 2.1 Number of farrowings per year and their intervals,
   - 2.2 Target number of days or weeks continuation, and
   - 2.3 Relative proportion of sows and gilts.
3. Target number of litters
   - 3.1 Percent "over breeding" to obtain enough litters to fill the farrowing house, and
   - 3.2 Disposition if over filled.

1/ In this thesis a strategy was used as in the literature on decision theory: Brown [4], Fishburn [9], Schlaifer [32], and Wagner [40]. "A strategy is a rule which prescribes exactly what act shall be chosen in every situation in which a choice may have to be made...," Schlaifer[32, p.60]. A strategy involves an appropriate decision for each possible state of nature. A management policy is defined as an *ex ante* set of objectives for the performance of the system. Thus, a policy may prove to be feasible or infeasible while a strategy is always feasible.

4. Selection and culling rules

    4.1 Selection and culling of the breeding herd, and

    4.2 Criteria for sales of butchers, old sows, and boars.

5. Space assignments

    5.1 Age and/or weight variables to define space assignment,

    5.2 Maximum number of sows or pigs per building.

2.1.2 Stochastic Variables

Stochastic variables,[1/] proposed as both random variables and of major importance in swine production, include (a) survival, (b) rate of gain, and (c) variables associated with the breeding-gestation of sows and farrowing of baby pigs.

Survival is an attribute of all animal categories throughout all time periods. However, survival has a specific probability distribution according to the age of the animal, and productive classification. Survival can be represented by a 0, 1 variable, i.e., there is survival to the next time period or not.

Rate of gain is also an attribute of all animals and has a specific probability distribution according to productive classification, and age.

Stochastic variables associated with breeding, gestation, and farrowing include (a) the uncertainty of detection of heat in the sow, (b) boar availability at a particular time, (c) conception rate,

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1/ These are also "control variables" from the point of view of the research model in the sense that the researcher specifies the distribution from which these values are drawn to run an experiment.

(d) embryonic mortality, (e) abortion, (f) stillbirths, and (g) the number of pigs born alive. Emphasis is placed on the stochastic elements of sow productivity because this is considered a most uncertain aspect of swine production. It is vital to model these important variables when modeling the stochastic nature of swine production.

2.1.3 Variables Not Included

Some other important features of swine production have been modeled by animal scientists and extension workers using traditional budgeting techniques. Labor requirements, and feed utilization are two aspects of swine production which have been included in deterministic budgets. A major part of the stochastic nature of feed utilization is directly associated with the incidence of disease. The day-to-day scheduling and handling of feed is primarily dependent upon the number and kinds of animals in the herd. For the purposes of this study, however, feed was assumed available but accounted for only as a simple cost of production based on weight gain. This simplification permitted the stochastic features of other variables to be modeled in more detail.

Labor available and the labor requirements of swine are major decision variables in the choice of enterprises for a farm plan. Labor requirements in swine production are stochastic as a result of the stochastic nature of the production processes. Labor was accounted for as a simple calculation of variable labor based on daily building inventories.

Contagious disease has repercussions on a swine breeding herd. The incidence of disease is a stochastic variable which greatly affects the payoff of management strategies. However, this aspect of the swine producer's problem was judged to be too complicated for a first attempt at modeling the swine breeding herd with stochastic variables. At best, inclusion of contagious disease would greatly complicate evaluation of the model because of its unpredictable and low incidence of occurrence.

Variables which would have allowed alternative farrowing systems were not included. Modeling of additional farrowing systems would have greatly expanded the size and complexity of the model. Each farrowing system considered would have required rearrangement of the opening inventory configuration. Each farrowing system would also have required a unique set of culling and selection rules to properly time breedings for target farrowing dates. Modeling a single system reflects a producers short term planning problem once a farrowing schedule has been decided. Comparison of systems would have involved many of the aspects of a unique model for each system.

A continuous time variable is another feature not investigated. One choice of time interval thought to provide sufficient realism is one day. A shorter interval would constitute more realistic modeling, i.e., be closer to the reality of continuous time. However, modeling hour by hour as compared to day by day would expand the size of model considerably. The number of states of nature are increased drastically, as well as the computations necessary to run the model, for a given experience interval of several years. These two factors combined would appear to be likely to have an exponential effect on the computer run time required for solution and at least a multiplicative effect on the number of relationships (complexity) in the model.[1] It is expected that more comprehensive extension models would use a day as the minimum and possibly a week or month as the basic time interval in a model of a swine production system.

Genetic inheritance as well as some environmental factors such as temperature, humidity and others considered under the title "stress" are significant determining factors of swine production. Many of these factors have been ignored or modeled in simplified, indirect or abstract ways in this study. It is hoped that experience gained in modeling stochastic variables may lead to more realistic treatment when comprehensive swine production models are constructed.

2.2 Modeling Alternatives

Exploring possible modeling techniques to discover the relative merits of some types that might be used is the general objective of this section. This study assumes there exists the motivation to model a swine breeding herd as part of the extension-research objective of developing computer models for farm planning decisions. Modeling is an accepted part of the scientific method, and computer modeling is already in use as an extension tool[2] to aid in decision

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1/ A vivid picture of this point can be seen by comparing the simplified 6-month models presented in section 2.2.1 and 2.2.2 with the monthly models in Chapter 3.

2/ Purdue University has several models operational as extension tools in the Top Farmer series of workshops. One of these: "Simulated Near-Optimal Growth Paths for Hog-Corn Farms Under Alternative Resource, Price and Efficiency Situations," is reviewed in section 2.3.3. Many other universities report operational computer programs in farm management [20].

making for the farmer. Model building is an integrated part of scientific philosophy: Naylor [25, p.5]

> "In its present day form scientific philosophy or the scientific method, as it is frequently called, consists of four well-known steps,
>
> 1. Observation of a physical system.
> 2. Formulation of a hypothesis (or in our case a mathematical model) that attempts to explain the observation of the system.
> 3. Prediction of the behavior of the system on the basis of the hypothesis by using mathematical or logical deduction, i.e., by obtaining solutions to the mathematical model or models.
> 4. Performance of experiments to test the validity of the hypothesis or mathematical model."

According to Naylor [25], it may not always be plausible to follow these four steps for a particular problem. An appropriate model may be a satisfactory substitute for steps in the procedure which cannot be expedited otherwise. It would surely have been too expensive to experiment with a swine breeding herd over the extended period of time required to generate the data desired for analysis in this study.

The complexity of the problem puts a severe restriction on the solution algorithm. One cause of this complexity is the large number of classifications of animals in the herd. It may be impossible to describe all the interrelationships with a relatively small set of mathematical equations. It is virtually impossible to describe the many probabilistic interactions necessary to obtain an analytical solution mathematically.1/

1/ An attempt at describing a herd as a binary model of 0, 1 variables with various subscripts for animal characteristics grows into a huge number of combinations for all but the simplest of models. See section 3.1.1.

Alternative models must be judged on the basis of the type of problem and objectives of the study. As will be seen, a Markov chain [1/] type model structure was selected. Modeling procedures of the following types will be discussed: (a) Models that lead in principle to known analytical algorithmic solutions.[2/] (b) Models useful for demonstration of the nature of the problem and the type of modeling procedures which will handle a problem of this nature, and (c) Simulation. The choice of a modeling technique is influenced by two levels of research: ultimate operational decision models for extension use and the more basic research of this study. For a research model it may be useful to go beyond the level of detail appropriate for an applied model. Simplifications can be made after obtaining basic experience with a research model.[3/]

2.2.1 Discrete Stochastic Programming

Discrete stochastic programming relaxes the single valued coefficients assumption of linear programming. Cocks [8] presents a method for solving linear programming problems where the objective function, restraints, and/or input-output coefficients are subject

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1/ Section 2.2.2 Markov Chain Analysis contains a definition and discussion of Markov Chain type models.

2/ Unfortunately, these models are too large to be solved on available computer facilities.

3/ The reverse strategy of building a simple model for extension, and later adding complexity for a research model, is less likely to be efficient since it is not until we have sensitivity analysis of the complex model, that we can tell which simplifications can safely be made in an extension model.

to discrete probability distributions.[1/]

The problem could conceivably have been modeled as a discrete stochastic program.[2/] The stochastic nature of production is properly reflected by probability distributions on input-output coefficients. Management options for breeding sows, assigning buildings, creating newborn pigs, etc., could have been modeled by the proper configuration of restraints and activities. A suitable objective function, such as maximizing expected profit could have been defined.

Discrete stochastic programming is well suited to multiple period production problems. Information comes forth to the manager as his production plan is executed, making it possible to decide issues as information becomes available, i.e., as the states of nature actually materialize. This method is especially well suited to handle a problem where timing of information is of the essence. Timing of information is important in scheduling of breeding for a target farrowing. The number of gilts or sows available would be known at a point in time but the actual number that can be successfully bred would not be known.

The problem modeled in this study is a discrete stochastic integer programming problem. However, an extremely large operational model results as evidenced by the following simple example.[3/]

1/ The introduction to this method is based on Cocks [8] with altered notation. For some other discussions and applications see Rae [30], Johnson, et al. [16], and Arnoff and Sengupta [2].

2/ Classed among mathematical programming problems, the problem under study here is a discrete stochastic integer programming problem.

3/ Cocks and others generally recognize that unmanageable working models may result, for an example, see Hutton [15, p. 1, 402].

The nonstochastic linear programming problem is

$$\max \quad Z = \underline{c}' \, \underline{x} \tag{2.1}$$

$$\text{subject to} \quad A \, \underline{x} \leq \underline{b} \tag{2.2}$$

$$\text{and} \quad \underline{x} \geq 0 \tag{2.3}$$

where

A = m X n matrix of input-output constants

$\underline{b}$ = a column vector of resource restraint constants

$\underline{c}$ = a column vector of pay-off constants, and

$\underline{x}$ = a column vector of activity levels to be determined

Introduce stochastic elements by defining the probability distribution for a total of K states of nature, one of which will materialize.

$$\text{Prob.} \{ (A, \underline{b}, \underline{c}) = (A_k, \underline{b}_k, \underline{c}_k) \} = p_k; \; k = 1,2,\ldots,K \tag{2.4}$$

$$\sum_{k=1}^{K} p_k = 1 \tag{2.5}$$

The activity vector $\underline{x}$ is now dependent on the state of nature k that turns up. The value of the program Z is a random variable.

$$\text{Prob.} \{ Z = Z_k \mid (A, \underline{b}, \underline{c}) = (A, \underline{b}, \underline{c})_k \} = 1 \tag{2.6}$$

The example introduced below has a discrete probability distribution on elements of A. The discrete stochastic programming problem is

$$\max \quad Z^* = E(Z) = \Sigma_k p_k Z_k \tag{2.7}$$

$$\text{subject to} \quad A_k \underline{x}_k \leq \underline{b} \; ; \qquad k = 1,\ldots,K \tag{2.8}$$

$$\text{and} \quad \underline{x}_k \geq 0; \qquad k = 1,\ldots,K \tag{2.9}$$

Where E(Z) is the expected value of Z. Consider a very small scale illustration which will show the way in which the problem under study here could have been modeled if it were not for the size of the matrix which results. Assume that it is desired to know the number of sows to mate and the number of their offspring to retain for replacement in a subsequent reproductive period. Let survival be considered the only stochastic variable. The outcomes of survival include: no deaths, or death of one sow and no pigs, or death of 2 sows and no pigs, etc.; or death of no sows but death of one pig, 2 pigs, 3 pigs, etc. etc., until an example herd of 50 sows with 8 pigs each would define 20,451 outcomes due to survival.

If the outcome which was to materialize was known before mating decisions were made, the problem would be a deterministic one. It would then be relatively easy to model as a nonstochastic linear programming problem. Let the following example (see Table 2.1) represent a portion of the system for a simplified case when it is known that no deaths will occur.

The simple example represented in Table 2.1 assumes there were 4 sows at the beginning of the first reproductive period. Column 1 allows for mating of sows, creation of their offspring and disposition of the sows themselves at the end of the period either as ending inventory or sows sold. Exactly 8 pigs are raised (see row 2 of column 1). Sows sold (.2) and ending inventory (.8) represent a 20% cull with no death loss. Costs of production have been ignored for simplicity but a Revenue row is included to account for generation of sales revenue.

Table 2.1 Zero Deaths Example

Column:		1 Mate Sows	2 Hold and Sell	3 Hold Sows Over	4 Save Replace-ments	5 Sell Hogs	6 Ending Inventory Sows	7 Sell Sows
Row:								
1. Open Sows	4 $\geq$	1	1	1				
2. Pigs Raised	0 $\geq$	-8			1	1		
3. Sows Sold	0 $\geq$	-.2	-1	-.3				1
4. Ending Sows	10 $\geq$	-.8		-.7	-1		1	
5. Revenue max						-50	100	-70

Column 2 allows the decision to sell sows rather than mate or hold them over to the next period. The sale of each sow generates \$70 of revenue for the system. Column 3 accounts for open sows held over and provides for culling. Columns 4 and 5 provide for saving pigs for use as replacements, or for their sale as hogs. Sales of hogs generate \$50 of revenue per hog sold. Column 6 provides for transfer of open sows to the following period. The value of an open sow to the next period (next section of the matrix, not shown) was assumed to be \$100, a value which could be determined by a complete model.

There are many possible survival outcomes. Table 2.2 is an example which assumes a death loss of 2 pigs and 1 sow. Column 1 of Table 2.2 reflects the results of mating one sow which farrows, say, 8 live pigs of which only 6 survive to be sold. Of the sows which are mated 20% are assumed culled but death loss results in only 15% available for sale. Likewise 60% remain as open sows. Columns 2 through 6 have an interpretation similar to the same columns in Table 2.1 except that death loss has been added.

Table 2.2 Death Loss Example

Column:		1 Mate Sows	2 Hold and Sell	3 Hold Sows Over	4 Save Replacements	5 Sell Hogs	6 Ending Inventory Sows	7 Sell Sows
Row:								
1. Open Sows	4 ≥	1	1	1				
2. Pigs Raised	0 ≥	-6			1	1		
3. Sows Sold	0 ≥	-.15	-.75	-.225				1
4. Ending Sows	10 ≥	-.6		-.525	-1		1	
5. Revenue max						-50	100	-70

If the forthcoming state of nature (death loss) were known before the decision to mate sows was made, a complete linear programming model could be used to find a solution. However, the forthcoming state of nature is not known except in a probability sense. It is possible to incorporate this probability information for the discrete survival outcomes in the form of a discrete stochastic programming model. Such a model is illustrated in Table 2.3 where the two hypothetical survival outcomes are represented as part of a discrete stochastic programming matrix.

Table 2.3 Discrete Stochastic Programming Illustration

		Mate Sows	Sell Sows	Hold Sows Over	State of Nature 1 Save Gilts	State of Nature 1 Sell Hogs	State of Nature 1 End Inv.	State of Nature 1 Sell Sows	...	State of Nature k Save Gilts	State of Nature k Sell Hogs	State of Nature k End Inv.	State of Nature k Sell Sows	...
Open Sows	$4 \geq$	1	1	1										
State of Nature 1														
Pigs Raised	$0 \geq$	-8			1	1								
Sows Sold	$0 \geq$	-.2	-1	-.3				1						
Ending Sows	$10 \geq$	-.8		-.7	-1		1							
State of Nature 2														
.														
.														
.														
State of Nature k														
Pigs Raised	$0 \geq$	-6								1	1			
Sows Sold	$0 \geq$	-.15	-.75	-.225									1	
Ending Sows	$10 \geq$	-.6		-.525						-1		1		
.														
.														
State of Nature K														
.														
.														
Revenue	$0 \geq$					R_2^1	R_3^1	R_4^1	...		R_2^k	R_3^k	R_4^k	...

Sections of the partial matrix of Table 2.3 represent two of the total possible outcomes K (see equation 2.4). Each outcome has some probability p_k of occurrence. The value of the program is directly related to the probability of the occurrence of the states of nature. For this example, the revenue generated would be:

$$(2.10) \quad Z^* = p_1 z_1 + \ldots + p_k z_k + \ldots; \; k = 1, 2, \ldots, K$$

Where

p_1 = the probability of state of nature 1

z_1 = revenue generated by $R_2^1 + R_3^1 + R_4^1$

p_k = the probability of state of nature k

z_k = revenue generated by $R_2^k + R_3^k + R_4^k$

Modeling as a discrete stochastic program requires a very large matrix to represent even the simplest of examples. It is obvious that inclusion of a realistic number of states of nature, additional stochastic variables, and completing the model by including a full set of time periods along with other necessary relationships would make such a model totally impractical to solve.

2.2.2 Markov Chain Analysis

"A _finite Markov chain_ is a stochastic process which moves through a finite number of states, and for which the probability of entering a certain state depends only on the last state occupied," Kemeny and Snell [18, p. 207]. A swine herd can be cast as an operational system as has been done in section 2.2.1. The simplified example given there describes the herd as a set of state of nature outcomes. A complete set of states can be used to describe the herd at a given point in time.[1/]

True Markov processes[2/] are defined for a system which has mutually exclusive system states. The system can be in one and only one of these states at a given time. Successive moves from one state to another (or back to the same) state at the end of a time unit is called a step.

For a Markov process a transition is defined as a change from state i to state j. The probability of a transition is called a <u>transition probability</u>: p_{ij}. These transition probabilities form an n x n matrix called the <u>transition matrix</u> for a system described by n mutually exclusive states.

(2.11) $$P = (p_{ij}) \; ; \; i, j = 1,2,\ldots,n$$

where p_{ij} is the conditional probability of a change from state i to state j at time t+1, given that it is in state i at time t. Equation 2.11 defines a transition matrix if

(2.12) $$p_{ij} \geq 0 \quad \text{for all } i,j$$

(2.13) $$\sum_{j=1}^{n} p_{ij} = 1 \text{ for each } i=1,2,\ldots,n$$

1/ Our interest will be limited to discrete time, finite processes. Markov theory has been developed for continuous time processes as well as for discrete time units. See Howard [14], Chapter 8.

2/ Kemeny, Snell, and Thompson [19, pp. 171-177] present a general introduction to Markov processes. Reilly has reviewed some applications to economic problems [31].

A particular row (i) of a transition matrix is called a probability vector. If we assume that a process begins in some particular state, a_i, then we can calculate the probability of being in every possible state at some future date. A process which has a specific beginning state, and refers to an entire sequence of transitions is known as a Markov chain.

Markov analysis is used to answer the following question: Suppose that a system is in state i. What is the probability that after a defined number of steps, it will be in state j?

Define a probability vector $\underline{p}$ for the starting time [1/] t = 0 and for any other future date as

$$(2.14) \qquad \underline{p}_t = (p_{tj}) \quad ; \quad j = 1,2,\ldots,n$$

Then the above question can be readily answered by matrix multiplication. The probability vector $\underline{p}_t$ where t = T, the future date of interest, contains the respective probabilities of being in one of the n possible states of the system after T steps. This is given by

$$(2.15) \qquad \underline{p}_T = \underline{p}_{(T-1)} \, P$$

implying step-by-step multiplication from the starting point t = 0.[2/]

Application of Markov analysis would require definition of the swine herd into system states where, for example, state number 1 is a herd of: 2 open sows, and 6 bred sows, and 60 pigs of all ages.

1/ A probability vector contains non-negative elements which sum to 1. A starting state may be given by assigning a particular state a_i the probability $p_{tj} = 1$; i=j and all other $p_{tj}=0$, or the vector may describe the respective probabilities of being in states a_i; i=1,2, ...,n.

2/ Kemeny, Snell and Thompson [19, p.218]. An equivalent result is obtained by first finding the T^{th} power of the transition matrix P, i.e., $\underline{p}_T = \underline{p}_o P^T$, p. 218.

Then state number 2 is a herd of 1 open sow, and 7 bred sows, and 60 pigs of all ages, etc., etc. This would have the advantage of making it possible to calculate the probability of each state in any time period. It would also have the advantage of allowing for management policies. For example, modeling an overfilled building would simply require additional states of the system representing over filled buildings. Forced sale of some animals, with a probability of 1 that animals are sold when this state is reached, would return the system to a normal condition. However, operationally the problem modeled in this way would be huge.

Fortunately useful information is obtainable from a much smaller configuration of the model. Define an inventory vector

$$(2.16) \qquad \underline{y}_t = (y_{tj}) \quad ; \quad j = 1,2,\ldots,n$$

where respective elements j for a given time t make up the set of states which can describe any animal in the herd. Inventory values y_{tj} are the number of animals in each state j at time t. The vector $\underline{y}_t$, for t = 0, is a beginning inventory distribution showing the number of animals in each category. Subsequent inventory vectors are

$$(2.17) \qquad \underline{y}_{t+1} = \underline{y}_t \, P$$

and contain the expected number in each inventory category.

This <u>inventory vector-transition matrix</u> approach can be used as demonstrated in the simple example below.[1/] Let P represent a 4 x 4 transition matrix for a swine herd, 6-month model.

1/ For examples of this approach as used in research on the size distribution of firms, see Hallberg [10], or Padberg [29].

$$(2.18) \qquad P = \begin{bmatrix} 0 & .7 & 0 & .3 \\ 0 & .8 & 8.0 & .2 \\ .1 & 0 & 0 & .9 \\ 0 & 0 & 0 & 1.0 \end{bmatrix}.$$

and the initial inventory contains 4 open sows, 6 bred sows, 60 pigs of all ages and 0 total sales

$$(2.19) \qquad \underline{y}_o = [\ 4 \quad 6 \quad 60 \quad 0\ ]$$

The creation of pigs is provided for by the element $p_{2,3}$ of the transition matrix P. Upon matrix multiplication, each bred sow in the inventory, $y_{t,2}$, will in effect create 8 pigs in the inventory $y_{t+1,3}$. This is similar to the effect of Howard's reward matrix 1/ which associates a "reward" with a particular transition from state i to j. For simplicity, the single "reward" has been added to the transition matrix.

The solution to this simplified model is calculated by matrix multiplication. The expected inventory at the end of the first 6-month period $\underline{y}_1$ is:

$$(2.20) \qquad \underline{y}_1 = \underline{y}_o\ P$$

$$(2.21) \qquad \underline{y}_1 = [\ 6.0 \quad 7.6 \quad 48.0 \quad 56.4\ ].$$

and expected inventory at the end of the second 6 month period $\underline{y}_2$ is:

$$(2.22) \qquad \underline{y}_2 = \underline{y}_1\ P = \underline{y}_o\ P^2$$

$$(2.23) \qquad \underline{y}_2 = [\ 4.8 \quad 10.28 \quad 60.8 \quad 102.92\ ]$$

and so on.

1/ There is a one period lag as compared to Howard's "reward" in which the reward is paid only if the state j is reached [14, p. 17].

The use of the inventory vector $\underline{y}$ approach has permitted calculation of expected numbers in inventory categories at future dates. Note, however, that this approach does not permit estimation of the variance of the numbers in each state as would the larger Markov chain of equation 2.15.

Some aspects of the problem with which this study is concerned can be modeled as a Markov type problem. The Markov type model is appropriate to demonstrate the role of probabilities in transitions from state to state of the individual (or groups of) animals in a swine herd. The model is flexible in that the length of a time unit can be appropriately chosen, stochastic variables are incorporated, and it is a simple, clear and concise framework to demonstrate these essential problem characteristics.

The next Chapter will further develop a model in the Markov context and bring in other adaptations to make it suitable for modeling a swine breeding herd.

2.2.3 Simulation[1/]

This section provides a brief summary of general simulation techniques as they are presented in the literature. Attention is then turned to the definition of simulation as it will be used in this study.[2/] Some of the advantages and pitfalls of simulation techniques are then discussed.

1/ Two useful bibliographies on simulation in business management and models in managerial economics are: Johnsson and Eisgruber, [17] and Vincent [39].

2/ See previous definition, page 4.

Simulation as generally used, describes a general approach to modeling, and has been applied to many diverse forms of model building.[1/] Morgenthaler [24, pp.366-371] discusses numerous applications in the engineering sciences and gives other examples such as military gaming. Orcutt[27], Shubik [35], and Clarkson et al. [7]review the use of simulation in micro and macro economic contexts.

There may have been an expanding use of simulation techniques in agricultural economics research since Burt's comment [5, p. 1, 425] in 1965 that simulation "...is looked upon more as a method of gaining general understanding of complex decision processes than an optimization model." Several substantial studies have been done in the interim using simulation techniques which seek to optimize an objective function. These include several examples of farm planning models,[2/] and farm management games.[3/] Most recently, policy decision models have been solved with simulation.[4/]

Simulation techniques provide a flexible method to overcome many of the difficulties of straight forward execution of the scientific method: duplication of the environment, of mathematical formulation, of lack of analytical solution techniques, or of experimental

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1/ Orcutt's review of the use of simulation is comprehensive, [27, pp. 893-897].

2/ Some of those which have come to this author's attention are: Sonntag [36], Lee [21], Anderson [1], Zusman and Amiad [41], and Halter and Dean [11].

3/ Babb and Eisgruber [3].

4/ Schechter and Heady [34], Halter, Hayenga and Manetsch [12], Naylor [26], Tyner and Tweetan [37], and Hayenga, Manetsch and Halter [13].

impossibilities.[1]

An important advantage in the use of simulation is that there are practically no limits dictated by structural form to hamper description of the problem in mathematical form.[2] The model may contain as many variables and relationships as needed to describe the problem realistically. Nor is there restriction as to the form the mathematical equations can take. Variables can be deterministic or be specified by random selection from probability distributions; equations can be linear, or non-linear; variables can be continuous or integer, and so on.

Simulation techniques provide a very convenient method of incorporating time into the model. Dynamic modeling is natural because of the ease of using output from a run or loop in a computer language program to feed into the next time period as data input.

"In extremely complex problems, particularly those of a stochastic nature, simulation...is about the only recourse we have for quantitative analysis."[3]

Some of the advantages of simulation techniques mentioned above can also turn into pitfalls. Simulation techniques imply that a model is constructed by the researcher that has no a priori set pattern or structure so that the pitfalls are not so well known nor widely publicized as they are for mathematical programming models.

1/ Morganthaler [24, p. 372].

2/ Although model size is as significant a limitation to simulation as it is to analytical algorithmic procedures.

3/ Burt, in a discussion of the merits of simulation [5, p. 1, 426].

Some errors are obvious because they result in nonsense answers. Events out of sequence, most syntax errors in computer language statements, and major errors of parameter specification are of this type and usually will turn up as impossible results when comparison is made to real world production possibilities. There are far more subtle (and therefore dangerous) errors that are difficult to recognize.

One problem common to any modeling procedure; omitted variables, can lead to unreliable experiments. If the variables omitted are significant to the model, the model is a poor representation of the real world. Omitting relatively unimportant variables is part of the abstraction of modeling; some variables should be left out.

Discrete time approximations of a continuous time process presents a pitfall for simulation techniques. Certain events in the real process happen simultaneously. An exaggerated example of this problem was encountered in the monthly model of section 2.2.2 where all sows in the state "bred sows" were assumed to produce pigs whereas those reaching the end of a 114 day pregnancy could more realistically be considered to have produced pigs at the end of gestation.

Morganthaler [24, p. 384] warns of problems that the model builder should be aware of. Transient decay 1/ may extend for longer simulation time than realized by the researcher.

1/ The effect of starting time values on subsequent results. See the preliminary model examples of section 3.2.1, and 3.2.2, where a lumpy opening inventory is gradually smoothed during simulation.

The use of expected values in place of random variables at intermediate stages should be suspect. Morganthaler warns against their use [1] [24, p. 385].

The use of the computer for computation means that calculation accuracy should be excellent for most purposes. However, possible machine errors, rounding errors and random number generator errors should be kept in mind.

Simulation involves constructing a model and using that model ("running" it) to conduct experiments.[2] This study was concerned with a specific application. A complex farm management problem was modeled, giving particular attention to stochastic variables. Given the type of problem involved, a Markov type model was developed. The conceptual model and small scale examples to demonstrate the model are found in chapter 3.

Simulation (use of a computer program to study the model) was chosen as the means to implement the model for quantitative study. The model does not include an objective function. Therefore the simulation does not include optimum seeking techniques. The simulation facilitated implementation of the stochastic nature of the model by generation of random variables, by convenient definition of daily time periods, and by providing a means of defining animal attributes and storing and

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1/ Wagner has called this the <u>fallacy of averages</u> [40, p. 350].

2/ See section 1.1.1 for a definition of simulation as used in this study. There is no such thing as "the simulation model." The term "simulation" in the context of this study means the procedures which are used to study the model.

summarizing results. Illustrative results of runs of the simulation are found in Chapter 4.

2.3 Review of Previous Studies

The use of operational computer decision models in extension work in swine production is a relatively new endeavor. Consequently, research experience in development of models specific to swine production is not extensive.

Three studies which give detailed emphasis to swine production problems are reviewed in the following three sections. Marten [23] modeled the finishing of purchased feeder pigs. Schroder [33] compared application of dynamic programming and linear programming to budgeting methods, and Sonntag [36] modeled the alternatives in growth of the swine enterprise.

2.3.1 Marten

The objective of the Marten study [23] was to construct a computer software program for a hog feedlot scheduling problem. Multiple period feedlot scheduling is emphasized with linkage to other farm management decisions by consideration of labor cost and availability, as well as corn production.

Marten chose a linear programming model. He states [23, p. 28], "The single-value expectation assumption is, theoretically, the most limiting assumption of linear programming as applied to the hog feedlot scheduling problem... In the final analysis, trade-offs existed between 'theoretical correctness' and 'practical availability' (of other solution algorithms)...". He has recognized that stochastic elements enter biological processes such as swine production.

Features of the model include the following user defined options: (a) length of time period, (b) number of periods, (c) availability and type of feeder pigs, and (d) building and management system options. The optimum results computed by the linear programming algorithm are presented in an easy to understand form usable by farmers and extension personnel.

The Marten study provides an operational extension tool for a particular swine production problem.1/ The model has the advantage of optimizing return above variable costs, and is flexible, allowing the user to define his specific hog feeding problem. However, the user is tempted by the nature of the input form to define a very large linear programming problem which is impractical to solve.2/ Thus, Marten's program is fully operational only for a sub-set of the alternatives available in the input form; and, in practice, has zero acceptance by farmers and extension agents.

The problem modeled in this study, as compared to the Marten study, includes the breeding of sows and raising of baby pigs, i.e., a farrow to finish problem. The nature of the scheduling problem (section 1.1) includes stochastic elements which are an important aspect of managing baby pig production and only enter into feedlot management to a lesser degree. Marten's choice of the linear programming structure excludes modeling the breeding herd both because of stochastic

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1/ Feeding of purchased feeder pigs is analogous to the finishing part of a farrow to finish operation.

2/ If all options are used, then 19,887 real activities and 197 restraints are defined. Moreover, the density of this matrix is relatively high. Marten suggests methods by which this program could be reduced in size, but these suggestions have not yet been implemented.

elements and the management practices required.

2.3.2 Schroder

Schroder [33] investigated the applicability of operations research models for swine management decision making. He studies two types of swine management problems: (a) scheduling sales and purchases for a hog feedlot and (b) selection of a housing-management system for the farrowing, nursery, and finishing stages of swine production. No input form or report writer was written to make the model applicable for extension use.

The feedlot problem is modeled using a dynamic programming approach. A FORTRAN IV computer program was written to solve the dynamic programming model. Results are compared to those obtained from budgeting procedures under several feeder pig buying policies and two knowledge situations. The model effectively handles the multiple decision periods nature of the problem. There are no stochastic variables in the model.

Turning to the problem of selection of a housing-management system for the farrowing, nursery, and finishing stages of swine production, Schroder chooses to model with linear programming and compare results with those obtained from traditional budgeting methods. Housing systems compared ranged from all pasture to complete confinement for each of the farrowing, nursery, and finishing buildings considered.

The linear programming formulation of the housing-management selection problem optimizes profit by selecting from all possible combinations of buildings and management systems. There are no integer requirements imposed and, therefore, solutions can turn out embarrase singly unrealistic. Results can contain certain linear combinations of management systems such as farrowing both 4 times per year and 6 times per year. This is analogous to optimizing a student's course scheduling problem by recommending he take 0.2 of Math. 223 and 0.8 of Math. 163.

Other limitations of the study which, given the problem definition and objectives of the present study, limit its usefulness include: (a) the model is static, there is no consideration of the timing of important details of the production process, and (b) no account is taken of stochastic elements in either prices or the production process.

Schroder [33, p. 100] points out that including stochastic variables such as "sow gestation time" may result in the necessity of having greater building capacities than when these stochastic variables are modeled with zero variance.

2.3.3 Sonntag

Sonntag [36] developed an operational extension model[1/] of the long run planning problems of corn-hog farmers. The growth process was emphasized in an examination of size, combination of production alternatives, techniques of production, and investments over time.

The model features a wide range of hog production-management alternatives. Combinations of farrow to finish, finished purchased feeder pigs,and producing feeder pigs for sale are offered. The

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1/ "Planning Growth of the Swine Farm," the title of the input form for extension use [36, pp. 306-328], is a "Top Farmer" extension model developed for use in Purdue University extension work.

alternatives over which the model must be solved are narrowed by the beginning situation and the user prerogative to exclude management systems, and/or building combinations from consideration. A few corn production alternatives are available on the input form to link hogs to corn production. Maximum terminal net worth is the objective of this decision model.

The production process contains no stochastic elements. The herd manager's scheduling problem of getting sows bred, pigs raised, and buildings and labor efficiently utilized are modeled with traditional, average coefficients of production and costs per unit. This model is solved for "near-optimal" plans by a simulation searching procedure. Integer solutions are realistically imposed on buildings, and on enterprise units (10 sows, 100 feeders, etc.). A complete, usable input form as well as easily interpretable output for extension use, were developed; and the program has been well accepted by farmers.

For the purpose of this study, the Sonntag approach had several limitations which made it inappropriate for the problem under investigation here. His modeling of biological production is deterministic. No stochastic elements are included to represent the effect of shocks on the system. The modeling of open and bred sow pools and the variability of the gestation-breeding process is excluded by statements such as: "10 percent more sows are maintained than needed for farrowing." The scheduling problems of breeding sows, and assigning housing are passed off as average capacity of building concepts, etc.

This abstract modeling of the production process is an acceptable first representation for long term planning of growth of the swine farm. For short term swine scheduling problems, however, much more detail of the nature of the production process is needed. It should be emphasized that the Sonntag model has been widely used in a workshop setting with hog farmers, and has been well accepted under these conditions.

As compared to the Marten, Schroder, and Sonntag studies, this thesis aims to add to the array of available hog production models, a first exploration of the implications of modeling the stochastic aspect of swine production. In particular, it should throw some light on the "average building capacities" which can reasonably be included in deterministic models such as those discussed above.

CHAPTER 3

CONCEPTUAL AND DEMONSTRATION MODELS

The nature of the modeling problem (sections 1.1 and 1.2) and the objectives of this study dictated the particular swine production features modeled. The characteristics of the modeling problem led to a special set of well known modeling alternatives (section 2.2). The purpose of this Chapter is to further conceptualize the modeling problem by constructing a more realistic demonstration of the nature of the problem and showing how these characteristics are represented by the modeling procedures chosen.

3.1 Conceptual Models

A simple binary mechanistic model is first presented and then the nature of a monthly Markov chain model is explored. Demonstration of these models follows in later sections of Chapter 3.

3.1.1 Simple Binary Mechanistic Model of a Swine Herd

The simple binary mechanistic model of a swine herd serves to illustrate the size and complexity of the modeling problem in relatively realistic detail. It presents the interrelationships between reproductive animals in a typical herd, using a daily time interval with each animal assigned an identity number. Essential animal attributes and transition probabilities are defined.

The binary mechanistic model is most simply stated as: given an initial state vector $\underline{x}_o$ of the herd at time t=0, calculate the resulting state vector of the herd $\underline{x}_t$; t=1,2,...,T in each of T subsequent periods, subject to appropriate transformation probabilities, P, where

$$(3.1) \qquad \underline{x}_t = P\underline{x}_{t-1} \; ; \qquad t=1,2,\ldots,T$$

The elements of $\underline{x}_t$ can be written: $\underline{x}_t = (x_{ijkLm})$, where

$$(3.2) \qquad x_{ijkLmt} = 0 \text{ or } 1$$

It is the characteristic of having 0 or 1 elements of the state variable $\underline{x}_t$ which leads to the term binary model, -- either there is an animal in this state, or there is not. The term mechanistic refers to the fact that the transition probabilities P are non-adaptive; they do not reflect changing husbandry practices in light of the levels of the state variables. An animal with the characteristics i, j, k, L, m, t, is equal to zero or one since herd numbers, m, are unique for individual animals.[1/] The following classification scheme defines equation (3.1) as a binary sexual state:

i = Age in days, $i = N^*_{jk}, N^*_{jk} + 1, \ldots, N_{jk}$; j=1,2,3. Where N^*_{jk} and

N_{jk} are defined in connection with subscripts j and k below.[2/]

j = Sex: = 1,2,3

1/ Note: (a) $x_{ijkLmt} = 0$ or 1, and (b) $\Sigma_{ijkLmt} x_{ijkLmt} = 0$ or 1; where i, j, k, and L describe attribute classifications, m is a unique herd number, and t is the day of simulation time.

2/ Birth on day t implies i = 1, if the animal survived to the end of day t.

Where

1 = purchased boars; $N^*_{1k} = 150 \le i \le 1825 = N_{1k}$

2 = female; $N^*_{2k} = 1 \le i \le 1825 = N_{2k}$

3 = barrow; $N^*_{3k} = 1 \le i \le 365 = N_{3k}$

k = Sex Subclass:

for j = 1: k = 1,2,3

Where

1 = newly purchased; $N^*_{11} = 150 \le i \le 395 = N_{11}$

2 = young boar; $N^*_{12} = 195 \le i \le 365 = N_{12}$

3 = mature boar; $N^*_{13} = 366 \le i \le 1825 = N_{13}$

for j = 2: k = 1,2,3,4

Where

1 = never ovulated; $N^*_{21} = 1 \le i \le 365 = N_{21}$

2 = ovulating, open; $N^*_{22} = 150 \le i \le 1825 = N_{22}$

3 = gestation; $N^*_{23} = 171 \le i \le 1825 = N_{23}$

4 = lactating; $N^*_{24} = 281 \le i \le 1825 = N_{24}$

for j = 3: k = 0; L = 0

L = Day Tally:

for j = 1; k = 1;

$L = 0,1,2,\ldots Z_k$; Z_1 = 30 days adjustment period.

for j = 1; k = 2;

$L = 0,1,2,\ldots,Z_k$; = number of fertile days; $L = Z_2$ if at least Z_2 days since use, $Z_2 \le 10$.

for $j = 1$; $k = 3$;

$L = 0,1,2,\ldots,Z_k$ = number of fertile days; $L = Z_3$ if at least Z_3 days since use, $Z_3 \leq 5$.

for $j = 2$; $k = 1$;

$L = 0$

for $j = 2$; $k > 1$;

$L = 1,2,\ldots,Z_k$ = day in cycle, $Z_2 \leq 90$, $Z_3 \leq 122$, and $Z_4 \leq 60$.

m = herd number, unique to each animal.

t = day of simulation = $0,1,2,\ldots,T$

T = number of days from initialization time ($t=0$) to T, the number of days to be simulated.

This classification provides a unique animal description x_{ijkLmt}. For example, if $x_{201,2,3,4,50,60} = 1$, then we know that there was an animal alive of age $i=201$; it was a female $j=2$; in gestation $k=3$; at the 4th day $L=4$; with a herd number $m=50$, at time t-60 days.

The above limitations placed on attribute subscripts defined a finite set of binary states. These biological characteristics highlight the reproductive attributes of swine. Accounting for days into gestation, day of the estrus cycle, days of lactation, and the age of the animal rapidly expands a daily model. A much larger set of binary states would have been conceived if one were to model in more detail and include other attributes such as inherited traits, environmental history, physical characteristics, or spacial characteristics such as location by building.

There are 450,756 daily binary state classifications outlined in Table 3.1. These are the number of states which can be taken by any one animal under the various reproductive attributes i, j, k, and L.[1/] The greatest cause of the large number of binary states is the day of age attribute i. Age cannot be ignored since it is the primary delineator of reproductive ability.[2/]

Simulation of a swine breeding herd involves solving the conceptual model, equation (3.1), by calculating the state to state transformations of animals through time. Transformation always involves at least the stochastic nature of survival. If $x_{ijkLmt} = 1$ then the daily binary state transformation probability is given by:

$$(3.3) \qquad \Pr\{x_{i+1,j'k'L'm',t+1} = 1\} = Q: \quad m=1,2,\ldots,M;\ t=0,1,2,\ldots,T-1$$

Where

j' = value of j in $t+1$

k' = value of k in $t+1$

L' = value of L in $t+1$

M = maximum number of animals in the herd

T = total simulation time in days.

1/ The number of state classifications is large because of the multiplicative effect of accounting for both age in days, i, and number of days in the specific reproductive class, L. For example, if j=2; k=3 (female in gestation), the animal may be of any age, 171-1825 days, and will be in one of the days of gestation, L=1-122. These include 1655 and 122 integer states respectively. The number of combinations (1655 X 122) is equal to 201,910. However, gilts of minimum age for pregnancy cannot be in the latter stages of the gestation tally which excludes 7,381 for a net total of 194,529 feasible combinations. See Table 3.1 and its footnote number 2.

2/ Weight, a continuous variable, is a less useful alternative for the purposes of the conceptual model because reproduction ability is being modeled largely as a function of age.

Table 3.1 Number of Possible Daily Binary States

Feasible Subscript Values					
j (sex)	k (Sub-class)	L (day tally)	i (day of age	Number of States for j, k, L, i Combinations 1/	
1	1	0-30	150-395	(7,626 - 465 2/)	= 7,161
1	2	0-10	195-365	(1,881 - 55 2/)	= 1,826
1	3	0-5	366-1825	(8,760 - 15 2/)	= 8,745
2	1	0	1-365		= 365
2	2	1-90	150-1825	(150,840 - 4,005 2/)	= 146,835
2	3	1-122	171-1825	(201,910 - 7,381 2/)	= 194,529
2	4	1-60	281-1825	(92,700 - 1,770 2/)	= 90,930
3	0	0	1-365		= 365
				Grand Total	= 450,756

1/ Number of possible states which can be taken by an individual animal with a given herd number m^* at time t^* in $x_{ijkLm^*t^*}$.

2/ Certain combinations in the multiplicative calculation of L and i are not feasible over the respective ranges of i,j,k and L. In general, if an animal is entering a classification at the minimum age, it cannot be more advanced than the beginning day tally for that class. Consider the classification: j=1, k=1, when i=150; a new boar of the minimum number of days of age for purchase; L=0 with no freedom to take the values 1-30. If we consider a boar of age i=151, there is freedom to have been purchased 1 day ago (L=1) or on the current day (L=0). A boar of age 152 could have L=1,2, or 3, and so on, to i=169. For i=170,171,...,395; the day tally has full freedom to range 0,1,2,...,30. The formula for calculating these exclusions involves summing the integers $1,2,\ldots,r_L-1$; where r_L is the range of L as given in the table.

There are $(450,756)^2$ possibilities $0 \leq Q \leq 1$; the probability of transition from every state of t to every state of t+1. However, the chronological nature of gestation, lactation, day of heat cycle, etc., results in only a relatively few feasible transformations with nonzero probabilities, i.e., $0 < Q \leq 1$. The number of transformation probabilities are further reduced by grouping them for approximation into ranges as expressed in Table 3.2.[1/] Even though this model allows us to distinguish 450,756 states which an animal taken at random from a herd on any given day could be in, only 17 distinct transition probabilities[2/] need be defined to account for daily transition between states. It is this small number of distinct probabilities which leads to the adjective simple binary mechanistic model.

The symbol α^S_{ijkL} represents the probability that an animal with the characteristic ijkL at time t, will survive with these characteristics to time t+1. Likewise the symbols α^V_{ijkL}, α^C_{ijkL}, α^R_{ijkL}, and α^F_{ijkL} represent the probabilities of ovulation, conception, premature termination of gestation, and Farrowing-lactation respectively. The symbols for these probabilities are given in the right hand column of Table 3.2. The following summary defines the probabilities associated with survival and reproductive categories:

1/ A more realistic alternative is to define the probability Q as a continuous function of i, j, k, and L to avoid the "lumpiness" of arbitrary grouping. The procedure of Table 3.2 is, however, more useful as a conceptualization.

2/ In addition, however, there are 189 probabilities; or a probability distribution for each litter of pigs born; see equation (3.16) which follows.

Table 3.2 Daily Binary State Transformation Probabilities

Description	Subscript Value in Time t 1/				Subscript in Time t+1 2/		
	r_i	r_j	r_k	r_L	k'	L'	Q 3/
Survival:							α^S_{ijkL}:
First week	1-7	2,3	0,1	0	r_k	0	α^1_{ijkL}
2-3 weeks	8-21	2,3	0,1	0	r_k	0	α^2_{ijkL}
Starting	22-56	2,3	0,1	0	r_k	0	α^3_{ijkL}
Market Hogs	57-240	2,3	0,1	0	r_k	0	α^4_{ijkL}
Ovulating, open	150-1825	2	2	1-90	2	r_L	α^5_{ijkL}
Gestation	150-1825	2	3	1-121	3	r_L	α^6_{ijkL}
Farrowing day	262-1825	2	3	110-122	4	1	α^7_{ijkL}
Lactating	263-1825	2	4	2-60	4	r_L	α^8_{ijkL}
Boars not in use	150-1825	1	1-3	1-10	r_k	r_L	α^9_{ijkL}
Boars in use	195-1825	1	2,3	1-10	r_k	r_L	α^{10}_{ijkL}
Ovulation:							α^V_{ijkL}:
Before 5 months	1-149	2	1	0	2	1	α^1_{ijkL}
5 mo.-5 years	150-1825	2	1,2	0-90	2	r_L	α^2_{ijkL}
Conception:							α^C_{ijkL}:
Gilts	150-365	2	2,3	1-63	3	1	α^1_{ijkL}
Sows	366-1825	2	2,3	1-63	3	1	α^2_{ijkL}

Table 3.2 (continued)

Description	Subscript Value in Time t1/ r_i	r_j	r_k	r_L	Subscript in Time t+1 2/ k'	L'	Q3/
Premature Termination:							α^R_{ijkL}:
Gilts or Sows	151-1825	2	3	1-22	2	1	α^1_{ijkL}
Farrowing-Lactation:							α^F_{ijkL}:
Gilts	262-449	2	3,4	1-121	4	1	α^1_{ijkL}
Sows	450-1825	2	3,4	1-121	4	1	α^2_{ijkL}

1/ r_i, r_j, r_k, and r_L indicate full range of integer subscripts within the range r.

2/ k' and L' indicate any interger in r_k, r_L, or first appearance of the attribute, e.g., k'=4, when L'=1 is first day of the suckling period, i.e., the day of farrowing.

3/ Probabilities α^S_{ijkL}, α^V_{ijkL}, α^C_{ijkL}, α^R_{ijkL}, or α^F_{ijkL} where i, j, k and L have values as defined in the Table.

Allowance for Death Loss

$$\text{If } x_{ijkLmt} = 1; \quad \begin{aligned} i &= 1,2,3,\ldots,1825 \\ j &= 1,2,3; \\ k &= 0,1,2,3,4 \\ L &= 1,2,3,\ldots,Z_k; \\ m &\leq M; \\ t &= 1,2,3,\ldots,T-1 \end{aligned}$$

then

(3.4) $\Pr\{x_{i+1,jkLm,t+1} = 1\} = \alpha^S_{jkL} \leq 1$ for survival, and

(3.5) $\Pr\{x_{i+1,jkLm,t+1} = 0\} = 1-\alpha^S_{ijkL} \leq 1$ for death

where $S = 1,2,\ldots,10$.

Onset of Ovulation

$$\text{If } x_{i,2,1,0,m,t} = 1; \quad \begin{aligned} i &= 1,2,\ldots,365; \\ m &\leq M; \\ t &= 1,2,\ldots,T-1 \end{aligned}$$

then

(3.6) $\Pr\{ x_{i+1,2,1,0,m,t+1} = 1 \} = \alpha^S_{ijkL}(1-\alpha^V_{ijkL}) \leq 1$

for survival and no ovulation and

(3.7) $\Pr\{ x_{i+1,2,2,1,m,t+1} = 1 \} = \alpha^S_{ijkL}\alpha^V_{ijkL} \leq 1$

for survival and ovulation where $S = 4$ or 5; $V = 1$ or 2.

Gestation, first day is conception

$$\text{If } x_{i,2,2,L,m,t} = 1; \quad \begin{aligned} i &= 151, 152,\ldots,1825 \\ L &= 1,2,\ldots,89; \\ m &\leq M; \\ t &= 1,2,\ldots,T-1 \end{aligned}$$

then

(3.8) $$\Pr\{ x_{i+1,2,2,L+1,m,t+1} = 1 \} = \alpha^{S}_{ijkL}(1-\alpha^{C}_{ijkL}) \leq 1$$

for survival without conception and

(3.9) $$\Pr\{ x_{i+1,2,3,1,m,t+1} = 1 \} = \alpha^{S}_{ijkL}\alpha^{C}_{ijkL} \leq 1$$

for survival and conception where S = 5; C = 1 or 2.

Continued Gestation

If $x_{i,2,3,L,m,t} = 1$; $i = 151, 152,\ldots,1825$
$L = 1,2,\ldots,121$;
$m \leq M$;
$t = 1,2,\ldots,T-1$

then

(3.10) $$\Pr\{ x_{i+1,2,3,L+1,m,t+1} = 1 \} = \alpha^{S}_{ijkL}(i-\alpha^{R}_{ijkL}) \leq 1$$

for survival and continuing gestation and

(3.11) $$\Pr\{ x_{i+1,2,2,1,m,t+1} = 1 \} = \alpha^{S}_{ijkL}\alpha^{R}_{ijkL} \leq 1$$

for survival and premature termination where S = 6; R = 1.

Lactation, first day is day of farrowing

If $x_{i,2,3,L,m,t} = 1$; $i = 262,263,\ldots,1825$
$L = 1,2,\ldots,121$;
$m \leq M$;
$t = 1,2,\ldots,T-1$

then

(3.12) $$\Pr\{ x_{i+1,2,3,L+1,m,t+1} = 1 \} = \alpha^{S}_{ijkL}(1-\alpha^{R}_{ijkL}) \leq 1$$

for survival and continuing gestation and

(3.13) $$\Pr\{ x_{i+1,2,4,1,m,t+1} = 1 \} \alpha^{S}_{ijkL}\alpha^{F}_{ijkL} \leq 1$$

for survival and farrowing where S = 7; R = 1; F = 1 or 2.

If $x_{i,2,4,L,m,t} = 1$; $i = 281, 282, \ldots, 1825$;
$L = 1, 2, \ldots, 59$;
$m \leq M$;
$t = 1, 2, \ldots, T=1$

then

(3.14) $\Pr\{ x_{i+1,2,4,L+1,m,t+1} = 1 \} = \alpha^S_{ijkL}\alpha^F_{ijkL} \leq 1$

for survival and continuing lactation and

(3.15) $\Pr\{ x_{i+1,2,2,1,m,t+1} = 1 \} = \alpha^S_{ijkL}(1-\alpha^F_{ijkL}) \leq 1$

for survival and discontinued lactation and

(3.16)1/ $\Pr\{ u(x_{1,2,1,0,m,t} = 1) \text{ and } v(x_{1,3,0,0,m,t} = 1) \} = \beta_{uv} \leq 1$;

for $u + v \leq 18$ newborn pigs;

where u = number of female, and
v = number of male (barrow) pigs born alive
S = 7 or 8
F = 1 or 2

The simple binary mechanistic model would be an appropriate description of a herd under non-adaptive husbandry conditions where transformation probabilities are independent of the current state of the system. Such a system assumes of course no building, target farrowing, or other restraints which require strategies in the model. The simple binary mechanistic model of a swine herd has the advantages of (a)

1/ Provision for creating baby pigs. Note that β_{uv} refers to the probability of farrowing various combinations of male and female pigs totaling 1,2,...,18. There are 189 male and female combinations resulting in 189 probabilities associated with creating live pigs at farrowing. These probabilities are in addition to the transition probabilities listed in Table 3.2.

placing emphasis on reproductive functions, (b) being a daily model, and (c) defining probabilities associated with transformation from state to state. This model incorporates probability data.

3.1.2 The Conceptual Model and Markov Analysis

The binary model presented in the previous section recognizes the stochastic and integer attributes of reproductive animals. Implementation of the model requires solution procedures which are capable of simulating the reproductive process through time. The transformation probabilities of the previous section define transformations from day t to t+1. These are the transition probabilities of a Markov process. All attributes of a given animal[1/] are described by the state classifications in time t.

The transition probabilities sum to one. The probability of finding any individual animal in a given state at time t depends upon the state which it occupied in t-1, and not how it got to this state. The history of the herd previous to t-1 is given by the number of animals in each state at t-1 and the transition probabilities. Thus the simple binary mechanistic model fulfills the requirements of a Markov process.[2/]

While especially useful to conceptualize the nature of stochastic relationships, the simple binary mechanistic model is too

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1/ Including death of the animal, the zero binary state.

2/ See section 2.2.2, Markov Chain Analysis and the simple example given there.

simple to be useful as a research model. The rapid expansion of the model by including the creation and raising of baby pigs, as well as other animal attributes and management decision variables, suggests some exploration of the characteristics of a simple demonstration model before specification of the complete research model.

As discussed previously the model presented above is a Markov type model which provides a convenient solution procedure. Subsequent adaptations of the Markov chain simulation procedure are suggested later to incorporate other elements of the research model.

The simple daily binary mechanistic model conforms to Markov analysis[1/] as a solution procedure. However, for a practical demonstration of the solution procedure, the size of this model is reduced by presenting a monthly example. Management rules, spacial considerations (building occupation), and economic measures of production are deferred until attention is returned to the daily research model of Chapter 4.

3.2 Demonstration Models and Transition to the Research Model

A monthly Markov chain process of a swine breeding herd is presented as a demonstration of solution procedures. The Markov process illustrates the simulation methods which are used to evaluate the research model. Example numerical probability data and an opening inventory are presented in Markov context. First, a monthly model is solved yielding expected number of animals in each inventory state classification. The multiplication process is then modified in recognition of integer requirements for individual animals. Short-

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1/ The Markov process transition matrix is 450,756 X 450,756.

comings of the demonstration models are discussed (section 3.2.3) as an indication of the additional features required in the research model.

3.2.1 Markov Chain Model of a Swine Herd[1/]

A monthly model of a swine breeding herd is defined by an inventory vector of 30 states. The inventory includes (a) two boar categories, (b) sixteen classes of growing-finishing by age in months, (c) three states for open sows, (d) four monthly gestation states, (e) lactation states for months 1 and 2, (f) states for total deaths, and (g) sales of butcher hogs and sows. The beginning inventory vector is

(3.17) $\underline{y}_t = (y_{tj}); \quad j = 1,2,\ldots,30; \quad t=0$

where the elements j, known with certainty, are described in Table 3.3 together with the opening inventory values. The monthly transition matrix is

(3.18) $P = (p_{ij}) \quad ; \quad i,j = 1,2,\ldots,30$

Where the elements of P are given in Table 3.4, the monthly Markov chain transition matrix.

The rows and columns of P, the 30 X 30 transition matrix are given coded state names "S" which correspond exactly to the 30 inventory states j with code names "Y", in Table 3.3. All elements of the matrix P conform to a transition matrix[2/] except $p_{17,3}$ and $p_{17,20}$ which provide

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1/ Markov theory and examples of Markov multiplication are given in section 2.2.2.

2/ For a transition matrix all elements ≤ 1, and rows sum to 1, see equations 2.11, and 2.12 of section 2.2.2.

Table 3.3 Monthly Markov Chain Inventories

Element No. j = 1/	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Code Name =	y_{110}	y_{120}	y_{211}	y_{212}	y_{213}	y_{214}	y_{215}	y_{216}	y_{217}	y_{218}	y_{221}	y_{222}	y_{223}	y_{231}	y_{232}
Opening Inventory Value 2/	2	4	50	50	0	0	50	45	10	0	15	10	5	25	0
End of Year Inventories															
1. Markov Simulation 3/															
Year 1	0.0	5.7	43.0	96.4	73.6	12.2	16.6	63.5	2.9	.9	9.3	1.0	1.6	15.1	8.6
Year 2	0.0	5.4	57.7	77.7	56.8	50.0	50.0	44.0	4.6	.8	6.8	2.3	1.9	14.8	15.1
Year 3	0.0	5.2	65.1	68.2	62.1	64.5	56.6	50.4	5.7	.6	7.6	2.9	1.8	16.7	17.0
Year 4	0.0	4.9	69.7	69.8	69.2	69.5	64.0	60.1	6.1	.6	8.7	3.1	1.8	18.3	18.2
Year 5	0.0	4.7	75.9	75.6	75.3	74.5	72.2	67.4	6.6	.7	9.7	3.3	2.0	19.9	19.7
Year 6	0.0	4.5	83.2	82.5	81.8	81.1	79.9	73.9	7.2	.7	10.5	3.6	2.2	21.6	21.5
2. Randomized Markov Simulation															
Year 1	0	6	20	87	59	0	20	63	3	0	7	1	0	13	4
Year 2	0	6	48	76	44	44	87	51	3	0	9	2	0	9	15
Year 3	0	6	104	76	56	67	66	52	3	2	5	3	0	19	21
Year 4	0	6	108	67	88	110	48	71	16	0	13	3	3	20	24
Year 5	0	5	84	95	95	130	100	90	7	1	17	4	3	27	30
Year 6	0	5	104	123	86	120	116	99	7	2	10	5	1	34	28

Table 3.3 (continued)

Element No. j = 1/	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Code Name =	y_{233}	y_{234}	y_{241}	y_{242}	y_{301}	y_{302}	y_{303}	y_{304}	y_{305}	y_{306}	y_{307}	y_{308}	y_{400}	y_{500}	y_{600}
Opening Inventory Value2/	0	25	0	15	50	50	0	0	50	45	10	0	0	0	0
End of Year Inventories															
1. Markov Simulation3/															
Year 1	10.3	13.4	10.4	23.5	43.0	96.4	73.6	12.2	16.6	68.2	6.3	1.9	18.8	1,011.8	38.4
Year 2	13.6	12.5	14.0	18.9	57.7	77.7	56.8	50.0	50.0	47.3	10.0	1.7	39.0	2,225.9	73.2
Year 3	15.2	15.1	15.7	16.6	65.1	68.2	62.1	64.5	56.6	54.3	12.2	1.4	61.1	3,554.7	111.7
Year 4	17.3	17.4	16.9	17.0	69.7	69.8	69.2	69.5	64.0	64.7	13.2	1.3	85.4	5,010.5	153.6
Year 5	19.3	19.2	18.3	18.4	75.9	75.6	75.3	74.5	72.2	72.5	14.3	1.4	111.9	6,608.1	199.2
Year 6	21.2	21.0	20.1	20.1	83.2	82.5	81.8	81.1	79.9	79.4	15.6	1.5	140.9	8,357.8	249.2
2. Randomized Markov Simulation															
Year 1	18	15	5	19	20	88	59	0	20	68	6	3	21	989	41
Year 2	23	12	12	19	48	76	44	44	88	56	4	3	33	2,054	65
Year 3	16	18	25	18	104	76	56	67	67	56	15	2	50	3,509	96
Year 4	20	20	25	17	108	68	87	111	47	79	20	0	76	5,165	147
Year 5	29	22	21	22	84	96	94	132	98	99	16	2	107	7,068	197
Year 6	31	28	23	31	104	123	87	119	116	105	16	3	150	9,395	272

1/ The j classifications are: 1 = young boars, 2 = mature boars, 3 = females 1 month of age, 4 = females 2 months age, 5 = females 3 months age, 6 = females 4 months age, 7 = females 5 months of age, 8 = females 6 months age, 9 = females 7 months age, 10 = females 8 months age, 11 = open sows, first month, 12 = open sows second month, 13 = open sows third month, 14 = gestation month 1, 15 = gestation mongth 2, 16 = gestation month 3, 17 = gestation month 4, 18 = lactating month 1, 19 = lactating month 2, 20 = males 1 month age, 21 = males 2 months age, 22 = males 3 months age, 23 = males 4 months age, 24 = males 5 months age, 25 = males 6 months age, 26 = males 7 month age, 27 = males 8 months age, 28 = total died, all ages, 29 = total sold, butchers: 1-8 months age, 30 = total sold, sows 9 months age and older.

2/ Also reported as "full inventory at time t=0" in Tables 3.5 and 3.6.

3/ End of the year inventory reported as "full inventory at time T=12" in Tables 3.5 and 3.6.

Table 3.4 Monthly Markov Chain Transition Matrix

t+1 →	j:	1	2	3	4	5	6	7	8	9	10	11	....	28	29	30
t ↓	Code:	S_{110}	S_{120}	S_{211}	S_{212}	S_{213}	S_{214}	S_{215}	S_{216}	S_{217}	S_{218}	S_{221}		S_{400}	S_{500}	S_{600}
i:	Code:															
1	S_{110}		.996										....	.004		
2	S_{120}		.996											.004		
3	S_{211}				.992									.008		
4	S_{212}					.998								.002		
5	S_{213}						.999							.001		
6	S_{214}							.999						.001		
7	S_{215}								.819			.18		.001		
8	S_{216}									.099				.001	.9	
9	S_{217}										.099			.001	.9	
10	S_{218}												....	.001	.999	

Table 3.4 (continued)

t+1 j:	Code:	....	3 SS_{211}	....	11 S_{221}	12 S_{222}	13 S_{223}	14 S_{231}	15 S_{232}	16 S_{233}	17 S_{234}	18 S_{241}	19 S_{242}	20 S_{301}	....	28 S_{400}	29 S_{500}	30 S_{600}
t i:	Code:																	
11	S_{221}	....		....		.349		.65							....	.001		
12	S_{222}						.599	.40								.001		
13	S_{223}							.20								.001		.799
14	S_{231}								.999							.001		
15	S_{232}									.999						.001		
16	S_{233}										.999					.001		
17	S_{234}		4.0									.967		4.0		.003		.03
18	S_{241}												.999			.001		
19	S_{242}	....		....	.249			.65							....	.001		.10

Table 3.4 (continued)

t+1 j:	Code:	....	S_{302}	S_{303}	S_{304}	S_{305}	S_{306}	S_{307}	S_{308}	S_{400}	S_{500}	S_{600}
			21	22	23	24	25	26	27	28	29	30
t i:	Code:											
20	S_{301}	....	.992							.008		
21	S_{302}			.998						.002		
22	S_{303}				.999					.001		
23	S_{304}					.999				.001		
24	S_{305}						.999			.001		
25	S_{306}							.199		.001	.8	
26	S_{307}								.099	.001	.9	
27	S_{308}									.001	.999	
28	S_{400}									1.		
29	S_{500}										1.	
30	S_{600}	....										1.

for the creation of 4 female (j=3) and 4 male pigs (j=20) of age one month from every sow in month four of gestation (i=17).

Probability data in matrix P and the opening inventory vector $\underline{y}$ are chosen to demonstrate the model for a fictitious herd. The element $p_{7,11}$ of the matrix P (with a value of .18 in Table 3.4) is considered the only decision variable in this model. This element, $p_{7,11}$, is the proportion of gilts selected. Females are taken from the inventory of 5 month old butcher hogs (i=7) and "selected" for the "open sow, first month" state (j=11). This variable directly affects the growth of the sow herd over time.

Solutions are found by Markov chain multiplication.

(3.19) $\underline{y}_{t+1} = P\,\underline{y}_t$

where $\underline{y}_t$ = an inventory vector of expected numbers in each state category y_{tj}.1/

Results of six years' simulation with a "gilts selection proportion" of 7 percent is given in yearly blocks in Table 3.5. Monthly inventory

---

1/ Known with certainty for t=0. For t>0, the expected number of an individual state category y_j is:

$$E[y_{tj}] = \sum_{m=0}^{M} m(\Pr\{\ y_{tj} = m\ \})\ ;\ \text{any } j=1,2,\ldots,\text{ or } 30;$$

where y_{tj} = inventory state j of time t,

$m = 0,1,2,\ldots,M$ the number of animals in state $y_{t-1,j}$.

The probability, $\Pr\{\ y_{tj} = m\ \}$, can be found by binomial formula if the probability vector (row of matrix P) contains two non-zero values, by multinomial formula if it contains more than two non-zero values. Expected values are reviewed by Wagner [40, p. 341].

values are summarized in seven sow and pig type categories[1] and are also given yearly as the expected number in each inventory state.[2]

Markov multiplication yields expected values, and as such provides a first useful analysis of the properties of the husbandry practices being modeled. It does not however, allow us to examine individual feasible time paths for the herd, nor does it provide estimates of variances around the expected values. Note that the solution procedure smooths the expected inventory values through time, i.e., sow and pig groupings are not maintained as identifiable groups after the opening inventory state. The effect is to simulate a herd breeding freely for continuous farrowing as if there were no target farrowing dates, or sow and pig groups. This is evidenced by the annual summary statistics. Note that the variance reported as a summary item each year is variance of the 12 expected inventory values, not an average of monthly variances. The variance of the expected values declines year-by-year and tends toward zero.

The following sections of this Chapter discuss modification of the multiplication procedure to allow variance estimates on inventory

---

1/ Open sows, and lactating sows are sums of more than one inventory state.

2/ Labeled "full inventory" at time T=12" in Table 3.5, they also appear in Table 3.3. These numbers appear as a series of 30 values printed in the order indicated as "identification for inventory states," also see the y code list in Table 3.3 where the 30 inventory states were first defined. The rather inconvenient summary arrangement of the full inventory reflects the fact that this program was developed simply to provide an example of the modeling procedures for exposition purposes in this thesis. The research model developed has considerably more readable reports.

Table 3.5 Monthly Markov Chain Simulation

MARKOV CHAIN MULTIPLICATION WILL BE USED TO SOLVE, INVENTORIES ARE TRUE EXPECTED NUMBERS.

GILTS SELECTED PROPORTION= .070
RANDOM NUMBER SOURCE IS CDC FUNCTION RANF(0)
T IMPLIES SIMULATION TIME AT THE END OF A MONTHLY TIME PERIOD

IDENTIFICATION FOR INVENTORY STATES.

BOARS-		FEMALES-							
Y110	Y120	Y211	Y212	Y213	Y214	Y215	Y216	Y217	Y218
OVULATING,OPEN-			GESTATING SOWS-				SOWS WITH PIGS-		BARROWS-
Y221	Y222	Y223	Y231	Y232	Y233	Y234	Y241	Y242	Y301
BARROWS(CONTINUED)-							T.DIED	T.SOLD1-8 MO	T.SOLD9-MO
Y302	Y303	Y304	Y305	Y306	Y307	Y308	Y400	Y500	Y600

FULL INVENTORY AT TIME T= 0 IS=

2.0	4.0	50.0	50.0	0.0	0.0	50.0	45.0	10.0	0.0
15.0	10.0	5.0	25.0	0.0	0.0	25.0	0.0	15.0	50.0
50.0	0.0	0.0	50.0	45.0	10.0	0.0	0.0	0.0	0.0

START YEAR= 1

	INVENTORY AT T				THIS MONTH		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	18.5	24.2	200.0	99.8	1.4	94.5	6.2
T= 2	5.7	24.2	0.0	99.0	2.1	95.8	4.8
T= 3	7.5	0.0	0.0	198.0	.7	14.4	4.9
T= 4	5.6	24.1	199.4	0.0	.6	1.4	2.0
T= 5	5.9	47.7	195.4	0.0	2.1	81.4	.7
T= 6	14.8	31.3	63.8	197.4	2.4	93.8	3.7
T= 7	11.1	24.4	138.3	193.5	1.4	175.9	3.5
T= 8	6.7	20.8	33.6	63.1	1.8	27.3	1.5
T= 9	13.0	7.0	24.6	136.9	1.1	2.8	3.9
T= 10	12.0	21.0	148.6	33.3	1.0	161.1	1.9
T= 11	8.0	41.4	194.3	24.5	1.8	183.6	1.3
T= 12	11.9	33.8	85.9	147.2	2.3	79.6	4.0

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE
LACTAT'G SOWS		24.991	171.584
PIGS MO.1	1284.05	107.004	6608.917
HOGS SOLD -8 MO.	1011.82	84.318	4196.203

FULL INVENTORY AT TIME T=12 IS=

0.0	5.7	43.0	96.4	73.6	12.2	16.6	63.5	2.9	.9
9.3	1.0	1.6	15.1	8.6	10.3	13.4	10.4	23.5	43.0
96.4	73.6	12.2	16.6	68.2	6.3	1.9	18.8	1011.8	38.4

Table 3.5 (continued)

START YEAR= 2

	INVENTORY AT T				THIS MONTH		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	10.8	23.3	107.3	192.3	1.6	122.7	4.0
T= 2	7.8	22.9	82.4	85.1	1.6	45.9	1.8
T= 3	11.0	18.3	68.7	106.3	1.5	26.3	3.1
T= 4	12.8	22.9	120.7	81.6	1.4	123.8	2.6
T= 5	10.0	35.8	175.5	68.0	1.7	176.5	2.1
T= 6	11.0	33.4	101.4	119.5	2.2	96.6	3.2
T= 7	11.7	23.8	95.9	173.7	1.7	100.6	4.0
T= 8	9.8	23.8	101.2	100.4	1.6	81.7	2.4
T= 9	10.6	24.4	101.2	95.0	1.6	67.7	2.8
T= 10	12.7	26.1	114.7	100.1	1.7	107.6	3.0
T= 11	11.2	32.8	156.6	100.2	1.8	158.3	2.7
T= 12	11.0	32.9	115.4	113.6	2.0	106.3	3.0

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE
LACTAT'G SOWS	---------	26.705	30.561
PIGS MO.1	1341.01	111.750	662.325
HOGS SOLD -8 MO.	1214.05	101.171	1833.230

FULL INVENTORY AT TIME T=12 IS=

0.0	5.4	57.7	77.7	56.8	50.0	50.0	44.0	4.6	.8
6.8	2.3	1.9	14.8	15.1	13.6	12.5	14.0	18.9	57.7
77.7	56.8	50.0	50.0	47.3	10.0	1.7	39.0	2225.9	73.2

START YEAR= 3

	INVENTORY AT T				THIS MONTH		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	11.9	26.0	99.7	155.0	1.8	93.1	3.8
T= 2	11.2	25.2	103.7	114.3	1.7	95.6	2.9
T= 3	11.1	27.7	120.2	98.7	1.7	96.2	2.8
T= 4	12.6	28.8	118.3	107.6	1.8	107.2	3.1
T= 5	12.1	31.6	143.4	119.0	1.8	142.8	3.2
T= 6	11.5	32.4	124.5	117.1	2.0	115.1	3.1
T= 7	12.1	28.3	109.9	142.0	1.9	97.7	3.6
T= 8	12.2	27.1	114.6	123.3	1.8	102.3	3.2
T= 9	11.8	29.6	130.4	108.8	1.8	112.6	3.0
T= 10	12.6	30.9	125.5	113.5	1.9	112.6	3.2
T= 11	12.7	31.8	137.5	129.1	1.9	132.9	3.4
T= 12	12.2	32.3	130.1	124.2	2.0	120.8	3.2

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE
LACTAT'G SOWS	---------	29.306	6.306
PIGS MO.1	1462.76	121.896	158.794
HOGS SOLD -8 MO.	1328.81	110.734	241.133

FULL INVENTORY AT TIME T=12 IS=

0.0	5.2	65.1	68.2	62.1	64.5	56.6	50.4	5.7	.6
7.6	2.9	1.8	16.7	17.0	15.2	15.1	15.7	16.6	65.1
68.2	62.1	64.5	56.6	54.3	12.2	1.4	61.1	3554.7	111.7

Table 3.5 (continued)

```
START YEAR= 4
         ----------------INVENTORY AT T----------------     ----------THIS MONTH---------------
         OPEN SOWS  LACTAT'G SOWS  PIGS MO.1    PIGS MO.3    TOT. DIED    SOLD-8MO.    SOLD 9-MO.
T=  1       12.5         30.4        121.1        136.1         2.0        106.9          3.5
T=  2       12.8         29.3        121.6        128.8         1.9        106.6          3.4
T=  3       12.6         31.1        136.1        119.9         1.9        121.7          3.2
T=  4       13.0         32.5        133.0        120.4         2.0        119.8          3.3
T=  5       13.2         32.7        137.3        134.7         2.0        129.1          3.6
T=  6       12.9         32.9        134.6        131.7         2.0        124.7          3.4
T=  7       13.0         32.1        131.0        135.9         2.0        116.6          3.6
T=  8       13.4         31.5        129.6        133.3         2.0        115.7          3.5
T=  9       13.3         32.6        140.5        129.7         2.0        127.4          3.5
T= 10       13.5         33.9        139.8        128.3         2.1        126.8          3.5
T= 11       13.7         33.9        140.8        139.1         2.1        130.0          3.7
T= 12       13.6         33.9        139.5        138.4         2.1        128.4          3.6
                        SUMMARY ITEM            TOTAL FOR YEAR        AVE MONTH          VARIANCE
                          LACTAT'G SOWS           ---------            32.220             2.062
                          PIGS MO.1               1604.81             133.734            46.911
                          HOGS SOLD -8 MO.        1455.79             121.316            62.658

FULL INVENTORY AT TIME T=12 IS=
   0.0       4.9      69.7      69.8      69.2      69.5      64.0      60.1       6.1        .6
   8.7       3.1       1.8      18.3      18.2      17.3      17.4      16.9      17.0      69.7
  69.8      69.2      69.5      64.0      64.7      13.2       1.3      85.4    5010.5     153.6


START YEAR= 5
         ----------------INVENTORY AT T----------------     ----------THIS MONTH---------------
         OPEN SOWS  LACTAT'G SOWS  PIGS MO.1    PIGS MO.3    TOT. DIED    SOLD-8MO.    SOLD 9-MO.
T=  1       13.6         33.7        139.4        139.4         2.1        125.2          3.7
T=  2       13.9         33.5        137.9        138.1         2.1        123.5          3.7
T=  3       14.0         34.2        145.2        138.0         2.1        132.1          3.7
T=  4       14.1         35.2        146.1        136.5         2.2        133.0          3.7
T=  5       14.2         35.3        146.2        143.7         2.2        133.8          3.8
T=  6       14.3         35.2        145.2        144.6         2.2        132.9          3.8
T=  7       14.3         35.3        146.8        144.7         2.2        132.7          3.8
T=  8       14.5         35.4        146.1        143.7         2.2        131.4          3.8
T=  9       14.7         35.9        150.7        145.3         2.2        137.1          3.9
T= 10       14.7         36.6        152.1        144.7         2.3        138.7          3.9
T= 11       14.8         36.8        152.5        149.2         2.3        139.0          4.0
T= 12       15.0         36.8        151.7        150.6         2.3        138.3          4.0
                        SUMMARY ITEM            TOTAL FOR YEAR        AVE MONTH          VARIANCE
                          LACTAT'G SOWS           ---------            35.313             1.217
                          PIGS MO.1               1759.87             146.656            21.845
                          HOGS SOLD -8 MO.        1597.61             133.135            24.367

FULL INVENTORY AT TIME T=12 IS=
   0.0       4.7      75.9      75.6      75.3      74.5      72.2      67.4       6.6        .7
   9.7       3.3       2.0      19.9      19.7      19.3      19.2      18.3      18.4      75.9
  75.6      75.3      74.5      72.2      72.5      14.3       1.4     111.9    6608.1     199.2
```

Table 3.5 (continued)

START YEAR= 6

	INVENTORY AT T				THIS MONTH		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	15.0	36.9	153.8	151.0	2.3	139.5	4.0
T= 2	15.2	37.2	154.1	150.2	2.3	139.1	4.0
T= 3	15.3	37.6	157.0	152.3	2.3	142.7	4.1
T= 4	15.4	38.1	158.4	152.5	2.4	144.4	4.1
T= 5	15.5	38.4	159.3	155.4	2.4	145.0	4.1
T= 6	15.6	38.4	158.9	156.6	2.4	144.4	4.2
T= 7	15.7	38.6	160.9	157.7	2.4	146.1	4.2
T= 8	15.8	39.0	161.8	157.3	2.4	146.5	4.2
T= 9	16.0	39.3	163.9	159.3	2.5	148.9	4.2
T= 10	16.1	39.8	165.2	160.2	2.5	150.5	4.3
T= 11	16.2	40.1	166.4	162.3	2.5	151.4	4.3
T= 12	16.3	40.2	166.5	163.5	2.5	151.2	4.3

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE
LACTAT'G SOWS		38.637	1.176
PIGS MO.1	1926.19	160.516	19.306
HOGS SOLD -8 MO.	1749.75	145.812	17.443

FULL INVENTORY AT TIME T=12 IS=

0.0	4.5	83.2	82.5	81.8	81.1	79.9	73.9	7.2	.7
10.5	3.6	2.2	21.6	21.5	21.2	21.0	20.1	20.1	83.2
82.5	81.8	81.1	79.9	79.4	15.6	1.5	140.9	8357.8	249.2

values, and to study feasible time paths for given inventory situations.

3.2.2 Modified Markov Chain Model

The Markov chain multiplication procedure of the previous section was modified to solve the model with the use of random numbers in the selection of transition paths. Individual animals are transformed from state to state resulting in stochastic integer results.

3.2.2.1 Individual Randomized Simulation

Consider a row vector $\underline{p}^*$ made up of a single row i^* of the transition matrix P. Positive elements p_{i^*j}; $j=1,2,\ldots,30$ of this probability vector[1/] prescribe the probability of an individual animal of inventory state i^* transferring to state j in time t+1 given that it was in state i^* in time t. A single random number is drawn for each animal of each inventory state in time t to randomly select, with probability defined by the probability row vector $\underline{p}^*$, the state j, into which this animal will move in time t+1.

This solution procedure was carried out by three Subroutines of a FORTRAN program. It is this general flow of the computer program that has generated the results reported in Table 3.6.[2/] These Subroutines are:

Subroutine EXECUTIVE
↓
Subroutine ROW I-LOOP
↓
Subroutine REPORT

1/ For a definition of a probability vector see equation (2.14).

2/ Additional features of the FORTRAN program, ignored here for clarity of presentation, include statistical calculating operations.

Table 3.6 Randomized Markov Chain Simulation

BRUTE FORCE SPINS OF RANDOM NUMBER GENERATOR WILL SOLVE, INVENTORIES ARE FREE TO RANGE STOCHASTICALLY.

GILTS SELECTED PROPORTION= .070
RANDOM NUMBER SOURCE IS CDC FUNCTION RANF(0)
T IMPLIES SIMULATION TIME AT THE END OF A MONTHLY TIME PERIOD

IDENTIFICATION FOR INVENTORY STATES.

BOARS-		FEMALES-							
Y110	Y120	Y211	Y212	Y213	Y214	Y215	Y216	Y217	Y218
OVULATING,OPEN-			GESTATING SOWS-				SOWS WITH PIGS-		BARROWS-
Y221	Y222	Y223	Y231	Y232	Y233	Y234	Y241	Y242	Y301
BARROWS(CONTINUED)-							T.DIED	T.SOLD1-8 MO	T.SOLD9-MO
Y302	Y303	Y304	Y305	Y306	Y307	Y308	Y400	Y500	Y600

FULL INVENTORY AT TIME T= 0 IS=

2.0	4.0	50.0	50.0	0.0	0.0	50.0	45.0	10.0	0.0
15.0	10.0	5.0	25.0	0.0	0.0	25.0	0.0	15.0	50.0
50.0	0.0	0.0	50.0	45.0	10.0	0.0	0.0	0.0	0.0

START YEAR= 1

	INVENTORY AT T				THIS MONTH		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	17.0	24.0	200.0	100.0	2.0	92.0	8.0
T= 2	4.0	24.0	0.0	97.0	5.0	105.0	6.0
T= 3	7.0	0.0	0.0	197.0	0.0	11.0	4.0
T= 4	4.0	24.0	200.0	0.0	0.0	0.0	2.0
T= 5	5.0	45.0	176.0	0.0	1.0	82.0	1.0
T= 6	16.0	28.0	56.0	199.0	2.0	96.0	4.0
T= 7	9.0	23.0	136.0	172.0	3.0	171.0	6.0
T= 8	9.0	21.0	40.0	56.0	3.0	32.0	1.0
T= 9	15.0	5.0	0.0	134.0	2.0	2.0	4.0
T= 10	5.0	14.0	120.0	40.0	0.0	161.0	1.0
T= 11	5.0	33.0	176.0	0.0	2.0	171.0	3.0
T= 12	8.0	24.0	40.0	118.0	1.0	66.0	1.0

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE
LACTAT'G SOWS	---------	22.083	140.083
PIGS MO.1	1144.00	95.333	6556.606
HOGS SOLD -8 MO.	989.00	82.417	3984.265

FULL INVENTORY AT TIME T=12 IS=

0.0	6.0	20.0	87.0	59.0	0.0	20.0	63.0	3.0	0.0
7.0	1.0	0.0	13.0	4.0	18.0	15.0	5.0	19.0	20.0
88.0	59.0	0.0	20.0	68.0	6.0	3.0	21.0	989.0	41.0

Table 3.6 (continued)

START YEAR= 2

	INVENTORY AT T				THIS MONTH		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	8.0	19.0	120.0	175.0	2.0	120.0	3.0
T= 2	6.0	32.0	144.0	39.0	0.0	54.0	0.0
T= 3	11.0	22.0	32.0	120.0	1.0	6.0	2.0
T= 4	12.0	16.0	104.0	144.0	1.0	96.0	1.0
T= 5	5.0	31.0	152.0	32.0	2.0	152.0	1.0
T= 6	9.0	25.0	56.0	104.0	1.0	58.0	2.0
T= 7	16.0	20.0	112.0	152.0	1.0	105.0	1.0
T= 8	13.0	35.0	176.0	56.0	0.0	138.0	1.0
T= 9	15.0	32.0	88.0	112.0	3.0	36.0	3.0
T= 10	14.0	22.0	88.0	175.0	0.0	101.0	4.0
T= 11	8.0	30.0	152.0	88.0	0.0	127.0	3.0
T= 12	11.0	31.0	96.0	88.0	1.0	70.0	3.0

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE

LACTAT'G SOWS		26.250	39.659
PIGS MO.1	1320.00	110.000	1758.545
HOGS SOLD -8 MO.	1065.00	88.750	1932.750

FULL INVENTORY AT TIME T=12 IS=

0.0	6.0	48.0	76.0	44.0	44.0	87.0	51.0	3.0	0.0
9.0	2.0	0.0	9.0	15.0	23.0	12.0	12.0	19.0	48.0
76.0	44.0	44.0	88.0	56.0	4.0	3.0	33.0	2054.0	65.0

START YEAR= 3

	INVENTORY AT T				THIS MONTH		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO
T= 1	16.0	24.0	96.0	152.0	2.0	104.0	1.0
T= 2	8.0	34.0	184.0	94.0	0.0	157.0	2.0
T= 3	5.0	37.0	120.0	95.0	2.0	93.0	2.0
T= 4	15.0	24.0	72.0	184.0	1.0	68.0	1.0
T= 5	14.0	29.0	176.0	119.0	0.0	134.0	5.0
T= 6	14.0	41.0	176.0	72.0	1.0	99.0	1.0
T= 7	16.0	35.0	112.0	174.0	2.0	95.0	3.0
T= 8	13.0	31.0	136.0	174.0	2.0	154.0	3.0
T= 9	12.0	33.0	136.0	111.0	4.0	126.0	1.0
T= 10	12.0	29.0	112.0	133.0	2.0	84.0	4.0
T= 11	13.0	31.0	152.0	135.0	0.0	153.0	5.0
T= 12	8.0	43.0	208.0	112.0	1.0	168.0	3.0

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE

LACTAT'G SOWS		32.583	34.992
PIGS MO.1	1680.00	140.000	1623.273
HOGS SOLD -8 MO.	1455.00	121.250	954.750

FULL INVENTORY AT TIME T=12 IS=

0.0	6.0	104.0	76.0	56.0	67.0	66.0	52.0	3.0	2.0
5.0	3.0	0.0	19.0	21.0	16.0	18.0	25.0	18.0	104.0
76.0	56.0	67.0	67.0	56.0	15.0	2.0	50.0	3509.0	96.0

Table 3.6 (continued)

START YEAR= 4

	----INVENTORY AT T----				----THIS MONTH----		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	16.0	42.0	144.0	152.0	3.0	113.0	1.0
T= 2	14.0	33.0	178.0	205.0	0.0	132.0	6.0
T= 3	11.0	36.0	168.0	144.0	2.0	129.0	1.0
T= 4	21.0	37.0	152.0	127.0	5.0	113.0	5.0
T= 5	23.0	30.0	104.0	164.0	3.0	127.0	2.0
T= 6	21.0	39.0	208.0	150.0	0.0	187.0	4.0
T= 7	20.0	45.0	160.0	104.0	2.0	141.0	6.0
T= 8	19.0	30.0	96.0	206.0	3.0	123.0	5.0
T= 9	20.0	39.0	224.0	157.0	1.0	165.0	4.0
T= 10	14.0	48.0	176.0	96.0	2.0	133.0	5.0
T= 11	18.0	37.0	136.0	222.0	1.0	109.0	4.0
T= 12	19.0	42.0	216.0	175.0	4.0	184.0	8.0

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE
LACTAT'G SOWS	---------	38.167	31.061
PIGS MO.1	1912.00	159.333	1727.515
HOGS SOLD -8 MO.	1656.00	138.000	712.182

FULL INVENTORY AT TIME T=12 IS=

0.0	6.0	108.0	67.0	88.0	110.0	48.0	71.0	16.0	0.0
13.0	3.0	3.0	20.0	24.0	20.0	20.0	25.0	17.0	108.0
68.0	87.0	111.0	47.0	79.0	20.0	0.0	76.0	5165.0	147.0

START YEAR= 5

	----INVENTORY AT T----				----THIS MONTH----		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	17.0	43.0	160.0	135.0	3.0	157.0	6.0
T= 2	25.0	38.0	160.0	214.0	2.0	103.0	3.0
T= 3	21.0	44.0	192.0	159.0	1.0	194.0	5.0
T= 4	22.0	44.0	160.0	158.0	3.0	177.0	7.0
T= 5	19.0	34.0	136.0	190.0	1.0	125.0	6.0
T= 6	20.0	37.0	184.0	159.0	2.0	197.0	5.0
T= 7	15.0	47.0	200.0	135.0	2.0	161.0	4.0
T= 8	18.0	50.0	200.0	183.0	3.0	150.0	2.0
T= 9	17.0	56.0	264.0	199.0	1.0	176.0	8.0
T= 10	17.0	55.0	192.0	199.0	3.0	162.0	1.0
T= 11	21.0	46.0	192.0	262 0	4.0	125.0	5.0
T= 12	24.0	43.0	168.0	169.0	6.0	176.0	3.0

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE
LACTAT'G SOWS	---------	44.750	44.932
PIGS MO.1	2208.00	184.000	1035.636
HOGS SOLD -8 MO.	1903.00	158.583	828.629

FULL INVENTORY AT TIME T=12 IS=

0.0	5.0	84.0	95.0	95.0	130.0	100.0	90.0	7.0	1.0
17.0	4.0	3.0	27.0	30.0	29.0	22.0	21.0	22.0	84.0
96.0	94.0	132.0	98.0	99.0	16.0	2.0	107.0	7068.0	197.0

Table 3.6 (continued)

START YEAR= 6

	INVENTORY AT T				THIS MONTH		
	OPEN SOWS	LACTAT'G SOWS	PIGS MO.1	PIGS MO.3	TOT. DIED	SOLD-8MO.	SOLD 9-MO.
T= 1	21.0	42.0	176.0	190.0	5.0	183.0	6.0
T= 2	25.0	49.0	232.0	165.0	4.0	192.0	5.0
T= 3	18.0	57.0	240.0	174.0	4.0	241.0	9.0
T= 4	19.0	56.0	216.0	230.0	3.0	189.0	6.0
T= 5	19.0	53.0	224.0	239.0	4.0	184.0	7.0
T= 6	23.0	46.0	160.0	210.0	7.0	160.0	7.0
T= 7	17.0	46.0	216.0	222.0	3.0	172.0	7.0
T= 8	20.0	54.0	232.0	157.0	2.0	203.0	5.0
T= 9	18.0	57.0	240.0	214.0	2.0	225.0	9.0
T= 10	19.0	51.0	176.0	232.0	3.0	212.0	4.0
T= 11	22.0	53.0	248.0	239.0	2.0	202.0	6.0
T= 12	16.0	54.0	208.0	173.0	4.0	164.0	4.0

SUMMARY ITEM	TOTAL FOR YEAR	AVE MONTH	VARIANCE
LACTAT'G SOWS		51.500	23.182
PIGS MO.1	2568.00	214.000	827.636
HOGS SOLD -8 MO.	2327.00	193.917	584.447

FULL INVENTORY AT TIME T=12 IS=

0.0	5.0	104.0	123.0	86.0	120.0	116.0	99.0	7.0	2.0
10.0	5.0	1.0	34.0	28.0	31.0	28.0	23.0	31.0	104.0
123.0	87.0	119.0	116.0	105.0	16.0	3.0	150.0	9395.0	272.0

Subroutine EXECUTIVE reads in data and prepares the problem for execution. Subroutine ROW I-LOOP accepts the prepared problem from Subroutine EXECUTIVE and executes it for a single time period. Subroutine REPORT writes the results of the execution and returns control to the EXECUTIVE for preparation of the next single period problem.

Subroutine EXECUTIVE notes the number of periods to be simulated, the total number of elements (total = J) in the opening inventory vector $\underline{y}_o$; and the size of the transition matrix P (J rows and J columns). Initialization of variables includes setting the vector $\underline{y}_{t+1} = 0$ and the counting variable i = 0. $\underline{y}_o$ and P are read in as data. Individual rows i; i=1,2,...,J; of the transition matrix P are then converted to a matrix of cumulative probabilities[1/] C, containing zeros, positive elements $0 < c_{ij} \leq 1$, and deterministic variables (>1). The cumulative probability elements are calculated by summing probability elements of P from left to right on rows while maintaining their positions as found in the original matrix P. Therefore, the probability elements of C indicate feasible transitions as they did in P.

Consider the J=4 example of Chapter 2 where equation (2.18) was presented:[2/]

$$(3.20) \qquad P = \begin{bmatrix} 0 & .7 & 0 & .3 \\ 0 & .8 & 8.0 & .2 \\ .1 & 0 & 0 & .9 \\ 0 & 0 & 0 & 1.0 \end{bmatrix}$$

1/ Conversion to cumulative probabilities was not required for the matrix multiplication of ordinary Markov Chain analysis.

2/ Recall from Chapter 2 that the four states of this example are: 1=open sows, 2=bred sows, 3=pigs of all ages, and 4=total sales.

Converted to a cumulative probability matrix, P becomes[1]

(3.21)
$$C = \begin{bmatrix} 0 & .7 & 0 & 1.0 \\ 0 & .8 & 8.0 & 1.0 \\ .1 & 0 & 0 & 1.0 \\ 0 & 0 & 0 & 1.0 \end{bmatrix}$$

Matrix C facilitates comparison of feasible transitions with the random number selected for each animal in the Subroutine ROW I-LOOP. Note that the deterministic element[2] $c_{2,3}$ remains equal to 8.0, resulting in the creation of 8 pigs from each sow farrowing.

The opening inventory vector $\underline{y}_o$ as used for ordinary Markov multiplication is:

(3.22)
$$\underline{y}_o = [4 \quad 6 \quad 60 \quad 0] .$$

After preparation of matrix C by Subroutine EXECUTIVE, control is passed to Subroutine ROW I-LOOP for execution. One row i at a time is used in an "I-LOOP" thereby accommodating transition of all animals contained in a single state i of $\underline{y}_t$[3] before turning to the animals in the next inventory state.

Consider the above example problem (equation 3.21 and 3.22) as it was solved by the FORTRAN program. Subroutine EXECUTIVE reads in matrix P and $\underline{y}_o$, converts P to C, recognizes the deterministic value

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1/ Elements c_{ij} are the cumulative probability of transferring to respective states. Each individual row vector $\underline{c}^*$ made up of a single row i^* of the cumulative probability matrix C fulfills the function of a row vector $\underline{p}^*$ described in the opening statement of of this section.

2/ This coefficient need not be deterministic. If it were stochastic, an extra random number loop would be needed to draw litter size from a probability distribution for this particular run, or particular sow as was done for this type variable in the research model presented in Chapter 4.

3/ y_{it} is used to refer to elements of $\underline{y}_t$ while y_{jt+1} is used to refer to elements of $\underline{y}_{t+1}$. See figure 3.1 Flow Chart of Subroutine ROW I-LOOP.

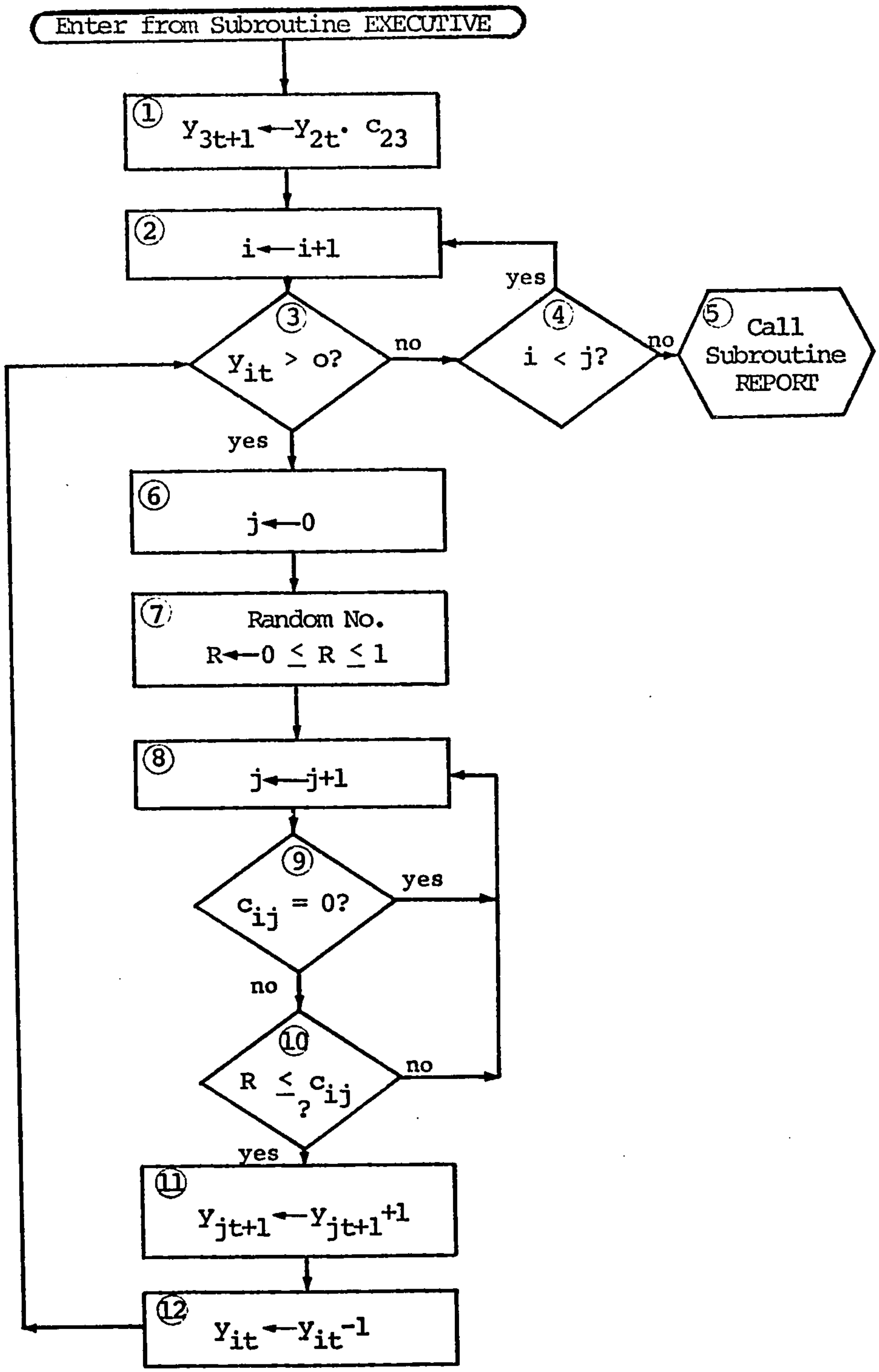

Figure 3.1 Flow Chart of Subroutine ROW I-LOOP

in $c_{2,3}$, and notes that there are 4 states ($J = 4$). Subroutine ROW I-LOOP then executes the transition from t to t+1 according to the Flow Chart in Figure 3.1. First, pigs are created by multiplication, box 1, and stored as the first addition to the inventory vector $\underline{y}_{t+1}$. In this example problem, eight pigs are added to state 3 for each bred sow of state 2 in the original inventory vector $\underline{y}_t$.[1/] The value of the counter i is then incremented: box 2, Figure 3.1. If state i, of $\underline{y}_o$ ($y_{1,0}$ of box 3) contains more than zero animals, the counter j (corresponding to states of the inventory vector for time t+1) is set to zero in box 6, and a random number is drawn in box 7. At this point an individual animal of state classification i, is to be transferred to one of its feasible transition states j in t+1.

The value of the counter j is incremented by one in box 8, to consider disposition of the animal to state 1 of $\underline{y}_{t+1}$. The model allows two possibilities: (a) that $c_{ij}=0$ in box 9, and is not a feasible transition or; (b) that $0 < c_{ij} \leq 1$ and is therefore a feasible transition for comparison with the random number R, from box 7. If there is not a successful match of $R \leq c_{ij}$ in box 10, control is returned to box 8 where the value of j is incremented by one[2/] and the immediately succeeding state j, (succeeding c_{ij}), is considered for transition.

1/ This side calculation could have involved a random variable for litter size as was used in the research model of Chapter 4.

2/ A successful match will be found on or before j takes the value J since a $c_{ij} = 1$ will be found on or before the point where j=J. See the matrix C, equation (3.21).

A successful match of $R \leq c_{ij}$ allows transfer of the animal to state j of the inventory vector y_{t+1} from state i of y_t by operation of boxes 11 and 12 respectively.[1/] Control now returns to box 2 where state i (y_{it}) is compared to determine if additional animals require disposition.

One animal at a time is thus transferred to one of its feasible states via operation of boxes 3-12. When all animals of any one state have been transferred, i is incremented so that succeeding states can be transferred in turn.

When all animals of all 4 example inventory states have been transferred, control is passed to Subroutine REPORT where the t+1 inventory vector is written. Control then returns to Subroutine EXECUTIVE and the process repeated for each additional period to be simulated.

Individual randomized simulation for the 30 state modified Markov chain model was carried out by similar operations of the Subroutines EXECUTIVE, ROW I-LOOP, and REPORT.

Solution of this modified model in a FORTRAN lanaguage computer program is relatively fast.[2/] Solutions were restricted to integer values since each animal was transformed to one and only one

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1/ In the example problem for i=1 a successful match would result if the random number drawn were say R=.3. The box 10 match would occur when j was equal to 2, since $.3 \leq .7$. The result is one open sow deleted from inventory t and one bred sow incremented for t+1.

2/ A total of 60 sec. of Central Processing time was required for this monthly model containing 30 inventory states, with 500 animals in opening inventory, and simulating 6 years of production. A random number is drawn for each animal and its disposition decided according to the probability of attaining each feasible state. A less efficient alternative computational procedure is discussed in Appendix A.

feasible state. Simulation results were free to range stochastically. Results from solution of the modified Markov chain model, designated "Model No. 2", are given in Table 3.6. Results are reported for a simulation run covering six years. Note that while inventory numbers in each state category are held to integer values, the grouping of sows and pigs is also smoothed through time as was the result of Markov multiplication.1/

Repetitive solution of this model would provide information for estimation of the probability distribution of results. Repeated runs would yield fully stochastic results simulating many of the important features of a breeding herd.

3.2.3 Shortcomings of the Demonstration Models

The conceptual model presented above defines the important features of the reproductive process of the swine breeding herd, with a daily time interval, and highlights the stochastic and integer nature of the productive animal.

The demonstration models reveal the operational nature of the modeling problem. Markov process models have demonstrated how probability data can be incorporated. The individual randomized simulation (Table 3.6), in particular, provides a general procedural pattern for studying the research model.

There are however, a number of important limitations of the demonstration models. These shortcomings are of two types: (a)

1/ This was evidenced by the decline in the month-to-month variance statistics over the 6 years of simulated results. Variance was greater than that of the Markov multiplication model and did not tend toward zero. End of the year inventories also appear for comparison purposes in Table 3.3.

limitations which can be overcome by improvement of the monthly individual randomized simulation, and (b) those which require a more complex and detailed model.

Major shortcomings under (a) are:

1. The number of pigs born alive per litter should have been a stochastic variable.
2. Baby pig survival should have depended on the survival of the nursing mother.
3. Number of sows bred should have depended on the number of boars as well as the number of sows available.
4. There should be synchronization of farrowings.
5. There should be provision for breeding policy to get a target number of sows bred for each farrowing, subject to the number of open sows and gilts as well as boar availability.
6. There should be grouping of pigs for housing assignment to confront housing availability.
7. Rules should be included for selection of gilts for breeding stock, weight to sell, maximum age to keep sows, etc.
8. There should be provision for conditional probabilities of conception, farrowing, etc., related to earlier events.[1/]

1/ Note that this modification would take us away from a simple Markov type structure and/or increase the size of the problem by several orders of magnitude.

The above limitations were overcome by reprogramming the three Subroutines detailed in the previous section and described in the Flow Chart of Figure 3.1. The changes required are discussed in section 3.2.3.1 below.

Major shortcomings which would require a substantially more complex model include:

1. A model which would allow experiments with heat synchronization, length of heat cycles, gestation, estrus cycles or other characteristics requiring the detail of a daily model.

2. A model which would allow adaptive behavior in the allocation of space or other scarce resources.

The latter shortcomings required a model with daily transformation.[1/] A daily model is required to answer questions related to: (a) scheduling of farrowing, (b) gilt versus sow production, (c) boar availability, (d) female fertility, etc. In short, the monthly model is too aggregate for modeling many stochastic aspects of production.

3.2.3.1 Limitations Which Could Have Been Overcome in a Monthly Model

Limitations which could have been incorporated into the monthly demonstrational model include those that require a simple development of the model, and management strategies which require a different type of model. In the list, 1-8 above, shortcomings 1-3 indicate a simple development of the model. Shortcomings 4-8 however, require

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1/ For a biological study of epidemic disease, an hourly, or even shorter time period, might be required.

greater modification of the structure of the model.

The number of pigs farrowed (shortcoming number 1) could have been made a stochastic variable by inserting a few FORTRAN statements. This would have made the number of pigs farrowed dependent upon a sow reaching the end of gestation. The number of pigs farrowed could then become a random variable, replacing the deterministic calculation in the demonstration model. When a deterministic value was encountered in the matrix of transition probabilities, this could be noted, and operations with bred sows carried out before pigs were created. This would result in a known number of sows surviving and farrowing, i.e., moving from state 17 (bred sows) to state 18 (first month of lactation).1/ An additional subroutine could then be used to create baby pigs for each of the surviving mothers which have farrowed and appear in state 18. This new subroutine would use the deterministic value discovered in the transition matrix as the mean, of say a truncated normal distribution, in conjunction with the random number generator to assign baby pigs stochastically to individual nursing mothers.

Herd numbers could be stored in an additional matrix M managed in parallel with the vector $\underline{y}$. For say 12 bred sows in the herd, matrix M would contain 12 unique herd numbers identified as block 17, i.e., $y_{17,t} = 12$. Matrix M for time t + 1 would then reflect those bred sows surviving and farrowing to become first month lactating sows of state 18. A herd numbering system is essential for assignment of a

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1/ States coded S_{234} and S_{241}, Table 3.4 Monthly Markov Chain Transition Matrix.

particular litter to an individual sow.[1/]

Baby pig survival could be dependent upon the survival of the nursing mother (shortcoming number 2) by inserting FORTRAN statements which make a check for survival of the nursing sow and only then allows survival of individual litters.[2/] Litters of pigs could be identified by a coded herd number which links the individual pig as offspring of a particular sow.[3/] A subroutine would be called, subject to the

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1/ The opening inventory y_0 for the example problem (equation 3.22) for the four state model containing 4, 6, 60 and 0 animals respectively would be:

$$M = \begin{bmatrix} 1 & 0001 \\ 1 & 0002 \\ 1 & 0003 \\ 1 & 0004 \\ 2 & 0001 \\ 2 & 0002 \\ \vdots & \vdots \\ 2 & 0006 \\ 3 & 0001 \\ 3 & 0002 \\ \vdots & \vdots \\ 3 & 0060 \\ 4 & 0000 \end{bmatrix}$$

M is an array of flexible sized blocks containing J rows, one for each of the J total number of states in the model; and 2 columns, one for the associated block (state i) to which the animal belongs and the other the herd number m.

2/ Baby pigs were assumed lost if the mother dies. In a very detailed model, pigs would realistically have a chance for survival dependent on transfer to other litters, and their age and stage of consumption of milk replacer or dry feeds at the time of the mother's death.

3/ A computer word of storage which allows 18 integer digits permits coding of several pieces of information into a herd number. For example, the number 01800090053 can represent a first month lactating sow (state 018), nine baby pigs in her litter (0009), and an individual chronological herd number of 0053. An individual pig in this sow's litter might have the herd number 00300530198 indicating a barrow in its first month (state 003), born to sow number 0053, which has a unique herd number 0198. The number of attributes which can be stored in one computer word is limited by the 18 integer digits storage capacity of the CDC 6500 at Purdue University. Ordinary FORTRAN statements using integer multiplication and division were used to interpret numbers "packed" in this way.

event that a nursing sow dies, which locates the dead sow's pigs and "kills" them. Other operations of the model would not change implying that the baby pig transition probabilities would then be defined as conditional probabilities, i.e., survival given that the nursing mother survived.

Interaction of boars and sows (shortcoming number 3) could be overcome by a check for boar availability. For the monthly model, a subroutine would be required which makes a check on the number of boars available (values of y_{1t} and y_{2t}) before the usual transitions for rows i = 11, 12, 13, and 19 are made.1/ This subroutine would adjust the appropriate transition probabilities of conception if boars were found to be in short supply.

The above adaptations of the monthly demonstration model could have been accomplished by adding FORTRAN statements or subroutines to check for biological feasibility and carry out appropriate adjustments.

Shortcomings which require management strategies demand rather major changes in the model and its flow of solution procedures. This type of shortcoming has to be overcome by writing a more complicated FORTRAN program2/ which is capable of carrying out management

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1/ See Table 3.4 column 14 showing transitions to the month-one bred sow state of the Monthly Markov Chain Transition Matrix.

2/ Such as the research model itself which was designed to overcome the limitations under discussion here.

strategies according to predetermined rules. The following discussion of how shortcomings 4-8 (in the list 1-8 above) were overcome mainly involves the nature of the additional programming required to overcome those shortcomings.1/

Synchronization of farrowing was overcome by designing a model which operates a particular kind of management system. Synchronization was accomplished by weaning sows to synchronize their heat periods. Gilts cannot be grouped in this way. The management system may demand say, a 3 week weaning season in an attempt to schedule breeding and farrowing in approximately three weeks. Using a very simple approach, the model was made to follow a calendar of breeding schedules so that breeding was allowed over appropriate dates with no breeding at other times. For the monthly model this would have meant a check for dates by Subroutine EXECUTIVE. If breeding were not allowed, transition probabilities would be altered to reflect the no breeding policy. These adjustments would have been made before Subroutine ROW I-LOOP executed the program.

Provision for a breeding policy to get a target number of sows bred required limiting exposure of sows to boars. The breeding season was closed when the target number of sows had been exposed. Building design capacity of the farrowing house provided a target number of sows to farrow (number of farrowing crates). The farrowing

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1/ Note that introduction of herd numbers, location codes, etc., required to overcome shortcomings 4-8, changes the complexion of the model. Attention is being given to simulation of the production path for individual animals and away from total number of animals in broadly defined states.

house is the most rigid space bottleneck in the production process. Modern farrowing facilities contain a given number of farrowing crates with no flexibility for adding crates or crowding more than one sow into one crate.[1/] The farrowing house is a high investment building, and requires emptying and cleaning after each farrowing season. Although in practice, as well as in the research model, breeding policy needed to focus primarily on farrowing capacity and the size of target farrowings.

Open sows are available from (a) the supply of female butcher hogs being finished (gilts), (b) from the stock of open sows being maintained in anticipation of an upcoming breeding season, and (c) from sows which were lactating in the immediate preceding period and could be weaned and bred before the end of the breeding season. Breeding strategy demands noting the number available from b and c, and selecting the number to be culled from five month old butcher lots and assigning them to the open sow state, two periods[2/] prior to the beginning of the breeding season. Subroutine EXECUTIVE needed to be reprogrammed to carry out these operations and start and stop the breeding season.

Grouping of pigs for housing assignment (shortcoming number 6)

1/ Early weaning, removal of the sow to maintenance and the pigs to a growing house, allows double use of the crate in a single farrowing season but not double occupancy. There are of course, associated influences on the number of pigs in the nursery, the number of sows being maintained and/or available for breeding. These effects were incorporated into the daily research model.

2/ Removal from finishing rations and conditioning for two months is required to complete sexual maturity and enhance reproductive ability.

was overcome by adding a housing subroutine to the monthly model. A housing code number was added to the individual animal herd number to reflect the building in which the animal is housed.1/ In addition, an inventory of building space must be maintained to evaluate occupancy rates for study of the model. This inventory requirement took the form of an array with accounting of subfiles to reflect coded housing types, their capacities and occupancy as the model was executed.

A set of production management options were provided for selection of gilts for breeding, weight to sell, maximum age to keep sows, etc. This took the form of additional computer program where a rather complete review of the inventory vector would first be made to determine qualifying animals and then appropriate disposition made in light of the criteria for gilt selection, selling weight, maximum ages, etc. For example, sales were handled as a search of all animals located in the finishing building. Those animals meeting the weight criteria, greater than or equal to say 215 pounds, are declared sold and removed from array storage. Production management strategies were much the same as the culling jobs the herdsman must execute.

Conditional probabilities, related to earlier events were accomplished by including key probabilities in the list of attributes throughout simulation for each individual animal entity. These are of two types: (a) those which are lifetime characteristics of the animal such as date of birth, litter size and length of estrus, and (b)

1/ A very detailed model could have included crate and pen numbers in this code.

those which cause a multiple period effect but are determined by a random event during simulation such as the availability of boar services and building space, and the length of a pregnancy.

Conditional probabilities of type (a) are incorporated by the Markov Chain approach to a solution procedure where previous history is summed up by the description of the current state occupied by an animal. The probability of transition to another state is a conditional probability (probability of transition given that earlier events placed the animal in the current state). Conditional probabilities of type (b) suggest a major departure from the Markov Chain solution procedures exemplified by an effects calendar. These operate as adjustments of transition probabilities and attribute values.[1/] Suppose Subroutine EXECUTIVE determines that the number of boars available results in only one boar service rather than the normal two services. The effect of reduced boar services would be carried out over the period in which they are in short supply. The severity and length of time over which conceptions were reduced could occur over several time periods. The resulting probabilities are conditional upon previous events and the duration of the effects of such events.

Accommodation of the above shortcomings 4-8 have been shown to require more and more attention to the individual animal as an

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1/ This is for computer efficiency. Note that attaching attribute values to individual animal entities is not a conceptual departure from the "state" definition of the Markov process, in that the "state" implied a well defined set of attributes. Given no practical limit on the number of "states," all stages of any condition could be represented by some series of states and the probability of transition one to another.

entity, turning away from the use of generalized "States". This is necessitated by the incorporation of the detail desired in the model. It was found necessary to identify individual animals and attach attributes[1/] for expedient operation of the FORTRAN program. Note that definition of these attributes is suggested by the Simple Binary Mechanistic Model of a Swine Herd of section 3.1.1. The characteristics i, j, k, L, m, and t (subscripts of the individual animal x) in equation (3.2), are the reproductive attributes of swine. The conceptual model demands daily considerations as suggested by the second major category of shortcomings.

The monthly model and its solution procedures provided the building block for a more complex research model. Limitations which required a more complex model are discussed in the following section.

3.2.3.2 Limitations Which Require a Daily Model

Even if the monthly individual randomized model were developed as suggested above, it would not have been detailed enough to allow experiments with characteristics of swine which require a model with a shorter time unit. A more complex daily model was required to incorporate the features of the reproductive animal.

A daily research model allowed experiments with heat synchronization, length of heat cycles, gestation, and estrus cycles by providing a time unit short enough to allow additional attributes as random variables. Allocation of space experiments were possible once the

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1/ Attributes already introduced above include: weight, building location, litter and dam identification.

daily model was developed. Many of the space bottlenecks may appear critical when modeled daily, even though they would not seem to be problems under the abstraction of a monthly model. The daily time interval allowed calculation of daily gains as well as many of the reproductive attributes of swine.

The strategy rules, adjustments to the transition matrix, and other operational aspects of the model suggested a flexible model which is more comprehensive than the demonstration models but at the same time includes the features of the inventory vector and transition probabilities of those models.

3.2.4 Transition to the Research Model

The demonstration models and the above discussion of their shortcomings indicate the way in which the stochastic nature of the swine breeding herd problem was visualized. Limitations of the demonstration models were overcome by the use of a daily time interval and the incorporation of greater detail and features in the research model beyond those of the demonstration models. These developments are discussed in greater detail in the next chapter.

CHAPTER 4

THE MODEL

Conceptual models have been developed and demonstrated in the form of a simplified monthly model in Chapter 3. The limitations of this monthly model led to the requirements of the research model. These limitations, and the modifications required to overcome them, have already been discussed. It is the purpose of this chapter to define the research model and discuss its implementation in accordance with the third objective of the study: to implement the model in the form of an operational computer program for use by research workers.

The research model provides for definition of all possible states which an animal can take at any point in simulation time, and for the transition mechanisms for all state to state transformations. Some of these mechanisms have been presented and demonstrated in Chapter 3. Additions to them are discussed in this chapter. Limits to transformations are set by specification of control parameters which define management practices and housing restrictions. The complete list of control parameters takes the form of an Input-Output Form which is included as Appendix B.

Section 4.1 defines the limits to animal attributes, combinations of which define animal states, as well as auxiliary characteristics of animals and the system.

Animal and building attributes characterize the model and facilitate its evaluation. Section 4.2 presents the computer implementation of the model and reviews the more important control parameters incorporated into the computer program.

4.1 Statement of the Model

The statement of the model defines states and characteristics of all animals and of the system as a whole. Animals have attribute values which define their productive state at any point in time. Attributes and their permissible ranges were defined following the notation of the conceptual model of Chapter 3. Whereas the conceptual model of Chapter 3 served to conceptualize the complexity of the interrelationships between reproductive animals, this statement of the research model has as its emphasis definition of all productive states of all animals. The research model also provides for evaluation of the condition of the herd at any point in time as well as measures of the use of building resources.

Permissible animal states are first defined. Then the auxiliary animal characteristics dictated by the limitations to the monthly models found in Chapter 3 are discussed. The auxiliary characteristics of the system itself are then presented.

4.1.1 Animal States

For the purposes of the research model, animals were conveniently classified into productive classes as (a) boars, (b) sows, or (c) market hogs. Let

(4.1) $B_{ikLmhuvstwg}$ = a unique boar state, where:

i = age in days = 150, 151, 152,...,730[1/]

k = subclass = 1 = newly purchased; $150 \leq i \leq 395$

= 2 = young boar; $195 \leq i \leq 365$

= 3 = mature boar; $366 \leq i \leq 730$[1/]

L = number of days in the herd

m = a unique herd number

h = boar building (file) number

u = daily use = 0 for $k = 1$, $L \leq 30$

= 0,1,2,3[1/] for $k = 1,2,3$, $L > 30$

v = weekly use = 0,1,2,...,10[1/] for $k = 1$

= 0,1,2,...,15[1/] for $k = 2$

s = total services count

t = simulation time in days

w = current weight in pounds

g = daily gain in pounds[2/]

If boar $B_{ikLmhuvstwg}$ survives[3/] to time t he is available for service only if u and v do not exceed their respective ranges, unavailable otherwise.

1/ A control variable set optionally by the user of the computer implementation, see section 4.3.4. Optional control variables will be simply footnoted as "optional value" in the remainder of this chapter.

2/ A random deviate discussed in section 4.1.2.

3/ Survival is stochastic as defined in Chapter 3.

Let

(4.2) $S_{ikLmhpeqstwg}$ = a unique sow state, where:

i = age in days - 160,161,162,...,1600 1/

k = subclass = 1 = never ovulated; $160 \leq i \leq 209$

= 2 = open sows; $210 \leq i \leq 1600$

= 3 = in gestation; 226 2/ $\leq i \leq$ 1754 3/

= 4 = in lactation; $336 \leq i \leq$ 1754 3/

L = days in k subclass

m = unique herd number

h = building file number = 4 = farrowing

= 6 = maintenance

= 9 = cull pen

p = number of pigs born alive 4/ = 4,5,6,...,or 16

e = estrus cycle length, days 5/ = 16,17,18,...,25

q = gestation length, days 4/ = 110,111,112,...,118

s = maximum exposures without conception = 0,1,2 6/

1/ Maximum age to keep a sow is waived if the sow is in gestation or lactation when reaching this age. This is a control variable: optional value.

2/ Age at first start of estrus cycle plus minimum 16 days estrus.

3/ Maximum age of 1600 plus maximum length of gestation and lactation, since producing sows are never culled because of age.

4/ Random deviate drawn for each farrowing, optional value.

5/ Random deviate drawn once for the life of the sow.

6/ Optional value.

t = simulation time in days

w = current weight in pounds

g = daily gain in pounds

Surviving sows gestate, farrow, and lactate within the limits of the management strategies defined for the herd. See sections 4.1.2 and 4.1.3 which discuss auxiliary characteristics of animals and the system.

Let

(4.3) $H_{ikmhdbtwg}$ = a unique market hog, where:

i = age in days; = 1,2,3,...240

k = subclass = 1 = female

= 2 = male

m = unique herd number

h = building file number = 4 = farrowing

= 5 = nursery

= 7 = finishing

d = dams herd number

b = birth weight;1/ $1.25 \leq b \leq 5.0$

t = simulation time in days

w = current weight in pounds

g = daily gain in pounds

Surviving hogs of all ages occupy building space until sold as butcher hogs or selected as female replacements for the sow herd.

1/ Optimal value.

See auxiliary management strategies: section 4.1.3 Auxiliary Characteristics of the System.

4.1.2 Auxiliary Animal Characteristics

Auxiliary characteristics of animals include those attributes added to the reproductive attributes to facilitate evaluation of the model. These include weight, w, daily gain, g, and the associated age categories used to select daily gain values as random normal deviates. Animal weights were a necessary addition to provide a realistic sales criteria and to permit cost of gain calculations. Sows experience a weight loss at parturition based upon number of pigs born alive.

Table 4.1 Standard Gain Parameters, presents the standard parameters which define the random normal distribution from which daily gains are drawn. Parameter values for gain are optional to the user of the model, see Appendix B Input-Output Forms and Instructions.

Daily gain is constant throughout the time period of each age or productive classification. For example, an individual sow receives a daily gain (drawn as a random deviate) at the beginning of her lactation period and gains at that rate throughout lactation.

She then receives another at the beginning of her maintenance period. Pigs likewise grow at constant rates within their age classifications. A new random deviate for the value of g is drawn as the pig enters each age class.

In general, the features necessary to overcome the limitations of section 3.2.3.1 which could have been overcome in a monthly model

Table 4.1 Standard Gain Parameters

Productive Class	Mean	Standard Deviation	Minimum	Maximum
All boars:	0.5	0.2	-5.0	10.0
Sows:				
Maintenance	1.0	0.2	-5.0	10.0
Lactation	-0.5	1.0	-5.0	10.0
Weight Loss per pig at parturition	5.0	0.5	-10.0	10.0
Market Hogs of age:				
1-7	0.45	0.07	-5.0	10.0
8-21	0.58	0.09	-5.0	10.0
22-56	0.75	0.11	-5.0	10.0
57-149	1.25	0.15	-5.0	10.0
150-sale[1/]	1.70	0.26	-5.0	10.0

were incorporated in the daily research model.[2/] The number of pigs farrowed was made a stochastic variable, as shown in equation (4.2) The number of pigs farrowed was made to reflect the productivity of gilts versus sows by adding an attribute which is obtained by drawing a random normal deviate with the Mean a function of the age of the sow. This was accompanied by the addition of a stochastic variable for

1/ Or in the case of a female, until selection as a sow herd replacement.

2/ For a complete list of optional parameters, see Appendix B.

length of gestation. Individual herd numbers were added to the model to link sows with their baby pigs which permitted making baby pig survival dependent upon survival of the nursing mother. If a lactating sow dies during the first week of lactation, all her pigs also die. If death takes place after the first week her pigs die with a probability of 50 percent.

The probability of pregnancy was made dependent upon the availability of boar services facilitated by the daily and weekly availability scheme defined by equations (4.1) and (4.2). Attributes u and v define daily and weekly limits on the number of services available from a boar. Boar services either are or are not available. Users of the computer implementation have the opportunity to make the number of pigs born as well as the probability of conception dependent upon there being 1 or 2 boar services available.

4.1.3 Auxiliary Characteristics of the System

The auxiliary characteristics of the system were necessary to correct the limitations of the monthly models and to incorporate the management strategies which required a different type of model.

The main feature required of the system was a schedule of events to control breeding, weaning, gilt selection, culling, and sales according to management policy. Let f represent farrowing season 1,2,..., or 6 in a six farrowing per year-blocked[1/] system.

1/ Blocked refers to blocking out of farrowings during Spring and Fall planting and harvesting seasons.

Then beginning dates of target farrowings[1/] within any one year can be represented as: t_f = 15 (January 15), 60 (March 1), 152 (June 1), 198 (July 17), 244 (September 1), or 355 (December 1). Corresponding times to begin breedings t_b are:

(4.4) $$t_b = t_f - q + D_q$$

Where

t_b = day to begin breeding for target farrowing f; b,f=1,2,...,6.

t_f = target day for first farrowing in season f=b.

q = Mean length of gestation in days.

D_q = Standard Deviation of q.

The Standard breeding season of 21 days defines a breeding season from: t_b to $t_b + 21$. The length of the breeding season; and the value of q, and D_q are all optional control parameters to the computer implementation.

Sows and gilts are available for breeding as they come into heat during the time the system is in a breeding season t_b to $t_b + 21$, if the count of the number exposed to boar services has not exceeded the target number of sows to be exposed.

If the target number exposed[2/] is reached, exposure to boars is terminated until the following breeding season. A 21 day breeding season accomplishes a moderate synchronization of farrowing subject to

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1/ The stochastic nature of farrowing leads to the use of the term target farrowing.

2/ Optional value.

the stochastic nature of the length of gestation and to the availability of sows and boars during the breading season.

Let w represent weaning season 1,2,...,or 6 for pigs born during the farrowing season f=w. Beginning days of weaning seasons t_w are:

(4.5) $$t_w = t_f + A$$

Where

t_w = day to begin the weaning season w.

t_f = Target day for first farrowing in season f,w=1,2,...,6.

A = Target age of pigs at weaning.1/

The Standard length of the weaning period1/ is 18 days. The actual weaning schedule (number of litters weaned on given days) provides for inspection of the inventory of litters at the beginning of the weaning season and a subschedule to uniformly wean all litters within days t_w and $t_w + 18$. The schedule consists of an assigned number of litters to be weaned each day of the weaning season.2/

1/ Optional value.

2/ The schedule is a subscripted array with one element for each of the days in the weaning period. It is constructed by adding to an empty array a digit 1 for each litter to be weaned. Additions to positions are in the order: t_w+18, t_w+17,...,t_w, t_w+18, t_w+17, ...,t_w, etc., etc., until all litters have been assigned. The distribution over the weaning period is therefore relatively uniform; but lumped toward the end of the season by at most 1 litter per day, unless by chance the number to be weaned is exactly divisible by the number of days in the weaning period.

Let g represent gilt selection day 1,2,..., or 6. Gilt selection occurs on day t_g where:

$$(4.6) \qquad t_g = t_b - 101$$

when gilts are approximately 5 months of age. Minimum age is the only gilt selection criteria. The first 10 1/ gilts encountered which met this criteria are slected prior to each breeding season, i.e. on day t_g.

Culling occurs as the result of routine probability culling at weaning time or as the result of reaching the maximum number of times permitted failure to conceive when exposed to boars. Twenty percent 1/ of first litter gilts and sows are routinely culled after weaning. Those culled are sold at the next regularly scheduled market hog sale.

Culling for nonception follows when the sow attribute s exceeds two 1/ exposures to the boar without conception. Detection of nonception for culling purposes is assumed to take place 60 1/ days after this limit is reached. Culled sows are eligible for sale.

Sales were scheduled every two weeks. 1/ Selling implies clearing the system of an animal entity after recording weight and value for reporting purposes. A market hog was sold if it met the minimum weight criteria of 215 2/ pounds. All sows located in the cull pen are also sold at that time.

1/ Optional value.

2/ Optional value. Special sales can take place when the finishing building becomes overfilled, see section 4.2.4.

A complete cleaning was performed on the farrowing house before each farrowing. During this cleaning period the farrowing house remains idle for seven1/ days.

4.1.3.1 Buildings

Buildings were added to the research model. Permissible building occupation by animals has been defined by equations (4.1), (4.2) and (4.3). Building design capacities assumed were:

Building Type	Capacity1/ and Target Age Limits	Absolute Age Limits for Occupancy
Farrowing	15 sows; $k = 4$, and 15 litters of pigs; $1 \leq i \leq 36$	$i \leq 44$
Nursery	125 head of pigs $37 \leq i \leq 82$	$28 \leq i \leq 150$
Maintenance	80 sows; $k = 1,2$, or 3; $160 \leq i \leq 1600$	none
Finishing	240 hogs; $83 \leq i \leq 180$	$i \geq 58$
Boars	no limit to number of head	none
Culls	no limit to number of head	none

Capacities of buildings are simple accounting values in the research model. These values are used to evaluate the use of buildings by simple arithmetic calculation of the percentage occupancy in each building.

Management strategies were required for movement of animals from building to building. At farrowing a sow and her litter enter

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1/ Optional value.

the farrowing house ($h = 4$ in equations 4.2 and 4.3) and remain there throughout lactation. Actual age at weaning is stochastic with a target age of 36[1/] days. The program allows early weaning, up to a point,[1/] if the farrowing house is overfilled.

Transfer of pigs from the farrowing house to the nursery is mandatory at weaning. Sows return to the maintenance building or go to the cull pen at weaning time.

Transfer from the nursery to finishing building occurs as the individual pig becomes 82 days of age.[1/] The program allows animals to remain in the nursery, up to a point,[1/] if the finishing house is full.

4.2 Computer Implementation

The research model was implemented in the form of a computer program written in FORTRAN IV for the CDC 6500 computer at Purdue University. Various features of the computer program are discussed as subsections of this final portion of Chapter 4.

A skipping process was developed to improve run time. This is the subject of section 4.2.1. Next, the system of filing animal attributes by packing 3 to 5 attributes into a single word of computer storage is discussed in section 4.2.2.

Optional sources of random numbers were provided by a subroutine. This is discussed in section 4.2.3 followed by section 4.2.4, a discussion of the Input-Output Form which was developed to define those parameters which are user options in the computer program.

1/ Optional value.

4.2.1 The Skipping Process

The models' emphasis upon scheduling of reproductive activities and housing bottlenecks led to the belief that for some purposes, the daily nature of the model was less important than at other parts of the production process. This allowed consideration of a longer time unit than one day at some points to improve computational efficiency. It was found that animals could be skipped forward while preserving the daily nature of the simulation process. Skipping saved time consuming calculations by reducing the number of times that an animal was required to be removed from a file, considered for survival, and updated for daily attributes such as age or weight and returned to a file. This was accomplished by skipping an animal forward in simulation time whenever it was appropriate to do so. Once skipped forward, an animal was counted as part of the inventory class and building in which he was located and could be skipped with regard to other calculations until simulation time caught up to him.

Skipping required multiplication of daily transition probabilities to reflect transition probabilities over the period being skipped. Animals were skipped various lengths of time but could not be skipped beyond dates for events which might affect them or beyond reporting dates requested on the input form. Application of a single random number for the time period skipped replaced use of a random number for each day, reducing computer time spent generating random numbers.

Primary candidates for skipping were the nursery and finishing stages of hog growth, sow gestation, open sows when breeding seasons were not in effect, and lactation after the first week and before the beginning of weaning. The skipping process was halted for finishing hogs prior to gilt selection from the finishing building and was halted before scheduled sales. Skipping was also halted for all sows during breeding seasons. Boars were never skipped forward because of the small number of animals involved.

4.2.2 Packed Attribute Storage and Filing System

Packing of more than one attribute into a single word of computer storage permitted the storage of up to 12 integer values (attributes of animals) in three computer words of 14 integer digits each. This reduced the computer memory requirements for storage of animal entities by approximately[1/] 3/4.

Packing involves splitting a word of storage into parts. Consider as an example, for the purpose of exposition, splitting a 14 digit word into 4 rightmost and 10 leftmost digits. Assignment is made to the rightmost section by simple FORTRAN assignment taking care that the resulting integer value of the rightmost 4 places will always be a value IR such that $0 \leq IR \leq 9999$.

Unpacking the rightmost digits involves remaindering to discover their value. For a 14 digit value N, the rightmost 4 digits are IR = N - N / 10000 *10000. The hierarchy of FORTRAN arithmetic operations insures that multiplication and division have equal precedence but are done before subtraction. The number N is first divided by 10000,

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1/ Approximately since some memory was required for those machine language statements which did the packing or unpacking operations.

truncating the rightmost 4 digits. Then multiplication by 10000 has the effect of moving the decimal point 4 places to the right, i.e. completing a two step replacement of the original 4 rightmost digits with zeros. The remaining arithmetic operation is to subtract the result from the original 14 digit value N. The value assigned to IR by this procedure is the value equal to the rightmost 4 digits of N.

Assignment of the leftmost portion IL involves simple set-over by integer multiplication of the digits IL before assignment: N = IL * 10000. IL is then unpacked by division: IL = N/10000, where division has removed the unwanted rightmost 4 digits by integer truncation.

Three to five attributes were packed into one word of computer storage by using combinations of the above techniques. While efficiency of use of computer memory was improved, access and reassignment of attribute values required several multiplication and/or division operations at a cost of increased computer run time.

Packed storage of attributes is accomplished only at the cost of the additional execution time required for their packing and unpacking before and after their manipulation as animal attributes in whole word variable names. Note that for packed storage with four integer attributes packed into one word of computer memory, a leftmost, two middle, and a rightmost attribute must be unpacked to provide access to all four attributes. A savings in get operations is traded for the time required to divide, multiply, and subtract the integer values as required to unpack the four attributes after a single get operation.

The leftmost attribute is unpacked in about 135 time units[1/] by an integer division. Each middle attribute requires both leftmost and rightmost type unpacking for a total of 422 units. The rightmost attribute is unpacked with an integer division (135 units), multiplication (112 units), and a subtraction (40 units) as discussed above. Unpacking the four attributes involves a total of about 1305 time units as compared to 156 for getting four separately stored integer attributes. Packing also involves a similar trade off of time spent in packing for that saved in the put operation.

A convenient filing system was used to store animal attributes as rows in one integer and one real array. Column subscripts were used to correspond to individual animals. Since the columnwise dimensioned size of a doubly dimensioned array is not used to find memory locations, the columnwise dimensioned size need be declared only in the main program. This made changing the size of the filing arrays a matter of changing their dimensioned size in the main program only.

Filing arrays were organized into subfiles corresponding to buildings to facilitate the terminology of writing subroutines to place animals in and to remove animals from buildings (files).[2/] Comment cards

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1/ The time unit used here is the minor cycle = 100 nanoseconds where 1 nanosecond = 10^{-9} seconds. Based on units requirement for arithmetic operations from information obtained in personal communication and from unpublished estimates by the Agricultural Economics Computer Laboratory, Purdue University.

2/ See Appendix C for a list of the computer program used to implement the research model.

found in the main program give an outline of the general organization of the program. Comment cards are used in the main program and in subroutines to indicate the purpose and use of major sections of the program should attention need be given to FORTRAN statements in the program itself. The Input-Output Forms have been designed to facilitate use of the model by providing a means to specify control parameters (see section 4.2.4).

4.2.3 Random Number Sources

Computer implementation of the research model provides a means of using alternative sources of random numbers. All random numbers used in the program are supplied in the program by calls to FUNCTION RANUM.

The standard source used in this study was the CDC 6500 FUNCTION RANF(0). The program FUNCTION RANUM (D) is also prepared to alternatively supply random numbers from a tape of random numbers R: $0.0 \leq R \leq 1.0$. Instructions for this alternative are given in the Input-Output Form, Appendix B.

4.2.4 Input-Output Forms

The use of a model is highly dependent on its structure. The choice of a Markov Chain type model permitted running the model as a computer program (simulation). Sensitivity analysis by running experiments to evaluate the model was further facilitated by provision of convenient input forms and easily read output.

The Input-Output Forms define those parameters of the computer implementation which are user options. Use of the computer program by research workers is further facilitated by providing optional report requests. These reports may take the form of a short report of production and costs incurred or they may extend to reporting of individual animal attribute values on a daily basis.

The Input-Output Forms are contained in Appendix B. Chapter 4 has presented the research model, including definition of the states which animals are permitted to take. Characteristics of the system and the attributes permitted for buildings were also discussed. A discussion of the computer implementation of the research model dealt with the more important features of the computer program. Chapter 5 will present the kind of results obtainable by running the program.

CHAPTER 5

ILLUSTRATIVE RESULTS

This chapter is intended to illustrate the capability of the implemented model. The results of a single run of one years' simulated swine production is presented, Table 5.1, to illustrate the information provided by the computer program.[1/] Section 5.1 discusses the use of buildings. The topic of section 5.2 is production information. Section 5.3 discusses costs and returns followed by a review of the financial results of synchronized (standard control values) as compared to nearly continuous breeding in section 5.4. Section 5.5 then presents some possible uses of the model in its present form as an experimental tool.

5.1 Building Utilization With Standard Control Values

Table 5.1 contains the report of a simulation run using standard values as defined on the input-output forms.[2/] The subsections of Table 5.1 all report some combination of building use, breeding results, farrowing results, weight gains, or costs and returns which were obtained from the simulation of a 365 day period.

1/ This portion of optional computer output is termed "periodic reports" because it was available covering any length period from 1 to 1600 days. Seasonal reporting is also available on farrowing, breeding, and sales. Other more voluminous reports and messages are provided as optional diagnostic aids. For a complete list of available output see Appendix B Input-Output Forms and Instructions.

2/ See Appendix B for a complete list of the optional control variables on building occupancy.

Table 5.1 Periodic Reports

```
            SWINE BREEDING HERD SIMULATOR

 REQUEST IS FOR 365 DAYS,            TODAYS DATE IS 12/16/72
 YOUR IDENTIFICATION CARD=

        STANDARD CONTROL PARAMETERS FOR A PRODUCTION AND BUILDING UTILIZATION EXAMPLE.


BUILDING USE PERIODIC REPORT ON DAY= 365
==============================================================================================
     PREVIOUS REPORT WOULD HAVE BEEN DUE ON DAY    0, TODAY IS DAY 365 OF YEAR 1

            (NO.TODAY)         PERCENT OF MAXIMUM CAPACITY OVER 365 DAYS
             --------- ---------------------------------------------------------------

     -------ITEM-------  -----MEAN-----  ---ST. DEV.---  ---MINIMUM---    ---MAXIMUM---

     NURSERY       (  0)=     66.54          32.99           0.00           123.20
       CAPACITY= 125
     FINISHING     (182)=     78.65          17.27          40.42           100.00
       CAPACITY= 240
     MAINTENANCE  ( 62)=      60.42          12.24          37.50            81.25
       CAPACITY=  80
     FARROW CRATES( 11)=      67.16          27.12           0.00           100.00
       CAPACITY=  15
===END BUILDING USE REPORT====================================================================


PERIODIC BREEDING REPORT ON DAY= 365
==============================================================================================
     TODAY IS DAY 365 OF YEAR 1

 BREEDINGS RESULTED IN      93 CONCEPTIONS.

     -------ITEM-------  -----MEAN-----  ---ST. DEV.---  ---MINIMUM---    ---MAXIMUM---

     AGE OF SOW AT FARROWING=  755.183        371.385         360.000        1564.000
     ASSIGNED LITTER SIZE=       9.828          2.958               4              16

 SOWS IN HEAT BUT NOT BRED                        =      206
   DUE TO- TARGET PREVIOUSLY REACHED              =       30
           LACK OF BOARS                          =        1
           FAILING PROBABILITY OF CONCEPTION TEST =        3
           SEASON CLOSED                          =      172

END PERIODIC BREEDING REPORT==================================================================
```

Table 5.1 (continued)

```
FARROWING PERIODIC REPORT ON DAY=  365
=====================================================================================
    TODAY IS DAY 365 OF YEAR 1

    -------ITEM-------  -----MEAN-----  ---ST. DEV.---  ---MINIMUM---   ---MAXIMUM---

FARROWED 75 LITTERS IN FARROW BLD.


    LITTER SIZE ALIVE=          9.893           3.069               4              16
    PCT. CRATES FULL AT BIRTH= 45.689          25.296           6.667         100.000
    BIRTH WEIGHT OF PIGS=       3.129            .534           1.272           4.717

LOST  0 LITTERS, BLD. NOT CLEANED

LOST  0 LITTERS, DUE TO BLD. OVERFLOW

END PERIODIC FARROWING REPORT========================================================


WEIGHT GAINS PERIODIC REPORT ON DAY= 365
=====================================================================================
    TODAY IS DAY 365 OF YEAR 1

PRODUCTION NET OF INVENTORY CHANGE-

                          -------NUMBER-------  ---WEIGHT LBS.----  ----VALUE DOL.----

    HOGS UNDER 240 DAYS =        517              132211.1             27103.3
    SOWS(ALL 240 AND UP)=         28               11284.8              1908.6

ENDING INVENTORY-

    HOGS UNDER 240 DAYS =        303               32859.3              6736.2
    SOWS(ALL 240 AND UP)=         58               26446.4              4495.9

END WEIGHT GAINS PERIODIC REPORT=====================================================
```

Table 5.1 (continued)

```
COSTS AND RETURNS PERIODIC REPORT ON DAY= 365
==============================================================================
    TODAY IS DAY 365 OF YEAR 1     PERIOD COVERED=  365 DAYS

    FEED COSTS SOWS= 3018.82 DOL. AT .14 PER DAY PER SOW

    FEED COSTS HOGS=15534.80 DOL. AT 11.75 PER 100 LBS. PRODUCED

 LABOR COSTS BY BUILDING INCLUDING CULL PEN AT 3.00 DOL. PER HOUR
    FARROWING=              1198.27
    NURSERY=                 323.71
    SOWS MAINT. +CULLS=      715.04
    FINISHING=              1001.73

 SOWS PRODUCED=      112.8 CWT.    AT VALUE OF      1918.42 DOL.

 HOGS PRODUCED=     1322.1 CWT.    AT VALUE OF     27103.27 DOL.


COSTS AND RETURNS SUMMARY OVER A  365 DAY PERIOD.
    TODAY IS DAY 365 OF YEAR 1

                                   -------SOWS-------  -------HOGS-------  ----TOTAL HERD----
                                         ($)                 ($)                 ($)
                                      (1)
    PRODUCTION NET OF INVENTORY CHANGE 1918.42            27103.27            29021.70
              (2)
    FEED COST                           3018.82            15534.80            18553.62
               (3)
    LABOR COST                          1913.31             1325.45             3238.76



    RETURN OVER FEED AND LABOR        -3013.71            10243.02             7229.31
 ------------------------------------------------------------------------------------
 (1) SOWS INCLUDE ANIMALS 240 DAYS OF AGE AND OVER, OTHERWISE THEY WHERE CLASSED AS HOGS AND PIGS.
 (2) FEED COST FOR SOWS BASED ON DAYS OF MAINTENANCE (INC. CULL PEN) AND LACTATION.
 (3) LABOR COST BASED ON BUILDING OCCUPANCY, ALL FARROWING HOUSE LABOR WAS ASSIGNED TO SOWS.
===END COSTS AND RETURNS SUMMARIES===================================================
```

Building utilization reports; including the Mean, Standard Deviation, Minimum, and Maximum percent of capacity; were calculated from daily observations. The number of head in each building was reported for the final day and the total capacity of the building noted.

On the last day of simulation the nursery building contained no animals, but on the average it was utilized to 66.5 percent of its 125 head capacity with a Standard Deviation of 33 percent. At least at one point, the building contained 123.2 percent of its 125 head capacity as reported in the Maximum column. Standard control parameters do not allow pigs to move from the nursery to the finishing building until they are 82 days of age.[1/] Overfilling of the nursery is an infeasibility which would, in practice, require some adaptive procedure. Moving pigs to the finishing building at an earlier age[2/] or housing pigs in the nursery under overcrowded conditions would be two possible adaptive strategies which could be used by the manager when the nursery building is overfilled.

The finishing building, with 182 head at the end of the year, was utilized to an average of 78.7 percent of its 240 head capacity. During the period, occupancy was as low as 40.4 percent and as high as 100 percent. This indicates that at some time the building was assigned to full capacity. Special sales can be held to reduce the number in the finishing building to maximum capacity. Special sales

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1/ See Appendix B for a complete list of the optional control variables on building occupancy.

2/ A user option, see Appendix B.

are made when the finishing building is overfilled, reducing numbers until no hogs over 190 pounds remain, or the building is no longer overfilled. A detailed report of these special sales may be requested as a user option.

The maintenance building with 62 head at the end of the period had been used to 60.4 percent of its 80 head capacity but never reached more than 81.3 percent at any time during the year.

At the end of the year the 15 farrowing crates in the farrowing building contained 11 Litters and had been used up to 67 percent. The farrowing building is empty for cleaning before each farrowing season and this results in a reported Minimum occupancy of zero. The farrowing house did not overflow. Overflow results in loss of litters when Standard control options are in effect. A check for this loss is made by inspecting the section of Table 5.1 entitled: "Farrowing Periodic Report on day = 365".[1/]

5.2 Production With Standard Control Variables

The portion of Table 5.1 entitled "Periodic Breeding Report on Day = 365" reveals that the six breeding seasons included in the reporting period resulted in a total of 93 sows conceived. Conceiving sows where estimated to average 755 days of age at farrowing time and the average litter size assigned (actual number born alive if the sow farrows) was equal to 9.8. A count shows that 206 sows were on heat but not bred, due either to the number exposed having been previously reached (30 cases), lack of boars (1 case), failing to conceive when exposed (3 cases), or the season being closed (172 cases).

1/ See the second page of Table 5.1.

The farrowing periodic report indicates 75 litters farrowed during the year. Single use of the 15 crates in 6 farrowings could have accommodated 90 litters. Note that crate occupancy observations include litters in the crates at opening inventory as well as those litters farrowed during the year. Average litter size born during the year was 9.9 live pigs. Building capacity, calculated from one observation per litter upon its first entry to the farrowing house, ranged from 6.67 to 100 percent. Average birth weight was 3.1 pounds. No litters were lost due to the farrowing house not being cleaned or due to building overflow as indicated by the messages at the conclusion of the farrowing report.

The report called "weight gains periodic report on day = 365" indicates the number of head, weight, and value produced net of inventory changes. These are allocated between hogs and sows for use in calculation of the financial results in the final portion of Table 5.1.

5.3 Costs and Returns With Standard Control Values

The costs and returns portion of Table 5.1 reconciles the variable costs of feed and labor with the net value of production. Cost options are intended to be an approximation of variable costs for feed and labor. Cost calculations are made daily based on inventories in buildings using Standard costs or user supplied rates. <u>No fixed costs were included in the costs and returns calculations</u>.

Feed cost for sows was based on an average day of maintenance and lactation at a rate of 14 cents per day.[1/] The $3,018. cost of

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1/ Standard value, at the users' option.

feed reported for sows was a simple summation over all sows in the maintenance and farrowing buildings. Feed costs of $15,535. for butcher hogs was calculated at the rate of $11.75 per 100 pounds[1/] of gain produced net of inventory.

Labor was assumed to cost $3 per hour[1/] regardless of the building in which it was incurred. Labor in minutes per litter, or per head, per day was calculated for each building. For the specific labor requirements and the variable cost options available, see Appendix B.

The cost and returns summary groups all animals into sows or hogs. For convenience of calculation, sows are defined as all animals 240 days of age and over, otherwise they are classed as hogs. The value of production net of inventory change was: sows = $1,918., hogs = $27,103. for a total herd value of $29,021. Feed costs at $3,019. for sows and $15,535. for all hogs totaled $18,553. for the herd. Labor costs for sows includes all farrowing house labor plus sow maintenance building and cull pen labor. This amounted to $1,913. and labor for hogs was $1,325., making the total herd labor charge $3,239.

The results called "return over feed and labor" shows a net return over variable feed and labor for sows of $3,014. but a gain of $10,243. for hogs. Return to the whole herd was calculated at $7,229. Note that this is a measure of return above those variable feed and labor costs included in the 14¢ per day per sow, the $11.75 per 100 lbs. of hog produced, and the $3 per hour labor charge. While

---

1/ Standard value, at the users' option.

inventory changes are accounted for, fixed costs and other variable costs are not accounted for in any way.

5.4 A Comparison of Synchronized and Nearly Continuous Breeding

A limited number of runs were made to demonstrate how the model can be used as a research tool and how the results would be interpreted to compare synchronized with continuous breeding.[1/] Six runs were made using standard data as found on the input form. The output given in Table 5.1 and reviewed above was chosen to represent the results of synchronized breedings.

Six comparative runs were then made to demonstrate the results obtainable for a nearly continuous breeding (farrowing) schedule. In these runs the breeding season was scheduled over 44 days[2/] rather than 21 days, and weaning over 44 days[2/] rather than 18 days as prescribed by the standard values. The outstanding difference between these two breeding policies is that the longer breeding season permits some sows to be exposed to boars over two heat periods. Some second occupancy of farrowing stalls over the longer farrowing season can also be expected.

The results of six runs made under each of these breeding policies demonstrates the stochastic nature of the outcomes. The expected returns (calculated Mean of 6 observations) were: $7,497 for standard-synchronized breeding[3/] and $7,663 for the continuous breeding

---

1/ The following section contains additional suggestions for use of the model as an experimental tool.

2/ Maximum values allowed by the computer program, see section 4.3 of Appendix B.

3/ Returns over feed and labor were $7,229, $7,687, $7,065, $7424, $8,066, and $7,514.

policy[1/]. Standard Deviations were calculated at $353 and $414 respectively.

This small number of runs is not sufficient to permit a conclusion as to whether these policies give significantly different financial results. However, for the purpose of exposition, the results for one of the runs will be considered typical of those obtained under the nearly continuous breeding policy. This report, shown in Table 5.2, reveals that continuous breeding resulted in more sows conceiving and greater total production for a larger return over feed and labor than was obtained with the standard-synchronized breeding policy.

The modest improvement in return over feed and labor apparently was gained through more efficient use of the sows maintained. A comparison of the number of sows (including boars and culls) maintained shows that the standard-synchronized policy required maintaining about 1.6 sows for each one farrowed while only 1.4 were maintained for each one farrowed under the continuous breeding policy.[2/]

Double use of some farrowing stalls occured at least during one farrowing as indicated by the 120 percent reported as maximum capacity in the building use report of 5.2. The continuous breeding policy resulted in an infeasible farrowing house bottleneck during the first two farrowings of the year.[3/] A total of 5 litters were lost due to lack of farrowing crates at birth.

1/ Returns over feed and labor were $7,333, $7,625, $8,100, $7,222, $7,468, and $8,232.

2/ Based on a "normal" 182 days of maintenance per sow farrowed: calculated from the "costs and returns periodic report" of Tables 5.1 and 5.2.

3/ This information is taken from detailed diagnostic reports not shown in Table 5.2.

Table 5.2 Periodic Reports for Nearly Continuous Breeding

```
            SWINE BR--DING HERD SIMULATOR

  REQUEST IS FOR 365 J. S.             TODAYS DATE IS 12/18/72
  YOUR IDENTIFICATION CARD=

          CONTINUOUS FARROWING EXAMPLE WITH STANDARD PARAMERTERS OTHERWISE.


BUILDING USE PERIODIC REPORT ON DAY= 365
==============================================================================
     PREVIOUS REPORT WOULD HAVE BEEN DUE ON DAY   0, TODAY IS DAY 365 OF YEAR 1

              (NO.TODAY)         PERCENT OF MAXIMUM CAPACITY OVER 365 DAYS
               --------  --------------------------------------------------

     -------ITEM-------  -----MEAN-----  ---ST. DEV.---  ---MINIMUM---   ---MAXIMUM---

     NURSERY       (  0)=    67.85          37.12            0.00          183.20
       CAPACITY= 125
     FINISHING     (185)=    86.00          15.24           45.42          125.83
       CAPACITY= 240
     MAINTENANCE   ( 55)=    59.85          11.00           38.75           80.00
       CAPACITY=  80
     FARROW CRATES( 13)=     61.66          37.93            0.00          120.00
       CAPACITY=  15
===END BUILDING USE REPORT====================================================


PERIODIC BREEDING REPORT ON DAY= 365
==============================================================================
     TODAY IS DAY 365 OF YEAR 1

 BREEDINGS RESULTED IN      105 CONCEPTIONS.

     -------ITEM-------  -----MEAN-----  ---ST. DEV.---  ---MINIMUM---   ---MAXIMUM---

     AGE OF SOW AT FARROWING=  743.724      369.872        344.000        1490.000
     ASSIGNED LITTER SIZE=       9.610        2.973              4              15

 SOWS IN HEAT BUT NOT BRED                     =     143
   DUE TO- TARGET PREVIOUSLY REACHED           =      72
           LACK OF BOARS                       =       0
           FAILING PROBABILITY OF CONCEPTION TEST =    5
           SEASON CLOSED                       =      66

END PERIODIC BREEDING REPORT==================================================
```

Table 5.2 (continued)

```
FARRCWING PERICCIC REFCRT CN CAY=  365
******************************************************************************************
    TCCAY IS CAY 365 CF YEAR 1

    -------ITEM-------  -----MEAN-----  ---ST. CEV.---  ---MINIMUM---   ---MAXIMUM---

FARRCWEC 78 LITTERS IN FARRCW BLC.


    LITTER SIZE ALIVE=          9.549         2.969            4            16
    FCT. CRATES FULL AT BIRTH= 52.137        30.079        6.667       113.333
    BIRTH WEIGHT CF FIGS=       3.119          .509        1.779         4.717

LCST  C LITTERS, BLC. NCT CLEANEC

LCST  5 LITTERS, CLE TC BLC. CVERFLCW
    LITTER SIZE LCST=           8.2CC         2.55C            4            11

ENC PERICCIC FARRCWING REFCRT*************************************************************



WEIGHT GAINS PERICCIC REFCRT CN CAY= 365
******************************************************************************************
    TCCAY IS CAY 365 CF YEAR 1

FRCCUCTICN NET CF INVENTCRY CHANGE-

                      -------NUMBER-------  ---WEIGHT LBS.----  ----VALUE CCL.----

    HCGS UNCER 24C CAYS =      549           147111.C            3C157.7
    SCWS(ALL 24C ANC UP)=       16             5272.1              694.C


ENCING INVENTCRY-

    HCGS UNCER 24C CAYS =      3C8            34664.9             71C6.3
    SCWS(ALL 24C ANC UP)=       52            23C34.1             3915.8

ENC WEIGHT GAINS PERICCIC REFCRT**********************************************************
```

Table 5.2 (continued)

```
COSTS AND RETURNS PERIODIC REPORT ON DAY= 365
=================================================================================================
    TODAY IS DAY 365 OF YEAR 1    PERIOD COVERED=  365 DAYS

    FEED COSTS SOWS= 2939.02 DOL. AT .14 PER DAY PER SOW

    FEED COSTS HOGS=17285.54 DOL. AT 11.75 PER 100 LBS. PRODUCED

LABOR COSTS BY BUILDING INCLUDING CULL PEN AT 3.00 DOL. PER HOUR
    FARROWING=             1100.12
    NURSERY=                324.66
    SOWS MAINT. +CULLS=     704.32
    FINISHING=             1092.17

SOWS PRODUCED=        53.7 CWT.    AT VALUE OF        913.26 DOL.

HOGS PRODUCED=      1471.1 CWT.    AT VALUE OF      30157.75 DOL.


COSTS AND RETURNS SUMMARY OVER A  365 DAY PERIOD.
    TODAY IS DAY 365 OF YEAR 1
```

	-------SOWS------- ($)	-------HOGS------- ($)	----TOTAL HERD---- ($)
PRODUCTION NET OF INVENTORY CHANGE (1)	913.26	30157.75	31071.01
FEED COST (2)	2939.02	17285.54	20224.56
LABOR COST (3)	1804.44	1416.83	3221.27
RETURN OVER FEED AND LABOR	-3830.21	11455.38	7625.17

```
(1) SOWS INCLUDE ANIMALS 240 DAYS OF AGE AND OVER, OTHERWISE THEY WHERE CLASSED AS HOGS AND PIGS.
(2) FEED COST FOR SOWS BASED ON DAYS OF MAINTENANCE (INC. CULL PEN) AND LACTATION.
(3) LABOR COST BASED ON BUILDING OCCUPANCY, ALL FARROWING HOUSE LABOR WAS ASSIGNED TO SOWS.
===END COSTS AND RETURNS SUMMARIES===============================================================
```

Inspection of the representative reports shown in Table 5.1 and Table 5.2 reveal that the policy of continuous farrowing resulted in more sows conceived, more litters farrowed, and in a higher return than that obtained with the Standard control values i.e. moderately synchronized breeding and farrowing.

5.5 Use of This Model In Its Present Form

One of the objectives of this study was to discover and implement a model for use by researchers. The model will be most useful when used to test the feasibility of management policies, or to generate the outcomes of production when control variables are specified as in an experimental setting.

Testing of the feasibility of management policies for a given herd and set of building capacities permits evaluation of the stochastic nature of swine production. The variability of breeding performance, conception rates, and farrowing can be observed. Production, its value, the variable cost incurred, and the building utilization realized can be reported.

Use of the model as an experimental tool has a large number of possibilities because of the flexibility built into the computer program as presented in the input-output forms. Parameter values which could be varied with respective runs tracing out stochastic outcomes include (a) conception rates, (b) length of estrus and gestation cycles, (c) survival rates, (d) litter size, (e) rates of gain, and (f) culling-replacement rates, (g) opening inventory herd size, and (h) building capacities.

Two breeding policies were considered by making comparative runs as reported in section 5.4 above. Many similar experiments can be made to compare management policies. The procedure required is to carefully select those control parameters which should be changed to represent the desired management policy, building capacities, or productive ability of animals. For example, the question of the importance of large litters versus more sows versus rate of conception could be compared by incrementing the litter size and/or conception rate parameters and comparing results with those obtained by maintaining a larger number of sows to produce a similar number of market hogs. Number of sows are controlled by parameters of the opening inventory and culling-replacement rates.

The question of gilts versus sows can be handled by making runs which compare culling-replacement policies. The parameters involved are the maximum age to keep a sow and the number of gilt replacements selected periodically. The relative litter size parameters for gilts and sows may also be adjusted on the input form.

Boar power can be experimented with by making runs with various numbers of boars for a given sow herd size as well as with boar maturity parameters.

The management policy questions of building size involve setting the building size parameters as well as growth rate parameters for the particular experiments desired. The rate of gain attained by growing-finishing pigs affects the amount of time spent in the nursery and finishing buildings and therefore the capacity requirements for a given production, or alternatively the number that can be produced for a given building size.

Use of the model permits economic analysis and/or analysis of the productivity of husbandry practices. Although the model itself is not an extension tool, it is capable of facilitating analyses for that type of application. The use of this model as a facilitating tool for further analysis in other projects agrees with the objectives under which it was developed.

CHAPTER 6

IMPLICATIONS OF THE STUDY

The experience gained in the preparation of this dissertation suggests implications for other research or extension oriented models. A discussion of these implications is the subject of the sections which follow.

Section 6.1 discusses several of the important limitations of the model including execution time, size and detail, and input-output. Section 6.2 makes suggestions for an extension model based on experience gained in the study, and section 6.3 presents some conclusions drawn from the knowledge gained in model development and the study as a whole.

6.1 Limitations of the Model

The complexity and stochastic nature of swine production dictated inclusion of mechanisms to represent probabilistic aspects of animals such as survival, conception, gestation, farrowing, and weight gains. Inclusion of only the most important attributes expanded the size of the model and its computer implementation beyond original expectations, excluding other details. Use of the model is limited by computer execution time and by the computer memory readily accessible for internal storage of the program and the relatively large arrays required to represent animal attributes.

6.1.1 Execution Time Problems

Execution of the program with the standard control values for one year of simulation required 1370 seconds of Central Processing time on the CDC 6500 at Purdue University. Seasonal reports were generated in addition to those shown in Table 5.1. The continuous farrowing example and other similar problems, run with the simple three page output requires 900-1100 seconds. Other problems either with greater amounts of output, more animals, and/or larger simulation times have used much greater amounts of execution time.

There is an initial block of time used to read data and build the opening inventory (approximately 50 seconds) after which execution time is proportional to the number of days of simulation requested. Time required to execute is also highly dependent upon the size of the herd being simulated. This is somewhat less than arithmetically proportional to the number of animals in the herd because the time spent writing reports is fixed for any optional set of reports. Execution time spent collecting the information for those reports is however, proportional to the number of animals in the herd, the number of sows farrowed, the number of days simulated, etc.

Experimental repetitions (repeated runs of the same control data but with a unique random number series) will be essential to the use of the model for experimental work. The cost of execution time required may limit use of the model to those experiments where a relatively small number of repetitions can be judged sufficient or to those where a relatively moderate sized herd is involved, say 1,000--1,200 total animals at any one time. Simulation of a large herd over a large number of days is feasible but may be too expensive. Nevertheless, while a real biological experiment would in most cases provide better data than the simulation, the simulator, despite its apparently high cost, might be both cheaper and faster than a biological experiment.

6.1.2 Size and Degree of Detail

The computer program contains approximately 3600 card images of source program and 300 data cards. The computer memory required to load was $102{,}000_8$ and to run was $63{,}600_8$ words. These requirements are for the Standard control values which provide for 1,500 total animals as an absolute maximum. A simulation run representing additional animals would require that the animal filing arrays be dimensioned larger, with correspondingly higher memory requirements.

The relatively large program was the results of including a large number of animal attributes and the associated statements needed by the daily model for checking, sorting, filing, and report writing.

6.1.3 Input-Output Limitations

Input to the model includes a data deck of 249 cards representing the attributes of 30 sows and 219 market hogs found on the Purdue Swine Farm on March 2, 1972. These animal attributes are used in building the opening inventory. A deck of 26 standard control values, as well as those optional control cards supplied by the user, complete the input data for each computer run.[1/]

1/ Appendix D Input Data is a list of herd and Standard control data required to run the program.

The basic herd at opening inventory is assembled from information from the control cards (schedules, weight gains, litter size, etc.) and the Purdue herd data. There is some influence of the basic herd data after opening inventory time, especially during the simulation startup in the first breeding and farrowing seasons. This is most pronounced with regard to the age distribution of sows in the herd, their initial weights, and day of farrowing within the time period allotted for the first farrowing and weaning seasons. Specifically, the model does not guarantee that these initial distributions will closely resemble those generated by the simulator at some later simulation time.

While designed to facilitate specification of control parameters by the research worker, the Input-Output Forms and Instructions require contemplation and care in preparation of experimental runs. No experimental design is built into the model or given in the Input Forms. The Input-Output Forms were not prepared for use with farmers and would have limited value in communicating with a farmer-producer.

Standard output from the simulator in its most concise form consists of the printed output in Table 5.1. However, the seasonal reports and other diagnostic aids optional to the user can become voluminous. This is true when a long series of seasons or daily information must be printed. Partial estimates of the volume of output were given as footnotes to the output options in Appendix B Input-Output Forms and Instructions.

The more obviously important information necessary to the evaluation of a simulation run has been programmed as optional output, in table format, where practical. However, all specific information required for every experimental purpose could not be anticipated and may not be available without some reprogramming of the FORTRAN statements. Should this be necessary, Appendix C contains a copy of the computer program in its final form as used in this study.

An input-output bottleneck was experienced in debugging and running test runs with the program. Built-in error messages indicated that unanticipated errors were occurring late in simulation time. A means of saving a partially completed run for a rerun from that point in simulation time would have facilitated debugging and reduced the amount of time used in debugging the program.

6.2 Suggestions for an Extension Model

There have been many management practices and biological relationships omitted from this model which should have attention given to them for other modeling purposes. Suggestions for an extension model provides a framework in which to cast one possible modeling purpose which might grow out of the experience gained from this study. The topics of this section are grouped under the heading of: 6.2.1 Farrowing Systems, 6.2.2 Minimum Time Unit, 6.2.3 Means of Obtaining Faster Execution, and 6.2.4 Other Husbandry Practices.

6.2.1 Farrowing Systems

The ability to consider alternative farrowing systems was thought to be an important part of a model which is to aid in analysis of production intensity. It was excluded from this model because of time limitations. Consideration of alternative farrowing systems would be particularly important to an extension model where the intensity decision revolved around the economics of swine production and the competitive nature of the enterprise in whole farm planning.

Given more time for the study, additional size and less costly execution for the computer program, this model could have been adapted to consider alternative farrowing systems. This would however, require reprogramming of the opening inventory subroutines and a substantial reprogramming of the scheduling mechanisms for breeding, farrowing, weaning, gilt selection, and sow culling.

6.2.2 Minimum Time Unit

A minimum time unit greater than one day would make the model more practical for research and would be essential to an extension model. Execution time would be reduced as well as the number of animal states which would need to be programmed for sorting and updating during each time period.

The development of a hybrid model which has aspects of both, say, a daily and a monthly model is possible. For the model used here, such a scheme would consider the breeding, farrowing, lactation and weaning strategies daily. Growth of market hogs after, say, their first month would be modeled monthly, replacing the skipping process used in this model. Such a procedure would, however, limit collection of data and reporting to monthly options unless intermonth estimates were acceptable. Such a hybrid model would likely have been more efficient with respect to execution time than the present model since checking for feasible skipping negated a significant portion of the time saved by the skipping process itself.

6.2.3 Means of Obtaining Faster Execution

A larger minimum time unit can be judged to be the most effective change for reduction of execution time. A week versus one day literally reduces to one-seventh the amount of transition calculations and updating of attributes required to run a model. This kind of execution activity represents a large part of the total execution time experienced with this program.

The research model developed here has nearly duplicated collection of data for preparation of reports: periodic and seasonal. Independence of the two reporting methods was necessary to offer the user a flexible range of time periods over which the periodic reports could be requested. A choice between seasonal and periodic reporting would reduce computer execution time to that required for the single reporting method.

Some FORTRAN statements are more efficient than other statements which can be made to do the same work. Attention to those which are relatively efficient with respect to execution time can save considerable time over the large number of programming statements in a simulator of this type.

6.2.4 Other Husbandry Practices

Some other possibilities for a research or extension model include (a) the effect of overcrowding on weight gains and health of the herd, (b) strategies for reaction to expected future prices, (c) more sophisticated timing and purchases of boars based on those in the herd and a predicted need for boar services, (d) optional replacement strategies to reflect more realistic culling practices, (e) additional cost calculations for labor involved in moving hogs and cleaning pens, (f) the effect of stress from moving and regrouping animals, and (g) provisions for pen versus field breeding.

A modeling decision as to the relative importance of the inclusion of these practices versus that of the time unit should be made with the purpose for modeling well in mind. For a research model, the execution time criteria may not be as important as it would be for an extension model.

6.3 Conclusions

A model was developed and implemented which successfully demonstrated that important stochastic elements of swine production can be modeled for research use. The primary disadvantages to the modeling procedures chosen were those of implementation which resulted in a relatively large and complex computer program requiring long run times.

Fortunately a simulator need be developed only for those problems or parts of problems where it is essential to model stochastic or very complex elements involving a large number of states of nature. Close attention should be given to deciding those aspects of a model which are required to contain these elements. Simulation techniques have useful possibilities for application in research, but this study has shown that they can be used to the point where they tax the limits of even present day computing equipment.

The usefulness of a simulator of the type developed in this study would be much more restrained for extension modeling than for research work. It appears that the very complex nature of daily swine production cannot be represented realistically in a sufficiently abstract way to run such a model in less than, say, 100 seconds for use in a routine extension application.

The experience of this study has also pointed up the importance of keen judgement as to what is important for inclusion in a model and what could be excluded or modeled in more efficient ways.

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APPENDICES

APPENDIX A

A COMPARISON OF ALTERNATIVE WAYS OF CALCULATING BINOMIAL RESULTS

APPENDIX TO CHAPTER 3

APPENDIX A: A COMPARISON OF ALTERNATIVE WAYS OF CALCULATING BINOMIAL RESULTS- APPENDIX TO CHAPTER 3

The basic transition transformation in the model involved n animals in state i at time t, each having the probability p of being in state j in time t+1 and the probability 1-p of being in some other state k in time t+1. This is exemplified by a survival-nonsurvival situation.

The probability of having 0,1,2,...,or n of these animals in state j in time t+1 is given by the well known binomial formula. The computer programming required to implement the binomial method involved calculating the probability of each outcome 0,1,2,...,n; conversion to cumulative probabilities; and finally comparison to a random number to decide an outcome. This procedure was suspected of requiring a relatively long time to execute as a simulation computer program.

An alternative method [1/] which was given the name "brute force spins" uses a random number to decide the outcome for animals one at a time. This method compares the probability of survival with the random number drawn for an individual animal, adds the animal to either the survival or nonsurvival category of time t+1, and turns to the next animal until all n have undergone transition from time t to t+1.

The two methods of calculating binomial results can be expected to yield the same results. Note in particular that the expected value

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1/ Yet another method: storage of a table of binomial (and multinomial) coefficients was rejected out of hand because of the amount of storage required to accommodate the many possible probability situations of the problem under study here.

of each method is equal to the expected number obtained directly by Markov type inventory multiplication as previously shown in Chapter 3.

A FORTRAN computer program was written which solves by (a) computing the binomial formula and (b) the "brute force spins" of the random number generator in respective subroutines. Calculation of the Markov "true" expected number serves as a check on these two methods. The binomial procedure involves drawing a random number R, where $0 \leq R \leq 1$, for each inventory state and then comparing R with the cumulative probability of having n,n-1,n-2,...,0 survivors; calculated by binomial formula. Successful comparison implies a solution for that state and terminates the calculation loop.[1/] The next state is then considered in turn.

These subroutines were solved 100 times for each of three different set of data: with the opening inventory and probabilities as indicated in Table A.1 Computation Method Results. Statistics were generated for 100 repetitions so that the Mean, Range, and Variance of the methods could be compared. Resulting ratios of Means are close to 1.0, [2/] as expected.

1/ This is a procedure adopted to cut computation time. More calculations are required (approaching twice as many for most problems) if the probability of all feasible results are calculated before comparison is made with the random number. Other schemes to gain efficiencies could be incorporated such as a heuristic for starting at an advantageous location or partitioning the series to reduce the number of binomials calculated.

2/ This was further substantiated by 20 additional runs of the above experiment using both function RANF and a tape of random numbers as the source of the random number series.

Table A.1 COMPUTATION METHOD RESULTS.

INVENTORY AND PROBABILITY VALUES FOR DATA:	Set 1	Set 2	Set 3
Opening Inventory Values			
State 1	4	5	6
State 2	6	7	8
Probability of Survival			
From State 1 to State 2	.776	.816	.866
From State 2 to State 2	.566	.616	.666
RESULTS FROM 100 REPETITIONS 1/			
True Markov Expected Value	6.46	8.39	10.52
Brute Force Spins Method			
Mean	6.38	8.24	10.61
Range	10	12	13
Variance	2.3	2.4	2.4
Ratio of Mean/True Markov	.9876	.9819	1.0082
Binomial Method			
Mean	6.51	8.38	10.66
Range	10	12	13
Variance	2.1	2.3	2.1
Ratio of Mean/True Markov	1.0077	.9986	1.0129

1/ The problem was solved 100 times for each of the data sets 1, 2, and 3 using a unique series of random numbers for each repetition.

The relative computation efficiency of the two methods was tested by solving the two subroutines separately and noting the computer run time required for each. Three data sets were used and each was repeated 999 times to exaggerate the computer time spent calculating solutions as opposed to time spent reading input data and writing output. The number of animals in each state was actually increased by 100 over those shown in Table A.1 to represent a more realistic problem situation.

The brute force spins method required 44 seconds of Central Processing (CP) computer time. The binomial method required more than 6 times as much time as compared to the brute force spins method. 1/ In addition, the binomial subroutine has approximately six times as many FORTRAN language statements as does the brute force spins subroutine. The individual brute force spins method was chosen for implementation of the model because of its relative efficiency.

1/ Only two of three data sets were completed when a time limit stopped execution of the binomial method. This indicates the binomial method required from 6-9 times as much CP time.

APPENDIX B

INPUT-OUTPUT FORMS AND INSTRUCTIONS

SIMULATION OF A SWINE BREEDING HERD

INPUT-OUTPUT FORMS
and
INSTRUCTIONS

August, 1972

Jay Strom

TABLE OF CONTENTS

I. Introduction

The swine producer is faced with short run planning problems once he has committed buildings, equipment, and a basic herd to swine production. Short and intermediate term decisions in management of the swine herd determine the profitability of the herd given that buildings and equipment are fixed. Yet these short term planning decisions must be made for a complex production enterprise in the light of stochastic and uncertain elements.

It is this complexity and the stochastic nature of swine production, together with the severe economic penalty and/or gains which result, that makes this a ripe area for economic analysis. Analysis of management decisions related to scheduling of breeding, farrowing, culling, and sales should be particularly valuable for extension use as swine production continues to become more intensive on the farm. Yet it is these kinds of decisions which seem to be some of the most complex to analyse.

Unfortunately this same variability and complexity faced by the producer very much complicates an economic analysis. Experiments would contribute to our knowledge of these outcomes yet, experimentation with a real herd is impractical. Lack of operational models which permit experimentation with the swine herd are thought to be a key to analysis of the swine producers short term planning problems.

Objectives of this project:

1. To provide a model for experimentation with scheduling of breeding, farrowing, culling, and sales, within a simulated swine breeding herd.

2. To implement that model in the form of an operational computer program.
3. To make use of the computer program relatively easy and trouble free by providing an appropriate input-output form for use by research workers.

The exploration of the type of model which is appropriate and the logic of that model is best presented in the thesis text, especially Chapters 2 and 3. The model is intended for use by the research analyst. The user should be familiar with the model before undertaking to use the computer implementation which is hopefully facilitated by these forms.

Purpose of this Input-Output Form

1. To make explicit those parameters of the model which the computer program permits to be user options.
2. To provide notes and reminders of the effect of settings of optional parameters of the model as well as to provide one feasible set of data in the form of "Standard" default values.
3. To facilitate communication between researcher and computer laboratory personnel.

Neither the model nor the computer program is designed to do an analysis, only to give the research worker a tool with which to make such analyses.

The model includes the effect of variability of: (a) conception rate, (b) number of pigs farrowed, (c) length of estrus and gestation cycles, (d) survival rates, and (e) the availability of animals for breeding.

The effects of alternative management policies can be measured by production realized and by the building utilization obtained. These effects are also reflected by the value of output and a measure of variable costs required to produce that value.

This input form describes the data required to run the swine breeding herd simulator. The attributes of individual animals in an initial herd are the starting point of simulation. This is called the opening inventory. The determinants of transition define day-to-day and group-to-group changes in attribute values. Attribute values represent the status of the herd permitting evaluation of the model.

Characteristics of the opening inventory are described in section II, "Opening Inventory", then the computer program updates daily the animal attributes and the building attributes of section III. This is carried out according to the Management Policy information given in section IV, "Management Options". Probability of Transition Data is given in section V, and output options are specified in section VI.

1.2 Identification and Punching Instructions

Name: Date:

First Card:
Col. No.: 1 — — — — — — — — — — — — — — — — — — 20

21 — — — — — — — — — — — — — — — — — — 40

41 — — — — — — — — — — — — — — — — — — 60

61 — — — — — — — — — — — — — — — — — — 80

The detailed instructions for filling in this input form are found on the left hand page with respect to each table of the form. Note the footnote number and consult the specific instruction on the preceding open page.

The first data card (above this page) is punched column by column according to the indicated column numbers. All following cards must conform to 10F7.0 format.[1/] The first field of each data card is the card number. In general, underlined spaces may be filled with any integer digit. Recognize the typed in decimal point. Some values will be automatically converted to integer numbers by the computer program. "Standard" values (following pages) default when the users option is blank. Therefore, punch only those cards which contain at least one "Users Option" value.

[1/] The first field is the card number. Decimals must be punched since the punched location overrides the F7.0 FORMAT. Punch the card number in field one, followed by data from the table (going down the page) until the next card number is encountered. Not all cards will have 10 fields. Following the first (title) card, data cards may be scrambled. If data cards are duplicated, only the first one is effective. The last data card must contain 9999., in place of the card number, followed by blanks. The first data card (identifier card above) and the terminal card (9999.ƀƀƀ....) are mandatory data cards.

Instructions for Simulation Control Options, Next Page

Fill in the blanks under "Users Option" for any values that you desire to change from the "Standard" value. "Users Option" values left blank, automatically default to "Standard" values.

Footnotes:

1/ Standard values are given for the users reference and are used in computing whenever the user's option column is left blank.

2/ Range is the feasible range over which the computer program will operate with respect to individual user option values. All user options set to maximize levels would exceed computer storage capacity as well as require an extremely long execution-time.

3/ Total number of days for a single repetition of the simulation. Days 1-365, 366-731, 732-1097, etc. are automatically reported as year 1, 2, 3, etc., respectively. Computer execution time is approximately proportional to the number of days specified here.

4/ A number used to start the random number series in the routine called RANF. A unique number here implies a unique series of random numbers for the run.

5/ See thesis text, Chapter 4, sec. 4.2.1 for explanation of the skipping mechanism used to improve computer execution time. MAXSKP set equal to 1. eliminates "skipping", while a setting of 1825. implies full reliance on the automatic protection built into the program.

6/ The tape source option requires a previously prepared tape of 0.,1. random numbers, while the RANF source does not.

1.3 Simulation Control Card

	Standard 1/	Range 2/	Users Option
		Card No.	51.
(a) Length of simulation			
Total Number of Days 3/	365.	1.-1460.	____.
(b) Random Number Seed 4/	1.	1.-9999.	____.
(c) Skipping process 5/			
Maximum Skip, value of "MAXSKP"	14.	1.-1825.	____.
(d) Source of Random Numbers			
= 1 for CDC Function RANF,			
= 2 for Tape Source 6/	1.	1.,2.	_.
(e) Maximum seconds of Execution	1950.	1.-99999.	_____.

II. Opening Inventory

The opening inventory consists of an inventory of animals in their respective buildings as of January 1. This inventory is generated automatically, based on the size of the herd defined by the user in this section. In addition, the user defines the boars available, in detail.

The user must specify opening inventory herd size in terms of number of sows in each of the 3 herd groups. One group is located in the farrowing house with their suckling pigs. The second group is in gestation for the first upcoming farrowing. Appropriate finishing hogs of 5-6 months of age correspond to an earlier farrowing of this group. The third group (open sows, available for breeding) has finishing pigs from a previous farrowing that are about 4 months of age. The number of pigs and finishing hogs which are related to these herd groups will depend upon litter size and other values specified in other sections of the input form.

"Herd group" is an opening inventory concept. After opening inventory the sow herd is treated as a pool of individuals with unique gestation and estrus attributes. Depending upon the control variables specified in other sections of this input form, a sow may turn up eligible for farrowing on any of the 6 times per year at some future date.

Generation of the opening inventory is based on the animal attributes which were available from a herd of 30 sows and 219 finishing hogs on the Purdue Swine Farm March 2, 1972. From this basic herd and other data required from this input form, the program generates a typical opening inventory for a herd which has farrowed beginning July 17 (sows rebred and

in gestation), September 1 (sows are rebred and in gestation, hogs are in the finishing house), and December 1 (sows and pigs are in the farrowing house).

Farrowings are planned for dates beginning January 15 (day 15), and March 1 (day 60). Continuation is automatic for farrowings scheduled for June 1 (day 152), July 17 (day 198), September 1 (day 244), and December 1 (day 335). This 6 times per year schedule is continued automatically, year after year. Options in other sections of this form permit specification of a range of farrowing plans from short, tightly grouped farrowings to continuous farrowing except for the extra break between Spring (March and June) and between Fall (September and December) farrowings.

Instructions for Opening Inventory Options, Next Page

Specify the size of the sow groups and the number of boars on the opening inventory. These are assumed known with certainty.

Card 1 has only two entries: the card number, and number of sows per group. Card 10, boars for the opening inventory, contains a full set of entries.

Footnotes:

1/ The number of sows in each of the three herd groups at opening inventory. Sows are automatically given appropriate atributes for upcoming farrowings beginning January 15th and March 1st. The program sets up breeding dates for subsequent farrowings from data elsewhere in this input form. Baby pigs and older hogs are generated as if a herd of this size had been in production the previous year. The number specified should not exceed farrowing house size, see Building Options, page 303.

2/ Boars are created for opening inventory from attribute information supplied here. Boar purchases are allowed, see section 4.2 (b). For a discussion of individual boar attributes, see thesis text pp.

3/ Newly purchased boars are not used for 30 days even if they are of minimum service age of 195 days.

4/ A young boar is defined by age as 195-365 days.

5/ A mature boar is defined by age as 366 days-1825 days. If a boar reaches the maximum age to keep a boar as specified in the Selection and Culling section page 409, he is sold.

6/ Zero is required if the intention is to exclude this type boar in the opening inventory.

1.2. Opening Inventory Options

	Standard:	Range:	Users Option:
Herd Size:			Cd.No. 1.
(a) Number of sows per Herd Group 1/	15.	1.-50.	_ _.
Boar Initialization: 2/			Cd.No. 1 0.
(a) Newly Purchased Boars 3/			
Multiples of this type boar	1.	0-99.	_ _. 6/
Age at opening inventory, days	180.	150.-395.	_ _ _.
Weight at opening inventory, lbs.	260.	200.-600.	_ _ _.
(b) Young Boars 4/			
Multiples of this type boar	1.	0-99.	_ _. 6/
Age at opening inventory, days	300.	195.-365.	_ _ _.
Weight at opening inventory, lbs.	350.	200.-600.	_ _ _.
(c) Mature boars 5/			
Multiples of this type boar	0.	0-99.	_ _. 6/
Age at opening inventory, days	730.	366-1600.	_ _ _.
Weight at opening inventory, lbs.	450.	200-600.	_ _ _.

II. Building Attributes

This group of forms requires listing of quantitative aspects of housing. All animals will be assumed to require some kind of housing space which is to be described here.

Buildings represent the housing and equipment restraint in swine production. Buildings have design capacities expressed in number of animals per unit space. The effect of overcrowding (housing more than the design capacity) may have adverse growth and survival implications. Overflow is optional for certain buildings (see p. 303), but it's effect on growth and survival rates is not included in this model.

Building capacities are to be specified in this section for Farrowing, Nursery, Sow Maintenance, and Finishing. The computer program treats these buildings as files. Additional files for boars and for call sows are assumed to have unlimited capacity.

Instructions for Building Options, Next Page

Some positive capacity is required in all buildings. Appropriate moving of animals, premature sale and/or diagnostic messages result when any individual house is overstocked.

Footnotes:

1/ One building containing the number of farrowing crates specified here is assumed available only after a cleaning period (Next line, see footnote number 2). Overflow results in loss of newborn litters and the sow returning to the open state in the sow maintenance building (see footnote no. 3).

2/ Litters are reported lost (diagnostic written) if farrowing occurs before house no. 4 is cleaned. Cleaning will wean any sows and litters in the farrowing house on the cleaning date whether the regularly scheduled weaning process is completed or not, see "weaning policy," section 4.3, page 407.

3/ If all crates are full, a litter is weaned early (maximum number of days early specified here) to make room for the sow about to farrow. If no litter is old enough newborn litters will be lost as a result of overflow.

4/ Capacity in number of head regardless of the size or age of animal. Overflow moves to the finishing house.

5/ Nursery pigs are normally moved to finishing at option age specified in section 4.3, page 407. However, if the finishing house is full the overflow factor permits their remaining in the nursery. When the overflow factor space is also full they are forced into the finishing building.

6/ Overflow results in a diagnostic but no change in animal location or attribute values. Culls are assumed to have a cull pen of unlimited capacity apart from the maintenance building.

7/ Total capacity in number of head. Overflow results in sale of those animals required to make room for incoming individuals. Heaviest animals are sold first.

3.1 Building Options

	Standard	Range	User Option
		Cd. No.	1 4.
1. Farrowing House			
(a) Total number of crates for sows and litters 1/	15.	1.-99.	_ _.
(b) Number of days idle for cleaning prior to expected beginning farrowing date 2/	7.	1.-14.	_ _.
(c) Number of days early litters may be weaned to prevent exceeding capacity 3/	0.	0.-14.	_ _.
2. Nursery Building		Cd. No.	1 5.
(a) Number of starting-growing pigs capacity, head 4/	125.	1.-999.	_ _ _.
(b) Overflow factor: permitted before forced to finishing 5/	1.	1.-1.4	_._ _
3. Sow Maintenance Building		Cd. No.	1 6.
(a) Number of sows housed, head 6/	80.	1.-999.	_ _ _.
4. Finishing Building		Cd. No.	1 7.
(a) Finishing building capacity, head 7/	240.	1.3000.	_ _ _ _.
(b) Overflow factor: permitted before forced sale at lighter weights	1.	1.-1.4	_._ _

IV. Management Options

In this section the user specifies the control variables which define the management policy for sales, mating, culling and building use.

The total number of animals in the herd is highly dependent upon the values specified in this section. A large herd requires both a large amount of computer storage and long execution time.

Instructions for Sales and Cost Options, Next Page

Sales are conducted regularly. If there are not animals meeting the specifications given here, none are sold. Costs are calculated and reported over the length of time specified in the Output Options section IV, pages 601-607.

Footnotes:

1/ A sale is conducted on the first day of simulation and repeated regularly after each period, the length of which is specified here.

2/ All butcher hogs greater than or equal to the weight specified are sold.

3/ Price for all butchers sold. However, sale weight of animals sold prematurely due to overflow is unpredictable. Heaviest animals are sold first to clear capacity for incoming animals.

4/ A "Basic Sow" of 350 pounds or less, farrowed or not. Selling price is discounted for weight over 350 pounds, i.e. according to (e) below.

5/ Cost options are intended to provide an approximation of variable costs for feed and labor. Any variable cost other than feed or labor may be included as a feed or labor cost if it is appropriate to the method of calculation used.

Cost calculations are made daily based on inventories in buildings. The "skipping" process can cause the number of animals to be slightly understated for daily calculations. See the discussion of the skipping process in the thesis text, Chapter 4, section 4.3.1. Standard transition probabilities are thought to result in negligible underestimation of costs.

6/ An average sow day of maintenance and lactation. Take into consideration the relative length of lactation as a result of the weaning policy you specify in section 4.3 page 407. The standard value is based on two 5 week lactations. See "Planning Growth of the Swine Farm, Input Forms and Instructions," Dept. of Agricultural Economics, Purdue University, July, 1972, pp. 14-19.

7/ Exclude sow feed. All gain up to sale or inventory weight is classed as butcher hog gain, if the animal is less than 240 days of age.

8/ Labor in minutes per litter or per head per day. These rates account only for labor which can be based on the number of animals in buildings. Standard values are estimated from information in: Lines, A.E. & D. H. Bache, "Planning Data for Hog Farms," Publication EC-408, January, 1972, page 14. The standard values are intended to represent feeding and routine cleaning labor.

4.1 Sales and Cost Options

	Standard	Range	Users Option
Sales of Butchers and Sows		Cd. No.	8.
(a) Sell butchers every (?) number of days 1/	14.	1.- 60.	_ _ _.
(b) Minimum weight for sale of butchers, pounds 2/	215.	100.-300.	_ _ _ _.
(c) Butcher hog selling price per hundred pounds, $ 3/	$20.50	$5.-$40.	$_ _._ _
(d) Sow sales price for basic sow 4/ $ per hundred pounds	$17.00	$5.-$40.	$_ _._ _
(e) Discounts, $ per 100 pounds for wt. of sows over 350 pounds	$ .50	$0.-$5.	$_ _._ _
Variable Cost Options 5/		Cd. No.	1 3.
(a) Feed Costs			
Per sow day of maintenance and lactation 6/	$ .14	$.01-.99	$._ _
Per 100 pounds of butcher hog produced 7/	$11.75	$1.-99.	$_ _._ _
(b) Variable Labor Costs by Building 8/			
Value of Labor, $/Hour	$ 3.00	$0.-99.	$_ _._ _
Farrowing Bld., min./day/litter	6.5	1.-99.	_ _._
Nursery Bld., min./head/day	.21	.01-.99	._ _
Sow Maintenance Bld., min./head/day	.8	.1 -.99	_._ _
Finishing Bld., min./head/day	.005	.01-.99	._ _ _

Instructions for Boar Management Options, Next Page

Specify maximum boar capacity and give instructions for replenishing boars by yearly purchase.

Footnotes:

1/ The number of times each boar has serviced a sow is tallied both for daily and weekly totals. If the maximums given here are reached, the boar is no longer available until next day. A diagnostic is printed if a sow is not mated for lack of an available boar.

2/ Purchase is assumed to take place once yearly.

3/ Newly purchased boars wait a 30-day adjustment period before being used even if they are of minimum age (195 days) for use.

4.2. Boar Management Options

	Standard	Range	Users Option Cd. No. 2 0.
(a) Services Permitted[1]			
Maximum services daily for young boar, no.	3.	1-9.	_.
Maximum services weekly for young boar, no.	10.	1-99.	_ _.
Maximum services daily for mature boar, no.	3.	1-9.	_.
Maximum services weekly for mature boar, no.	15.	1-99.	_ _.
(b) Purchases of New Boars[2]			
Number purchased once per year, no.	2.	0-99.	_ _.
Date of yearly purchase, day of year	60.	1-365.	_ _ _.
Age at purchase date, days[3]	180.	150-395.	_ _ _.
Weight at purchase date, pounds	260.	200-600.	_ _ _.

Instructions for Breeding, Weaning and Nursery Options, Next Page

Specify here the length of breeding season, target numbers of sows and gilts to be served with the boar and the weaning criteria desired for all farrowings.

Footnotes:

1/ Breedings are scheduled automatically: planned beginning date = first day of farrowing - Mean length of gestation + one Standard Deviation; where first day of farrowings are respectively: Jan. 15, March 1, June 1, July 17, September 1, and December 1. Length of gestation is an input form option, see section 5.3, page 507.

2/ Number of days over which sows and gilts coming into heat are served by the boar, if a boar is available.

3/ Maximum number to be exposed to boars for breeding. The number of sows and gilts exposed as they come in heat is counted and exposure terminated when this number is reached. The number of sows conceiving is assumed not known by the manager until the immediately following breeding season. At that time non-breeders will be coming in heat and are available for breeding.

4/ A weaning schedule will be automatically followed to wean all the litters in the farrowing house at the time of the beginning of the weaning schedule. Weaning will commence as if the first litter had been born on the beginning date of that farrowing. Litters are weaned over the number of days specified on the following line, see footnote 5.

5/ Specify the number of days over which weaning will take place. The number of litters to be weaned are divided equally among the number of days given here. The oldest litters are weaned first. Scheduled cleaning of the farrowing house will automatically wean those litters remaining in the farrowing house at cleaning time, whether they have reached target weaning age or not. See Cleaning Option, section 3.1, page 303.

4.3 Breeding, Weaning, and Nursery Options

	Standard	Range	Users Options
1. Breeding of Sows and Gilts 1/ .		Cd. No.	2.
(a) Length of Breeding Season, days 2/	21	1.-44.	__ __.
(b) Target Number to Breed, No. Sows 3/	17.	1.-999.	__ __.
2. Weaning Policy			
(a) Target Age of Pigs at Weaning, days 4/	36.	22.-44.	__ __.
(b) Length of Weaning Period, days 5/	18.	1.-44.	__ __.
3. Nursery			
(a) Age at which pigs are moved from Nursery to Finishing, days	82.	57.-150.	__ __ __.

Instructions for Gilt Selection and Sow Culling Options, Next Page.

Footnotes:

1/ Gilts are selected, if available, from the finishing building and placed in the reproductive herd. They obtain estrus attributes as defined in Section 5.2, page 505. The number of gilts specified here are selected so that they would be eligible to farrow at one year of age. Minimum age is the only selection criteria.

2/ If the sow or gilt passes this number she is sold at the next regularly scheduled culling date. If the sow does conceive before reaching this maximum, this count is reset to zero. A sow or gilt gets one count toward her maximum each time she comes into heat but fails to conceive either because of lack of boars or because of failing the probability of conception test. The length of breeding season specified, (page 407), will determine the number of times it is possible for a sow to come in heat during any one breeding season.

3/ If bred, the sow will be sold after weaning the current litter.

4/ Percent routinely culled after weaning. Use this value to simulate culling rate desired (i.e., speed of sow turnover, approximation of sow: gilt ratios, and culling for health reasons). This type of culling is at random, on the surviving individuals (i.e., with the probability taken from the percent specified here). Gilts are assumed to be less than 450 days of age or they are assumed to be sows for this criteria.

A 100% declaration on line (d) implies gilt only production. A 100% declaration on line (e) implies 2 litters per sow at most.

5/ Until detected sows remain in the maintenance building. On the detection date they are moved to the cull pen for sale on the next regularly scheduled sale day.

4.4 Gilt Selection and Sow Culling

	Standard	Range	Users Option
		Cd. No.	1 1.
(a) Number of new gilts selected prior to each breeding season[1], no. gilts	10.	0.-999.	---.
(b) Maximum number of failures to conceive per sow[2]	2.	1.-29.	--.
(c) Maximum age to keep sow[3], days	1600.	1.-1825.	----.
(d) Culled of first litter gilts[4], %	20.%	0.-100.%	---.
(e) Culled from sows farrowing[4], %	20.%	0.-100.%	---.
(f) Maximum age to keep a boar, days	730.	300.-1825.	----.
(g) Number of days to detection following maximum failures to conceive[5]	60.	0.-999.	---.

V. Transition Probabilities

In this section the user specifies the transition probability data involved with survival, estrus, conception, gestation, litter size, and rates of gain. Probability data are applied where an animal is to change from one state to another.

Daily survival probability determines the chance of becoming one day older. Conception probabilities represent the fertility level of the herd and influence the production obtained. Sows are assigned estrus and gestation cycle lengths as random normal deviates based on specifications given here. The number of pigs farrowed alive is drawn as a random normal deviate based upon probability data of this section. Rate of gain is drawn as a random normal deviate for each growth or sexual category.

Data for this section requires Range and Standard Deviation as well as the Mean value. Mean values are more commonly available than are Standard Deviation and Range. Standard values are based upon referenced publication material in those cases where they were found to be available. Some of the data was calculated from original herd records of the Purdue Swine Farm research projects. Other of the Standard values are judgement values based on the experience of research workers and extension personnel.

The Users Option column should be used to change transition probability data found to be unsatisfactory.

Instructions for Survival Probability Options, Next Page

Death Loss is specified and then the program converts to daily survival probabilities for comparison with random numbers.

Footnotes:

1/ Daily survival probabilities s are calculated from the relation:

$$S_N = s^N$$

where: N = total number of days in the time period,

S_N = probability of survival over the time period of N days,

s = probability of survival for a single day in the series of days i = 1, 2, 3, ..., N.

Death loss ($1-S_N$) values are converted to survival values and then daily survival probabilities are found by taking the N^{th} root of S_N.

2/ Suggestion for farm conditions from J. Foster and W. Singleton, Animal Science. Probability of survival of pigs 1-21 days of age also is conditional upon birth weight of the particular pig. This adjustment is made automatically and is based on: N. C. Speer, "Maximizing the Reproductive Efficiency of the Sow", Feedstuffs, Vol. 42, No. 46, Nov., 1970, pp. 27-28. The linear approximation used is: ± Probability of survival of .06 over 21 days (.0049 daily) for each 1 pound deviation from the mean birth weight of all pigs.

3/ Lines, A. E., and D. H. Bache, "Planning Data for Hog Farms", Pub. EC-408, p. 13.

4/ Source: EC-408, p. 13, see footnote 3.

5/ Source: EC-408, p. 13, see footnote 3.

6/ A boar in use is assumed to be 5 times as likely to die during days he is used than when not in use (due to fighting, accident, etc.).

5.1 Survival Probabilities

Category	Days of Age Definition		Probability of Death Loss 1/ Standard	Range	Users Option
				Cd. No.	3.
Baby Pigs	1-7	for 7 days =	.10 2/	.01-.9	- - - .
2nd-3rd week	8-21	for 14 days =	.10 2/	.01-.9	- - - .
Start, not weaned	22-56	for 35 days =	.035 3/	.001-.9	- - - .
Start, weaned	22-56	for 35 days =	.05	.001-.9	- - - .
Growing-Finishing	57-180	for 124 days =	.015 4/	.001-.9	- - - .
Sow & Gilts	181-1825	for 1 year =	.015 5/	.001-.9	- - - .
Boar not in use	150-1825	for 1 year =	.015	.001-.9	- - - .
Boars in use	195-1825	for 1 year =	.075 6/	.001-.9	- - - .

Instructions for Estrus and Conception Options, Next Page

Footnotes:

1/ Portion of animals which will never be able to reproduce due to abnormalities. Standard probability for farm conditions suggested by Wayne Singleton.

2/ Standard distribution parameters are based on a range of 18-23 including 75% as reported in: Cole, H. H., and P. T. Cupps, Reproduction in Domestic Animals, 2nd edition, Academic Press 1969, p. 221. Standard deviation is approximated from the normal distribution.

3/ Number of times a sow or gilt is served by the boar is dependent only upon boar availability. If a boar is available which can give two services without passing either his daily or weekly maximum, the sow is assumed to receive two services. Otherwise a boar with one available service is used, if such a boar is available.

4/ Specify probability of conception on the second service conditional on not conceiving on the first service. Standard values of $p_1 = .75$ and $p_2 = .60$ imply that the total probability, P, when two services are available, is .90, i.e., $P = p_1 + (1-p_2)p_2$.

5/ The mean number of pigs born alive is adjusted by this amount for the number of services from the boar. This value is used to represent the effect of "Boar Power" on litter size. Standard deviation and range are left unchanged.

6/ Standard values imply conception is 10% less likely during the months of July, August and September. See the discussion, "Effect of Temperature and Humidity on Reproduction", by H. S. Teague in, "Effect of Disease and Stress on Reproductive Efficiency in Swine - Symposium Proceedings", Animal Science Department, University of Nebraska, 1970, pp. 21-26.

7/ If the animal in heat is a gilt (less than 365 days of age at breeding), this additional reduction in probability of conception is applied.

5,2 Estrus and Conception

	Standard	Range	Users Option
			Cd. No. 4.
1. Probability of abnormal reproductive tracts in gilts 1/	.05	.0-.2	.__ __
2. Length of estrus cycle 2/ for potentially reproductive animals			
Mean length, days	20.7	10.-30.	__ __.__
Standard deviation, days	2.1	0.-9.9	__ __.__
Minimum length, days	16.0	≥16.	__ __.__
Maximum length, days	25.0	≤25.	__ __.__
3. Conception as related to number of services per sow 3/			
a) Probability of sow conceiving with one service available	.75	.2-.99	.__ __
b) Probability of sow conceiving from the second service if failing to conceive on the first 4/	.60	.2-.99	.__ __
c) Pigs born adjustment for single service, no. pigs 5/	-0.5	0.-(neg)3.	- __.__
d) Pigs born adjustment for two services, no. pigs 5/	0.5	0.-3.	__.__
4. Conception Probability Adjustments			Cd. No. 1 2.
a) Summer season 6/	-.10	(neg).20 -0.	-.__ __
b) If gilt 7/	-.05	(neg).15 -0.	-.__ __

Instructions for Gestation Options, Next Page

Footnotes:

1/ Length of gestation is drawn once as a random normal deviate for each pregnancy.

2/ If termination occurs, the animal is returned to the open-cycling state. No pigs survive. Termination is assumed a "natural occurance", not due to epidemic disease. Standard values suggested by J. Foster and W. Singleton, Animal Science. Conversion is to daily probabilities follows the procedures outlined in footnote 1, Survival Probabilities, section 4.1.

5.3 Gestation

	Standard	Range	Users Option
			Cd. No. 5.
(a) Length of gestation 1/			
Mean length for sows and gilts, days	114.0	110-118.	__ __ __.__
Standard deviation length, days	2.0	0-10.	__ __.__
Minimum length, days	110.0	≥ 110.	__ __ __.__
Maximum length, days	118.0	≤ 118.	__ __ __.__
(b) Probability of Premature Termination of Gestation 2/			
During first week, for 7 days =	.04	0-.4.	.__ __ __
Weeks 2-15, for 100 days =	.035	0-.3.	.__ __ __
Final Week, for 7 days =	.02	0-.2.	.__ __ __

Instructions for Pigs Farrowed Options, Next Page

The number of pigs farrowed alive is drawn as a Random Normal Deviate after adjustment of the Mean for the age of the sow at farrowing time, as well as for the number of boar services which resulted in pregnancy.

Footnotes:

1/ Number of pigs farrowed alive to a 545 day old sow (at approximate age for farrowing second litter). The mean is adjusted for age of the sow as defined in footnote 2 below. Standard deviation and range are not adjusted from those given on the input form.

2/ The mean number of pigs born alive to a second litter sow (base age) is adjusted as follows:

$$MEAN = v + 5.867 + .01A - .00000446A^2 \quad \text{for } A \leq 1300, \text{ or}$$

$$MEAN = v + 5.867 + .01(1300) - .00000446(1300)^2 - .0016(A-1300)$$

Where: v = adjustment for number of services from the boar (section 4.2) + the amount the deviation of the specified mean (input form next page) is from 10 pigs per litter born alive.

A = age of sow at farrowing time.

Example actual MEAN values are as follows for the standard specification of 9.5 pigs born alive:

Age of Sow	Value of MEAN from the above formula
365 (1 year old gilt)	8.4
545 (approx. age and litter)	9.5
725 (2 year old)	10.3
1090 (3 year old)	11.0
1200 days	10.9
1300 days	10.8
1600 days	10.3
1825 days	10.0

The above function is derived from: Urban, W. E., Jr., C. E. Shelby, A. B. Chapman, J. A. Whitley, Jr., and V. A. Garwood, "Genetic and Environmental Aspects of Litter Size in Swine", J. Animal Science, Vol. 25, 1966, pp. 1148-1153. Very few observations were used to estimate this function beyond the maximum number of pigs born (Age = 1121 days). To negate the rapid decline of the function value for older sows, the number of pigs born is assumed to decline linearly after the age of 1300 days.

3/ Based on Purdue swine farm herd data: 2.24 in Fall, 1967, 3.46 in Spring, 1968. 42 and 39 litters were farrowed respectively.

5.4 Pigs Farrowed

Cd. No. 6.

	Standard	Range	Users Option
(a) Number of pigs farrowed alive per litter to a sow of base age 1/			
Mean number of pigs born 2/	9.5	4.-16.	___.
Standard deviation pigs born	3.0 3/	0.-10.	___.
Minimum number pigs born	4.0	≥ 4.	___.
Maximum number pigs born	16.0	≤ 16.	___.
(b) Birth weights 4/			
Mean birth weight, pounds	3.0 5/	1.-5.	___.
Standard deviation, pounds	0.4 6/	0.-5.	___.
Minimum weight, pounds	1.25	≥ 1.	___.
Maximum weight, pounds	5.0	≤ 5.	___.

(continued from previous page).

4/ Random Normal Deviates are drawn for individual pigs birth weight after adjusting the Mean for number of pigs born in the litter (-.09 pounds per pig born in the litter deviation from the input form "Mean No. of Born" given in section (a) above). Standard deviation and range is not adjusted for size of the litter. For birth weight to number of pigs born relationships see: "Relationship of Gestation Length, Age, and Weight at Breeding, and Gestation Gain to Sow Productivity at Farrowing", J. Animal Science, Vol. 24, No. 2, 1969, an article by Omtvedt, I.T., C. M. Stanislaw, and J. A. Whatley, Jr.

5/ Based on Swine Farm Herd Data, mean was 3.01 in Fall, 1967 and 3.08 spring, 1968.

6/ Approximate mean of the variances calculated for individual litters of Swine Farm Herd in fall of 1967 and spring of 1968.

Instructions for Rate of Gain Options, Next Page.

The Mean rate of gain must be specified on this form. Standard deviations and range is calculated by the program, see the following footnotes.

Footnotes:

1/ Standard means result in an expected 200 pound market hog at 6 months of age.

2/ Applies to all 5 age categories. Estimation from experiments conducted on farms by J. Foster. Standard deviation of weight gain is calculated as a percent of the above specified mean in each use. Range is assumed -5 to 10 pounds to allow fully stochastic deviation. Standard deviation of gain in the Foster experiments was approximately 20% from 1-4 weeks; 14% from 1-20 weeks.

3/ Approximate value for confined sows gain during gestation reported from Purdue Housing-Management Systems, see Jones, H. W., V. B. Mayrose, and D. H. Bache, "Confined Sow Management Systems", ID-80, Purdue University Cooperative Extension Service, 1972, p. 2.

4/ If additional loss (in addition to loss at parturition, see part (c) below) a negative sign must be specified. The standard value (-0.5) results in a total loss during lactation as indicated in ID-80, see footnote 3 above.

5/ Range is assumed -10 to 10 pounds.

5.5 Rate of Gain

			Standard	Range	Users Option
(a) Mean daily gain of pigs and hogs by age category 1/					Cd. No. 7.
Age Category	Days of Age Definition				
1st week	1- 7	mean, pounds	0.45	.1-1.	_._ _
2-3 weeks	8- 21	mean, pounds	0.58	.1-1.	_._ _
starting	22- 56	mean, pounds	0.75	.1-2.	_._ _
growing	57- 149	mean, pounds	1.25	.1-2.	_._ _
finishing	150-sale	mean, pounds	1.70	.1-3.	_._ _
Standard deviation as % of above means 2/			15.0%	0.-99%	_ _._
(b) Daily gain of sows					Cd. No. 9.
Mean-sow and gilt in maintenance, pounds			1.0 3/	.1-9.	_._
Standard deviation sow and gilt in maintenance, pounds			.2	0.- 9.	_._ 4/
Mean- sow in lactation, pounds			-0.5	(neg)5.-5.	_ _._
Standard deviation, sows in lactation, pounds			1.0	0.-9.	_._
(c) Sow weight loss at Parturition 5/ per pig farrowed, loss, pounds			5.	0.-9.	_._
Standard deviation			.5	0.-5.	_._

VI. Output Options

Output options are provided to enable an evaluation of the model while keeping the computer print volume to a minimum.

There are three general types of reports. The first type, called "Summary Reports", is generated periodically to report the productivity as well as simple cost and return measures. These reports are designed to reflect the productivity of the herd over a planning period of say one year. The length of the period is, however, a user option.

The second type of report, called "Event and Daily Reports", is more detailed and may be used to evaluate seasonal events and daily status of the herd.

The third type of report, called "Diagnostic Reports", is for use in debugging the operation of the program. Attributes of individual animals can be inspected daily by writing them out in this way. However, this type of report results in very large volumes of output and will increase computer execution time significantly.

Instructions for Summary Report Options, Next Page

Summary reports are made periodically. Specify the length of reporting period and indicate those reports desired. This group of reports appear on the resulting output before those of the next section.

Footnotes:

1/ Specify the number of days between summary reports. A request made larger than the number of days of simulation will result in no report of either production or cost and returns even if some of the individual items are requested with the 1=yes option.

2/ Building use includes current inventory of animals in each building as well as the average occupancy rate over the period. If overflow occurred, it can be reported daily, see the overflow message option of Section 6.2 page 605.

3/ The breeding report is a summary over all breeding completed in this reporting period. Sows bred and those failing to conceive are reported along with the number of services given to reach conception.

4/ The farrowing report is a summary over all farrowing in this reporting period.

5/ Weight gains for the period requested=ending inventory weight + sales weight - opening inventory weight. Ending inventory is used as the subsequent opening inventory for the next periodic report. Number of animals and value of production is also reported.

6.1 Summary Reports

		Standard	Range	Users Option
			Cd. No.	5 3.
Schedule Summary Reports Every ? days:1/		365.	1-9999	----.
Production Summary				
(a) Building Use2/	1=yes, 0=no	1.	0.,1.	-.
(b) Breeding3/	1=yes, 0=no	1.	0.,1.	-.
(c) Farrowing4/	1=yes, 0=no	1.	0.,1.	-.
(d) Weight Gains5/	1=yes, 0=no	1.	0.,1.	-.

			Cd. No.	5 4.
Costs and Returns Summaries				
Omit Switch: zero to omit all (a)-(f)		1.	0.,1.	-.
(a) Feed Costs Sows	1=yes, 0=no.	1.	0.,1.	-.
(b) Feed Costs Butcher Hog Gains	1=yes, 0=no	1.	0.,1.	-.
(c) Labor Costs	1=yes, 0=no	1.	0.,1.	-.
(d) Value of Sows Sold, Adjusted for Inv.	1=yes, 0=no	1.	0.,1.	-.
(e) Value of Butchers Sold, Adj. for Inv.	1=yes, 0=no	1.	0.,1.	-.
(f) Costs and Returns Summary Table	1-yes, 0=no	1.	0.,1.	-.

Instructions for Event and Daily Report Options, Next Page

Specify those reports required to clarify the experiment being conducted. Users are warned that seasonal and daily reporting can result in a large volume of output. These reports appear in order by simulation time as generated.

Footnotes:

1/ The major events schedule as followed in the simulation run. This includes dates of sales, breeding, selection of gilts, cleaning of the farrowing house, weaning, and boar buying.

2/ Reported at close of the respective season.

3/ Specify starting and ending dates. One report is generated for each day requested. Each building request generates 2 lines of output per report.

4/ Zero specification results in an end of day 0 report i.e., the opening inventory, and is a legal request. The standard value: -1. results in no report of this type.

5/ Building overflow and error message reporting generally results in one or two lines per building per.day that is in the overflow condition.

6.2 Event and Daily Reports

		Standard	Range	Users Option
				Cd. No. 5 5.
Coded Schedule of Major Events 1/ (1-2 pages)	1=yes, 0=no	0.	0,1.	_.
Seasonal Events 2/				
(a) Sales as they occur (½ page per sale)	1=yes, 0=no	0.	0,1.	_.
(b) Farrowings at end of season (1 page per season)	1=yes, 0=no	0.	0,1.	_.
(c) Breedings at end of season (1 page per season)	1=yes, 0=no	0.	0,1.	_.
Consecutive Daily Inventory by Building 3/				Cd. No. 5 6.
Start Daily Inventory date, day 4/		-1.	(neg)1.-9999.	_ _ _ _.
End Daily Inventory date, day 4/		-1.	(neg)1.-9999.	_ _ _ _.
(a) Nursery Bld.	1=yes, 0=no	0.	0,1.	_.
(b) Finishing Bld.	1=yes, 0=no	0.	0,1.	_.
(c) Maintenance Bld.	1=yes, 0=no	0.	0,1.	_.
(d) Boars	1=yes, 0=no	0.	0,1.	_.
(e) Farrowing Bld., Sows and Pigs	1=yes, 0=no	0.	0,1.	_.
(f) Misc. births & deaths	1=yes, 0=no	0.	0,1.	_.
Building Overflow Messages 5/	1=yes, 0=no	0.	0,1.	_.

Instructions for Diagnostic Report Options, Next Page

Diagnostic Reports are recommended only as a last resort in investigating unexpected results and for debugging errors in the program. Large volumes of output are generated and computer execution time is extended by this type of request. Temporary reduction in herd size at opening inventory and reduced condeption and/or birth rates while debugging will reduce execution time required.

Footnotes:

1/ Computer packed storage (multiple variables in a single word) is decoded and given appropriate labels as to individual animal attributes. This process is simply repeated at the end of each day requested in the string of days from the specified "start" to "end" day for those buildings desired.

2/ Zero specification here results in a day zero, i.e., opening inventory report. The standard value (-1.) results in no report of this type.

3/ A CØMMØN variable which can be set equal to a subroutine number to trigger those debugging aids built into individual subroutines. Other debugging write statements could be placed in the program to be triggered in this way.

4/ A CØMMØN variable available for a programmer's use as a switch.

6.3 Diagnostic Reports

	Standard	Range	Users Option
			Cd. No. 5 7.
Individual Daily Animal Attributes 1/			
Start Daily Animal Attributes, day 2/	-1.	(neg)1.-9999.	_ _ _ _.
End Daily Amimal Attributes, day 2/	-1.	(neg)1.-9999.	_ _ _ _.
(a) Nursery Bld. 1=yes, 0=no	0.	0,1.	_.
(b) Finishing Bld. 1=yes, 0=no	0.	0,1.	_.
(c) Maintenance Bld. and Cull Pen 1=yes, 0=no	0.	0,1.	_.
(d) Boars 1=yes, 0=no	0.	0,1.	_.
(e) Farrowing Bld. 1=yes, 0=no	0.	0,1.	_.
Subroutine Oriented Diagnostic Switches			
			Cd. No. 5 8.
Individual Subroutine: NS1= 3/	0.	0.-25.	_ _.
Special Use Switch: NS2= 4/	0.	0.-9999.	_ _ _ _.

Mandatory Last Data Card, first columns: 9 9 9 9.

APPENDIX C

THE FORTRAN PROGRAM

```
EXECUT
      PROGRAM EXECUT(INPUT,OUTPUT,TAPE2=157,TAPE5=157,TAPE15=115,
     2TAPE50=335,TAPE60,TAPE6=175,TAPE8=175,TAPE13=175,TAPE7=175)
C
C      THE MAIN PROGRAM EXECUT AND ASSOCIATED SUBROUTINES SET UP AND
C MANAGE THE SIMULATION RUN(S).  SUBROUTINE MGT CONTAINS THE
C MASTER TIME AND REPORTING CONTROL.  SUB. MGT3 CHECKS AND
C PREPARES REPORTS ON THE SYSTEM.  SUB. EVNTS CALLS FOR EXECUTION OF
C THE UPDATING OF ANIMAL ATTRIBUTES.  REPORTS ARE WRITTEN BY THE
C SUBROUTINES OUT, REPT1, AND REPT2.  FILEM, REMOV, AND FIND ARE
C SUBROUTINES FOR PLACING, REMOVING AND FINDING ANIMALS IN A
C FILE.
C SUBROUTINES OF SUPPORT GROUP INCLUDE-
C        STATISTICAL -ZROSUM,COLLT,STATS FOR CALCULATION OF  MEAN ETC.
C        RANDOM DEVIATES-
C              FUNCTION RANUM  FOR RANDOM NUMBERS
C              FUNCTION RNORM(RMEAN,STD,RMIN,RMAX)  FOR NORMAL DIST.
C ARRAY STORAGE-
C       IN(R,C), VEN(R,C)  ARE THE INVENTORY FILING ARRAYS
C             DIMENSION BOTH TO (R,C) HERE,   TO (R,1) IN SUBROUTINES.
C             SEE PRITSKER -SIMULATION WITH GASPII-  PP. 23-24.
C
C LABELED COMMON IS NAME KEYED,  SEE SUBROUTINE USAGE.
      COMMON/INIT/NR,NW,ND,NT7,NT8,NDAT,NS1,NS2,NOWD
     2 /RAN/ IRN(54),KRANUM,RLIMIT,NRNOPT,ITAPE
     3/STAT/SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10),SUM5(5,10)
     4 /GEN/ITOT,ISIZE,NOWT,NOWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5/HOUSE/NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4,X1,X2,X4
     6 /SALES/ MDSELL,WTS,NXTSAL,NSLD(4),WTSLD(4),VSLD(4),PRIH,PRIS
     7/SALE2/NSLDP(4),WTSLDP(4),VSLDP(4),DIS
     7 /BRED/LBREED,NBREED,IFAR(6,5),IDB(30),KAGEW,LGTHW,NAGEM
     3/SCH/KS(2,500),IPT,IEVT,KODE,IWE,IWN(45),NKT
     4/CULL/NGLTS,MXSRV,MXAGS,PCULG,PCULS,PSSR,PRGT,MXBOR,LDP
     8 /BRED2/ ABNORG,GESM,GESS,GMIN,GMAX,ESTM,ESTS,EMIN,EMAX
     9 /BRED3/ PTRM1,PTRM2,PTRM16,PCON1,PCON2,ADJ1,ADJ2
     1 /SKIP/ ISTOP4,ISTOP5,ISTOP6,ISTOP7,MAXSKP
     2/SURVIV/PW1,PW23,PSRT,PSFIN,PSOWS,PBORS,PBORS1,MDEAD(8),PSRT2
     3 /GAIN/GW1,GW23,GSRT,GFIN1,GFIN2,GSOWM,GSOWL,SDP,SSOWM,SSOWL
     4 /BIRTH/ BRNM,BRNS,BMIN,BMAX,BWTM,BWTS,BWMIN,BWMAX,NOBRN
     5 /CLEAN/NDPREP,NH4CLN,LOSSL,SWTLP,SSLP,KL4
      COMMON /BOAR/ MXSDY,MXSWY,MXSDM,MXSWM,NPUR,IPDAT,KAGE,WTPB,IBS
     5/BRED4/KBRD,KSWGT(4),NONB(4),NONBK(4)
     2 /MG3/ NHH(6),MDEADH(8),NHP(6),MDP(6),KCALL,KPRET,KNSLD4,KPREP
     7 /KRS/ KRS1,KRS2,KRS3,KRS4,KRS5,KRS6,KRS7,KRPT
     1 /RPT1/ISMYP,ISMB,ISMBG,ISMF,ISMW,ISMS,ISMM
     2 /RPT2/ISMYC,ISMCS,ISMCH,ISML,ISMSS,ISMSH,ISMGR
     3 /RPT3/MJEV,ISALS,IFARS,IBRDS
     4 /RPT4/IDCS,IDCE,IDCN,IDCF,IDCM,IDCB,IDCFS,IDCFP,IOFLW
     5 /RPT5/IAAS,IAAE,IAAN,IAAFN,IAAM,IAAB,IAAFR
     3 /COST/FCS,FCB,CLAB,TFAR,TNUR,TSOW,TFIN,VAR(3),COST(30)
     6/WRT1/ KW
     4 /GAIN2/SOP(6),HOP(6),SSLD(6),HSLD(6),SEND(6),HEND(6)
      DIMENSION IN(3,1500),VEN(2,1500)
      DIMENSION EQARR(1802)
      EQUIVALENCE (NR,EQARR(1))
C
C
C
C ARRAYS  IN(3,J), VEN(2,J) OVERLOAD PROTECTION,  SEE SUB. FILEM.
C      SET  KRS3=J, COLUMN SIZE FOR THE ABOVE DIMENSIONED ARRAYS.
C      ITOT (TOTAL NO. OF ANIMALS) MAY NOT EXCEED  KRS3 AT ANYTIME.
```

```
1     KRS3=1500
C
C
C
C INITIATE THE PROGRAM IN SUBROUTINE INITN.
C     ASSIGN READ-WRITE TAPES, READ CONTROL PARAMETERS.
      CALL INITN(IN,VEN)
C
C PREPARE OPENING INVENTORY-  READ ORIGINAL HERD DATA
      CALL OPEN(IN,VEN)
C
C
C
C SET UP INVENTORY REPORTING IN SUBROUTINE MGT3.
      CALL MGT3(IN,VEN)
C
C
C LET SUBROUTINE MGT MANAGE THIS SIMULATION RUN.
 2    CALL MGT(IN,VEN,EQARR)
C
      STOP
      END
```

```
      SUBROUTINE INITN(IN,VEN)
      COMMON/INIT/NR,NW,ND,NT7,NT8,NDAT,NS1,NS2
     2 /RAN/ IRN(54),KRANUM,RLIMIT,NRNOPT,ITAPE
     3 /STAT/ SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10)
     4 /GEN/ITOT,ISIZE,NOWT,NOWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5/HOUSE/NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4,X1,X2,X4
     6 /SALES/ MDSELL,WTS,NXTSAL,NSLD(4),WTSLD(4),VSLD(4),PRIH,PRIS
     7 /BRED/LBREED,NBREED,IFAR(6,5),IDB(30),KAGEW,LGTHW,NAGEM
     8 /BRED2/ ABNORG,GESM,GESS,GMIN,GMAX,ESTM,ESTS,EMIN,EMAX
     9 /BRED3/ PTRM1,PTRM2,PTRM16,PCON1,PCON2,ADJ1,ADJ2
     1 /SKIP/ ISTOP4,ISTOP5,ISTOP6,ISTOP7,MAXSKP
     2/SURVIV/PW1,PW23,PSRT,PSFIN,PSOWS,PBORS,PBORS1,MDEAD(8),PSRT2
     3/GAIN/GW1,GW23,GSRT,GFIN1,GFIN2,GSOWM,GSOWL,SDP,SSOWM,SSOWL
     4 /BIRTH/ BRNM,BRNS,BMIN,BMAX,BWTM,BWTS,BWMIN,BWMAX,NOBRN
     5 /CLEAN/NDPREV,NH4CLN,LOSSL,SWTLP,SSLP
     4/CULL/NGLTS,MXSRV,MXAGS,PCULG,PCULS,PSSR,PRGT,MXBOR,LDP
     3 /COST/ FCS,FCB,CLAB,TFAR,TNUR,TSOW,TFIN
      COMMON /BOAR/ MXSDY,MXSWY,MXSDM,MXSWM,NPUR,IPDAT,KAGE,WTPB,IBS
     1/RPT1/ ISMYP,ISMB,ISMBG,ISMF,ISMW,ISMS,ISMM
     2/RPT2/ ISMYC,ISMCS,ISMCH,ISML,ISMSS,ISMSH,ISMGR
     3/RPT3/MJEV,ISALS,IFARS,IBRDS
     4/RPT4/IDCS,IDCE,IDCN,IDCF,IDCM,IDCB,IDCFS,IDCFP,IOFLW
     5/RPT5/ IAAS,IAAE,IAAN,IAAFN,IAAM,IAAB,IAAFR
     7/SALE2/DUMMY(12),DIS
     7/KRS/KRS1,KRS2,KRS3,KRS4,KRS5,KRS6,KRS7,KRPT
      DIMENSION RR(10),STRR(10)
      INTEGER XMINUS
      DATA XMINUS/00000000000000007777/
      DIMENSION ISTRR(10)
      EQUIVALENCE (ISTRR(1),STRR(1))
C ASSIGN TAPES
C        READ=NR= WRITE=NW, DIAGNOSTIC=ND, BASE HERD DATA TAPE=NDAT,
C                 RANDOM NOS. =ITAPE
      NR=2
      NR5=5
      NW=6
      ND=13
C  MAY SET TO 8 FOR JUNKING VIA CARD 56.
      NT7=13
      NDAT=15
      ITAPE=50
      MR=0
C
C
C INITIATE VARIABLES OUTSIDE SUBROUTINES
      KRANUM=0
      RLIMIT= 2.**48.-1.0
      ITOT=0
      DO 90 II=1,6
 90   NH(II)=0
      NOWY=0

C PRESET STATISTICAL COLLECTION ARRAYS
      DO 100 JVARBL=1,20
 100  CALL ZROSUM(SUM,JVARBL)
      DO 200 IVARBL=1,10
      CALL ZROSUM(SUM2,IVARBL)
      CALL ZROSUM(SUM3,IVARBL)
 200  CALL ZROSUM(SUM4,IVARBL)
```

```
C
C
C
C PRESET FARROWING DATES FOR FIRST YEAR
C
      IFAR(1,1)=15
      IFAR(2,1)=60
      IFAR(3,1)=152
      IFAR(4,1)=198
      IFAR(5,1)=244
      IFAR(6,1)=335
C
C
C
C MARK BEGINNING OF PRINTED OUTPUT
      WRITE(ND,606)ND
      WRITE(NT7,606)NT7
      WRITE(NW,606)NW
606   FORMAT(*8   BEGIN PRINT TAPE*I4* REPORTS*)
C
C
C READ  NR=TAPE5 DATA AND LIST THEM.
      READ(NR,705) RR
705   FORMAT(10A8)
706   FORMAT(//* FREE FORM IDENT CARD FOLLOWED BY*
     2 * DEFAULT DATA, USER OPTION CARDS */* APPEAR AFTER THE *
     3 *CORRESPONDING DEFAULT CARD*//5X,10A8)
      READ(NR5,705) RR
      WRITE(ND,706) RR
C
C READ STANDARD 10F7.0, FIRST CELL IS CARD NO., OTHERS
C  REPLACE WITH NON-BLANK CELLS IF FIND USER OPTION CARD NO.
C
30    READ(NR,50) RR
      WRITE(ND,60) RR
      IR=RR(1)
      IF(IR.EQ.8888) GO TO 999
355   READ(NR5,50) STRR
      MR = STRR(1)
      IF(MR-999) 301, 354, 354
301   IF(MR-IR) 355, 305, 355
305   WRITE(ND,60) STRR
      DO 353 I=1,10
      IF(ISHFTR(ISTRR(I),48).EQ.XMINUS) STRR(I)=RR(I)
353   RR(I)=STRR(I)
50    FORMAT(10F7.0)
60    FORMAT(5X,10F9.3)
354   REWIND NR5
      READ(NR5,705) ALPHA
      IF(IR.GT.20) GO TO 500
      GO TO(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20) IR
C
C ISIZE OF OPENING INVENTORY HERDS
 1    ISIZE=RR(2)
C
      GO TO 30
C FARROWING CONTROL
 2    LBREED=RR(2)
      NBREED=RR(3)
      KAGEW=RR(4)
      LGTHW=RR(5)
      NAGEM=RR(6)
      GO TO 30
```

```
C
C SURVIVAL PROBABILITIES, CONVERT TO DAILY, PUT INTO /SURVIV/.
3     PW1=(1.-RR(2))**(1./7.)
      PW23=(1.-RR(3))**(1./14.)
      PSRT=(1.-RR(4))**(1./35.)
      PSRT2=(1.-RR(5))**(1./35.)
      PSFIN=(1.-RR(6))**(1./124.)
      PSOWS=(1.-RR(7))**(1./365.)
      PBORS=(1.-RR(8))**(1./365.)
      PBORS1=(1.-RR(9))**(1./365.)
      GO TO 30
C
C FILL /BRED2/  AND /BRED3/
C ABNORMAL GILTS, ESTRUS LENGTH, PROBABILITY OF CONCEPTION, ADJ. NO BORN
 4    ABNORG=RR(2)
      ESTM=RR(3)
      ESTS=RR(4)
      EMIN=RR(5)
      EMAX=RR(6)
      PCON1=RR(7)
      PCON2=RR(8)
      ADJ1=RR(9)
      ADJ2=RR(10)
      GO TO 30
C GESTATION LNEGTH AND PREMATURE TERMINATION.
 5    GESM=RR(2)
      GESS=RR(3)
      GMIN=RR(4)
      GMAX=RR(5)
      PTRM1=1.-((1.-RR(6))**(1./7.))
      PTRM2=1.-((1.-RR(7))**(1./100.))
      PTRM16=1.-((1.-RR(8))**(1./7.))
      GO TO 30
C
C FILL  /BIRTH/
 6    BRNM=RR(2)
      BRNS=RR(3)
      BMIN=RR(4)
      BMAX=RR(5)
C
C WEIGHTS FILLED INTO /BIRTH/
      BWTM=RR(6)
      BWTS=RR(7)
      BWMIN=RR(8)
      BWMAX=RR(9)
      GO TO 30
C
C WEIGHT INTO /GAIN/
 7    GW1=RR(2)
      GW23=RR(3)
      GSRT=RR(4)
      GFIN1=RR(5)
      GFIN2=RR(6)
      SDP=RR(7)/100.
      GO TO 30
C
C SALES CONTROL INTO /SALES/
 8    MDSELL=RR(2)
      WTS=RR(3)
      PRIH=RR(4)
      PRIS=RR(5)
      DIS=RR(6)/100.
```

```
      GO TO 30
C
C
C SOW GAINS
9     GSOWM=RR(2)
      SSOWM=RR(3)
      GSOWL=RR(4)
      SSOWL=RR(5)
C         ADD TO /CLEAN/
      SWTLP=RR(6)
      SSLP=RR(7)
      GO TO 30
C
C OPENING INVENTORY, BOARS - NEW, YOUNG, THEN MATURE.
10    NB1=RR(2)
      IF(NB1.LT.1) GO TO 6200
      DO 6101 K= 1,NB1
      IATRIB(1)=RR(3)
      IATRIB(2)=1
      IATRIB(3)=1
      IATRIB(4)=1
      IATRIB(5)=88*1000+K
      ATRIB(1)=RR(4)
      ATRIB(2)=RNORM(GSOWM,SSOWM,-5.,10.)
      CALL FILEM(IN,VEN,8)
6101  CONTINUE
C
6200  NB2=RR(5)
      IF(NB2.LT.1) GO TO 6300
      DO 6201 K=1,NB2
      IATRIB(1)=RR(6)
      IATRIB(2)=1
      IATRIB(3)=2
      IATRIB(4)=1
      IATRIB(5)=88*1000+NB1+K
      ATRIB(1)=RR(7)
      ATRIB(2)=RNORM(GSOWM,SSOWM,-5.,10.)
      CALL FILEM(IN,VEN,8)
6201  CONTINUE
C
6300  NB3=RR(8)
      IF(NB3.LT.1) GO TO 30
      DO 6301 K=1,NB3
      IATRIB(1)=RR(9)
      IATRIB(2)=1
      IATRIB(3)=3
      IATRIB(4)=1
      IATRIB(5)=88*1000+NB2+NB1+K
      ATRIB(1)=RR(10)
      CALL FILEM(IN,VEN,8)
6301  CONTINUE
      GO TO 30
C
C
C CULLING OF GILTS AND SOWS IN /CULL/
11    NGLTS=RR(2)
      MXSRV=RR(3)
      MXAGS=RR(4)
      PCULG=RR(5)/100.
      PCULS=RR(6)/100.
      MXBOR=RR(7)
      LDP=RR(8)
      GO TO 30
```

```
C
C CONCEPTION ADJUSTMENT, ADDED TO /CULL/
12     PSSR=RR(2)
       PRGT=RR(3)
       GO TO 30
C
C COST CARD
13     FCS=RR(2)
       FCB=RR(3)
       CLAB=RR(4)
       TFAR=RR(5)
       TNUR=RR(6)
       TSOW=RR(7)
       TFIN=RR(8)
       GO TO 30
C
C BUILDING OPTIONS, BUILDINGS ARE NOT IN FILES AS ARE ANIMALS.
14     MX1=RR(2)
       NDPREV=RR(3)
       X1=RR(4)
       GO TO 30
15     MX2=RR(2)
       X2=RR(3)
       GO TO 30
16     MX3=RR(2)
       GO TO 30
17     MX4=RR(2)
       X4=RR(3)
       GO TO 30
C
C NO SUCH CARDS
18     GO TO 1350
19     GO TO 1350
C
C BOAR MANAGEMENT OPTIONS
20     MXSDY=RR(2)
       MXSWY=RR(3)
       MXSDM=RR(4)
       MXSWM=RR(5)
       NPUR=RR(6)
       IPDAT=RR(7)
       KAGE=RR(8)
       WTPB=RR(9)
       GO TO 30
C
C CARDS 51. AND GREATER
C
500    IF(IR-51) 1350,51,502
502    IF(IR-53) 52, 53, 504
504    IF(IR-55) 54, 55, 506
506    IF(IR-57) 56, 57, 508
508    IF(IR-59) 58, 1350, 1350
C
C SIMULATION CONTROL -NDAYS,NRUNS
 51    NDAYS=RR(2)
       SEED=RR(3)
       SEED=RANF(SEED)
       MAXSKP=RR(4)
       NRNOPT=RR(5)
       KRS4=RR(6)
       GO TO 30
C
```

```
C
C NO CARD 52.
52     GO TO 1350
C
C PRODUCTION SUMMARY REPORT CONTROL
53     ISMYP=RR(2)
       ISMB=RR(3)
       ISMBG=RR(4)
       ISMF=RR(5)
       ISMW=RR(6)
       ISMM=RR(7)
       ISMM=RR(8)
       GO TO 30
C
C COSTS AND RETURNS SUMMARY REPORT CONTROL
54     ISMYC=RR(2)
       ISMCS=RR(3)
       ISMCH=RR(4)
       ISML=RR(5)
       ISMSS=RR(6)
       ISMSH=RR(7)
       ISMGR=RR(8)
       GO TO 30
C
C EVENTS AS THEY OCCUR REPORT CONTROL
55     MJEV=RR(2)
       ISALS=RR(3)
       IFARS=RR(4)
       IBRDS=RR(5)
       GO TO 30
C
C
C DAILY INVENTORY REPORT CONTROL
56     IDCS=RR(2)
       IDCE=RR(3)
       IDCN=RR(4)
       IDCF=RR(5)
       IDCM=RR(6)
       IDCB=RR(7)
       IDCFS=RR(8)
       IDCFP=RR(9)
       IOFLW=RR(10)
       GO TO 30
C
C INDIVIDUAL DAILY ANIMAL ATTRIBUTES CONTROL
57     IAAS=RR(2)
       IAAE=RR(3)
       IAAN=RR(4)
       IAAFN=RR(5)
       IAAM=RR(6)
       IAAB=RR(7)
       IAAFR=RR(8)
       GO TO 30
C
C NS1, NS2 DIAGNOSTIC SWITCHES
58     NS1=RR(2)
       NS2=RR(3)
       GO TO 30
1350   WRITE(ND,1351) RR(1)
1351   FORMAT(* ERROR SUB. INITN, DATA CARD .GT. PERMITED,=*F8.2)
       GO TO 30
C
999    DAY=DATE(0)
```

```
      REWIND NR5
      READ(NR5,705) RR
      WRITE(NW,998)NDAYS,DAY,RR
998   FORMAT(1H1,//18X*SWINE BREEDING HERD SIMULATOR*//7X
     2*REQUEST IS FOR*I4* DAYS,                TODAYS *
     3*DATE IS *A8/
     37X*YOUR IDENTIFICATION CARD=*///17X,10A8)
C
      RETURN
      END
```

```
OPEN
      SUBROUTINE OPEN(IN,VEN)
      COMMON/INIT/NR,NW,NC,NT7,NT8,NDAT,NS1,NS2
     3 /STAT/ SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10)
     4 /GEN/ITOT,ISIZE,NCWT,NCWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/ NH(6),N1,N2,N3,N4,N5,N6
     5/CLEAN/DUM(5),KL4
     4 /BIRTH/ BRNM,BRNS,BMIN,BMAX,BWTM,BWTS,BWMIN,BWMAX,NOBRN
     8 /BRED2/ ABNCRG,GESM,GESS,GMIN,GMAX,ESTM,ESTS,EMIN,EMAX
     3/GAIN/GW1,GW23,GSRT,GFIN1,GFIN2,GSOWM,GSOWL,SDP,SSOWM,SSOWL
     4/GAIN2/SOP(6),HOP(6),SSLD(6),HSLD(6),SEND(6),HEND(6)
     6/SALES/DUMMY(15),PRIH,PRIS
      DIMENSION IN(3,1),VEN(2,1)
C
C
C READ IN BASIC HERD DATA FROM TAPE NDAT.
C         BASE HERD IS 30 SOW AND 219 FINISHING HOGS.,
C                 SOWS ARE READY TO FARROW,  HOGS ARE 5.5-6.0 MONTHS.
C CREATE OPENING INVENTORY FOR 6 FARROWING SYSTEM,  AT T=0.
C         -ADJUST ATTRIBUTES TO  T=0  FOR SOWS AND FINISHING, CREATE
C                 BABY PIGS FOR HERD GROUP NUMBER THREE.
C         - ADJUSTMENTS FOR 3 HERD GROUPS TO FARROW BEGINNING-
C                    HERD 1  JANUARY 15(T=15), AND JULY 15(T=196)
C                    HERD 2  MARCH 1(T=60),   AND SEPTEMBER 1(T=244)
C                    HERD 3  JUNE1(T=152),   AND DECEMBER 1(T=335)
C
C LET ITOT= TOTAL NUMBER OF ANIMALS AT ANY TIME DURING SIMULATION.
C LET ISIZE= NO. OF SOWS IN EACH HERD GROUP CREATED.
C ATTRIBUTES ARE CONTROL PARAMETER DEPENDENT.
C
C
      SIZE=ISIZE
      IFIN=SIZE*(BRNM*.78)+.5
C LOOP 3 HERDS, ID=1 IMPLIES SOW ADJUSTMENT,  ID=2 FINISHING .
C
      DO 9999 IHERD=1,3
      REWIND NDAT
      ID=1
 550  READ(NDAT,500) IAGE, JSEX,KLAS,LTAL,LOCA,MNUM,WT
 500  FORMAT(I4,I1,I1,I3,I3,I6,7X,F5.0)
      IF(IAGE.NE.6666) GO TO 449
      REWIND NDAT
      GO TO 550
449   IF(IAGE.NE.7777) GO TO 551
      REWIND NDAT
      DO 776 KI=1,31
776   READ(NDAT,6666)
      GO TO 550
 551  IF(LOCA.GT.10) LOCA=LOCA/100
      GO TO (1001,2001,3001)IHERD
C HERD 1, ADJUST BACK 15 DAYS
 1001 IF(ID.EQ.2) GO TO 1031
      LTAL=LTAL-15
      WT=WT-12.
 131  IAGE=IAGE-15
      MNUM=ITOT+1+10000
 3    IATRIB(1)=IAGE
      IATRIB(2)=JSEX
      IATRIB(3)=KLAS
      IATRIB(4)=LTAL
      IATRIB(5)=MNUM
      ATRIB(1)=WT
```

```
      ATRIB(2)=G
      CALL FILEM(IN,VEN,LOCA)
      IF(IHERD.EQ.2) GO TO 550
      IF(NH(3).GE.ISIZE.A.ID.EQ.1) GO TO 77
      IF(NHOGS.GE.IFIN) GO TO 9999
      GO TO 550
 1031 NHOGS=NHOGS+1
      IF(IAGE-149) 1032, 1032, 1033
1032  G=RNORM(GFIN1,GFIN1*SDP,-5.,10.)
      GO TO 131
1033  G=RNORM(GFIN2,GFIN2*SDP,-5.,10.)
      GO TO 131
C HERD I, ADJUST BACK 60 DAYS
 2001 IF(ID.EQ.2) GO TO 2031
      IH2= IH2+1
      IF(IH2.GT. ISIZE) GO TO  77
      LTAL=LTAL-60
      WT=WT-48.
 231  IAGE=IAGE-60
      MNUM=ITOT+1+20000
      G=RNORM(GFIN1,GFIN1*SDP,-5.,10.)
      GO TO 3
2031  NHOGS=NHOGS+1
      IF(NHOGS.GT.IFIN)GO TO 9999
      WT=WT-107.1
      GO TO 231
C HERD 3, ADD 30 DAYS TO AGE, CREATE BABY PIGS FOR EACH SOW.
3001  DO 333 II=1,ISIZE
      IAGE=IAGE+30
      KLAS=KLAS+1
      LTAL=30+LTAL-114
      LOCA=LOCA-2
      WT=WT-0.8*LTAL
      MNUM=ITOT+1+30000
      NOSOW=MNUM
      AGE=IAGE+GESM
C ADJUST NO. PIGS FOR AGE SOW, DEVIATION OF MEAN -BRNM- FROM 10 INTERCE
C         ASSUME NO SOWS OVER 1300 DAYS IN OPENING INVENTORY.
      V=BRNM-10.
      BR=V+5.867+.01*AGE-.00000446*AGE**2.
      IPIGS=RNORM(BR,BRNS,BMIN,BMAX)+0.5
      IATRIB(1)=IAGE
      IATRIB(2)=JSEX
      IATRIB(3)=KLAS
      IATRIB(4)=LTAL
      IATRIB(5)=MNUM
      IATRIB(8)=IPIGS
      ATRIB(1)=WT
      CALL FILEM(IN,VEN,LOCA)
C         CREATE BABY PIGS FOR SOW II LOOP
      DO 380 IK=1,IPIGS
      IAGE=LTAL
      IF(RANUM(D).GT.0.5) 101,102
 101  JSEX=2
      KLAS=1
      GO TO 103
 102  JSEX=3
      KLAS=0
C         CALCULATE WEIGHT BY BIRTH WT. + .5 LB. DAY, STD.=3.6
 103  BTWT=RNORM(BWTM,BWTS,BWMIN,BWMAX)
      WT=BTWT+RNORM(.5*IAGE,3.6,5.0,25.0)
      MNUM=ITOT+1+30000
```

```
      IBT=BTWT*100.
      IATRIB(1)=IAGE
      IATRIB(2)=JSEX
      IATRIB(3)=KLAS
      IATRIB(5)=MNUM
      IATRIB(8)=NOSCW
      IATRIB(11)=IBT
      ATRIB(1)=WT
      CALL FILEM(IN,VEN,4)
 380  CCNTINUE
381   READ(NDAT,500)IAGE,JSEX,KLAS,LTAL,LCCA,MNUM,WT
      IF(IAGE.NE.6666) GC TC 331
      REWINC NDAT
      GC TC 381
331   LCCA=LCCA/100
 333  CCNTINUE
      GC TC 9999
C
C DUMMY READ SKIPS SOW CATA RECCRDS
77    READ(NDAT,6666)NSTCP
6666  FCRMAT(I4)
      IF(NSTCP.EQ.6666) GC TO 6667
      GO TC 77
6667  IC=2
      NHCGS=0
      IH2=0
      GC TC 550
C
C
C      SET FARRCWING HOUSE LITTER CCUNT KL4.
9999  KL4=ISIZE
C ADD ESTRUS CYCLES TC CPENING INVENTCRY SCWS IN  PRCDUCTICN.
      LNH4=NH(1)
      DC 678 K4=1,LNH4
      CALL REMOV(IN,VEN,1)
      IF(IATRIB(1)-21) 673, 673, 671
623   ATRIB(2)=RNORM(GW23,GW23*SDP,-5.,10.)
      GC TC 678
671   IF(IATRIB(1)-200) 673, 673, 675
673   ATRIB(2)=RNORM(GSRT,GSRT*SCP,-5.,10.)
      GC TC 678
675   IATRIB(10)=RNCRM(ESTM,ESTS,EMIN,EMAX)+0.5
      ATRIB(2)=RNCRM(GSCWL,SSCWL,-5.,10.)
678   CALL FILEM(IN,VEN,4)
      LNH6=NH(3)
      DC 567  K6=1,LNH6
      CALL REMCV(IN,VEN,N2+1)
      A=IATRIB(1)
      C=BRNM-10.
      BR=C+5.867+.01*A-.00C00446*A**2.0
      IATRIB(8)=RNORM(BR,BRNS,BMIN,BMAX)+0.5
      IATRIB(10)=RNCRM(ESTM,ESTS,EMIN,EMAX)+0.5
      IATRIB(11)=RNCRM(GESM,GESS,GMIN,GMAX)+0.5
      ATRIB(2)=RNCRM(GSCWM,SSCWM,-5.,10.)
 567  CALL FILEM(IN,VEN,6)
C
C
C OPENING INVENTORY WEIGHTS AND VALUE
C    SOWS AND HOGS COUNT AND WT CNLY.
C ARRAYS GAIN2- 1=NC., 2=WT., 3=VALUE OF WT.
      DC 7009  I=1,ITCT
      ICHK=IN(1,I)/1000000000
      IF(ICHK-240) 7001, 7005, 7005
```

```
C         HOGS ANC PIGS .LT. 240 CAYS CF AGE.
7001   HOP(1)=HOP(1)+1.
       HCP(2)=HOP(2)+VEN(1,I)
       HOP(3)=HOP(3)+VEN(1,I)*PRIH/100.
       GC TC 7009
C        CVER 240 DAYS OF AGE.
7005   SOP(1)=SOP(1)+1.
       SOP(2)=SOP(2)+VEN(1,I)
       SOP(3)=SOP(3)+VEN(1,I)*PRIS/100.
7009   CONTINUE
C
C
       IF(NS1.EQ.13) CALL CLT(IN,VEN,1,ITOT,131313.9)
C
       RETURN
       END
```

MGT

```
      SUBRCUTINE MGT(IN,VEN,EGARR)
      CCMMCN/INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2,NCWC
     2 /RAN/ IRN(54),KRANUM,RLIMIT,NRNCPT,ITAPE
     3 /STAT/ SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10)
     4 /GEN/ITCT,ISIZE,NCWT,NCWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/ NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4
     6/SALES/MDSELL,WTS,NXTSAL,NSLC(4),WTSLC(4),VSLC(4),PRIF,PRIS
     7 /BREC/ LBREED,NBREED,IFAR(30),IDB(30),KAGEW,LGTHW,NAGEM
     8 /BREC2/ ABNORG,GESM,GESS,GMIN,GMAX,ESTM,ESTS,EMIN,EMAX
     9 /BREC3/ PTRM1,PTRM2,PTRM16,PCCN1,PCCN2,ADJ1,ADJ2
     1 /SKIP/ ISTOP4,ISTCP5,ISTCP6,ISTOP7,MAXSKP
     2 /SURVIV/ PW1,PW23,PSRT,PSFIN,PSOWS,PBORS,PBCRS1,MDEAC(8)
     3 /GAIN/ GW1,GW23,GSRT,GFIN1,GFIN2,GSCWM,GSOWL
     4 /BIRTH/ BRNM,BRNS,BMIN,BMAX,BWTM,BWTS,BWMIN,BWMAX,NCBRN
     5 /CLEAN/ NDPREV,NH4CLN,LCSSL
     7 /KRS/ KRS1,KRS2,KRS3,KRS4,KRS5,KRS6,KRS7,KRPT
      CCMMCN/RPT5/ IAAS, IAAE
     1/RPT1/ISMYP,ISMB,ISMBG,ISMF,ISMW,ISMS,ISMM
     3 /SCH/KS(2,500),IPT,IEVT,KCDE,IWE,IWN(44),NKT
     6/WRT1/KW

      DIMENSION IN(3,1),VEN(2,1)
C GENERAL MANAGEMENT OF THE SIMULATICN RUN.
C
C LET MGT2 BUILD EVENTS FILE INTC ARRAY KS(2,500)
C
      KCDE=1
      CALL MGT2(IN,VEN)
C
C
C
C LCOP NDAYS OF SIMULATICN, INCREMENTING NOWT AND NCWY.
C
C ISTOP4-7 SET TO NCAYS HERE, MAY TEMPORARLY LOWER ELSEWHERE.
      KRS2=ISMYP
      ISTCP4=KRS2
      ISTOP5=KRS2
      ISTOP6=KRS2
      ISTOP7=KRS2
C
       NOWT=0
C
C
C         INDIVICUAL DAILY ANIMAL ATTRIBUTE CALL 7777
      CALL CUT(IN,VEN,7777)
      IF(NS2-2) 8888,788,8888
788   CALL CUT(IN,VEN,1,ITCT,2788.0)
C
C
8888  NCWT=NOWT+1
      NCWY=(NOWT-1)/365+1
      NCWD=NOWT-(NCWY-1)*365
C
C
      CALL EVNTS(IN,VEN)
C
C  INDIVIDUAL DAILY ATTRIBUTE REPCRT IN SUB. CUT(,,,7777)
      IF(IAAS-NCWT) 782, 782, 786
782   IF(IAAE-NCWT) 786, 784, 784
784   CALL CUT(IN,VEN,7777)
      IF(NS2-2) 786, 785, 786
```

```
785   CALL CUT(IN,VEN,1,ITCT,28888.7)
C    CALL MGT3 EVERY DAY, TEST FCR CAILY INVENTCRY REPCRT THERE.
C
C   KRS1 SWITCH SENSES CHANGE IN TOTAL INVENTCRY
786   IF(ITCT-KRS1) 787, 789, 787
787   KRS1=1
789   CALL MGT3(IN,VEN)
      KRS1=ITOT
C
C
C PRODUCTION SUMMARY REPCRTS CALLED
C   KRS2 HOLCS CAY OF NEXT CALL
      IF(NCWT-KRS2) 80C, 4C1, 4C1
401   KRS2=KRS2+ISMYP
      ISTOP4=KRS2
      ISTOP5=KRS2
      ISTOP6=KRS2
      ISTOP7=KRS2
      IF(ISMB)5 ,5,  404
404   KW=4
      CALL REPT1(IN,VEN)
      KW=0
5     IF(ISMBG) 6, 6, 505
505   KW=5
      CALL REPT1(IN,VEN)
      KW=0
6     IF(ISMF) 7, 7, 606
606   KW=6
      CALL REPT1(IN,VEN)
C
C PRODUCTICN GAINS AND CCST SUMMARY REPCRTS IN SUB. REPT1,
C     SUB. REPT1 CALLS REPT2 FCR COSTS AND RETURNS
C
7     KW=7
      CALL REPT1(IN,VEN)
      KW=0
800   CCNTINUE
C
      CALL SECOND(T)
      KT=T
      IF(KT-KRS4) 8C1, 8C1, 999
999   WRITE(NW,961) KRS4, ITCT, NCWT
961   FCRMAT(///*   STCP DUE TC TIME EXCEECING LIMIT OF*I6
     2* SECCNDS,  TOTAL NC. ANIMALS=*I6* AT DAY=*I5)
      STOP
801   CCNTINUE
C
C
 88   IF(NCWT.LT.NDAYS) GC TC 8888
C
C
      RETURN
      END
```

```
MGT2
      SUBROUTINE MGT2(IN,VEN)
      COMMON /INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2
     4 /GEN/ ITCT,ISIZE,NCWT,NCWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4
     6/SALES/MDSELL,WTS,NXTSAL
     7 /BREC/ LBREED,NBREEC,IFAR(6,5),ICB(30),KAGEW,LGTHW,NAGEM
     8 /BREC2/ ABNCRG,GESM,GESS
     1 /SKIP/ ISTOP4,ISTOP5,ISTOP6,ISTOP7,MAXSKP
     5 /CLEAN/ NDPREV,NH4CLN,LOSSL
     1 /BOAR/ MXSDY,MXSWY,MXSDM,MXSWM,NPUR,IPCAT,KAGE,WTPB,IBS
     3 /SCH/ KS(2,500),IPT,IEVT,KCCE,IWE
     3/RPT3/ MJEV
C
C
C MGT2 SETS UP SCHEDULES IN ARRAY KS(2,500) AND THEN SENDS THEM TO EVN
C
C            IFAR(I,1),I=1,6 IS FIRST YEARS FARROWING SCH. FROM  S. INIT
C    IEVT  1=SELECT,  NGLTS  PRIOR TC EACH BREEDING.
C          2=BREED,  ON FOR LBREED  DAYS WITH IBS=1, OFF IBS=2
C          3=CLEAN4, PREVIOUS TC FARROWING BY NDPREV  DAYS.
C          4=WEAN,  CN  FOR LGTHW   DAYS WITH IWE=1,  OFF  IWE=2
C          5=SELL,  EVERY  MDSELL  DAYS.
C          7=BOAR PURCHASES
C           6=UPDATES -CALLED EVERY DAY,  NOT INC. IN SCH. IN KS(,)
C
C  BRANCH TO 1000 FOR SET UP,  TO 2000  FOR USING THE SCHEDULE.
C
      IF(KCCE-2)1000,2000,1390
C
C     COMPLETE FARROWING DATES ARRAY.
1000  DO 365 I=1,6
      DO 365 K=2,5
365   IFAR(I,K)=IFAR(I,1)+365*(K-1)
C
C     CALCULATE BREEDING DATES ARRAY  ICB().
      DO 114 K=1,5
      M=(K-1)*6
      DO 114I=1,6
114   ICB(I+M)=IFAR(I,K)-GESM+GESS
      IF(NS1.EQ.3) WRITE(NC,1314) ICB
1314  FORMAT(/* MGT2 SET UP BREEDING SEASONS=*/10X,15I5/
     2 10X,15I5/)
C
C
C FILL DAY TO START BREEDING AND STOP BREEDING,  START SET AT OFF
      IBS=2
      II=0
      DO 101 I=1,60,2
      II=II+1
      KS(1,I)=ICB(II)
      KS(2,I)=2
      KS(1,I+1)=KS(1,I)+LBREED
101   KS(2,I+1)=2
C
C FILL DAY TO SELECT GILTS
      IAJ=GESM-114
      DO 103 I=61,90
      KS(1,I)=ICB(I-60)-101+IAJ
103   KS(2,I)=1
C
C FILL DAY TO CLEAN HOUSE 4  NDPREV TO FARROWING.
```

```
      IAJ=GESM-GESS-NDPREV
      DC 105  I=91,120
      KS(1,I)=IDB(I-90)+IAJ
105   KS(2,I)=3
C
C FILL DAY TC BEGIN WEANING PROCESS,  SET UP LATER FCR  LGTHW DAYS.
      IAJ= KAGEW+GESM-GESS
      DC 107 I=121,150
      KS(1,I)=IDB(I-120)+IAJ
107   KS(2,I)=4
C
C FILL SELL EVENTS, NO. DEPENDING UPCN SIZE OF  MDSELL.
      IDO=NDAYS/MDSELL+150
      IF(IDC.GT.498) WRITE(ND,1309) IDO
1309  FCRMAT(* ERRCR MGT2,  ATTEMPT TC LOAD*I4*  ITEMS INTO*
     2 * SCHEDULE ARRAY  KS(2,500).*)
      NXTSAL=1
      IDAT=1
      DC 109 I=151,IDO
      KS(1,I)=IDAT
      KS(2,I)=5
109   ICAT=IDAT+MDSELL
C
C         ADC ONE FCR LAST DAYS.
      KS(1,IDO+1)=NDAYS
      KS(2,IDO+1)=5
C
C FILL BOAR PURCHASE DATES CCDE=7
      K7=IDC+1
      DC 201 I=1,5
      K7=K7+1
      IDAT=IPDAT+(365*(I-1))
      KS(1,K7)=IDAT
201   KS(2,K7)=7
C
C
C SPECIAL WEAN FOR OPENING INVENTCRY PIGS, 30 DAY MIN AGE WEAN.
C
      IDAT=KAGEW-30
      IF(ICAT.LT.1) IDAT=1
      KS(1,K7+1)=IDAT
      KS(2,K7+1)=4
C
C ORDER THSE EVENTS BY TIME,  I.E. RCW 1.
C         BUBBLE SORT
      I=1
10    J=I
11    IF(KS(1,I)-KS(1,I+1)) 98, 98, 9
9     KTS1=KS(1,I)
      KTS2=KS(2,I)
      KS(1,I)=KS(1,I+1)
      KS(2,I)=KS(2,I+1)
      KS(1,I+1)=KTS1
      KS(2,I+1)=KTS2
      IF(I .EQ. 1) GC TC 98
      I=I-1
      GC TO 11
98    I=J+1
      IF(I.LT.500)  GC TC 10
C         FINISHED W. BUBBLE SCRT.
C
C DROP EMPTY COLUMNS ANC THCSE SCHECULEC BEFORE NCWT=1
```

```
      IF(KS(1,1).GT.0) RETURN
      DC 117  I=1,500
      IF(KS(1,I).LT.1) GC TC 117
      CC 118 K=1,I
C
C             PREVENT EXCEEDING DIMENSIONS.
      L=I+K-1
      IF(L-501)144, 119, 119
144   KS(1,K)=KS(1,L)
118   KS(2,K)=KS(2,L)
117   CCNTINUE
119   IPT=0
C
C
C ND TAPE WRITE SCHEDULE
      IF(MJEV) 1306, 1306, 1302
1302  WRITE(ND,1303) NDAYS
1303  FCRMAT(//,3X*SCHECLLE CF EVENTS SET UP FCR A RUN CF*I5
     2*DAYS*/,5X*CCDES FCLLCWING DATES ARE  1=SELECT, 2=*
     3 *BREED, 3=CLEAN4, 4=WEAN, 5=SELL, 6=UPCATE, 7=BUY BOARS*)
C
      IIDO=IDO+1
      WRITE(ND,1305)((KS(I,J),I=1,2),J=1,IIDO)
1305  FCRMAT((3X,12(I6,I2)/))
1306  RETURN
C
C
C KODE  2000  FCR FINDING NEXT EVENTS.
C
2000  IPT=IPT+1
      IF(KS(1,IPT)-NOWT) 2CC0, 3C0, 400
C
C EXECUTE THE EVENT.
300   IEVT= KS(2,IPT)
      RETURN
C
C NEXT DAY ITEM.
400   IPT=IPT-1
      IEVT=6
      RETURN
1390  WRITE(ND,1391) NCWT,IPT,KCDE,IDC
1391  FCRMAT(/* ERRCR MGT2, NCWT=*I6* IPT=*I4* KOCE=*
     2 I3*  IDC=*I7*   RETLRNING*/)
C
C
      RETURN
      END
```

```
MGT3
      SUBROUTINE MGT3(IN,VEN)
      COMMON /INIT/NR,NW,ND,NT7,NT8,NCAT,NS1,NS2
C
     4 /GEN/ITOT,ISIZE,NOWT,NOWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5/HOUSE/NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4,X1,X2,X4
     2 /SURVIV/DUMY(7),MDEAD(8)  /BIRTH/DUM(8),NOBRN
     6 /SALES/ MDSELL,WTS,NXTSAL,NSLD(4),WTSLD(4),VSLD(4),PRIH,PRIS
     2 /MG3/ NHH(6),MDEADH(8),NHP(6),MDP(6),KCALL,KPRET,KNSLD4,KPREB
     7 /KRS/ KRS1,KRS2,KRS3,KRS4,KRS5,KRS6,KRS7,KRPT
     5 /CLEAN/NDPREV,NH4CLN,LCSSL,SWTLP,SSLP,KL4
     3 /SCH/ KS(2,500),IPT,IEVT,KCDE,IWE,IWN(45),NKT
     7 /BREC/ LBREED,NBREED,IFAR(6,5),ICB(30),KAGEW,LGTHW,NAGEM
     3 /COST/ FCS,FCB,CLAB,TFAR,TNUR,TSCW,TFIN
     4 ,VAR(3),COST(30)
     4 /RPT4/ IDCS,IDCE,IDCN,IDCF,IDCM,IDCB,IDCFS,IDCFP,ICFLW
     4/CULL/NGLTS,MXSRV,MXAGS,PCULG,PCULS,PSSR,PRGT,MXBCR
     3/GAIN/GW1,GW23,GSRT,GFIN1,GFIN2,GSOWM,GSCWL,SDP,SSCWM,SSCWL
     3/STAT/SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10),SUM5(5,10)
      DIMENSION IN(3,1),VEN(2,1)
C
C      KRS1 SWITCH IS SET=1 IN SUB. MGT IF HAS BEEN CHANGE IN INV.
C
C        CALCULATE DIFERENCES
      NSLD4=NSLD(4)-KNSLD4
      NOBR=NOBRN-KPREB
      DO 4K=1,5
      NHP(K)=NH(K)-NHH(K)
4     MDP(K)=MDEAD(K+3)-MDEADH(K+3)
C
      GO TO 789
500   WRITE(ND,510) NOBR, NOBRN
510   FORMAT(27X*PIGS BORN*13X*=*I9,I21/)
      WRITE(ND,512)(MDP(J),MDEAD(J+3),J=1,5)
512   FORMAT(27X*FARROWING BLD. DEATHS =*I9,I21/
     227X*NURSERY BLD. DEATHS    =*I9,I21/
     3 27X*SOW MAINT. BLD. DEATHS=*I9,I21/
     4 27X*FINISHING BLD. DEATHS =*I9,I21/
     5 27X*BOAR DEATHS*11X*=*I9,I21)
      WRITE(ND,515) NSLD4,NSLD(4)
515   FORMAT(/27X*SALES OF BUTCHERS      =*I9,I21)
C
C
      GO TO 1271
C
789   KNSLD4=NSLD(4)
      KPREB=NOBRN
      KPRET=NOWT
      DO 7 I=1,6
 7    NHH(I)=NH(I)
      DO 8 II=1,8
 8    MDEADH(II)=MDEAD(II)
      IF(NOWT-IDCS) 2000, 1201, 1201
1201  IF(NOWT-IDCE) 1203, 1203, 2000
C
C
C WRITE CONSECUTIVE DAILY INVENTORY BY BUILDING IF REQUESTED.
1203  WRITE(ND,1205) NOWT, ITOT
1205  FORMAT(/////5X*DAILY INVENTORY ON DAY=*I5*  TOTAL ANIMALS=*
     2I6/5X,95(1H=))
      IF(IDCN)1213, 1213, 1207
```

```
C
C        NURSERY INFORMATION.
1207  NH2=NH(2)
      IF(NH2) 1213, 1213, 1209
1209  WT=0.
      NN1=N1+1
      DO 1210 I=NN1,N2
1210  WT=WT+VEN(1,I)
      AWT=WT/NH2
      WRITE(ND,1212) NH2, AWT
1212  FORMAT(/6X*NURSERY HAS*I6* PIGS AT*F5.1* LBS. AVE. WT.*)
C        FINISHING BLD.
1213  IF(IDCF) 1219, 1219, 1215
1215  NH4=NH(4)
      IF(NH4) 1219, 1219, 1216
1216  WT=0.
      NN1=N3+1
      DO 1217 I=NN1,N4
1217  WT=WT+VEN(1,I)
      AWT=WT/NH4
      WRITE(ND,1218) NH4, AWT
1218  FORMAT(/6X*FINISHING HAS*I6* PIGS AT*F7.1* LBS. AVE. WT.*)
C
C           MAINTENANCE BUILDING + CULL PEN FOR SALE.
1219  IF(IDCM) 1227, 1227, 1221
1221  NH3=NH(3)
      IF(NH3) 1227, 1227, 1223
1223  LNONC=0
      LCPEN=0
      LPREG=0
      DO 1225 I=1,NH3
      CALL REMOV(IN,VEN,N2+1)
      IF(IATRIB(3)-2) 1231, 1232, 1233
1231  LNONO=LNONO+1
      GO TO 1225
1232  LCPEN=LCPEN+1
      GO TO 1225
1233  LPREG=LPREG+1
1225  CALL FILEM(IN,VEN,6)
      WRITE(ND,1226) NH3, LNONO, LCPEN,LPREG, NH(6)
1226  FORMAT(/6X*MAINTENANCE HAS*I5* TOTAL SOWS CLASSED AS*
     2* FOLLOWS-*/10X*NONOVULATING=*I3*, OPEN=*I3*, IN GESTATION=*
     5I3/10X*IN ADDITION*I4* SOWS AWAIT SALE IN THE CULL PEN*)
1227  IF(IDCB) 1241, 1241, 1228
1228  NH5=NH(5)
      IF(NH5) 1241, 1241, 1229
1229  WRITE(ND,1230) NH5
1230  FORMAT(/6X*BOARS TOTAL= *I3)
C        FARROWING BLD. KL4= NO SOWS IN FARROWING HOUSE.
1241  IF(IDCFS) 1261, 1261, 1243
1243  IF(N1) 1261, 1261, 1245
1245  LPIGS=N1-KL4
      WRITE(ND,1247) N1, KL4, LPIGS
1247  FORMAT(/6X*FARROWING HAS*I4* TOTAL WHERE SOWS=*
     2I3*, PIGS=*I4)
C          SALES, BIRTHS, MORTALITY MISC.
1261  IF(IDCFP) 1271,  1271, 1263
1263  WRITE(ND, 1265)
1265  FORMAT(/6X*BIRTHS, DEATHS, SALES  MISC.*/
     250X*CHANGE=*10X*TOTAL TO DATE=*)
C          USE STATEMENTS ABOVE.
      GO TO 500
1271  WRITE(ND,1273)
```

```
1273  FCRMAT(/5X*END DAILY INVENTCRY REPORT*69(1H=))
2000  CCNTINUE
C
C
C
C CVERFLOW CHECKING AND REPCRTING
C      FARRCWING HOUSE CHECKED IN SUB. FAROW.
C
C NURSERY SEND CVERFLOW TC FINISHING.
C        IF FINISHING IS FULL, NURSERY MAY BE CVERSTCCKED UP TO MX2*X2.
C         NURSERY PIGS ARE MCVED BY S. UPDATE AT CPTICN AGE.
C       CAPACITY CALCULATICN FCR PERCENT CCCUPANCY=SUM4( ,1)
      RNH=NH(2)
      RMX=MX2
      CALL CCLLT(SUM4,1,RNH/RMX*1CO.)
      NI5=NH(2)
C IF FINISHING HAS RCOM APPLY MX2, ELSE MX2*X2
      IF(NH(4)-MX4) 251, 251, 253
251   MFLCW=NI5-MX2
      GC TO 255
253   RNI5=NI5
      MFLCW=RNI5-RMX*X2
255   IF(MFLCW ) 300, 300, 201
201   II=0
      DC 203 I=1,MFLCW
205   CALL REMOV(IN,VEN,N1+1)
      IF(IATRIB(1)-22) 211, 215, 215
211   CALL FILEM (IN,VEN,5)
      GC TC 203
215   CALL FILEM(IN,VEN,7)
      II=II+1
203   CCNTINUE
      IF(IOFLW) 300, 30C, 291
291   WRITE(ND,292) NOWT, II
292   FCRMAT(/3X*NURSERY CVERFLCW DAY=*I5*,   *I4
     2 *PIGS MCVED TC FINISHING*)
C
C MAINTENANCE CVERFLOW CHECK ANC REPORTED ONLY.
C       CAPACITY CALCULATICN MAINT., SUM4( ,3)
300   RNH=NH(3)
      RMX=MX3
      CALL COLLT(SUM4,3,RNH/RMX*100.)
      MFLCW=NH(3)-MX3
      IF(MFLOW) 308, 308,303
303   IF(ICFLW) 308, 308, 333
333   WRITE(ND,304) MFLCW, NCWT
304   FCRMAT(/3X*MAINTENANCE CVERFLCW BY*I4* SOWS, DAY=*I5)
C
C FINISHING -FIRST NORMAL SALE,  IF NCT SATISFIED CROP MIN. WEIGHT
C            BY 1C LBS. AND SELL MORE UNTIL WITHIN MX4.
C         MX4 CVERFLOW REPCRTED, BUT FCRCE SELL CNLY AT MX4*X4.
C       CAPACITY CALCULATICN- FINISHING, SUM4( ,2)
308   RNH=NH(4)
      RMX=MX4
      CALL COLLT(SUM4,2,RNH/RMX*100.)
      SAVWTS=WTS
      KISTCP7=ISTOP7
      CHG=0.
      LFLOW=RNH-RMX*X4
C
C MX4 IS DESIGN CAPCITY, X4 IS CVER FLCW FACTOR ALLCWED,
C   FORCED SALE TAKES PLACE CNLY IF MX4*X4 IS EXCEEDED.
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```
401   IF(LFLOW)408, 408, 403
403   WTS=WTS-CHG
      IF(WTS.LT.191.) GC TC 407
      CALL SELL(IN,VEN)
      RNH4=NH(4)
      LFLCW=RNH4-RMX*X4
      MFLCW=NH(4)-MX4
      IF(ICFLW)400, 400, 418
418   WRITE(ND,419) WTS, MFLCW, NCWT
419   FCRMAT(/3X*FINISHING OVERFLCW SALE AT MINIMUM WEIGHT=*
     2F5.0* REDUCED CVERFLCW TC*I4* AT CAY=*I5)
400   CHG=1C.
      GO TC 401
407   WRITE(ND,406) NOWT, NH(4), MX4, X4
406   FCRMAT(/5X*FINISHING HCUSE CVERFLCW SALES CURTAILEC AT 19C*
     2* LBS. MINIMUM TC ALLCW HCG GRCWTH.*/
     3 10X*DAY=*I5* BLD. HAS*I6* ANIMALS WITH CAPACITY=*I6
     4* CVERFLOW FACTOR=*F5.2)
408   WTS=SAVWTS
      ISTCP7=KISTOP7
C
C
C   CAPACITY CALCUL., FARRCWING CRATES,  OVERFLOW CCNE IN FARRCW.
      RNH=KL4
      RMX=MX1
      CALL CCLLT(SUM4,4,RNH/RMX*100.)
C
C
C
C WEANING, FCLLCW NC. WEAN IN  IWN(NKT).
C       SCHEDULE MADE IN SUB. EVENTS.
C       DAILY WEANING DCNE HERE.
C       SEASCN ENCS WITH CLEANING CAY, SUB. CLEAN4.
C
      IF(IWE-1) 5000, 4000,5000
C
C WEAN CURING WEANING SEASCN CF LGTHW DAYS.
4000  NKT=NKT+1
      IF(NKT.GT.45) GO TC 5000
C
C        NKT=CURRENT DAY CF SEASCN, IWN(NKT)= NC. TC WEAN.
      IF(NKT) 4013, 4013, 4002
4002  NWN=IWN(NKT)
      IF(NWN) 5000, 5000, 4005
4005  DO 4100 I=1,NWN
C
C          FINC SCW ANC REMCVE, THEN HER PIGS
C                FIRST IN  FIRST CUT CRDER.
      CALL FIND(0,1,4,4,KCL,IN,VEN)
      IF(KCL) 4100, 4100, 4006
4006  CALL REMCV(IN,VEN, KCL)
      IF(IATRIB(1)-200) 4013, 4013, 4008
4008  IATRIB(3)=2
      IATRIB(4)=IATRIB(10)/3*2+2
      IATRIB(8)=0
      IATRIB(11)=0
      NAME=IATRIB(5)
      ATRIB(2)=RNCRM(GSCWM,SSCWM,-5.,10.)
C
C PROBABILITY CULLING HERE ANC IN SUB. CLEAN4.
C       PRCB. PCULG FCR GILTS,  PCULS FCR SCWS.
C       IF CULLED PUT IN FILE 9 FCR SALE AT NEXT SALE SCHEDULED.
      RN=RANUM(D)
```

```
      IF(IATRIB(1)-450) 4905, 4901, 4901
4901  PROB=PCULS
4903  IF(PROB-RN) 4909, 4909, 4908
4905  PROB=PCULG
      GO TO 4903
C GET READY FOR NEXT SALE DATE NXSAL, GAIN AT MAINT. RATES.
4908  ISKIP=NXSAL-NOWT
      SKIP=ISKIP
      IATRIB(9)=IATRIB(9)+ISKIP
      IATRIB(1)=IATRIB(1)+ISKIP
      ATRIB(1)=ATRIB(1)+SKIP*RNORM(GSOWM,SSOWM,-5.,10.)
      CALL FILEM(IN,VEN,9)
      GO TO 4018
4909  CALL FILEM(IN,VEN,6)
C LOOK FOR ABOVE SOWS LITTER.
4018  KCC=0
      CALL FIND(NAME,5,4,8,KCC,IN,VEN)
      IF(KCC) 4100, 4100, 4009
4009  CALL REMOV(IN,VEN,KCC)
      IF(IATRIB(1)-200) 4011, 4100, 4100
4011  CALL FILEM(IN,VEN,5)
      GO TO 4018
C
4100  CONTINUE
      GO TO 5000
C        DIAGNOSTIC WRITE.
4013  WRITE(ND,4014) NKT, IATRIB(1), NOWT
4014  FORMAT(/5X*SUBROUTINE MGT3 ERROR, NKT=*I5* AGE=*I5* AT DAY=*I5)
C
C
5000  CONTINUE
C
C
C   GATHER SOW DAYS IN MAINTENANCE AND LOBR MINUTES HERE.
C       COST(1)=SOW DAYS, (2)=FARROW BLD. MIN,(3)=NURSERY BLD. MIN,
C            (4)=MAINT. BLD.MIN.,(5)=FINISHING BLD.MIN.
C   REPORT WRITER IS IN SUB. REPT2.
C     SOWS INCLUDE CULLS IN CULL PEN (IGNORES BOARS)
      RNH=KL4
      COST(1)=COST(1)+RNH+NH(3)+NH(6)
C   LABOR IN MINUTES
      COST(2)=COST(2)+RNH*TFAR
      COST(3)=COST(3)+NH(2)*TNUR
      COST(4)=COST(4)+(NH(3)+NH(6))*TSOW
      COST(5)=COST(5)+NH(4)*TFIN
C
C
      RETURN
      END
```

```
      SUBROUTINE EVNTS(IN,VEN)
      COMMON /INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2
     4 /GEN/ITCT,ISIZE,NCWT,NCWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/ NH(6),N1,N2,N3,N4,N5,N6
     3/SCH/ KS(2,500), IPT,IEVT,KOCE,IWE,IWN(45),NKT
     7 /BREC/LBREEC,NBREEC,IFAR(6,5),IDB(3C),KAGEW,LGTHW,NAGEM
     1/SKIP/ ISTOP4,ISTCP5,ISTCP6,ISTCP7,MAXSKP
     4 /CULL/NGLTS,MXSRV,MXAGS,PCULG,PCULS,PSRR,PRGT
     6 /SALES/ MCSELL
     5 /CLEAN/ DUM(5),KL4
     1 /BOAR/ MXSDY,MXSWY,MXSDM,MXSWM,NPUR,IPCAT,KAGE,WTP8,IBS
      COMMON/WRT1/KW
     4/BREC4/KBRD
      DIMENSION IN(3,1), VEN(2,1)
C
C GET EVENTS FROM FILE  CNE AT  A TIME AND CALL FCR EXECUTICN.
C
C
C
      KCDE=2
1111  CALL MGT2(IN,VEN)
      IF(IEVT-2) 1, 2, 33
 33   IF(IEVT-4) 3, 4,  55
55    IF(IEVT-6) 5, 6, 77
77    IF(IEVT-8) 7, 98,98
C
C
C UPCATE ALL ANIMALS, HCUSE AT TIME.
6     NDO1=NH(1)
      IF(NDC1.LT.1)GO TC 545
      NN=0
      DC 444 M=1,NDO1
      KCL=1+NN
      IF(MOC(IN(2,KCL),1000000).GE.NCWT) GO TO 443
      CALL REMCV(IN,VEN,KCL)
      CALL UPDATE(IN,VEN)
      GO TO 444
443   NN=NN+1
444   CCNTINUE
545   NDO2=NH(2)
      IF(NDC2.LT.1)GO TC 656
      NN=0
      KPN=N1
      DC 555 M=1,NDO2
      KCL=N1+NN+1
      IF(MOC(IN(2,KOL),1000000).GE.NCWT) GO TO 553
      CALL REMOV(IN,VEN,KOL)
      CALL UPDATE(IN,VEN)
      IF(N1.NE.KPN)NN=NN+N1-KPN
      KPN=N1
      GO TO 555
553   NN=NN+1
555   CCNTINUE
656   NDO3=NH(3)
      IF(NDC3.LT.1) GO TO 767
      NN=0
      KPN=N2
      DC 666 M=1,NDO3
      KCL=N2+NN+1
      IF(MCC(IN(2,KCL),1000000).GE.NCWT) GO TO663
      CALL REMOV(IN,VEN,KOL)
```

```
      CALL UPDATE(IN,VEN)
      IF(N2.NE.KPN)NN=NN+N2-KPN
      KPN=N2
      GO TO 666
663   NN=NN+1
666   CONTINUE
767   ND04=NH(4)
      IF(NDC4.LT.1) GO TO 878
      NN=0
      KPN=N3
      DO777 M=1,ND04
      KCL=N3+NN+1
      IF(MOD(IN(2,KCL),1000000).GE.NCWT) GO TO 773
      CALL REMOV(IN,VEN,KCL)
      CALL UPDATE(IN,VEN)
      IF(N3.NE.KPN)NN=NN+N3-KPN
      KPN=N3
      GO TO 777
773   NN=NN+1
777   CONTINUE
878   NDC5=NH(5)
      IF(NDC5.LT.1) GO TO 99
      DC 888 M=1,NDC5
      CALL REMOV(IN,VEN,N4+1)
888   CALL UPDATE(IN,VEN)
      GC TO 99
C
C
C
C SELECT
C      MINIMUM AGE TARGET=150, 140 ALLOWS FOR VARIANCE.
1     CALL SELECT(IN,VEN,NGLTS,140)
      GC TO 1111
C
C BREED FLIP SWITCH
2     IF( IBS  .EQ. 2)  GO TO 22
      IBS=2
C          SET=2 IMPLIES END OF SEASON, CALL REPT1 WITH KW=3
      KW=3
      CALL REPT1(IN,VEN)
      KW=0
C     SET NO SOWS EXPOSED (TARGET NO.) =0.
      KBRD=0
      GC TC 1111
22    IBS=1
      GC TO 1111
C
C
C CLEAN4, SETS CLEAN  FLAG=1.
3     CALL CLEAN4(IN,VEN)
      KL4=0
      GO TO 1111
C
C WEAN,  SET HOUSE 4 NOT CLEAN.
4     NH4CLN=2
C
C NO. FARROWING WITHIN YEAR NOWY, STORE IN IFAR(30)
      IFAR(30)=IFAR(30)+1
      IF(IFAR(30)-6) 400, 400, 47
47    IFAR(30)=1
400   CONTINUE
C
```

```
C
C FIRST DAY WEANING, SET UP SCHEDULE HERE IN  IWN(45)
C         SET BY SUB. CLEAN4.
C      NKT SET=0 FOR COUNTER START IN SUB. MGT3.
      NKT=0
      IWE=1
C             IF  LGTHW=1 DAY, USE  CLEAN4  TO WEAN ALL.
      IF(LGTHW-2) 401, 420, 420
401   CALL CLEAN4(IN,VEN)
      GO TO 1111
420   IF(KL4) 449, 449, 435
C
C SCHEDULE  -KL4-  WEANINGS WITHIN  -LGTHW- DAYS.
C             METHOD- ADD DIGITS FROM RIGHT TO LEFT INTO THE
C                       LGTHW WORDS OF  IWN().
435   KNT=0
      DO 437 I=1,45
437   IWN(I)=0
439   DO 441 K=1,LGTHW
      KK=LGTHW-K+1
      KNT=KNT+1
      IF(KNT-KL4) 440, 440, 449
440   IWN(KK)= IWN(KK)+1
441   CONTINUE
      IF(KNT-KL4) 439, 449, 449
C          NKT= WEANING SEASON DAY COUNTER FOR SUB. MGT3.
449   NKT=0
      GO TO 1111
C
C SELL
5     CALL SELL(IN,VEN)
      GO TO 1111
C
C
C BUY BOARS ROUTINE
7     IF(NPUR) 1111,1111, 701
701   DO 708 I=1,NPUR
      IATRIB(1)=KAGE
      IATRIB(2)=1
      IATRIB(3)=1
      IATRIB(4)=1
      IATRIB(5)=88*1000+NCWY*100+I
      ATRIB(1)=WTPB
      CALL FILEM(IN,VEN,8)
708   CONTINUE
      WRITE(ND,709)NCWY,NCWT,NPUR
709   FORMAT(/3X*BOAR PURCHASE FOR YEAR*I2* AT DAY=*I5
     2 * ADDED* I3* NEW BOARS*)
      GO TO 1111
98    WRITE(ND,1309)NOWT,IEVT,IPT,KODE,IWE
1309  FORMAT(/* ERROR EVNTS, NOWT=*I6* IEVT=*I3*IPT=*
     2 I6* KODE=*I3* IWE=*I2/)
99    RETURN
      END
```

```
LPCATE
      SUBRCLTINE UPDATE(IN,VEN)
      CCMMON /INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2
     4 /GEN/ITOT,ISIZE,NCWT,NCWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOLSE/NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4
     1 /SKIP/ ISTOP4,ISTCP5,ISTCP6,ISTOP7,MAXSKP
     2/SURVIV/PW1,PW23,PSRT,PSFIN,PSCWS,PBCRS,PBORS1,MCEAC(8),PSRT2
     3/GAIN/ GW1,GW23,GSRT,GFIN1,GFIN2,GSOWM,GSOWL,SDP,SSCWM,SSCWL
     4 /BIRTH/ BRNM,BRNS,BMIN,BMAX,BWTM,BWTS,BWMIN,BWMAX,NCBRN
     7/BREC/LBREED,NBREEC,IFAR(6,5),ICB(30),KAGEW,LGTHW,NAGEM
     8 /BREC2/ CUM(3),GMIN
     9 /BREC3/ PTRM1,PTRM2,PTRM16
     5 /CLEAN/NCPREV,NH4CLN,LOSSL,SWTLP,SSLP,KL4
     4 /CULL/ NGLTS,MXSRV,MXAGS,PCULG,PCULS,PSSR,PRGT,MXBCR
      COMMCN/SALES/MDSELL,WTS,NXTSAL
      DIMENSION IN(3,1), VEN(2,1)
C CALLED FRCM SUB. EVNTS, APPLY SKIP TESTS, SURVIVAL PRCB.,  I.E.
C        GENERAL UPDATE CF ANIMALS IN FILES.    SUB. FARCW IS PART CF
C        UPDATE.
C
C BRANCH TC HOUSE SECTICN 4,5,6,7,CR 8.
      IC=IATRIB(6)
      IF(IC-4) 1380, 4000, 5555
5555  IF(IC-6) 5000, 60C0, 7777
7777  IF(IC-8) 7000, 80C0, 1380
C
C
C GENERAL RETURN TO FILE ACCCRCING TC IATRIB(6)
700   CALL FILEM( IN, VEN, IATRIB(6))
      RETURN
C
C BCAR UPDATING, DAY AT A TIME.
8C00  IAT1=IATRIB(1)
      IAT1C=IATRIB(10)
      K=IATRIB(3)
      IAT4=IATRIB(4)
      IF(ATRIB(2).LE.O.) ATRIB(2)=RNCRM(GSCWM/2.,SSCWM,-5.,10.)
C
C SCRT FOR MAXIMUM AGE TC KEEP BCAR -MXBOR-
      IF(IAT1-MXBOR) 80C5, 8002, 8002
8002  SKIP=NXTSAL-NCWT
      ATRIB(1)=ATRIB(1)+ATRIB(2)*SKIP
      CALL FILEM(IN,VEN,9)
      RETURN
8005  IF(IAT10) 6081, 6C81, 6082
6081  IF(RANUM(D).GT.PBCRS) GC TC 613
      GC TC 6083
6082  IF(RANUM(D).GT.PBCRS) GO TC 613
6083  IAT1=IAT1+1
      IATRIB(1)=IAT1
      IATRIB(9)=IATRIB(9)+1
      ATRIB(1)=ATRIB(1)+ATRIB(2)
C
C CHECK K SUB-CLASS FOR NEW STATUS
      IF(K.EQ.1) GO TO 8011
C
C
C CCNVERT DAILY SERVICES (10) TC 6 CAY PACKED TALLY IN (11).
      IAT11=IATRIB(11)
      IATRIB(11)= MCD(IAT11*10+IAT1C,100000C)
      IATRIB(10)=0
```

```
C
C CCNTINUE CHECKING
      IF(IAT1.EG.195) GC TC 8011
      IF(IAT1.EG.366) GC TC 8017
C
6085  IATRIB(4)=IAT4+1
      GC TO 700
C
8011  IF(IAT4.GT.29) GC TC 8013
      GC TC 6085
8013  IF(IAT1.GT.194) GC TC 8015
      GO TC 6085
C YOUNG BOAR, START TALLY 4 GAIN LIKE SCW/2, VARIANCE LIKE SCWS
8015  IATRIB(3)=2
      IATRIB(4)=1
      ATRIB(2)=RNORM(GSCWM/2.,SSCWM,-5.,10.)
      GC TC 700
C MATURE BOAR, START TALLY 4, GAIN REDUCED TO ARBITRARY SMALL AMOUNT.
8017  IATRIB(3)=3
      IATRIB(4)=1
      ATRIB(2)=.001
C
C
      GC TO 700
C SCWS IN LAC. AND SUCKLING PIGS WK 1, WK 2-3, OR STARTING AGE.
C               HOLD SOWS ISKIP CCWN TC HER PIGS AGE CLASSES.
C
C   NH4CLN IS HELD=1 UNTIL WEANING BEGINS THEN SET =2
4000  IF(NH4CLN-1) 4001, 4C02, 4001
4001  ISTOP4=NOWT
      GC TC 4009
4002  IF(ISTOP4-(NOWT+6)) 4003, 4009, 4009
4003  ISTOP4=NOWT+6
4009  ISKIP=ISTOP4-NOWT+1
      IF(ISKIP.GT.MAXSKP)ISKIP=MAXSKP
      IAGE=IATRIB(1)
      LTAL=IATRIB(4)
      IF(IAGE.GT.200) ISKPT=LTAL
      IF(IAGE.LE.200) ISKPT=IAGE
      IF(ISKPT.LT.8) ISKIP=1
      IF(ISKIP.GT.7) ISKIP=7
      SKIP=ISKIP
C PIGS  HERE,  SOWS IN  4500.
      IF(IAGE.GT.200) GC TC 4500
C
C BABY PIGS IN HOUSE 4.
      IF(IAGE-56) 4320, 4320, 5000
4320  BW=IATRIB(11)
      BRTHW=BW/100.
      IF(IAGE.LE.7) GO TC 4007
      IF(IAGE.LE.21) GC TC 4021
C        PIGS AGE 22, UP TC 56 BUT NCT WEANED.
      P=PSRT**SKIP
      IF(IAGE-22) 4201, 4202, 4201
4202  ATRIB(2)=RNORM(GSRT,SCP*GSRT,-5.,10.)
4201  G=ATRIB(2)*SKIP
      GC TO 4050
C        BABY PIGS 1, AND 2-3 WKS. ADJ. WT.
C        DAILY SURV. PROB. ADJ=.0049*DEVIATION BIRTHWT, SPEER REF.
4021  IF(IAGE+ISKIP-22) 4023, 4023, 4022
4022  ISKIP=22-IAGE
      SKIP=ISKIP
4023  P=(PW23+(.0049*(BRTHW-BWTM)))**SKIP
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```
      IF(IAGE-8) 4029, 4027, 4029
4027  ATRIB(2)= RNORM(GW23,SDP*GW23,-.5, 10.)
4029  G=ATRIB(2)*SKIP
      GO TO 4050
4007  P=(PW1+(.0049*(BRTHW-BWTM)))**SKIP
      IF(ATRIB(2)) 4019, 4008, 4019
4008  ATRIB(2)= RNORM(GW1,SDP*SW1,-5.,10.)
4019  G=ATRIB(2)*SKIP
4050  IF(RANUM(D).GT.P) GO TO 613
C               IF SURVIVED, FILE.
 4051 IATRIB(1)=IATRIB(1)+ISKIP
      IATRIB(9)=IATRIB(9)+ISKIP
      ATRIB(1)=ATRIB(1)+G
      GO TO 700
C SOWS OF HOUSE 4 I.E. IN LACTATION WITH BABY PIGS
4500  IF(RANUM(D).GT.PSOWS**SKIP)GO TO 4613
C
C SOW WITH 1 PIG OR LESS MOVED VIA TERMINATION TO HOUSE 6
      IF(IATRIB(8).GT.1) GO TO 4515
      IATRIB(6)=6
      GO TO 6355
4515  IATRIB(4)=LTAL+ISKIP
      G=ATRIB(2)*SKIP
C               SURVIVES, FILE BACK TO HOUSE 4.
      GO TO 4051
C
C         LACTATING SOW DIES, KILL SOW, CHECK ON BABY PIGS WELFARE.
4613  NPIGS=IATRIB(8)
      NUSOW=IATRIB(5)
      MDEAD(4)=MDEAD(4)+1
C
C ADJUST LITTER COUNT (KL4) IN FARROWING HOUSE.
      KL4=KL4-1
C         FIND PIGS, .LT. 7 DAY DIE, 50 PERCENT LIVE AFTER 7 DAYS AGE.
4623  CALL FIND(NUSOW,5,4,8,KKOL,IN,VEN)
      IF(KKOL.EQ.0) RETURN
C     CALL REMOV(IN,VEN,KKOL)
      IF(IATRIB(1).LE.7) GO TO 4623
      IF(RANUM(D).GT.0.5) GO TO 4623
      IATRIB(8)=0
      IATRIB(13)=77
      CALL FILEM(IN,VEN,4)
      GO TO 4623
C
C     STARTING PIG= 22-56 DAYS, GROWING = 57-180
C NURSERY HOUSE PIGS
5000  ISKIP=ISTOP5-NOWT+1
      IF(ISKIP.GT.MAXSKP) ISKIP=MAXSKP
      IAGE=IATRIB(1)
      IF(IAGE.GT.55) GOTO 5500
C          PIGS AGE 22-56, ALLOWED TO SKIP TO 57 ONLY.
      IF(IAGE+ISKIP-57) 5005, 5005, 5003
5003  ISKIP=57-IAGE
5005  IF(IAGE-22) 5006, 5006, 5007
5006  ATRIB(2)= RNORM(GW23,SDP*GW23,-5.,10.)
5007  SKIP=ISKIP
C         PIGS AGE 22, UP TO 56 BUT WEANED.
      P=PSRT2**SKIP
      RGAIN=ATRIB(2)
C            TEST, ADJUST AND FILE VIA 7045
      GO TO 7045
C
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```
C         PIGS AGE 57-150
5500  IF(IAGE-149) 551, 5509, 5509
551   IF(IAGE-57) 5057, 5057, 5058
5057  ATRIB(2) = RNCRM(GFIN1,GFIN1*SDP,-5.,10.)
5058  IF(IAGE-NAGEM) 552, 5509,5509
552   IF(IAGE+ISKIP-NAGEM)558, 558, 5070
5070  ISKIP=NAGEM-IAGE
      GO TO 558
C
C MOVE TO HOUSE 7 AND ADD ONE DAY TO ITS UPDATE.
C        IF FINISHING HOUSE FULL, STAYS IATRIB(6)=5
C           MOVING DECISION IS THEN IN SUB. MGT3. DAILY.
5509  IF(NH(4)-MX4) 5512, 5514, 5514
5512  IATRIB(6)=7
5514  ISKIP=1
558   SKIP=ISKIP
      P=PSFIN**SKIP
      RGAIN=ATRIB(2)
C          TEST, ADJUST AND FILE VIA 7045
      GO TO 7045
C
C
C SOW AND GILT OF MAINTNACE BUILDING NO. 6.
6000  IAT1=IATRIB(1)
      IF(IAT1-MXAGS) 6001, 6001, 6900
C
C        AGE CAN BE SET ARTIFICALLY HIGH IN SUB. BREED FOR CULL FLAG.
C SOW OVER AGE SEND TO FILE 9 FOR SALE AS CULL.
6900  IF(IATRIB(3)-3) 6901, 6001, 6901
6901  ISKIP=NXTSAL-NOWT
      SKIP=ISKIP
      IATRIB(9)=IATRIB(9)+ISKIP
      IATRIB(1)=IATRIB(1)+ISKIP
      ATRIB(1)=ATRIB(1)+SKIP*RNCRM(GSOWM,SSOWM,-5.,10.)
      CALL FILEM(IN,VEN,9)
      RETURN
6001  ISKIP=ISTOP6-NOWT+1
      IF(ISKIP.GT.MAXSKP)ISKIP=MAXSKP
      SKIP=ISKIP
      J=IATRIB(2)
      K=IATRIB(3)
      IAT10=IATRIB(10)
      IAT4=IATRIB(4)
C
C
C GO TO VALUE OF K.
      IF(K-2)6100,6200,6300
C
C K=1 YOUNG AND OR ABNORMAL GILTS SET IN SUB. SELECT.
C           SUB. SELECT PUTS GILTS INTO HOUSE 6 BEFORE 210 DAYS OF AGE
C
6100  IF(IATRIB(10).EQ.99) GO TO 6204
      IF(IAT1 + ISKIP .GT. 209) ISKIP=210-IAT1
      IF(IAT1.NE.210) GO TO 6204
      IATRIB(3)=2
      IATRIB(4)=0
      IATRIB(10)= RNCRM(ESTM,ESTS,EMIN,EMAX)+.5
      GO TO 6204
C
C
C K=2, OVULATING SOWS AND GILTS.
6200  IF(IAT4-IAT10) 6202, 6201, 6201
C
```

```
C ISKIP=1, PUTS SOW IN HEAT, SENDS TO SUB. BREED.
6201  ISKIP=1
      CALL BREED (IN,VEN)
C         TEST FOR K=2,3  AND CONTINUE ITS UPDATE.
      IF(IATRIB(3)-3) 6204, 6300, 1380
6202  IF(IAT4+ISKIP.GT.IAT10) ISKIP=IAT10-IAT4
6204  SKIP=ISKIP
      IF(RANUM(D) .GT. PSOWS**SKIP) GO TO 613
      IATRIB(1)=IAT1+ISKIP
C          IATRIB(4) CAN BE ZERO FROM SUB. BREED.
      IATRIB(4)=IATRIB(4)+ISKIP
      IATRIB(9)=IATRIB(9)+ISKIP
      ATRIB(1)=ATRIB(1)+ATRIB(2)*SKIP
      CALL FILEM(IN,VEN,6)
      RETURN
C
C
C
C SOW IN GESTATION, K=3, APPLY PROBABILITY OF SURVIVAL,  PREMATURE
6300  IA4=IATRIB(4)
      IF(IA4+ISKIP.GT.GMIN-2) GO TO 6305
      IF(IA4.GE.8)   GO TO 6325
      IF(IA4-7) 6301, 6302, 1380
C
C GESTATION SOWS.
C           FIRST WEEK PREGNANCY- SURVIV NOPRETERM, SURVIV PRETERM
6301  IF(ISKIP.GT.7-IA4) ISKIP=7-IA4
6302  SKIP=ISKIP
      RN=RANUM(D)
      P1=(PSOWS*(1.-PTRM1)) **SKIP
      IF(RN.LE.P1) GO TO 6350
      P2=(PSOWS*PTRM1)**SKIP
6326  IF(RN.LE.P1+P2) GO TO 6355
      GO TO 613
C         NO PRETERM
6350  IATRIB(1)=IATRIB(1)+ISKIP
      IATRIB(4)=IATRIB(4)+ISKIP
      IATRIB(9)=IATRIB(9)+ISKIP
      ATRIB(1)=ATRIB(1)+ATRIB(2)*SKIP
C FILE SOWS BACK IN HOUSE 6
      GO TO 700
C TERMINATION.
6355  IATRIB(3)=2
C SET TO HEAT IN TRUNCATED 1/3 LENGTH ESTRUS-1
      ISKIP=1
      SKIP=1.
      IATRIB(4)=IATRIB(10)/3*2+1
      IATRIB(8)=0
      IATRIB(11)=0
      GO TO 6350
C FOR  8-107 DAYS OF GESTATION.
6325  RN=RANUM(D)
      P1=(PSOWS*(1.-PTRM2) )**SKIP
      IF(RN.LT.P1) GO TO 6350
      P2=(PSOWS*PTRM2) **SKIP
      GO TO 6326
C
C          108 DAYS TO FULL TERM AT LENGTH=IATRIB(11)
6305  IA11=IATRIB(11)
C BRANCH TO SUBROUTINE FARCW
      IF(IA11-IA4.LE.1) GO TO 6099
      IF(ISKIP.GE.IA11-IA4) ISKIP=IA11-IA4-1
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      SKIP=ISKIP
C               NOT FARRCWING
      RN=RANUM(D)
      P1=(PSOWS*(1.-PTRM16) )**SKIP
      IF(RN.LE.P1) GO TC 6350
      P2=(PSOWS*PTRM16) **SKIP
      GO TC 6326
C   RETURNED OPEN AND SENT TO STATEMENT 6355.
6099  CALL FARCW(IN,VEN)
      IF(IATRIB(1).EQ.0) RETURN
      ISKIP=1
      SKIP=1.
      IF(NH4CLN-1) 6355, 6665, 6355
6665  IF(MX1-KL4) 6355, 6666, 6666
6666  RETURN
C
C FINISHING HOUSE PIGS
C
C          MAXSKP=14 DEFAULT, ISTOP7 FIRST SET TO NDAY THEN IN SUB. SELL
7000  ISKIP=ISTOP7-NOWT+1
      IF(ISKIP.GT.MAXSKP)ISKIP=MAXSKP
      IF(IATRIB(1)-56) 7020,7040,7040
7020  ISKI=56-IATRIB(1)
      IF(ISKI-ISKIP) 7021, 7023, 7023
7021  ISKIP=ISKI
7023  SKIP=ISKIP
      RGAIN=ATRIB(2)
      P=PSRT**SKIP
      GO TC 7045
7040  IF(IATRIB(1)-150) 7430, 7041, 7041
7430  IF(IATRIB(1)-56) 7431, 7431, 7433
7431  ATRIB(2)=RNORM(GFIN1,GFIN1*SDP,-5.,10.)
7433  RGAIN=ATRIB(2)
      IF(IATRIB(1)+ISKIP-150) 7438, 7437, 7437
7437  ISKIP=150-IATRIB(1)
7438  SKIP=ISKIP
      P=PSFIN**SKIP
      GO TO 7045
7041  IF(IATRIB(1)-150) 7042, 7042, 7043
7042  ATRIB(2)=RNORM(GFIN2,GFIN2*SDP,-5.,10.)
7043  RGAIN=ATRIB(2)
      SKIP=ISKIP
      P=PSFIN**SKIP
7045  IF(RANUM(D).GT. P) GO TO 613
      IATRIB(1)=IATRIB(1)+ISKIP
      IATRIB(9)=IATRIB(9)+ISKIP
C            GAIN ADDED.
      ATRIB(1)=ATRIB(1)+RGAIN*SKIP
C FINISHED WITH ONE PIG FROM FINISHING HOUSE.
      CALL FILEM(IN,VEN,IATRIB(6))
      RETURN
C DEAD TALLY.
 613  IAB=IATRIB(6)
      MDEAD(IAB)=MDEAD(IAB)+1
      RETURN
C  ERROR AND FINISHED WRITES.
1380  WRITE(NO,1378)NOWT,KCL,(IATRIB(M),M=1,15)
1378  FORMAT(* ERROR UPDATE, NOWT=*I5* ,KCL=*I5* ,IATRIB()=*/10X,15I6
      RETURN
      END
```

```
FAROW
      SUBROUTINE FAROW(IN,VEN)
      COMMON /INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2
     4 /GEN/ITCT,ISIZE,NCWT,NCWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     7 /BRED/LBREED,NBREED,IFAR(30),ICB(30),KAGEW,LGTHW,NAGEM
     2 /SURVIV/ PW1,PW23,PSRT,PSFIN,PSOWS,PBORS,PBCRS1,MCEAC(8)
     3 /GAIN/GW1,GW23,GSRT,GFIN1,GFIN2,GSCWM,GSCWL,SDP,SSCWM,SSCWL
     4 /BIRTH/ BRNM,BRNS,BMIN,BMAX,BWTM,BWTS,BWMIN,BWMAX,NCBRN
     5/CLEAN/NDPREV,NH4CLN,LOSSL,SWTLP,SSLP,KL4
     5/HOUSE/NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4,X1,X2,X4
     4 /RPT4/ IDCS,IDCE,IDCN,ICCF,ICCM,IDCB,ICCFS,ICCFP,ICFLW
     3/RPT3/MJEV,ISALS,IFARS,IBRDS
     3/STAT/SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10)
     1/RPT1/ISMYP,ISMB,ISMBG,ISMF,ISMW,ISMS,ISMM
      DIMENSION IN(3,1),VEN(2,1)
C BRANCH OF SUBROUTINE UPDATE FROM 6000 S.
C SOW IS TO FARROW AND CREATE PIGS= IATRIB(8)
C
C
C
C     WEANING TO MAKE ROOM FOR THIS SOW TO FARROW.
C
      IF(KL4-MX1) 409, 18, 18
18    IF(NH4CLN) 99,  99,   19
19    JX1=X1
      IF(JX1) 199, 199, 21
21    KDO= NH(1)
C
C          LOOK FOR LITTER OF LEGEL WEANING AGE= KAGEW-X1.
C          TEMP. STORE SOW IN IDB()
      DO 22 I=5,18
22    IDB(I)=IATRIB(I-4)
      XAT1=ATRIB(1)
      XAT2=ATRIB(2)
      DO 27 I=1,KDO
      CALL REMOV(IN,VEN,1)
      IF(IATRIB(4)-KAGEW-JX1) 26, 29, 29
26    CALL FILEM(IN,VEN, 4)
27    CONTINUE
      GO TO 39
C FOUND SOW WITH LITTER, WEAN HER  AND PIGS.
29    IATRIB(3)=2
      IATRIB(4)=IATRIB(10)/3*2+1
      IATRIB(8)=0
      IATRIB(11)=0
      ATRIB(2)=RNORM(GSCWM,SSCWM,-5.,10.)
      CALL FILEM(IN,VEN,6)
30    IF(VEN(1,1)-100.) 31, 31, 33
C          OVER 100 POUNDS IS NEXT SOW, I.E. HAVE ALL OF LITTER, STOP
31    CALL REMOV(IN,VEN,1)
      CALL FILEM(IN,VEN,5)
      GO TO 30
C STOP WEANING, ALLOW ORIGINAL SOW TO FARROW.
33    DO 35 I=5,18
35    IATRIB(I-4)=IDB(I)
      ATRIB(1)=XAT1
      ATRIB(2)=XAT1
      GO TO 410
C
C
39    DO 41 I=5,18
```

```
41     IATRIB(I-4)=ICB(I)
       ATRIB(1)=XAT1
       ATRIB(2)=XAT2
       GC TC 199
C END SPECIAL HOUSE OVERFLCW WEANING PRCCECURE.
C
C
C
C IF BUILDING HAS BEEN CLEANED NH4CLN=1
409    IF(NH4CLN) 99, 99,  410
C
C
C SOW IS FARRCWING.
410    NAMDAM=IATRIB(5)
       NP=IATRIB(8)
       IATRIB(1)=IATRIB(1)+1
       IATRIB(3)=4
       IATRIB(4)=1
       IATRIB(9)=IATRIB(9)+1
       IF(RANUM(D).GT.PSCWS) GC TC 613
C        COUNT CF LITTERS +1
       KL4=KL4+1
C          WT. LOSS AT FARRCWING.
       WTL=NP*RNCRM(SWTLP,SSLP,-10.,10.)
       ATRIB(1)=ATRIB(1)-WTL
       ATRIB(2)=RNORM(GSCWL,SSCWL,-5.,10.)
C CCLLECT SEASCNAL REPCRT STATS CN SCW FARRCWING.
C      SEASACNAL IN SUM2(),  TERM REPCRTS IN SUM3().
       RMX1=MX1
       RKL4=KL4
       FILL=RKL4/RMX1*100.
       RNP=NP
       RNOWT=NOWT
       IF(IFARS) 398, 398, 300
300    CALL COLLT(SUM2,1,RNP)
       CALL CCLLT(SUM2,2,RNCWT)
       CALL CCLLT(SUM2,3,FILL)
398    IF(ISMF) 397, 397, 310
310    CALL COLLT(SUM3,1,RNP)
       CALL CCLLT(SUM3,3,FILL)
C
C FILE THE SOW
397    CALL FILEM(IN,VEN,4)
C CREATE NP  PIGS FCR ABCVE SCW,  ALSC FILE IN HOUSE 4
C               INCREASE TCTAL BIRTHS -NCBRN-  CCUNTER.
       DC 63 KP=1,NP
       NOBRN=NOBRN+1
C            FILL ZEROED ATTRIBUTES.
       IATRIB(1)=1
       IF(ISEX.NE.1) GO TC 8
       IATRIB(2)=3
       ISEX=C
       GC TC 9
 8     IATRIB(2)=2
       IATRIB(3)=1
       ISEX=1
C
C LET IFAR(30)= CURRENT FARRCWING 1-6 OF CURRENT YEAR NCWY.
C            SET IN SUBRCUTINE EVENTS.
       MFAR=IFAR(30)
 9     IATRIB(5)=MFAR*10CO0+NCBRN
       IATRIB(6)=4
       IATRIB(8)=NAMDAM
```

```
      IATRIB(9)=NOWT
C BIRTH WT) =  MEAN ADJUSTED BY -.09 FOR DEVIATION FROM AVERAGE NO.
C          OF PIGS IN THE THE LITTER,  OMTVEDT, ET. AL.
      RNP=NP
      BWME=BWTM+(RNP-BRNM)*.09
      BT=RNORM(BWME,BWTS,BWMIN,BWMAX)
      IATRIB(11)=BT*100.
      ATRIB(1)=BT
      ATRIB(2)=0.
C          FILE THIS PIG.
C
C COLLECT SEASONAL REPORT STATS ON PIG IN SUM2(), TERM  IN SUM3().
      IF(IFARS)399, 399, 301
301   CALL COLLT(SUM2,4,BT)
399   IF(ISMF) 400, 400, 303
303   CALL COLLT(SUM3,4,BT)
C
C      FILE THIS PIG.
400   CALL FILEM(IN,VEN,4)
 63   CONTINUE
C
      RETURN
613   IATRIB(1)=0
      MDEAD(6)=MDEAD(6)+1
      RETURN
99    LOSSL=LOSSL+1
      RNP=IATRIB(8)
      CALL COLLT(SUM2,5,RNP)
      WRITE(ND,1303)NOWT,NH4CLN,(IATRIB(M),M=1,15)
 1303 FORMAT(* LOSS NEW LITTER, NOWT=*I5,
     2 * ,NH4CLN=*I2* ,IATRIB()=*/10X,15I5)
      RETURN
 199  LOSSL=LOSSL+1
      RNP=IATRIB(8)
      CALL COLLT(SUM2,6,RNP)
      CALL COLLT(SUM3,6,RNP)
 C TAPE NO OVERFLOW MESSAGE OPTION.
      IF(IOFLW) 1309, 1309, 1307
 1307 WRITE(ND,1304) MX1,NOWT
 1304 FORMAT(/3X*FARROWING OVERFLOW, SOW RETURNED OPEN*
     2* AND LITTER LOST.  ALL*I3* CRATES FULL AT DAY=*I5)
 1309 RETURN
      END
```

```
SELL
      SUBROUTINE SELL(IN,VEN)
      COMMON /INIT/NR,NW,ND,NT7,NT8,NCAT,NS1,NS2
C
     4 /GEN/ITOT,ISIZE,NOWT,NOWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/ NH(6),N1,N2,N3,N4,N5,N6
     6 /SALES/ MDSELL,WTS,NXTSAL,NSLD(4),WTSLD(4),VSLD(4),PRIH,PRIS
     4/GAIN2/SOP(6),HOP(6),SSLD(6),HSLD(6),SEND(6),HEND(6)
     7/SALE2/NSLDP(4),WTSLDP(4),VSLDP(4),DIS
     3 /COST/FCS,FCB,CLAB,TFAR,TNUR,TSOW,TFIN
     4  ,VAR(3),FEED(2,5),ABOR(2,10)
     1 /SKIP/ ISTOP4,ISTOP5,ISTOP6,ISTOP7,MAXSKP
     3 /RPT3/ MJEV,ISALS,IFARS,IBROS
C
C  SWITCH DIAGNOSTIC
      IF(NS1.NE.8) GO TO 800
C
      CALL OUT(IN,VEN,N3+1,N4,8888.2)
C SELL FROM HOUSE 7 FIRST
C
800   CONTINUE
      NH4=NH(4)
      IF(NH4) 901, 901, 801
801   DO 810 J=1,NH4
      CALL REMOV(IN,VEN,N3+1)
      AT1=ATRIB(1)
      IF(AT1-WTS) 805, 850, 850
805   CALL FILEM(IN,VEN,7)
      GO TO 810
C            SELL BY RECORDING SALE.
850   NSLD(4)=NSLD(4)+1
      WTSLD(4)=WTSLD(4)+AT1
      VSLD(4)=VSLD(4)+PRIH/100.*AT1
C
C RECORD SALES FOR PRODUCTION SUMMARY.
      HSLD(1)=HSLD(1)+1.
      HSLD(2)=HSLD(2)+AT1
      HSLD(3)=HSLD(3)+AT1*PRIH/100.
C
810   CONTINUE
C
C
C SELL CULL SOWS AND GILTS FROM FILE 9, REPORT BELOW.
901   NH6=NH(6)
      IF(NH6) 811, 811, 900
900   DO 910 J=1,NH6
      CALL REMOV(IN,VEN,N5+1)
C     CULL SOW SALES USE NSLD(3), NSLDP(3), BUT WT6, WS6, ETC.
      NSLD(3)=NSLD(3)+1
      AT1=ATRIB(1)
      WTSLD(3)=WTSLD(3)+AT1
      PS=PRIS/100.
      IF(AT1-350.) 821, 821, 815
C        DIS  IS A DISCOUNT/LB. OVER ALL WT.
815   PS=PS-DIS
821   VSLD(3)=VSLD(3)+PS*AT1
C RECORD SALES FOR PRODUCTION SUMMARY.
      SSLD(1)=SSLD(1)+1.
      SSLD(2)=SSLD(2)+ATRIB(1)
      SSLD(3)=SSLD(3)+AT1*PS
C
C
```

```
910    CCNTINUE
C
C REPORT CN TAPE IJK, SALES MADE
811    IJK=NC
       NSTCT=0
C CALCULATE CHANGE SINCE LAST SALES CATE.
       CC 5 I2=3,4
 5     NSTCT=NSTCT+NSLD(I2)
       NS4=NSLD(4)-NSLDP(4)
       WT4=WTSLC(4)-WTSLCP(4)
       VS4=VSLD(4)-VSLDP(4)
       AVWT=WT4/NS4
       NS6=NSLD(3)-NSLDP(3)
       WT6=WTSLD(3)-WTSLCP(3)
       VS6=VSLD(3)-VSLDP(3)
       AVWT6=WT6/NS6
       KTCT46=NS6+NS4
C
       IF(ISALS) 1243, 1243, 1201
1201   IF(KTCT46) 1243, 1243, 1202
1202   WRITE(IJK,1203) KTCT46, NCWT
1203   FCRMAT(/////* SALES SEASCNAL REPCRT*
      2 /1X,60(1H=)/16X*REPCRT OF*I5* SALE(S) CN DAY*I5)
       IF(NS4) 1903, 1903, 1204
1204   WRITE(IJK,1205) NS4,AVWT, VS4
1205   FCRMAT(/* FRCM FINISHING HCUSE*/7X*SOLD*I3* HCGS AT*
      2F6.1* POUNDS AVERAGE WEIGHT*/7X*SALES VALUE WAS*F10.2* CCL.*)
1903   IF(NS6) 1906, 1906, 1904
1904   WRITE(IJK,1905) NS6, AVWT6, VS6
1905   FORMAT(/* CULL SCWS ANC GILTS */7X*SOLD*I3* HEAC AT*
      2F6.1* POUNDS AVERAGE WEIGHT*/7X*SALES VALUE WAS*F7.2*COL.*)
1906   WRITE(IJK,1210) NSTCT
1210   FCRMAT(/* TOTAL NUMBER SCLC TC DATE=*I5/*====END SALES REPORT*
      2 40(1H=))
C
1243   DC 1245 JK=1,4
       NSLCP(JK)=NSLC(JK)
       WTSLCP(JK)=WTSLD(JK)
1245   VSLDP(JK)=VSLD(JK)
C
C
C ISTOP7 SET FCR DATE CF NEXT SALE NXTSAL.
       NXTSAL=NOWT+MDSELL
       ISTCP7=NXTSAL
C
C CIAGNCSTICS SWITCH CALLS
       IF(NS1.EQ.8)CALL CUT(IN,VEN,N3+1,N4,8888.8)
C
C
C
C
       RETURN
       END
```

BREED

```
      SUBROUTINE BREED(IN,VEN)
      COMMON/INIT/NR,NW,ND,NT7,NT8,NDAT,NS1,NS2,NCWD
     4 /GEN/ITOT,ISIZE,NCWT,NCWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4
     7/BRED/LBREED,NBREED,IFAR(6,5),IDB(30),KAGEW,LGTHW,NAGEM
     8 /BRED2/ ABNORG,GESM,GESS,GMIN,GMAX
     4 /BIRTH/ BRNM,BRNS,BMIN,BMAX,BWT,BWTS,BWMIN,BWMAX,NCBRN
     9 /BRED3/ D(3),PCON1,PCON2,ADJ1,ADJ2
     4/CULL/NGLTS,MXSRV,MXAGS,PCULG,PCULS,PSSR,PRGT,MXBCR,LCP
      COMMON /BCAR/ MXSDY,MXSWY,MXSDM,MXSWM,NPUR,IPCAT,KAGE,WTPB,IBS
     3/GAIN/GW1,GW23,GSRT,GFIN1,GFIN2,GSCWM,GSCWL,SDP,SSCWM,SSCWL
     3/STAT/SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10),SUM5(5,10)
     4/BRED4/KBRD,KSWGT(4),NCNB(4),NCNBK(4)
      DIMENSION KATRIB(12),BTRIB(2)
C
C SOW OR GILT IN HEAT IS SENT FROM UPDATE.
C        IF IN BREEDING SEASON  IBS=1
C        SOW RETURNED AS OPEN, K=2,   OR IN GESTATION, K=3
C
C
C
C TEST FOR BREEDING SEASON
      IATRIB(4)=0
      IF(IBS-1) 127, 28, 127
28    IF(KBRD-NBREED) 29, 27 ,27
27    NCNB(1)=NCNB(1)+1
      NCNBK(1)=NCNBK(1)+1
      IF(NCNB(4)) 107, 107, 109
107   NCNB(4)=NCWT
109   RETURN
C      COUNT SOWS IN HEAT BUT NO BREEDING SEASON.
127   NCNBK(4)=NCNBK(4)+1
      RETURN
C SAVE FEMALES ATTRIBUTES
C       COUNT NO.  SOWS EXPOSED (TARGET NO.)
29    KBRD=KBRD+1
      DO 30 KX=1,12
30    KATRIB(KX)=IATRIB(KX)
      DO 32 KX=1,2
32    BTRIB(KX)=ATRIB(KX)
C
C FIND AVAILABLE BOAR IN FILE 8
      NSERV=0
      NH5=NH(5)
      IF(NH5.LT.1) GO TO 9138
C LOOP FOR BOAR SEARCH
      DO 777 MK=1,NH5
      KUSE=0
      CALL REMOV(IN,VEN,N4+1)
      K=IATRIB(3)
      IF(K-1) 9138, 776,  41
 41   IAT10=IATRIB(10)
      IAT11=IATRIB(11)
      IF(IAT11.LT.1) GO TO 47
C           SUM WEEK SERVICES TALLY
      IT=IAT11/100000
      IT=IAT11/10000-IT*10+IT
      IT=IAT11/1000-(IAT11/10000*10)+IT
      IT=IAT11/100-(IAT11/1000*10)+IT
      IT=IAT11/10-(IAT11/100*10)+IT
      IT=IAT11-(IAT11/10*10)+IT
```

```
      GC TC 49
47    IT=0
49    IF(K-2) 9138, 5, 50
C
C YCUNG BCARS CHECK MAX. DAILY AND WEEKLY SERVICES AVAILABLE.
5     IF(IT+IAT10-MXSWY) 6,  776,  776
6     IF(IAT10+1-MXSDY) 149, 148, 776
C
C MATURE BCARS CHECK MAX. CAILY ANC WEEKLY SERVICES.
50    IF(IT+IAT10-MXSWM) 52, 776,  776
52    IF(IAT10-MXSDM) 149,148, 776
C
C ASSIGN KUSE TC SERVICES USED FCR THIS BOAR.
148   KUSE=1
      GC TO 150
149   KUSE=2
      GC TC 150
776   CALL FILEM(IN,VEN,8)
777   CCNTINUE
      IF(NSERV-1) 1377, 161, 161
C
C DRCP THRCUGH 777 LCOP IMPLIES NC SERVICES AVAILABLE IF NSERV .EQ. 0.
1377  GO TO 161
C
C ADJUST BCAR USE ATTRIBUTES ANC RE-ENTER LCOP OR RETURN SCW  AND QUIT.
C
C      NSERV BECOMES 1,2, CR 3(1 FRCM 1 BOAR+2 FRCM SECCNC).
150   NSERV=NSERV+KUSE
153   IATRIB(10)=IAT10+KUSE
      IATRIB(12)=IATRIB(12)+KUSE
      IF(NSERV-2) 776, 151, 151
C
C FILE BCAR, BRING BACK SCW ATTRIBUTES.
151   CALL FILEM(IN,VEN,8)
161   DC 35 KX=1,12
35    IATRIB(KX)=KATRIB(KX)
      DO 37 KX=1,2
37    ATRIB(KX)=BTRIB(KX)
      IF(NSERV)152, 152, 155
C
C LACK BOARS NCN CCNCEPTICN CCUNT FCR NCNB(2)
C          CHECK FAILS TC CCNCEIVE IN BREEDING SEASCN CCUNT.
152   IATRIB(12)=IATRIB(12)+1
      IF(IATRIB(12)-MXSRV) 154, 154, 159
C       SET AGE UP TO AUTCMATICALLY CULL IN   LDP   DAYS.
159   IATRIB(1)=MXAGS-LDP
      IATRIB(10)=99
154   NCNB(2)=NCNB(2)+1
      NCNBK(2)=NCNBK(2)+1
      RETURN
C
C CCNCEPTICN TEST
155   IF(NSERV.GT.1) GC TC 175
C     PROB. OF CCNCEPTICN WHEN 1 SERVICE GIVEN.
      PC=PCCN1
C
C   ADJUSTMENT FOR SUMMER CAYS 183-243
173   IF(NCWD-183)  183, 184, 184
184   IF(NCWD-243) 185, 185, 183
185   PC=PC+PSSR
C   ADJUSTMENT IF GILT.
183   IF(IATRIB(1)-365) 190, 193, 193
```

```
190     PC=PC+PRGT
193     RN=RANUM(C)
        IF(RN-PC) 205, 205, 9300
C       PROB. OF CONCEPTICN WHEN 2 SERVICES= PRCB. CN FIRST+
C               PRCB. CN SECCNC IF NCT CCNCEIVED ON FIRST.
175     PC=PCCN1+(1.-PCCN2)*PCON2
        GO TO 173
C
C BRED SOW RETURNED WITH GESTATICN ATTRIBUTES.
205     IATRIB(3)=3
        IATRIB(12)=0
C
C NC. PIGS ATTRIBUTE ADJUSTED FCR AGE SCW AND NO. SERVICES.
        AGE=IATRIB(1)+GESM
        V=BRNM-10.
        IF(AGE.GT.1300.) GC TC 207
        BRM=V+5.867+.01*AGE-.00000446*AGE**2.
        GC TC 209
207     BRM=V+5.867+.01*1300.-.00CC0446*1690000.-.0016*(AGE-130C.)
        IF(NSERV.GT.1) GC TC 708
        BRM=BRM+ACJ1
        GC TO 209
7C8     BRM=BRM+ACJ2
209     NPIGS=RNORM(BRM,BRNS,BMIN,BMAX) +0.5
        IATRIB(8)=NPIGS
        IATRIB(11)=RNCRM(GESM,GESS,GMIN,GMAX)+0.5
C
C
C STATS FOR SEASCNAL BREEDING REPCRT.
C    SUM2( ,7)=AGE AT FARRCWING (APPRCX.)
C    SUM2( ,8)= LITTER SIZE IF SCW FARROWS.
        CALL COLLT(SUM2,7,AGE)
        CALL CCLLT(SUM3,7,AGE)
        RNPIGS=NPIGS
        CALL CCLLT(SUM2,8,RNPIGS)
        CALL CCLLT(SUM3,8,RNPIGS)
        RNCWT=NCWT
        CALL COLLT(SUM2,9,RNCWT)
        RETURN
9138    WRITE(ND,9136) NCWT
9136    FCRMAT(5X*BREEDING SEASCN CN DAY=*I5*, NO BCARS EXIST,*
       2* SCW RETURNED OPEN*)
C INCREASE FAILS TC BREED CCUNT.
93CC    IATRIB(12)=IATRIB(12)+1
        IF(IATRIB(12)-MXSRV) 9309, 9309, 9302
C
C
C CHECK FAILS TC CCNCEIVE IN BREEDING SEASON COUNT.
C    SET AGE UP TO AUTOMATICALLY CULL IN  LDP  DAYS.
9302    IATRIB(1)=MXAGS-LCP
        IATRIB(10)=99
C
C NCN CCNCEPTICN COUNT FCR NONB(3).
9309    NCNB(3)=NCNB(3)+1
        NCNBK(3)=NONBK(3)+1
        RETURN
        END
```

```
SELECT
      SUBROUTINE SELECT(IN,VEN,JSLT,MAGE)
      COMMON /INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2
     4 /GEN/ ITOT,ISIZE,NCWT,NCWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/ NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4
     3/GAIN/GW1,GW23,GSRT,GFIN1,GFIN2,GSOWM,GSOWL,SDP,SSOWM,SSOWL
     8/BRED2/ABNORG,GESM,GESS,GMIN,GMAX,ESTM,ESTS,EMIN,EMAX
     4/BRED4/KBRD,KSWGT(4),NCNB(4)
     4/CULL/NGLTS,MXSRV,MXAGS,PCULG,PCULS,PSSR,PRGT,MXBCR,LDP
     3/RPT3/MJEV,ISALS,IFARS,IBRDS
C
      DIMENSION IN(3,1),VEN(2,1)
C
C AGE .GT. 208 DAYS IS NEVER SELECTED, OLDEST SELECTED FIRST .
C   -JSLT- =NO. DESIRED,  -MAGE-  = MINUM AGE CRITERIA.
C
C
      KSLT=JSLT
      NAGE=MAGE
      NH4=NH(4)
      TWT=0
      KAGE=0
      NUM=0
C
C CHECK FEASIBILITY.
      IF(NH4.LT.1) GO TO 1308
      IF(KSLT.LT.1) GO TO 1308
C
C LOOP TO SELECT GILTS.
      DO 1010 KI=1,NH4
      CALL REMOV(IN,VEN,N3+1)
      IAT1=IATRIB(1)
      J=IATRIB(2)
      IF(J.NE.2) GO TO 1008
      IF(IAT1.LT.NAGE) GO TO 1008
      IF(IAT1.LT.209) GO TO 1018
 1008 CALL FILEM(IN,VEN,7)
      GO TO 1010
 1018 IATRIB(8)=0
C   ESTRUS=99 MEANS ABNORMAL, OTHERWISE SOURCE IS RNORM.
      RN=RANUM(D)
      IF(ABNORG-RN) 1103, 1103, 1101
 1101 IATRIB(10) = 99
C       SET AGE FOR AUTOMATIC CULL IN   LDP DAYS.
      IATRIB(1)=MXAGS-LDP
      GO TO 1109
 1103 IATRIB(10)=RNORM(ESTM,ESTS,EMIN,EMAX)
      RIA10=IATRIB(10)
      IATRIB(4)=RANUM(D)*RIA10
 1109 IATRIB(11)=0
      ATRIB(2)=RNORM(GSOWM,SSOWM,-5.,10.)
      KAGE=KAGE+IAT1
      TWT=TWT+ATRIB(1)
      NUM=NUM+1
      CALL FILEM(IN,VEN,6)
      IF(NUM.GE.KSLT) GO TO 1012
 1010 CONTINUE
 1012 RNUM=NUM
      AGE=KAGE
      AGE=AGE/RNUM
      TWT=TWT/RNUM
```

```
      IF(IBRDS) 1308, 1308, 1049
1049  WRITE(ND,1050) KSLT,NUM,NCWT,AGE,TWT
1050  FCRMAT(//5X*SELECTICN CF GILT REPLACEMENTS WITH A TARGET CF*
     2I4* RESULTED IN*I4* MCVED TC THE MAINTENANCE BUILCING*
     3* ON CAY*I6/20X* AVERAGE AGE=*F6.0*, AVERAGE WT.=*
     4F8.1* PCUNDS*/)
C
C
C
C BREEDING SEASONAL REPCRT PART 1 FCR NO. ANIMALS AVAIL.
C  THIS CALL TO SELECT IS BEGINNING CF SEASCN.
1308  KBRD=0
      DC 1319 I=1,3
      NCNB(I)=0
1319  KSWGT(I)=0
      NCNB(4)=-999
C
C      COUNT KSWGT(1)= CPEN GILTS, KSWGT(2)=OPEN SCWS, KSWGT(3)=
C                     ALL CTHERS IN MAINT. BLC., &SWGT(4)=NCWT
      KSWGT(4)=NCWT
      NH3=NH(3)
      IF(NH3) 1378, 1378, 1321
1321  DC 1341 I=1,NH3
      CALL REMCV(IN,VEN,N2+1)
      IF(IATRIB(3)-2) 1325, 1323, 1329
1323  IF(IATRIB(1)-365) 1325, 1337, 1337
1325  KSWGT(1)=KSWGT(1)+1
      GC TC 1327
1337  KSWGT(2)=KSWGT(2)+1
      GO TC 1327
1329  KSWGT(3)=KSWGT(3)+1
1327  CALL FILEM(IN,VEN,6)
1341  CCNTINUE
      RETURN
1378  WRITE(ND,1309) NH(4),NCWT,KSLT,NAGE
1309  FCRMAT(//* SELECT INFEASIBLE, HCUSE 7 HAS*I5* HCGS AT NCWT=*I6
     2 * REQUESTED KSLT=*I3* MIN AGE=*I3)
C
C
      RETURN
      END
```

```
CLEAN4
      SUBRCUTINE CLEAN4(IN,VEN)
      CCMMON /INIT/NR,NW,NC,NT7,NT8,NDAT,NS1,NS2
     4 /GEN/ ITCT,ISIZE,NCWT,NOWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HCUSE/ NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4
     5 /CLEAN/ NDPREV,NH4CLN,LCSSL,SWTLP,SSLP,KL4
     3/SCH/ DUMY(1000),IPT,IEVT,KCDE,IWE,IWN(45),NKT
     4/CULL/NGLTS,MXSRV,MXAGS,PCULG,PCULS,PSSR,PRGT,MXBCR
     6/SALES/MDSELL,WTS,NXTSAL
     3/GAIN/GW1,GW23,GSRT,GFIN1,GFIN2,GSOWM,GSOWL,SDP,SSCWM,SSCWL
     6/WRT1/KW
     3/RPT3/MJEV,ISALS,IFARS,IBRDS
C
      TLTAL=0.
      KS=0
      KP=0
C
C NS1 DIAGNCSTICS SWITCH.
      IF(NS1.NE.11) GO TO 1349
      WRITE(NT7,130C) NCWT,NH(1)
1300  FCRMAT(* ENTER CLEAN4 AT NCWT=*I5* ,HCUSE4 HAS *I5
     2 * ANIMALS*)
      CALL CLT(IN,VEN,1,N1,11.2)
C
C
C CLEAN4 REMOVES ALL SOWS ANC PIGS FRCM HCUSE 4.
C
1349  MH=NH(1)
      IF(MH) 1399, 99, 50
50    DC 444 IM=1,MH
      CALL REMCV(IN,VEN,1)
C SCRT FOR SCWS .GT. 199 DAYS,AND PIGS GC TC 5000.
      IAGE=IATRIB(1)
      IF(IAGE.LT.200) GC TC 5000
C
C SOWS
      KS=KS+1
C
C SET TC OVLLATE IN 4-6 DAYS AFTER WEANING.
      IATRIB(3)=2
      IATRIB(4)=IATRIB(10)/3*2+2
      IATRIB(8)=0
      IATRIB(11)=0
      ATRIB(2)=RNORM(GSCWM,SSCWM,-5.,10.)
C
C
C FILE IN 6 OR IN 9 FOR SALE.
C PROB. CULL HERE AND SEE WEANING IN SUB. MGT3
C      FCRM SOW AND GILT CULLING PATTERN.
      RN=RANLM(D)
      IF(IATRIB(1)-450) 4905, 4901, 4901
4901  PRCB=PCULS
4903  IF(PRCB-RN) 4909, 4909, 4908
4905  PROB=PCULG
      GC TO 4903
4908  ISKIP=NXTSAL-NOWT
      SKIP=ISKIP
      IATRIB(9)=IATRIB(9)+ISKIP
      IATRIB(1)=IATRIB(1)+ISKIP
      ATRIB(1)=ATRIB(1)+SKIP*RNCRM(GSCWM,SSCWM,-5.,10.)
      CALL FILEM(IN,VEN,9)
```

```
      GO TO 444
4909  CALL FILEM(IN,VEN,6)
      GO TO 444
C
C PIGS MOVED TO HOUSE NO 5 I.E. FILE 5
5000  KP=KP+1
      CALL FILEM(IN,VEN,5)
444   CONTINUE
C
C SET CLEAN HOUSE FLAG -NH4CLN- =1
99    NH4CLN=1
C
C  KL4 I.E. LITTERS IN FARROWING HOUSE SET=0
      KL4=0
C
C IWE  SET TO OFF, I.E.=2
      IWE=2
C
C
C ISTOP4  SET UP TO ESTIMATED WEANING DATE.
      ISTOP4=NOWT+NDPREV+KAGEW
      WRITE(ND,1380)KS,KP,NOWT
1380  FORMAT(40X*NOTE(1) CLEANING MOVED*I4* SOWS, AND*I5
     2* PIGS ON DAY=*I6)
C
C
C
C
C FARROWING SEASON REPORTING CALL TO SUB. REPT1
C      STATS COLLECTED IN SUB. FARROW, REPORT VIA  KW=2.
      IF(IFARS) 999, 999, 200
200   KW=2
      CALL REPT1(IN,VEN)
      KW=0.
999   RETURN
1399  WRITE(ND,1398)NOWT, NH(1)
1398  FORMAT(3X*ERROR CLEAN4 AT NOWT=*I5* NH(1)=*I4)
      END
```

FILEM

```
      SUBRCUTINE FILEM(IN,VEN,JJ)
      CCMMON/INIT/NR,NW,ND,NT7,NT8,NCAT,NS1,NS2
     4 /GEN/ITCT,ISIZE,NCWT,NCWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/ NH(6),N1,N2,N3,N4,N5,N6
     7/KRS/KRS1,KRS2,KRS3
      DIMENSION IN(3,1),VEN(2,1)
      JH=JJ
C
C ITOT= TOTAL NUMBER, AND NH()= NUMBER IN EACH HOUSE FILE, INCREMENTED.
C JH IMPLIES THE  J HCUSE=J FILE CF CCLUMNS IN ARRAYS IN, VEN.
C PLACES ATTRIBUTES  IATRIB(4) AND ATRIB(2) INTC JH FILES OF IN AND VEN
C IATRIB(I)-1=IAGE,2=JSEX,3=KLAS,4=LTAL,5=MNUM,6=LCC,7=PEN NO.,
C         8=SCW NO. (OR NC. CF PIGS)
C ATRIB(I) -1=WT
C IATRIB AND ATRIB ARE ZERCED BEFCRE RETURN.
      NTCT=0
      DC 13 IK=1,6
 13   NTOT=NTOT+NH(IK)
      IF(NTCT.NE.ITOT)WRITE(ND,1301) JH,(NH(KI),KI=1,6),ITOT
 1301 FCRMAT(* ERRCR FILE, ITCT .NE. TCTAL IN FILES, JH=*
     2 I2* NH()=*6I6*  ITCT=*I7)
       JH=JH-3
      IF(JH.LT.1.OR.JH.GT.6) GO TO 99
      NH(JH)=NH(JH)+1
      JNH=NH(JH)
C INCREMENT TOTAL FILE SIZE ITOT AND LOAD AT END CF JH FILE.
C JNH NCW HCLDS THE TOTAL NUMBER IN FILE=NH(JH), AFTER INSERTICN.
C
      ITOT=ITOT+1
C
C CVERLCAD PRCTECTICN FCR IN(), VEN() FILE STCRAGE.
      IF(ITCT-KRS3) 400, 4C0, 1387
C
 400  IATRIB(6)=JH+3
C        PRCVIDE FILE SPACE AT JNH CF FILE JH BY PUSHING CNE CCLUMN
      IF(JH-2) 1,2,303
1     NP=ITCT-NH(1)
      GC TO 704
2     NP=ITCT-NH(1)-NH(2)
      GC TC 704
303   IF(JH-4) 3, 4, 505
3     NP=ITCT-NH(1)-NH(2)-NH(3)
      GO TC 704
4     NP=ITCT-NH(1)-NH(2)-NH(3)-NH(4)
      GC TC 704
505   IF(JH-6) 5, 6, 99
5     NP=ITCT-NH(1)-NH(2)-NH(3)-NH(4)-NH(5)
      GO TC 704
6     NP=0
      GC TO 504
704   DC 41C K=1,NP
      DC 402 I=1,3
 402  IN(I,ITOT-K+1)=IN(I,ITOT-K)
      DO 403 II=1,2
 403  VEN(II,ITCT-K+1)=VEN(II,ITCT-K)
 41C  CCNTINUE
C PLACE ATTRIBUTES IN FILE SPACE PRCVIDED BY PUSHING, CCLUMN=ITCT-NP
C
 504  IN(1,ITOT-NP)=IATRIB(1)*1CCCC00000+IATRIB(2)*10000COCCC+
     2 IATRIB(3)*100000000+IATRIB(4)*100000+IATRIB(5)
```

```
      IN(2,ITOT-NP)=IATRIB(6)*1000000000000+IATRIB(7)*
     2  1000000000C+IATRIB(8)*1000000+IATRIB(9)
      IN(3,ITOT-NP)=IATRIB(10)*1000000000000+IATRIB(11)*
     2  1000000+IATRIB(12)
      VEN(1,ITCT-NP)=ATRIB(1)
      VEN(2,ITCT-NP)=ATRIB(2)
888   DC 88 IK=1,12
88    IATRIB(IK)=0
      DC 89 IKK=1,4
 89   ATRIB(IKK)=0.
      N1=NH(1)
      N2=N1+NH(2)
      N3=N2+NH(3)
      N4=N3+NH(4)
      N5=N4+NH(5)
      N6=N5+NH(6)
      RETURN
 99   JH=JH+3
      WRITE(ND,98) JH,NCWT
 98   FCRMAT(* ERRCR FILEM, JH REQUESTED HOUSE=*I4* ,NCWT=*I8)
      WRITE(ND,1399) (IATRIB(I),I=1,12)
1399  FCRMAT(4X*IATRIB(1-12)=*12I7)
          CALL CUT(IN,VEN,1,ITCT,161399.9)
      RETURN
1387  WRITE(NW,1389) KRS3, NCWT, ITCT
1389  FCRMAT(1H2/////*  ANIMALS TCTAL IS GREATER THAN THE*
     2* DIMENSICNED SIZE CF  IN(3,I),VEN(2,I)  WHERE I=*I8/
     3*       PRCGRAM STCP AT DAY=*I5*,  TCTAL ANIMALS=*I10)
      STOP
      END
```

```
REMOV
      SUBROUTINE REMOV(IN,VEN,KC)
C
      COMMON /INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2
     4 /GEN/ITOT,ISIZE,NCWT,NCWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/ NH(6),N1,N2,N3,N4,N5,N6
      DIMENSION IN(3,1), VEN(2,1)
C
      KCL=KC
C REMOVES FILE COLUMN KCL, DECREMENT NH(KCL) BY ONE.
C      ATTRIBUTES PUT INTO IATRIB(), AND ATRIB().
C      ITOT (TOTAL ENTRIES IN FILE) DECREMENTED.
C
      IF(KCL)88,88,200
  200 IF(KCL-ITOT)333,333,88
  333 IF(KCL-N1)1,1,20
    1 KF=1
      GO TO 555
   20 IF(KCL-N2)2,2,30
    2 KF=2
      GO TO 555
   30 IF(KCL-N3)3,3,40
    3 KF=3
      GO TO 555
   40 IF(KCL-N4)4,4,50
    4 KF=4
      GO TO 555
   50 IF(KCL-N5)5,5,60
    5 KF=5
      GO TO 555
   60 IF(KCL-N6)6,6,88
    6 KF=6
555    IATRIB(1)=IN(1,KCL)/1000000000
       IATRIB(2)=MOD(IN(1,KCL)/100000000,10)
       IATRIB(3)=MOD(IN(1,KCL)/10000000,10)
       IATRIB(4)=MOD(IN(1,KCL)/10000,1000)
       IATRIB(5)=MOD(IN(1,KCL),10000)
 C WORD NO. 2
       IATRIB(6)=IN(2,KCL)/1000000000000
       IATRIB(7)=MOD(IN(2,KCL)/10000000000,100)
       IATRIB(8)=MOD(IN(2,KCL)/100000,100000)
       IATRIB(9)=MOD(IN(2,KCL),100000)
 C WORD NO. 3
       IATRIB(10)=IN(3,KCL)/1000000000000
       IATRIB(11)=MOD(IN(3,KCL)/1000000,1000000)
       IATRIB(12)=MOD(IN(3,KCL),1000000)
 C ATRIB()
       ATRIB(1)=VEN(1,KCL)
       ATRIB(2)=VEN(2,KCL)
 C
 C PUSH DOWN FILES, BRING /HOUSE/ COMMON UP TO DATE.
       DO 300 K=KCL,ITOT
       DO 302 I=1,4
  302  IN(I,K)=IN(I,K+1)
       DO 304 II= 1,2
  304  VEN(II,K)=VEN(II,K+1)
  300  CONTINUE
       NH(KF)=NH(KF)-1
       ITOT=ITOT-1
       N1=NH(1)
       N2=N1+NH(2)
```

```
      N3=N2+NH(3)
      N4=N3+NH(4)
      N5=N4+NH(5)
      N6=N5+NH(6)
      RETURN
   88 WRITE(ND,87)KCL,NCWT
   87 FORMAT(* ERROR REMCV, KCL REQUESTED=*I4*  ,NCWT=*I8)
      RETURN
      END
```

```
FINC
      SUBRCUTINE FIND(NXVA,MXCCD,J,JAT,KCO,IN,VEN)
C LCCATES THE CCLUMN CALLEC KCOL IN FILE JH.
C CESIGNATE AN MXCCDE RELATICNSHIP TC VALUE XVAL  FRCM-
C FCLLCWING OPTIONS,  .LT. 10= FCR IATRIB(),  .GT. 10 FCR ATRIB().
C MXCODE=1,11 MAX GREATER THAN XVAL
C        2,12 MIN GREATER THAN XVAL
C        3,13 MAX LESS THAN XVAL
C        4,14 MIN LESS THAN XVAL
C        5,15 VALUE EQUAL TC XVAL
C        6.16 FIRST FINC GREATER THAN XVAL
C        7,17 FIRST FINC LESS THAN XVAL
C JATT IS THE ATTRIBUTE NUMBER  I  IN IATRIB(I) OR ATRIB(I).
C KCOL IS THE CCLUMN NUMBER OF THE LCCATEC ENTRY,  SEE P. 7C GASPII.
C
      DIMENSION IN (3,1), VEN(2,1),IA(18)
      CCMMON /INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2
     4 /GEN/ITCT,ISIZE,NCWT,NCWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     5 /HOUSE/ NH(6),N1,N2,N3,N4,N5,N6
      EQUIVALENCE(NVAL,XVA)
      NVAL=NXVA
      MXCCDE=MXCCD
      JH=J-3
      JATT=JAT
      KCOL=KCO
C
C
C HANCLE INTEGERS OF IATRIB HERE, REAL IN SECTION GC TO NC. 1CCC.
C          BEST CANDIDATE CCLUMN IS KBEST.
      KBEST=0
C          NEXT TC CONSIDER IS NEXTK
      NHH=C
      DC 50C KK=1,JH
 500  NHH=NHH+NH(KK)
      NH1=NHH-NH(JH)+1
      NEXTK=NH1
      IF(NH(JH).LE.0) GC TC 160
      IF(MXCODE.GT.10) GC TC 1000
      IF(NEXTK)160,10,2
10    KCO=KBEST
      RETURN
2     GC TC(1,1C2,3,104,5,106,7,8,1C9,110,111,112)JATT
 1    IA(1)=IN(1,NEXTK)/1CCC000CCC0
      GC TC 21
 102  IA(2)=MOD(IN(1,NEXT)/100000C000,10)
      GC TC 21
 3    IA(3)=MOD(IN(1,NEXTK)/100000000,10)
      GO TO 21
 104  IA(4)=MOD(IN(1,NEXTK)/10000C,1C00)
      GC TC 21
 5    IA(5)=MOD(IN(1,NEXTK),100000)
      GO TC 21
 106  IA(6)=IN(2,NEXTK)/1C00000C0C0000
      GO TO 21
 7    IA(7)=MOD(IN(2,NEXTK)/100000000000,100)
      GO TO 21
 8    IA(8)=MOD(IN(2,NEXTK)/100CCCC,100000)
      GC TC 21
109   IA(9)=MOD(IN(2,NEXTK),100000C)
      GC TO 21
110   IA(10)=IN(3,NEXTK)/1C00000000000
```

```
      GC TC 21
111   IA(11)=MOC(IN(3,NEXTK)/1000C00,100000C)
      GC TC 21
112   IA(12)=MOC(IN(3,NEXTK),1000000)
      GC TC 21
 21   GC TO (11,12,13,14,11,16,17) MXCCDE
 11   MGRNV=1
      NMAMN=1
      GC TC 20
 12   MGRNV=1
      NMAMN=-1
      GC TC 20
 13   MGRNV=-1
      NMAMN=1
      GC TC 20
 14   MGRNV=-1
      NMAMN=-1
      GC TC 20
 16   IF(IA(JATT).GT.NVAL) GC TC 15
 166  NEXTK=NEXTK+1
      IF(NEXTK-NHH)2,2,666
666   KCO=0
      GC TC 160
 17   IF(IA(JATT).LT.NVAL) GC TC 15
      GC TC 166
20    IF(MGRNV*(IA(JATT)-NVAL))4,201,66
C WHEN EQUALITY OBTAINEC, TEST FCR MXCODE=5
 201  IF(MXCCDE-5)4,15,4
 66   IF(MXCODE-5)6,4,6
 6    IF(KBEST) 160,80,70
70    IF(NMAMN*(IA(JATT)-KBHLC))4,4,80
 80   KBEST=NEXTK
      KBHLD=IA(JATT)
 4    NEXTK=NEXTK+1
      IF(NEXTK-NHH)2,10,10
15    KCO=NEXTK
      RETURN
 160  WRITE(ND,1305)KBEST,NEXTK,MXCCDE,JH,JATT,KCOL,NHH
1305  FCRMAT(* ERROR FINC, KBEST=*I8* NEXTK=*I8* PARMS=*5I8)
C REAL COMPARISCNS FOR THE ARRAY VEN()
      RETURN
1000  XVAL=XVA
      MXCCDE=MXCODE-10
      GC TC (1100,1200,1300,1400,1100,1600,1700)MXCCDE
1100  RNV=1.
      AMN=1.
      GO TO 2000
1200  RNV=1.
      AMN=-1.
      GC TC 2000
1300  RNV=-1.
      AMN=1.
      GC TC 2000
1400  RNV=-1.
      AMN=-1.
2000  IF(RNV*(VEN(JATT,NEXTK)-XVAL))400,2100,6600
2100  IF(MXCODE-5)400,15,400
6600  IF(MXCODE-5)600,400,600
 600  IF(KBEST) 1600,800,700
700   IF(AMN*(VEN(JATT,NEXTK)-VEN(JATT,KBEST)))400,400,800
800   KBEST=NEXTK
400   NEXTK=NEXTK+1
      IF(NEXTK-NHH)2000,10,10
```

```
1600  IF(VEN(JATT,NEXTK).GT.XVAL) GC TO 15
1660  NEXTK=NEXTK+1
      IF(NEXTK-NHH)1600,1600,666
1700  IF(VEN(JATT,NEXTK).LT.XVAL) GC TO 15
      GC TC 1660
      END
```

```
      SUBROUTINE ZROSUM(SUM,JVARBL)
C*************************************************************STATPK
C                    ZROSUM(SUM,JVARBL)                  -INITIATION
C                    COLLT(SUM,JVARBL,X)                 -COLLECTION
C                    STATS(SUM,JVARBL,AVE,VAR,STD)       -CALCULATION
C EACH COLUMN -JVARBL- WILL HANDLE STATISTICS FOR ONE VARIABLE.
C DECLARE AN ACTUAL ARRAY LIKE -SUM()-  IN THE CALL PROGRAM TO (5,J)
C        WHERE       5 IS ABSOLUTE
C                    J= MAXIMUM NUMBER OF VARIABLES FOR COLLECTION.
C INITIATE BY CALLING ZROSUM(SUM,JVARBL) WITH JVARBL= 1,2,... FOR THE
C        FIRST,SECOND, ETC. VARIABLE TO BE INITIATED.
C CALL COLLT(SUM,JVARBL,X) TO COLLECT THE OBSERVATION -X-.
C CALL STATS(SUM,JVARBL,AVE,VAR,STD) FOR CALCULATION OF AVE,VAR,STD.
C        MIN,MAX,SUM X'S,SUM SQS, AND NO. OBS ARE IN -SUM()- ANYTIME.
C*******************************************************************
      DIMENSION SUM(5,1)
      SUM(1,JVARBL)=0.
      SUM(2,JVARBL)=0.
      SUM(3,JVARBL)=0.
      SUM(4,JVARBL)=1.E25
      SUM(5,JVARBL)=-1.E25
      RETURN
      END
```

COLLT

```
      SUBROUTINE COLLT(SUM,JVARBL,X)
      DIMENSION SUM(5,1)
      SUM(1,JVARBL)=SUM(1,JVARBL)+X
      SUM(2,JVARBL)=SUM(2,JVARBL)+X*X
      SUM(3,JVARBL)=SUM(3,JVARBL)+1.
      SUM(4,JVARBL)=AMIN1(SUM(4,JVARBL),X)
      SUM(5,JVARBL)=AMAX1(SUM(5,JVARBL),X)
      RETURN
      END
```

```
      SUBRCUTINE STATS(SUM,JVARBL,AVE,VAR,STD)
      CCMMCN /INIT/NR,NW,NC,NT7,NT8,NDAT,NS1,NS2
      DIMENSION SUM(5,1)
      XS=SUM(1,JVARBL)
      XSS=SUM(2,JVARBL)
      XN=SUM(3,JVARBL)
      AVE=XS/XN
      IF(XN.LE.1.) GC TC 1
      VAR=((XN*XSS)-(XS*XS))/(XN*(XN-1.0))
      IF(VAR)1,1,7
7     STD=VAR**.5
      RETURN
 1    VAR=0.
      STD=0.
      RETURN
      END
C******************************************************ENC CF STATPK**
```

```
RANUM
      FUNCTION RANUM(DUMMY)
C
C RANDOM NUMBER RETURNED AS VALUE OF RANUM =.0-1. FROM SOURCE-
C          -RANF(0),   SYSTEM FUNCTION,   IF NRNOPT=1
C          -TAPE OF RANDOM NUMBERS IF NRNOPT=2,  REQUIRES REQUEST I.E.
C                      -REQUEST(TAPE50,987,MT,HI,READ) IN CONTROL CARDS.
      COMMON /RAN/RRN(54),KRANUM,RLIMIT,NRNOPT,ITAPE
      IF(NRNOPT-1)2,2,20
    2 RANUM=RANF(0)
      RETURN
 20   KRANUM=KRANUM+1
      IF(KRANUM-55)28,26,28
   26 KRANUM=1
   28 IF(KRANUM-1)50,40,50
   40 READ(ITAPE)RRN
      IF(EOF,ITAPE) 41, 50
 41   REWIND ITAPE
      GO TO 40
   50 RANUM=RRN(KRANUM)
      RANUM=RANUM/RLIMIT
      RETURN
      END
```

RNORM

```
      FUNCTION RNORM(RMEAN,STD,RMIN,RMAX)
C ASSIGNS TRUNCATED RANDOM NORMAL DEVIATE TO FUNCTION NAME  RNORM,
C        ASSIGNS THE VALUE  RMIN  OR  RMAX,  NOT REDRAWN WHEN
C        OUTSIDE THE RANGE   RMIN,   RMAX.
C WHEN STD.=0., RNORM IS SET= RMEAN LEAVING MIN AND MAX INEFFECTIVE.
      IF(STD)99, 99, 1
1     RA=RANUM(D)
      RB=RANUM(D)
      V=(-2.0*ALOG(RA))**0.5*COS(6.283*RB)
      RNORM=V*STD+RMEAN
      IF(RNORM-RMIN) 6, 7, 8
 6    RNORM=RMIN
 7    RETURN
 8    IF(RNORM-RMAX) 7, 7,9
 9    RNORM= RMAX
      RETURN
99    RNORM=RMEAN
      RETURN
      END
```

```
OUT
      SUBRCUTINE OUT (IN,VEN,ISTART,ISTCP,ICENT)
C PRINT INVENTCRY LCCATICNS FRCM ISTART TC ISTCP, CEBUGGING TCOL
      CCMMCN/INIT/NR,NW,CUMY,NT7,NT8,NDAT,NS1,NS2,NCWC
     4/GEN/ ITCT,ISIZE,NCWT,NCWY,NCAYS,NRUNS,IATRIB(18),ATRIB(4)
     5/CLEAN/ DUM(5),KL4
     5 /HCUSE/ NH(6),N1,N2,N3,N4,N5,N6
     5/RPT5/ IAAS,IAAE,IAAN,IAAFN,IAAM,IAAB,IAAFR
      CIMENSICN IN(3,1),VEN(2,1)
C
C
C CHECK ISTART=7777 IMPLIES ANIMAL ATTRIBUTE PRINTING BY BLC.
      INTEGER SHFTR
      IF(ISTART-7777) 70, 500, 70
70    NC=NT7
      INN=SHFTR(IDENT,48)
      IF(INN.EC.0) GO TC 900
      WRITE(ND,80)NCWT,(NH(I),I=1,6),N6,ICENT
 80   FCRMAT(* CUT,NCWT=*I5*  NH(I)=*6I3*  N6=*I5*  ICENT=*F15.3)
      GC TO 12
 900  WRITE(ND,90)NCWT,(NH(I),I=1,6),N6,IDENT
 90   FCRMAT(* CUT,NOWT=*I5*  NH(I)=*6I3*  N6=*I5*  ICENT=*I15)
 12   WRITE(ND,299)
299   FCRMAT(2X*1---234--5---- 67-8----9----- 1011----12---- 1314*
     2 *----15---- 1---------.--- 2---------.---*)
      CC 3C K=ISTART,ISTCP
30    WRITE(ND,300)(IN(I,K),I=1,3),(VEN(II,K),II=1,2),K
300   FCRMAT(1X,3I15,15X,2F15.3,I8)
      RETURN
C
C
C ANIMAL ATTRIBUTE PRINTING HCUSE BY HCUSE REQUEST.
C
500   IF(IAAS-NOWT) 502, 502, 899
502   IF(IAAE-NCWT) 899,504, 504
C        HEADING FOR NCWT CAILY ANIMAL ATTRIBUTES
504   NH2=NH(2)
      NH4=NH(4)
      NH3=NH(3)
      NH5=NH(5)
      NH1=NH(1)
      WRITE(NT7,5004) NCWT,NH2,NH4,NH3,NH5,NH1
 5004 FCRMAT(1H1,///,5X*CIAGNCSTIC REPORT OF ANIMAL ATTRIBUTES*
     2* AT END CF DAY*I5/1CX*INVENTCRY IS- NURSERY=*I4
     3*, FINISHING=*I5*, SCW MAINTENANCE=*I4*,  *I3* BOARS, AND*
     4* FARRCWING=*I4)
 C NURSERY WRITE ATTRIBUTES
      N777=0
      IF(IAAN) 700, 700, 550
 550  IF(NH2) 700, 700, 552
 552  WRITE(NT7,5552)
 5552 FCRMAT(/5X*NURSERY BLD., SEX CLASS J=2 IS FEMALE, J=3 IS MALE,*
     2*  SUBCLASS K=1 IS NEVER CVULATED.*)
      WRITE(NT7,5005)
 5005 FCRMAT(15X*HERD NC.=        AGE=    SEX J=    SUB.K=  DAY SIM.*
     2*     BRTWT=       WT.=       GAIN= *)
      NI=N1+1
      NF=5
      N77=NH2
 706  CC 559 I=1,N77
      CALL REMCV(IN,VEN,NI)
```

```
      R11=IATRIB(11)
      BRTWT=R11/100.
      WRITE(NT7,5559) IATRIB(5), IATRIB(1),IATRIB(2),IATRIB(3),
     2 IATRIB(9),BRTWT,ATRIB(1),ATRIB(2)
5559  FCRMAT(12X,5I10,3F10.2)
      CALL FILEM(IN,VEN,NF)
559   CCNTINUE
      IF(N777) 700, 700, 600
C FINISHING HOUSE WRITE ATTRIBUTES
700   IF(IAAFN) 600, 600, 702
702   IF(NH4) 600, 600, 704
704   WRITE(NT7, 5704)
5704  FCRMAT(/5X*FINISHING BLC., SEX CLASS J=2 IS FEMALE, J=3 IS*
     2* MALE,  SUBCLASS K=1 IS NEVER CVULATED.*)
      WRITE(NT7,5005)
C        USE NURSERY LCCP ABOVE, GC TO MAINTENANCE AFTER
      NI=N3+1
      NF=7
      N77=NH4
      N777=1
      GC TC 706
600   IF(IAAM) 800, 800, 6C2
602   IF(NH3) 6900, 690C, 604
604   WRITE(NT7,5604)
5604  FCRMAT(/5X*MAINTENANCE BLC., SEX CLASSJ=2 IS FEMALE, SUBCLASS*
     2* K=1 IS NEVER OVULATED, K=2 IS*/8X*CVULATING OPEN, K=3 IS*
     3* GESTATICN, K=4 IS LACTATICN,  LTAL= NC. DAYS IN ABOVE SUB*
     4*CLASS,*/8X*PIGS= NC. CF PIGS AT BIRTH, LEST= NC. CAYS IN*
     5* ESTRUS CYCLE,  LGST= NC. DAYS FCR THIS GESTATICN*)
      WRITE(NT7,5606)
5606  FCRMAT(7X*HERD NC.=      AGE=    SEX J=    SUB.K=     LTAL=*
     2*     PIGS=     LEST=     LGST= CAY SIM.     WT.=     GAIN=*)
      DC 659 I=1,NH3
      CALL REMOV(IN,VEN,N2+1)
      WRITE(NT7,5669) IATRIB(5),IATRIB(1),IATRIB(2),IATRIB(3),
     2 IATRIB(4),IATRIB(8),IATRIB(10),IATRIB(11),IATRIB(9),
     3ATRIB(1),ATRIB(2)
5669  FCRMAT(5X,9I9,2F9.2)
      CALL FILEM(IN,VEN,6)
659   CCNTINUE
6900  NH6=NH(6)
      WRITE(NT7,6905) NH6
6905  FCRMAT(5X*CULL PEN HAS*I5* SCWS FCR SALE IN ACDITICN*
     2* TO THOSE IN MAINT. BLC.*)
      IF(NH6) 800, 800, 6958
6958  DC 6959 I=1,NH6
      CALL REMOV(IN,VEN,N5+1)
      WRITE(NT7,5669) IATRIB(5),IATRIB(1),IATRIB(2),IATRIB(3),
     2IATRIB(4),IATRIB(8),IATRIB(10),IATRIB(11),
     3IATRIB(9),ATRIB(1),ATRIB(2)
      CALL FILEM(IN,VEN,9)
6959  CCNTINUE
800   IF(IAAB) 400, 400 ,802
802   IF(NH5) 400, 400, 804
804   WRITE(NT7,5804)
5804  FCRMAT(/5X*BCARS, SEX CLASS J=1 WITH SUBCLASS K=1 FCR NEW*
     2* K=2 FOR YOUNG, K=2 FCR MATURE,  LTAL=CAYS IN*/8X*SUBCLASS*
     3* K   WEEK=6 DIGIT USE WITH RIGHTMOST RECENT DAY, ETC., *
     4* SERVS= TOTAL SERVICES TC CATE*)
      WRITE(NT7,5806)
5806  FCRMAT(7X*HERD NC.=      AGE=    SEX J=    SUB.K=     LTAL=     *
     2*WEEK=    SERVS= DAY SIM.=     WT.=     GAIN*)
      DC 859 I=1,NH5
```

```
      CALL REMCV(IN,VEN,N4+1)
      WRITE(NT7,5889)IATRIB(5),IATRIB(1),IATRIB(2),IATRIB(3),
     2IATRIB(4),IATRIB(11),IATRIB(12),IATRIB(9),ATRIB(1),ATRIB(2)
5889  FCRMAT(5X,8I9,2F9.2)
      CALL FILEM(IN,VEN,8)
859   CCNTINUE
400   IF(IAAFR) 788, 788, 402
402   IF(NH1) 788, 788, 404
404   WRITE(NT7,5404)
5404  FCRMAT(/5X*FARROWING BLC., SEX CLASS J=2 FOR FEMALE, J=3 *
     2*IS MALE, SUBCLASS K=4 FCR SCWS IN LCATATICN,*/8X*K=1 CR C FCR*
     3* BABY PIGS,  LTAL= NC. DAYS IN SUBCLASS K FCR SOW BUT=0*
     4* FORM PIGS,  PIGS/DAM=*/8X*NC. PIGS AT BIRTH FCR SOW,*
     5* BUT HERC NO. OF DAM IF A PIG.  BRTHWT= WT. AT BIRTH,*
     6*=0 FCR SCWS*)
      WRITE(NT7,5406)
5406  FCRMAT(7X*HERC NC.=      AGE=   SEX J=   SUB.K=    LTAL=*
     2* PIGS/DAM DAY SIM.= BRTHWT=    WT.=     GAIN=*)
      DC 459 I=1,NH1
      CALL REMOV(IN,VEN,1)
      R11=IATRIB(11)
      BRW=R11/100.
      WRITE(NT7,5449)IATRIB(5),IATRIB(1),IATRIB(2),IATRIB(3),
     2IATRIB(4),IATRIB(8),IATRIB(9),BRW,ATRIB(1),ATRIB(2)
5449  FCRMAT(5X,7I9,3F9.2)
      CALL FILEM(IN,VEN,4)
459   CCNTINUE
788   WRITE(NT7,6788)
6788  FCRMAT(5X*END ANIMAL ATTRIBUTES DIAGNCSTIC REPORT*
     2* FRCM SUBROUTINE CUT*//)
899   RETURN
      END
```

REPT1

```
      SUBROUTINE REPT1 (IN,VEN)
C REPORT SUMMARY FOR HERD BASIS
      COMMON/INIT/NR,NW,NC,NT7,NT8,NCAT,NS1,NS2,NCWD
     2 /RAN/ IRN(54),KRANUM,RLIMIT,NRNOPT,ITAPE
     3 /STAT/ SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10)
     4 /GEN/ITOT,ISIZE,NCWT,NOWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5/HOUSE/NH(6),N1,N2,N3,N4,N5,N6,NXTFAR,MX1,MX2,MX3,MX4
     6/WRT1/KW
     1/RPT1/ISMYP,ISMB,ISMBG,ISMF,ISMW,ISMS,ISMM
     4/BRED4/KBRD,KSWGT(4),NCNB(4),NCNBK(4)
     4/GAIN2/SCP(6),HOP(6),SSLD(6),HSLD(6),SEND(6),HEND(6)
     6/SALES/MDSELL,WTS,NXTSAL,NSLD(4),WTSLD(4),VSLD(4),PRIH,PRIS
      COMMON/CLEAN/D(5),KL4
      DIMENSION IN(3,1),VEN(2,1)
C
C SEND TO KW TYPE OF REPORT.
C      =2 IS FARROWING SEASON REPORT.
      IF(KW-3) 2000, 3000, 40
40    IF(KW-5) 4000, 5000, 60
60    IF(KW-7) 6000, 7000, 4
4     RETURN
C
C
C
C SEASONAL FARROWING REPORT  CD. 55 CELL 4 IS  ON.
2000  WRITE(ND,501) NCWT,NCWY,NCWD
501   FORMAT(////5X*SEASONAL FARROWING REPORT ON DAY=*I4/
     25X,95(1H=)/10X*YEAR=*I2*, DAY OF YEAR=*I3*, THE FARROWING*
     3* HOUSE WAS CLEANED TODAY, SEE (1)*)
      WRITE(ND,503)
503   FORMAT(/10X*-------ITEM-------  -----MEAN-----  ---ST. DEV.---*
     2*  ---MINIMUM---     ---MAXIMUM---*)
C
C KW=2 IMPLIES SEASONAL FARROWING REPORT IN SUM2()
C      SUM2( ,1)=LITTER SIZE SEASON, NO. OBS.=NO. LITTERS.
C      SUM2( ,2)=DATE OF BIRTH.
C      SUM2( ,3)=PERCENTAGE BLD. IS FILLED.
C      SUM2( ,4)=BIRTH WEIGHTS PIGS.
C      SUM2( ,5)=NO. PIGS LOST FOR BLD. NOT CLEAN.
C      SUM2( ,6)=NO. PIGS LOST FOR EXCEEDING CAPACITY.
      NL=SUM2(3,1)
      WRITE(ND,505) NL
505   FORMAT(/6X*FARROWED*I3* LITTERS IN FARROW BLD.*)
C
C
      IF(NL)504, 504, 506
504   IF(NCWT-10) 1505, 1505, 530
1505  WRITE(ND,508)
508   FORMAT(/20X*ZERO OBSERVATIONS, LITTERS WERE BORN*
     2* BEFORE DAY ZERO OF SIMULATION, REPORT TERMINATED*)
      GO TO 530
506   CONTINUE
      CALL STATS(SUM2,1,ASIZ,VAR,SSIZ)
      MNSIZ=SUM2(4,1)
      MXSIZ=SUM2(5,1)
      WRITE(ND,507)ASIZ,SSIZ,MNSIZ,MXSIZ
507   FORMAT(10X*LITTER SIZE ALIVE=  *F13.3,F16.3,2I16)
      CALL STATS(SUM2,2,ADAT,VAR,SDAT)
      MNDAT=SUM2(4,2)
      MXDAT=SUM2(5,2)
      WRITE(ND,509) ADAT,SDAT,MNDAT,MXDAT
```

```
509   FCRMAT(10X*DATE CF BIRTH=        *F13.3,F16.3,2I16)
      CALL STATS(SUM2,3,ACAP,VAR,SCAP)
      RNCAP=SUM2(4,3)
      RXCAP=SUM2(5,3)
      WRITE(ND,511) ACAP, SCAP, RNCAP, RXCAP
511   FCRMAT(10X*CAPACITY BLC., PCT.=*F13.3,F16.3,2F16.3)
      CALL STATS(SUM2,4,AWT,VAR,SWT)
      RNWT=SUM2(4,4)
      RXWT=SUM2(5,4)
      WRITE(ND,513) AWT,SWT,RNWT,RXWT
513   FCRMAT(10X*BIRTH WEIGHT CF PIGS=*F12.3,3F16.3)
      NL=SUM2(3,5)
      WRITE(ND,515) NL
515   FCRMAT(/6X*LCST*I3* LITTERS, BLC. NCT CLEANEC*)
      IF(NL) 520, 520, 516
516   CALL STATS(SUM2,5,ALCS,VAR,SLCS)
      MNL=SUM2(4,5)
      MXL=SUM2(5,5)
      WRITE(ND,517) ALCS,SLCS,MNL,MXL
517   FCRMAT(10X*LITTER SIZE LCST=     *F13.3,F16.3,2I16)
520   NL=SUM2(3,6)
      WRITE(ND,521) NL
521   FORMAT(/6X*LOST*I3* LITTERS, CUE TO BLD. OVERFLOW*)
      IF(NL) 53C, 530, 523
523   CALL STATS(SUM2,6,ALCS,VAR,SLCS)
      MNL=SUM2(4,6)
      MXL=SUM2(5,6)
      WRITE(ND,527) ALCS,SLCS,MNL,MXL
527   FCRMAT(10X*LITTER SIZE LCST=     *F13.3,F16.3,2I16)
530   WRITE(ND,531)
531   FCRMAT(/6X*ENC SEASCNAL FARRCWING REPCRT*65(1H=))
C
C  ZERC COLLECTING ARRAYS FCR NEXT SEASCN.
      DC 561 I=1,6
561   CALL ZRCSUM(SUM2,I)
      RETURN
C
C
C
C SEASCNAL BREEDING REPCRT
C      START SEASCN IN SUB. SELECT FCR INVENTORY CF SCWS AVAIL.
C        KBRC IS AVAILABLE= TCTAL NC. EXPCSEC (TARGET NO. TC BREED)
C              DURING THE SEASON.
C        KSWGT() 1=OPEN GILTS, 2=CPEN SCWS, 3= CTHERS., 4= CAY
C SUB. BREEC COLLECTS STATS FCR CCNCEIVING SCWS ANC GILTS
C        SUM2( ,7)=AGE OF SCW AT FARRCWING.
C        SUM2( ,8)=ASSIGNEC LITTER SIZE.
C        SUM2( ,9)= CAY CF CONCEPTICN.
C        COUNT NCN CCNCEIVING IN ARRAY NCNB().
C        NONB() 1= NC. REFUSEC BECAUSE MAX PREVICUSLY REACHEC.
C                 2= NC. FCR LACK CF BCARS, 3= NO. FAILING PRCB. TEST.
C                 4= DAY TARGET REACHEC, -999 IF NCT REACHEC.
3000  WRITE(ND,3501) NCWT, NCWY, NCWD
3501  FCRMAT(/////5X*SEASCNAL BREEDING REPORT CN CAY=*I4/5X,
     295(1H=)/10X*YEAR=*I2*, DAY CF YEAR=*I3*, BREECING*
     3* SWITCH TURNED CFF TCCAY.*)
      ITO=0
      DO 3505 I=1,3
3505  ITC=ITC+KSWGT(I)
      WRITE(ND,3507)ITC,KSWGT(4),KSWGT(1),KSWGT(2),KSWGT(3)
3507  FCRMAT(/6X*AFTER GILT SELECTICN MAINTENANCE BLC. HAC*I3
     2* FEMALES ON CAY=*I5/10X*CPEN GILTS*9X*=*I4/1CX*OPEN SCWS*
```

```
     310X*=*I4/10X*CTHERS, MAINT. BLC.=*I4)
C
C GEST STATS ON BREEDINGS ANC PRINT THEM OUT.
      NB=SUM2(3,7)
      WRITE(ND,3509) NB
3509  FCRMAT(/6X*BREEDINGS RESULTEC IN*I4* CONCEPTIONS*)
      IF(NB) 3516, 3516, 3510
3510  IF(NCNB(4)+999) 3598, 3592, 3598
3592  WRITE(ND,3593)
3593  FCRMAT(1H+,48X*  TARGET NC. NCT REACHED*)
      GC TC 3599
3598  WRITE(ND,3597) KBRD, NCNB(4)
3597  FCRMAT(1H+,44X*, TARGET NC. EXPCSED=*I4* REACHED CAY=*I6)
3599  WRITE(ND,503)
      CALL STATS(SUM2,7,AAG,VAR,SAG)
      AMN=SUM2(4,7)
      AMX=SUM2(5,7)
      WRITE(ND,3511)AAG,SAG,AMN,AMX
3511  FCRMAT(/10X*AGE CF SCW AT FARRCWING=*F9.3,3F16.3)
      CALL STATS(SUM2,8,ALS,VAR,SLS)
      MN=SUM2(4,8)
      MX=SUM2(5,8)
      WRITE(ND,3513) ALS,SLS,MN,MX
3513  FCRMAT(10X*ASSIGNEC LITTER SIZE=*F12.3,F16.3,2I16)
      CALL STATS(SUM2,9,ACY,VAR,SCY)
      MN=SUM2(4,9)
      MX=SUM2(5,9)
      WRITE(ND,3515) ACY,SCY,MN,MX
3515  FCRMAT(10X*DAY CF BREECING=*F17.3,F16.3,2I16)
C       NON CONCEIVING SECTICN, NCNB(4)=DAY MAX REACHED.
3516  ITO=0
      DC 3517 I=1,3
3517  ITO=ITO+NCNB(I)
      WRITE(ND,1319) ITC, NCNB(1),NCNB(2),NCNB(3)
1319  FORMAT(/6X*SOWS IN HEAT BUT NCT BRED*24X*=*I8/6X
     2*  DUE TC- TARGET PREVICUSLY REACHEC*14X*=*I8/16X
     3*LACK OF BOARS*26X*=*I8/16X*FAILING PROBABILITY CF*
     4* CONCEPTION TEST =*I8)
      WRITE(ND,1321)
1321  FCRMAT(/5X*END SEASCNAL BREECING REPORT*67(1H=))
      DC 1329 I=1,3
      NCNB(I)=0
1329  CALL ZRCSUM(SUM2,I+6)
      NCNB(4)=-999
      RETURN
C
C
C
C BUILCING USE PERIOCIC REPCRT.
C  KW=4 CALL,   CALCULATICN IS IN SUB. MGT3 WITH CVERFLCW CHECKS.
C      SUM4( ,1)= NURSERY STATS CN PERCENT CAPACITY
C      SUM4( ,2)= FINISHING BUILDING STATS
C      SUM4( ,3)= MAINTENANCE STATS
C      SUM4( ,4)= FARRCW CRATES STATS
C
4000  LCAY=NOWT-ISMYP
      WRITE(NW,4003) NCWT,LCAY,NCWC,NCWY
4003  FCRMAT(/////5X*BUILDING USE PERIOCIC REPORT CN DAY=*I4/
     25X,95(1H=)/10X*PREVICUS REPCRT WOULD HAVE BEEN CUE CN DAY*
     3I4*, TODAY IS CAY*I4* CF YEAR*I2)
      WRITE(NW,4005) ISMYP
4005  FCRMAT(/20X*(NO.TCDAY)*10X*PERCENT OF MAXIMUM CAPACITY OVER*
     2I4* CAYS*)
```

```
      WRITE(NW,4007)
4007  FCRMAT(21X*-------- *68(1H-))
      WRITE(NW,503)
C         NURSERY
      CALL STATS(SUM4,1,AVE,VAR,STC)
      RMIN=SUM4(4,1)
      RMAX=SUM4(5,1)
      WRITE(NW,4011) NH(2),AVE,STC,RMIN,RMAX,MX2
4011  FCRMAT(/10X*NURSERY       (*I3*)=*F10.2,3F16.2
     2 /12X*CAPACITY=*I4)
C         FINISHING
      CALL STATS(SUM4,2,AVE,VAR,STC)
      RMIN=SUM4(4,2)
      RMAX=SUM4(5,2)
      WRITE(NW,4015) NH(4),AVE,STC,RMIN,RMAX,MX4
4015  FCRMAT(10X*FINISHING     (*I3*)=*F10.2,3F16.2/12X*CAPACITY=*I4)
C          MAINTENANCE
      CALL STATS(SUM4,3,AVE,VAR,STC)
      RMIN=SUM4(4,3)
      RMAX=SUM4(5,3)
      WRITE(NW,4021) NH(3),AVE,STC,RMIN,RMAX,MX3
4021  FCRMAT(10X*MAINTENANCE   (*I3*)=*F10.2,3F16.2/12X*CAPACITY=*I4)
C        FARROWING CRATES
      CALL STATS(SUM4,4,AVE,VAR,STD)
      RMIN=SUM4(4,4)
      RMAX=SUM4(5,4)
      WRITE(NW,4027) KL4,AVE,STD,RMIN,RMAX,MX1
4027  FCRMAT(10X*FARROW CRATES(*I3*)=*
     2F10.2,3F16.2/12X*CAPACITY=*I4)
      WRITE(NW,4029)
4029  FCRMAT(5X*===END BUILCING USE REPCRT*69(1H=))
C SET SUM4, 1-4 =ZERO
      DC 4031 I=1,4
4031  CALL ZROSUM(SUM4,I)
      RETURN
C
C
C
C KW=5 PERICDIC BREEDING REPCRT
C  SUM3() 7,8 USED FCR AGE ANC LITTER SIZE.
C  NCNBK() 1-3 ARE MAX REACHED,  LACK BCARS, FAILS PROB.,
C      BUT 4 IS COUNTER FCR NC IN SEASCN.
C
5000  CCNTINUE
      WRITE(NW,5501)NOWT,NCWD,NCWY
5501  FCRMAT(///5X*PERICCIC BREECING REPORT ON CAY=*I4/5X,
     2 95(1H=)/10X*TCDAY IS CAY*I4* CF YEAR* I2)
      NB=SUM3(3,7)
      WRITE(NW,5509)NB
5509  FCRMAT(/6X*BREEDINGS RESULTED IN*I8* CONCEPTICNS.*)
      IF(NB) 5516, 5516, 5510
5510  WRITE(NW,503)
C        AGE OF SOW
      CALL STATS(SUM3,7,AAG,VAR,SAG)
      AMN=SUM3(4,7)
      AMX=SUM3(5,7)
      WRITE(NW,3511) AAG,SAG,AMN,AMX
C       SIZE CF LITTERS
      CALL STATS(SUM3,8,ALS,VAR,SLS)
      MN=SUM3(4,8)
      MX=SUM3(5,8)
      WRITE(NW,3513) ALS,SLS,MN,MX
```

```
5516  ITO=0
      CC 5517 I=1,4
5517  ITO=ITC+NCNBK(I)
      WRITE(NW,1319) ITC,NCNBK(1),NCNBK(2),NCNBK(3)
      WRITE(NW,5519) NONBK(4)
5519  FCRMAT(16X*SEASCN CLCSED*26X*=*I8)
      WRITE(NW,5321)
5321  FCRMAT(/5X*END PERICCIC BREEDING REPCRT*67(1H=))
      CC 5329 I=1,4
5329  NCNBK(I)=0
      CALL ZROSLM(SLM3,7)
      CALL ZROSUM(SUM3,8)
      RETURN
C
C
C
C PERICCIC FARRCWING REPCRT
C     KW=6,  SUM3() WITH AS IN SEASCNAL REPCRT
C
6000  WRITE(NW,6501) NCWT,NCWD,NCWY
6501  FCRMAT(1H1,5X*FARRCWING PERICCIC REPCRT CN DAY=*I5/5X,
     295(1H=)/1CX*TCDAY IS CAY* I4* CF YEAR*I2)
      NL=SUM3(3,1)
      WRITE(NW,503)
      WRITE(NW,505) NL
C       LITTER SIZE
      IF(NL) 6533, 6533, 6505
6505  CALL STATS(SUM3,1,ASIZ,VAR,SSIZ)
      MNSIZ=SUM3(4,1)
      MXSIZ=SUM3(5,1)
      WRITE(NW,507)ASIZ,SSIZ,MNSIZ,MXSIZ
C       CAPACITY
      CALL STATS(SUM3,3,ACAP,VAR,SCAP)
      RNCAP=SUM3(4,3)
      RXCAP=SUM3(5,3)
      WRITE(NW,511) ACAP,SCAP, RNCAP, RXCAP
C       BIRTH WTS.
      CALL STATS(SUM3,4,AWT,VAR,SWT)
      RNWT=SUM3(4,4)
      RXWT=SUM3(5,4)
      WRITE(NW,513)AWT,SWT,RNWT,RXWT
C       LOST LITTERS
6533  NL=SUM3(3,5)
      WRITE(NW,515) NL
      IF(NL) 620, 620, 616
616   CALL STATS(SUM3,5,ALCS,VAR,SLCS)
      MNL=SUM3(4,5)
      MXL=SLM3(5,5)
      WRITE(NW,517) ALOS,SLCS,MNL,MXL
620   NL=SLM3(3,6)
      WRITE(NW,521) NL
      IF(NL) 63C, 630, 623
623   CALL STATS(SUM3, 6,ALCS,VAR,SLOS)
      MNL=SLM3(4,6)
      MXL=SLM3(5,6)
      WRITE(NW,527) ALCS, SLCS, MNL,MXL
630   WRITE(NW,631)
631   FCRMAT(/6X*END PERIOCIC FARRCWING REPCRT*65(1H=))
      CC 635 I=1,6
      CALL ZROSLM(SLM3,I)
635   CCNTINUE
      RETURN
C
```

```
C
C
C
C WEIGHT GAINS PERICDIC REPCRT,  ENC INVENTCRY TAKEN HERE.
C
C       COMMCN USED IS  4/GAIN2/...
7000  IF(ISMW.GT.0) WRITE(NW,75C1)NCWT,NOWD,NOWY
7501  FCRMAT(/////5X*WEIGHT GAINS PERICDIC REPCRT CN CAY=*I4/5X,
     2 95(1H=)/10X*TODAY IS CAY*I4* CF YEAR* I2)
C
C CALCULATE AN ENDING INVENTCRY WT., USE IT,  THEN
C     COPY IT TO OPENING ANC ZERC THE COUNTERS  OF
C     ARRAY (1)=NO., (2)= WT., (3)= VALUE
C
C SALES ARE ADDED IN SUB. SELL
C ORIGINAL CPENING INVENTCRY FOUNC IN SUB. CPEN.
C
      DC 70C9 I=1,ITCT
      ICHK=IN(1,I)/1000C00000
      IF(ICHK-240) 7001, 7C05, 7005
C HCGS AND PIGS .LT. 240 CAYS CF AGE
7001  HEND(1)=HEND(1)+1.
      HEND(2)=HEND(2)+VEN(1,I)
      HEND(3)=HEND(3)+VEN(1,I)*PRIH/100.
      GC TC 7009
C SCWS AND BCARS OVER 240 CAYS CF AGE
7005  SEND(1)=SENC(1)+1.
      SEND(2)=SEND(2)+VEN(1,I)
      SEND(3)=SEND(3)+VEN(1,I)*PRIS/100.
7009  CCNTINUE
C   WT.= ENC INV. + SALES - CPENING INV.
C    HCGS LESS THAN 240 DAYS.
      IF(ISMW)7077, 7077, 7010
7010  NW1=HEND(1)+HSLD(1)-HCP(1)
      W2=HEND(2)+HSLD(2)-HCP(2)
      W3=HEND(3)+HSLD(3)-HCP(3)
      WRITE(NW,7011)
      WRITE(NW,7013)
7011  FCRMAT(/6X*PRODUCTICN NET CF INVENTORY CHANGE-*)
7013  FCRMAT(/30X*-------NUMBER-------  ---WEIGHT LBS.-----*
     2*  ----VALUE DOL.-----*)
      WRITE(NW,7015)NW1,W2,W3
7015  FCRMAT(/10X*HOGS UNDER 240 DAYS =*I11,2F20.1)
C SOWS I.E. OLCER THAN 239 CAYS CF AGE.
      NW1=SEND(1)+SSLD(1)-SCP(1)
      W2=SEND(2)+SSLD(2)-SCP(2)
      W3=SEND(3)+SSLD(3)-SCP(3)
      WRITE(NW,7017) NW1, W2, W3
7017  FCRMAT(10X*SCWS(ALL 24C ANC UP)=*I11,2F20.1)
      WRITE(NW,7019)
7019  FCRMAT(//6X*ENDING INVENTCRY-*)
      NHENC=HENC(1)
      WRITE(NW,7015) NHEND, HEND(2), HEND(3)
      NSEND=SEND(1)
      WRITE(NW,7017) NSENC,SEND(2),SEND(3)
      WRITE(NW,7021)
7021  FCRMAT(/5X*END WEIGHT GAINS PERIODIC REPCRT*63(1H=) )
C
C
C  CALL REPT2  FOR COSTS AND RETURNS SUMMARY.
C        COUNTERS ARE ZERCEC THERE.
7077  CALL REPT2(IN,VEN)
```

```
RETURN
END
```

```
      SUBROUTINE REPT2(IN,VEN)
      COMMON/INIT/NR,NW,ND,NT7,NT8,NDAT,NS1,NS2,NOWD
     3/STAT/SUM(5,20),SUM2(5,10),SUM3(5,10),SUM4(5,10),SUM5(5,10)
     4/GEN/ITOT,ISIZE,NOWT,NOWY,NDAYS,NRUNS,IATRIB(18),ATRIB(4)
     5/HOUSE/NH(6),N1,N2,N3,N4,N5,N6,NXFAR,MX2,MX3,MX4
     6/SALES/D(15),PRIH,PRIS
     5/COST/FCS,FCB,CLAB,TFAR,TNUR,TSOW,TFIN,VAR(3),COST(30)
     1/RPT1/ISMYP
     2/RPT2/ISMYC,ISMCS,ISMCH,ISML,ISMSS,ISMSH,ISMGR
     4/GAIN2/SOP(6),HOP(6),SSLD(6),HSLD(6),SEND(6),HEND(6)
      DIMENSION IN(3,1),VEN(2,1)
C
C
C  COST AND RETURNS SUMMARY REPORT
C     COLLECTED IN SUB. MGT3,  CALLED FROM REPT1 PERIODICALLY.
C     GAINS ARRAYS ZEROED HERE.
C COST() 1=T. SOW DAYS, 2=FARROW BLD. MINUTES, 3=NURSERY BLD. MIN.,
C   4=MAINT. BLD + CULL MIN., 5= FINISHING BLD. MIN.
C
      IF(ISMYC) 898, 898, 801
801   WRITE(NW,803) NOWT, NOWD, NOWY, ISMYP
803   FORMAT(1H1,5X*COSTS AND RETURNS PERIODIC REPORT ON DAY=*I4/
     2 5X,95(1H=)/10X*TODAY IS DAY*I4* OF YEAR*I2*    PERIOD*
     3* COVERED=*I5* DAYS*)
C  FEED COST SOWS  C1
      C1=COST(1)*FCS
      IF(ISMCS)8200, 8200, 8100
8100  WRITE(NW,8105) C1, FCS
8105  FORMAT(/10X*FEED COSTS SOWS=*F8.2* DOL. AT*F4.2* PER DAY PER SOW*
C  FEED COST PER 100 LBS. HOGS PRODUCED.
8200  G=(HEND(2)+HSLD(2)-HOP(2))/100.
      CH=G*FCB
      IF(ISMCH)8300, 8300, 8201
8201  WRITE(NW,8205) CH, FCB
8205  FORMAT(/10X*FEED COSTS HOGS=*F8.2* DOL. AT*F6.2* PER*
     2* 100 LBS. PRODUCED*)
C LABOR COSTS BY BLD.
8300  C2=COST(2)/60.*CLAB
      IF(ISML) 8400, 8400, 8301
8301  WRITE(NW,8305) CLAB, C2
8305  FORMAT(/6X*LABOR COSTS BY BUILDING INCLUDING CULL PEN AT*
     2F5.2* DOL. PER HOUR*/10X*FARROWING=*F20.2)
8400  C3=COST(3)/60.*CLAB
      C4=COST(4)/60.*CLAB
      C5=COST(5)/60.*CLAB
      WRITE(NW,8309) C3, C4, C5
8309  FORMAT(10X*NURSERY=*F22.2/10X*SOWS MAINT. +CULLS=*F11.2/
     210X*FINISHING=*F20.2)
C
C VALUE PRODUCED
      S2=(SEND(2)+SSLD(2)-SOP(2)) / 100.
      VS2= S2* PRIS
      IF(ISMSS) 8500, 8500, 8401
8401  WRITE(NW,8405) S2, VS2
8405  FORMAT(/6X*SOWS PRODUCED=*F12.1* CWT.    AT VALUE OF*
     2F14.2* DOL.*)
8500  H2=(HEND(2)+HSLD(2)-HOP(2)) /100.
      VH2= H2* PRIH
      IF(ISMSH) 8600, 8600, 8501
8501  WRITE(NW,8505) H2, VH2
8505  FORMAT(/6X*HOGS PRODUCED=*F12.1* CWT.    AT VALUE OF*
```

```
      2F14.2* DOL.*)
C COSTS AND RETURNS NUTSHELL SUMMARY.
C     USE ABOVE CALCULATIONS FOR TABLE
8600  IF(ISMGR) 8650, 8650, 8601
8601  WRITE(NW,8603) ISMYP, NOWD,NOWY
8603  FORMAT(///5X*COSTS AND RETURNS SUMMARY OVER A*
     2I5* DAY PERIOD.*/10X*TODAY IS DAY*I4* OF YEAR*I2)
      WRITE(NW,8605)
8605  FORMAT(/41X*-------SOWS-------  -------HOGS-------  ----*
     2*TOTAL HERD----*/32X,3(17X,3H($)))
      TV2=VS2+VH2
      WRITE(NW,8611) VS2, VH2, TV2
8611  FORMAT(44X*(1)*/10X*PRODUCTION NET OF INVENTORY *
     2*CHANGE*F9.2,2F20.2)
      TCF=C1+CH
      WRITE(NW,8617) C1,CH,TCF
8617  FORMAT(19X*(2)*/10X*FEED COST*14X,3F20.2)
      C24=C2+C4
      C35=C3+C5
      TCL=C24+C35
      WRITE(NW,8621) C24, C35, TCL
8621  FORMAT(20X*(3)*/10X*LABOR COST*13X,3F20.2)
      RS=VS2-C1-C2-C4
      RH=VH2-CH-C3-C5
      GR=TV2-TCF-TCL
      WRITE(NW,8631)RS,RH,GR
8631  FORMAT(/10X*RETURN OVER FEED AND LABOR*F17.2,2F20.2)
      WRITE(NW,8641)
8641  FORMAT(6X,93(1H-)/6X*(1) SOWS INCLUDE ANIMALS 240 DAYS OF*
     2* AGE AND OVER, OTHERWISE THEY WHERE CLASSED AS HOGS AND PIGS.*
     3/6X*(2) FEED COST FOR SOWS BASED ON DAYS OF MAINTENANCE*
     4 * (INC. CULL PEN) AND LACTATION.*/6X*(3) LABOR COST BASED*
     5* ON BUILDING OCCUPANCY, ALL FARROWING HOUSE LABOR WAS*
     6* ASSIGNED TO SOWS.*)
8650  WRITE(NW,8651)
8651  FORMAT(5X*===END COSTS AND RETURNS SUMMARIES*61(1H=))
C  ZERO COST ARRAY
C
898   DO 8801 I=1,5
8801  COST(I)=0.
C
C  ZERO GAIN ARRAYS.
      DO 899 I=1,3
      HOP(I)=0.
      SOP(I)=0.
      HSLD(I)=0.
      SSLD(I)=0.
      HOP(I)=HEND(I)
      SOP(I)=SEND(I)
      HEND(I)=0.
899   SEND(I)=0.
      RETURN
      END
```

APPENDIX D

INPUT DATA

547231146	1	478.
362231096	2	370.
367231136	3	363.
110823 996	4	524.
744231146	5	498.
1106231046	6	486.
748231036	7	487.
92923 996	8	555.
928231116	9	485.
54623 996	10	425.
360231126	11	395.
922231136	12	499.
929231136	13	469.
749231016	14	471.
359231036	15	384.
1106231136	16	550.
74823 996	17	525.
358231096	18	388.
542231106	19	421.
359231146	20	408.
349231046	21	397.
751231096	22	507.
355231006	23	389.
1110231046	24	502.
65023 996	25	489.
650231096	26	479.
545231006	27	514.
545231006	28	498.
54523 996	29	457.
36523 996	30	389.
6666		
18230 07	31	188.
18021 07	32	174.
18330 07	33	204.
18321 07	34	210.
18330 07	35	224.
17921 07	36	208.
17921 07	37	196.
17830 07	38	260.
17821 07	39	196.
17830 07	40	226.
17621 07	41	230.
17621 07	42	204.
17621 07	43	216.
17530 07	44	228.
17521 07	45	216.
17530 07	46	212.
17330 07	47	206.
17321 07	48	200.
17321 07	49	182.
17221 07	50	224.
16721 07	51	196.
16630 07	52	236.
16630 07	53	182.
16621 07	54	196.
16321 07	55	198.
18221 07	56	206.
18321 07	57	160.
18321 07	58	198.
18321 07	59	198.
17830 07	60	232.

17630	07	61	208.
17521	07	62	206.
17530	07	63	198.
17321	07	64	200.
17321	07	65	174.
17330	07	66	210.
17321	07	67	194.
17330	07	68	238.
17330	07	69	248.
17321	07	70	208.
17230	07	71	244.
17230	07	72	210.
16721	07	73	202.
16730	07	74	226.
16721	07	75	190.
16621	07	76	192.
16621	07	77	172.
16621	07	78	196.
16621	07	79	158.
17130	07	80	218.
18030	07	81	202.
18330	07	82	228.
18321	07	83	202.
17930	07	84	216.
17830	07	85	231.
17830	07	86	264.
17821	07	87	234.
17621	07	88	228.
17630	07	89	225.
17530	07	90	224.
17521	07	91	220.
17521	07	92	186.
17321	07	93	208.
17330	07	94	174.
17121	07	95	184.
16721	07	96	200.
16730	07	97	210.
16621	07	98	204.
16621	07	99	206.
16630	07	100	222.
16621	07	101	182.
16630	07	102	240.
16621	07	103	176.
16330	07	104	196.
18221	07	105	192.
18231	07	106	184.
18231	07	107	206.
18021	07	108	206.
18321	07	109	202.
18330	07	110	228.
17921	07	111	228.
17930	07	112	232.
17830	07	113	222.
17830	07	114	200.
17621	07	115	224.
17630	07	116	202.
17621	07	117	225.
17621	07	118	212.
17621	07	119	206.
17630	07	120	228.
17521	07	121	192.
17330	07	122	190.
17130	07	123	222.

17121	07	124	220.
17121	07	125	186.
16730	07	126	232.
16621	07	127	174.
16321	07	128	204.
16330	07	129	214.
18221	07	130	208.
17921	07	131	216.
17621	07	132	212.
17330	07	133	206.
17230	07	134	234.
17121	07	135	202.
16730	07	136	236.
16721	07	137	158.
16730	07	138	234.
16730	07	139	224.
16630	07	140	214.
16621	07	141	200.
16621	07	142	202.
16630	07	143	210.
16621	07	144	164.
16621	07	145	200.
16630	07	146	198.
16621	07	147	198.
16621	07	148	202.
16621	07	149	202.
18230	07	150	188.
18021	07	151	174.
18330	07	152	204.
18321	07	153	210.
18330	07	154	224.
17921	07	155	208.
17921	07	156	196.
17830	07	157	260.
17821	07	158	196.
17830	07	159	226.
17621	07	160	230.
17621	07	161	204.
17621	07	162	216.
17530	07	163	228.
17521	07	164	216.
17530	07	165	212.
17330	07	166	206.
17321	07	167	200.
17321	07	168	182.
17221	07	169	224.
16721	07	170	196.
16630	07	171	236.
16630	07	172	182.
16621	07	173	196.
16321	07	174	198.
18221	07	175	206.
18321	07	176	160.
18321	07	177	198.
18321	07	178	198.
17830	07	179	232.
17630	07	180	208.
17521	07	181	206.
17530	07	182	198.
17321	07	183	200.
17321	07	184	174.
17330	07	185	210.

17321	07	186	194.
17330	07	187	238.
17330	07	188	248.
17321	07	189	208.
17230	07	190	244.
17230	07	191	210.
16721	07	192	202.
16730	07	193	226.
16721	07	194	190.
16621	07	195	192.
16621	07	196	172.
16621	07	197	196.
16621	07	198	158.
17130	07	199	218.
18030	07	200	202.
18330	07	201	228.
18321	07	202	202.
17930	07	203	216.
17830	07	204	231.
17830	07	205	264.
17821	07	206	234.
17621	07	207	228.
17630	07	208	225.
17530	07	209	224.
17521	07	210	220.
17521	07	211	186.
17321	07	212	208.
17330	07	213	174.
17121	07	214	184.
16721	07	215	200.
16730	07	216	210.
16621	07	217	204.
16621	07	218	206.
16630	07	219	222.
16621	07	220	182.
16630	07	221	240.
16621	07	222	176.
16330	07	223	196.
18221	07	224	192.
18231	07	225	184.
18231	07	226	206.
18021	07	227	206.
18321	07	228	202.
18330	07	229	228.
17921	07	230	228.
17930	07	231	232.
17830	07	232	222.
17830	07	233	200.
17621	07	234	224.
17630	07	235	202.
17621	07	236	225.
17621	07	237	212.
17621	07	238	206.
17630	07	239	228.
17521	07	240	192.
17330	07	241	190.
17130	07	242	222.
17121	07	243	220.
17121	07	244	186.
16730	07	245	232.
16621	07	246	174.
16321	07	247	204.
16330	07	248	214.

18221 07 249 208.
7777

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STANDARC CCNTRCL DATA AS CF 9-17-72
51.      365.    1.      14.     1.      1950.
    1.     15.
10.      1.      180.    260.    1.      300.    350.    0.      73C.    450.
14.      15.     2.      0.
15.      125.    1.
   16.     80.
17.      24C.    1.
8.       14.     215.    20.5    17.     .50
13.      .14     11.75   3.      6.5     .21     .8      .005
   20.      3.      10.      3.      15.      2.      60.     180.    260.
12.      -.1C    -.05
11.      10.     2.      1600.   20.     20.     730.    60.
3.       .10     .10     .C35    .05     .015    .015    .015    .075
    4.      .05     20.7     2.1     16.0    25.0     .75     .6C    -C0.5    0.
2.       21.     17.     28.     18.     82.
    5.   114.0      2.0  110.0   118.0    .040    .035    .020
    6.     9.5      3.0    4.0    16.C      3.    C.47    1.25     5.C
    7.    0.45     0.58   0.75    1.25    1.70    15.0
    9.     1.0       .2   -0.5     1.0      5.      .5
53.      365.    1.      1.      1.      1.      1.      1.
54.      1.      1.      1.      1.      1.      1.      1.
55.      0.      0.      0.      0.
56.      -1.     -1.     0.      0.      0.      0.      0.      0.      0.
57.      -1.      -1.    0.      0.      0.      0.      0.
58.      0.       0.
8888.
```

VITA

VITA

Name: Jay Loren Strom

Birth: February 1, 1937 at Worthington, Minnesota

Citizenship: United States of America

Marital Status: Married Margaret H. Hess, 1964

Children: Two sons, Channing, born August 18, 1969
Eric, born November 18, 1972

Education:

(1) Worthington High School, Worthington, Minnesota

(2) McPherson College, McPherson Kansas 1955-56

(3) University of Minnesota, B. S. in Animal Science 1956-59

(4) Purdue University, M. A. in Agricultural Economics 1965-67

(5) Purdue University, Ph.D. in Agricultural Economics, Candidate, May, 1973

Professional Experience: Farm Management Consulting - Purdue Fellows in Argentina 1967-69

Employment: Self Employed in Farming 1961-65

Purdue University Fellows Program

Purdue University Cooperative Extension

CANFARM, Canadian Farm Management Data System, Guelph, Ontario 1972-