A COMPARISON OF DAIRY WASTE HANDLING SYSTEMS AND COMPONENTS THROUGH THE USE OF AN INTERACTIVE COMPUTER PROGRAM

By

Winston George Ingalls

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Dairy Science

1980

ABSTRACT

A COMPARISON OF DAIRY WASTE HANDLING SYSTEMS AND COMPONENTS THROUGH THE USE OF AN INTERACTIVE COMPUTER PROGRAM

By

Winston George Ingalls

Twenty-five dairymen averaging 120 milking cows were interviewed to gain information on the type of waste handling equipment routinely used and the labor requirements of various waste handling tasks. In addition, 60 equipment manufacturers were canvassed for cost and performance data of waste handling equipment. The data from the two studies were utilized to describe each task according to initial cost, ownership costs, energy use and cost, labor use and cost, value of retained nutrients and net annual costs. The complete waste handling process was divided into eight sections and each section contained several options. An interactive computer program was subsequently designed to allow construction of all feasible systems for 100 to 300 cow dairy herds. Handling dairy wastes as a liquid provided the greatest number of feasible systems, but storage costs were generally much higher than with solids. Opportunities for saving labor exist primarily at the alley cleaning and movement to storage phases. In general, no single system emerged as always the best; rather, it depended on the owners' personal needs.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to his wife Ann for her patience and support during the course of the Ph.D. program.

Sincere appreciation is also extended to Doctors Lassiter and Hafs, who served as chairmen of the Dairy Science Department during the course of the thesis work and provided financial assistance for the program. Also I would like to recognize the assistance of my committee members, Dr. John Speicher of Dairy Science, Dr. Ted Loudon of Agricultural Engineering, Dr. Larry Connor of Agricultural Economics, and Dr. Maurice Vitosh of the Soil Science Department.

Finally, a very special note of thanks is extended to Dr. Roger Neitzel and Dr. Lee Shull who helped in a great many ways to make this effort a success.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The enactment of the 1972 Federal Water Pollution Control Act and the subsequent development of supporting regulations created the impetus for economists, engineers, etc., to research the effects of compliance with such rules on all segments of the Nation's industry. This act specifically identified agriculture as a contributor of pollutants to the waterways of the Nation, from both point and non-point sources. Particulate matter, organic matter, bacteria as well as nitrogen, phosphorus and potassium compounds have all been discussed as emanating from agriculture.

The total agricultural community, from farmer to academician, has entered into the controversy regarding pollution control regulations on several fronts. One effort has been to involve agriculture supporters, those knowledgeable in modern agriculture practices, on committees which review proposals and develop plans of action for pollution control. Another major undertaking involved accumulation of reliable data from agriculture pursuant to the pollution problem. The Environmental Protection Agency and state agencies were given the task of formulating effective and reasonable pollution control standards. Finally it was the role of the agricultural academic community to use various objective analysis techniques to assess the impact of potential rules and regulations on production agriculture.

For livestock operations, such considerations as no spreading of manure on frozen or snow-covered ground, immediate soil incorporation and mandatory six months manure storage have been examined. Most studies were macro in nature, designed to assess total industry impact rather than specific farm effect.

In conjunction with the uncertainty of future pollution control regulations, many Michigan dairymen have been expanding to benefit from the scale effect of a larger operation. Expansion has involved new, larger facilities and/or additions to existing facilities. Many dairymen currently are in a position whereby consideration of all existing and potential rules dealing with pollution control must be examined to avoid future confrontations. For most, expansion via new construction allows incorporation of many desired features because all options are available with the only restrictions being those which are self-imposed. Many options exist for waste handling on dairy farms. Producers generally choose a system based on such factors as initial cost, labor demands, convenience, nutrient retaining ability, etc. It was in this framework that this project was initiated. The primary objective was to construct an interactive computer program which allows a dairyman flexibility to design and compare feasible systems for waste handling.

REVIEW OF LITERATURE

Historical Perspective of Animal Waste Handling Systems and Research

Material reviewed in this section has been published within the past 100 years. Obviously, reports on this subject were published prior to 1878; however, it was felt that most of the documented research relevant to this project occurred within this period and consequently only this material was reviewed. Also, publications of this era were examined to gain a general impression of research techniques and waste handling systems rather than specific methodologies.

A somewhat surprising and significant finding in the literature of this period was that not much has changed in 100 years relevant to manure nutrient content and the fate of such nutrients under various conditions. Scientists of then were aware of the nitrogen (N), phosphorus (P), and potassium (K) needs of plants. Chemical analysis of manures yielded N, P and K values comparable to present-day estimates. Table 1, comparing manure nutrient values from Roberts (1884) and MWPS-18 (1975), best illustrates this.

The material in Roberts' sample contained much bedding and would resemble manure from a bedded pack in a loafing barn and is quite similar to the MWPS-18 sample, which is solid manure with bedding. Despite 92 years of reexamination and improvement in

Table 1.--Comparison of manure nutrient values from Roberts (1884) and MWPS-18 (1975).

	Roberts (1884)	MWPS-18 (1975)
Moisture	72.95%	79.00%
Nitrogen	0.78%	0.45%
Phosphorus	0.40%	0.20%
Potassium	0.84%	0.50%

laboratory techniques, the figures published by Roberts (1884) remain reasonable estimates for dairy waste with bedding. In addition, Roberts (1884) established a value of the manure based on the concentration of the three major components. He applied values of 17¢/lb. of nitrogen, 7¢/lb. of phosphoric acid, and 4.25¢/lb. of potash, which resulted in a price of $3.61 per ton of stable manure. These appear high compared with present-day prices. Vitosh (1975) valued cattle waste at $5-10 per ton based on the N, P and K content.

Roberts (1891) published data on daily manure production per cow and the nutrient content of both liquid and solid fractions was analyzed separately. He found urine to have a high nitrogen content, which prompted his recommendation that the liquid portion of cattle waste be conserved to retain the nitrogen of the waste material. In his 1891 report to the Cornell University Experiment Station, the comment was included that he found it difficult to persuade farmers to change their waste handling methods. Most farmers were unwilling to protect manure from the elements to maximize nutrient retention.

Sempers (1893) described farmyard manure as containing all the constituents of plant food. He cited manure as causing some disintegration of soils, having a warming effect on cold, clayey soils, and helping retain soil moisture and ammonia compounds. Sempers (1893), among others of this period, felt that faulty fermentation and leaching action of storms on unprotected manure caused great nutrient losses and rendered it practically useless as a fertilizer.

Fermentation was considered the most important process in proper management of farmyard wastes. Both anaerobic and aerobic processes were known to exist, and rotted manure was considered to contain more soluble organic matter than fresh manure. Caution was often taken to avoid "fire-fanging" of manure since it was believed this lessened its value. This process referred to the tremendous heat generated by piles of horse manure. Sempers (1893) suggested that to produce the highest quality manure it had to be kept under cover, with no drainage allowed and kept sufficiently high in moisture to reduce ammonia volatilization.

In 1913, Wheeler published a book entitled Manures and Fertilizers. He cited experiments conducted at Rothamstead Experiment Station in England as early as 1843, in which manure was used as a fertilizer source. Much of this early work dealt with plant nitrogen needs and how effectively manure met this need. Wheeler

(1913) wrote that practical utilization of manures involved hauling and rapid soil incorporation to conserve maximum nitrogen. He suggested also that manure should not be spread on frozen or ice-covered slopes due to potential runoff problems and loss of nutrients. Reference was made also to the timeliness problem of handling wastes; if manure was not applied as produced, a farmer might handicap himself in the spring by having to haul manure when planting should be scheduled. This could then lead to a series of delays and losses throughout the course of the year.

Over the past 80 to 100 years, most of the concerns cited by the aforementioned authors have not changed. Increased population and larger and more concentrated livestock industries, however, have focused substantially more attention on pollution control and recovery of animal waste nutrients as plant fertilizers.

Agricultural Trends and Rural Population Profiles

In order to understand the nature and scope of present agricultural waste management problems, some insight into the changes occurring in agriculture in general and dairying in particular must be gained. An appreciation must also come to exist of the constant reorganization of the makeup of the rural population in Michigan and other states.

The Michigan State University Agricultural Experiment Station and the Cooperative Extension Service in 1972 published a report entitled "The Michigan Dairy Industry of 1985." The intent was to project the status of the Michigan dairy industry in 1985. Some of the following predictions were made by authors contributing to the report:

1. The number of active dairymen in Michigan has been declining for the past 20 years, and it is expected that by 1985 only 3500-4500 Grade A dairymen will be selling milk.

2. The number of milk cows in 1985 will range from 320,000-400,000.

3. Herd sizes will dramatically increase. More than 25 percent of all dairies will have greater than 100 cows and 50 percent of all milk cows or more will be located on dairies with greater than 100 cows.

4. Man equivalents per farm will decrease to 2.5 by 1985, even though milk output per man will have dramatically increased.

5. Feed sources will consist of increased amounts of corn silage and grain mixes and less hay.

6. A great increase will occur in total confinement housing systems. It is estimated that by 1985, 35 percent of all herds and 55 percent of all cows will be in covered facilities.

Another point of concern for Michigan dairymen was illustrated by Hoglund et al. (1972) in an Agricultural Economics Report on waste management practices and systems for Michigan dairy farms. Their results indicated that 50 to 60 percent of all dairymen surveyed for their report had non-farm neighbors living within one-half mile of their barn area, and even a higher percentage had non-farm neighbors living within one-half mile of fields where manure might be spread.

In this same questionnaire, another potential problem reported by dairymen was their nearness to bodies of water. Thirty to 44 percent of dairymen with different types of housing and manure handling systems were within one-half mile of a lake or stream and 33 to 56 percent of these same dairymen indicated that one or more of the fields where they hauled manure was within a half mile of a stream or lake. In cases where land application of manure is close to navigable waterways, consideration must be given to proper procedures to avoid pollution.

Participating dairymen were asked, "Are you concerned about laws and regulations that might be passed or pressures from neighbors concerning manure odors or noise factors or water pollution? If so, how?" Sixty-five to 70 percent of all dairymen replied affirmatively, and the reasons varied from fear that the cost of complying with such regulations would be high to fear that non-farm neighbors would have no tolerance for animal odors. Another major concern was the uncertainty of what future environmental regulations might be promulgated by Federal and state agencies.

In general terms, Michigan dairymen will be milking greater numbers of cows per farm, the per-farm labor needs will increase as well as crop acreage, and more dairy farms will have non-farm neighbors near them. This set of projected conditions means increased potential for pollution by dairymen and their opportunities for confrontations with non-farm residents intolerant of odors, etc., will rise. This may force adoption of different waste handling methods to meet this problem.

Pollution Control Legislation and the Livestock Industry

Point Source Pollution

The demand for a cleanup of the Nation's water and air has been ongoing for decades. Such demands became even greater during the 1960's and eventually resulted in Congressional enactment of the 1972 Federal Water Pollution Control Act (F.W.P.C.A.). The stated objective of this legislation is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. The agency charged with the responsibility of achieving these objectives is the Environmental Protection Agency (EPA).

On May 22, 1973, the EPA published in the Federal register its initial version of the policies and procedures for the National Pollutant Discharge Elimination System (NPDES) for agriculture. The significant factor for livestock owners was the specific identification of livestock operations as potential point sources of pollution which must either be contained or eliminated. The NPDES established a permit program which applied to specific point sources of pollution and considered only those operations which met certain criteria as outlined by EPA.

The level of pollution control, the timetable for achieving such standards and the control technology to be applied were stated in the following sections of the Federal Water Pollution Control Act:

Section 301.(b) (1) (A)
not later than July 1, 1977 effluent limitations for point sources, other than publicly owned treatment

works will require the application of the best practicable control technology currently available as defined by the administration.

Section 301 (b) (2) (A)
not later than July 1, 1983 effluent limitations for categories and classes of point sources shall require application of the best available technology economically achievable for such category or class.

The point sources to be considered were as follows (Fed. Reg., Nov. 20, 1975):

a. Man made drainage ditches, flushing systems or other such devices where measurable waste results and is discharged into water.

b. Natural runoff from confined livestock operations if the following animal concentrations are exceeded: 1000 beef cattle, 700 dairy cows, 200,000 broiler chickens, 180,000 laying hens, 55,000 turkeys, 4500 slaughter hogs, 35,000 feeder pigs, 12,000 sheep or lambs, and 145,000 ducks.

c. Any feedlot operations which result in direct discharge of wastes into a stream which traverses the feedlot regardless of number of animals involved.

Any animal feeding operation falling into one of the previous categories was required to apply for and obtain a permit. The permit application, if accepted, would specify allowable amounts and constituents to be discharged and a schedule for achieving compliance. On March 18, 1976, in the Federal Register, EPA published some minor revisions to the permit program. Humenik (1976) has summarized the current permit requirements and has stated it as follows:

1. Permits are required for feedlots with 700 mature dairy cows that discharge pollutants.

2. Permits are required for feeding operations with less than 700 but more than 200 dairy cows only if

discharges of pollutants occur (a) through a man made conveyance or (b) directly into navigable waters which pass through the confined area.

3. Feedlots with less than 200 diary cows are not subject to the permit requirements unless there is an on-site inspection and the owner or operator is notified in writing that such an application is required.

The enforcement of this program has been given to the states in most cases. In Michigan jurisdiction over this area rests with the Water Resources Commission, which is responsible for reviewing and issuing permit applications. Due to the nature of the livestock industry in Michigan, few permit requests have been submitted, and in those cases where a permit application has been made, the Commission has suggested elimination of the pollution via holding basins, etc., rather than issue a permit to discharge (personal communication).

Non-Point Source Pollution

Livestock operators have the potential to be point source pollutors via feedlot runoff, milk house drains, drainage from waste storage facilities, etc. The EPA, however, recognized the major sources of agricultural pollution to be non-point source in nature (Federal Register, November 20, 1975). The F.W.P.C.A. (Section 208) also recognized non-point pollution to be a major problem both for agriculture and non-agricultural areas. Section 208 (a) (2) specifically assigned to the Governor of each state the responsibility of designating representative organizations to assess non-point pollution problems in various state areas and make recommendations for abatement. With regard to agriculture, such designated groups have the following responsibilities:

> Section 208.(b) (2) (F)
> such a group shall consider a process to (i) identify if appropriate, agriculturally and silviculturally related non-point sources of pollution including runoff from manure disposal areas and from land used for livestock and crop production and (ii) set forth procedures and methods (including land use requirements) to control to extent feasible such sources.

At the state level, the Michigan Legislature (1970) passed the Environmental Protection Act. This act allows the Attorney General, any citizen, corporation, organization, governmental unit, or any other legal entity the right to bring action in the circuit courts of the state against any other citizen--entity for declaratory and equitable relief for the purpose of protecting the air, water and other natural resources of the state from pollution, impairment or destruction.

The implications of this bill are far reaching and somewhat indeterminate. Under this legislation one case (Clinton County Circuit Court File No. 844 [1971] was brought to court. In this case the farmer won, but many more challenges are likely to be seen in the future.

It is within the framework of ever-increasing rules and regulations pertaining to agriculture that tomorrow's dairymen must exist.

Nutrient Losses Associated With Waste Handling Systems

Nutrient Content of Dairy Waste

Loehr (1974), Midwest Plan Service-18 (1975) and Walsh et al. (1975), in addition to many others, have published representative figures on the nutrient content of animal waste. Caution must be exercised when dealing with such figures due to the variety of conditions under which they were generated, and on what basis they were reported. Some reports cite values for the minor elements, but practically all concentrate on nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O). The reports previously noted indicate that dairy cattle manure (feces and urine combined) as it is excreted contains approximately 10.3 pounds N, 2.4 pounds P_2O_5, and 9.8 pounds K_2O on a per ton basis. Recently with higher priced commercial fertilizer, energy shortages and legislative mandates to control water and air pollution, more attention has been focused on the quantity of nutrients generated by animal industries and the ultimate fate of such nutrients.

Nitrogen Losses

Nitrogen loss from waste systems generally is of greatest concern due to its mobility, pollutant potential and value as a crop nutrient. Fogg (1974) described N losses from various systems ranging from 15 to 85 percent, and Vanderholm (1975) cited comparable figures. Vanderholm (1975) also indicated that 50 percent of the nitrogen in fresh dairy manure is in the ammonia form, which is highly volatile and rapidly lost under many circumstances. Heck (1936) described large nitrogen losses during the interval between hauling and spreading and soil incorporation. Nearly 75 percent of the ammonia nitrogen was lost in seven days post spreading if not incorporated into the soil. Lauer et al. (1976) reported similar ammonia losses from surface applied waste. Total ammonia loss ranged from 61 to 99 percent over a 5 to 25 day time period.

Another route of loss for nitrogen is via surface runoff. Young and Mutchler (1976) reported up to 20 percent of the manure nitrogen applied to alfalfa plots appeared in spring runoff. Loehr (1974) and the 1975 Agricultural Waste Management Field Manual of the Soil Conservation Service also include discussions on nitrogen loss from runoff in addition to losses via nitrate leaching.

Phosphorus and Potassium Losses

Phosphorus occurs primarily in soil as water insoluble compounds of aluminum, iron or calcium. In most cases these metals appear as free metals on clay particles and this helps explain the strong adsorption of phosphorus to soil particles (Loehr, 1974). Apart from feedlot and field runoff, agricultural practices which effectively control soil erosion should not contribute substantial amounts of phosphorus to streams and lakes. Potassium is not generally considered to be a problem in water pollution.

Therefore, in dealing with pollution from livestock operations, reduction of nitrogen losses assumes the highest priority due to its mobility in soil and water. The control of phosphorus and potassium is no less important, but due to their stability in storage units and in the soil, they present less of a control problem.

Economic Impact of Controlling Agricultural Pollution

Agriculture's Contribution to Water and Air Pollution

Some monitoring of pollutant runoff from manure covered fields and open feedlots or corrals has taken place in recent years. Such research has had two major goals. First, there needed to be established a data base for future pollution control guidelines, and second, such data could be used in answering the questions relevant to effective systems for storing and handling manure to reduce pollution and maximize nutrient retention for crops.

Reports on this subject are to be found in the 1969, 1972, and 1974 Proceedings of the Cornell Agricultural Waste Management Conferences and the Proceedings of the 1st, 2nd, and 3rd International Symposia on Livestock Wastes. R. C. Loehr (1974) deals extensively with this matter in his book, Agricultural Waste Management. Some of the most frequently used journals for publishing research pertinent to waste disposal and nutrient movement are:

a. Journal of Environmental Quality
b. Transactions of the American Society of Agricultural Engineers
c. Water Resources Research
d. Environmental Science and Technology

It is beyond the scope of this thesis to detail nutrient movement in soils, nutrient transformation or crop utilization of applied nutrients. A previous section on nutrient content of manure and nutrient losses has briefly outlined these topics. Suffice it to say that it is an actively researched area with a rapidly growing body of literature.

Economic Impact of Controlling
Feedlot Runoff

Enactment of the Federal Water Pollution Control Act (1972) caused all segments of the livestock industry to assess the economic impact of both point source and non-point source pollution control. Buxton and Ziegler (1974) estimated that if all U.S. dairymen were to control runoff from a 10 year maximum, 24 hour storm the total industry investment would approach $780 million. This added investment would hit hardest the dairymen with 20 or less cows. They felt overall industry efficiency might improve, however, due to some smaller farms quitting the business or expanding and adopting more efficient techniques. The technology suggested by Buxton and Ziegler (1974) was designed primarily for larger herds. There may be control systems such as grass filtration areas, etc., which would suit the smaller producer and not prove to be financially overburdening.

Johnson and Davis (1974) analyzed the effect of pollution control regulations on the U.S. feed-beef industry. They focused on the 18 major beef states producing 95 percent of the U.S. beef. They determined that approximately 49,000 beefmen would have to make improvements totalling $133 million.

A similar economic impact study for the swine industry suggested that 86,000 producers would be forced to invest to some degree in new pollution control technology (Van Arsdall, 1974). The ultimate effect on consumer prices, however, appeared to be minimal because of improved efficiency as a result of new waste handling technology.

Overall Impact of Non-Point Source Pollution Regulation

Murphy (1974) noted that a comprehensive non-point source control program was inevitable. Section 208.(b) (2) (F) of the 1972 F.W.P.C.A. specifically applied to agriculture and it specified that agriculture non-point sources of pollution shall be identified and control measures recommended. Non-point source pollution control is mandated now, but the question is: how will it be implemented and what impact will implementation have on the dairy industry?

Buxton and Ziegler (1975) examined non-point source control measures in effect or under consideration by several states. They reported the following general categories of guidelines:

1. Restrictions on application rates of waste per acre. Such restrictions usually limit the amount of nitrogen, manure tonnage or number of animals per acre.
2. Restrictions on spreading manure on land adjacent to water or residences or on land exceeding a certain slope.
3. Restrictions on spreading on frozen or snow-covered ground.

Several studies have been conducted to determine the effect on livestock producers of certain point source and non-point source pollution control measures. Good (1972), using linear programming techniques and synthesized representative dairy farms, measured the impact of applying the following controls:

1. Mandatory retention and disposal of surface runoff at the production site.
2. No winter spreading of wastes on the land.
3. Mandatory subsurface disposal of wastes.

The effect was measured in terms of labor requirements, costs of production and returns to the operator's labor and management. The absolute costs of various equipment were also included. Synthesized dairies were organized around specific herd sizes, housing systems and waste handling systems. Good (1972) found that compliance with the above control policies necessitated additional capital investment in waste handling equipment and increased the costs of milk production in all cases. Cold covered housing units incurred the least increase in total costs, while stanchion barns and open lot systems experienced the most increase. Cold covered, 160 cow operations had only a 5 percent reduction in returns to operator's labor, but stanchion operators with 40 cows suffered a 37 percent reduction. Therefore, the size factor was considered a potential cause of smaller operators either leaving the dairy business or expanding. Such regulation would in effect favor larger operations.

Using beef feedlots as the model and pollution abatement policies similar to Good's (1972), Forster (1974) indicated compliance would cause some reduced beef production and increased production costs. Economies of size were again noted with operations feeding greater than 100 head experiencing less added costs per head than those feeding lesser numbers. For all feedlots, adoption of the rules would tend to increase asset fixity due to investment in durables. Effect on consumers was considered to be very limited, with the main impact being a reduction in beef surpluses. Small feedlot cutbacks might be offset by larger feedlot increases. Forster (1974) concluded that the main implications of imposing such rules would be highly uncertain and unidentified benefits.

Another approach used to assess runoff control costs was presented by Schaffer et al. (1974). Their working model consisted of a small watershed in New York State. They developed predictive equations for estimating losses of nitrogen, phosphorus and soil. Once the losses were calculated, an economic analysis was done to determine the costs of farmers of reducing these losses by specific amounts. Results indicated significant costs to farmers if nutrient and soil losses were to be reduced by any substantial percentage.

One of the more obvious conclusions resulting from the various economic impact studies is that small farm units will suffer more costs per cow than larger units. This may force smaller units to either terminate their business or expand to take advantage of economies of size. Economies of size exist with all other farm systems, so there is a constant pressure to expand.

Stoll (1974) analyzed problems associated with expansion of Michigan dairy farms. Of the 47 herds studied, the problems cited in order of importance were: animal health, labor, heat detection and manure handling. Expanded farms experienced some production losses, increased culling, 13.1 percent increased veterinary usage during early expansion, and 8 percent increased calf losses during years one and two of expansion. Reproductive problems also increased significantly. Finally, nearly 68 percent of all expansions experienced cash flow problems lasting approximately two years with 10 percent of those being considered serious.

It appears that the assumptions used in many economic analyses are so rigid that there is no way to include changes in managerial effectiveness which may accompany many of the expansion projects. This is difficult to quantify, but it may explain some of the trends noted by Stoll (1974) and should be brought to the attention of the farmer who is considering expansion.

To summarize the economic impact of controlling agricultural pollution, certain conclusions can be drawn. First, more extensive pollution control measures are inevitable and agriculture must be prepared to comply. Second, waste handling is only one of many farm activities and is certainly not considered a revenue generating unit. Therefore, waste handling techniques will have to be selected which interfere minimally with other farm enterprises. This means multidisciplinary thinking is needed to develop the best total system.

Livestock Waste Handling System Selection and Comparison

Waste Handling Routines

The EPA guidelines and permit program prompted three main questions from livestock producers:

a. What are the standards to be met?
b. What systems are available to meet these standards?
c. How much will compliance cost?

Environmental Protection Agency guidelines were finalized by 1976, but even prior to that most farmers were aware of the standards relevant to point sources. Regarding non-point sources, however, the specific requirements to be followed have still not been fully formulated or published. Much speculation still exists about the specific nature of these controls.

Many authors have characterized the waste handling routine on livestock farms. Ogilvie et al. (1975) described the process as involving the following four basic steps: (1) collection of manure; (2) transfer to storage; (3) storage; and (4) transfer to land. Cluever and Lubinus (1977) and the Soil Conservation Service (1975) both presented on-farm waste handling routines very similar to Ogilvie et al. (1975). Each author described how, within each phase of the operation, a variety of equipment is available. The job then becomes one of choosing the various components of the complete system to produce a workable unit which is compatible with the farmer's capital and labor restrictions.

Several authors have examined viable components and systems and calculated their initial costs, operating costs, and labor needs. Johnson et al. (1972) reviewed many feasible systems on this basis. They examined herd size, barn styles, etc., in various geographic regions of the nation. Runoff problems varied greatly; open lots have greater compliance problems than other systems. Most dairies would have to invest in additional storage capacity if field spreading is to be done at times of the year when runoff would be minimal, i.e., before spring planting and immediately post harvest.

Graves (1975), in an update of an earlier report by Berge (1971), evaluated waste systems available for 50 and 100 cow herds. He described a daily haul system as having the lowest initial investment and a stacking system for solids had the lowest total annual cost. Below building tank systems cost the most, but the cost of the floor was not included. Slotted floor units were considered to be less expensive than below building tank systems. This was due mainly to no expenditures for alley cleaning equipment. On a total annual cost basis stacking cost the least while tanks or silo systems were the most expensive. The high annual costs of ownership assoicated with liquid systems more than offset the labor savings.

Hoglund (1976) developed investment costs, annual costs, labor needs, tractor power and electrical energy requirements for several waste management options designed for 40 to 200 cow herds. In all cases below building storage proved to be the most expensive.

Selection of Components for a Complete Waste Handling System

Within each phase of a waste system many different components are capable of fulfilling the job requirements. The main differences among components are their labor needs, energy consumption or initial cost. The technique of selecting components and building a system has been discussed by various authors. The objective is usually to assemble a system for the least initial cost, least annual costs or least labor.

When evaluating time to do a particular job, techniques such as PERT (Program Evaluation and Review Technique) or SPNA (Shortest Path Network Analysis) have application. Hanratty (1975) outlined PERT and its mode of application. Use of this technique allows computation of the earliest completion time of a project by selection of components which use the least time.

Ogilvie et al. (1975), using SPNA, determined least cost swine and dairy waste handling systems. They figured the fixed, variable and labor costs for 100 potentially usable components and on this basis calculated a least cost network. Economies of size were also noted for the system studied. The high fixed costs of liquid systems made total costs less favorable for larger herds, but variable costs of liquid units ranged from 50 to 70 percent of the variable costs of all other systems over all herd sizes considered.

Safley (1974), using what he termed "network analysis," conducted a study similar to that of Ogilvie et al. (1975). His program allowed a large number of components to be interchanged and the initial and annual costs were calculated for each complete system as well as the labor requirements. With this method, oxidation ditch systems and covered manure storage proved the most expensive to build and operate, while daily haul and outdoor stacks were the cheapest.

Safley and Price (1976) added to the network analysis by incorporating a factor for manure nutrient value into the various systems. This fertilizer value was then subtracted from the operating costs to give a value for "net system cost per year." By using this method any system which had the capacity to retain nutrients would be favored. Systems with daily haul or outdoor stacks still ranked high due to their low initial investment, while liquid systems with injection had the highest fertilizer value. Based on the network analysis Safley (1977) had one very sound conclusion. He stated that there is no one "best" system for all farms and that the decision for system choice depends on a combination of factors such as net annual costs, personal preference, odor control and management requirements.

Selection of a "Best" Waste Handling System

Despite Safley's (1977) statement that there is no one "best" system, several authors have attempted to define one (Pherson, 1974; Forster, 1974; Good, 1972). Their analysis techniques have used simulation or linear programming and, in certain cases, the two have been used in combination. In such situations "best" is generally reserved for that system which either minimizes costs or labor associated with waste handling or allows maximization of farm profits. When the criteria for systems comparisons are costs, labor needs or energy requirements, the programs work well. However, when the criteria for selection become more abstract (i.e., water quality, air quality or aesthetics), such techniques are less feasible.

Whereas the literature cited in the previous section did not concern itself with labor or capital restrictions, several optimizing routines have been devised which do. Amir and Ogilvie (1977), working with swine waste systems, constructed a model to choose the best combination of components to minimize annual operating costs.

Their results showed different systems were optimum for different herd sizes but in all cases a fully slotted floor with underfloor tanks, pump and tanker was the second best choice. No inverse relationship was found between capital invested and the required manpower.

Safley et al. (1977) extended their previously cited work by devising an optimization routine for dairy manure handling systems based on linear programming techniques. The model was for a specific herd size and designed to examine a complete year. The object of the model was to minimize the cost of manure handling. Those factors which were constrained were labor, energy, herd size, land available and fertilizer value of manure. Solution of their model indicated a daily haul system had the lowest annual operating costs.

Mote and Taiganides (1975) simulated a swine farm and devised subroutines for each component that influenced the disposal of wastes. The following subroutines were included:

1. Waste production rate for a specific swine population
2. Waste storage
3. Soil trafficability
4. Field application of waste

The program called for field application when the storage unit reached a preestablished level, but before hauling commenced, soil conditions, crop growth and previous waste application had to be checked. If for any reason the waste could not be hauled, the excess was considered overflow and assigned a cost.

Two problems were noted. Large storage units which were allowed to completely fill up tended to need emptying when soil trafficability was poor or crop development prohibited spreading. The second problem was the need for cropping programs which included some land available for waste application. Cropping programs with all corn proved to be the worst in this regard for swine operations. Although not an optimization program, this model did consider all phases of the farm operation and their interaction.

As was indicated previously, enterprise interdependence is an important consideration in systems design. Not only is the total labor required critical, but more importantly, when is it required? With waste handling, the goal is to build a system which permits the farmer to minimize labor competition with other jobs both on a daily and seasonal basis.

Pherson (1974) recognized this situation when he examined ways of defining the optimal beef farmer response to Minnesota environmental regulations. He dealt with both direct and indirect costs associated with compliance and, using a whole farm analysis approach, attempted to maximize profits. Indirect costs were crop yield reduction due to late planting or harvesting because of the necessity of having to dispose of animal wastes at critical times. Pherson (1974) used linear programming to maximize profits when options were available on housing styles, cropping plans, feeding calves or yearlings, and waste handling techniques. Linear program modelling allowed the development of a year-round schedule for all activities including planting schedules, and the waste system was then matched to best fit other farm operations.

Results indicated a slotted floor, liquid system generated the greatest returns to labor and the solid waste systems ranked second. Pherson suggested the following reasons for this ranking:

1. Slotted floors seemed to have a faster cattle turnover rate.
2. No bedding is necessary.
3. Earlier planting and harvesting was possible due to more rapid waste handling.

This approach considered interactions among various farm operations and timeliness of these operations as important factors. A premium was placed on systems which allowed cattlemen to get onto cropland early in the spring and devote time to cropping. Similarly, waste systems which detracted minimally from harvesting routines were rated higher. Other systems were recognized to be so inflexible that competition resulted between them and other farm routines. Such systems were penalized by suffering increased indirect costs. The method used by Pherson (1974) combines elements of maximizing returns and constructing compatible enterprises on a whole farm basis.

To summarize a review of the literature, it is clear that federal and state pollution regulations, proximity to navigable waterways and non-farm rural residents, farm expansion and system convenience are major factors that will need to be considered in evaluating existing and future waste handling systems. Safley (1974) concluded that no "best" system exists for the dairy industry. Furthermore, each unit must be constructed in a manner to accommodate the personal preferences of individual dairymen. The criteria by which dairy farmers select a system are numerous. However, it appears the following list encompasses most of these factors: (a) total initial cost; (b) daily labor requirements; (c) peak labor demands; and, when they occur, (d) energy demands; (e) maintenance needs; and (f) nutrient conserving ability of the system. The main problem confronting dairymen is not having an organized method to incorporate selected evaluation criteria so that comparisons of several complete units can be made with little or no previous knowledge about actual systems.

RESEARCH OBJECTIVES

It has been previously noted that the number of total possible waste handling systems available to dairymen is large. The best way for an operator to appraise a system he is considering is to locate a functioning unit and spend time discussing it with the owners and observing the individual components during operation. Unfortunately, time often does not allow this and, when it does, only a few systems might be observed. With these considerations in mind, the main objectives of this research were as follows:

1. Identify components available for each phase of waste handling systems.

2. Collect up-to-date price and performance information for waste handling equipment.

3. Gather labor data for equipment usable at each phase of the waste handling process.

4. Develop or adapt a methodology which would allow large numbers of feasible systems to be assembled and analyzed on the basis of initial cost, energy and labor needs, nutrient conserving ability, annual total costs and net annual costs.

5. Evaluate and compare systems and individual components over various herd sizes.

RESEARCH METHODS AND PROCEDURES

The ability to synthesize large numbers of functional waste handling systems from individual components and subsequently compare them depends on two factors. The first is a data base which accurately represents individual components, thus allowing construction of representative systems. Secondly, due to the large number of systems that potentially exist, the high speed computational ability of present-day computers must be utilized or otherwise time becomes a limiting factor when attempting to assemble and compare systems.

For the systems which shall be described later, data collection was needed for the following categories of factors:

a. Cost figures for equipment, labor, energy and bedding
b. Labor demands of various waste handling jobs
c. Energy needs of each task
d. Depreciation, interest, repair and insurance rates
e. Bedding requirements
f. Volumes and nutrient content of waste
g. Performance data for various equipment.

There exist in the literature large amounts of data pertaining to the previous list. Unfortunately, much of it is insufficiently documented or detailed to be of use to this project. Those studies which did report data with a detailed discussion of their collection methods and system design were utilized only when the present study failed to provide such information.

Labor and Bedding Requirements of Waste Handling Systems

Labor data for specific waste handling tasks are limited and often subject to interpretation due to inadequate descriptions of the methods used for data collection. MacLachlan (1966) and Safley (1974) have both published well documented labor statistics for various waste handling tasks. MWPS-11 (1972) has also published labor requirements for various irrigation methods when used for handling animal wastes. These three reports comprise the bulk of usable labor data pertaining to handling of animal wastes.

In order to establish a sizable data base on labor needs of waste handling components, a survey was conducted on 35 Michigan dairy farms with 100 or more milking cows. This lower limit in herd size was chosen due to the large number of dairy herd expansions which culminate with that number of milking cows. A second reason was that most expansion projects involve construction of new facilities capable of housing increased cattle numbers. Expansion minded dairymen usually attempt to examine feasible alternatives and during this planning stage the only restrictions are those which are self-imposed.

Farm Study of Labor and Bedding Needs of Waste Handling Systems

The main study involved 32 dairymen in Clinton County, located 20 to 30 miles north of the Michigan State University campus.

Farmers were selected through the recommendations of the Clinton County Extension agents who were familiar with the county dairymen. The only selection criterion was that dairymen have approximately 100 or more milking cows. The waste handling systems in use were expected to represent a majority of the system components and systems most frequently observed for such herd sizes. With 32 farms on the study, sufficient numbers of each system component were anticipated for the most commonly used equipment to allow statistical comparisons.

Location of Farms

The dairymen identified by the county agents were located in each of the various townships within the county. In order to facilitate the process of identifying each farm, where it was located, and adjacency to other dairymen, a county platt book was purchased and each dairyman's location was identified and marked.

Questionnaire and Arranging for Interview

Prior to actually identifying specific farms, a questionnaire was prepared for use at each farm. It was designed to gather most of the relevant information about each dairyman's waste handling technique. The questions as they appeared in the questionnaire are listed in Appendix Table A.1. This material was not sent directly to the dairymen; rather, it was prefaced by a letter of introduction explaining what the project involved and who was conducting it. Subsequent to the preface letter, each farmer was telephoned and the intent of the project was again explained and a farm visit request was made. If the farmer was unwilling to participate for whatever reason, he was not coerced into it; rather, he was thanked for his time and it was suggested that the results of the study might eventually be of some assistance to him.

It was expected that a two or three hour block of time would be required for each farm visit, so at best three visits per day would be the maximum. Prior to calling to arrange for an interview, the farm locations within each township were noted. This allowed dairymen in the same vicinity to be scheduled for interviews on the same day and thus reduced the miles driven between interviews. All interviews were to be conducted in July and August, and this meant a schedule which had to avoid conflicts with haying, wheat harvest and vacations.

The time gap between the telephone call and farm visit was important due to the tendency of farmers to forget appointments. Within two days of the phone call they still anticipated the visit, but by day four their reaction was much less positive, nearly surprise in some cases. When a dairyman expected the interviewer's arrival, he was generally prepared to give his time freely, but when he was a bit unprepared, it usually required some diplomacy to get him into the proper mood to cooperate and participate fully.

On Farm Interview

The previously described telephone contact established a day and a specific time for the interview. First interviews of the day were generally scheduled for 8:30 or 9 a.m. Most dairymen had finished milking, eaten breakfast and were cleaning up by this time. Initially a second morning visit was attempted, but farmers enjoy talking and so usually only one morning interview was completed. A second visit was scheduled with another farm at 1 p.m. and, if possible, a third was arranged for 3 p.m. Many dairymen start milking about 3:30 p.m., so this time slot was not always used. A self-imposed factor in the interview procedure was punctuality. Being punctual did not force alterations in the farmer's schedule, established a degree of confidence and allowed for a more organized interview. Farm operators are extremely busy and plagued by many unexpected interruptions, so an interviewer should not further complicate a dairyman's schedule.

The farm interview was intended to be conducted directly with the individuals involved with waste handling. In many cases this was a son, partner or hired man. In such cases, both the owner and assistant were involved in the interview. In no instance was an interview conducted without first talking to the owner. Most owners also needed reassuring at the outset that all information was to be kept confidential and we only wanted data pertaining to their waste handling system.

The farm visit was not to gather time-motion data on various waste handling chores. Rather, the laborer was quizzed regarding how much labor and time each job required and what equipment was used for each job. It was felt that each worker routinely did the same job over a period of months or years and consequently was able to provide sufficiently accurate data for each event. In many cases farmers would elaborate on an answer and such comments were included if pertinent.

Initially 32 farms were available, but due to rejections and farms that had too few cows, the final number of usable herds was 25. The raw data were summarized and are presented in the results and discussion section.

Equipment Cost and Performance Survey

In order to price complete waste handling systems, individual component prices were necessary. New equipment prices are subject to wide ranges depending on equipment size, options selected and terms of sale. For this work prices reflect factory prices on new equipment, sized and equipped in a comparable manner to that which was described by dairymen in the farm survey. As an example, the farm survey indicated most dairymen with solids handling systems used a 280 bushel capacity solids spreader equipped with tandem wheels and a hydraulic end gate. Consequently, performance and price information was solicited for this spreader.

Each January, Dairy Herd Management magazine publishes an extensive list of manufacturers and dealers of farm equipment according to type of use. Using this listing, approximately 60 firms which sell waste handling equipment were identified. Following company identification, a general cover letter was prepared to accompany the requests for information. The contents specified why such information was needed and what use would be made of information provided. In addition, it was made clear in the letter that specific company names would not be endorsed or used in the study but that all cooperating firms would be acknowledged. This letter is presented in Appendix Table A.2.

Accompanying the letter to each firm was a standardized list of the various types of equipment for which cost and performance figures were required. When this list was sent to specific firms, those pieces of equipment manufactured by that company were checked on the list and this indicated to the letter recipients what information was being requested (Appendix Table A.3).

As the equipment information was supplied by various companies, it was summarized according to category of use on the basis of cost and, in the case of powered equipment, on the basis of fuel consumption, i.e., garden tractors, skidsteer loaders, etc.

Another extensive source of information on tractors and some other equipment was the Official Guide Tractors and Farm Equipment (1977). It is issued quarterly and contains cost figures on new and used equipment as well as fuel consumption and horsepower ratings of both later and earlier model tractors. Solids spreaders were also listed in this guide. This source provided data for fuel consumption and initial price of the various sized tractors used in the systems.

These two sources provided most of the equipment specifications. Various local dealers were also contacted, but in most cases they had no interest in the project and consequently were usually reluctant to provide even minimal information. There were some very cooperative dealers also, but many were either too busy or too suspicious to provide necessary data.

Computer Program Development for Comparison of Waste Handling Systems

Ogilvie et al. (1975) outlined the process of handling animal wastes on the farm. Their concepts of this procedure involved up to seven distinct steps. Within each step there are several possible options. If a farmer were to build a new system, he would need to select from among various options for each phase of the system. The decision would be based on few or no restrictions if a completely new facility is constructed, or it might include existing equipment combined with new options to create a new unit. Table 2 presents the various phases of a complete waste handling system for dairy which were utilized in this project. Each phase also has a designated section number.

Table 2.--Phases of dairy waste handling systems.

Waste Handling Phases	Section Number
1. Stall type	01
2. Bedding material and method of distribution to stalls	02
3. Floor style	03
4. Floor cleaning procedure	04
5. Movement to storage	05
6. Storage	06
7. Storage agitation and emptying	07
8. Movement to field and land application	08

Phases 1 and 2 are not considered by most authors. However, it was felt they are important here because they are involved in decision making and a decision influences subsequent option selection; thus, they were included. An example of their importance is illustrated by assuming sand is the desired bedding material. Sand's lack of absorbancy makes it a poor choice for concrete stalls and it is incompatible with liquid systems.

Following the selection of the waste handling phases, consideration was next given to available options within each phase. Table 3 lists all options for liquid and solids systems. This list formed a table of option titles which were stored as a permanent file at the MSU computer center under the permanent file name, WITITLES.

The second aspect of the decision model involved development of a table which listed only feasible option combinations from adjoining phases and eliminated impossible pairings regardless of reason. Elimination of a solids spreader from a liquids system using an impellor pump for storage emptying is an example.

The starting point for this task commenced with the assignment of a number (Section Number) to each waste handling phase and to each option (Option Number) with each phase (Table 3). As can be seen, a two digit number was assigned to designate individual phases of the system and they were numbered as follows: Stall Type (01), Bedding and Method of Distribution (02), Floor Style (03), Alley Cleaning Systems (04), Movement to Storage (05), Storage (06),

Table 3.--System phases and available options.

Waste Handling Phase	Section Number	Available Options	Option Number
Stall Type	01	Clay	01
		Concrete	02
Bedding Material and Distribution Method	02	Sawdust (SKS)*	01
		Sawdust (FEL)**	02
		Chopped Straw (SKS)	03
		Chopped Straw (FEL)	04
		Sand (SKS)	05
		Sand (FEL)	06
		Rubber Mats, Shavings (SKS)	07
		Rubber Mats, Shavings (FEL)	08
		Rubber Mats, Chopped Straw (SKS)	09
		Rubber Mats, Chopped Straw (FEL)	10
Floor Style	03	Solid	01
		Slatted	02
Floor Cleaning	04	Automatic Alley Scraper	01
		Skidsteer Loader	02
		Garden Tractor	03
		Utility Tractor & Blade	04
		Flushing	05
		None	06
Movement to Storage	05	Cross Conveyor & Short Elevator	01
		Cross Conveyor & Stacker	02
		Piston Pump & PVC Pipe	03
		Cross Conveyor, Piston Pump, PVC	04
		Cross Conveyor, Compressed Air Unit, PVC	05
		Concrete Ramp	06
		None	07
		Concrete Flume	08
		None (Slatted Floor)	09
Storage	06	Cement Silo	01
		Steel Silo	02
		Earth Basin (Solids) & Liquids Basin	03
		Earth Basin Liquids	04
		Paved Slurry Basic	05
		Concrete Pit Under Slats	06
		Concrete Tank Under Barn	07
		None	08
		Settling Basin & Lagoon	09

Table 3.--Continued.

Waste Handling Phase	Section Number	Available Options	Option Number
Agitation and Emptying	07	Impellor Pump	01
		Front End Loader	02
		Skidsteer Loader	03
		Self-Loading Spreader	04
		None	05
		Impellor & Irrigation Pumps	06
Movement to Field and Land Application	08	Self-Loading Spreader	01
		Tanker (3200 gal.)	02
		Tanker & 4-Row Injectors	03
		Solids Spreader	04
		Aluminum Pipe & Stationary Big Gun Sprinkler	05
		Aluminum Pipe, Flexible Hose Traveling Gun Sprinkler	06

*SKS = skidsteer

**FEL = Front End Loader

Agitation and Storage Unloading (07), and Movement to Field and Land Application (08).

Each option within a phase of the system was then numbered with a two digit number, 01 being Option 1 in each phase. For example, Alley Cleaning Systems (04) has six options numbered 01 to 06, and Movement to Storage (05) has options numbered 01 to 09. This procedure was followed for all eight system phases.

The next step involved creation of all feasible option-option combinations beginning with Phase 01, Option 01, and Phase 02, Option 01, and continuing through Phase 07, Option 06 and Phase

08, Option 06. By doing this, all feasible stall/bedding, bedding/floor, floor/cleaning method, cleaning method/move to storage, move to storage/storage, storage/storage emptying, and storage emptying/movement to field combination--were assembled. Table 4 is an example of the option-option combinations. These actual examples represent 12 of the 103 total combinations.

Table 4.--Feasible option combinations.

	Section Number	Previous Option	New Option	Actual Code of New Option
1	01	01	01	01
2	01	01	02	02
3	02	01	01	10
4	02	01	02	11
5	02	01	03	12
6	02	01	04	13
7	02	01	05	14
8	02	01	06	15
9	02	02	01	10
10	02	02	02	11
11	02	02	03	12
12	02	02	04	13

For an explanation of how the option combinations are listed, an examination of lines 1, 2, 3 and 9 from Table 4 is necessary. In lines 1 and 2, section number 01 refers to stall type as listed in Table 2. Since stall type selection represents the initial decision, there is no previous option, but 01 is entered in this slot as a filler. The new option code, 01, designates the first option within stall type and in this case refers to clay stalls. Line 2 is identical except that new option 02 is used, which represents concrete stalls. The actual code of the new option refers to the permanent numerical code given each option and is reported in Table 3. In the case of the first two lines, the new option numerical code and the actual code of the option are identical because of stalls being the starting point of system description.

Line 3 presents the first option combination between two phases, stall type and bedding type. Previous option 01 refers to clay stalls from line 1 and new option 01 designates the first compatible bedding source (sawdust [skidsteer]), which has as its actual code the numerical designation, 10. All feasible clay stall, bedding type combinations are subsequently defined in a similar manner. Line 9 reflects a switch to a new stall type. It is still in section number 02, but concrete stalls (02) now become the previous option. The first compatible new option (01) again refers to sawdust bedding with a skidsteer, and in Table 4 this is coded 10. This process was repeated until all concrete stall, bedding combinations were established. It then advanced to section 03, floor style, and all compatible floor styles and bedding combinations were listed. The establishment of combinations was completed when the last emptying of storage, movement to field pairing had been constructed. All option combinations were stored for future use under the permanent file name, WICODES.

Construction and Implementation of Interactive Program

Prior discussion described various phases and options available for waste handling systems. In this section, the equations used to describe individual options and complete systems shall be discussed. In the research objectives section, a list was formulated which represented the majority of factors used by dairymen in selecting a manure management scheme. Based on that list, a series of equations was developed for each option which defined initial cost, or DIRTI costs, energy usage and cost, labor requirements and cost, bedding needs, annual costs for operating and total annual costs, the nutritive value of the waste material and net annual costs. The complete series of equations appears in Appendix Table B.1.

Variable Names and Descriptive Equations

Each factor used to describe some aspect of a particular option was assigned a variable name which in most cases was mnemonic. Table 5 lists several variable names together with a description.

Table 5.--Variable names and descriptions.

Variable Name	Description
CSLABOR	Labor costs per hour
STDIRTR	Stall DIRTI rate
STWCSTD	Daily straw costs
UTOPCSY	Utility tractor operating costs/year
EBSDIGC	Cost/cubic yard to dig an earthen basin

Variable names were limited to seven digits, and if they referred to an integer number they commenced with the letters, I, J, K, L, M, or N as is the rule for standard Fortran language.

Many of the variable names describe some aspect of an option that is constant, i.e., amount of urine and feces produced per cow per day. Although there is some variation in this factor, it is often assumed to be fixed. Other variable names define rates of production or usage. Two examples from the slotted floor section of Appendix B illustrate this:

(a) SLOTCFT = 2.25

(b) SLFDEPR = 0.05

The first example defines the cost of a square foot of slatted floor at $2.25, and item (b) describes the per annum depreciation rate as 5 percent. For each of the approximately 1400 variable names there is an accompanying comment statement describing each one. The variable name, SLOTCFT, described above is preceded in the program by a statement which reads: cost of slotted floor alley ($/sq. ft.). The values associated with each fixed variable were derived primarily from data gathered in the two studies described earlier. In some instances literature values were used when the survey data failed to provide them.

The second type of equation describes values derived from calculations involving multiple variables. In all cases such equations and the associated variable name define a total for cost, labor, etc., relative to a specific herd size. An example from Appendix Table B.1 is:

$$VOLMSTW = TVMANDY + WSMHTFT + VOLSTDY$$

In this case, VOLMSTW describes the total daily volume of manure, milk, house waste and straw entering the manure storage unit. The variable name TVMANDY refers to the total daily volume of urine and feces, WSMHTFT designates the total daily volume of milkhouse wastes entering the storage unit, and VOLSTDY specifies the daily volume of straw.

With the completion of all the variable names used to describe the options, all the necessary components to build a complete waste handling system were available. The final essential element was a computer program which could assemble various systems in their entirety and describe them in designated terms. It was decided that the technique allowing the greatest flexibility and opportunity to personalize the systems was an interactive model which could be operated by an operator with a minimal amount of computer training. With this approach as a goal and the expert technical assistance of Dr. Roger Neitzel, the effort to develop such a program commenced.

The language chosen was Fortran. It was compatible with the CDC 6500 computer available at MSU and posed no problems in terms of writing the program. All inputs and outputs were dimensioned at the beginning of the program. Section titles and option titles from the WITITLES and file, and feasible options from the WICODES permanent file, were all read in according to the appropriate format. At this point with the interactive model, a user of this program receives a printed statement from the computer which specifies the program's cabilities. Table 6 is an example of the type of interaction that occurs between user and computer during operation of the program.

It can be seen in Table 6 how a decision at each phase forces the program to advance to the subsequent section and present compatible options. Option selection is made by typing in the appropriate three-digit code for the desired choice. Following this step the computer asks if you wish to use the option selected. If the reply is affirmative, it proceeds to the next section. If the response is negative, all options for that section will again be presented and the user can make an alternate choice.

Following the last decision in section 8, the operator is asked to indicate via a three-digit number how many cows the system is to accommodate. Finally, a choice of barn styles is allowed; either a two alley, four alley or a custom built facility can be

Table 6.--Sample run of interactive program.

This program calculates the cost associated with a particular waste management system.

There are eight sections of criteria needed to complete this task. The sections are as follows:

1 Stall type
2 Bedding type
3 Floor type
4 Alley cleaning systems
5 Movement to storage
6 Storage systems
7 Emptying and agitating equipment
8 Field transport and application

For each section there are several options. When prompted with an asterisk, type in the code for the option desired in I3 format, IE 002. For all possible options from this point on-type 000.

Section 1 Code	Stall Type Option
1	Clay stalls
2	Cement stalls

You wish to use clay stalls. Is that correct?
Type Y for Yes, N for No

Section 2 Code	Bedding Type Option
10	Sawdust (Skidsteer)
11	Sawdust (Front End Loader)
12	Chopped Straw (Skidsteer)
13	Chopped Straw (Front End Loader)
14	Sand (Skidsteer)
15	Sand (Front End Loader)

You wish to use Sawdust (Skidsteer). Is that correct?
Type Y for Yes, N for No.

Section 3 Code	Floor Type Option
20	Solid floor
21	Slatted floor

You wish to use solid floor. Is that correct?
Type Y for Yes, N for No.

Table 6.--Continued.

Section 4 Code	Alley Cleaning Systems Option	
30	Auto alley scraper	
31	Skidsteer	
32	Garden tractor	
33	Utility tractor	
34	Flushing	
You wish to use auto alley scraper. Type Y for Yes, N for No.		Is that correct?
Section 5 Code	Movement to Storage Option	
40	Cross conveyor and short elev	
41	Cross conveyor and stacker	
43	Cross conveyor ram and PVC	
44	Cross conveyor and air unit	
46	None	
You wish to use cross conveyor and stacker. Type Y for Yes, N for No.		Is that correct?
Section 6 Code	Storage Systems Option	
62	Earth basin solids and liquids B	
You wish to use earth basin solids and liquids B. Type Y for Yes, N for No.		Is that correct?
Section 7 Code	Emptying and Agitating Equipment Option	
81	Front end loader	
82	Skidsteer loader	
You wish to use skidsteer ladder. Type Y for Yes, N for No.		Is that correct?
Section 8 Code	Field Transport and Application Option	
103	Solids spreader	
You wish to use solids spreader. Type Y for Yes, N for No.		Is that correct?

utilized. Once the barn style has been designated, the user's input is complete and the program makes the appropriate calculations relative to costs, labor, energy, etc. In fact, calculations are not made for specific systems; rather, all calculations are made for a designated herd size and the calculated values are entered into appropriate arrays. Subsequent to this the operator receives a listing of the system options he previously selected. Finally, the appropriate figures for the system selected are taken from their array locations and printed out with explanatory headings, etc. A typical output from the program is demonstrated in Table 7.

After the complete system is listed as in Table 7, the program automatically readies itself for another possible run. All values which were calculated are zeroed out and the files containing WITITLES and WICODES are rewound to the beginning. Following this the operator is asked if he wants to analyze another system. An affirmative response starts the series of questions described in Table 6. If the response is negative, the interaction ends and the user is able to log out.

Creation of All Possible Systems

In addition to the need for an interactive computer model to create selected waste systems, it was also necessary to develop all possible systems for various herd sizes. This would then permit comparisons on the basis of labor, energy costs, etc. An operator prerogative was included in the program for this purpose. Following the presentation of the two stall choices, if the three-digit code

Table 7.--Output from computer run for typical system.

The following options have been selected for system number 1

Section	Component	Option
1	Stall type	Clay stalls
2	Bedding type	Sawdust (Skidsteer)
3	Floor type	Solid floor
4	Alley cleaning systems	Auto alley scraper
5	Movement to storage	Cross conveyor and stacker
6	Storage systems	Earth basin solids and liquids B
7	Emptying and agitating equipment	Skidsteer loader
8	Field transport and application	Solids spreader

Network analysis output for dairy waste handling systems.
Outputs are based on the number of cows in the herd: 100

System Components	Initial Costs	Annual Cost of Ownership PCT(DIRTI)	Annual DIRTI Totals
Stall type	1080.00	.14	242.55
Bedding material	90.03	0.00	345.60
Floor style	9625.00	.14	1299.38
Alley cleaning system	5042.00	.26	1326.05
Movement to storage	3241.50	.28	917.34
Storage system	14440.74	.15	2093.91
Unloading of storage	10500.00	0.00	193.45
Movement to field and application	5000.00	.25	1250.00
Total System Costs	49019.24	1.21	7668.27

	Yrly Mhrs of Labor Used (Comp-Event)	Yearly Labor Costs	Units of Energy Used Per Year (Comp-Event)
Stall Type	0.00	0.00	0.00
Bedding material	43.20	151.20	120.95
Floor style	0.00	0.00	0.00
Alley cleaning system	17.16	60.06	16118.40
Movement to storage	29.20	102.20	503.70
Storage system	0.00	0.00	0.00
Unloading of storage	24.18	84.63	67.71
Movement to field and application	87.54	306.39	418.56
Total System Costs	201.23	704.48	

Table 7.--Continued.

	Yearly Energy Costs (Comp-Event)	Yearly Bedding Used	Yearly Bedding Costs	Annual Costs (Comp-Event)
Stall type	0.00	0.00	0.00	242.55
Bedding material	70.16	78.84	1576.80	2143.76
Floor style	0.00	0.00	0.00	1299.38
Alley cleaning system	805.00	0.00	0.00	2191.11
Movement to storage	25.19	0.00	0.00	1044.73
Storage system	0.00	0.00	0.00	2093.91
Unloading of storage	39.27	0.00	0.00	317.35
Movement to field and application	217.65	0.00	0.00	2430.57
Total System Costs	1157.26	78.84	1576.80	11763.35
Yearly value of manure				5004.15
Net System Cost				6759.20

Do you want an analysis of another system?

000 was entered in place of either 001 or 002, all feasible systems would be constructed and non-feasible combinations deleted. Due to the large number of possible systems, the output was stored on tape for further reference with each system being coded for later identification.

RESULTS AND DISCUSSION

The results of this project shall be discussed in two general sections. The first section will deal with the farm survey and the cost and performance data acquired from the manufacturers of waste handling equipment. From the farm survey the discussion will center on type of equipment, type of storage and labor requirements of various waste handling tasks. The second section will deal with the initial cost, labor and energy requirements, nutrient conserving ability and net annual cost of the many systems which were generated by the computer program.

Farm Survey and Equipment Survey Information

General Discussion

Approximately 25 of the original 32 farms selected for the survey supplied usable data for the project. Farms were deleted for a variety of reasons, including (a) too few cows; (b) owners who did not agree to participate; and (c) inability to make contact with the farm operator or establish a mutually acceptable interview time. Table 8 summarizes the general characteristics of the 25 farms used. Herd size averaged 120 cows and ranged from 70 to 160 milking cows. This satisfied the initial requirement of a 100 cow average herd size. The daily labor force of three full-time men

Table 8.--General description of 25 participating farms.

Average number of cows	120 ± 39
Average daily labor force (full time)	3 ± .84
Confinement housing	8
Open lot with freestalls	17
Clay stalls	66%
Cement stalls	34%
Sawdust bedding	61%
Straw bedding	23%
Sand	16%
Storage--3 months or more	9
Liquid storage	3
Solids storage	6
Average hauling distance (miles)	.33 ± .20

usually included the owner, a son or relative and a full-time hired man or two. In several cases the work force consisted solely of family members. Farmers tend to avoid hired labor if possible, so full-time employees are kept to a minimum. It appeared that most farmers delegate the waste handling chores to sons or the hired man and opted to use their seniority to do other tasks.

Eight of the 25 facilities visited were confinement barns and only one of the eight was a warm enclosed building. All total confinement units had been built within the past seven years, while all facilities with outside lots were older. Most older barns had four or five 40 to 50 foot alleys which were perpendicular to the barn length and each alley was flanked by freestalls. New barns had two or four alleys which ran parallel to the barn length, the full length of the building. The new confinement facilities have no need for multiple access to an outside lot, so parallel alleys are more logical.

Clay or dirt bottomed stalls were favored by two-thirds of the dairymen and concrete base stalls were used by the others. Many farmers with clay stalls inquired about concrete stalls. Most were concerned that they would be too cold in the winter or they would cause cow discomfort. The main complaint from clay stall owners was the necessity to occasionally fix holes in the stall bottom caused by cows digging out dirt with their feet. This job was usually done twice yearly and involved about 15 minutes per stall to add fresh material and level out the dirt base.

Bedding Material

Sawdust (61 percent), straw (34 percent), and sand (16 percent) were the bedding materials used. Sawdust and shavings are still quite plentiful and inexpensive. Some operators only pay hauling costs and the material is free. If purchased, the price is $20 to $30 per ton delivered compared to $50 to $75 per ton for straw and $3.00 to $4.00 per cubic yard of sand. Sawdust is preferred due to ease of handling, price, and compatibility with both liquid and solid systems. Straw was used mainly in a chopped form with a few daily haul situations using long-stemmed baled straw.

Many dairymen grow oats or wheat and provide their own bedding material for the cost of processing and storage. Chopping the straw makes it pack better, provides more surface area for moisture absorption, it stays in the stalls better and is compatible with pumps used for moving manure slurries.

Sand was used on six farms. Those using it felt the cows stayed clean and its availability and cost also favored its use. The sand generally came from the immediate vicinity of the farm, and the cost of acquisition amounted to digging and hauling costs. Dairymen not using it questioned its ability to keep cattle clean and dry and its coldness in winter weather. Sand bedding was observed to have two limitations. With liquid systems it is very abrasive on pumps, causing accelerated wear, and in storage units it settles out to form a non-pumpable layer on the bottom. The second limitation was with a flushing unit. As cows drag sand out of the stalls it builds up in two or three days in sufficient quantities to divert the flow of water and lessen the efficiency of flush cleaning. This necessitates scraping the alleys with a tractor and blade two or three times weekly to remove the impediment to water flow.

Bedding of Freestalls

The movement of bedding material to stalls and into each stall is accomplished with a skidsteer loader or a utility tractor equipped with a front mounted bucket. These units generally do double duty by also cleaning the alleys. During the farm survey, dairymen were asked how frequently the stalls were rebedded, what equipment was used, how many people were involved, and how much time was required. Three observations were not included due to uniqueness. One added baled straw daily by hand, a second replaced the sawdust bedding every six months, while the third dairyman used an unloader trailer normally used for fence line feeding. It took him 20 minutes weekly to bed 220 stalls. Due to lack of data on this bedding method, it was not used as an option, but due to its labor-saving potential it should eventually be included. Table 9 summarizes the 22 observations on frequency of adding bedding. Sawdust was the most commonly used bedding material. In Table 10 the average interval between addition of fresh material is shown for the three bedding types.

Table 9.--Frequency of bedding stalls with different bedding material.

Bedding Replacement Intervals (Weeks)	No. Observations/Bedding Material			Total
	Sand	Sawdust	Straw	
0.5	-	-	1	1
1.0	1	3	3	7
1.5	-	1	-	1
2.0	2	2	1	5
3.0	-	-	-	0
4.0	1	6	1	8
	4	12	6	22

Table 10.--Replacement interval for bedding (weeks).

	Bedding Type			All Types
	Sand	Sawdust	Straw	
Replacement Interval (Weeks)	2.3 ± 1.3	2.7 ± 1.4	1.6 ± 1.3	2.3 ± 1.4

Straw is replaced more often than either sand or shavings or sawdust. Two explanations for this are possible. First, straw, even when chopped, is more easily pushed out of stall bottoms by cows than either sand or sawdust. Second, straw is generally stored on the farm near the barns, which allows easy access to it. Usually a one-year supply is readily available. Both sand and sawdust are generally procured from a more distant source in quantities sufficient to bed all stalls once and when again needed this procedure is repeated. This inconvenience often deters dairymen from bedding stalls more often, especially if other jobs are pressing.

Time and Labor to Rebed Stalls

According to Table 10, bedding material is routinely added to stalls about every two weeks on the average. The time and manpower required are shown in Tables 11-A and 11-B.

Due to only four observations with sand bedding, no major conclusions can be drawn. It appears that use of a skidsteer loader and two men is an efficient combination. Those dairymen using sand bedding and skidsteer loaders all indicated the maneuverability of the skidsteer allowed the sand to be dumped directly into the stalls.

Table 11.A.--Time and men required to add sand bedding.

Farm Number	Loader Used	Hours to Add Sand to All Stalls	Number of Stalls	Number of Men
1	Front End loader	6.00	85	1
2	Skidsteer	0.75	120	2
3	Skidsteer	1.00	110	2
4	Skidsteer	1.00	105	2
		$\bar{X}$ = 2.2 ± 2.5	$\bar{X}$ = 105 ± 14.7	$\bar{X}$ = 1.75 ± 0.5

Table 11.B.--Time and men required to add straw or sawdust twice monthly to stalls.

Farm Number	Loader Used	Time to Rebed Stalls Twice Monthly (Hrs)	Number of Stalls	Men Involved
1	FEL*	0.75	110	3
2	FEL	1.50	65	1
3	FEL	4.00	180	1
4	FEL	5.00	90	1
5	FEL	1.00	110	4
6	SKS**	1.00	100	1
7	FEL	1.50	80	3
8	FEL	2.50	90	1
9	SKS	1.00	85	2
10	FEL	1.50	80	3
11	SKS	0.50	110	2
12	SKS	2.00	115	2
13	FEL	1.00	75	2
14	SKS	4.00	90	2
15	SKS	1.00	115	2
16	FEL	3.00	145	1
		$\bar{X}$=1.95 ± 1.36	$\bar{X}$=102.5 ± 28.58	$\bar{X}$=1.94 ± .93

*FEL = Front end loader; **SKS = Skidsteer

This greatly reduced hand labor involved with spreading the heavy sand. The front end loader, being physically larger and less maneuverable, does not allow the sand to be optimally placed, resulting in a good deal of hand labor. The use of one man with a front end loader for sand bedding appears to be slow and inefficient.

Chopped straw and sawdust were combined in Table 11.B due to their similar bulkiness and handling characteristics. Two men may be involved in the task, but one man doing it alone is also common. However, the total time involved with one man is usually somewhat higher. With two men doing the bedding, the average time for 102 stalls is nearly two hours using either a skidsteer or front end loader. The data of Table 11.B are expressed according to type of loader used in Tables 12.A and 12.B.

Table 12.A.--Time and men required to bed stalls with chopped straw or sawdust using a skidsteer loader.

Hours Required to Bed Stalls	Number of Stalls	Men Involved	Man-Hours Per Stall
1.0	100	1	.01
1.0	85	2	.02
0.5	110	2	.01
2.0	115	2	.03
4.0	90	2	.09
1.0	115	2	.02

Table 12.B.--Time and men required to bed stalls with chopped straw or sawdust using a front end loader.

Hours Required to Bed Stalls	Number of Stalls	Men Involved	Man-Hours Per Stall
0.75	110	3	.02
1.50	65	1	.02
4.00	180	1	.02
5.00	90	1	.06
1.00	110	4	.04
1.50	80	3	.06
2.50	90	1	.03
1.50	80	3	.06
1.00	75	2	.03
3.00	145	1	.02
2.18	102.5	2.0	0.04

It appears that use of a skidsteer slightly reduces the time required to bed freestalls, but both systems average two men when rebedding. Leveling and distributing the sawdust or straw is not a strenuous task, thus leaving the laborer with small amounts of idle time between bucket loads. This open time is not sufficient, however, to allow anything else to be accomplished due to its limited duration.

When the bedding time was computed on a monthly basis as time per stall, the average was .04 hours/stall/month using two people or .08 manhours/stall/month.

Alley Cleaning Systems

Among the survey farms, six were confinement facilities using some type of tractor scraper to clean the alleys, and one utilized an automatic alley scraper. The six tractor scraped facilities were combined with two other such farms which were part of an earlier study comparing alternate alley cleaning systems. Table 13 summarizes the alley dimensions of the barns, the type of equipment used to clean alleys and the time required for cleaning using the various equipment available.

Table 13 reveals that confinement barns with either two or four alleys are the most common for herd sizes of 80 to 160 cows. Alley length is a function of cattle numbers and number of alleys, and in this study the range was 150 feet to 320 feet. The shorter barns allow manure to be pushed to one end of the facility for removal or movement to storage. When barn lengths approach 200 feet, the tendency is to scrape one-half the alley to each end or from each end to the middle. It may be pushed into a pit or tank under the barn, off a ramp directly into a storage basin, or into a cross conveyor for movement to a stacker or piston pump. One problem with scraping long alleys all to one end is that the manure generally spills over or off the blade, thus reducing scraping efficiency. This situation is more of a problem for automatic alley scrapers than tractor scrapers.

Alleys in five of the eight confinement facilities were scraped twice daily. Confinement lessens floor space per animal,

Table 13.--Tractor scraping of confinement barn alleys.

Farm No.	Number of Alleys	Scrapings/ Day	Minutes/ Alley	Minutes/ Scraping Event	Total Time/ Day	Alley Length	Tractor Type
1	2	1	10	20	20	280	Utility
2	2	1	15	30	30	320	Utility
3	2	2	6	12	24	150	Utility
4	4	2	4	15	30	150	Skidsteer
5	2	2	10	20	40	150	Utility
6	2	1	15	30	30	260	Skidsteer
7	2	2	9	18	36	184	Garden
8	2	2	10	20	40	175	Garden
	$\overline{X} = 2.25$	$\overline{X} = 1.6 \pm 5$	$\overline{X} = 9.9 \pm 3.8$	$\overline{X} = 20.6 \pm 6.4$	$\overline{X} = 31.3 \pm 7.2$	$\overline{X} = 208.6 \pm 67.8$	

and their feet are always wet. Manure accumulation per square foot of area is greater in confinement barns and this factor, combined with concern for cow cleanliness and foot problems, has many dairymen convinced that twice daily scraping is essential. Greater incidence of foot problems has not been substantiated, and stall cleanliness is probably more of a determinant of cow cleanliness. Finally, clean floors make the barn more presentable to visitors and to many dairymen this is important enough to justify the frequent cleaning with an alley scraper.

Cleaning time per alley averaged about 10 minutes regardless of the type of tractor used or alley length. Most barn lengths range from 170 to 250 feet and, as previously mentioned, long alleys usually are scraped in halves. Consequently, turning ability is important to speed of cleaning in many circumstances. Each of the three tractor types have specific advantages which offset each other. The utility tractor is less maneuverable but has a wider blade and is faster than either skidsteers or garden tractors. The skidsteer and garden tractor are more maneuverable than utility tractors when tight turns are necessary. Apart from the tractors themselves, alley design is the largest factor determining speed of cleaning. If curbs are straight or have no abutments projecting into the alley, the job is easy to complete in a short time. In many barns such obstructions exist which may increase cleaning time. With tractor scraping as described in this section, daily scraping time would be approximately 40 minutes, or 243 hours annually.

The utility tractors being used for alley cleaning are not the old, 25 HP Fords or Fergusons of 25 years ago. The average horsepower rating was 53 for utility tractors and 38 for skidsteers. Such utility tractors are popular due to their versatility for scraping, loading, moving wagons and use on PTO driven equipment. The skidsteer is limited mainly to scraping and loading operations and this makes it difficult for many dairymen to justify owning one.

Table 14 presents the cost for new utility tractors and skidsteer loaders of the horsepower rating previously described. The initial cost of the utility tractor and blade is about $1,100 more than a skidsteer loader and, partly due to its greater horsepower rating, consumes more fuel. This initial price was charged entirely to the waste handling routine, but ownership costs, etc., were charged only according to the amount of time the unit was used on a yearly basis in doing that job, i.e., scraping, loading, etc. Charging all of the initial cost to waste handling is meant only to show how much such equipment would cost if it had to be purchased. Ownership costs are a more realistic view of machinery costs as it takes into consideration the time that machine is used for a particular job. Based on 500 to 600 yearly hours of use, the hourly fixed costs when using the utility tractor were calculated to be approximately $7.75 and for skidsteer loaders it was $8.00 per hour. This higher hourly charge for the skidsteer reflects the lesser number of hours the machine is utilized.

Table 14.--Cost and energy usage of scraping tractors (1978 figures).

50-60 HP Utility Tractor & Blade	Initial Cost ($)	Fuel Used Per Hour	35-40 HP Skidsteer	Initial Cost ($)	Fuel Used Per Hour
1	11,415	4.2	1	10,295	2.8
2	12,876	4.1	2	8,645	3.2
3	10,823	-	3	8,635	3.4
4	12,092	4.0	4	8,496	3.1
5	11,353	3.9	5	10,100	3.2
6	11,635	4.0	6	9,793	-
7	11,337	4.2	7	12,896	2.6
8	11,350	4.3	8	13,587	2.5
	$\overline{X}$=11610.13 ± 621.20	$\overline{X}$=4.10 ± 0.14		$\overline{X}$=10,435.73 ± 1,864.84	$\overline{X}$=2.95 ± 0.32

Automatic Alley Scrapers For Confinement Housing

When cleaning freestall barn alleys with tractor scrapers, the routine usually involves moving one group of cows into the holding pen for milking and then scraping the alley which the cows just vacated. Because this routine requires labor and the use of a fairly expensive tractor, some dairymen have looked for alternatives. Several firms currently manufacture automated alley scrapers which generally consist of some type of scraper blade attached to a continuous chain or cable set in a groove in the concrete floor that runs the entire length of the barn. This continuous chain is

pulled by a drive unit similar to that in a gutter cleaner. It generally is powered by an instant reversing 2.0 horsepower electric motor. The blades may be either rigid or folding. Both types of scrapers are illustrated in Figures 1A and 1B.

The blade is pulled down the alley at eight to ten feet per minute and the manure is pushed along in front of it. This speed is slow enough to allow cattle to step over it or move out of the way with no problem. Such cleaners generally have a safety switch designed to automatically stop the motor if the blade is obstructed, such as with a cow lying in the alley. Despite this safeguard, some mishaps have still occurred. The alley cleaners may be operated continuously, manually or with a time clock set for any interval desired. The latter is the most commonly observed.

Such scrapers allow floors to be cleaned frequently without moving the cows or disturbing them. They save labor and keep floors quite clean depending on the scraping interval. They are well suited for high density housing situations where excessive manure buildup could pose a problem. Also, cattle do not have to be moved out during cleaning. They are limited, however, by barn lengths exceeding 200 feet due to blade overloading. In such cases nearly continuous operation is required which results in increased wear and greater energy consumption. In most cases observed the units ran approximately 10 to 12 hours per day, or about one-half hour out of each hour.

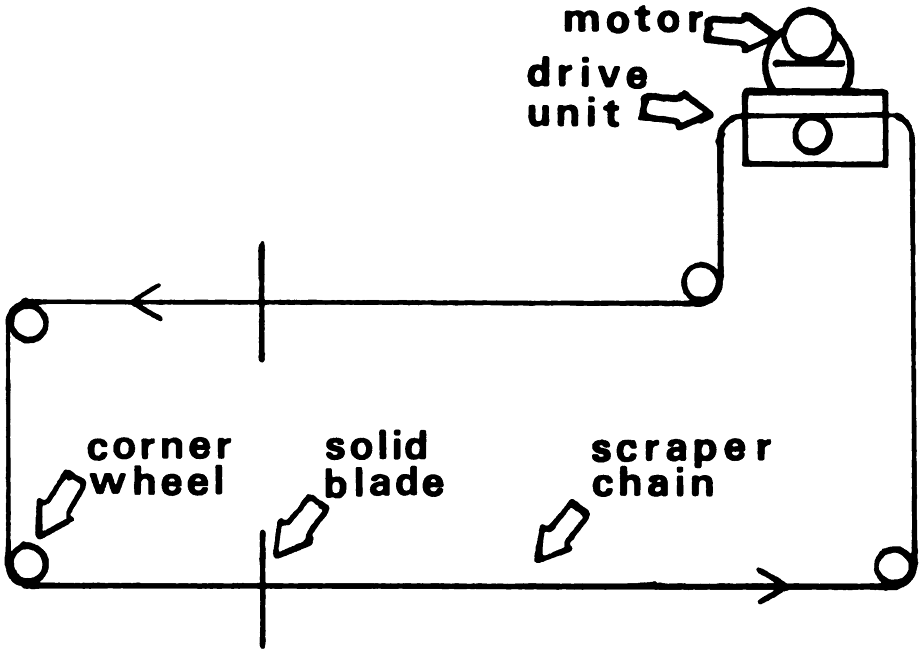

Figure 1A.--Solid blade scraper.

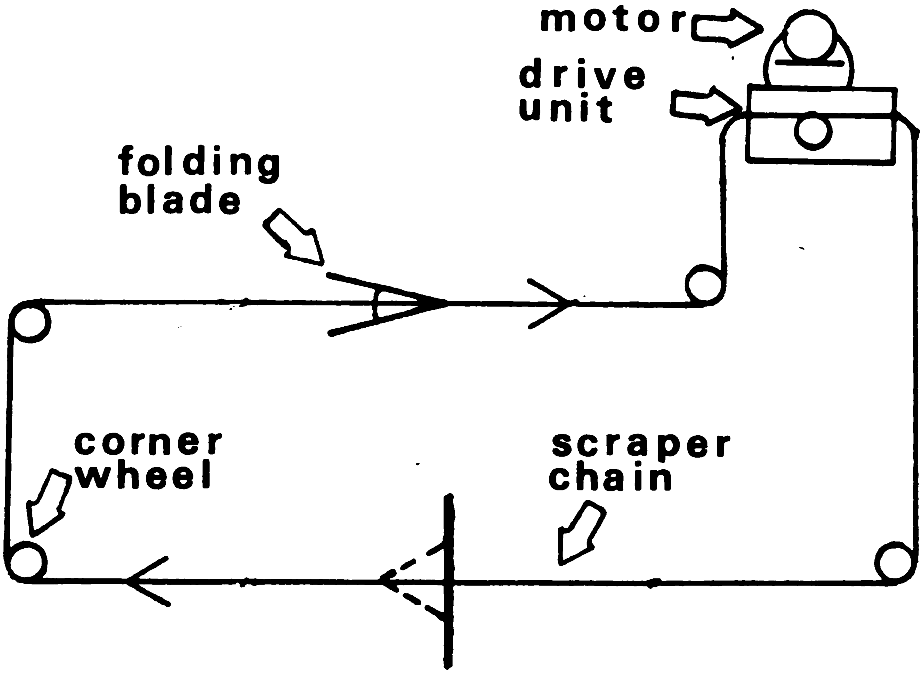

Figure 1B.--Folding blade scraper.

The cost of such units varies according to the manufacturer and a total cost is comprised of the cost for the chain, motor, drive unit, corner wheels and blades. Typical cost figures for several different brands are shown in Table 15.

Table 15.--Cost figures for alley scraper components (1978).

Company	2 HP Motor & Drive Unit & Corner Wheels ($)	Cost/Foot of Chain	Cost/Foot of Groove Liner	Blades
1	2,686.00	-	-	226.45
2	2,175.00	5.40	-	260.00
3	2,575.00	6.50	1.85	145.00
4	1,702.00	5.05	2.00	225.00
5	1,986.00	5.40	1.50	250.00
	$\bar{X}$=2,224.50 ± 365.56	$\bar{X}$=5.59 ± 0.63	$\bar{X}$=1.78 ± 0.26	$\bar{X}$=221.29 ± 45.23

A drive unit package usually includes the gearing system, four corner wheels and the transmission. The cost of a single phase, reversing 2 horsepower motor must be added to the drive unit package. Chain costs and runner costs amount to approximately $7.37 per foot. The groove liner listed in Table 15 is a plastic type track that fits into the bottom of the groove in the concrete floor. It resists wear and, due to its smoothness, lessens chain wear as well. Example 1 in Table 15 used a 3/8 inch cable to pull the blade. It was strung about two inches above the floor and needed no groove in which to run. This system is less common than those with drag chains running in a groove. The standard chain costs about $5.60 per foot and is nearly identical to gutter cleaner chain. Finally, scraper blades cost about $220.00 apiece and there is one per alley. The abrasiveness of the concrete causes wear, and may increase the frequency of repair or replacement depending on how frequently they are operated.

Movement of Waste Material to Various Storage Units

The method used to move manure to storage depends primarily on the consistency of the material and the type of storage utilized. The most basic combination involves a slatted floor over a pit. Defecated waste drops directly through the slots or is worked through by the action of cattle hooves. Another simple technique utilizes a concrete pit under a barn, with the barn floor being part of the tank roof. A slot is built into the floor and manure is scraped to it and allowed to drop into the tank. Tractor scrapers and automatic alley scrapers can be used with this type of storage. Both systems eliminate the equipment, labor and energy necessary to move waste to storage, but storage costs can be high. Concrete pits cost approximately $1.00 per cubic foot of storage and when urine, feces and milk house cleaning water is all added to the pit the volume per cow per day can approach 3.0 cubic feet. One hundred eighty-day storage costs approximately $54,000 per 100 cows. Such storage units are only for liquid wastes; too many solids create emptying problems.

Other liquid storage units include above-ground concrete and steel silos and earth basins. Here again, about 3.0 cubic feet/cow/day is needed along with a factor to account for rainfall that may add to the volume to be stored. Concrete silo storage costs about $0.70 per cubic foot and steel silos cost approximately $0.90 per cubic foot. Earth basins with no concrete in the bottom and a cement ramp average about $1.25 per cubic yard excavated. This lack of concrete makes the earth basin the most economical form of storage.

The most common method used to fill silos and earth basins is with a piston pump which is situated in the barn. The manure is moved into the receiving hopper and it is then forced by the piston through a 12-inch diameter PVC pipe which empties into the bottom of the storage unit. Figure 2 illustrates how this type of system might work with various types of storage. The manure can be scraped directly into the hopper. More liquid materials facilitate pumping. Drier material is difficult to pump for long distances and may cause plugging. Often the parlor waste water is pumped into the cross conveyor or water is added directly to the receiving hopper from a water source near the pumping unit to optimize pumping.

The piston itself can be either hollow or solid. The hollow piston tends to plug more easily with coarse bedding. Turns in the pipe are kept to a minimum with each elbow being embedded in concrete to stabilize it. Pumping distances up to 160 feet are possible. Greater pumping distances increase the risk of plugging. This causes many such units to be manually operated and observed while

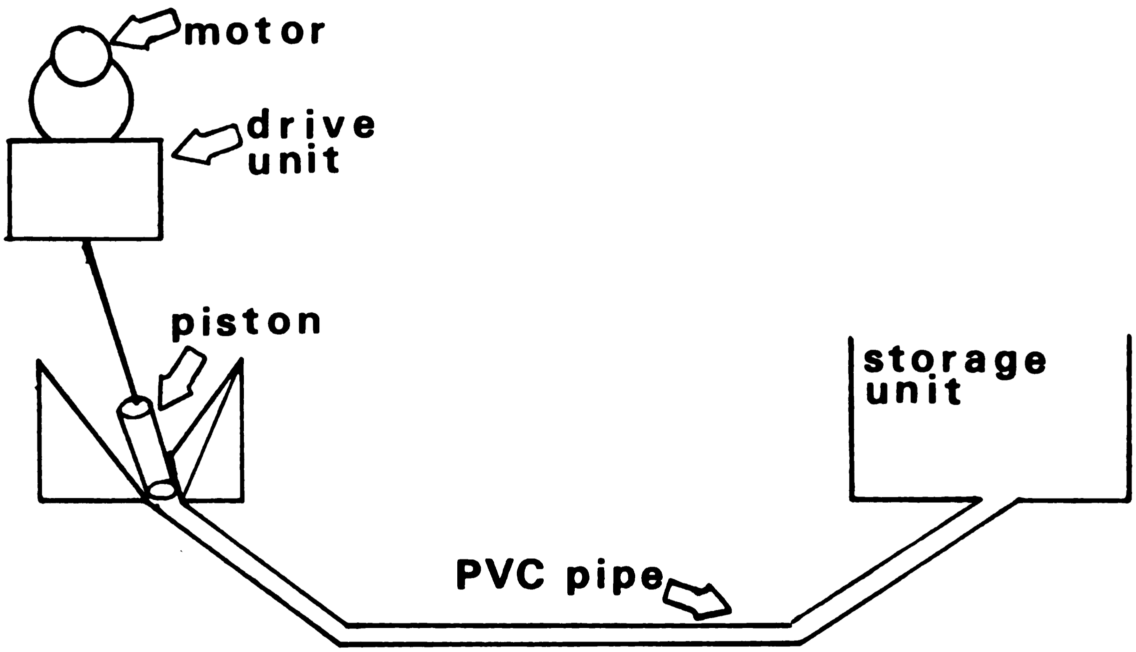

Figure 2.--Piston pump and PVC pipe.

in operation. This may require extra labor but tends to reduce breakdowns and shutdowns due to plugging. The power source is generally a 10 HP electric motor and pumping time usually involves two 15-minute periods per day.

The advantages of the piston pump system are (1) underground pipe prevents freezing, and (2) bottom filling of storage facilities limits the exposure of fresh manure to air, which reduces odors and improves retention of nutrients mainly by preventing ammonia loss. Straw or sawdust bedding in liquid storage forms a thick crust or mat which serves to keep odors in and lessens nutrient loss. The main disadvantage of the mat is the difficulty in breaking it up when the facility is being emptied. It requires a high volume impellor pump in combination with a 80-90 HP tractor and 12 to 14 hours of agitation time to homogenize the stored material. Periodic agitation during storage unloading is also necessary to keep the solids in suspension.

The most common solids storage is a concrete slab with at least one wall available for pushing against when loading. Currently many of the slabs have been placed in a six to eight foot deep earthen basin with the earth walls on the inside of the basin having a 2:1 or 3:1 slope. The cement slab is surrounded by earth walls on three sides and on the fourth side is located a gradually sloped cement exit ramp. This ramp is generally about 40 feet wide to allow a loader to maneuver. Graves and Loudon (1977) and MWPS-18 (1972) offer more detailed descriptions and designs for such facilities.

A major problem with such units is the accumulation of rain water which makes the stored waste too sloppy to remove with a front loader, and too thick and solids laden to pump with an impellor pump. Several types of dewatering devices have been used, such as perforated pipes and a "picket dam" which is 2x6's placed on end with small gaps in between. This latter approach has been used successfully on many Michigan farms. The drained-off fluid has a high pollution potential and must be kept from waterways by allowing it to drain through grass waterways or collect in small basins which may also be used to store milkhouse wastes. Such liquids have a low solids content which allows it to be easily pumped out if the need arises.

Loading such solids holding facilities is most commonly done with a cross conveyor and a 40- to 60-foot stacker or a push-off ramp. This allows manure to be dropped into the deepest part of the pit. Obtaining a certain amount of solids buildup before severe freezing occurs is necessary to prevent the whole pile from freezing and building up too high. When there is the initial manure buildup, the bottom manure won't freeze but slowly spreads out, allowing the cone to slowly sink down. Solids storage facilities can also be filled from the bottom with a piston pump. In the latter case fresh manure is always added to the inside of the pile. Although such a technique is frequently described, it is not commonly used in Michigan. The various equipment and storages previously described have been summarized in Tables 16A and 16B.

Table 16.A.--Manure transfer equipment for solid waste material (cross conveyor and stacker).

Manu-facturer Number	Basic System Cost*	2HP Motor Cost**	Chain Cost per Foot	Complete Unit Cost for 40 Foot Barn Plus 50 Foot Stacker
1	2,750	248	7.50	4,348
2	2,820	248	6.75	4,283
3	3,698	248	6.90	5,188
4	3,400	248	6.89	4,888
5	2,650	248	8.45	4,419
6	2,469	248	6.60	3,845
	$\overline{X}$=2,964.50 ± 479.28	$\overline{X}$=248 ± 0.0	$\overline{X}$=7.18 ± 0.69	$\overline{X}$=4,495.16 ± 475.30

*Drive unit, 50-foot elevator plus supports.

**Same brand name motor used for each system.

Table 16.A lists the cost of individual components needed for movement of solid wastes to storage. A 2 HP motor provides sufficient power and total costs approximate $4,500.00 for the 40-foot wide barn. Liquid transfer systems are more expensive, with the piston pump combination costing about $6,500.00 versus $9,800.00 for the compressed air system. A 10 HP motor with the piston pump provides sufficient power to handle all wastes without undue motor strain. Some early piston pump installations used 7.5 HP motors, but overloading caused the switch to more powerful motors. Compressed air systems are a new concept and not widely used in Michigan. The concept is simple, but it appears they can be used in combination with silo storage.

Table 16.B.--Manure transfer systems using piston pump or compressed air unit.

Unit	Basic Unit Cost*	10 HP Motor Cost**	Cost/Foot 12" O.D. PVC Pipe	Complete System Costs with 140' Distance to Storage****
		Piston Pump Units		
1	4,450	700	8.10	6,284
2	4,500	700	10.00	6,600
3	4,500	700	7.50	6,250
4	4,000	700	8.50	5,890
5	4,590	700	-	-
6	5,500	700	-	-
	$\bar{X}$=4,590 ± 492.34	$\bar{X}$=700	$\bar{X}$=8.53 ± 1.07	$\bar{X}$=6,256 ± 290.47
		Compressed Air Unit		
1	8,120	480***	8.50	9,790

*Includes collection hopper, drive unit, piston and check valves.

**Same brand name electric motor used for all systems.

***5 HP electric motor.

****Does not include installation fee.

Concrete push-off ramps can be used with tractor scrapers to move both solids and semisolids into appropriate storage basins. Accurate cost figures for ramps are unavailable, but $1,000.00 would probably be a fair estimate. They provide one of the simplest methods for loading storage facilities along with slats and floor openings with pits underneath. They are dangerous and some users have installed a heavy steel railing across the front to prevent accidentally driving a tractor off the ramp into the manure pit.

Table 17 presents cost figures for the various storage systems and includes all the costs involved for excavating, concrete work, etc. It does not include unloading equipment, etc. The table indicates concrete pits are the most expensive to initially install, steel silos the next most expensive, and an earth basin for liquids the least expensive. Earth basins for solids and slurry basins both cost about one-fourth that of the pits and silos. Each unit requires a large volume of concrete and the solids basin cost includes a picket fence dewatering device and a small liquids basin for runoff water and milkhouse waste water. The least expensive storage is the earthen basin for liquids which has a narrow concrete ramp. The price includes the cost of concrete and the price for excavating and building of the earthen berms.

Impellor Pump for Emptying Liquid Storage Units

Most dairy farms utilize significant amounts of fibrous bedding material to keep cattle clean and dry. This material eventually ends up in the storage facility and, with liquids storage, it tends to float to the surface and form a thick mat. This mat keeps odors in, but at emptying it must be blended into the rest of the mixture to allow pumping. The most frequently utilized piece of equipment for this task is a low head, high volume impellor pump powered by an 80-90 HP tractor. The intake impellor is usually equipped with cutting blades which allow the bedding

Table 17.--Cost of various storages designed for 100 cows and 180 day storage.

Storage Type	Cost
Cement silo	$35,280
Steel silo	45,360
Earth Basin, Solids	11,190
Earth Basin, Liquids	3,750
Cemented Slurry Basin	11,101
Pit Under Slats	50,400
Tank Under Barn	50,400

material to be chopped finer and be more easily pumpted. Up to 20 hours of agitation time may be necessary to properly homogenize a volume from 100 cows for six months.

Once the slurry has been adequately mixed and is pumpable, the same impellor pump can be used to fill tank wagons. Loading rates of 2,000 gallons per minute are feasible if the liquid wastes are sufficiently dilute. Such pumping rates allow 3,200 gallon tankers to be filled in 1½ to 2 minutes.

Impellor Pump and Irrigation Pump for Emptying Liquid Storage Units

In circumstances where large volumes of dilute liquids such as lot runoff, flush water or milkhouse and parlor waste water are added to manure storage units, irrigation appears to be a convenient way of transferring it to fields. Despite the extra water, such material usually needs substantially more dilution water to allow pumping with irrigation pumps. This may involve adding one to two volumes of fresh water per volume of stored wastes to lower the solids content to 3 or 4 percent. Mixing this complete mixture with an impellor pump is generally done in conjunction with using the irrigation pump. The dilution water may triple the total volume to be pumped and total pumping time may be increased due to the low pumping rates of irrigation pumps and the large volume to be pumped. A pumping rate of 300 to 500 gallons per minute is common for such pumps.

One note of caution is the need to have ventilation systems functioning properly when agitating pits under slats. Trapped gases may be released in sufficient quantities to asphyxiate or poison cattle if air transfer is inadequate. Another problem associated with agitation is that it allows a lot of ammonia gas to be released, which lessens the nutrient content of the waste. Tables 18 and 19 summarize the costs and pumping capacities of commonly used impellor and irrigation pumps.

Many companies manufacture impellor pumps, and the average price was $3,500.00, while the average price of three irrigation pumps capable of moving liquid manure through a half mile of pipe and out a sprinkler gun was $2,570.00.

Previously it was explained how a basin with a bottom liner of concrete was sometimes used to collect and store manure and rain water. The resulting mixture is often too flowable to handle with a front end loader and not dilute enough to be pumped

Table 18.--Cost, agitating capacity and pumping capacity of impellor pumps.

Company	Impellor Pump Cost	Pumping Capacity (GPM)
1	3,332	1,850
2	3,487	2,000
3	3,230	-
4	3,392	1,950
5	4,733	1,900
6	3,150	1,850
7	3,263	-
8	3,213	1,950
9	3,360	2,000
10	3,550	1,850
11	3,806	1,900
12	3,032	-
	$\overline{X}$=3,462.33 ± 448.43	$\overline{X}$=1,916.67 ± 61.24

Table 19.--Cost of irrigation pumps.

Company	Cost
1	2,887
2	2,450
3	2,375
	$\overline{X}$=2,570.66 ± 276.51

with an impellor pump. One firm manufactures and markets a self-loading spreader for such slurry type material. The unit is backed directly into the flowable mixture and a continuous paddle belt at the rear of the spreader is immersed into the waste material. When operated this continuous paddle belt moves the waste to an intake auger which loads the tank wagon. The main restriction is the waste material must be fluid enough to flow to the paddle belt. Such a unit is manufactured in three sizes ranging from 1500 to 3200 gallon capacity. Loading time for the 2200 gallon model is approximately seven minutes and the cost of the spreader is $8,500.00. At this time their use is limited, but they are available.

Solids Storage Unloading Equipment

Solids material stored on concrete slabs surrounded by earthen walls is removed with either a skidsteer loader or a utility tractor equipped with a front end loader. On farms where manure is handled as solids, these tractors would also be used to scrape the alleys. In each case these units would have multiple uses, but waste handling would utilize the most equipment time. Ownership costs per hour of use were $4.75 for the skidsteer and $8.00 per hour for the utility tractor. This lower rate for the utility tractor is due to its being used more hours annually than the skid-steer. The front end loader unit was valued at $2,500.00 with approximately 50 percent of its use time being for loading manure and bedding replacement. Total ownership costs for the utility tractor, front end loader combination consisted of both tractor and front loader ownership costs. In Table 20, time to load a 275 bushel spreader with either a skidsteer or front end loader is given.

Table 20.--Time to load 275 bushel solids spreader with skidsteer or front end loader.

Farm Number	FEL Load Time (min)	Farm Number	SKS Load Time (min)
1	10	1	8
2	15	2	3
3	10	3	10
4	3	4	5
5	8	5	5
6	10	6	3
7	5		$\bar{X}$=5.7 ± 2.8
8	5		
9	10		
10	5		
11	10		
12	8		
13	5		
14	4		
15	7		
	$\bar{X}$= 7.7 ± 3.2		

Based on 15 survey responses, loading time with a front end loader is 7.7 minutes, with the range being 3 to 15 minutes. The time involved and variability depend a great deal on the consistency of the manure, the loading area and room for maneuvering. On the average, skidsteer loaders used 5.7 minutes to load a spreader. Superior maneuverability in confined areas and faster shifting time may partially explain the more efficient loading time.

Movement of Waste Materials From Storage to the Field

Four choices exist for this job, and the selection depends partially on the consistency of the waste material. The use of liquid hauling tankers or solids spreaders had no effect on the hauling distance, which averaged 0.3 miles from site of loading to the unloading location.

Solids Spreaders.--Spreader capacity for those dairymen handling manure as solids averaged 270 bushels. The spreaders are equipped with tandem wheels and a hydraulic end gate. In many cases the manure being transported is quite sloppy and would flow out the back of the spreader if the end gates were not used. The average price for the spreader was $5,000.00 and required a 75-80 HP tractor to pull it. Unloading time based on farm survey responses averaged 5.7 ± 2.8 minutes for 18 operators and this did not include transit time to and from the field.

Liquid Tankers.--Eight farm survey participants used liquid spreaders to convey waste material to the field. Table 21 summarizes unloading times and spreader capacities for those eight dairymen.

Table 21.--Spreader capacities and unloading times for liquid tankers.

Farm Number	Spreader Capacity (Gallons)	Unloading Time (Minutes)	Unloading Rate (GPM)
1	1,500	2.5	600
2	3,250	5.0	650
3	3,200	5.0	640
4	3,200	5.0	640
5	2,250	5.0	450
6	3,000	5.0	600
7	3,200	4.0	800
8	3,000	5.0	600
	$\overline{X}$=2,825 ± 626.8	$\overline{X}$=4.56 ± .90	$\overline{X}$=622.5 ± 5.7

Most dairymen use a liquid spreader with about 3,000 gallon capacity with no injectors. The unloading rate for such units is about 600 gallons per minute with an average unloading time for a 3,000 gallon spreader being nearly five minutes. The combined spreader and load weight is nearly 15 tons and requires a 90-100 HP tractor to pull it. Also, the weight can cause soil compaction in row crops or soil which is wet. The use of injectors is possible with liquid spreaders and both 2-row and 4-row assemblies are available. A commonly used unit is a 4-row set of injectors on a tractor mounted tool bar. Liquid manure is forced through a hose connecting the spreader and injectors and the manure exits behind the chisels. When injecting the chisels are forced into the ground about ten inches deep and the waste is deposited in the furrow and then covered with dirt. This method greatly reduces odor and conserves maximum amounts of nitrogen, but does require a 100-120 HP tractor to do the job. According to manufacturers, injecting does not slow down the unloading process because four large diameter exit ports prevent restrictions. Row crop injecting does go slower due to turning at row ends and attempting to minimize crop damage.

The average cost for a 3,200 gallon liquid spreader was $7,335.00 and a set of four injectors added another $2,500.00 in costs.

Irrigation Equipment for Waste Handling

With longer storage time and larger herd sizes, the large volumes of accumulated liquid wastes cause many farmers to seriously consider irrigation equipment for storage emptying and field application. None of the 25 survey farms had irrigation, but several were interested in it. For this project, manufacturer supplied performance and cost data were used in conjunction with Midwest Planning Service Manual-18 (1975) and the Soil Conservations's Field Hand Book (1975). Two basic irrigation systems were examined.

One involved use of aluminum pipe and a manually relocated big gun sprinkler nozzle with a 1¼ to 1½ inch diameter nozzle. The second system involved a combination consisting of aluminum pipe, flexible hose and a traveling sprinkler nozzle with a potential total run length of 800 yards.

Stationary Big Gun Sprinkler.--This particular system involves a lower investment than the traveler system but requires much more manual labor. The large bore nozzle is set up with a stabilizing stand and attached to the irrigation pump with six inch diameter aluminum pipe. Such equipment would seldom be purchased simply to irrigate liquid waste and for the computer program it was assumed 25 percent of the use time would be for waste handling. The normal wetted circle diameter was approximately 400 feet, or about three acres. Following the completion of each set the unit must be shut down, the pipe disconnected and the stand and nozzle relocated for the next set. It was assumed one man could do this in one hour.

Traveling Gun Sprinkler.--This unit involves some of the same equipment as the big gun sprinkler. A similar impellor pump and irrigation pump are used along with 800 yards of six inch diameter aluminum pipe. In addition, 400 yards of flexible hose is used to connect the aluminum pipe outlets to the traveling gun sprinkler. The traveler itself is comprised of a portable winch powered by a 20 HP gas motor. The winch unit is anchored firmly and the cable is reeled out to its maximum and attached to a threewheeled trailer on which is mounted a 1¼ to 1½ inch diameter nozzle. To the nozzle is attached the flexible hose through which is piped the liquid waste from the storage unit. As the material is pumped through the nozzle the winch pulls it along at a predetermined rate which essentially governs the rate of waste application. The process continues until the cable is completely reeled in and then the rig must be reset by repositioning the winch. Labor usage is minimal with this system; mainly it is used in conjunction with a tractor to reposition the winch and trailer and handle the agitating process.

Table 22 presents a comparison of the cost of both systems along with labor requirements for specific tasks involving each unit as used in the computer program.

It is obvious that these two systems represent different levels of labor-saving technology. The traveler system is much less of a labor user, but initial cost and energy usage are greater. The traveler unit is probably the smallest user of labor of all waste application systems. One of the penalties for use of an irrigation system is the loss of a large amount of nitrogen to the air. Agitation results in some losses and the spraying of the material into the air in a large arc further increases the escape of ammonia nitrogen, which detracts somewhat from the labor savings. The hand set sprinkler is probably no less of a user of labor than hauling solids or liquids with a spreader. Due to the tripling of the total volume with dilution water, many sets have to be made and this causes a large input of labor. If such a system is used

Table 22.--Comparison of stationary big gun sprinkler and the traveling gun system for irrigating liquid wastes.

	Stationary Gun Sprinkler	Traveler System
Length of aluminum pipe (feet)	3,960	2,640
Feet of flexible hosing	-	1,320
Cost/foot--aluminum pipe	\$3.25	\$3.25
Cost/foot--flexible hose	-	\$8.50
Cost for 1¼ to 1½ nozzle and support	\$750.00	-
Cost for traveling gun sprinkler	-	\$8,000
Percent of time used to irrigate waste	25	25
Men used to set up	2.0	2.0
Hours to set up	2.0	2.0
Time to set up from scratch (hours)	5.0	4.0
Hours/set (0.5 inch application rate)	2.0	-
Area covered/set	3.0	24
Time to reset (hours)	1.0	1.0
Men to reset	1.0	1.0
Men to dismantle	2.0	2.0
Time to dismantle (hours)	5.0	2.0

with a flush system where the dilution water is already added to some extent, then irrigation is much more useful than with other systems.

Comparison of Systems Available for 100 Cow Herds

When the program was working properly and the descriptive equations had been specified, all possible systems were synthesized for a 100 cow unit by using the 000 option at the beginning of the program. This generated 4,208 feasible systems based on the restrictions that had been incorporated to prevent impossible option-option combinations. Liquids storage was used for 2,672 systems, 1,024 handled wastes in the solid form and 512 slurry basin systems were possible. Handling animal wastes as a liquid appears to permit a lot more flexibility in system design. In order to make some meaningful comparisons among systems, two approaches were taken.

Comparison Method 1

All feasible systems were developed for the 100 cow herd and were stored on a permanent file tape for later analysis. For this herd size only, all options were compared on the basis of total initial cost, annual costs of ownership (DIRTI), yearly labor needs and labor cost, annual energy needs and cost, yearly bedding used and its cost, total annual costs, nutrient value of the material and net annual costs.

Clay stalls for 100 cows cost $1,080.00 for curbing and clay while concrete platform stalls were $3,900.00. The concrete costs made up the approximately $2,000.00 difference in price. The initial bedding costs were $90.00 for sawdust, $169.00 for shavings and $270.00 for sand. If rubber mats were used in concrete stalls, they added another $50.00 per stall initially but did lessen bedding usage in stalls to some degree. Addition of bedding material with a skidsteer loader used about one-third as many man hours of labor as did the front end loader. This results primarily from the superior in-barn maneuverability of the skidsteer. The faster addition of bedding and more precise dumping into stalls results in a lot less labor for leveling the material. The skidsteer is very handy with heavy sand bedding for the above-mentioned reasons.

The annual bedding material used cost $1,576.00, $3,450.00 and $2,956.00 for shavings, straw and sand, respectively. The per unit costs used were the market prices for the individual bedding materials. Farmers may be able to obtain bedding cheaper than this if they grow their own straw or use sand from their farm.

Slatted vs. Solid Floors.--Slats cost approximately $2.25 per square foot to install versus $1.75 for solid floors. Cattle on slats usually are given less floor space per animal, which helps force the manure through the slots and into the pit beneath. Using less space per cow somewhat offsets the higher per unit costs, but the slatted floor still costs $10,125.00 compared to $7,500.00 for the solid surface.

Alley Cleaning Options.--Floor cleaning labor requirements in many systems represent 50 to 60 percent of the total labor annually used to handle wastes. If labor is to be saved, this is one place to attempt it. Many floor cleaning options exist, and in Table 23 those available in the computer program are listed and compared.

Table 23.--Cost, labor and energy needs of floor cleaning options.

Option	Initial Cost	Annual Cost	Annual Energy Costs	Annual Labor Costs	Total Annual Own and Operating Costs
Alley scraper	5,042	1,326	503	60	1,889
Skidsteer	10,500	1,927	419	843	3,289
Garden Tractor	2,500	410	196	843	1,448
Utility Tractor	11,500	1,144	501	843	2,488
Flushing	10,950	3,074	211	559	3,445

If the initial purchase price of a skidsteer and utility tractor were charged solely to alley cleaning, then flushing and tractor scrapers would have the highest initial cost, with automatic alley scrapers being next and the garden tractor would cost the least. The ability to use the tractors for other jobs spreads the cost of ownership over several enterprises and makes the utility tractor's annual costs comparable to those of the alley scraper. The skidsteer is less versatile and has higher ownership costs, while flushing is the highest at $3,074.00.

Energy costs for the alley scraper and skidsteer are both $500.00 annually, while the garden tractor and flushing use about $200.00 yearly, which is the least.

The main advantage the alley scraper provides is less labor. Apart from repairs, the only labor needed is a few minutes per week to lubricate and check the system. This compares with approximately 20 minutes per alley per day when tractor scraping twice daily. Flushing also uses less labor but winter scraping and occasional alley scraping result in higher labor needs than the alley scraper.

On the basis of total annual costs, the garden tractor is lowest, the alley scraper is next, and the flushing system is the highest. If a dairyman were interested in lessening the labor needed for waste handling, an alley scraper or flush system might fit his needs.

Storage of Waste and Waste Transfer Equipment.--When an operator decides to build waste storage, he actually has to make three major decisions. One involves the style of the storage unit and the other two involve how he will fill and empty the facility.

In Table 24 are presented the most commonly used storage systems for Michigan conditions. The five liquid units range in price from $3,750.00 for an earth basin to $50,400.00 for concrete pits under the barn. For solids storage some form of the concrete bottom earth basin is most commonly used. It is similar to the earth basin for liquids, but the large amount of concrete in the bottom forces up the price. The concrete lined slurry basin also has a higher cost due to the great amount of poured concrete.

The under-barn pits for liquids may have the highest initial cost, but they do eliminate storage filling equipment in those systems where they are used, and this may be an $8,000.00 expenditure. The upright silo storages are generally filled with a

Table 24.--Comparison of storage units for 100 cow herd size.

Storage Facility	Initial Cost	Annual DIRTI Costs
Cement silo	35,280	4,410
Steel silo	45,360	5,670
Earth basin, solids	11,190	1,622
Earth basin, liquids	3,750	544
Concrete slurry basin	11,100	1,332
Concrete tank under barn	50,400	6,300
Concrete pit under slats	50,400	6,300
None	0	0
Settling basin, Flush lagoon	17,850	2,588

piston pump located in the barn and linked to the storage by underground PVC pipe. This unit is also used to fill earthen basins for liquids and solids. The cross conveyor and stacker combination are the most common units to fill concrete-bottomed earth basins, but in some cases concrete push-off ramps are used in conjunction with tractor scraping. The options available for storage filling are listed and compared in Table 25.

Whenever a piston pump or compressed air unit is used in a waste handling system, it will be the most expensive transfer unit in terms of initial cost, annual ownership costs, labor and energy requirements and total annual costs. As indicated in Table 25, cross conveyors are less expensive in all categories, while the concrete push-off ramp is the least expensive.

Table 25.--Storage filling options.

Option	Initial Cost	Annual Costs of Owning	Yearly Labor Costs	Annual Energy Costs	Total Annual Costs
Cross conveyor, short elev.	3,267	925	102	25	1,052
CC + stacker	4,706	1,331	102	25	1,459
Piston pump, PVC	6,665	1,953	639	105	2,697
CC, PP, PVC	9,438	2,738	639	130	3,507
CC, air, PVC	12,863	3,358	639	84	4,081
Ramp	1,000	135	0	0	135
None	0	0	0	0	0
Concrete flume	1,575	197	0	0	0
None (slats)	0	0	0	0	0

When storage is utilized, it must eventually be emptied and this may pose some problems in certain situations if adequate unloading equipment is unavailable. With liquids storage the bedding material tends to float to the top and, before emptying, this must be thoroughly mixed in as described previously. Only one option, the impellor pump, is designed for this agitation and unloading job. If the mixture is well homogenized first with an impellor pump and is sufficiently dilute, an irrigation pump may be used to empty and transfer the material to the field.

For solids removal both front end loaders and skidsteer loaders are used to load spreaders. If the material is high in solids, these loaders can fill a 275 bushel spreader in five to seven minutes. The skidsteer is a bit faster due to its superior maneuverability, but utility tractors designed for loading also are very efficient. Table 26 compares the various unloading units available for 100 cow operations.

Table 26.--Storage unit emptying options.

Option	Initial Cost	DIRTI Costs	Annual Labor Costs	Energy Costs	Total Annual Costs
Impellor pump	3,500	1,025	209	202	1,886
Front end loader	14,000	454	104	46	746
Skidsteer	10,500	193	84	39	317
Self-unloading spreader	8,400	738	344	306	2,126
None	0	0	0	0	0
Impellor and irrigation pump	6,100	1,216	175	1,029	4,606

Handling stored wastes as liquids or as a slurry requires equipment which costs the most, uses the most labor and energy, and has the highest total annual costs. This is due to at least two factors. One is the large volumes of water which are moved with liquid manure and this takes more energy and labor. In addition, there is a great deal of time and energy expended to break up the crust of bedding and thoroughly blend it into the liquid portion. In all cases except the skidsteer in Table 26, total annual cost column has in it an ownership factor for the tractor used to power the unloading equipment. As an example, for an 80-90 HP tractor used to power the impellor pump, this amounts to the hourly use charge for the tractor for ownership multiplied by the hours actually used annually. In this case it amounts to $450.00.

Unloading solids from storage requires less labor and energy and is accomplished with multiple use equipment that is usually available on dairy farms. The self-unloading spreader requires a large tractor to power it, is slow to load and has a fairly high initial cost but is useful in situations where the waste material is too thick to pump but too liquid to load with conventional loaders.

Movement to Field and Land Application.--For this project deposition of manure on the land was the only end-point considered. With the exception of irrigation of highly diluted wastes, some type of liquids or solids spreader was used. The specifics of the various options have been previously described, and Table 27 presents a comparison of them on the basis of cost, energy and labor.

The figures in Table 27 deal only with movement of waste material to fields and do not pertain to loading time or the energy required to pump the material. Such data were presented in Table 26. Irrigation systems are very expensive to buy, especially

Table 27.--Equipment used to move dairy wastes to the field.

Option	Initial Cost	Annual Cost	Labor Costs	Energy Costs	Total Annual Costs
Self-loading tanker	8,400	1,512	283	252	2,667
3200 gallon tanker	9,500	2,688	229	179	3,588
Tanker plus 4-row injectors	12,000	3,313	234	212	4,361
Solids spreader	5,000	1,250	306	218	2,431
Aluminum pipe & stationary sprinkler	13,620	817	330	0	1,147
Aluminum pipe, hose, traveling gun sprinkler	27,800	1,460	124	172	2,937

traveler units, but it was assumed for this study that only 25 percent of their total use time would be allocated to application of wastes to the field. On an annual cost basis, the tanker with injectors was the most expensive and the stationary gun sprinkler the least costly. All the transfer to field equipment other than irrigation options is used only for manure movement, which causes their ownership costs to be higher than multiple-use irrigation works.

The labor needs of the stationary gun sprinkler unit was the highest of all options. This system must deal with a doubled or tripled volume of wastes due to the addition of dilution water and the sprinkler and pipe must be repositioned after each area has been irrigated. This need for a lot of hand labor plus the extra volume makes this a heavy user of labor. At the other extreme is the traveler system. Given sufficient hose and a large field, the unit may run 8 to 12 hours with no need for labor. When it has to be repositioned, this is accomplished with a man and tractor. Of the spreader units, the solids spreader has a bit higher labor requirement than the others, with the 3,200 gallon liquids hauler having the least.

Energy usage is zero for a stationary sprinkler system in this program because all the pumping energy has been charged to the emptying and agitation option. Other movement to field options use energy, with the large tanker requiring the least and the self-loading spreader the most. Injecting and application from a solids spreader require about the same amount of energy. This may be due to the larger number of trips to the application site with the smaller volume solids spreader. Dairymen with 100 cows might use a 2,200 gallon unit with injectors; however, tractor mounted 4-row injectors would require about the same amount of energy because the rolling resistance offered by the tanker is small compared to that of the injector.

On the basis of total annual costs, the injector unit with a 3,200 gallon liquid spreader was highest, followed by the traveler system, while the stationary gun sprinkler was lowest.

If dairymen want to use irrigation equipment for transferring liquid wastes to the field, they should understand that stationary, hand moved systems require at least as much labor as other hauling units. Traveling gun sprinklers use much less labor than other units but initial cost would prohibit installing such a system just for waste removal, unless it could be purchased as second hand equipment for a reasonable price. In many cases farmers buy such equipment to irrigate corn and then using it for waste removal is feasible and justified.

Comparison of Waste Handling Systems for 100 Cows on the Basis of Storage Type

Most systems are classified as either liquids or solids and, while technically this refers to the solids content of the waste material, it can also define storage types. To compare various systems using different storage types, mean totals were calculated for all complete eight option systems using each of the storage facilities. A complete listing of all criteria mean totals is presented in Table 28.

Total component costs for systems using under-barn concrete pit or tank storage were the most expensive, followed by the silos. The daily haul system was by far the cheapest in terms of initial cost. When earthen basins were used, waste handling components up to the storage phase were quite similar and storage costs were also about the same as were the total systems cost. Flushing increased total system costs a substantial amount due to the cost for extra

Table 28.--Summary of waste systems according to storage types.

Storage Types	Total Initial Cost	Annual Costs of Ownership	Annual MHRS Labor Cost	Annual Energy Costs	Annual Operating Costs	Annual Bedding Costs	Total Annual Costs	Manure Nutrient Value	Net Annual Costs
Cement silo	77,139	13,781	2,649	1,323	3,972	1,996	21,868	5,136	16,731
Steel silo	87,219	15,041	2,649	1,323	3,972	1,996	23,128	5,136	17,991
Earth basins for solids	52,141	7,201	1,498	658	2,156	1,996	12,021	4,978	7,042
Earth basin liquids (non flush)	53,445	9,433	2,053	914	2,967	1,996	14,396	4,792	9,604
Earth basin liquids (flush)	58,654	10,193	2,410	1,570	3,980	1,996	16,169	4,792	11,377
Concrete slurry basin	51,541	8,870	2,364	1,434	3,793	1,996	12,708	5,083	7,625
Concrete pit	89,582	12,380	1,726	1,471	3,197	1,996	19,635	4,900	14,734
Concrete tank	89,954	12,452	1,783	1,497	3,280	1,996	19,873	4,898	14,975
None	27,292	5,136	1,372	634	2,006	1,996	9,734	5,083	4,650
Settling basin and lagoon	62,544	10,809	1,696	1,389	3,085	1,996	17,634	4,687	12,948

storage capacity. With silo storage systems, storage costs account for 50 to 60 percent of the total system costs, whereas with lagoons or earth basins the storage costs as a percent of total system costs ranged from 6 percent for the earth basin for solids to approximately 30 percent for the settling basin and lagoon for the flush system. Liquid systems in general require more labor due to extensive pumping times and greater volumes to be handled.

Energy usage was greatest for liquid basin systems and next highest for below building tanks and silos. The first two system types were compatible with irrigation unloading equipment, which has the greatest energy needs of any of the unloading units, as is noted in Table 26. Also, liquid systems in general use more energy for the same reasons they require more labor. This is also reflected in total annual operating costs and total annual costs, which show liquids systems to have higher costs than solids systems.

Nutrient Retaining Ability of Systems

One other factor that needs to be considered when selecting a waste handling system is its ability to retain nutrients. This topic was discussed in the review of literature section. Loss of nutrients at any stage of the waste handling operation is of concern to both the farmer and to the environment as well.

It was assumed for this project that freshly defecated fecal material contained 100 percent of the phosphorus, potassium and nitrogen. As the manure is moved through each waste handling phase, the potential exists for losses, especially of nitrogen in the form of volatile ammonia. Phosphorus and potassium are more stable and losses tend to be low.

Nitrogen losses concern the farmer because of its value as a plant nutrient especially for corn, and its loss to the environment contributes to the pollutant load of streams and lakes. For nitrogen losses, literature reports were used to assign a percentage loss to each waste handling option. All losses for the eight sections were totaled and subtracted from the original 100 percent which left the cow. Of the total nitrogen making it to the field, only 50 percent of it will be available to growing crops during the first year post application. This quantity was multiplied by the per unit price of commercial nitrogen to obtain a value for the nitrogen portion. It was assumed 60 percent of the phosphorus would be available and 100 percent of the potassium. Each was also priced on a basis similar to nitrogen and the three added to give a total value for the manure nutrients.

People are correct in assuming that liquids systems have the potential to save the most nutrients, especially nitrogen, but various handling procedures associated with liquid wastes may drastically reduce its nutrient content. Agitation with an impellor may cause losses of ammonia from stored liquids greater than those associated with emptying a solids basin with a front end loader. Systems using impellor pumps were penalized accordingly and if irrigation was used they were further penalized. Another factor in nutrient losses is the post application procedure. If waste is not rapidly incorporated into soil, up to 80 percent of the ammonia may be lost in three to five days. Farmers need to be aware of this factor in addition to which handling procedures cause the greatest nutrient loss. No attempt was made to calculate losses of nutrients associated with post application practices for this study.

Based on the procedures used for this study to assess nutrient losses, silo storage systems were ranked the best, followed by daily haul and cemented slurry basins. Earth lagoons for liquids systems were ranked as the worst for nutrient conserving ability. As mentioned earlier, liquid storage is an efficient conserver of nitrogen compounds, and Safley (1977) indicated a steel silo had retained 99 percent of the nitrogen up to the time of emptying. Most liquid units require a lot of agitation and pumping and if irrigation is used there is more potential for loss. Each procedure causes ammonia loss which may more than offset the superior nitrogen retaining ability of the liquids storage unit. Each 5 percent loss of nitrogen results in a loss of about 1,000 pounds of total nitrogen per 100 cows on an annual basis. This amounts to about $180.00 per 5 percent nitrogen loss when nitrogen is valued at 18¢ per pound. In terms of total nutrient value, two systems would have to differ a great deal in the nitrogen conserving ability before a great difference would be noted. This area of nutrient losses is difficult to accurately estimate and is subject to interpretation in most cases.

When all factors are considered, daily haul systems had much the lowest net annual costs, solids basin systems were next, while silo systems resulted in the highest net annual costs followed by the underbarn tank systems and the flush lagoon systems. Nutrient retention was not sufficient to lower the liquid storage systems net annual costs to those of the solids or slurry system.

Comparison of Commonly Used Waste Handling Systems

The trend toward larger herd sizes and confinement housing, coupled with a scarcity of farm labor and rising energy costs, has forced dairymen to adopt energy and labor efficient waste handling systems as well as other farm systems. Herd sizes considered for this part of the study ranged from 100 to 300 milking cows. This range was chosen for two reasons. First, many Michigan dairy herd expansions result in this approximate number of cows. Second, individual confinement barns can usually accommodate up to 300 cows. When cow numbers exceed this, buildings are replicated. With most expansions, only one building is considered.

Rather than attempt to somehow compare all feasible systems over a range of herd sizes, 58 systems common to Michigan or showing potential for Michigan dairymen were chosen. This group was then ranked to discover the five highest and lowest in terms of initial cost/cow, annual labor/cow, yearly energy costs/cow, total annual costs/cow, and net annual costs/cow. The ranking procedure was conducted for 100, 150, 200, 250, and 300 cow herds. Appendix Tables C-1 to C-5 contain the output for the 58 systems according to herd size.

Initial Cost

The most expensive systems ranged in price from $900.00 to $1,050.00 per cow at the 100 herd size. Such units utilized liquid storage, either below building tanks or above ground steel silos. Irrigation equipment or liquid tankers with injectors were used for movement of waste to the field. As herd size increased, per-cow costs declined. This scale effect has been noted by Forster (1974) and Ogilvie et al. (1975), among others. Even though per-head costs decline, the same systems which proved most costly for 100 cow herds also were highest for the 300 cow operation. Unit costs of $710.00 to $775.00 per cow existed at this herd size.

At the other extreme, the least expensive systems at all herd sizes were either daily haul solids systems or units with earth basin storage for solids. Daily haul systems averaged $220.00 per cow at the 100 cow herd size and $150.00 per cow with 300 cows.

Energy and Labor Needs

Despite their high cost, many dairymen have installed or are considering systems with slatted floors, below building storage, silo storage, and irrigation equipment. The intent is to exchange capital for labor and energy. When the 58 systems were ranked according to labor needs, several of the tank and slatted floor combinations required the least labor annually irrespective of herd size. Slatted floor systems averaged 1.29 man hours/cow/year at the 100 cow herd size and 0.81 man hours/cow/year with 300 cows. However, a daily haul system also ranked among the five systems requiring the least labor. Unfortunately there is no accurate or easy way of affixing a cost factor to the inconvenience of daily hauling of waste or to the potential for environmental damage due to runoff and water contamination.

The units requiring the most labor were flush systems and liquid basin systems. These systems have a fairly high labor demand at each phase and require a lot of labor and energy for agitation and pumping due to crust formation and the increased waste volume associated with flushing. The annual per-cow labor needs ranged from 7.0 man hours for 100 cow herds to 5.5 man hours at the 300 cow level.

Energy demands of the slatted floor systems using tankers or stationary gun sprinklers were the lowest among the 58 units selected. Such systems use little or no energy for alley cleaning or movement of waste to storage. This lowers annual energy costs to $4.00 to $5.00 per cow for 100 cow herds and $3.00 to $4.00 for 300 cow herds. Irrigation with the hand moved gun sprinkler system is a labor demanding job, however, so there is a tradeoff between energy and labor when this component is used. In most cases the slatted floor units are the costliest, but they do allow a reduction in the labor and energy required.

Systems using silo storage units are the next most expensive in terms of initial cost, but they have a high energy and labor requirement at all phases. This tends to make them less acceptable because there really is no tradeoff between capital investment and labor or energy.

The heaviest energy users were flush system utilizing irrigation equipment. This was true at all herd sizes. Energy for pumping water, occasional scraping, agitation and pumping of a greatly increased volume of waste material forces the energy costs to be high. For 100 cows the five most costly systems in terms of energy costs ranged from $31.50/cow/year for a flush system with a traveler unit for irrigation to $17.50 for the flush unit utilizing a tanker plus injectors for field application of waste. Siphoning flush water from the lagoon could reduce energy demands both by lessening the volume to be handled and cutting down on energy needs for fresh water pumping.

When compared on total annual costs, silo systems and flush systems were the most expensive due primarily to high costs of ownership associated with expensive storage facilities. In addition, both systems use great amounts of energy and labor, as has been previously discussed. Daily haul systems and slurry basin systems had the lowest annual costs for ownership and operating. They both use moderately priced equipment, there is no agitation required, and there is no need for elaborate and expensive movement to storage equipment. Such factors contribute to higher ownership and energy costs.

The liquid systems have the highest nutrient conserving ability, but this does not lower the total annual costs sufficiently to allow them to approach the low net annual costs of daily haul and slurry system. If as stated earlier a value could be placed on inconvenience of daily hauling and the associated pollution potential, the outcome might well be reversed or rearranged. As it is, silo and flush systems have the highest net annual costs for all herd sizes.

CONCLUSIONS AND RECOMMENDATIONS

Two primary objectives existed for this study. First was the development of an interactive computer program capable of assembling operator designated components into complete waste handling systems. Objective two involved comparing various waste handling systems based on costs, energy and labor needs and nutrient conserving ability.

The computer program has been completed and is capable of interacting with an operator via telephone. With the options provided for each section, approximately 4,000 individual systems can be assembled. The program is also capable of accepting new options without revamping the complete package. This may be of benefit in future years as new equipment evolves.

During the farm visits for data collection, it was made clear by dairymen that labor savings, convenience and minimal intrusion on the time available for other farm activities were the main factors dictating the choice of waste systems. Initial cost and nutrient conserving ability were considered to a lesser degree. Waste handling is still viewed by most dairymen as strictly a labor and energy demanding function with little return on their investment.

Many dairymen use outside lots for cattle and the potential for runoff exists in many cases. Few dairymen feel threatened by current EPA regulations, but most new facilities being constructed do include storage units capable of holding 180 days waste material. Also, many of the new units are total confinement barns. Environmental regulations contribute some to this trend, but the improved ability to production group and mechanize feeding and waste handling activities has also been a major factor.

Many more options exist for handling dairy wastes as a liquid than as a solid. This stems primarily from the large assortment of storage facilities and movement to field options. With the exception of earth basin storage, systems utilizing liquids storage are much more expensive than solids systems. Such facilities may represent 50 to 70 percent of total system costs.

The two heaviest users of labor were the twice daily cleaning of barn alleys and the movement of waste material from storage to the field. Automatic alley scrapers and slatted floors provided the only reduction of labor needed for daily cleaning. Flushing also is a labor saver, which may have application in Michigan, but some winter scraping may be required.

Storage emptying requires a large amount of labor and energy regardless of whether solids or liquids are being handled. With liquids, added water from several sources increases the total volume to be hauled and this causes them to utilize more energy and labor than solids. Irrigation requires the addition of large amounts of dilution water and unless a traveling sprinkler unit is used, the amount of labor involved is as great as with other emptying systems.

The nutrient conserving ability of liquids systems is higher than solids systems, mainly due to the storage facility. However, most liquid storage units require large amounts of agitation which causes nitrogen losses, and some of the advantage may be lost. In terms of its monetary value as a fertilizer, a lot of nitrogen can be lost and yet the dollar loss may be only $200.00 or $300.00. As a consequence, most dairymen do not consider their manure supply to be worth as much as some of the research reports would indicate.

This program has potential to benefit dairymen considering new facilities. The designing of a successful waste system involves defining the needs of the operator, incorporating his preferences and limitations, and then assembling the appropriate components to meet those needs. The program would allow this to be done for several feasible systems to allow comparison. The most logical user of the program would be dairy specialists at the county agent level.

In order to do this the program should be made available as a Michigan Tel-Plan program. Extension people are knowledgeable in the use of such programs from prior experience with other such units. Someone would have to take responsibility for getting it into the proper format and keep cost figures, etc., in the program current.

SUMMARY

An interactive computer program has been developed which allows individual dairymen to assemble waste handling systems that meet their specific needs. The user can construct systems for 100 to 300 cows and receive an output describing total costs, annual labor and energy costs, value of the manure, total annual costs and net annual costs. The program was designed with enough flexibility to accommodate new options and allow new systems to be assembled and compared.

When all systems were compared, it was found that no single system emerged as best. Rather, it depended on the operator's needs. Exchanging large sums of initial capital in some cases lowered annual labor needs, but usually increased energy needs. Only two opportunities exist where major savings of labor can occur. One is at the alley cleaning phase and the other is with movement of waste to storage. Automatic alley scrapers, flushing, and slats lessen alley cleaning labor, while below-building tanks, cross conveyors and stackers and gravity flow flumes reduce movement to storage labor. The traveling gun irrigation system is the only way to reduce movement to field labor, but the energy requirement is high.

Liquids storage with the exception of earthen basis is expensive, often constituting 50 to 70 percent of the total system.

They also require a lot of energy and labor to agitate the contents due to the formation of a tough layer of bedding material. Liquid storage is the best method to conserve nitrogen, but many of the post storage phases for liquids tend to lose a good deal of the retained nitrogen.

Liquid system combinations are much more numerous than solids systems, with great ranges occurring in initial price, labor and energy needs. With all systems a scale effect was noted as herd size increased. This was true for liquids and solids systems.

Nearly 70 percent of farms interviewed for this study either used outside lots and needed to incorporate runoff control or had no storage facility. It is also reasonable to assume that many Michigan dairymen will be altering their system sufficiently to require the use of the program which has been developed. The most logical user of this program is the county extension dairy specialist, who has both the need for such a program and the opportunity to run it often enough to become proficient at it.

BIBLIOGRAPHY

BIBLIOGRAPHY

Agpro Incorporated. 1977. Waste handling equipment information. Paris, Texas.

Agromatic Division of A.F. Klinzing Co., Inc. 1977. Unpublished price list and equipment information. Fond Du Lac, Wisconsin.

Amir, I. and J.R. Ogilvie. 1977. A mixed integer programming model for choosing an optimal swine manure handling system. ASAE, Paper No. 77-4028. St. Joseph, Michigan.

Barker, J.C. 1975. Livestock manure production rates and approximate fertilizer content. Leaflet 198, North Carolina Agricultural Extension Service, North Carolina State University, Raleigh, North Carolina.

Berge, O.J. 1971. Waste management, what does it cost? Hoard's Dairyman. April, 10.

Bomgardner, J.H. 1977. Unpublished price list and equipment information. Hesston Corporation, Hesston, Kansas.

Boyd, L.J.; A.L. Rippen; C.R. Hoglund; J.S. Boyd; and G. McBride. 1972. The Michigan dairy industry of 1985. Research Report 183. Agricultural Experiment Station and Cooperative Extension Service, Michigan State University, East Lansing, Michigan.

Buxton, B.M. and S.J. Ziegler. 1974. Economic impact of controlling surface water runoff from U.S. dairy farms. Agricultural Economic Report No. 260, U.S. Department of Agriculture, Economic Research Service.

Calhoun, G.D. 1977. Unpublished price list and equipment information. The DeLaval Separator Company, Poughkeepsie, New York.

Clay Equipment Corporation. 1977. Unpublished price list and equipment information. Fort Wayne, Indiana.

Clinton County Circuit Court File No. 844. 1971. St. Johns, Michigan.

Cleuver, L. and L. Lukinus. 1977. Animal waste management. Confinement, 2:5.

Cristafulli, F.D. 1977. Unpublished price list and equipment information. The Cristafulli Pumps Company, Inc. Glendive, Montana.

Diggs, R.E. 1977. Unpublished price list and equipment information. General Irrigation Company, Carthage, Missouri.

Dorsetl, W. 1977. Unpublished price list and equipment information. Valmont Industries, Valley, Nebraska.

Enpo-Cornell Pump Company. 1977. Unpublished price list and equipment catalog.

Environmental Protection Agency. 1973. National pollutant discharge elimination system (NPDES). Federal Register, 38.

________. 1975. National pollutant discharge elimination system. Concentrated animal feeding operations. Federal Register, 40:54182.

________. 1976. National pollutant discharge elimination system. Concentrated animal feeding operations. Federal Register, 41:11458.

Farmway Company, Inc. 1977. Unpublished price list and equipment information. Manawa, Wisconsin.

Fleming Manufacturing Company. 1977. Unpublished price list and equipment information. Long Lake, Minnesota.

Fogg, C.E. 1974. Use of manure for nitrogen fertilizer. Personal communication, 1978.

Forster, D.L. 1974. The effects of selected water pollution control rules on the simulated behavior of beef feedlots. Ph.D. Thesis, Michigan State University.

Fowler, S. 1976. Unpublished price list and equipment information. A.O. Smith Harvestore Products, Inc.

Gage, L.E. 1977. Unpublished price list and equipment information. H.D. Hudson Manufacturing Company, Chicago, Illinois.

Gehl Company. 1977. Unpublished price list and equipment information. West Bend, Wisconsin.

Gingerich, J. 1977. Unpublished price list and equipment information. Gingway Products Co., Plain City, Ohio.

Good, D. 1972. Potential impacts of environmental pollution abatement alternatives on the Michigan dairy farming industry. Ph.D. Thesis, Michigan State University.

Graves, R.E. 1975. Considerations in selecting dairy manure handling systems. AEN-7, Agricultural Engineering Department, University of Wisconsin, Madison, Wisconsin.

Hale Fire Pump Company. 1977. Unpublished price list and equipment catalog. Conshohocken, Pennsylvania.

Hanratty, M. 1975. PERT programming methods for project appraisal --A computer program. Agricultural Economics Report 290. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Hawk Bilt Company. 1977. Unpublished price list and equipment information. Vinton, Iowa.

Hedlund Manufacturing Company, Inc. 1977. Unpublished price list and equipment information. Boyceville, Wisconsin.

Heck, A.F. 1931. Conservation and availability of the nitrogen in farm manure. Soil Sci., 31:467.

Heubet, E.L. 1977. Unpublished price list and equipment information. Avco New Idea, Farm Equipment Division, Coldwater, Ohio.

Hoglund, C.R.; L.J. Connor; and J.B. Johnson. 1972. Waste management practices and systems on Michigan dairy farms. Agricultural Economics Report 208. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Hoglund, C.R. 1976. Dairy systems analysis handbook. Agricultural Economics Report 300. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Horsfield, B.D.; R.Z. Wheaton; J.C. Nye; and J.V. Mannering. 1973. Irrigation for land application of animal waste. ID-88, Cooperative Extension Service, Purdue University, West Lafayette, Indiana.

Humenik, F.J. 1976. Federal regulations relative to dairy waste management. Paper presented at American Dairy Science Association National Meeting, North Carolina State University, Raleigh, North Carolina.

Hunt, E.H. 1976. Unpublished price list and equipment information. Badger Northland, Inc., Kaukauna, Wisconsin.

Johnson, J.B. and G.A. Davis. 1974. The economic impact of imposing EPA effluent guidelines on the U.S. fed-beef industry. Proceedings of the 1974 Cornell Agricultural Waste Management Conference, Syracuse, New York.

Johnson, J.B.; C.R. Hoglund; and B. Buxton. 1972. An economic appraisal of alternative dairy waste management systems designed for pollution control. Symposium: Animal Waste Management. J. Dairy Sci. 56.

Knight Manufacturing Corporation. 1977. Unpublished price list and equipment information. Brodhead, Wisconsin.

Lauer, D.A.; D.R. Bouldin; and S.D. Klausner. 1976. Ammonia volatilization from dairy manure spread on the soil surface. J. Environ. Qual., 5:134.

Loehr, R.C. 1974. Agricultural Waste Management. Academic Press, New York, New York.

Loudon, T. 1975. Irrigation of animal waste. Agricultural Engineering Facts. No. 45, Department of Agricultural Engineering, Michigan State University, East Lansing, Michigan.

Maclachlan, D.L. 1967. A study of dairy chore labor under different systems of free-stall housing. M.S. Thesis, Michigan State University, East Lansing, Michigan.

Maddex, R.L. 1975. Waste handling systems identification. Agricultural Engineering Facts, No. 49, Department of Agricultural Engineering, Michigan State University, East Lansing, Michigan.

Midwest Plan Service. 1975. Livestock Waste Facilities Handbook.

Morgan, R.J. 1977. Unpublished price list and equipment information. Butler Manufacturing Company, Jamesway Division, Fort Atkinson, Wisconsin.

Morton Ford Tractor, Inc. 1977. Unpublished price list and equipment information. Lansing, Michigan.

Mote, C.R. and E.P. Taiganides. 1975. A computer simulation of storage and land disposal of wastes. The Proceedings of the 3rd International Symposium on Livestock Wastes. American Society of Agricultural Engineers. St. Joseph, Michigan.

Murphy, T.A. 1974. Nonpoint source control to meet water quality goals. Proceedings of the 1974 Cornell University Agricultural Waste Management Conference, Syracuse, New York.

Nesseth Incorporated. 1976. Unpublished price list and equipment information. Dafter, Michigan.

North Central Regional Publication 222. 1975. Livestock Waste Management with Pollution Control.

Nye, J.C.; D.D. Jones; D. Bache; and A.L. Sutton. 1975. Selecting a waste management system. Publication ID-107, Cooperative Extension Service, Purdue University, West Lafayette, Indiana.

Official Guide Tractors and Farm Equipment, Fall, 1977. National Farm and Power Equipment Dealers Association, St. Louis, Missouri.

Ogilvie, J.R.; P.A. Phillips, and K.W. Lievers. 1975. Shortest path network analysis of manure handling systems to determine least cost-dairy and swine. The Proceedings of the 3rd International Symposium on Livestock Wastes. American Society of Agricultural Engineers, St. Joseph, Michigan.

Pearson Bros. Company. 1977. Unpublished price list and equipment information. Galia, Illinois.

Pherson, C.L. 1974. Beef waste management economics for Minnesota farmer-feeders. Proceedings of the 1974 Cornell Agricultural Waste Management Conference, Rochester, New York.

Price, D.R.; L.M. Safley, Jr.; and D.A. Haith. 1977. System studies of waste management alternatives. Dairy Chore Reduction Program Progress Report.

Public Law 92-500. 1972. Federal Water Pollution Control Act Amendments of 1972. United States Congress.

Roberts, I.P. 1884. Experiments on the cost and value of stable manure. Third Report of the Cornell University Experiment Station, Cornell University, Ithaca, New York.

________. 1891. The production and core of farm manures. Fourth Annual Report of the Cornell University of Agricultural Experiment Station, Cornell University, Ithaca, New York.

Rohlf, T. 1977. Unpublished price list and equipment information. Calumet Company, Inc., Algoma, Wisconsin.

Safley, L.M., Jr. 1974. Decision model for animal manure handling. M.S. Thesis, Cornell University, Ithaca, New York.

________. 1977. System selection and optimization models for dairy manure handling systems. Ph.D. Thesis, Cornell University, Ithaca, New York.

Safley, L.M., Jr., and D.R. Price. 1976. Systems analysis of animal waste handling alternatives. American Society of Agricultural Engineers. Paper No. 76-5537.

Safley, L.M., Jr.; D.A. Haith; and D.R. Price. 1977. Decision tools for dairy manure handling systems selection. American Society for Agricultural Engineers. Paper No. 77-4028.

Salesky, A.J. 1977. Unpublished price list and equipment information. Allegan Pipe and Supply Company, Allegan, Michigan.

Sempers, F.W. 1893. Manures: How to Make and Use Them. 2nd Edition, W.A. Burpee and Company, Philadelphia, Pennsylvania.

Schaffer, W.H.; J.J. Jacobs; and G.L. Casler. 1974. An economic analysis of policies to control nutrient and soil losses from a small watershed in New York State. Proceedings of the 1974 Cornell Agricultural Waste Management Conference. Syracuse, New York.

Smith, M.R. 1977. Unpublished price list and equipment information. Starline Division of Chromalloy, Harvard, Illinois.

Stoll, T.L. 1974. An analysis of the effect of expansion on cash flow, management income, and various management factors. M.S. Thesis, Michigan State University, East Lansing, Michigan.

Taylor, H.E. 1977. Unpublished price list and equipment information. Stevens Point, Wisconsin.

Trimble, R.L.; L.J. Connor; and J.R. Brake. 1971. Michigan farm management handbook. Agricultural Economics Report 191. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

United States Department of Agriculture Soil Conservation Service. 1975. Agricultural waste management field manual.

Van Arsdall, R.N. 1974. Economic impact of controlling surface water runoff from point sources in U.S. hog production. Proceedings of the 1974 Cornell Agricultural Waste Management Conference, Rochester, New York.

Van Dale. 1977. Unpublished price list and equipment information. Long Lake, Minnesota.

Vanderholm, D.H. 1976. Nutrient losses from livestock waste during storage, treatment, and handling. The Proceedings of the 3rd International Symposium on Livestock Wastes, University of Illinois, Urbana-Champaign, Illinois.

Vermeer Manufacturing Company. 1977. Unpublished price list and equipment information. Pella, Iowa.

Vitosh, M.L. 1975. Unpublished news release, personal communication.

Walsh, L.M.; R.F. Hensler; and E.E. Schulte. 1975. Manage manure for its value. University of Wisconsin Extension Bulletin, A1672, University of Wisconsin, Madison, Wisconsin.

Warfel, R.R. 1977. Unpublished price list and equipment information. Sperry New Holland, New Holland, Pennsylvania.

Waud, D.C. 1977. Unpublished price list and equipment information. King Hydraulic Power Ltd., Woodstock, Ontario.

Wheeler, H.J. 1913. Manures and Fertilizers. The Macmillan Company, New York, New York.

Williamston Irrigation, Inc. 1977. Unpublished price list and equipment information. Williamstown, New York.

Young, R.A. and C.K. Mutchler. 1976. Pollution potential of manure spread on frozen ground. J. Environ. Qual., 5:174.

APPENDIX A

SURVEY QUESTIONNAIRE FORMS

Table A-1. Farm survey form for waste handling systems

1. Farm Code______________

2. Farm Owners Name____

3. Number of cows housed in the facility___________

4. Available labor on a daily basis__________

HOUSING SYSTEMS

1. Which style housing is used for milking herd

    a. Cold enclosed freestall, total confinement_________

    b. Cold enclosed freestall, outside lot_______

    c. Warm enclosed freestall, total confinement_______

    d. Warm enclosed freestall, outside lot__________

    e. Stanchion barn_________

    f. Bedded pack, outside lot_________

2. If outside lot used, how much area must be scraped daily________

3. If freestalls used, indicate the following:

    a. Number of alleys__________

    b. Length of alleys__________

    c. Width of alleys___________

4. What type of bedding is used

    a. sawdust_________

    b. straw_______

    c. woodchips or shavings________

    d. sand_________

    e. other______________________

Table A-1 (cont'd.)

5. What type of equipment or method is used to clean alleys in the freestall barn

   a. automatic alley scraper_____
   b. skid steer style loader_____
   c. garden tractor with blade_____
   d. 25-70 HP tractor_____
   e. flushing with occasional tractor scrape_____
   f. slotted floors_____

6. How many times/day is alley cleaned___________

7. When is the alley cleaning done

   1. continuously_________
   2. only while cows are in holding pen_________
   3. while cows are in freestall barn________

8. How long does each cleaning require________________

9. How many men required per cleaning____________

10. Is the manure cleaned from each stall every day Yes_____No_____

11. How many times/day is this done 1_____ 2_____

12. How much time does this require on a daily basis_________________

13. How often is bedding material normally replaced or added to

   1. once/week________
   2. once/2 week__________
   3. once/3 week__________
   4. other___________

14. How long does this require each time

   1. 1-2 hours_________
   2. 2-3 hours_________
   3. 3-4 hours_________
   4. 4-5 hours_________
   5. more______________

Table A-1 (cont'd.)

15. How is manure handled

    a. scraped directly into a cross conveyor__________

    b. " " " a piston pump_____________

    c. " " " storage unit______________

    d. " " " an area with a buck wall__________

    e. " " " a pile in a lot area__________

    f. flushed directly into a flume or sump_____________

16. If a cross conveyor is used, how many times per day is it operated

    a. one time_________

    b. 2 times__________

    c. more_____________

17. How long does it run with each operation ________minutes

18. Does someone observe it while it's operating Yes_____ No_____

19. If a piston pump is used, how many times/day is it operated _____

20. Time/operation___________

21. Does someone observe it while it is working Yes_____ No_____

SOLIDS HANDLING SYSTEMS

1. Which method is used to load spreaders

    a. push manure off from a ramp directly into a spreader_________

    b. use of a skid steer loader___________

    c. use of a conventional tractor with a bucket__________

    d. gutter cleaner and short elevator_________

2. Spreader size in bushels A.________ B.________

3. How much time is needed to load the spreader with a loader_______

4. Approximately how far is it to the most commonly used unloading site_______________

5. How long does it take to unload a load______________

Table A-1 (cont'd.)

6. Approximately how many days of manure storage do you have________

7. How long does it take to empty when full ________days

LIQUID AND SEMI LIQUID SYSTEMS

1. Which type of storage is used for manure storage only

    a. upright steel silo____________

    b. upright cement silo___________

    c. earthen lagoon__________

    d. underground cement tank__________

    e. under barn pit__________

2. Storage unit dimensions

    a. height or depth_______________

    b. length________________

    c. width_____________

3. What is approximate storage time with this system________________

4. Is washwater and milking parlor water added to the storage system Yes_____ No_____

5. How long must storage unit be agitated prior to pumping ____days

6. What is capacity of the pump used for agitating and filling tanks _________GPM

7. What is volume of tankers being used A.________Gal. B.________Gal.

8. How long is required to load a tanker______________

9. What HP tractor is used on the pump ________HP

10. What HP tractor is used on the tanker ________HP

11. How long does it normally take to unload a load ______minutes

12. With irrigation, how long does the initial setup take____________

13. How many people needed_____________

14. How long for each reset_____________

Table A-1 (cont'd.)

15. How many people__________
16. How long per set___________
17. How many people to observe___________
18. How completely do you empty the storage___________%
19. How long does this take______________

YOUNG STOCK INFORMATION

1. Number
2. Housing style
3. Frequency cleaned
4. Storage system used
5. Time needed to clean

Table A-2. Introductory letter to equipment dealers

MICHIGAN STATE UNIVERSITY

College of Agriculture and Natural Resources · East Lansing · Michigan · 48824
Department of Dairy Science · Anthony Hall
Telephone (517) 355-8433

Dear Sir:

I am currently a graduate student in the Dairy Department at Michigan State University and part of my thesis project involves a very detailed cost and labor analysis of commonly used waste systems for dairy cattle. The herd sizes being considered are 75-400 milking cows. Due to the detail and scope of this study I am requesting information from more companies than before and also I'm asking for updated catalogues and price lists from companies that may have participated previously.

I realize there are reservations on the part of companies to divulge price information for something such as this. Let me assure you that my only need for such figures is to compute an average price and a range in prices for each components of each waste handling system. No ranking or comparison of systems by brand name will be made and all contributing companies will be acknowledged.

If possible I would greatly appreciate receiving an up to date equipment catalogue as well as a current price list. In the event a catalogue is unavailable, please include any available information and prices regarding the items checked on the following page. If this is not possible please advise me of the name and location of your nearest dealer so that I might discuss my needs with him.

Sincerely,

Winston Ingalls

Return to:

Winston Ingalls
Dairy Department
Room 17 Anthony Hall
Michigan State University
East Lansing, Michigan 48824

WI/lb
Enc.

Table A-3. Equipment information check list

I Would Appreciate Receiving Technical Information and Cost Data on the Following Items:

_____ 1. Front end loaders for use with a 45-60 H.P. tractor

_____ 2. 250-350 bushel conventional solids spreader with hydraulic end gate

_____ 3. 2500-3500 gallon liquid manure spreaders

_____ 4. Injector systems for liquid manure spreaders

_____ 5. Flail type tank spreaders

_____ 6. Self loading slurry spreader

_____ 7. Cross conveyors for barns up to 100 feet wide

_____ 8. Manure stacker or elevator (30-50 feet)

_____ 9. Portable liquid manure pumps for agitating and filling tankers

_____ 10. Stationary pump to agitate and fill tank wagons

_____ 11. Irrigation pump designed to move lagoon wastes up to one-half mile through irrigation pipe and big gun sprinkler

_____ 12. Big gun sprinkler for manure slurry

_____ 13. Irrigation pipe (price/foot or per standard length)

_____ 14. Traveling gun sprinkler

_____ 15. Free stall barn alley scrapers (chain, blade, drive unit)

_____ 16. Above ground liquid manure tanks with recycling pump

_____ 17. Hollow piston or solid piston manure pumps (pump, drive unit, hopper and PVC pipe)

_____ 18. Compressed air manure mover

_____ 19. Slotted floors for dairy cattle (cement)

APPENDIX B

COMPUTER PROGRAMS FOR DETERMINING COSTS, ENERGY DEMANDS AND LABOR DEMANDS FOR VARIOUS WASTE HANDLING SYSTEMS

```
      PROGRAM WASTE(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3)
      DIMENSION MTITLE(8,4),MOTITLE(110,4),MOT(4),IFESS(10,10,10)
      DIMENSION COSTINT(8,10),DIRTPCT(8,10),DIRTTOT(8,10)
      DIMENSION HRLABOR(8,10),COSTLAB(8,10),UNITENE(8,10),COSTENE(8,10)
      DIMENSION ANNBED(8,10),COSTAB(8,10),COSTOP(8,10),T(10)
      DIMENSION IS(10)
      DIMENSION IOP(10)
      DIMENSION VALN(10,10)
      DIMENSION ISO(8)
      NSN=1
      DO 40 I=1,10
      DO 40 J=1,10
      DO 40 K=1,10
40    IFESS(I,J,K)=0
C READ IN SECTION TITLES
      DO 2 I=1,8
2     READ(1,1)(MTITLE(I,J),J=1,4)
1     FORMAT(2X,4A8)
C READ IN OPTION TITLES
4     READ(1,3)ISE,(MOT(J),J=1,4)
3     FORMAT(I3,4A8)
      IF(EOF(1))10,5
5     DO 5 I=1,4
6     MOTITLE(ISE,I)=MOT(I)
      GO TO 4
C READ IN FEASIBLE OPTIONS
10    READ(2,7)ISE,IPO,INO,IOC
7     FORMAT(3I2,I3)
      IF(EOF(2))20,8
8     IFESS(ISE,IPO,INO)=IOC
      GO TO 10
C ASK QUESTIONS
20    PRINT 11
11    FORMAT(*1THIS PROGRAM CALCULATES THE COSTS ASSOCIATED*/,
     +* WITH A PARTICULAR WASTE MANAGEMENT SYSTEM*)
      PRINT 13
13    FORMAT(*0THERE ARE 8 SECTIONS OF CRITERIA NEEDED TO*/,
     +* COMPLETE THIS TASK*)
      PRINT 14
14    FORMAT(*0THE SECTIONS ARE AS FOLLOWS:*)
      DO 15 I=1,8
15    PRINT16,I,(MTITLE(I,J),J=1,4)
16    FORMAT(I5,5X,4A8)
      PRINT 17
17    FORMAT(*0FOR EACH SECTION THERE ARE SEVERAL OPTIONS*)
      PRINT 18
18    FORMAT(* WHEN PROMPTED WITH AN ASTERISK,TYPE IN THE*/,
     +* CODE FOR THE OPTION DESIRED IN I3 FORMAT,IE 002*/,
     +* FOR ALL POSSIBLE OPTIONS FROM THIS POINT ON-TYPE 000*)
      NN=11
      DO 50 I=1,8
      DO 50 J=1,10
      COSTINT(I,J)=DIRTPCT(I,J)=DIRTTOT(I,J)=HRLABOR(I,J)=0
      COSTLAB(I,J)=UNITENE(I,J)=COSTENE(I,J)=ANNBED(I,J)=0
50    COSTAB(I,J)=COSTOP(I,J)=0
      IFLAG=0
      DO 44 I=1,10
      IS(I)=0
44    T(I)=0
      J=1
      DO 100 I=1,8
      PRINT 33 ,I,(MTITLE(I,L),L=1,4)
33    FORMAT(*0SECTION *,I2,5X,4A8)
      PRINT 34
34    FORMAT(* CODE        OPTION*)
      DO 23 K=1,10
      IF(IFESS(I,J,K).EQ.0)GO TO 23
      L=IFESS(I,J,K)
      PRINT 27,IFESS(I,J,K),(MOTITLE(L,LL),LL=1,4)
27    FORMAT(1X,I3,5X,4A8)
23    CONTINUE
24    READ 25,KODE
25    FORMAT(I3)
      IF(KODE.EQ.0) GO TO 105
      DO 43 K=1,10
      IF(IFESS(I,J,K).EQ.KODE)GO TO 41
43    CONTINUE
      PRINT 42
42    FORMAT(*0THIS IS NOT A FEASIBLE OPTION,RETYPE CODE*)
      GO TO 24
41    PRINT 29,(MOTITLE(KODE,LL),LL=1,4)
```

```
29     FORMAT(* YOU WISH TO USE *,4A8,* IS THAT CORRECT=*/,
      +* TYPE Y FOR YES, N FOR NO*)
       READ 28,IR
28     FORMAT(R1)
       IF(IR.EQ.318) GO TO 26
31     PRINT 30
30     FORMAT(* TYPE IN NEW OPTION*)
       GO TO 24
26     IF(I.EQ.1)GO TO 101
       IF(I.GE.6)NN=NN-10
       J=KODE-(I*10)+NN
       IS(I)=J
       GO TO 102
105    PRINT 106
106    FORMAT(* YOU WISH TO MAKE NO MORE CHOICES,IS THAT CORRECT=*/
      +* TYPE Y FOR YES,N FOR NO*)
       READ 28,IR
       IS(I)=KODE
       IF(IR.EQ.318) GO TO 102
       GO TO 31
101    J=KODE
       IS(1)=J
102    IF(KODE.EQ.0)GO TO 200
100    CONTINUE
C READ IN VARIABLE CRITERIA
200    PRINT 201
201    FORMAT(*4TYPE IN THE FOLLOWING VARIABLES WHEN ASKED*)
204    PRINT 203
203    FORMAT(*0 NUMBER OF COWS IN I3 FORMAT,IE 080*)
       READ 205,NCOWS
205    FORMAT(I3)
       PRINT 202,NCOWS
202    FORMAT(*     SYSTEM COSTS WILL BE CALCULATED FOR *,I3,* COWS*/
      +* IS THAT CORRECT= TYPE Y FOR YES, N FOR NO*)
       READ 28,IR
       IF(IR.EQ.318)GO TO 500
       PRINT 207
207    FORMAT(* TYPE IN NEW NUMBER OF COWS*)
       GO TO 204
500    PRINT 300
       COWS=NCOWS
300    FORMAT(*4TYPE IN STYLE OF BARN YOU HAVE*)
       PRINT 301
301    FORMAT(* 1=PENN STYLE DRIVE THRU,CENTRAL ALLEY,4 ALLEYS*)
       PRINT 302
302    FORMAT(* 2=CENTER FEED-2 ALLEYS*)
       PRINT 303
303    FORMAT(* 3=NONE OF THE ABOVE*)
       READ 304,IBARN
304    FORMAT(I1)
       GO TO(310,311,312)IBARN
310    ALLEYNO=4.0
       ALLLNTH=((COWS*0.9/ALLEYNO)+0.20*(COWS*0.9/ALLEYNO))*3.5+20
       GO TO  400
311    ALLEYNO=2.0
       ALLLNTH=(COWS*0.9/ALLEYNO)*3.5
       GO TO 400
312    PRINT 313
313    FORMAT(* TYPE IN NUMBER OF ALLEYS IN YOUR BARN*)
       READ 314, ALLEYNO
314    FORMAT(F2.0)
       PRINT 315,ALLEYNO
315    FORMAT(* YOU WILL HAVE*,F3.0,*ALLEYS IN YOUR BARN,CORRECT=*,
      +* TYPE Y FOR YES,N FOR NO*)
       READ 28, IR
       IF(IR.EQ.318) GO TO 316
       GO TO 312
316    PRINT 317
317    FORMAT(* TYPE IN THE ALLEY LENGTH PER ALLEY,I.E.BARN LENGTH*)
       READ 318,ALLLNTH
318     FORMAT(F3.0)
       PRINT 319, ALLLNTH
319    FORMAT(* THE ALLEY LENGTH OF BARN WILL BE*,F5.0,/
      +* IS THAT CORRECT=,TYPE Y FOR YES,N FOR NO*)
       READ 28,IR
       IF(IR.EQ.318)GO TO 400
       GO TO 316
400    CONTINUE
       CPA=COWS/ALLEYNO
       IF(CPA.LE.75)GO TO 401
       PRINT 402
```

```
402    FORMAT(*YOU WILL HAVE MORE THAN 75 COWS PER ALLEYWHICH*/
      +*MAY RESULT IN ALLEY LENGTHS APPROACHING 300 FEET WHICH*/
      +*EXCEEDS THE LENGTH THAT A ALLEY SCRAPER MAY HANDLE.*/
      +*DO YOU WISH TO CONSIDER CHANGING THE NUMBER OF COWS OR*/
      +* BARN TYPE (I.E.NO OF ALLEYS),TYPE Y FOR YES,N FOR NO*)
       READ 29,IR
       IF(IR.EQ.318) GO TO 204
401    CONTINUE
       IF(IS(4).NE.0) GO TO 440
       PRINT 430
430    FORMAT(* TYPE IN 2 FOR FLUSH SYSTEM*/
      +* TYPE IN 0 FOR NON-FLUSH SYSTEM*)
       READ 431,IS(10)
431    FORMAT(I1)
440    CONTINUE
C ALL CALCULATIONS AND CONSTANTS
C INITIALIZATION OF DEFAULT VARIABLES
C STALL SPECIFICATIONS AND BEDDING NEEDED
C LABOR COSTS PER HOUR
       CSLABOR=3.50
C CEMENT COSTS PER CUYD
       CEMCSTY=28.00
C COST PER SQ FOOT OF CEMENT POURED FOR FLOORING
       CFCSSQF=1.50
C COST OF CONCRETE PER SQFT FOR STORAGE
       CONCSQF=1.25
C COST OF CLAY/CUYD
       CLAYCST=5.00
C INITIAL VOL OF CLAY/STALL (CUYDS)
       CLPERST=1.00
C VOL OF CEMENT PER FOOT OF 10INCH CURB (CUYDS)
       CURBCEM=0.016
C CURB COST PER FOOT
       CURBCFT=2.00
C COST OF INDIVIDUAL COW MATS
       COSTMAT=50.00
C NUMBER OF STALLS PER COW
       STNPCOW=0.9
C SAND USED PER DAY/STALL (CUYDS)
       SANDDAY=.03
C INITIAL SAND COVER PER STALL (CUYDS)
       SNDCOVS=1.0
C COST OF SAND/CUYD ($/YD)
       SNDCSTY=3.00
C COST OF SHAVINGS/LB ($/LB
       SSCSTLB=0.01
C INITIAL SHAVINGS/STALL (LBS)
       STALLSS=100
C COST OF STRAW/LB ($/LB)
       STAWCST=0.025
C INITIAL STRAW/STALL (LBS)
       STAWUSE=75.0
C STALL DEPTH FROM CURB TO FRONT(FT)
       STDEPTH=7.0
C SHAVINGS USED/MATTED STALL/DAY
       SMATHSD=2.4
C DAILY STRAW/MATTED TALLS
       SMATTSD=2.1
C CEMENT THICKNESS IN BASE OF STALL (FT)
       STTHCK=0.33
C WIDTH OF EACH STALL(FT)
       STWIDTH=3.5
C WEIGHT OF SHAVINGS USED PER STALL PER DAY(LBS)
       WTSHSTD=4.8
C WEIGHT OF STRAW USEC PER STALL PER DAY (LBS)
       WTSTSTD=4.2
C YRLY TIME SPENT FIXING EACH CLAY STALL
       CLSFIXT=0.5
C STALL DEPR RATE
       STDEPR=0.05
C STALL INT RATE
       STINTR=0.05
C STALL RHI RATE
       STRHIR=0.035
C CURB SALVAGE VALUE
       CURBSLV=0.00
C DAILY N EXCRETED PER COW
       CLYNNPC=0.58
C YRLY TOTAL N EXCRETED
       YRLYNN=DLYNNPC*COWS*365
C DAILY PHOSPHOROUS PER COW
```

```
      CLYPHPC=0.22
C YRLY TOTAL P EXCRETED
      YRLYPH=DLYPHPC*COWS*365
C DAILY K EXCRETED PER COW
      DLYKKPC=0.56
C CURB AND CEMENT PLATFORM SALVAGE VALUE
      CURBPSV=0.00
C YRLY TOTAL K PRODUCED
      YRLYKK=DLYKKPC*COWS*365
C PRICE/POUND OF N
      PRICEN=0.20
C PRICE/LB OF P
      PRICEP=0.20
C PRICE/LB K
      PRICEK=0.12
C CALCULATIONS TO BE MADE
C SECTION ON STALLS AND BEDDING
C NUMBER OF STALLS
      STALLSN=(0.9*COWS)
C TOTAL CURB LENGTH
      CURBLTH=(STALLSN*STWIDTH)
C TOTAL   CEMENT IN CURB
      CURBCTO=(CURBLTH*CURBCEM)
C COST OF CURB CEMENT
      CURBCST=CURBCFT*CURBLTH
C TOTAL YRLY TIME SPENT FIXING CLAY STALLS
      CLSYFXT=0.5*STALLSN
C YRLY LABOR COSTS TO REPAIR CLAY STALLS
      CLSFXLC=CLSYFXT*CSLABOR
C STALL DIRT RATE
      STDIRTR=(STDEPR+STINTR+STRHIR)
C CLAY OWNERSHIF COSTS
      CLSTOCS=CURBCST*STDIRTR+CLSFXLC
C TOTAL SAND USED TO INITIALLY FILL STALLS
      SNDTOTS=(SNDCOVS*STALLSN)
C TOTAL SAND COST FOR INITIAL SAND
      SANDTOC=(SNDTOTS*SNDCSTY)
C TOTAL SHAVINGS USED INITIALLY
      SSTOLBS=(STALLSS*STALLSN)
C TOTAL COST OF INITIAL SHAVINGS
      SSTOCST=(SSTOLBS*SSCSTLB)
C TOTAL STRAW USED INITIALLY IN STALLS
      STWLBS=(STALLSN*STAWUSE)
C TOTAL COST OF INITIAL STRAW
      STWTCST=(STWLBS*STAWCST)
C DAILY SAND COSTS
      SANDCST=SANDDAY*STALLSN*SNDCSTY
C YEARLY SAND USED (CUYDS)
      SANDY=SANDDAY*365*STALLSN
C YEARLY SAND COSTS
      SNDCSYR=(SANDCST*365)
C SHAVINGS USED PER DAY FOR ALL STALLS
      SHVDAY=WTSHSTD*STALLSN
C SHAVINGS COST/DAY
      SHCSTD=(SHVDAY*SSCSTLB)
C YEARLY SHAVINGS USED
      SHVYR=SHVDAY*365/2000
C YEARLY SHAVINGS COSTS
      SHCSTYR=(SHCSTD*365)
C STRAW USED/DAY  ALL STALLS
      STWDAY=(WTSTSTD*STALLSN)
C DAILY STRAW COSTS USED FOR BEDDING
      STWCSTD=(STWDAY*STAWCST)
C YEALY STRAW USED
      STRWYR=STWDAY*365/2000
C YEARLY COST OF STRAW BEDDING
      STRCSYR=(STWCSTD*365)
C SHAVINGS USED/DAY ALL MATTED STALLS
      SMATHD=(SMATHSD*STALLSN)
C YRLY SHAVINGS WITH MATS
      SMATHYR=(SMATHD*365)/2000
C YRLY MAT SHAVINGS COST
      SMATHCY=(SMATHYR*SSCSTLB)
C SHAVINGS COSTS/YR,MATS,FEL.
      SHYRMFC=SMATHCY
C TOTAL STRAW USED IN MATTED STALLS
      SMATTD=(SMATTSD*STALLSN)
C YEARLY STRAW WITH MATS
      SMATTYR=(SMATTD*365)/2000
C YRLY STRAW COSTS WITH MATS
      SMATTCY=(SMATTYR*STAWCST)
```

```
C STRAW COSTS/YR,MATS,FEL.
      STWMFCY=SMATTCY
C TOTAL CLAY USED
      CLAYTOT=(STALLSN*CLPERST)
C SHAVINGS/YR WITH MATTED STALLS,FEL.
      SHYRMFL=SMATHYR
C TOTAL CLAY INITIALLY USED (COST)
      CLATOCS=(CLAYTOT*CLAYCST)
C CURB AND INITIAL CLAY COSTS
      CLCRBCS=(CURBCST+CLATOCS)
C COST OF CURB,SAND AND CLAY
      CSTSCC=(SANDTOC+CLATOCS+CURBCST)
C TOTAL COST OF CEMENT CURB CLAY   BASE AND SHAVINGS
      STCCLCS=(CURBCST+CLATOCS+SSTOCST)
C TOTAL COST OF CURB+ CLAY BASE +STRAW
      STCCLSW=(CURBCST+CLATOCS+STWTCST)
C CEMENT VOL PER STALL PLATFORM (CUYDS)
      STCONVL=(STWIDTH*STDEPTH*STTHCK)/27
C TOTAL YDS CEMENT IN STALLS
      STCEMTO=(STCONVL*STALLSN)
C COST OF STALL PLATFORM CEMENT
      STPLCST=((CFCSSQF*STWIDTH*STDEPTH)*STALLSN)
C COST OF CURB AND PLATFORM
      CURBPLC=(STPLCST+CURBCST)
C CEMENT STALL AVE VALUE
      CURBPOC=(CURBPLC*STDIRTR)
C TOTAL COSTS OF MATS+INITIAL SHAVINGS
      TOSTMAT=(COSTMAT*STALLSN)+(0.5*SSTOCST)
C TOTAL COST OF MATS+INITIAL STRAW
      TOCWMAT=(COSTMAT*STALLSN)+(0.5*STWTCST)
C COST OF CURB+CEMENT PLATFORM+MATS
      STPLCMC=(STPLCST+CURBCST+SSTOCST)
C COST OF CEMENT PLATFORM+CURB+INITIAL SHAVINGS
      STPLCSS=(STPLCST+CURBCST+SSTOCST)
C COST OF CEMENT PLATFORM CURB AND STRAW
      STPLCSW=(STPLCST+CURBCST+STWTCST)
C WASTE PRODUCTION VOLUMES ETC
C INITIALIZATION OF DEFAULT VALUES
C DAILY VOL OF FECES AND URINE(CUFT)/COW
      VMANDAY=1.85
C DAILY MILKHOUSE WASTE VOLUME (CU FT PER COW)
      WSMHTDY=0.60
C DAILY VOLUME OF SAND ENTERING WASTE SYSTEM (CUFT)
      VSANDDY=.03
C WASTE PRODUCTION CALCULATED VALUES
C TOTAL DAILY VOLUME OF MILKHOUSE WASTE PRODUCED DAILY
      WSMHTFT=(WSMHTDY*COWS)
C TOTAL DAILY MANURE PRODUCED
      TVMANDY=(1.85*COWS)
C DAILY VOLUME OF SHAVINGS ENTERING MANURE STORAGE
      VOLSHDY=((WTSHSTD*STALLSN*0.5)/8)
C DAILY VOL OF STRAW ENTERING STORAGE
      VOLSTDY=((WTSTSTD*STALLSN*0.5)/8)
C DAILY VOL SHAVINGS AND MANURE
      VOLMSHV=VOLSHDY+TVMANDY
C DAILY VOL OF MANURE SHAVINGS AND WASTE WATER
      VOLMSHW=(VOLSHDY+WSMHTFT+TVMANDY)
C 90DAY SHAV AND MANURE ETC
      VLS90DY=(90*VOLMSHW)
C 180DAY SHAV AND WASTES
      VLS180D=(180*VOLMSHW)
C 270DAY SHAV AND WASTES
      VLS270D=(270*VOLMSHW)
C 365DAY SHAV AND WASTES
      VLS365D=(365*VOLMSHW)
C 365 DAY VOLUME SHAVINGS AND MANURE
      V365MSH=365*VOLMSHV
C DAILY VOL OF MANURE STRAW AND WASTE WATER
      VOLMSTW=(TVMANDY+WSMHTFT+VOLSTDY)
C 90 DAY STRAW AND WASTE VOL
      VL90ST=(90*VOLMSTW)
C 180DAY STRAW WASTE VOL
      VL180ST=(180*VOLMSTW)
C 270DAY VOL STRAW
      VL270ST=(270*VOLMSTW)
C 365DAY VOL STRAW
      VL365ST=(365*VOLMSTW)
      IF(IS(4).EQ.5) VL365ST=VL365ST*5.5
      IF(IS(10).NE.0) VL365ST=VL365ST*5.5
C DAILY VOLUME OF MANURE,SAND AND PARLOR WATER
      VLMSNDW=(VSANDDY+VMANDAY+WSMHTFT)
```

```
C 90DAY SAND AND WASTE VOLUME
      VL90SD=(90*VLMSNOW)
C 180DAY SAND WASTE VOL
      VL180SD=(180*VLMSNOW)
C 270 DAY SAND WASTE
      VL270SD=(270*VLMSNOW)
C 365 DAY SAND WASTE VOL
      VL365SD=(365*VLMSNOW)
C DEFAULT VARIABLES ASSOCIATED WITH UTILITY TRACTOR
C UTILITY TRACTOR DEP RATE
      UTDPPER=0.10
C HOURS/DAY UTILITY TRACTOR USED FOR SCRAPING ONE ALLEY 2X DAILY
      UTHRSDY=0.33
C UTILITY INTEREST RATE
      UTINTPR=0.06
C UTILITY MISC RATE
      UTMSCPR=0.02
C COST OF NEW UTILITY TRACTOR AND BLADE
      UTNCOST=11500.00
C UTILITY TRACTOR HRLY FIXED COSTS
      UTHRFXC=4.75
C GALLONS/HR OF FUEL USED
      UTGALHR=3.0
C RHI RATE
      UTRHIPR=0.10
C SALVAGE VALUE AFTER 10 YRS
      UTSALVV=0.00
C PERCENT OF TRACTORS TOTAL TIME USED FOR SCRAPING
      UTSCRPR=0.30
C COST OF GASOLINE
      FUELCST=0.53
C DIESEL FUEL COSTS
      FUEDSLC=0.52
C CALCULATED VALUES FOR UTILITY TRACTOR
C HRS UTILITY TRACTOR USED PER DAY FOR SCRAPING
      UTHRDSC=ALLEYNO*UTHRSDY
C HOURS USED SCRAPING/YR
      UTHRSYR=(UTHRDSC*365)
C LABOR COSTS/YR FOR SCRAPING
      UTLABYR=(UTHRSYR*CSLABOR)
C FUEL USED/DAY
      UTFUELD=(UTGALHR*UTHRSDY*ALLEYNO)
C FUEL/YR
      UTFUELY=(UTFUELD*365)
C FUEL COSTS/YR
      UTFCSTY=(UTFUELY*FUEDSLC)
C OPERATING COSTS FOR YR
      UTOPCSY=(UTLABYR+UTFCSTY)
C UTILITY TRACTOR DIRTI RATE
      UTDIRTP=(UTDPPER+UTINTPR+UTMSCPR+UTRHIPR)
C YRLY OWNERSHIP COSTS FOR UTILITY TRACTOOR
      UTYOWCS=UTDIRTP*UTNCOST
C UTILITY TRACTOR OWN COSTS DUE TO SCRAPING
      UTOWNCS=UTHRSYR*UTHRFXC
C TOTAL YEARLY COSTS OF OWNERSHIP PLUS OPERATING
      UTTOOCS=(UTOWNCS+UTOPCSY)
C FLOOR OR ALLEY DIMENSIONS
C INITILIZATION OF DEFAULT VALUES
C SLOTTED FLOOR AREA/COW(SQFT)
      SLOTACW=45.0
C COST OF SLATTED FLOOR ALLEY ($/SQFT)
      SLOTCFT=2.25
C SLOTTED FLOOR DEP RATE
      SLFDEPR=0.05
C SLOT FLOOR INT RATE
      SLFINTR=0.05
C SLOT FLOOR RHI RATE
      SLFRHIR=0.035
C SOLID FLOOR DEP RATE
      SOFDEPR=0.05
C SOLID FLOOR INT RATE
      SOFINTR=0.05
C SOLID FLOOR RHI RATE
      SOFRHIR=0.035
C ALLEY AREA PER COW ON SOLID FLOORS
      CFACOW=50.0
C THICKNESS OF CEMENT IN ALLEYS(FT)
      CFTHICK=0.33
C CALCULATED VALUES FOR FREESTALL ALLEYS
C TOTAL SLOTTED FLOOR AREA
      SLOTATL=(SLOTACH*COWS)
```

```
C COST OF TOTAL SLOTTED FLOOR
      SLOTTCS=(SLOTCFT*SLOTATL)
C SLOTTED FLOOR DIRT RATE
      SLFDRTR=(SLFDEPR+SLFINTR+SLFRHIR)
C YEARLY SLOTTED FLOOR OWN COSTS
      SLFOCS=(SLOTTCS*SLFDRTR)
C TOTAL AREA OF SOLID FLOOR
      TOTCEMA=(COWS*CFACOW)
C VOLUME OF CEMENT IN FLOORS OR ALLEYS(CUYDS)
      CFCVOL=(TOTCEMA*CFTHICK)/27
C COST OF CEMENT IN SOLID FLOOR
      CSTCFLO=CFCSSQF*COWS*CFACOW
C SOLID FLOOR DIRT RATE
      SOFDRTR=(SOFDEPR+SOFINTR+SOFRHIR)
C YEARLY SOLID FLOOR OWN COSTS
      SOFOCS=(SOFDRTR*CSTCFLO)
C INITIALIZATION OF VALUES FOR SKID STEER LOADER
C FUEL CONSUMPTION PERHR
      GALNHR=2.8
C SKIDSTEER AVE TRADE IN OF OLD LOADER
      SKAVESP=0.00
C NEWPRICE FOR SKID STEER
      SKCOST=10500
C HOURS USED/DAY HANDLING MANURE (SCRAPING ALLEYS) 1 ALLEY,2X DAILY
      SKHRDSA=0.33
C TIME TO LOAD 1 SPREADER(280BU)
      SKLOACT=5.5
C C/OOF TIME SKIDSTEER USED FOR MANURE HANDLING ACTIVITIES
      SKMSPER=0.35
C SKIDS DEPR
      SKSDEPR=0.125
C SKIDSTEER INT RATE
      SKSINTR=0.05
C SKS RHI RATE
      SKSRHIR=0.065
C SKS MISC RATE
      SKSMSCR=0.02
C PERCENTAGE OF SKS TIME SCRAPING
      SKSPERT=0.25
C HRLY FIXED COSTS ON SKS
      SKHRFXC=8.00
C CALCULATED VALUES FOR SKID STEER
C TOTAL SKS DIRT RATE
      SKSDIRT=(SKSDEPR+SKSINTR+SKSRHIR+SKSMSCR)
C HRS/DAY SKIDSTEER USED FOR SCRAPING
      SKSHDSC=ALLEYNO*SKHRDSA
C HOURS PER YEAR SKIDSTEER USED FOR MANURE HANDLING SCRAPING ALLEYS
      SKHRYR=SKSHDSC*365
C SKIDSTEER LABOR COSTS FOR YEAR SCRAPING
      SKLCST=(SKHRYR*CSLABOR)
C TOTAL FUEL USED IN A YR SCRAPING
      FUELYR=(SKHRYR*GALNHR)
C FUEL COSTS/YEAR SCRAPING
      SKFCSTY=(FUELCST*FUELYR)
C SKS OWN COSTS
      SKSOWNC=((SKSDIRT*SKCOST)*SKSPERT)
C OWNERSHIP COSTS ON SKS DUE TO ALLEY SCRAPING
      SKALSOC=SKHRYR*SKHRFXC
C SKID STEER TOTAL COSTS
      SKTCSTS=SKALSOC+SKFCSTY+SKLCST
C TIME TO BED COWS WITH STRAW OR SAWDUST USING EITHER A SKIDSTER OR FRON
C COST OF FEL
      FELCST=2500.00
C TOTAL COST OF UTILITY TRACTOR AND FEL
      FELUTTC=FELCST+UTNCOST
C DEPRECIATION RATE ON FEL
      FELDEPR=0.10
C INTEREST RATE ON LOADER
      FELINTR=0.06
C RHI RATE ON FEL
      FELRHIR=0.07
C MISC RATE ON LOADER
      FELMISR=0.02
C SALVAGE VALUE OF FEL
      FELSALV=0.00
C PERCENTAGE OF FRONT LOADERS TOTAL TIME SPENT ON BEDDING (DEFAULT VARIA
      BDTTPER=0.10
C PERCENT OF TIME FEL USED BEDDING MATS
      BDMFLPR=0.06
C NUMBER OF PEOPLE DOING BEDDING WITH FRONT LOADER
      BEDLABR=2
```

```
C NUMBER OF MEN USED TO BED WITH SKIDSTER
      BEDSKLB=1
C PERCENTAGE OF TOTAL TIME SKIDSTER USED FOR BEDDING
      BDSKPER=.05
C TIME PER MONTH TO BED 1 STALL WITH FRONT LOADER
      BEDFL1S=0.07
C TIME/MONTH TO BED MATS WITH FEL,SHAVINGS.
      BDFLM1S=0.04
C TIME/MONTH TO BED MATS WITH FEL AND STRAW
      BDFLM1W=0.04
C TIME PER MONTH TO BED WITH SKIDSTER (STRAW OR SHAVINGS,NO MATS),4880.
      BEDSK1S=0.04
C TIME/MONTH TO BED MATS WITH SKS AND SHAVINGS
      BDSKM1S=0.02
C TIME/MONTH TO BED MATS WITH SSKS AND STRAW
      BDSKM1W=0.02
C CALCULATED VALUES FOR SKIDSTER AND FEL  FOR STRAW,SHAVINGS ANC SAWDUST
C HRS/YR UTILITY TRACTOR USED IN BEDDING WITH SHAVINGS
      BDFLH12=BEDFL1S*STALLSN*12
C FEL TOTAL DRHI RATE
      FELDRTT=(FELDEPR+FELINTR+FELMISR+FELRHIR)
C FEL OWN COSTS
      FELOCST=(FELDRTT*FELCST)
C MONTHLY MANHRS TO BED CATTLE WITH FEL
      BDMONMH=BEDLABR*BEDFL1S*STALLSN
C YRLY MHRS TO BED WITH FEL AND SHORT STRAW
      BDYRLMH=(BDMONMH*12)
C YEARLY LABOR COSTS WITH FEL
      BDYRLCS=(CSLABOR*(12*BDMONMH))
C YRLY MHRS TO BED MATS WITH FEL AND SHAVINGS
      BDFLMYS=BDFLM1S*STALLSN*12*BEDLABR
C YRLY MHRS TO BED MATS WITH FEL AND STRAW
      BDFLMYW=BDFLM1W*STALLSN*12*BEDLABR
C FUEL USE FOR FEL FOR BEDDING STRAW ETC
      BDFUELU=BDFLH12*UTGALHR
C FUEL COSTS FOR FEL FOR BEDDING
      BDFUELC=(FUEDSLC*BDFUELU)
C FEL OWNERSHIP COSTS ATTRIBUTED TO BEDDING
      BDOWNCS=(FELOCST*BDTTPER)+(BDFLH12*UTHRFXC)
C OWN COSTS FOR BEDDING WITH FEL MATS SHAVINGS
      BDOWMSF=(BDMFLPR*FELOCST)+(12*BDFLM1S*UTHRFXC*STALLSN)
C OWN COSTS FOR FEL MATS STRAW
      BDOWMWF=(BDMFLPR*FELOCST)+(12*BDFLM1W*UTHRFXC*STALLSN)
C YEARLY TOTAL COST FOR FEL BEDDING
      BDYRCST=(BDFUELC+BDOWNCS+BDYRLCS)
C LABOR COSTS SHAVINGS MATS FEL
      BDLCMSF=CSLABOR*BDFLMYS
C LABOR COSTS SHAVINGS MATS FEL
      BDLCMWF=CSLABOR*BDFLMYW
C SKIDSTER HRS PER MONTH SPENT BEDDING
      BEDSKMN=BEDSK1S*STALLSN
C TOTAL MONTHLY MAN HRS FOR BEDDING WITH SKIDSTER
      BEDSKMH=(BEDSKLB*BEDSKMN)
C YEARLY MANHRS SPENT BEDDING WITH SKIDSTER
      BDSKYHR=(12*BEDSKMH)
C ANNUAL LABOR COSTS ASSOCIATED WITH SKIDSTER BEDDING
      BDSKLBC=(CSLABOR*BDSKYHR)
C YRLY MHRS TO BED MATS WITH SKS AND SHAVINGS
      BDSKMHS=BDSKM1S*STALLSN*12*BEDSKLB
C YRLY MHRS TO BED MATS WITH SKS AND STRAW
      BDSKMHW=BDSKM1W*STALLSN*12*BEDSKLB
C LABOR COSTS SHAVINGS MATS SKS
      BDLCMSS=CSLABOR*BDSKMHS
C LABOR COSTS STRAW MATS SKS
      BDLCMWS=CSLABOR*BDSKMHW
C ANNUAL SKIDSTER FUEL USE FOR BEDDING
      BDSKFUE=12*STALLSN*BEDSK1S*GALNHR
C FUEL USED MATS,SHAVINGS FEL
      BDFMSFL=UTGALHR*BDFLM1S*STALLSN*12
C FUEL USED MATS STRAW FEL
      BDFMWFL=UTGALHR*BDFLM1W*STALLSN*12
C FUEL USED MATS SHAVINGS SKS
      BDFMSSK=UTGALHR*BDSKM1S*STALLSN*12
C FUEL USED MATS STRAW SKS
      BDFMWSK=UTGALHR*BDSKM1W*STALLSN*12
C ANNUAL SKIDSTER FUEL COSTS ASSOCIATED WITH BEDDING
      BDSKFLC=(BDSKFUE*FUELCST)
C FUEL COSTS ,SHAVINGS,MATS FEL
      BDFCSMF=BDFMSFL*FUEDSLC
C FUEL COSTS,STRAW,MATS FEL
      BDFCWMF=BDFMWFL*FUEDSLC
```

```
C FUEL COSTS,SHAVINGS,MATS,SKS
      BDFCSMS=BDFMSSK*FUELCST
C FUEL COSTS STRAW MATS SKS
      BDFCWMS=BDFMWSK*FUELCST
C ANNUAL SKIDSTER OWNERSHIP COSTS DUE TO BEDDING (NO MATS)
      BDSKOCS=SKHRFXC*BEDSK1S*STALLSN*12
C OWN COSTS FOR BEDDING MATS WITH SKS SHAVINGS
      BDSKOMS=SKHRFXC*BDSKM1S*12*STALLSN
C OWN COSTS TO BED MATS WITH SKS AND STRAW
      BDSKOMW=SKHRFXC*BDSKM1W*12*STALLSN
C ANNUAL TOTAL COSTS ASSOCIATED WITH SKST AND BEDDING
      SKSTTYC=(BDSKFLC+BDSKLBC+BDSKOCS)
C BEDDING WITH SAND BEDDING
C INITIALIZATION OF DEFAULT VARIABLES
C NUMBER OF PEOPLE NEEDED WITH FRONT LOADER
      FLSMEN=3
C TIME/MONTH TO BED 1STALL WITH SAND AND FRONT LOADER
      FLSND1S=0.05
C PERCENTAGE OF TOTAL TIME FEL IS USED FOR SAND BEDDING
      FLSNPER=0.20
C MEN NEEDED TO BED COWS WITH SAND USING A SKIDSTER
      SNDSSLB=2.0
C TIME/MONTH TO BED 1 STALL WITH SAND USING SKIDSTER
      SNDSS1S=0.03
C PERCENT OF TIME SKST USED FOR SAND BEDDING
      SNDSSPR=0.05
C CALCULATED VALUES FOR SAND BEDDING
C TIME TO BED COMPLETE HERD/MONTH WITH SAND AND FL
      FLSTOTM=FLSND1S*STALLSN
C YRLY UTILITY TRACTOR TIME TO BED WITH SAND
      FLSTYTM=FLSTOTM*12
C TOTAL MONTHLY MANHRS TO BED WITH SAND AND FRONT LOADER MONTHLY
      FLMMHRS=(FLSTOTM*FLSMEN)
C YRLY MHRS TO BEDWITH SAND AND FEL
      FLSYRMH=(FLMMHRS*12)
C YEARLY LABOR COSTS FOR SAND AND FL
      FLSYLCS=((12*FLMMHRS)*3.50)
C YEARLY FUEL USED TO BED WITH SAND AND FRONT LOADER
      FLSNFLU=((FLSTOTM*12)*UTGALHR)
C YEARLY FUEL COSTS DUE TO THIS JOB
      FLSNYFC=(FLSNFLU*FUEDSLC)
C YEARLY OWNERSHIP COSTS DUE FRONT LOADER AND SAND
      FLSNOCS=(FELOCST*FLSNPER)+(UTHRFXC*FLSTYTM)
C TOTAL YEARLY COSTS OF OPERATING FRONT LOADER FOR SAND BEDDING
      FLSNTYC=(FLSNYFC+FLSNOCS+FLSYLCS)
C TOTAL MONTHLY TIME TO BED ALL STALLS,SAND AND SKS
      SNDSSTT=SNDSS1S*STALLSN
C TOTAL MANHRS PER MONTH NEEDED TO BED WITH SAND AND SKST
      SNDTMLB=(SNDSSTT*SNDSSLB)
C YEARLY LABOR FOR BEDDING WITH SAND AND SKIDSTER
      SNDSSYL=(SNDTMLB*12)
C YEARLY LABOR COSTS FOR SAND AND SKIDSTER
      SNDSSLC=(SNDSSYL*CSLABOR)
C YEARLY FUEL USE FOR SAND BEDDING AND SKIDSTER
      SNDSSFU=(SNDSSTT*GALNHR)
C YEARLY FUEL COSTS WITH SAND AND SKIDSTER
      SNDSSFC=(SNDSSFU*FUELCST)
C YEARLY OWNERSHIP COSTS OF SKST DUE TO BEDDING SAND
      SNDSSYO=SNDSSTT*12*SKHRFXC
C TOTAL YEARLY COSTS OF OPERATING SKIDSTER
      SNDSSTC=(SNDSSFC+SNDSSYO+SNDSSLC)
C INITIALIZATION OF ALLEY SCRAPER DEFAULT VARIABLES
C HOURS ALLEY SCRAPER MOTOR(S) RUN DAILY
      ALLMHRS=10.0
C AMPERAGE OF WORKING MOTOR FOR SCRAPER
      AMPSCRM=12
C COST OF CHAIN/FT
      CHNCSTF=6.00
C COST OF TIME CLOCKS
      CLCKCST=70.00
C COST OF DRIVE UNIT
      CSTDRUN=1700.00
C COST OF CORNER WHEEL
      CSTCWHL=60.00
C HORSEPOWER OF SCRAPER MOTOR
      HPMOSCR=2.0
C COST OF KWH OF ELECTRICITY (DOLLARS)
      HKWCOST=0.05
C MOTOR COSTS-PLUS REVERSING SWITCH
      COSTMOT=350.00
C NUMBER OF CORNER WHEELS PER UNIT
```

```
      CORNWNO=4.0
C NO.OF MEN REQD TO OPERATE SCRAPERS
      ALMENNO=1.0
C NO. OF SCRAPER BLADES
      SCRPENO=2.0
C NO.OF HOURS SPENT BY PERSONS RUNNING SCRAPER FOR/ROUTINE UPKEEP PER WK
      SCOPHRS=0.33
C SCRAPER BLADE COST
      SCRCOST=240.00
C VOLTAGE OF SCRAPER MOTOR
      VLTSCRM=230
C WIDTH BETWEEN TWO ALLEYS ON SAME SCRAPER
      WIDMIDD=16.0
C ALLEY SCRAPER DEP RATE
      ALDEPR=0.143
C ALLEY SCRAPER INTEREST RATE
      ALINTR=0.06
C ALLEY SCRAPER RHI RATE
      ALRHIR=0.C4
C ALLEY SCRAPER MISC RATE
      ALMISCR=0.02
C CALCULATED VALUES FOR ALLEYSCRAPERS
C ALLEY SCRAPER DRIR
      ALDIRTH=(ALDEPR+ALINTR+ALRHIR+ALMISCR)
C TOTAL ALLEY SCRAPER CHAIN
      ALCHAIN=((2*WIDMIDD)+(2*ALLLNTH))+20
C TOTAL CHAIN NEEDED
      TOTCHN=((ALLEYNO/2)*ALCHAIN)
C TOTAL COST OF CHAIN
      TOTCHNC=(CHNCSTF*TOTCHN)
C NUMBER OF DRIVE UNITS
      DRIVUNT=(ALLEYNO/2)
C TOTAL COST OF DRIVE UNITS
      TODRUNC=(DRIVUNT*CSTDRUN)
C NO OF SCRAPER MOTORS
      ALNMOTR=(ALLEYNO/2)
C TOTAL COST OF MOTORS
      TOMOCST=(ALNMOTR*COSTMOT)
C TOTAL COST OF SCRAPER BLADES
      TOTSCCS=(SCRPLNO*SCRCOST)*(ALLEYNO/2)
C TOTAL NUMBER OF CORNER WHEELS
      TOTWHLS=(CORNWNO*(ALLEYNO/2))
C TOTAL COSTS OF WHEELS
      TOTWCST=(TOTWHLS*CSTCWHL)
C TOTAL ALLEY SCRAPER COSTS
      TOTALCS=(TOMOCST+TODRUNC+TOTWCST+TOTSCCS+TOTCHNC)
C NO OF CLOCKS
      CLOCKNO=(ALLEYNO/2)
C TOTAL COST OF CLOCKS
      TOCLCST=(CLCKCST*CLOCKNO)
C TOTAL COSTS OF SCRAPER AND CLOCKS
      TCLALLC=(TOCLCST+TOTALCS)
C TOTAL ANNUAL OWNERSHIP COSTS
      DIRTMAL=TCLALLC*ALDIRTM
C WEEKLY MANHRS OF LABOR
      WKYMHRS=SCOPHRS*ALMENNO
C WEEKLY LABOR COSTS
      WKYLCST=CSLABOR*WKYMHRS
C ALLEY SCRAPER MHRS/YR
      ALYMHRS=WKYMHRS*52
C YEARLY LABOR COSTS
      YRLCST=WKYLCST*52
C DAILY ELECTRICITY USED/MOTOR
      HKWDAY=((VLTSCRM*AMPSCRM*ALLMHRS)/1000)
C TOTAL DAILY KWH
      THKWDAY=(HKWDAY*ALNMOTR)
C YEARLY KWS USED
      HKWYRLY=(THKWDAY*365)
C YEARLY ELECTRICITY COSTS
      KWCSTYR=(HKWCOST*HKWYRLY)
C TOTAL ANNUAL COSTS OF OWNING ELECTRICITY AND LABOR
      ALLANCS=(DIRTMAL+KWCSTYR+YRLCST)
C-INITIALIZATION OF DFAULT VALUES FOR GARDEN TRACTOR
C GARDEN TRACTOR HOURLY FUEL CONSUMPTION (GAL/HR)
      GONFUEL=1.4
C GARDEN TRACTOR DAILY USE(ONE ALLEY 2X DAILY)
      GONHDAY=0.33
C GARDEN TRACTOR COST INCLUDING BLADE
      GONTCST=2500.00
C DEPRECIATION RATE FOR GDN TRACTOR
      GONTDEP=0.014
```

```
C INTEREST RATE ON GDNTRACTOR
      GDNTINT=0.06
C MISCELLANEOUS FACTORS FOR GARDEN TRACTORS
      GDNTMIS=0.02
C RH1 FACTOR FOR GARDEN TRACTORS
      GDNTRHI=0.07
C SALVAGE VALUE OF 8 YR OLD GARDEN TRACTOR
      GDNTSAL=0.00
C CALCULATED VALUES FOR GARDEN TRACTORS
C HRS GARDEN TRACTOR USED / DAY FOR SCRAPING
      GDTHDSC=GDNHDAY*ALLEYNO
C HOURS PER YEAR FOR GARDEN TRACTOR
      GDNHYR=(GDTHDSC*365)
C ANNUAL OWNERSHIP - FOR GARDEN TRACTOR
      GDNORHT=GDNTDEP+GDNTINT+GDNTRHI+GDNTMIS
C FUEL USED PER YEAR
      GDNFLYR=(GDNHYR*GDNFUEL)
C FUEL COSTS FOR YEAR
      GDNFCYR=(FUELCST*GDNFLYR)
C YEARLY LABOR COSTS FOR RUNNING GARDEN TRACTOR
      GDNLCYR=CSLABOR*GDNHYR
C TOTAL OWNERSHIP COSTS FOR GARDEN TRACTOR
      GDNOCST=GDNTCST*GDNORHT
C TOTAL OWNERSHIP AND OPERATING COSTS
      GDNOOCS=(GDNOCST+GDNLCYR+GDNFCYR)
C INITIALIZATION OF FLUSH SYSTEM VARIABLES
C DEPRECIATION ON FLUSH EQUIPMENT(RATE)
      FLDEPP=0.065
C DAYS OF YEAR FLUSH SYSTEM USED AS FLUSH SYSTEM
      FLDY305=305
C FUEL USED BY TRACTOR WHEN SCRAPING (GAL/HR)
      FLFUELU=3.0
C GALLONS OF WATER USED DAILY FOR FLUSHING PER COW
      FLWGDCW=100
C COST OF ONE FLUSH GATE
      FLGATEC=750.00
C NUMBER OF FLUSH GATES
      FLGATEN=ALLEYNO
C FLUSH EQUIPMENT  INTEREST    PERCENTAGE
      FLINTP=.06
C LABOR PER DAY TO FLUSH SYSTEM (HRS)
      FLLBRDY=0.25
C PUMP MOTOR AMPERAGE
      FLMOAMP=50
C FLUSH MOTOR HP FOR PUMP
      FLMOTHP=10.0
C FLUSH MOTOR VOLTAGE
      FLMOVLT=220
C PUMP CAPACITY (GAL/MIN)
      FLPMPCP=250
C TIMES PER DAY ALLEYS FLUSHED
      FLTIMDY=2.0
C FLUSH PUMP COST
      FLPUMPC=800.00
C NO OF PUMPS USED
      FLPUMPN=1
C APPROXIMATE COST OF WELL
      FLWELCS=8000
C WELL DEPRATE
      FLWDPR=.05
C WELL INT RATE
      FLWINTR=.05
C INTEREST RATE ON WELL
      FLWINMS=.01
C RHI PERCENTAGE FOR FLUSH EQUIPMENT
      FLRHIP=0.065
C NO OF FLUSH TANKS
      FLTNKNO=2
C TANK COST PER GALLON STORAGE CAPACITY
      FLTNCGL=0.13
C PERCENT OF TOTAL TRACTOR TIME USED FOR SCRAPING
      FLTUPER=0.15
C DAILY LABOR FOR WINTER SCRAPING 1 ALLEY,2X DAILY
      FLWSHR=0.33
C WEEKLY LABOR FOR SCRAPING DURING NON-WINTER SEASON
      SCWKLBR=1.0
C MISCELLANEOUS PERCENTAGE ON FLUSH EQUIP
      FLPMISC=0.02
C VALUE OF UTILITY TRACTOR+BLADE USED WITH FLUSH SYSTEM
      FLTUVAL=12000
C FLUSH TRACTOR DEP RATE
```

```
      FLTDEPR=0.065
C FLUSH TRACTOR INT RATE
      FLTINTR=0.06
C FLUSH TRACTOR RHI RATE
      FLTRHIR=0.045
C FLUSH TRACTOR MISC RATE
      FLTMISR=0.02
C CALCULATIONS FOR FLUSH SYSTEMS
C FLUSH TRACTOR TOTAL DIRTI RATE
      FLTDRTR=(FLTDEPR+FLTINTR+FLTRHIR+FLTMISR)
C FLUSH DAILY LABOR FOR 305 DAYS OF FLUSHING
      FLL305=(FLLBRDY*305)
C FLUSH DAILY LABOR COSTS FOR 305DAY PERIOD (OPERATING THE FLUSH UNIT)
      FLLC305=(FLL305*CSLABOR)
C FLUSH SYSTEM 44 WEEK LABOR FOR SCRAPING
      FLL44WK=SCWKLBR*44
C FLUSH LABOR COSTS FOR SCRAPING FOR 44WKS
      FLLCSCR=(FLL44WK*CSLABOR)
C 60 DAY LABOR FOR WINTER SCRAPING
      FLWSCLB=FLWSHR*ALLEYNO*60
C COST  FOR LABOR FOR WINTER SCRAPING
      FLWLCST=FLWSCLB*CSLABOR
C TOTAL YEARLY FLUSH LABOR
      FLLABTO=(FLL305+FLL44WK+FLWSCLB)
C FLUSH TRACTOR OWN COSTS DUE TO SCRAPING
      FLTUOWN=(UTHRFXC*FLLABTO)
C TOTAL YEARLY LABOR FOR FLUSH SYSTEM(COSTS)
      FLLABTC=(FLWLCST+FLLCSCR+FLLC305)
C TOTAL FLUSH WATER USED DAILY
      FLTWDAY=COWS*FLWGDCW
C FLUSH TANK CAPACITY
      FLTNKCP=(((COWS/ALLEYNO)*FLWGDCW)/FLTIMDY)
C HOURS FLUSH PUMPS RUN/DAY
      FLPMPHR=(FLTWDAY/(FLPMPCP*60))
C DAILY KW USED BY MOTORS ON FLUSH TANK PUMPS
      FLMDYKW=((FLMOVLT*FLMOAMP*FLPMPHR)/1000)*FLPUMPN
C KW USED TO PUMP WATER FOR 305 DAYS
      FLKW305=(FLMDYKW*305)
      FLYRKWC=FLKW305*KWCOST
C TOTAL FUEL USED BY TRACTOR FOR SCRAPING
      FLTOTFL=((FLL44WK+(60*FLWSHR))*FLFUELU)
C TOTAL FUEL COSTS FOR FLUSH SYSTEM
      FLFLCST=(FLTOTFL*FUEDSLC)
C TOTAL COST OF FLUSH GATES
      FLGATTC=(FLGATEN*FLGATEC)
C FLUSH TANK TOTAL COST
      FLTNKTC=FLTNCGL*FLTNKCP*FLTNKNO
C TOTAL COSTS OF FLUSH PUMPS
      FLPMPCS=(FLPUMPN*FLPUMPC)
C WELL DIRTI RAYTE
      FLWDRTR=FLWDPR+FLWINTR+FLWINMS
C ANNUAL OWNERSHIP COSTS ON WELL
      FLWOWNC=FLWLCST*FLWDRTR
C FLUSH TANK,GATES AND MOTOR COSTS
      FLTGMCS=(FLTNKTC+FLGATTC+FLPMPCS+FLWELCS)
C FLUSH EQUIPMENT TOTAL OWN PERCENTAGE
      FLEQDRH=FLDEPP+FLINTP+FLRHIP+FLMMISC
C TOTAL OWNERSHIP COSTS OF FLUSH SYSTEM
      FLOWCST=FLEQDPH*FLTGMCS+FLWOWNC
C FLUSH YEARLY ENERGY COSTS
      FLYENGC=FLYRKWC+FLFLCST
C YRLY  OWNERSHIP COSTS FOR TRACTOR+FLUSH EQIPMENT
      FLTOWNC=(FLTUOWN+FLOWCST)
C YRLY  OWN AND OPERATING COSTS FOR FLUSH SYSTEM
      FLTOOPC=FLTOWNC+FLFLCST+FLYRKWC+FLLABTO
C CC DAILY LABOR
      CRCDYLB=0.50
C CC DEPR RATE
      CRCDEPR=0.143
C CC INT RATE
      CRCINTR=0.06
C CC MOTOR AMPERAGE
      CRCMAMP=12
C CCMOTOR HRS/DAY
      CRCMHRD=0.50
C CC MISC RATE
      CRCMSCR=0.02
C   CC MOTOR VOLTAGE
      CRCMVLT=230
C CC RHI RATE
      CRCRHIR=0.06
```

```
C CC COST/FOOT OF CHAIN
      CRCCPCF=7.25
C CC NUMBER OF CORNER WHEELS
      CRCCRNW=1.0
C CC COST OF CORNER WHEELS
      CRCCRNC=80.00
C CC DRU COST
      CRCDRUC=1750.00
C CC NUMBER DRUS
      CRCDRUS=1.0
C CC MOTOR HP
      CRCMHP=2.0
C CC MOTOR COST
      CRCMCST=250.00
C CC NUMBER OF MOTORS
      CRCNMOT=1.0
C CC CLOCK COST
      CRCTCCS=70.00
C CC CLOCK MECHS
      CRCCMEC=1.0
C CCSALV
      CRCSALV=0.00
C CALCULATED VALUES FOR CC ONLY
C CC YRLY LABOR
      CRCLBY=CRCDYLB*365
C CC YRLY LABOR COSTS
      CRCYRLC=(CRCLBY*CSLABOR)
C CC MOTOR DAILY KW USED
      CRCMKWD=((CRCMVLT*CRCMAMP*CRCMHRD)/1000)*CRCNMOT
C CC YRLY KW USED
      CRCMKWY=(CRCMKWD*365)
C CC YRLY ELEC COSTS
      CRCELCY=(CRCMKWY*KWCOST)
C CC YRLY OP COSTS
      CRCYOPC=(CRCYRLC+CRCELCY)
C BARN WIDTH
      BARNWD=(ALLEYNO*21.5)+(ALLEYNO-2)*0.5
C CC CHAIN LENGTH
      CRCCHNL=(2*BARNWD)
C CC CHAIN COST
      CRCCHNC=(CRCCHNL*CRCCPCF)
C CORNNER WHEEL COST FOR CC
      CRCCNTC=(CRCCRNW*CRCCRNC)
C CC DRIVE WHEEL COST
      CRCTDUC=(CRCDRUC*CRCDRUS)
C  CC MOTOR COSTS
      CRCMCTT=(CRCMCST*CRCNMOT)
C CC CLOCK COSTS
      CRCTCTC=(CRCTCCS*CRCCMEC)
C  CC TOTAL COST
      CRCTCST=CRCTCTC+CRCMCTT+CRCTDUC+CRCCNTC+CRCCHNC
C CC TOTAL DIRTI
      CRCTDRH=(CRCINTR+CRCDEPR+CRCMSCR+CRCRHIR)
C CCYRLY OWN COSTS
      CRCOCST=(CRCTDRH*CRCTCST)
C CC YRLY OP+OWN COSTS
      CRCOOCS=(CRCOCST+CRCYOPC)
C CROSS CONVEYOR DEFAULT VARIABLES
C WEEKLY LABOR REQD FOR CROSSCONVEYOR
      CCDAYLB=0.08
C DEPR RATE
      CCDEPR=0.143
C INT RATE
      CCINTR=0.06
C AMPERAGE OF MOTOR
      CCMAMP=12
C HRS/DAY MOTORS RUN
      CCMHRDY=0.50
C MISC RATE FOR CONVEYOR
      CCMISCR=0.02
C MOTOR VOLTAGE
      CCMVOLT=230
C RHIRATE
      CCRHIR=0.06
C CONVEYOR CHAIN AND PADDLES COST/FT
      CONCSFT=7.25
C NUMBER OF CORNER WHEEL ASSEMBLIES
      CORNWH=1.0
C COST/CORNER WHEEL
      CORNWHC=80.00
C DRIVE UNIT COSTS/UNIT
```

```
      DRUCST=1750.00
C NUMBER OF DRIVE UNITS
      DRUNITS=1.0
C COST/FOOT OF ELEVATOR
      ELVCOST=30.00
C ELEVATOR LENGTH INCLUDING DISTANCE TO DRIVE WHEEL
      ELVLNTH=22
C NUMBER OF ELEVATORS
      ELVNOS=1.0
C CONVEYOR MOTOR HP
      CCHPMOT=2.0
C COST/MOTOR
      CSTMOT=250.00
C NUMBER OF MOTORS
      CCNMTRS=1.0
C COST PER TIME CLOCK MECHANISM
      TCCOST=70.00
C NUMBER OF CLOCK MECHANISMS
      TCMECHS=1.0
C SALVAGE VALUE OF COMPLETE UNIT
      TUSALVV=0.00
C CALCULATED VALUES FOR CROSS CONVEYOR UNIT
C CC TOTAL DIRT PERCENTAGE
      CCORHIT=(CCDEPR+CCINTR+CCMISCR+CCRHIR)
C CROSS CONVEYOR ANNUAL LABOR
      CCYRLB=CCDAYLB*365
C LABOR COSTS/DAY TO OPERATE
      CCLABCD=(CCDAYLB*CSLABOR)
C LABOR COST/YR ON SYSTEM (
      CCYRLBC=(CCLABCD*365)
C KWH USED/DAY BY MOTOR
      CCMKWDY=((CCMVOLT*CCMAMP*CCMHRDY)/1000)*CCNMTRS
C KWH USED/YEAR
      CCMKWYR=(CCMKWDY*365)
C ELECTRICITY COSTS/YR TO RUN THE CROSS CONVEYOR
      CCELCSY=(CCMKWYR*HKWCOST)
C YEARLY OPERATING COSTS
      CCYROPC=(CCYRLBC+CCELCSY)
C TOTAL CHAIN LENGTH
      CONVTLH=2*BARNWD+2*ELVNOS*ELVLNTH+20
C TOTAL COST OF CONVEYOR SYSTEM
      CNVTCST=(CONCSFT*CONVTLH)
C TOTAL COST OF CORNER WHEELS
      CORNTCS=(CORNWHC*CORNWH)
C DRIVE UNIT TOTAL COST
      DRUTCST=(DRUNITS*DRUCST)
C MOTOR COSTS
      TCSTMOT=(CSTMOT*CCNMTRS)
C COST OF TIME CLOCK UNITS
      TCTCOST=(TCCOST*TCMECHS)
C TOTAL COST OF ELEVATORS
      TOTELCS=ELVNOS*ELVCOST
C TOTAL COST OF COMPLETE CROSS CONVEYOR
      CCTCOST=TCSTMOT+DRUTCST+CORNTCS+TOTELCS+CNVTCST
C TOTAL COST OF CLOCKS AND CONVEYOR UNITS
      CCTOCST=(TCTCOST+CCTCOST)
C OWN COSTS WITH CC AND SHORT ELEV
      CCOWNC=(CCORHIT*CCTOCST)
C TOTAL COSTS OF OWNING AND OPERATING
      CCTOOCS=(CCYROPC+CCOWNC)
C CROSS CONV+LONG ELEV DEFAULT VARIABLES
C CC LONG ELEV DAILY LABOR
      CCLDAYL=0.08
C CCLONG ELEV DEP RATE
      CCLDEPR=0.143
C CCLONG ELEV INTR RATE
      CCLINTR=0.06
C CCLONG ELEV MOTOR AMPS
      CCLMAMP=12
C CCLONG ELEV MOTOR HRS/DAY
      CCLMHDY=0.50
C CC LONG ELEV MISC RATE
      CCLMSCR=0.02
C CC LONG ELEV MOTOR VOLTAGE
      CCLMVLT=230
C CC LONG ELEV RHI RATE
      CCLRHIR=0.06
C CC LONG ELEV COST/FOOT OF CHAIN AND PADDLES
      CCLCHCF=7.25
C CC LONG ELEV NUMBER OF CORNER WHEELS
      CLORNWH=1.0
```

```
C CC LONG ELEV COST/CORNER WHEEL
      CLORNWC=80.00
C CC LONG ELEV DRIVE UNIT COST/UNIT
      CLDRUCS=1750.00
C CC LONG ELEV NO OF DRIVE UNITS
      CLDRUNS=1.0
C CC LONG ELEV COST/FOOT
      CLELVCS=30.0
C CCLONG ELEV LENGTH
      CLEVLN=45.0
C CC LONG ELEV NOS
      CLELVNS=1.0
C CC LONG MOTOR HP
      CLMOTHP=2.0
C CC LOMNG MOTOR COSTS
      CLMOTCS=250.00
C CC LONG MOTORS(NO)
      CLNMOT=1.0
C CC LONG COST/TIME CLOCK
      CLTCCST=70.00
C CC LONG NUMBER OF CLOCK MECH
      CLTCMCH=1.0
C CC LONG SALV VALUE
      CLTUSLV=0.00
C CC LONG ELEV CALCULATED COSTS
C LABOR COSTS/DAY WITH LONG ELEV
      CCLLBYR=CCLDAYL*365
C DAILY LABOR COSTS FOR CC+LONG ELEVATOR
      CCLBCO=(CCLDAYL*CSLABOR)
C CC LONG LABOR COST/YR
      CCLYLBC=(CCLBCO*365)
C CC LONG MOTOR KW/DAY
      CCLMKWD=((CCLMVLT*CCLMAMP*CCLMHOY)/1000)*CLNMOT
C CC LONG KWH/YR
      CCLMKWY=(CCLMKWD*365)
C CC LONG YRLY ELEC COST
      CCLELCY=(CCLMKWY*HKWCOST)
C CC LONG YRLY OP EXPENSES
      CCLYOPC=(CCLYLBC+CCLELCY)
C CC LONG  CHAIN LNTH
      CCLCHLN=2*BARNWD+2*ELVNOS*CLEVLN
C CC LONG TOTAL COST
      CCLNVCS=(CCLCHCF*CCLCHLN)
C CCLONG TOTAL COST OF CORNER WHEELS
      CCLCRNC=(CLORNWC*CLORNWH)
C CC LONG TOTAL DRIVE UNIT COSTC
      CCLDRTC=CLDRUNS*CLDRUCS
C CC LONG MOTOR COSTS
      CCLMCST=(CLMOTCS*CLNMOT)
C CC LONG TIME CLOCKS
      CCLTCCS=(CLTCCST*CLTCMCH)
C CC LONG ELEV TOTAL COSTS
      CCLTELC=CLELVCS*CLEVLN*CLELVNS
C CC LONG TOTAL COSTS
      CCLTCST=CCLMCST+CCLDRTC+CCLNVCS+CCLTELC+CCLCRNC
C CC LONG CLOCK AND CONVEYOR COSTS
      CCLCLCC=CCLTCST+CCLTCCS
C CCLONG TOTAL CHRT
      CCLDRHT=(CCLDEPR+CCLINTR+CCLMSCR+CCLRHIR)
C CC LONG TOTAL OWN COSTS
      CCLOWNC=(CCLDRHT*CCLTCST)
C CC LONG YRLY OWN AND OP COSTS
      CCLTOOC=(CCLOWNC+CCLYOPC)
C SLOTTED FLOOR DEFAULT VARIABLES
C DAILY LABOR WITH SLOTTED FLOOR
      SFDAYLB=0.00
C SLOTTED FLOOR DEPRECIATION RATE
      SFDEPR=0.05
C SLOTTED FLOOR INTEREST RATE
      SFINTR=0.05
C SLOTTED FLOOR MISC RATE
      SFMISCR=0.01
C SLOTTED FLOOR RHI RATE
      SFRHIR=0.035
C SLOTTED FLOOR SALVAGE VALUE
      SFSALVV=0.00
C CALCULATED VALUES FOR SLOTTED FLOOR
C SLOTTED FLOOR DAILY LABOR COST
      SFDLCST=(CSLABOR*SFDAYLB)
C SLOTTED FLOOR YEARLY LABOR COSTS
      SFYRCSL=(SFDLCST*365)
```

```
C SLOTTED FLOOR AVE VALUE
      SFAVEVL=(SLOTTCS+SFSALVV)/2
C SLOTTED FLOOR DRHT RATE
      SFDRHTR=SFDEPR+SFINTR+SFMISCR+SFRHIR
C SLOTTED FLOOR YEARLY TOTAL COSTS
      SFYTCST=(SLFOCS+SFYRCSL)
C PISTON PUMP DEFAULT VARIABLES
C NUMBER OF CHECK VALUES IN SYSTEM
      CHKVLVN=1.0
C COST/CHECK VALUE
      CSTPVLV=75.00
C COST/ELBOW
      ELBOCST=50.00
C NUMBER OF ELBOWS USED
      ELBOWS=2.0
C PISTON PUMP COST
      PPCOST=4600.00
C PISTON PUMP DEP RATE
      PPDEPR=0.143
C PISTON PUMP INTEREST RATE
      PPINTR=0.05
C DAILY LABOR WITH PISTON PUMP
      PPLABOR=0.50
C AMPS FOR PISTON PUMP MOTOR
      PPMAMPS=50
C PISTON PUMP HRS OPERATED/DAY
      PPMHRSD=0.50
C PISTON PUMP MISC RATE
      PPMISCR=0.02
C PISTON PUMP MOTOR COST
      PPMOCST=700.00
C PISTON PUMP MOTOR HP
      PPMOTHP=10.0
C PISTON PUMP MOTOR VOLTAGE
      PPMOVLT=230
C PISTON PUMP RHI RATE
      PPRHIR=0.07
C PVC COST PER FOOT
      PVCCSFT=8.50
C NUMBER OF FEET OF PVC PIPE
      PVCFEET=140
C SALVAGE VALUE OF SYSTEM
      SALVPP=0.00
C CALCULATED VALUES FOR PISTON PUMP
C PISTON PUMP YEARLY LABOR
      PPYLABR=(PPLABOR*365)
C PISTON PUMP TOTAL ANNUAL COSTS FOR LABOR
      PPANCSL=(PPYLABR*CSLABOR)
C KWHRS USED PER DAY WITH PISTON PUMP
      PPHKWD=((PPMOVLT*PPMAMPS*PPMHRSD)/1000)
C PISTON PUMP ANNUAL KWHR ELECTRICITY
      PPHKWY=PPHKWD*365
C ELECTRICITY COSTS FOR PISTON PUMP/DAY
      PPELCS=(PPHKWD*HKWCOST)
C TOTAL PVC PIPE COSTS
      PVCTCST=(PVCFEET*PVCCSFT)
C COST OF CHECK VALUES
      CHVCSTS=(CHKVLVN*CSTPVLV)
C TOTAL COSTS OF ELBOWS
      TOTLBOC=(ELBOWS*ELBOCST)
C PISTON PUMP YEARLY ELECTRIC COSTS
      PPYELCS=(PPELCS*365)
C TOTAL COST OF PISTON PUMP SYSTEM
      PPSYSCS=(CHVCSTS+TOTLBOC+PVCTCST+PPMOCST+PPCOST)
C PP TOTTAL DIRH RATE
      PPDRHTR=(PPDEPR+PPINTR+PPRHIR+PPMISCR)
C PP ANNUAL OWN COSTS
      PPOCSTS=(PPDRHTR*PPSYSCS)
C PP ANNUAL OP COSTS
      PPOPCY=(PPANCSL+PPELCS)
C TOTAL ANNUAL COSTS FOR PISTON PUMP SYSTEM
      PPANCST=(PPANCSL+PPYELCS+PPOCSTS)
CCC +RAM PUMP
C CCR DRHT
      CCRDRHT=CRCTDRH
C CCR YRLY LABOR
      CCRLBTY=CRCLBY
C CCR TOTAL COST
      CCRMTC=(CRCTCST+PPSYSCS)
C CC+PISTON ANNUAL OWNERSHIP COSTS
      CCROWNC=PPOCSTS+CRCOCST
```

```
C CCR YRLY LABOR
      CCRLBCY=CCRLBTY*CSLABOR
C CCR YRLY KWHS
      CCRYHKW=(CRCMKWY+PPHKWY)
C CCR YRLY ELEC COST
      CCRYELC=(CCRYHKW*HKWCOST)
C CCR YRLY OP COSTS
      CCROPCY=(CCRLBCY+CCRYELC)
C CCR YRLY OP AND OWN COSTC
      CCROOCY=(CCROPCY+CCROWNC)
C DEFAULT VALUES FOR COMPRESSED AIR UNIT (CA)
C COMPRESSED AIR MOTOR AMPS
      CAAMPS=28.0
C NO OF CHECK VALVES FOR CA
      CACHKVN=0.00
C COST PER CHECK VALVE
      CACHKVC=75.00
C COMPRESSED AIR UNIT COST
      CACSTS=8100.00
C CA DEPRECIATION RATE
      CADEPR=0.10
C DAILY LABOR FOR CA UNIT (HRS)
      CADLAB=0.50
C INTEREST RATE ON CA SYSTEM
      CAINTR=0.06
C COST/KWH
      CAHKWC=0.05
C NO OF ELBOWS USED
      CALBOS=2.0
C COST/ELBOW
      CALBOCS=50.00
C CA HRS/DAY USED
      CAMCST=700.00
C DAILY HOURS COMPRESSED AIR SYSTEM USED
      CAMHRD=0.50
C CA MISC RATE
      CAMISCR=0.02
C CA MOTOR HP
      CAMOHP=5.0
C CA PVC PIPE COSTS/FOOT
      CAPVCCS=8.50
C FEET OF PVC USED FOR CA SYSTEM
      CAPVCFT=140.00
C RHI RATE FOR CA UNIT
      CARHIR=0.075
C SALVAGE VALUE OF CA UNIT
      CASALV=0.00
C VOLTAGE OF CA MOTOR
      CAVOLTS=230
C CALCULATED VALUES FOR COMPRESSED AIR UNIT
C DAILY LABOR COST FOR CA UNIT
      CADLCST=CADLAB*CSLABOR
C YEARLY LABOR TOTAL
      CAYRLTO=(CADLAB*365)
C YEARLY LABOR COSTS
      CAYRLCS=(CAYRLTO*365)
C KWH USED/DAY
      CAHKWD=((CAVOLTS*CAAMPS*CAMHRD)/1000)
C CA TOTAL YRLY LABOR
      CAHKWY=(CAHKWD*365)
C CAIR YRLY ELEC COSTS
      CAYELCS=(CAHKWY*CAHKWC)
C TOTAL VALUE OF CHECK VALVES
      CACVTCS=CACHKVC*CACHKVN
C TOTAL COST OF CA PVC PIPE
      CAPVCTC=(CAPVCCS*CAPVCFT)
C CA ELBOW COSTS
      CATLBOC=(CALBOCS*CALBOS)
C TOTAL SYSTEM COSTS
      CASYSCS=(CACVTCS+CAPVCTC+CATLBOC+CAMCST+CACSTS)
C CAIR TOTAL DIRT RATE
      CADRHIR=(CADEPR+CAINTR+CARHIR+CAMISCR)
C CAIR OWN COSTS
      CAOWNCY=(CADRHIR*CASYSCS)
C TOTAL YEARLY OWN AND OPERATING COSTS
      CATYRCS=(CAYRLCS+CAOWNCY+CAYELCS)
C CEMENT RAMP
C COST OF CEMENT PUSH-OFF RAMP
      CRMPCST=1000.00
C CEMENT RAMP DEPPECIATION RATE
      CRMPDPR=0.05
```

```
C RAMP INTEREST RATE
      CRMPINR=0.05
C RAMP RHI RATE
      CRRHIRT=0.035
C RAMP TOTAL DIRHI RATE
      CRDRHTR=CRRHIRT+CRMPINR+CRMPDPR
C RAMP YEARLY OWNERSHIP COSTS
      CRYOWNC=CRDRHTR*CRMPCST
C CC+AIR UNIT
C CCADRH RATE
      CCADRHT=CFCTDRH
C CCA YRLY TOTA (LABOR
      CCALBTY=CAYRLTO
C CCA TOTAL COSTS
      CCAMTC=(CFCTCST+CASYSCS)
C CCA OWN COSTS
      CCAOWNC=CAOWNCY+CRCOCST
C CCA YRLY LABOR COSTS
      CCALBCY=CCALBTY*CSLABOR
C CCA YRLY KWHS
      CCAYKWH=(CRCMKWY+CAHKWY)
C CCA HRLY ELEC COSTS
      CCAYELC=(CCAYKWH*HKWCOST)
C CCA YRLY OP COSTS
      CCAOPCY=CCALBCY+CCAYELC
C CCA YRLY OP+OWN COSTS
      CCAOOCY=(CCAOPCY+CCAOWNC)
C CEMENT FLUME (4*2.5)
C LENGTH OF FLUME
      CFLLNTH=140
C COST/FOOT OF FLUME LENGTH
      CFLCFT=11.25
C TOTAL FLUME COST
      CFLTCST=CFLLNTH*CFLCFT
C ANNUAL DIRTI RATE
      CFLDRR=0.125
C ANNUAL OWN COSTS ON FLUME
      CFLOWNC=CFLDRP*CFLTCST
C ANNUAL OWN + OPERATING COSTS
      CFLOOPC=CFLOWNC
C DEFAULT VALUES FOR COVERED TANK
C COST/CUFT
      CTCCUFT=1.00
C DEP RATE ON CEMENT TANK
      CTDEPR=0.05
C INTEREST RATE ON CEMENT TANK
      CTINTR=0.05
C MISC ON CEMENT TANK
      CTMISCR=0.00
C RHI FACTOR RATE ON TANK
      CTRHIR=0.025
C SALVAGE VALUE OF TANK
      CTSALVV=0.00
C USEABLE VOLUME OF TANK (PERCENT
      CTUSVOL=0.85
C VOLUME REQD/DAY/COW (CUFT)
      CTVOLDC=2.80
C DAYS STORAGE REQD
      CTVOLDY=180
C CALCULATED VALUES FOR CEMENT TANK
C CUBIC FT OF TANK NEEDED
      CTCFNED=(CTVOLDC*COWS*CTVOLDY)
C TOTAL COST TO BUILD A CEMENT TANK
      CTTCOST=(CTCFNED*CTCCUFT)
C CEMENT TANK TOTAL DRHI RATE
      CTDRHIT=(CTDEPR+CTINTR+CTRHIR+CTMISCR)
C CEMENT TANK OWN COSTS
      CTOWNCS=(CTDRHIT*CTTCOST)
C DEFAULT VARIABLES FOR PIT UNDER SLATS
C COST/CUFT OF PIT STORAGE
      PITCCFT=1.00
C DEP RATE ON PIT
      PITDEPR=0.05
C INTEREST RATE ON PIT
      PITINTR=0.05
C PIT MISC RATE
      PITMSCR=0.00
C PIT RHI RATE=0.025
      PITRHIR=0.025
C PIT SALVAGE VALUE
      PITSALV=0.00
```

```
C USEABLE PIT VOLUME (PERCENT)
      PITUSVL=0.85
C VOL REQD/COW/DAY
      PITVLDC=2.80
C DAYS STORAGE REQD
      PITVLCY=180
C PIT CALCULATED VALUES
C CUBIC FEET OF PIT NEEDED
      PITCFT=(COWS*PITVLDC*PITVLDY)
C TOTAL PIT COST
      PITCSTT=(PITCFT*PITCCFT)
C PIT TOTAL DRHI RATE
      PITDRHT=PITDEPR+PITINTR+PITRHIR+PITMSCR
C PIT YLY OWN COSTS
      PITOWNC=PITDRHT*PITCSTT
C CEMENT SILO
C CS DEP RATE
      CSLDEPR=0.05
C CS DIAMETER
      CSLDIAM=61.0
C CS I T RATE
      CSLINTR=0.05
C CSRHI RATE
      CSLRHIR=0.025
C CS SALV VALUE
      CSLSLVV=0.00
C CSCS SUMP COST
      CSLSMPC=1000.00
C COST PER CUFT OF STORAGE FOR CEMENT SILOS
      CSLCCFT=0.70
C CUBIC FEET NEEDED PER CIW
      CFWCDAY=2.80
C CS TOTAL COST
      CSLTCST=CSLCCFT*COWS*180*CFWCDAY
C TOTAL CS DRHIT RATE
      CSLDRHT=(CSLDEPR+CSLINTR+CSLRHIR)
C CS YRLY OWN COSTS
      CSLOWNC=(CSLDRHT*CSLTCST)
C COST PER CUFT OF STORAGE FOR STEEL SILOS
      SSLCCFT=0.90
C SS DEP RATE
      SSLDEPR=0.05
C SS INTEREST RATE
      SSLINTR=0.05
C SS RHI RATE
      SSLRHIR=0.025
C SS SALVAGE VALUE
      SSLSLVV=0.00
C SX SUMP COST
      SSLSMOC=1000.00
C SS TOTAL COST
      SSLTCST=SSLCCFT*COWS*180*CFWCDAY
C SS DRHI TOTAL
      SSLDRHT=SSLDEPR+SSLINTR+SSLRHIR
C SS YRLY OWN COSTS
      SSLOWNC=(SSLDRHT*SSLTCST)
C DEFAULT VARIABLES FOR EARTH BASIN FOR LIQUIDS
C AREA CEMENTED INCLUDING RAMP AND BOTTOM (SQFT)
      EBCEMA=1000
C THICKNESS OF CEMENT
      EBCMTHK=0.50
C COST PER CUBIC YD OF BASIN EXCAVATED
      EBCYDCS=1.25
C DEPRECIATION RATE ON BASIN
      EBDEPR=0.065
C INTEREST RATE ON EARTH BASIN
      EBINTR=0.06
C MISC RATE ON EARTH BASIN
      EBMISCR=0.01
C EARTH BASIN RHI RATE
      EBRHIR=0.01
C CUBIC FEET OF VOLUME IN BASIN
      EBVC180=540
      IF(IS(4).EQ.5) EBVC180=EBVC180*5.5
      IF(IS(10).NE.0)EBVC180=EBVC180*5.5
C BASIN SALVAGE VALUE
      EBSALVV=0.000
C CALCULATED VALUES FOR EARTH BASIN FOR LIQUIDS
C VOLUME TO BE EXCAVATED FOR 180 DAY STORAGE
      EBVOLCF=COWS*EBVC180
C EXCAVATION COSTS FOR EARTH BASIN
```

```
      EBEXCST=(EBCYDCS*(EBVOLCF/27))
C EARTH BASIN CEMENT COSTS
      EBCEMCS=EBCEMA*CONCSQF
C EARTH BASIN TOTAL COST
      EBTCOST=(EBEXCST+EBCEMCS)
C EARTH BASIN LIQUIDS DRHI RATE
      EBLDRTR=(EBDEPR+EBINTR+EBMISCR+EBRHIR)
C EARTH BASIN OWN COSTS
      EBOWNC=(EBLDRTR*EBTCOST)
C DEFAULT VARIABLES FOR EARTH BASIN FOR SOLIDS WITH LIQUID STORAGE
C AREA OF CONCRETE BOTTOM AND RAMP(SQFT PER COW FOR 180 DAYS)
      EBSCEMA=65
C CEMENT THICKNESS (FT)
      EBSCTHK=0.5
C DEPRECIATION RATE ON EB FOR SOLIDS
      EBSDEPR=0.065
C COST/CUYD STORAGE TO DIG BASIN
      EBSDIGC=1.25
C INTEREST RATE ON EB STORAGE
      EBSINTR=0.06
C VOLUME OF EB LIQUID RETENTION POND(CU FT) PER COW PER 180 DAYS
      EBSLB18=220
C COST OF LIQUID-SOLID SEPARATION DEVICE
      EBSLQSC=400.00
C COST OF SUMP PUMP IF USED
      EBSLQSM=700.00
C MISCELLANEOUS CHARGES RATE
      EBSMISR=0.01
C RHI RATE ON BASIN FOR SOLIDS
      EBSRHIR=0.01
C SALVAGE VALUE OF EB FOR SOLIDS
      EBSSALV=0.00
C VOLUME OF BASIN FOR SOLIDS (CUFT)
      EBSVC18=380
C TOTAL  BASIN VOLUME FOR SOLIDS
      EBSTVOL=(EBSLB18+EBSVC18)*COWS
C TOTAL WASTE VOLUME+RAINFALL VOLUME
      EBSVOL=EBSTVOL+0.10*EBSTVOL
C SETTLING BASIN FOR FLUSH SYSYTEM
C SETTLING BASIN COST
      FLSBCST=2000.00
C VOL OF LAGOON/COW/DAY FOR FLUSHING(CUFT)
      FLLAGVL=16.2
C CEMENT RAMP COSTS FOR FLUSH LAGOON
      FLLGRMC=1000.00
C FLUSH LAGOON OWNERSHIP RATE
      FLLGDRR=EBLDRTR
C VOL OF LAGOON/COW FOR 180 DAY STORAGE
      FLGV180=FLLAGVL*180
C 180 DAY TOTAL  VOLUME+RAIN(CUFT)
      FLLG18V=FLGV180*COWS+.10*(FLGV180*COWS)
C COST TO DIG FLUSH LAGOON
      FLLGEXC=(FLLG18V/27)*EBSDIGC
C COST OF LAGOON+SETTLING BASIN
      FLLGTCS=FLSBCST+FLLGEXC+FLLGRMC
C FLUSH LAGOON ANNUAL COSTS(OWNERSHIP)
      FLLGOWN=FLLGDRR*FLLGTCS
C YRLY VOLUME OF WASTE WITH FLUSHING
      FLLG365=FLLAGVL*COWS*305+(60*CFWCDAY)
C  CALCULATED VARIABLES FOR EB-SOLIDS AND WATER RETENTION POND
C  COST OF DIGGING EARTH BASIN
      EBSEXCS=(EBSVOL/27)*EBSDIGC
C  COST FOR LIQUID BASIN
      EBSLIQC=(EBSLB18/27)*EBSDIGC
C  TOTAL COST OF EXCAVATING BOTH BASINS
      EBSTEXC=(EBSEXCS+EBSLIQC)
C CEMENT AREA FOR UNIT
      EBSCTAR=EBSCEMA*COWS
C  CEMENT COSTS FOR ALL SYSTEM
      EBSCCST=EBSCTAR*CONCSQF
C  TOTAL VALUE OF SYSTEM
      EBSTAVL=EBSCCST+EBSTEXC
C EB+LIQUID BASIN DRHI RATE
      EBSDRTR=(EBSDEPR+EBSINTR+EBSMISR+EBSRHIR)
C EBS OWN COST
      EBSOWNC=(EBSDRTR*EBSTAVL)
C DEFAULT VALUES FOR CEMENTED SLURRY BASIN
C CEMENT VOLUME FOR SLURRY BASIN (CUYDS) PER COW PER 180 DAYS
      CSBCEMV=2.10
C DEPRECIATION RATE ON SLURRY BASIN
      CSBDEPR=0.05
```

```
C COST OF EXCAVATING (PER CUYD)
      CSBDIGY=1.25
C SLURRY BASIN INTEREST RATE
      CSBINTR=0.05
C SLURRY BASIN MISC RATE
      CSBMISR=0.01
C RHI RATE FOR SLURRY BASIN
      CSBRHIR=0.01
C SALVAGE VALUE FOR SLURRY BASIN
      CSBSALV=0.00
C CEMENT AREA/COW FOR 180 DAY STORAGE WITH 8 FT. DEPTH
      CSBCMA=74
C VOLUME OF SLURRY BASIN (CUFT)
      CSBVOL=40000
C CALCULATED VALUES FOR CEMENTED SLURRY BASIN
C TOTAL CSB CEMENT AREA
      CSBTCEM=CSBCMA*COWS
C COST OF CEMENT USED IN SLURRY BASIN
      CSBCCST=CSBTCEM*CONCSQF
C TOTAL EXCAVATION COSTS FOR SLURRY BASIN
      CSBEXCS=CSBDIGY*(CSBVOL/27)
C TOTAL COST OF SLURRY BASIN
      CSBTCST=(CSBEXCS+CSBCCST)
C CSB DRHI RATE
      CSBDRTR=(CSBDEPR+CSBINTR+CSBMISR+CSBRHIR)
C CSB OWN COSTS
      CSBOWNC=(CSBDRTR*CSBTCST)
C DEFAULT VARIABLES FOR LIQUID MANURE PUMP
C 80-90 HP TRACTOR HRLY FIXED COSTS
      TR90FXC=7.50
C HRS OF AGITATION PRIOR TO EACH DUMPING PERIOD
      PLMAGT=20.0
C COST OF LIQUID MANURE PUMP
      PLMCST=3500.00
C DEPRECIATION RATE ON LIQUID MANURE PUMP
      PLMDEPR=0.143
C GALLONS/HR TO OPERATE TRACTOR
      PLMGHR=6.5
C GALLONS/MIN PUMPING CAPACITY
      PLMGMIN=2000
C HP USED ON PUMP
      PLMHP=90.0
C INTEREST RATE ON PUMP
      PLMINTR=0.06
C MISCELLANEOUS RATE ON PUMP
      PLMMISR=0.02
C RHI RATE ON PUMP
      PLMRHIR=0.07
C SALVAGE VALUE ON PUMP
      PLMSALV=0.00
C NUMBER OF TIMES STORAGE EMPTIED/YR
      EMPTYNO=2.0
C LIQUID MANURE PUMP MEN TO OPERATE
      PLMMOP=1.0
C CALCULATED VARIABLES FOR LIQUID MANURE PUMP
C YEARLY AGITATION TIME WITH PUMP
      PLMAGTY=(PLMAGT*EMPTYNO)
C PLM MANHRS TO AGITATE
      PLMAGMH=(PLMAGTY*PLMMOP)
C TIME TO PUMP OUT 100/0 OF VOLUME IN STORAGE UNIT
      PPLMTIM=(VL365ST*7.48/PLMGMIN)/60
C PLM MHRS TO PUMP
      PPLMMH=(PPLMTIM*PLMMOP)
C PLM YRLY TOTAL MHRS
      PLMYLBR=(PPLMMH+PLMAGMH)
C TOTAL YRLY PUMPING AND AGITATING TIME
      PLTYRT=PLMAGTY+PPLMTIM
C YEARLY LABOR COSTS TO RUN THE PUMP
      PLMLCST=(PLMYLBR*CSLABOR)
C YEARLY FUEL USED
      PLMYFL=(PLMGHR*PLTYRT)
C YEARLY FUEL COSTS
      PLMFLCY=(FUEDSLC*PLMYFL)
C PLM DRHI RATE
      PLMDRTR=(PLMDEPR+PLMINTR+PLMMISR+PLMRHIR)
C PLM YRLY OWN COSTS
      PLMOCST=(PLMDRTR*PLMCST)
C TRACTOR FIXED COSTS ASSOCIATED WITH PUMPING/YR
      PLT90FC=PLTYRT*TR90FXC
C TOTAL YEARLY OWNERSHIP AND OPERATING COSTS FOR LIQUID PUMP
      PLMOOCS=(PLMOCST+PLMLCST+PLMFLCY+PLT90FC)
```

```
C DEFAULT VALUES FOR IRRIGATION PUMP
C COST OF NEW IRRIGATION PUMP
      RPCOST=2600.00
C DEP RATE ON IRRIGATION PUMP
      RPDEPR=0.143
C FUEL/HR TO RUN PUMP
      RPGHR=4.0
C INTEREST RATE  ON IRR PUMP
      RPINTR=0.06
C MISC RATE ON IRR PUMP
      RPMISCR=0.02
C RHI RATE ON IRR PUMP
      RPRHIR=0.07
C IRRIGATION PUMP SALVAGE VALUE
      RPSALVV=0.00
C PERCENTAGE OF TOTAL USE SPENT WITH WASTE HANDLING
      RPWHPER=0.25
C PUMPING CAPACITY OF DILUTED MANURE SLURRY (GAL/MIN)
      PMPSLCP=300
C HRS/YR TO OVERSEE PUMP WHEN RUNNING
      PMPYLBR=10.0
C CALCULATED VARIABLES FOR IRRIGATION PUMP
C TOTAL VOL TO BE PUMPED YRLY
      RPTVPMP=(3*VL365ST)
C TOTAL TIME SPENT YEARLY PUMPING WASTE (HRS)
      RPTPMPT=(((7.48*(RPTVPMP))/PMPSLCP)/60)
C YEARLY LABOR COST TO RUN PUMP
      RPLABCS=(PMPYLBR*CSLABOR)
C IP YRLY FUEL USED
      RPFUELY=(RPGHR*RPTPMPT)
C IP YRLY FUEL COSTS
      RPYFCST=(RPFUELY*FUEDSLC)
C IRRIGATION PUMP DRHI RATE
      RPDIRTR=(RPDEPR+RPINTR+RPRHIR+RPMISCR)
C IP OWN COSTS
      RPOWNCS=(RPDIRTR*RPCOST)
C 50-70 HP  TRACTOR FIXED COSTS
      RPTFIXC=UTHRFXC*RPTPMPT
C YEARLY OWNERSHIP COSTS DUE TO IRRIGATING SLURRY
      RPYCSTS=(RPWHPER*RPOWNCS)
C TOTAL OWNERSHIP AND OPERATING COSTS
      RPTOOCS=(RPYCSTS+RPLABCS+RPYFCST+RPTFIXC)
C DEFAULT VARIABLES FOR FRONT END LOADER
C CAPACITY OF LOADER WHEN USED WITH 50-70HP UTILITY TRACTOR(CUFT/HR)
      FELCAP=2600.00
C FUEL/HR TO RUN LOADER
      FELFHR=3.0
C PERCENT OF TIME LOADER USED FOR WASTE HANDLLING AND BEDDING
      FELPERW=0.50
C CALCULATED VARIABLES FOR FEL
C HRS/YR TO RUN LOADER AND HANDLE WASTE
      FELLYR=(V365MSH/FELCAP)
C TRACTOR FIXED COSTS
      FELTFXC=FELLYR*UTHRFXC
C TOTAL YEARLY LABOR CHARGES
      FELTLCS=(FELLYR*CSLABOR)
C FUEL COST PER HOUR TO RUN LOADER
      FELCSTH=(FELFHR*FUEDSLC)
C FEL YRLY FUEL TO LOAD
      FELYFLU=(FELFHR*FELLYR)
C FEL YRLY FUEL COSTS
      FELYFC=(FELYFLU*FUEDSLC)
C OWNERSHIP COSTS ATTRIBUTED TO WASTE HANDLING
      FELOCW=(FELOCST*FELPERW)+(FELLYR*UTHRFXC)
C TOTAL OWNING AND OPERATING COSTS FOR FEL
      FELOOCS=(FELOCW+FELYFC+FELTLCS+FELTFXC)
C USE OF SKIDSTEER LOADER TO LOAD MANURE
C DEFAULT VARIABLES FOR SKL
C LOADING CAPACITY (CUFT/HR) OF  SKIDSTEER
      SKLCAPH=3200.00
C PERCENT OF TOTAL TIME SKIDSTEER USED FOR LOADING
      SKLPERL=0.20
C CALCULATED VALUES FOR SKIDSTEER LOADER
C HRS PER YR LOADER USED
      SKLHRSY=(V365MSH/SKLCAPH)
C LABOR COSTS/YR FOR LOADING
      SKLLBRC=(SKLHRSY*CSLABOR)
C SKIDSTEER YRLY FUEL TO LOAD
      SKLFYR=(SKLHRSY*GALNHR)
C SKL YRLY FUEL COSTS
      SKLYFC=(SKLFYR*FUELCST)
```

```
C OWNERSHIP COSTS FOR SKL DUE TO LOADING
      SKLOWNC=SKHRFXC*SKLHRSY
C TOTAL OWNERSHIP AND OPERATING COSTS
      SKLOOCS=SKLYFC+SKLLBRC+SKLOWNC
C SELF LOADING SPREADER FOR SLURRY DEFAULT VALUES
C MEN NEEDED TO LOAD SLS2
      SLSMLD2=1.0
C COST OF 2000 GAL SLS
      SLSCST2=8400.00
C DEPRECIATION RATE ON SLS2
      SLSDPR2=0.143
C GALLONS OF FUEL/HR TO FILL IT
      SLSGHR2=6.0
C HOURS TO LOAD ONE LOAD WITH SLS
      SLSHLD2=0.08
C HRS TO HAUL,UNLOAD AND RETURN WITH SLS2
      SLSHSRT=0.20
C HP NEEDED TO HANDLE SLS2
      SLSHP2=90.0
C INTEREST RATE ON SLS2
      SLSINR2=0.06
C RHI RATE ON SLS2
      SLSRHR2=0.08
C MISC RATE ON SLS2
      SLSMIR2=0.02
C SALVAGE VALUE OF      SLS2
      SLSSLV2=0.00
C PERCENTAGE OF TIME SLS2 SPENT LOADING
      SLSPRL2=0.25
C PERCENTAGE TIME SLS2 SPENT HAULING AND HAULING
      SLS2HPT=0.60
C CALCULATED VALUES FOR 2000 GAL SLS
C TOTAL LOADS/YR WITH SLS2
      SLSLYR2=(((VL365ST+(0.10*VLS365D))*7.48)/2000)
C TOTAL TIME/YR TO LOAD SLS2
      SLSTHR2=(SLSHLD2*SLSLYR2)
C YRLY MHRS TO LOAD SLS2
      SLSYMH2=(SLSTHR2*SLSMLD2)
C LABOR COSTS/LOAD WITH SLS2
      SLSLBL2=(SLSHLD2*CSLABOR)
C TOTAL LABOR COSTS FOR LOADING SLS2
      SLSTLC2=(SLSLBL2*SLSLYR2)
C TOTAL FUEL USED/YR TO LOAD SLS2
      SLSGFL2=(SLSGHP2*SLSTHR2)
C TOTAL YEARLY FUEL COSTS TO LOAD SPREADER
      SLSFCS2=(SLSGFL2*FUEDSLC)
C 90-90 HP TRACTOR FIXED COSTS ASSOCIATED WITH SLS2
      SLSFTC=TR90FXC*SLSTHR2
C TOTAL YRLY HAUL AND UNLOAD TIME
      SLSTHUT=SLSHSRT*SLSLYR2
C YRLY FUEL USED FOR HAULING,ETC WITH SLS2
      SLSYRFH=SLSGHR2*SLSTHUT
C YRLY FUEL COSTS FOR HAULING,UNLOADING ETC.
      SLSFHCY=SLSYRFH*FUEDSLC
C SLS2 YRLY ORT RATE
      SLSORT2=SLSDPR2+SLSINR2+SLSRHR2+SLSMIR2
C SLS2 YRLY OWN COSTS
      SLSOWC2=(SLSORT2*SLSCST2)
C YRLY OWN COSTS DUE TO LOADING
      SLSOCL2=SLSPRL2+SLSFTC
C TOTAL YRLY SLS2 COSTS
      SLSOOL2=SLSOCL2+SLSTLC2+SLSFCS2+SLSFTC
C TOTAL YRLY MHRS FOR HAULUNG ETC.
      SLSTHMH=SLSTHUT*SLSMLD2
C YRLY LABOR COSTS FOR HAULING,ETC
      SLSYHLC=SLSTHMH*CSLABOR
C YRLY OWN COSTS DUE TO HAULING AND SPREADING WITH SLS2
      SLSOCHS=SLS2HPT*SLSOWC2+SLSTHUT*TR90FXC
C TOTAL OWN AND OPERATING COSTS ON  SLS2 FOR HAULING
      SLSOOHS=SLSFHCY+SLSOCL2+SLSYHLC
C IRIM COST
      RRIMCST=(RPCOST+PLMCST)
C IRIM YRLY LABOR
      RRIMLBR=(PMPYLBR+PLMAGTY)
C IRIM LABOR COSTS
      RRIMYLC=(RRIMLBR*CSLABOR)
C IRIM YRLY OWN COSTS
      RRIMOCS=(RPYCSTS+PLMOCST)
C FIXED COSTS FOR TRACTORS USED WITH PUMPS
      IRIMTFC=RFTFIXC+TR90FXC*PLMAGTY
C IRIM YRLY FUEL USED
```

```
      RRIMYEN=RFFUELY+PLMYFL
C IRIM YRLY FUEL COSTS
      RRIMYEC=RRIMYEN*FUEDSLC
C IRIM YRLY OP COSTS
      RRIMOCC=(RRIMOCS+RRIMYEC+RRIMYLC+IRIMTFC)
C LIQUID SPREADER       (3200GAL) DEFAULT VALUES
C LQS NO OF MEN NEEDED
      SLQNMEN=1.0
C CAPACITY OF LIQUID SPREADER IN GALLONS
      SLQCAP=3200
C COST OF LIQUID SPREADER
      SLQCOST=9500.00
C LIQUID SPREADER DEP RATE
      SLQDEPR=0.143
C FUEL/HOUR TO RUN SPREADER TO AND FROM FIELD
      SLQFCH=6.0
C HP NEEDED TO RUN LIQUID SPREADER
      SLQHP=90
C HAULING SPEED (MPH)
      SLQHSP=8.0
C INTEREST RATE ON SPREADER
      SLQINTR=0.06
C LOADED HAULING DISTANCE (MILES)
      SLQLHD=0.5
C TIME TO LOAD SPREADER (MIN)
      SLQLTM=0.06
C MISCELLANEOUS RATE  ON LIQUID SPREADER
      SLQMISR=0.02
C LIQUID RHI RATE
      SLQRHIR=0.06
C LIQUID SPREADER RETURN SPEED
      SLQRSP=8.0
C SALVAGE VALUE OF SPREADER
      SLQSLV=0.00
C LIQUID SPREADER UNLOADING RATE (G/MIN)
      SLQULR=530
C HRLY FUEL USE BY SPREADER TRACTOR WHILE UNLOADING
      SLQUFC=7.5
C
C LIQUID SPREADER CALCULATED VALUES
C LOADS/YR WITH LIQUID SPREADER
      SLQLDS=(VL365ST/(SLQCAP/7.48))
C TOTAL YRLY LOAD TIME WITH LIQUID SPREADER
      SLQLTY=(SLQLDS*SLQLTM)
C HAULING TIME/LOAD
      SLQHTM=(SLQLHD/SLQHSP)
C UNLOADING TIME/LOAD (HRS)
      SLQULT=(SLQCAP/SLQULR)/60
C TIME TO RETURN TO LOADING AREA
      SLQRTM=(SLQLHD/SLQRSP)
C TOTAL YEARLY TIME SPREADER USED (LABOR)
      SLQLYR=(SLQULT+SLQRTM+SLQHTM+SLQLTM)*(SLQLDS)
C YRLY FIXED TRACTOR COSTS WITH LQS
      SLQFTC=TR90FXC*SLQLYR
C LQS YRLY MHRS
      SLQMHRY=(SLQNMEN*SLQLYR)
C LQS YRLY LABOR COST
      SLQLCY=(SLQMHRY*CSLABOR)
C FUEL/LOAD OUT AND BACK
      SLQFLD=((SLQHTM+SLQRTM)*SLQFCH)
C FUEL TO UNLOAD ONE LOAD
      SLQUFL=(SLQUFC*SLQULT)
C LIQUID SPREADER FUEL/LOAD
      SLQFLC=(SLQFLD+SLQUFL)
C ANNUAL FUEL USED WITH LIQUID SPREADER
      SLQFLYR=SLQLDS*SLQFLC
C LIQUID SPREADER FUEL COSTS/YR
      SLQFCY=SLQFLYR*FUEDSLC
C LQS OWNT RATE
      SLQORTR=SLQDEPR+SLQINTR+SLQMISR+SLQRHIR
C LQS YRLY OWN COSTS
      SLQOWNC=SLQORTR*SLQCOST
C TOTAL ANNUAL OWN AND OPERATING COSTS
      SLQOOC=(SLQOWNC+SLQLCY+SLQFCY+SLQFTC)
C DEFAULT VARIABLES FOR LIQUID SPREADER AND 4ROW INJECTORS
C LQS+INJNO OF MEN
      INJ=SLQNMEN
C COST OF INJECTORS
      INJCOST=2500.00
C DEP RATE ON INJECTORS
      INJDEPR=0.10
```

```
C INTEREST RATE ON INJECTORS
      TNJINTR=0.06
C MISC RATE ON INJECTORS
      TNJMISR=0.02
C RHI RATE ON INJECTORS
      TNJRHIR=0.07
C SALVAGE VALUE ON INJECTORS
      TNJSALV=0.00
C FUEL CONSUMPTION/HR WITH TRACTOR AND INJECTORS FOR HAULING
      SLIJFCH=7.0
C FUEL CONSUMPTION/HP WHEN INJECTING
      SLIJFCI=8.5
C HP ON INJECTOR TRACTOR
      SLIJHP=100.00
C FIXED COSTS ON 100 HP TRACTOR/TR OPERATED
      TR100FC=9.00
C HAULING SPEED WITH INJECTORS
      SLIJHSP=SLQHSP
C LOADED HAULING TIME
      SLIJHTM=SLQHTM
C LOADED HAULING DISTANCE
      SLIJLHD=SLQLHD
C LOAD TIME
      SLIJLTM=(SLQLTM)
C LOAD TIME/YR
      SLIJLTY=SLQLTY
C RETURN SPEED WITH INJECTORS
      SLIJRSP=SLQRSP
C RETURN TIME WITH INJECTORS
      SLIJRTM=SLQRTM
C UNLOADING RATE FOR INJECTORS (GPM)
      SLIJULR=500
C YRLY LOADS HAULED
      SLIJYLD=SLQLDS
C CALCULATED VALUES FOR INJECTORS
C INJ ORH RATE
      TNJORT=TNJOEPR+TNJINTR+TNJMISR+TNJRHIR
C INJECTORS OWN COSTS
      TNJOWN=(TNJORT*TNJCOST)
C COST OF LQS AND INJECTORS
      SLIJCST=(SLQCOST+TNJCOST)
C UNLOADING TIME WITH INJECTORS
      SLIJULT=(SLQCAP/SLIJULR)/60
C TOTAL INJPLQS OWN COSTS
      SLIJOWN=(SLQOWNC+TNJOWN)
C FUEL USE/LOAD WHEN INJECTING
      SLIJUFL=SLIJFCI*SLIJULT
C FUEL TO TAKE LOAD OUT AND EMPTY RETURN
      SLIJFLD=(SLIJHTM+SLIJRTM)*(SLIJFCH)
C FUEL/LOAD UNLOADING PLUS OUT AND BACK)
      SLIJFLC=(SLIJFLD+SLIJUFL)
C YRLY FUEL WITH INJECTORS
      SLIJYFL=SLIJYLD*SLIJFLC
C FUEL COSTS/YR
      SLIJFCY=SLIJYFL*FUEDSLC
C YEARLY LABOR WITH INJECTORS
      SLIJLYR=(SLIJULT+SLIJRTM+SLIJHTM+SLIJLTM)*(SLQLDS)
C FIXED TRACTOR COSTS ASSOCIATED WITH 100 HP UNIT
      SLIJFTC=SLIJLYR*TR100FC
C LABOR COSTS/YR
      SLIJLCY=(SLIJLYR*CSLABOR)
C YEARLY OPERATING AND OWNERSHIP COSTS
      SLIJOOC=(SLIJOWN+SLIJLCY+SLIJFCY+SLIJFTC)
C SOLIDS SPREADER (275-300BUSHEL) CAPACITY WITH HYDRAULIC GATE
C SOLIDS SPREADER DEFAULT VARIABLES
C NO OF MEN FOR SOLIDS SPREADER
C CAPACITY OF SOLIDS SPREADER IN BUSHELS
      SOLSCAP=275
      SOLSMEN=1.0
C COST OF SOLIDS SPPREADER
      SOLSCST=5000.00
C DEP RATE
      SOLSDPR=0.10
C FUEL USED/HR TO RUN SPREADER
      SOLSFCH=6.0
C HP OF TRACTOR PULLING UNIT
      SOLSHP=85
C HAULING SPEED MPH
      SOLSHSP=6.0
C SOLID SPREADER INTEREST RATE
      SOLSINR=0.06
```

```
C NORMAL HAULING DISTANCE TO UNLOADING SITE
      SOLSLHD=0.5
C SPREADER LOADING TIME
      SOLSLTM=0.09
C MISCELLANEOUS RATE ON UNIT
      SOLSMIR=0.02
C RHI RATE ON SOLID SPREADER
      SOLSRHR=0.07
C RETURN SPEED WITH EMPTY SPREADER
      SOLSRSP=6.0
C SALVAGE VALUE OF OLD SPREADER
      SOLSSLV=0.00
C UNLOADING RATE  CUFT/HR
      SOLSULR=2600
C UNLOADING FUEL CONSUMFTION/HR
      SOLSUFC=6.5
C CALCULATED VALUES FOR SOLIDS SPREADER
C SPREADER CAPACITY CU FT.
      SOLSCCF=SOLSCAP*1.25
C HAULING TIME/LOAD
      SOLSHTM=(SOLSLHD/SOLSHSP)
C UNLOAD TIME/LOAD
      SOLSULT=(SOLSCCF/SOLSULR)
C TIME TO RETURN TO LOADING AREA
      SOLSRTM=(SOLSLHD/SOLSRSP)
C LOADS/YR WITH SOLIDS SPREADER
      SOLSLOS=(V365MSH/SOLSCCF)
C TOTAL YEARLY TIME WITH SPREADER
      SOLSLYR=(SOLSULT+SOLSRTM+SOLSHTM+SOLSLTM)*(SOLSLOS)
C FIXED COSTS OF TRACTOR
      SOLSFTC=SOLSLYR*TR90FXC
C MHRS/YEAR ON SOLIDS SPREADER
      SOLSMHR=SOLSMEN*SOLSLYR
C LABOR COST/YR FOR HAULING WITH SOLIDS SPREADER
      SOLSLCY=(SOLSLYR*CSLABOR)
C FUEL TO UNLOAD ONE LOAD
      SOLSUFL=(SOLSUFC*SOLSULT)
C FUEL/LOAD OUT AND RETURN
      SOLSFLD=((SOLSHTM+SOLSRTM)*SOLSFCH)
C SOLID SPREADER FUEL/LOAD
      SOLSFLC=(SOLSFLD+SOLSUFL)
C TOTAL YEARLY LOAD TIME WITH SOLID SPREADER
      SOLSLTY=(SOLSLTM*SOLSLOS)
C SOLIDS SPREADER YRLY FUEL USE
      SOLSFYR=SOLSLOS*SOLSFLC
C SOLIDS SPREADER FUEL COSTS/YR
      SOLSFCY=SOLSFYR*FUEDSLC
C AVERAGE VALUE OF SOLIDS SPREADER
C SOLIDS SPREADER TOTAL DRHI RATE
      SOLSORR=SOLSDPR+SOLSINR+SOLSRHR+SOLSMIR
C YRLY OWN COSTS SOLIDS SPREADER
      SOLSOWN=SOLSORR*SOLSCST
C TOTAL YEARLY OWNERSHIF AND OPERATING COSTS
      SOLSOOC=(SOLSOWN+SOLSLCY+SOLSFCY+SOLSFTC)
C BIG GUN SPRINKLEP SYSTEM
C DEFAULT VARIABLES FOR BGS
C ALUMINUM PIPE COST/FT FOR 6 INCH DIAM
      ALPCSTF=3.25
C FEET OF AL PIPE USED
      ALPFEET=3960
C COST OF GUN SPRINKLEP PLUS STAND
      RRRBGCS=750.00
C DEP RATE ON PIPE ETC
      RRRDEPR=0.10
C NO MEN INVOLVED IN DISMANTLING IRR EQUIPMENT
      RRRDISL=2.0
C HRS/YR INVOLVED IN DISMANTLING IRR
      RRRDIST=10.0
C SET TIME/SETTING
      RRRHSET=2.0
C INT RATE ON IRR
      RRRINTR=0.05
C LABOR(MEN) NEEDED TO OBSERVE WORKING UNIT
      RRRLSET=1.0
C MISC RATE FOR IRR
      RRRMISR=0.02
C PERCENT OF TOTAL USE FOR MANURE SLURRY
      RRRPTMS=0.25
C RHI RATE FOR IRR
      RRRRHIR=0.070
C MEN NEEDED TO RESET BGS
```

```
      RRRRMEN=1.0
C TIME TO RESET BGS
      RRRRSET=1.00
C MEN INVOLVED IN INITIAL SETUP
      RRRSETM=2.0
C NO OF TIMES UNIT SET UP FOR WASTE
      RRRSETN=2.0
C INITIAL SET UP TIME
      RRRSETU=5.0
C GALLLONS PUMPED/BGS SET AT .5 INCHES/SET AND 400 FT DIAM.
      RRRGSET=39102
C CALCULATED VALUES FOR IRRIGATION SYSTEM
C TOTAL YRLY MANHRS FOR SET UP
      RRRSTMH=((RRRSETU*RRRSETM)*RRRSETN)
C NUMBER SETS/YR WITH BGS
      RRRNSTY=3*VL3o5ST*7.48/RRRGSET-2.0
C TOTAL YRLY LABOR TO RESET IRR EQUIP
      RRRRSTL=(RRRRSET*RRRRMEN*RRRNSTY)
C MHRS/YR TO DISMANTLE BGS IRRIGATION EQUIPMENT
      RRRDSMT=RRRDISL*RRRDIST
C TOTAL YRLY LABOR FOR IRRIGATION
      RRRTYRL=(RRRRSTL+RRRSTMH+RRRDSMT)
C TOTAL YEARLY LABOR COST FOR ALL IRR ACTIVITIES)
      RRRLCST=(RRRTYRL*CSLABOR)
C C ALUMINUM PIPE TOTAL COST
      ALPTCST=(ALPCSTF*ALPFEET)
C TOTAL PIPE AND BG COST
      RRRPBGC=(RRRBGCS+ALPTCST)
C BGS TOTAL ORT RATE
      RRRDRHT=(RRRDEPR+RRRINTR+RRRRHIR+RRRMISR)
C BGS OWN COSTS
      RRROWCS=(RRRDRHT*RRRPBGC*RRRPTMS)
C TOTAL YRLY OWN AND OPERATING COSTS
      RRROOCS=(RRROWCS+RRRLCST)
C DEFAULT VARIABLES FOR TRAVELLING GUN SPRINKLER
C TG PERCENTAGE OF TIME USED FOR MANURE
      TGPMANS=0.25
C COST OF TRAVELLING GUN SPRINKLER
      TGCOST=8000.00
C DEP RATE ON TGS
      TGDEPR=0.10
C FUEL(GAL/HR)TO RUN TGS
      TGFUELH=3.0
C COST OF HOSE/FT
      TGHOSEC=8.50
C FEET OF HOSE NEEDED
      TGHOSEF=1320
C HPS TO SET UP TGS SYSTEM
      TGHRSUP=4.0
C INT RATE ON TGS SYSTEM
      TGINTR=.02
C SALVAGE VALUE OF TGS SYSTEM
      TGIRSLV=0.00
C MEN NEEDED TO DISMANTLE TGS
      TGMDISM=2.0
C MISC RATE ON TGS
      TGMISCR=0.02
C MEN INVOLVED IN RESETTING
      TGMRSET=1.0
C AREA COVERED PER QUARTER MILE TGS RUN
      TGARERN=12
C DEPTH OF APPLICATION
      TGAPPOP=0.5
C GALLONS/ACRE INCH
      ACINCHG=27154
C NUMBER OF TIMES/YR UNIT IS SETUP
      TGNSTUP=2.0
C  HP REQD ON PUMP
      TGPMPHP=60.0
C  FUEL/HR USED BY PUMP
      TGPMPFH=4.0
C PUMPING RATE OF SYSTEM GALLON/HR
      TGPMPR=18000.00
C RHI RATE ON TGS
      TGRHIR=0.07
C PEOPLE NEEDED TO OBSERVE DURING OPERATION
      TGSETMN=1.0
C MEN NEEDED TO SET UP TGS SYSTEM
      TGSTMEN=2.0
C TIME TO DISMANTLE
      TGTDISM=2.0
```

```
C TIME TO RESET UNIT
      TGTRSET=1.0
C TG ALUMINUM PIPE NEEDED
      TGALPFT=2640
C CALCULATED TGS VALUES
C TOTAL VOLUME OF WASTE APPLIED PER RUN
      TGTVRUN=TGARERN*TGAPPDP*ACINCHG
C TOTAL MANHRS/SET UP
      TGSUMHR=(TGHRSUP*TGSTMEN)
C TOTAL YRLY LABOR FOR SET UP
      TGSTUPL=(TGSUMHR*TGNSTUP)
C TOTAL VOLUME OF WASTE TO BE PUMPED
      TGWVOLP=3*VL365ST
C NUMBER RESETS PER YEAR
      TGNRSET=TGWVOLP*7.48/TGTVRUN-2.0
C TOTAL SET TIME PER YR
      TGSETTM=(TGWVOLP*7.48)/TGPMPR
C TOTAL YRLY MHRS FOR SET TIME
      TGSETMH=(TGSETTM*TGSETMN)
C TOTAL RESET MHRS/YEAR
      TGRSMHR=(TGNRSET*TGTRSET*TGMRSET)
C TOTAL MAN HRS/YR FOR DISMANTLING
      TGPYRHD=(TGTDISM*TGMDISM*TGNSTUP)
C TOTAL LABOR/YR FOR TGS
      TGTLBRY=(TGPYRHD+TGRSMHR+TGSTUPL)
C TOTAL YRLY LABOR COSTS
      TGYLCST=(TGTLBRY*CSLABOR)
C FUEL/YR TO RUN TG
      TGYRFUL=(TGFUELH*TGSETTM)
C TOTAL YRLY FUEL COSTS
      TGYRFLC=(TGYRFUL*0.58)
C TG ALUMINUM PIPE COST
      TGALPCS=TGALPFT*ALPCSTF
C COST OF ALL HOSE
      TGTHCST=(TGHOSEC*TGHOSEF)
C COST OF HOSE PLUS GUN SPRINKLER+ALUMINUM PIPE
      TGIRRHC=TGCOST+TGTHCST+TGALPCS
C TGS DRHI RATE
      TGDRHRT=(TGDEPR+TGINTR+TGRHIR+TGMISCR)
C TG YRLY OWN COSTS
      TGOWNC=(TGDRHRT*TGPMANS*TGIRRHC)
C TOTAL OWN + OPERATING COSTS
      TGOOCS=(TGOWNC+TGYRFLC+TGYLCST)
      COSTINT(1,1)=CLCRBCS
      COSTINT(1,2)=CURBFLC
      COSTINT(2,1)=SSTOCST
      COSTINT(2,2)=SSTOCST
      COSTINT(2,3)=STWTCST
      COSTINT(2,4)=STWTCST
      COSTINT(2,5)=SANDTOC
      COSTINT(2,6)=SANDTOC
      COSTINT(2,7)=TOSTMAT
      COSTINT(2,8)=TOSTMAT
      COSTINT(2,9)=TOCWMAT
      COSTINT(2,10)=TOCWMAT
      COSTINT(3,1)=CSTCFLO
      COSTINT(3,2)=SLOTTCS
      COSTINT(4,1)=TCLALLC
      COSTINT(4,2)=SKCOST
      COSTINT(4,3)=GDNTCST
      COSTINT(4,4)=UTNCOST
      COSTINT(4,5)=FLTGMCS
      COSTINT(5,1)=CCTOCST
      COSTINT(5,2)=CCLTCST
      COSTINT(5,3)=PPSYSCS
      COSTINT(5,4)=CCRMTC
      COSTINT(5,5)=CCAMTC
      COSTINT(5,6)=CRMPCST
      COSTINT(5,8)=CFLTCST
      COSTINT(6,1)=CSLTCST
      COSTINT(6,2)=SSLTCST
      COSTINT(6,3)=CBSTAVL
      COSTINT(6,4)=EBTCOST
      COSTINT(6,5)=CSBTCST
      COSTINT(6,6)=PITCSTT
      COSTINT(6,7)=CTTCOST
      COSTINT(6,9)=FLLGTCS
      COSTINT(7,1)=PLMCST
      COSTINT(7,2)=FELUTTC
      IF(IS(4).EQ.4) COSTINT(7,2)=FELCST
      COSTINT(7,3)=SKCOST
```

```
IF(IS(4).EQ.2) COSTINT(7,3)=0
COSTINT(7,4)=SLSCST2
COSTINT(7,6)=RRIMCST
COSTINT(8,1)=SLSCST2
COSTINT(8,2)=SLQCOST
COSTINT(8,3)=SLIJCST
COSTINT(8,4)=SOLSCST
COSTINT(8,5)=RRRPBGC
COSTINT(8,6)=TGIRRHC
DIRTPCT(1,1)=STDIRTR
DIRTPCT(1,2)=STDIRTR
DIRTPCT(3,1)=SOFDRTR
DIRTPCT(3,2)=SLFDRTR
DIRTPCT(4,1)=ALDIRTM
DIRTPCT(4,2)=SKSDIRT
DIRTPCT(4,3)=GDNDRHT
DIRTPCT(4,4)=UTDIRTP
DIRTPCT(4,5)=FLEQDRH
DIRTPCT(5,1)=CCDRHIT
DIRTPCT(5,2)=CCLDRHT
DIRTPCT(5,3)=PPDRHTR
DIRTPCT(5,4)=CCRDRHT
DIRTPCT(5,5)=CCADRHT
DIRTPCT(5,6)=CRDRHTR
DIRTPCT(5,8)=CFLDRR
DIRTPCT(6,1)=CSLDRHT
DIRTPCT(6,2)=SSLDRHT
DIRTPCT(6,3)=EBSDRTR
DIRTPCT(6,4)=EBLDRTR
DIRTPCT(6,5)=CSBDRTR
DIRTPCT(6,6)=PITDRHT
DIRTPCT(6,7)=CTDRHIT
DIRTPCT(6,9)=FLLGDRR
DIRTPCT(7,1)=PLMDRTR
DIRTPCT(7,2)=FELDRTT
DIRTPCT(7,4)=SLSDRT2
DIRTPCT(7,6)=RPDIRTR
DIRTPCT(8,1)=SLSDRT2
DIRTPCT(8,2)=SLQDRTR
DIRTPCT(8,3)=TNJDRT
DIRTPCT(8,4)=SOLSDRR
DIRTPCT(8,5)=RRRDRHT
DIRTPCT(8,6)=TGDRHRT
DIRTTOT(1,1)=CLSTOCS
DIRTTOT(1,2)=CURBPOC
DIRTTOT(2,1)=BDSKOCS
DIRTTOT(2,2)=BDOWNCS
DIRTTOT(2,3)=BDSKOCS
DIRTTOT(2,4)=BDOWNCS
DIRTTOT(2,5)=SNDSSYO
DIRTTOT(2,6)=FLSNOCS
DIRTTOT(2,7)=BDSKCMS
DIRTTOT(2,8)=BDOWMSF
DIRTTOT(2,9)=BDSKOMW
DIRTTOT(2,10)=BDOWMWF
DIRTTOT(3,1)=SOFOCS
DIRTTOT(3,2)=SLFOCS
DIRTTOT(4,1)=DIRTMAL
DIRTTOT(4,2)=SKALSOC
DIRTTOT(4,3)=GDNOCST
DIRTTOT(4,4)=UTOWNCS
DIRTTOT(4,5)=FLTOWNC
DIRTTOT(5,1)=CCOWNC
DIRTTOT(5,2)=CCLOWNC
DIRTTOT(5,3)=PPOCSTS
DIRTTOT(5,4)=CCROWNC
DIRTTOT(5,5)=CCAOWNC
DIRTTOT(5,6)=CRYOWNC
DIRTTOT(5,8)=CFLOWNC
DIRTTOT(6,1)=CSLOWNC
DIRTTOT(6,2)=SSLOWNC
DIRTTOT(6,3)=EBSOWNC
DIRTTOT(6,4)=EBOWNC
DIRTTOT(6,5)=CSBOWNC
DIRTTOT(6,6)=PITOWNC
DIRTTOT(6,7)=CTOWNCS
DIRTTOT(6,9)=FLLGOWN
DIRTTOT(7,1)=PLMOCST
DIRTTOT(7,2)=FELOCH
DIRTTOT(7,3)=SKLOWNC
DIRTTOT(7,4)=SLSOCL2
```

```
DIRTTOT(7,6)=RRIMCCS
DIRTTOT(8,1)=SLSOCHS
DIRTTOT(8,2)=SLQOWNC
DIRTTOT(8,3)=SLIJOWN
DIRTTOT(8,4)=SOLSOWN
DIRTTOT(8,5)=RRROWCS
DIRTTOT(8,6)=TGOWNC
HRLABOR(2,1)=BDSKYHR
HRLABOR(2,2)=BDYPLMH
HRLABOR(2,3)=BDSKYHR
HRLABOR(2,4)=BDYPLMH
HRLABOR(2,5)=SNDSSYL
HRLABOR(2,6)=FLSYRMH
HRLABOR(2,7)=BDSKMHS
HRLABOR(2,8)=BDFLMYS
HRLABOR(2,9)=BDSKMHW
HRLABOR(2,10)=BDFLMYW
HRLABOR(4,1)=ALYMHRS
HRLABOR(4,2)=SKHRYR
HRLABOR(4,3)=GDNHYR
HRLABOR(4,4)=UTHRSYR
HRLABOR(4,5)=FLLABTO
HRLABOR(5,1)=CCYRLB
HRLABOR(5,2)=CCLLBYR
HRLABOR(5,3)=PPYLABR
HRLABOR(5,4)=CCRLBTY
HRLABOR(5,5)=CCALBTY
HRLABOR(5,6)=0
HRLABOR(5,8)=0
HRLABOR(7,1)=PLMYLBR
HRLABOR(7,2)=FELLYR
HRLABOR(7,3)=SKLHRSY
HRLABOR(7,4)=SLSYMH2
HRLABOR(7,6)=RRIMLBR
HRLABOR(8,1)=SLSTHMH
HRLABOR(8,2)=SLQMHRY
HRLABOR(8,3)=SLIJLYR
HRLABOR(8,4)=SOLSMHR
HRLABOR(8,5)=RRRTYRL
HRLABOR(8,6)=TGTLBRY
COSTLAB(2,1)=BDSKLBC
COSTLAB(2,2)=BDYRLCS
COSTLAB(2,3)=BDSKLBC
COSTLAB(2,4)=BDYRLCS
COSTLAB(2,5)=SNDSSLC
COSTLAB(2,6)=FLSYLCS
COSTLAB(2,7)=BDLCMSS
COSTLAB(2,8)=BDLCMSF
COSTLAB(2,9)=BDLCMWS
COSTLAB(2,10)=BDLCMWF
COSTLAB(4,1)=YRLCST
COSTLAB(4,2)=SKLCST
COSTLAB(4,3)=GDNLCYR
COSTLAB(4,4)=UTLABYR
COSTLAB(4,5)=FLLABTC
COSTLAB(5,1)=CCYRLBC
COSTLAB(5,2)=CCLYLBC
COSTLAB(5,3)=PPANCSL
COSTLAB(5,4)=CCRLBCY
COSTLAB(5,5)=CCALBCY
COSTLAB(5,6)=0
COSTLAB(5,8)=0
COSTLAB(7,1)=PLMLCST
COSTLAB(7,2)=FELTLCS
COSTLAB(7,3)=SKLLBRC
COSTLAB(7,4)=SLSTLC2
COSTLAB(7,6)=RRIMYLC
COSTLAB(8,1)=SLSYHLC
COSTLAB(8,2)=SLQLCY
COSTLAB(8,3)=SLIJLCY
COSTLAB(8,4)=SOLSLCY
COSTLAB(8,5)=RRRLCST
COSTLAB(8,6)=TGYLCST
UNITENE(2,1)=BDSKFUE
UNITENE(2,2)=BDFUELU
UNITENE(2,3)=BDSKFUE
UNITENE(2,4)=BDFUELU
UNITENE(2,5)=SNDSSFU
UNITENE(2,6)=FLSNFLU
UNITENE(2,7)=BDFMSSK
UNITENE(2,8)=BDFMSFL
```

```
UNITENE(2,9)=BDFMWSK
UNITENE(2,10)=BDFMWFL
UNITENE(4,1)=HKWYRLY
UNITENE(4,2)=FUELYR
UNITENE(4,3)=GDNFLYR
UNITENE(4,4)=UTFUELY
UNITENE(4,5)=0
UNITENE(5,1)=CCMKWYR
UNITENE(5,2)=CCLMKWY
UNITENE(5,3)=PPHKWY
UNITENE(5,4)=CCRYHKW
UNITENE(5,5)=CCAYHKW
UNITENE(5,6)=0
UNITENE(5,8)=0
UNITENE(7,1)=PLMYFL
UNITENE(7,2)=FELYFLU
UNITENE(7,3)=SKLFYR
UNITENE(7,4)=SLSGFL2
UNITENE(7,6)=PRIMYEN
UNITENE(8,1)=SLSYRFH
UNITENE(8,2)=SLQFLYR
UNITENE(8,3)=SLIJYFL
UNITENE(8,4)=SOLSFYR
UNITENE(8,6)=TGYRFUL
COSTENE(2,1)=BDSKFLC
COSTENE(2,2)=BDFUELC
COSTENE(2,3)=BDSKFLC
COSTENE(2,4)=BDFUELC
COSTENE(2,5)=SNDSSFC
COSTENE(2,6)=FLSNYFC
COSTENE(2,7)=BDFCSMS
COSTENE(2,8)=BDFCSMF
COSTENE(2,9)=BDFCWMS
COSTENE(2,10)=BDFCWMF
COSTENE(4,1)=KWCSTYR
COSTENE(4,2)=SKFCSTY
COSTENE(4,3)=GDNFCYR
COSTENE(4,4)=UTFCSTY
COSTENE(4,5)=FLYENGC
COSTENE(5,1)=CCELCSY
COSTENE(5,2)=CCLELCY
COSTENE(5,3)=PPYELCS
COSTENE(5,4)=CCRYELC
COSTENE(5,5)=CCAYELC
COSTENE(5,6)=0
COSTENE(5,8)=0
COSTENE(7,1)=PLMFLCY
COSTENE(7,2)=FELYFC
COSTENE(7,3)=SKLYFC
COSTENE(7,4)=SLSFCS2
COSTENE(7,6)=PRIMYEC
COSTENE(8,1)=SLSFHCY
COSTENE(8,2)=SLQFCY
COSTENE(8,3)=SLIJFCY
COSTENE(8,4)=SOLSFCY
COSTENE(8,6)=TGYRFLC
ANNBED(2,1)=SHVYR
ANNBED(2,2)=SHVYR
ANNBED(2,3)=STRWYR
ANNBED(2,4)=STRWYR
ANNBED(2,5)=SANDY
ANNBED(2,6)=SANDY
ANNBED(2,7)=SMATHYR
ANNBED(2,8)=SMATHYR
ANNBED(2,9)=SMATTYR
ANNBED(2,10)=SMATTYR
COSTAB(2,1)=SHCSTYR
COSTAB(2,2)=SHCSTYR
COSTAB(2,3)=STRCSYR
COSTAB(2,4)=STRCSYR
COSTAB(2,5)=SNDCSYR
COSTAB(2,6)=SNDCSYR
COSTAB(2,7)=SMATHCY
COSTAB(2,8)=SMATHCY
COSTAB(2,9)=SMATTCY
COSTAB(2,10)=SMATTCY
COSTOP(1,1)=CLSTOCS
COSTOP(1,2)=CURBPOC
COSTOP(2,1)=SKSTTYC+SHCSTYR
COSTOP(2,2)=BDYRCST+SHCSTYR
COSTOP(2,3)=SKSTTYC+STRCSYR
```

```
      COSTOP(2,4)=BDYRCSI+STRCSYR
      COSTOP(2,5)=FLSNTYC+SNOCSYR
      COSTOP(2,6)=SNDSSTC+SNOCSYR
      COSTOP(2,7)=BDSKOMS+SMATHCY
C     CSTOP(2,8)=BDOWMSF+SMATHCY
      COSTOP(2,9)=BDSKOFM+SMATTCY
      COSTOP(2,10)=BDOWMWF+SMATTCY
      COSTOP(3,1)=SOFOCS
      COSTOP(3,2)=SLFOCS
      COSTOP(4,1)=ALLANCS
      COSTOP(4,2)=SKTCSTS
      COSTOP(4,3)=GUNOOCS
      COSTOP(4,4)=UTTOOCS
      COSTOP(4,5)=FLTOOPC
      COSTOP(5,1)=CCTOOCS
      COSTOP(5,2)=CCLTOOC
      COSTOP(5,3)=PPANCST
      COSTOP(5,4)=CCROOCY
      COSTOP(5,5)=CCAOOCY
      COSTOP(5,6)=CRYOWNC
      COSTOP(5,8)=CFLOWNC
      COSTOP(6,1)=CSLOWNC
      COSTOP(6,2)=SSLOWNC
      COSTOP(6,3)=EBSOWNC
      COSTOP(6,4)=EBOWNC
      COSTOP(6,5)=CSBOWNC
      COSTOP(6,6)=PITOWNC
      COSTOP(6,7)=CTOWNCS
      COSTOP(6,9)=FLLGOWN
      COSTOP(7,1)=PLMOOCS
      COSTOP(7,2)=FELOOCS
      COSTOP(7,3)=SKLOOCS
      COSTOP(7,4)=SLSCOL2
      COSTOP(7,6)=RPIMOCC
      COSTOP(8,1)=SLSOOHS
      COSTOP(8,2)=SLOOOC
      COSTOP(9,3)=SLIJOOC
      COSTOP(8,4)=SOLSOOC
      COSTOP(8,5)=RRPOOCS
      COSTOP(8,6)=TGOOCS
      VALN(2,1)=0.00
      VALN(2,2)=0.00
      VALN(2,3)=0.00
      VALN(2,4)=0.00
      VALN(2,5)=0.05
      VALN(2,6)=0.05
      VALN(2,7)=0.00
      VALN(2,8)=0.00
      VALN(2,9)=0.00
      VALN(2,10)=0.00
      VALN(6,1)=0.05
      VALN(6,2)=0.05
      VALN(6,3)=0.20
      VALN(6,4)=0.10
      VALN(5,5)=0.15
      VALN(5,6)=0.05
      VALN(6,7)=0.05
      VALN(6,8)=0.10
      VALN(6,9)=0.15
      VALN(7,1)=0.10
      VALN(7,2)=0.00
      VALN(7,3)=0.00
      VALN(7,4)=0.00
      VALN(7,5)=0.05
      VALN(7,6)=0.10
      VALN(8,1)=0.05
      VALN(8,2)=0.05
      VALN(8,3)=0.00
      VALN(8,4)=0.05
      VALN(8,5)=0.25
      VALN(8,6)=0.25
  510 I1=J1=IS(1)
      I2=J2=IS(2)
      I3=J3=IS(3)
      I4=J4=IS(4)
      I5=J5=IS(5)
      I6=J6=IS(6)
      I7=J7=IS(7)
      I8=J8=IS(8)
      IF(IS(1).NE.0) GO TO 520
      I1=1
```

```
      J1=2
520   IF(IS(2).NE.0) GO TO 530
      I2=1
      J2=10
530   IF(IS(3).NE.0) GO TO 540
      I3=1
      J3=2
540   IF(IS(4).NE.0) GO TO 550
      I4=1
      J4=6
550   IF(IS(5).NE.0) GO TO 560
      I5=1
      J5=9
560   IF(IS(6).NE.0) GO TO 570
      I6=1
      J6=9
570   IF(IS(7).NE.0) GO TO 580
      I7=1
      J7=5
580   IF(IS(8).NE.0) GO TO 700
      I8=1
      J8=5
700   DO 807 M=I1,J1
      DO 806 MM=I2,J2
      DO 805 MMM=I3,J3
      DO 804 MMMM=I4,J4
      DO 803 N=I5,J5
      DO 802 NN=I6,J6
      DO 801 NNN=I7,J7
      DO 800 NNNN=I8,J8
      IOP(1)=M
      IOP(2)=MM
      IOP(3)=MMM
      IOP(4)=MMMM
      IOP(5)=N
      IOP(6)=NN
      IOP(7)=NNN
      IOP(8)=NNNN
      J=1
      DO 62 I=1,8
      K=IOP(I)
      KK=IFESS(I,J,K)
      IF(KK.NE.0) GO TO 416
      IGO=I
      GO TO(807,806,805,804,803,802,801,800)IGO
416   ISO(I)=KK
62    J=K
      DO 414 I=1,8
414   IS(I)=IOP(I)
      PRINT 60,NSN
60    FORMAT(*4 THE FOLLOWING OPTIONS HAVE BEEN SELECTED FOR*/
     +* SYSTEM NUMBER*,I5)
      PRINT 61
61    FORMAT(*0  SECTION   COMPONENT                          OPTION*/)
      DO 699 I=1,8
699   PRINT 63,I,(MTITLE(I,J),J=1,4),(MOTITLE(ISO(I),LL),LL=1,4)
63    FORMAT(I6,5X,4A8,4A8)
C PRINT SUMMARY
      YRVALN=(YRLYNN*(1.00-VALN(2,MM)-VALN(6,NN)-VALN(7,NNN)
     +-VALN(8,NNNN)))*0.50*PRICEN
      YRVALP=YRLYPH*0.60*PRICEP
      YRVALK=YRLYKK*PRICEK
      YRVLMAN=YRVALN+YRVALP+YRVALK
      PRINT 701,NCOWS
701   FORMAT(*1NETWORK ANALYSIS OUTPUT FOR DAIRY WASTE HANDLING SYSTEMS*
     +/* OUTPUTS ARE BASED ON THE NUMBER OF COWS IN THE HERD:*,I5/)
      PRINT 702,NSN
702   FORMAT( * SYSTEM NUMBER=*,I5)
      PRINT 703
703   FORMAT(36X,*ANNUAL COST*/1X,*SYSTEM*,14X,*INITIAL*,8X,
     +* OF OWNERSHIP  DISTI*/1X,* COMPONENTS*,18X,*COSTS*,10X,
     +*PCT(DIRTI)          TOTALS*)
      PRINT 710,COSTINT(1,M),DIRTPCT(1,M),DIRTTOT(1,M)
710   FORMAT(*0STALL TYPE*,10X,4(F8.2,7X))
      PRINT 711,COSTINT(2,MM),DIRTPCT(2,MM),DIRTTOT(2,MM)
711   FORMAT(*0BEDDING MATERIAL*,4X,4(F8.2,7X))
      PRINT 712,COSTINT(3,MMM),DIRTPCT(3,MMM),DIRTTOT(3,MMM)
712   FORMAT(*0FLOOR STYLE*,9X,4(F8.2,7X))
      PRINT 723
      PRINT 713,COSTINT(4,MMMM),DIRTPCT(4,IS(4)),DIRTTOT(4,IS(4))
723   FORMAT(*0ALLEY CLEANING*)
```

```
713    FORMAT(* SYSTEM*,14X,4(F8.2,7X))
       PRINT 714,COSTINT(5,N),DIRTPCT(5,N),DIRTTOT(5,N)
714    FORMAT(*0MOVEMENT TO STORAGE *,4(F8.2,7X))
       PRINT 715,COSTINT(6,NN),DIRTPCT(6,NN),DIRTTOT(6,NN)
715    FORMAT(*0STORAGE SYSTEM*,6X,4(F8.2,7X))
       PRINT 716,COSTINT(7,NNN),DIRTPCT(7,NNN),DIRTTOT(7,NNN)
716    FORMAT(*0UNLOADING OF STORAGE*,4(F8.2,7X))
       PRINT 727
       PRINT 717,COSTINT(8,NNNN),DIRTPCT(8,NNNN),DIRTTOT(8,NNNN)
727    FORMAT(*0MOVEMENT TO FIELD*)
717    FORMAT(* AND APPLICATION*,5X,4(F8.2,7X))
       DO 760 I=1,8
       T(1)=T(1)+COSTINT(I,IS(I))
       T(2)=T(2)+DIRTPCT(I,IS(I))
       T(3)=T(3)+DIRTTOT(I,IS(I))
       T(4)=T(4)+HRLABOR(I,IS(I))
       T(5)=T(5)+COSTLAB(I,IS(I))
       T(6)=T(6)+UNITENE(I,IS(I))
       T(7)=T(7)+COSTENE(I,IS(I))
       T(8)=T(8)+ANNBED(I,IS(I))
       T(9)=T(9)+COSTAB(I,IS(I))
       T(10)=T(10)+COSTOP(I,IS(I))
760    CONTINUE
       PRINT 718,(T(J),J=1,3)
718    FORMAT(*0TOTAL SYSTEM COSTS  *,4(F8.2,7X))
       PRINT 728
728    FORMAT(1H0)
       PRINT 750
750    FORMAT(21X,*YRLY MHRS OF    YEARLY*,9X,*UNITS OF ENERGY*/
      +1X,*SYSTEM*,14X,*LABOR USED      LABOR*,10X,*USED PER YEAR*/
      +1X,*COMPONENTS*,10X,*(COMP-EVENT)   COSTS*,10X,*(COMP-EVENT)*)
       PRINT 710,HRLABOR(1,M),COSTLAB(1,M),UNITENE(1,M)
       PRINT 711,HRLABOR(2,MM),COSTLAB(2,MM),UNITENE(2,MM)
       PRINT 712,HRLABOR(3,MMM),COSTLAB(3,MMM),UNITENE(3,MMM)
       PRINT 723
       PRINT 713,HRLABOR(4,MMMM),COSTLAB(4,IS(4)),UNITENE(4,IS(4))
       PRINT 714,HRLABOR(5,N),COSTLAB(5,N),UNITENE(5,N)
       PRINT 715,HRLABOR(6,NN),COSTLAB(6,NN),UNITENE(6,NN)
       PRINT 716,HRLABOR(7,NNN),COSTLAB(7,NNN),UNITENE(7,NNN)
       PRINT 727
       PRINT 717,HRLABOR(8,NNNN),COSTLAB(8,NNNN),UNITENE(8,NNNN)
       PRINT 718,(T(J),J=4,5)
       PRINT 728
       PRINT 770
770    FORMAT(21X,*YEARLY ENERGY  YEARLY*,9X,*YEARLY      ANNUAL*/
      +1X,*SYSTEM*,14X,*COSTS*,10X,*BEDDING*,8X,*BEDDING  COSTS*/
      +1X,*COMPONENTS*,10X,*(COMP-EVENT)   USED*,11X,*COSTS*,5X,
      +*(COMP-EVENT)*)
       PRINT 710,COSTENE(1,M),ANNBED(1,M),COSTAB(1,M),
      +COSTOP(1,M)
       PRINT 711,COSTENE(2,MM),ANNBED(2,MM),COSTAB(2,MM),
      +COSTOP(2,MM)
       PRINT 712,COSTENE(3,MMM),ANNBED(3,MMM),COSTAB(3,MMM),
      +COSTOP(3,MMM)
       PRINT 723
       PRINT 713,COSTENE(4,MMMM),ANNBED(4,IS(4)),COSTAB(4,IS(4)),
      +COSTOP(4,MMMM)
       PRINT 714,COSTENE(5,N),ANNBED(5,N),COSTAB(5,N),
      +COSTOP(5,N)
       PRINT 715,COSTENE(6,NN),ANNBED(6,NN),COSTAB(6,NN)
      +,COSTOP(6,NN)
       PRINT 716,COSTENE(7,NNN),ANNBED(7,NNN),COSTAB(7,NNN),
      +COSTOP(7,NNN)
       PRINT 727
       PRINT 717,COSTENE(8,NNNN),ANNBED(8,NNNN),COSTAB(8,NNNN),
      +COSTOP(8,NNNN)
       PRINT 718,(T(J),J=7,10)
       PRINT 411,YRVLMAN
411    FORMAT(*0YRLY VALUE OF MANURE*,45X,F8.2)
       COSTNET=T(10)-YRVLMAN
       PRINT 412,COSTNET
412    FORMAT(* NET SYSTEM COST*,50X,F8.2)
       WRITE(3,417)NSN,(IOP(I),I=1,8),YRVLMAN,COSTNET,NCOWS,IBARN
417    FORMAT(9I3,2F10.2,2I3)
       DO 418 I=1,8
418    WRITE(3,420)COSTINT(I,IOP(I)),DIRTPCT(I,IOP(I)),DIRTTOT(I,IOP(I)),
      +HRLABOR(I,IOP(I)),COSTLAB(I,IOP(I)),UNITENE(I,IOP(I)),
      +COSTENE(I,IOP(I)),ANNBED(I,IOP(I)),COSTAB(I,IOP(I)),
      +COSTOP(I,IOP(I))
       WRITE(3,420) (T(I),I=1,10)
420    FORMAT(10F10.2)
```

```
      NSN=NSN+1
      DO 413 I=1,10
413   T(I)=0
800   CONTINUE
801   CONTINUE
802   CONTINUE
803   CONTINUE
804   CONTINUE
805   CONTINUE
806   CONTINUE
807   CONTINUE
      REWIND1
      REWIND2
      PRINT 900
900   FORMAT(* DO YOU WANT AN ANALYSIS OF ANOTHER SYSTEM=*/
     + *TYPE Y FOR YES, N FOR NO*)
      READ 29,IR
      IF(IR.EQ.31B) GO TO 20
      CONTINUE
      END
```

APPENDIX C

COMPARISON OF 58 COMMONLY USED WASTE HANDLING SYSTEMS FOR 100-300 COW HERDS

Table C-1: Summary of systems for 100 cows.

Sys. No.	Option Codes								System Invest.	Annual Ownership Costs	Annual MIRS Labor	Annual Labor Costs	Annual Energy Costs	Tons of Bedding	Annual Bedding Costs	Total Annual Costs	Manure Nutrient Value	Net Annual Costs
1	1	1	1	2	1	8	5	4	27433.	5703.	401.	1403.	704.	79.	1577.	10043.	5110.	4933.
2	1	2	1	4	1	8	5	4	28438.	4996.	509.	1791.	737.	79.	1577.	9746.	5110.	4636.
3	1	1	1	2	2	3	3	4	40167.	7926.	425.	1498.	743.	79.	1577.	12390.	5004.	7386.
4	1	1	1	2	6	3	3	4	35361.	6729.	396.	1335.	719.	79.	1577.	11066.	5004.	6062.
5	1	2	1	4	2	3	2	4	43567.	7479.	539.	1995.	783.	79.	1577.	12522.	5004.	7518.
6	1	2	1	4	6	3	2	4	39961.	6282.	539.	1783.	758.	79.	1577.	11198.	5004.	6194.
7	1	2	1	3	2	3	2	4	46167.	6745.	539.	1985.	603.	79.	1577.	11608.	5004.	6603.
8	1	1	1	3	2	3	3	4	42567.	6409.	425.	1488.	548.	79.	1577.	10677.	5004.	5673.
9	1	1	1	1	1	8	5	4	21983.	5101.	177.	620.	816.	79.	1577.	8771.	5110.	3661.
10	1	2	1	1	1	8	5	4	21983.	5177.	255.	996.	864.	79.	1577.	9272.	5110.	4162.
11	1	1	1	1	2	3	3	4	45109.	7325.	231.	704.	855.	79.	1577.	11118.	5004.	6114.
12	1	2	1	1	2	3	2	4	45509.	7661.	315.	1192.	910.	79.	1577.	12048.	5004.	7044.
13	1	2	1	4	6	5	4	1	49372.	6664.	505.	1768.	847.	79.	1577.	9207.	5110.	4097.
14	1	1	1	2	6	5	4	1	49372.	7370.	397.	1390.	814.	79.	1577.	9504.	5110.	4394.
15	1	1	1	2	4	4	1	2	45359.	10523.	578.	2024.	927.	79.	1577.	15087.	5004.	10083.
16	1	1	1	2	4	4	1	3	47859.	11148.	580.	2028.	910.	79.	1577.	16661.	5110.	11551.
17	1	1	1	2	4	4	6	5	52179.	8843.	611.	2138.	1002.	79.	1577.	14439.	4581.	9858.
18	1	1	1	2	4	4	6	6	66259.	9485.	592.	1932.	1214.	79.	1577.	15088.	4581.	10508.
19	1	2	1	4	4	4	1	2	46359.	9816.	696.	2432.	959.	79.	1577.	15591.	5004.	10587.
20	1	2	1	4	4	4	1	3	49959.	13441.	689.	2436.	992.	79.	1577.	16364.	5110.	11254.
21	1	2	1	4	4	4	6	5	53079.	9136.	719.	2516.	1034.	79.	1577.	14142.	4581.	9562.
22	1	2	1	4	4	4	6	6	67259.	9778.	660.	2310.	1247.	79.	1577.	14792.	4581.	10211.
23	1	1	1	2	4	2	1	2	86969.	15650.	578.	2024.	927.	79.	1577.	21014.	5110.	15904.
24	1	1	1	2	4	2	1	3	89469.	16275.	580.	2028.	960.	79.	1577.	21787.	5216.	16571.
25	1	2	1	4	4	2	1	2	87969.	14943.	696.	2402.	959.	79.	1577.	20717.	5110.	15607.
26	1	2	1	4	4	2	1	3	90469.	15568.	688.	2436.	992.	79.	1577.	21490.	5216.	16275.
27	1	1	1	2	7	7	1	2	82570.	13542.	396.	1385.	797.	79.	1577.	18137.	5110.	13027.
28	1	1	1	2	7	7	1	3	85070.	14167.	397.	1390.	830.	79.	1577.	18910.	5216.	13695.
29	1	1	1	2	7	7	6	5	89290.	11861.	428.	1499.	811.	79.	1577.	16699.	4697.	12002.
30	1	1	1	2	7	7	6	6	103470.	12593.	370.	1234.	1084.	79.	1577.	17338.	4697.	12651.
31	1	2	1	4	7	7	1	2	83570.	12835.	504.	1763.	829.	79.	1577.	17840.	5110.	12730.
32	1	2	1	4	7	7	1	3	86070.	13460.	505.	1768.	862.	79.	1577.	18614.	5216.	13398.
33	1	2	1	4	7	7	6	5	90293.	11154.	535.	1977.	904.	79.	1577.	16392.	4697.	11705.
34	1	2	1	4	7	7	6	6	104473.	11796.	473.	1672.	1117.	79.	1577.	17041.	4687.	12355.
35	1	1	2	6	9	6	1	2	74695.	11969.	155.	542.	405.	79.	1577.	15330.	5110.	10220.
36	1	1	2	6	9	6	1	3	77195.	12594.	156.	547.	438.	79.	1577.	16103.	5216.	10887.
37	1	1	2	6	9	6	6	5	81415.	11288.	187.	656.	490.	79.	1577.	13881.	4687.	9195.
38	1	1	2	6	9	6	6	6	95595.	11930.	129.	450.	653.	79.	1577.	14531.	4697.	9844.
39	1	2	2	6	9	6	1	2	74695.	12045.	263.	920.	453.	79.	1577.	15831.	5110.	10721.
40	1	2	2	6	9	6	1	3	77195.	12670.	264.	925.	496.	79.	1577.	16605.	5216.	11389.
41	1	2	2	6	9	6	6	5	81415.	11364.	295.	1034.	528.	79.	1577.	14393.	4697.	9697.
42	1	2	2	6	9	6	6	6	95595.	11306.	237.	928.	741.	79.	1577.	15032.	4687.	10346.
43	1	1	1	5	9	4	1	2	49195.	14762.	637.	2228.	1517.	79.	1577.	18935.	5004.	13931.
44	1	1	1	5	9	4	1	3	51695.	11390.	644.	2255.	1698.	79.	1577.	20377.	5110.	15267.
45	1	1	1	5	8	4	6	5	55915.	9380.	601.	2102.	1929.	79.	1577.	17780.	4581.	13200.
46	1	1	1	5	8	4	6	6	70095.	9722.	349.	1223.	3099.	79.	1577.	18713.	4581.	14133.
47	1	1	1	5	9	9	1	2	52045.	11174.	637.	2228.	1517.	79.	1577.	19349.	4898.	14450.
48	1	1	1	5	9	9	1	3	54545.	11799.	644.	2255.	1698.	79.	1577.	20790.	5004.	15786.
49	1	1	1	5	8	9	6	5	59765.	9493.	601.	2102.	1929.	79.	1577.	18194.	4475.	13719.
50	1	1	1	5	8	9	6	6	72945.	11135.	349.	1223.	3098.	79.	1577.	19127.	4475.	14652.
51	1	2	1	5	9	4	1	2	49195.	13837.	745.	2606.	1564.	79.	1577.	19437.	5004.	14433.
52	1	2	1	5	9	4	1	3	51695.	11462.	752.	2633.	1746.	79.	1577.	20879.	5110.	15769.
53	1	2	1	5	8	4	6	5	55915.	9156.	739.	2480.	1976.	79.	1577.	16282.	4581.	11701.
54	1	2	1	5	8	4	6	6	70095.	9798.	457.	1601.	3146.	79.	1577.	19215.	4581.	14634.
55	1	2	1	5	9	9	1	2	52045.	11250.	745.	2606.	1564.	79.	1577.	19850.	4898.	14952.
56	1	2	1	5	8	9	1	3	54545.	11875.	752.	2633.	1746.	79.	1577.	21292.	5004.	16288.
57	1	2	1	5	8	9	6	5	59765.	9569.	739.	2480.	1976.	79.	1577.	18695.	4475.	14221.
58	1	2	1	5	8	9	6	6	72945.	11211.	457.	1601.	3146.	79.	1577.	19628.	4475.	15153.

Table C-2: Summary of systems for 150 cows.

Sys. No.	Option Codes								System Invest.	Annual Ownership Costs	Annual MHRS Labor	Annual Labor Costs	Annual Energy Costs	Tons of Bedding	Annual Bedding Costs	Total Annual Costs	Manure Nutrient Value	Net Annual Costs
1	1	1	1	2	1	8	5	4	31773.	6503.	466.	1632.	848.	118.	2365.	12333.	7665.	4668.
2	1	2	1	4	1	8	5	4	32773.	5803.	628.	2199.	904.	118.	2365.	12256.	7665.	4591.
3	1	1	1	2	2	3	3	4	29992.	4633.	512.	1759.	907.	118.	2365.	15649.	7506.	8143.
4	1	1	1	2	6	3	3	4	46285.	9437.	473.	1656.	892.	118.	2365.	14325.	7506.	6819.
5	1	2	1	4	2	3	2	4	53492.	9169.	673.	2355.	974.	118.	2365.	16059.	7506.	8552.
6	1	2	1	4	6	3	2	4	49786.	7971.	644.	2253.	949.	118.	2365.	14734.	7506.	7228.
7	1	2	1	3	2	3	2	4	55992.	8433.	673.	2355.	794.	118.	2365.	15144.	7506.	7638.
8	1	1	1	3	2	3	3	4	52492.	8116.	502.	1753.	711.	118.	2365.	13936.	7506.	6430.
9	1	1	1	1	1	8	5	4	27260.	5150.	242.	849.	950.	118.	2365.	11309.	7665.	3644.
10	1	2	1	1	1	8	5	4	27260.	6233.	404.	1415.	1032.	118.	2365.	12030.	7665.	4365.
11	1	1	1	1	2	3	3	4	55979.	9281.	279.	976.	1019.	118.	2365.	14625.	7506.	7119.
12	1	2	1	1	2	3	2	4	53479.	9598.	449.	1572.	1101.	118.	2365.	15833.	7506.	8327.
13	1	2	1	4	5	5	4	1	59132.	9450.	637.	2231.	1082.	118.	2365.	12419.	7665.	4754.
14	1	1	1	2	6	5	4	1	57132.	8150.	475.	1664.	1026.	118.	2365.	12496.	7665.	4831.
15	1	1	1	2	4	4	1	2	50944.	11505.	636.	2224.	1062.	118.	2365.	18262.	7506.	10755.
16	1	1	1	2	4	4	1	3	53444.	12130.	638.	2232.	1111.	118.	2365.	19109.	7665.	11444.
17	1	1	1	2	4	4	6	5	57664.	9824.	661.	2312.	1174.	118.	2365.	16946.	6871.	9974.
18	1	1	1	2	4	4	6	6	71944.	10466.	580.	2032.	1493.	118.	2365.	17526.	6871.	10655.
19	1	2	1	4	4	4	1	2	51944.	10865.	797.	2791.	1118.	118.	2365.	18185.	7506.	10678.
20	1	2	1	4	4	4	1	3	54444.	11430.	800.	2799.	1168.	118.	2365.	19032.	7665.	11367.
21	1	2	1	4	4	4	6	5	58664.	9124.	823.	2879.	1230.	118.	2365.	16769.	6871.	9897.
22	1	2	1	4	4	4	6	6	72944.	9766.	742.	2599.	1549.	118.	2365.	17449.	6871.	10578.
23	1	1	1	2	4	2	1	2	113984.	13285.	636.	2224.	1062.	118.	2365.	26042.	7665.	18377.
24	1	1	1	2	4	2	1	3	116484.	13910.	638.	2232.	1111.	118.	2365.	26889.	7824.	19065.
25	1	2	1	4	4	2	1	2	114984.	13585.	797.	2791.	1118.	118.	2365.	25965.	7665.	18300.
26	1	2	1	4	4	2	1	3	117484.	14210.	800.	2799.	1168.	118.	2365.	26812.	7824.	18989.
27	1	1	1	2	7	7	1	2	112105.	17492.	453.	1586.	932.	118.	2365.	23480.	7665.	15815.
28	1	1	1	2	7	7	1	3	114505.	18117.	455.	1593.	981.	118.	2365.	24328.	7824.	16504.
29	1	1	1	2	7	7	6	5	118825.	15611.	478.	1673.	1044.	118.	2365.	22064.	7030.	15034.
30	1	1	1	2	7	7	6	6	133005.	16454.	398.	1393.	1383.	118.	2365.	22745.	7030.	15715.
31	1	2	1	4	7	7	1	2	113105.	15792.	615.	2153.	988.	118.	2365.	23403.	7665.	15738.
32	1	2	1	4	7	7	1	3	115605.	17417.	617.	2160.	1037.	118.	2365.	24251.	7824.	16427.
33	1	2	1	4	7	7	6	5	119925.	15111.	640.	2240.	1130.	118.	2365.	21987.	7030.	14957.
34	1	2	1	4	7	7	6	6	134005.	15753.	560.	1960.	1419.	118.	2365.	22668.	7030.	15638.
35	1	1	2	6	9	8	1	2	105543.	15097.	212.	743.	540.	118.	2365.	20850.	7665.	13185.
36	1	1	2	6	9	8	1	3	108043.	15722.	214.	750.	590.	118.	2365.	21698.	7824.	13874.
37	1	1	2	6	9	8	6	5	112263.	14416.	237.	830.	653.	118.	2365.	19434.	7030.	12404.
38	1	1	2	6	9	8	6	6	126443.	15058.	157.	550.	972.	118.	2365.	20115.	7030.	13085.
39	1	2	2	6	9	8	1	2	105543.	16179.	374.	1310.	612.	118.	2365.	21571.	7665.	13906.
40	1	2	2	6	9	8	1	3	108043.	16804.	376.	1317.	662.	118.	2365.	22419.	7824.	14595.
41	1	2	2	6	9	8	6	5	112263.	14498.	399.	1397.	724.	118.	2365.	20155.	7030.	13125.
42	1	2	2	6	9	8	6	6	126443.	15141.	319.	1117.	1013.	118.	2365.	20836.	7030.	13806.
43	1	1	1	5	8	4	1	2	60730.	12626.	855.	2993.	2158.	118.	2365.	24471.	7506.	16965.
44	1	1	1	5	8	4	1	3	63230.	13251.	867.	3033.	2430.	118.	2365.	26321.	7665.	18656.
45	1	1	1	5	8	4	6	5	67450.	10945.	777.	2719.	2776.	118.	2365.	23495.	6871.	16624.
46	1	1	1	5	8	4	6	6	81630.	11587.	408.	1428.	4530.	118.	2365.	24602.	6871.	17730.
47	1	1	1	5	8	9	1	2	64130.	13119.	855.	2993.	2158.	118.	2365.	24964.	7347.	17616.
48	1	1	1	5	8	9	1	3	66630.	13744.	867.	3033.	2430.	118.	2365.	26814.	7506.	19308.
49	1	1	1	5	8	9	6	5	70950.	11438.	777.	2719.	2776.	118.	2365.	23988.	6712.	17276.
50	1	1	1	5	8	9	6	6	85030.	12080.	408.	1428.	4530.	118.	2365.	25095.	6712.	18382.
51	1	2	1	5	8	4	1	2	60730.	12709.	1017.	3560.	2229.	118.	2365.	25192.	7506.	17686.
52	1	2	1	5	8	4	1	3	63230.	13334.	1029.	3600.	2502.	118.	2365.	27042.	7665.	19377.
53	1	2	1	5	8	4	6	5	67450.	11028.	939.	3286.	2847.	118.	2365.	24217.	6871.	17346.
54	1	2	1	5	8	4	6	6	81630.	11670.	570.	1995.	4602.	118.	2365.	25323.	6871.	18452.
55	1	2	1	5	8	9	1	2	64130.	13202.	1017.	3560.	2229.	118.	2365.	25685.	7347.	18338.
56	1	2	1	5	8	9	1	3	66630.	13827.	1029.	3600.	2502.	118.	2365.	27535.	7506.	20029.
57	1	2	1	5	8	9	6	5	70950.	11521.	939.	3286.	2847.	118.	2365.	24710.	6712.	17997.
58	1	2	1	5	8	9	6	6	85030.	12163.	570.	1995.	4602.	118.	2365.	25816.	6712.	19104.

Table C-3: Summary of systems for 250 cows.

Sys. No.	Option Codes								System Invest.	Annual Ownership Costs	Annual MHRS Labor	Annual Labor Costs	Annual Energy Costs	Tons of Bedding	Annual Bedding Costs	Total Annual Costs	Manure Nutrient Value	Net Annual Costs
1	1	1	1	2	1	8	5	4	36746.	3411.	772.	2704.	1383.	158.	3154.	17965.	10220.	7745.
2	1	2	1	4	1	8	5	4	37746.	7935.	938.	3463.	1448.	158.	3154.	17309.	10220.	7089.
3	1	1	1	2	2	3	3	4	69555.	13449.	921.	2873.	1462.	158.	3154.	22250.	10008.	12242.
4	1	1	1	2	6	3	3	4	56211.	12071.	792.	2771.	1467.	158.	3154.	20745.	10008.	10737.
5	1	2	1	4	2	3	2	4	64055.	12181.	1049.	3668.	1541.	158.	3154.	22139.	10008.	12131.
6	1	2	1	4	6	3	2	4	59711.	11803.	1019.	3566.	1516.	158.	3154.	20634.	10008.	10626.
7	1	2	1	3	2	3	2	4	66555.	11302.	1048.	3668.	1180.	158.	3154.	19900.	10008.	9892.
8	1	1	1	3	2	3	3	4	63055.	11004.	821.	2873.	1071.	158.	3154.	18415.	10009.	8406.
9	1	1	1	1	1	8	5	4	37566.	9534.	308.	1077.	1609.	158.	3154.	15686.	10220.	5466.
10	1	2	1	1	1	8	5	4	37566.	9623.	524.	1933.	1703.	158.	3154.	16627.	10220.	6407.
11	1	1	1	1	2	3	3	4	71975.	12572.	356.	1247.	1696.	158.	3154.	19971.	10008.	9963.
12	1	2	1	1	2	3	2	4	75375.	12869.	533.	2042.	1796.	158.	3154.	21457.	10008.	11448.
13	1	2	1	4	6	5	4	1	66992.	11380.	1010.	3536.	1693.	158.	3154.	17994.	10220.	7774.
14	1	1	1	2	6	5	4	1	65992.	12856.	794.	2780.	1628.	158.	3154.	19649.	10220.	9429.
15	1	1	1	2	4	4	1	2	57167.	14594.	934.	3268.	1599.	158.	3154.	23978.	10008.	13970.
16	1	1	1	2	4	4	1	3	59667.	15219.	937.	3278.	1654.	158.	3154.	24900.	10220.	14680.
17	1	1	1	2	4	4	6	5	63887.	12913.	951.	3329.	1738.	158.	3154.	22595.	9162.	13434.
18	1	1	1	2	4	4	6	6	73067.	13556.	850.	2974.	2163.	158.	3154.	23308.	9162.	14146.
19	1	2	1	4	4	4	1	2	59167.	13118.	1150.	4024.	1653.	158.	3154.	23322.	10008.	13314.
20	1	2	1	4	4	4	1	3	61667.	13743.	1153.	4034.	1719.	158.	3154.	24244.	10220.	14024.
21	1	2	1	4	4	4	6	5	64887.	11437.	1167.	4085.	1803.	158.	3154.	21940.	9162.	12778.
22	1	2	1	4	4	4	6	6	79067.	12079.	1066.	3730.	2228.	158.	3154.	22652.	9162.	13490.
23	1	1	1	2	4	2	1	2	141637.	25028.	934.	3268.	1588.	158.	3154.	34412.	10220.	24192.
24	1	1	1	2	4	2	1	3	144137.	25653.	937.	3278.	1654.	158.	3154.	35334.	10432.	24902.
25	1	2	1	4	4	2	1	2	142637.	23552.	1150.	4024.	1653.	158.	3154.	33756.	10220.	23536.
26	1	2	1	4	4	2	1	3	145137.	24177.	1153.	4034.	1719.	158.	3154.	34678.	10432.	24246.
27	1	1	1	2	7	7	1	2	141640.	23370.	751.	2630.	1458.	158.	3154.	31985.	10220.	21765.
28	1	1	1	2	7	7	1	3	144140.	23995.	754.	2639.	1524.	158.	3154.	32907.	10432.	22475.
29	1	1	1	2	7	7	6	5	149360.	21699.	763.	2691.	1608.	158.	3154.	30602.	9373.	21229.
30	1	1	1	2	7	7	6	6	162540.	22331.	667.	2335.	2033.	158.	3154.	31314.	9373.	21941.
31	1	2	1	4	7	7	1	2	142640.	21893.	967.	3386.	1523.	158.	3154.	31329.	10220.	21109.
32	1	2	1	4	7	7	1	3	145140.	22518.	970.	3395.	1589.	158.	3154.	32251.	10432.	21819.
33	1	2	1	4	7	7	6	5	149360.	20213.	985.	3447.	1672.	158.	3154.	29946.	9373.	20573.
34	1	2	1	4	7	7	6	6	163540.	20855.	863.	3091.	2059.	158.	3154.	30658.	9373.	21285.
35	1	1	2	6	9	6	1	2	136390.	20224.	270.	943.	675.	158.	3154.	26370.	10220.	16150.
36	1	1	2	6	9	6	1	3	138890.	20849.	272.	953.	742.	158.	3154.	27292.	10432.	16860.
37	1	1	2	6	9	6	6	5	143110.	15543.	287.	1004.	825.	158.	3154.	24987.	9373.	15614.
38	1	1	2	6	9	6	6	6	157290.	13186.	195.	649.	1251.	158.	3154.	25700.	9373.	16327.
39	1	2	2	6	9	6	1	2	136390.	20314.	486.	1699.	771.	158.	3154.	27311.	10220.	17091.
40	1	2	2	6	9	6	1	3	138890.	20939.	490.	1703.	837.	158.	3154.	28233.	10432.	17802.
41	1	2	2	6	9	6	6	5	143110.	18633.	503.	1760.	921.	158.	3154.	25928.	9373.	16555.
42	1	2	2	6	9	6	6	6	157290.	14275.	401.	1405.	1306.	158.	3154.	26641.	9373.	17268.
43	1	1	1	5	9	4	1	2	73115.	14873.	1113.	3896.	2799.	158.	3154.	30428.	10008.	20419.
44	1	1	1	5	8	4	1	3	75615.	15498.	1128.	3949.	3162.	158.	3154.	32686.	10220.	22466.
45	1	1	1	5	8	4	6	5	79835.	13192.	993.	3475.	3623.	158.	3154.	29631.	9162.	20469.
46	1	1	1	5	9	4	6	6	94015.	13835.	506.	1772.	5962.	158.	3154.	30910.	9162.	21749.
47	1	1	1	5	8	9	1	2	77365.	15446.	1113.	3896.	2799.	158.	3154.	31001.	9797.	21204.
48	1	1	1	5	8	9	1	3	79865.	16071.	1128.	3949.	3162.	158.	3154.	33259.	10008.	23251.
49	1	1	1	5	8	9	6	5	93785.	13765.	993.	3475.	3623.	158.	3154.	30204.	8950.	21254.
50	1	1	1	5	9	9	6	6	97965.	14408.	506.	1772.	5962.	158.	3154.	31483.	8950.	22533.
51	1	2	1	5	8	4	1	2	73115.	14963.	1329.	4652.	2994.	158.	3154.	31369.	10008.	21361.
52	1	2	1	5	8	4	1	3	75615.	15588.	1344.	4705.	3257.	158.	3154.	33627.	10220.	23407.
53	1	2	1	5	9	4	6	5	79835.	13252.	1209.	4231.	3718.	158.	3154.	30572.	9162.	21410.
54	1	2	1	5	9	4	6	6	94015.	13924.	722.	2528.	6058.	158.	3154.	31951.	9162.	22690.
55	1	2	1	5	9	9	1	2	77365.	15536.	1329.	4652.	2894.	158.	3154.	31942.	9797.	22145.
56	1	2	1	5	8	9	1	3	79565.	16161.	1344.	4705.	3257.	158.	3154.	34200.	10008.	24192.
57	1	2	1	5	8	9	6	5	93785.	13855.	1209.	4231.	3718.	158.	3154.	31145.	8950.	22195.
58	1	2	1	5	8	9	6	6	97965.	14497.	722.	2528.	6058.	158.	3154.	32424.	8950.	23474.

Table C-4: Summary of systems for 250 cows.

Sys. No.	Option Codes								System Invest.	Annual Ownership Costs	Annual MIRS Labor	Annual Labor Costs	Annual Energy Costs	Tons of Bedding	Annual Bedding Costs	Total Annual Costs	Manure Nutrient Value	Net Annual Costs
1	1	1	1	2	1	8	5	4	41091.	10211.	939.	2932.	1527.	197.	3942.	20254.	12775.	7479.
2	1	2	1	4	1	8	5	4	42081.	9742.	1138.	3677.	1616.	197.	3942.	19918.	12775.	7143.
3	1	1	1	2	2	3	3	4	70481.	13156.	899.	3144.	1625.	197.	3942.	25509.	12510.	12999.
4	1	1	1	2	6	3	3	4	66137.	13779.	869.	3242.	1600.	197.	3942.	24004.	12510.	11494.
5	1	2	1	4	2	3	2	4	73381.	13869.	1182.	4138.	1732.	197.	3942.	25676.	12510.	13165.
6	1	2	1	4	6	3	2	4	69637.	12492.	1153.	4036.	1707.	197.	3942.	24171.	12510.	11660.
7	1	2	1	3	2	3	2	4	76481.	11991.	1132.	4138.	1371.	197.	3942.	23437.	12510.	10926.
8	1	1	1	3	2	3	3	4	72981.	11712.	898.	3144.	1234.	197.	3942.	21674.	12510.	9163.
9	1	1	1	1	1	8	5	4	43035.	9632.	373.	1306.	1752.	197.	3942.	18274.	12775.	5499.
10	1	2	1	1	1	8	5	4	43035.	9729.	643.	2251.	1871.	197.	3942.	19434.	12775.	6659.
11	1	1	1	1	2	3	3	4	92935.	14577.	434.	1518.	1850.	197.	3942.	23528.	12510.	11018.
12	1	2	1	1	2	3	2	4	86435.	14856.	718.	2512.	1987.	197.	3942.	25292.	12510.	12781.
13	1	2	1	4	6	5	4	4	75952.	13166.	1142.	3999.	1928.	197.	3942.	21205.	12775.	8430.
14	1	1	1	2	6	5	4	4	74952.	13636.	872.	3054.	1840.	197.	3942.	21641.	12775.	8866.
15	1	1	1	2	4	4	1	3	62752.	15576.	991.	3469.	1723.	197.	3942.	26352.	12510.	13842.
16	1	1	1	2	4	4	1	3	65252.	15221.	995.	3481.	1806.	197.	3942.	27349.	12775.	14574.
17	1	1	1	2	4	4	6	5	63472.	13835.	1031.	3503.	1910.	197.	3942.	25002.	11452.	13550.
18	1	1	1	2	4	4	6	5	93652.	14537.	878.	3073.	2442.	197.	3942.	25746.	11452.	14294.
19	1	2	1	4	4	4	1	3	63752.	14136.	1262.	4414.	1812.	197.	3942.	25916.	12510.	13406.
20	1	2	1	4	4	4	1	3	66252.	14731.	1265.	4426.	1994.	197.	3942.	26913.	12775.	14138.
21	1	2	1	4	4	4	6	5	70472.	12425.	1271.	4448.	1999.	197.	3942.	24566.	11452.	13114.
22	1	2	1	4	4	4	6	5	94652.	13068.	1149.	4318.	2531.	197.	3942.	25310.	11452.	13858.
23	1	1	1	2	4	2	1	3	169652.	21663.	991.	3469.	1723.	197.	3942.	39440.	12775.	26665.
24	1	1	1	2	4	2	1	3	171152.	23288.	995.	3491.	1806.	197.	3942.	40436.	13040.	27396.
25	1	2	1	4	4	2	1	2	169552.	27194.	1261.	4414.	1812.	197.	3942.	39004.	12775.	26229.
26	1	2	1	4	4	2	1	3	172152.	27819.	1265.	4426.	1994.	197.	3942.	40000.	13040.	26960.
27	1	1	1	2	7	7	1	2	171175.	27320.	839.	2831.	1593.	197.	3942.	37328.	12775.	24553.
28	1	1	1	2	7	7	1	3	173575.	27945.	812.	2843.	1676.	197.	3942.	38324.	13040.	25284.
29	1	1	1	2	7	7	6	5	177895.	23639.	818.	2865.	1780.	197.	3942.	35977.	11717.	24261.
30	1	1	1	2	7	7	6	6	192075.	25281.	646.	2434.	2312.	197.	3942.	36721.	11717.	25004.
31	1	2	1	4	7	7	1	2	172175.	23850.	1079.	3776.	1692.	197.	3942.	36892.	12775.	24117.
32	1	2	1	4	7	7	1	3	174675.	25475.	1082.	3798.	1784.	197.	3942.	37888.	13040.	24848.
33	1	2	1	4	7	7	6	5	178895.	24170.	1068.	3810.	1869.	197.	3942.	35541.	11717.	23825.
34	1	2	1	4	7	7	6	5	193675.	24812.	966.	3379.	2401.	197.	3942.	36285.	11717.	24568.
35	1	1	2	6	9	6	1	2	167238.	24352.	327.	1144.	811.	197.	3942.	31890.	12775.	19115.
36	1	1	2	6	9	6	1	3	169733.	24977.	330.	1156.	893.	197.	3942.	32887.	13040.	19847.
37	1	1	2	6	9	6	6	5	173953.	22671.	337.	1178.	998.	197.	3942.	30540.	11717.	18823.
38	1	1	2	6	9	6	6	6	188138.	23313.	214.	749.	1530.	197.	3942.	31284.	11717.	19567.
39	1	2	2	6	9	6	1	2	167238.	24448.	597.	2089.	930.	197.	3942.	33051.	12775.	20276.
40	1	2	2	6	9	6	1	3	169738.	25073.	600.	2101.	1013.	197.	3942.	34047.	13040.	21008.
41	1	2	2	6	9	6	6	5	173958.	22767.	607.	2123.	1117.	197.	3942.	31701.	11717.	19984.
42	1	2	2	6	9	6	6	6	188138.	23409.	484.	1693.	1649.	197.	3942.	32444.	11717.	20728.
43	1	1	1	5	8	4	1	2	84488.	15705.	1332.	4661.	3440.	197.	3942.	35929.	12510.	23419.
44	1	1	1	5	8	4	1	3	86988.	17330.	1351.	4727.	3893.	197.	3942.	38596.	12775.	25821.
45	1	1	1	5	8	4	6	5	91208.	15624.	1169.	4092.	4470.	197.	3942.	35312.	11452.	23860.
46	1	1	1	5	9	4	6	5	105388.	15666.	565.	1978.	7394.	197.	3942.	36764.	11452.	25313.
47	1	1	1	5	9	9	1	2	88989.	17357.	1332.	4661.	3440.	197.	3942.	36582.	12246.	24336.
48	1	1	1	5	8	9	1	3	91467.	17982.	1351.	4727.	3893.	197.	3942.	39249.	12510.	26738.
49	1	1	1	5	9	9	6	5	95709.	15676.	1169.	4092.	4470.	197.	3942.	35964.	11187.	24777.
50	1	1	1	5	9	9	6	6	109889.	16319.	565.	1973.	7394.	197.	3942.	37417.	11187.	26230.
51	1	2	1	5	9	4	1	2	84488.	15801.	1612.	5606.	3559.	197.	3942.	37090.	12510.	24580.
52	1	2	1	5	9	4	1	3	86988.	17426.	1631.	5672.	4013.	197.	3942.	39757.	12775.	26982.
53	1	2	1	5	8	4	6	5	91208.	15120.	1439.	5037.	4599.	197.	3942.	36472.	11452.	25021.
54	1	2	1	5	9	4	6	6	105388.	13762.	835.	2923.	7514.	197.	3942.	37925.	11452.	26473.
55	1	2	1	5	8	9	1	2	88988.	17453.	1602.	5606.	3559.	197.	3942.	37742.	12246.	25497.
56	1	2	1	5	9	9	1	3	91487.	19078.	1621.	5672.	4013.	197.	3942.	40409.	12510.	27899.
57	1	2	1	5	9	9	6	5	95708.	15773.	1439.	5037.	4599.	197.	3942.	37125.	11187.	25938.
58	1	2	1	5	8	9	6	5	109989.	16415.	835.	2923.	7514.	197.	3942.	38577.	11187.	27390.

Table C-5: Summary of systems for 300 cows.

Sys. No.	Option Codes								System Invest.	Annual Ownership Costs	Annual MHRS Labor	Annual Labor Costs	Annual Energy Costs	Tons of Bedding	Annual Bedding Costs	Total Annual Costs	Manure Nutrient Value	Net Annual Costs
1	1	1	1	2	1	8	5	4	45415.	11012.	913.	3161.	1671.	237.	4730.	22544.	15330.	7214.
2	1	2	1	4	1	8	5	4	46416.	9549.	1227.	4295.	1784.	237.	4730.	22328.	15330.	6998.
3	1	1	1	2	2	3	3	4	80406.	16864.	976.	3415.	1789.	237.	4730.	28768.	15012.	13756.
4	1	1	1	2	5	3	3	4	76062.	15487.	947.	3313.	1704.	237.	4730.	27263.	15012.	12251.
5	1	2	1	4	2	3	2	4	83906.	15557.	1317.	4608.	1923.	237.	4730.	29212.	15012.	14200.
6	1	2	1	4	6	3	2	4	79562.	14180.	1287.	4506.	1899.	237.	4730.	27707.	15012.	12695.
7	1	2	1	3	2	3	2	4	86406.	13679.	1317.	4698.	1562.	237.	4730.	26973.	15012.	11961.
8	1	1	1	3	2	3	3	4	82906.	13420.	976.	3415.	1398.	237.	4730.	24932.	15012.	9920.
9	1	1	1	1	1	8	5	4	43504.	13731.	439.	1535.	1896.	237.	4730.	20861.	15330.	5531.
10	1	2	1	1	1	8	5	4	43504.	17834.	763.	2669.	2039.	237.	4730.	22242.	15330.	6912.
11	1	1	1	1	2	3	3	4	93994.	16583.	511.	1789.	2013.	237.	4730.	27086.	15012.	12073.
12	1	2	1	1	2	3	2	4	97494.	10843.	852.	2982.	2178.	237.	4730.	29126.	15012.	14114.
13	1	2	1	4	6	5	4	4	94912.	14952.	1275.	4461.	2164.	237.	4730.	24417.	15330.	9087.
14	1	1	1	2	6	5	4	4	83912.	16425.	951.	3327.	2051.	237.	4730.	24634.	15330.	9304.
15	1	1	1	2	4	4	1	3	68337.	16557.	1049.	3670.	1858.	237.	4730.	28727.	15012.	13714.
16	1	1	1	2	4	4	1	3	73937.	17182.	1053.	3635.	1937.	237.	4730.	29797.	15330.	14467.
17	1	1	1	2	4	4	6	5	75557.	14877.	1051.	3677.	2083.	237.	4730.	27408.	13742.	13666.
18	1	1	1	2	4	4	6	6	89237.	15519.	906.	3172.	2721.	237.	4730.	28194.	13742.	14441.
19	1	2	1	4	4	4	1	2	69337.	15095.	1373.	4804.	1971.	237.	4730.	28510.	15012.	13498.
20	1	2	1	4	4	4	1	3	71937.	15726.	1377.	4819.	2070.	237.	4730.	29581.	15330.	14251.
21	1	2	1	4	4	4	6	5	76057.	13414.	1375.	4811.	2155.	237.	4730.	27192.	13742.	13450.
22	1	2	1	4	4	4	6	6	90237.	14056.	1230.	4306.	2834.	237.	4730.	27967.	13742.	14225.
23	1	1	1	2	4	2	1	2	195667.	32299.	1049.	3670.	1858.	237.	4730.	44468.	15330.	29138.
24	1	1	1	2	4	2	1	3	198167.	32924.	1053.	3685.	1957.	237.	4730.	45538.	15648.	29991.
25	1	2	1	4	4	2	1	2	196667.	30836.	1373.	4804.	1971.	237.	4730.	44252.	15330.	28922.
26	1	2	1	4	4	2	1	3	199167.	31461.	1377.	4819.	2070.	237.	4730.	45322.	15648.	29674.
27	1	1	1	2	7	7	1	2	200710.	31270.	866.	3031.	1728.	237.	4730.	42671.	15330.	27341.
28	1	1	1	2	7	7	1	3	203210.	31895.	870.	3046.	1827.	237.	4730.	43741.	15648.	28094.
29	1	1	1	2	7	7	6	5	207430.	29590.	868.	3039.	1953.	237.	4730.	41352.	14060.	27293.
30	1	1	1	2	7	7	6	6	221610.	30232.	724.	2534.	2591.	237.	4730.	42128.	14060.	28068.
31	1	2	1	4	7	7	1	2	201710.	29808.	1190.	4165.	1841.	237.	4730.	42454.	15330.	27124.
32	1	2	1	4	7	7	1	3	204210.	30433.	1194.	4180.	1940.	237.	4730.	43525.	15648.	27877.
33	1	2	1	4	7	7	6	5	208430.	29127.	1192.	4173.	2065.	237.	4730.	41136.	14060.	27076.
34	1	2	1	4	7	7	6	6	222610.	29769.	1049.	3668.	2763.	237.	4730.	41911.	14060.	27852.
35	1	1	2	6	9	6	1	2	198085.	24479.	354.	1345.	946.	237.	4730.	37411.	15330.	22081.
36	1	1	2	6	9	6	1	3	200585.	24104.	399.	1360.	1045.	237.	4730.	38481.	15648.	22834.
37	1	1	2	6	9	6	6	5	204905.	25798.	336.	1352.	1170.	237.	4730.	36092.	14060.	22033.
38	1	1	2	6	9	6	6	6	219985.	27441.	242.	847.	1819.	237.	4730.	36968.	14060.	22908.
39	1	2	2	6	9	6	1	2	198085.	25582.	709.	2479.	1089.	237.	4730.	38791.	15330.	23461.
40	1	2	2	6	9	6	1	3	200585.	27207.	712.	2494.	1188.	237.	4730.	39861.	15648.	24214.
41	1	2	2	6	9	6	6	5	204905.	25901.	710.	2486.	1314.	237.	4730.	37473.	14060.	23413.
42	1	2	2	6	9	6	6	6	219985.	27544.	566.	1981.	1912.	237.	4730.	38248.	14060.	24188.
43	1	1	1	5	9	4	1	2	95960.	13536.	1550.	5425.	4080.	237.	4730.	41431.	15012.	26418.
44	1	1	1	5	8	4	1	3	93360.	13161.	1573.	5505.	4625.	237.	4730.	44506.	15330.	29176.
45	1	1	1	5	9	4	6	5	102580.	15955.	1345.	4709.	5317.	237.	4730.	40993.	13742.	27250.
46	1	1	1	5	9	4	6	6	115760.	17497.	624.	2184.	8826.	237.	4730.	42619.	13742.	28976.
47	1	1	1	5	9	9	1	2	100910.	13268.	1550.	5425.	4080.	237.	4730.	42153.	14695.	27458.
48	1	1	1	5	8	9	1	3	103410.	19893.	1573.	5505.	4625.	237.	4730.	45238.	15012.	30226.
49	1	1	1	5	9	9	6	5	107630.	17587.	1345.	4709.	5317.	237.	4730.	41725.	13425.	28300.
50	1	1	1	5	8	9	6	6	121910.	19230.	624.	2184.	9826.	237.	4730.	43351.	13425.	29926.
51	1	2	1	5	9	4	1	2	95960.	13639.	1874.	6559.	4224.	237.	4730.	42811.	15012.	27798.
52	1	2	1	5	8	4	1	3	93360.	19264.	1897.	6639.	4768.	237.	4730.	45986.	15330.	30556.
53	1	2	1	5	9	4	6	5	102580.	16958.	1669.	5843.	5460.	237.	4730.	42373.	13742.	28631.
54	1	2	1	5	8	4	6	6	115760.	17600.	948.	3318.	8969.	237.	4730.	43999.	13742.	30257.
55	1	2	1	5	9	9	1	2	100910.	14371.	1874.	6559.	4224.	237.	4730.	43543.	14695.	28848.
56	1	2	1	5	8	9	1	3	103410.	19996.	1897.	6639.	4768.	237.	4730.	46618.	15012.	31606.
57	1	2	1	5	9	9	6	5	107630.	17690.	1669.	5843.	5460.	237.	4730.	43105.	13425.	29681.
58	1	2	1	5	8	9	6	6	121910.	18333.	948.	3318.	8969.	237.	4730.	44731.	13425.	31307.