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DAIRY MANURE MANAGEMENT METHODS

WASHINGTON STATE UNIVERSITY

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New pens for the confinement and feeding of dairy cattle were constructed under a continuous roofed area to prevent the addition of precipitation to the cattle excrement. The manure was collected in underground sumps, pumped to large anaerobic lagoons for wet-season storage, and subsequently applied to crop land during the comparatively drier summer months. Observations were made to, at least partially, evaluate the effect of the roofed environment upon the cattle. Some unsuccessful attempts were made to collect the excrement by hydraulic flushing techniques alone. The pump and pipeline transport of manure slurry either to storage or to large bore field irrigation nozzles was quite successful. Observations of surface ponding and runoff, soil penetration, and crop response indicated that the concept of seasonal storage and seasonally scheduled crop land disposal of dairy manure slurry can be an environmentally acceptable and agriculturally compatible method of dairy manure management. Attempts to aerobically treat manure slurry supernatant liquor were technically successful but still impractical.

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DAIRY MANURE MANAGEMENT METHODS

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SECTION I

CONCLUSIONS

1. Manure, generated by dairy cattle in concentrated, paved, confinement pens, can be transported and stored in slurry form in open anaerobic lagoons for long periods of time without necessarily causing problems of odors, fly breeding, or other insect problems.

2. By storing liquid manure slurry, it can be applied to agriculturally productive land at such times and in such amounts as to minimize, if not eliminate, problems of air, ground water, or surface water quality degradation.

3. Such environmentally acceptable applications of stored or freshly generated manure slurry to crop lands are compatible with, and supportive of, maximum feed or forage production on that land. In limited tests and observations of this Project, the application of stored manure slurry to silage corn test plots before seeding resulted in approximately one-third more yield and two weeks earlier maturity than for similar plots receiving commercial fertilizer.

4. Test feeding of green cut corn silage, having nitrate-nitrogen concentrations as high as 0.34 percent of dry weight, to high producing dairy cows, pregnant dairy heifers, and steers, did not give any indications of declining milk yield, abortions, slower rates of weight gain, or other distress that have been attributed to "nitrate-poisoning".

5. The application of excessive amounts of manure slurry at one time to forage crops containing clover can result in the loss of clover from the stand. Single applications of less than 25,000 gallons per acre did not have this effect, while applications greater than 50,000 gallons per acre appeared to eliminate nearly all clover in the stand.

6. The application of manure slurry to crop lands during seasons of high precipitation can lead, to a significant extent, to both chemical and bacteriological pollution of surface waters. Fecal coliform and fecal streptococci organisms survive, and thus retain polluting capabilities, significantly longer on ground surfaces when or where quick draining and partial drying are prevented.

7. When reasonable amounts of manure slurry--up to 50,000 gallons per acre--are applied to very fine textured soils, the bacteria of the slurry are almost completely retained in or on the upper layers of the soil. Soluble constituents such as chlorides will be carried downward by percolating water from either the applied slurry or of subsequent precipitation.

8. Dairy manure can be transported successfully and economically in slurry form by properly designed pump and pipeline systems. It can be uniformly applied to land by large bore spray irrigation nozzles. Though pipeline lengths of only about 3,000 feet were involved in this Project, it appears likely that pipeline transport could be extended to several miles, if necessary.

   Avoiding blind sections (i.e. pressurized but without positive flow) of slurry distribution lines appears to be essential in avoiding the formation of plugs of fibrous solids in the lines.

9. The exclusion of rainwater and snowmelt water from dairy manure involves a significant capital investment to provide a roof over the confinement area and storm drains to convey the intercepted precipitation. This one-time investment is at least partially offset by a significant reduction in capital cost for manure storage facilities. Operating cost reductions are also realized, since the volume of slurry and the land required for its disposal are reduced for each year of the life of the roof. There may well be additional benefits derived from the roof as a result of a less severe environment for the confined cattle.

10. Aerobic biological treatment of stratified liquor withdrawn from stored manure slurry can cause Biochemical Oxygen Demand reductions as great as 95 percent. Color is not significantly reduced and the treated effluent would seldom be of adequate quality to allow direct discharge to surface waters.

SECTION II

RECOMMENDATIONS

The results of the limited period of operation and observations of this Project were quite encouraging but do not necessarily reveal the long-term consequences of such an operation. Further or more extensive evaluation is needed relative to: (a) the consequences of the changes in cattle environment provided by totally roofed confinement, (b) the agronomic and environmental consequences of controlled seasonal applications of stored manure slurry on various soils used for various crops, (c) the possibility that bacteria or other organisms can become airborne after evaporation of the moisture in fine droplets of sprayed manure slurry, and (d) the labor and cost factors associated with all aspects of operation.

Hydraulic flushing of manure from the confinement slabs was not successfully demonstrated, but it should not be assumed that hydraulic flushing is impractical. Modification of the confinement pens and flushing provisions could still lead to a low cost, aesthetically acceptable method of maintaining pen sanitation. Low-pressure high volume flushing techniques are currently used on some dairy farms where the resulting large volumes of manure slurry do not constitute a critical problem.

The method of agitating and removing stored manure slurry from the anaerobic storage lagoons was usable but certainly not the optimum method. Research and development aimed at a more convenient recovery system is needed.

It is recommended that seasonal storage and seasonal land application of manure slurry is probably the cheapest and most environmentally acceptable means of dairy manure slurry available to most dairymen of the Pacific Northwest, and that this practice should be implemented in a majority of such dairies.

SECTION III

INTRODUCTION

The production of food resources by agriculture is not a new or recent development. The capacity or capability to produce food resources has, in general and until now at least, developed as rapidly as our increasing needs have developed. It is nothing short of miraculous that a constantly dwindling number of people in agriculture, working on an ever decreasing non-urban land area, have been able to produce food and fiber for an ever increasing population.

This increased food and fiber production capability has been made possible only by accepting changes. These changes have been technological, economic, and social. As examples; tractors have replaced horses, capital investment per worker has sky rocketed, and an employee now works at tasks that once were performed exclusively by members of the farmer's own family. While many of the changes associated with the development of today's productive agricultural system are readily seen as improvements, some changes must be viewed as having serious or deleterious consequences. Environmental pollution problems associated with agricultural practices must be regarded as changes that we would prefer not to have occurred. This is not to say that the undesirable changes were predictable or avoidable. They represent one of the costs that we have paid for a desired situation of abundancy. Today we must ask whether the environmental problems of agriculture are correctable and whether society is able and willing to pay the correction costs. The correction costs may take the form of reduced abundancy of farm derived products, higher unit costs for those products, or, more probably, a combination of both.

DAIRY MANURE MANAGEMENT PROBLEMS, GENERAL

Dairying, as one segment of agriculture, has undergone extensive changes. Cows still eat, produce milk, and excrete urine and feces. Virtually all else has changed.

Even with an increasing population exerting an increasing demand for dairy products, the total number of cows held in milk production operations has been decreasing. Milk production per cow-day has been improved to permit this reduction in number. The modern cow of high productivity does, however, have a bigger appetite and produces more excrement than her ancestors.

The advantages of specialization of effort that became apparent on industry's assembly lines have motivated specialization in agriculture as well. The diversified family farm where grain and forage were raised; chickens, pigs, and cows were fed; and milk, meat and eggs were sold has yielded to specialty farm endeavors. As a result, dairy manure is often produced on farms with a large number of cows but very limited land.

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Confinement rearing of dairy cows, as with swine, poultry or fattening beef cattle, tends to restrict the production of manure to even more limited areas. Often this manure is defecated on paved surfaces where intentional management is mandatory and frequent. Because of the requirements of milk sanitation, the dairyman has long been accustomed to some degree of regulatory control of manure management, whereas beef, swine or poultry farm operators have only recently begun to experience regulation because of concern for environmental protection.

Another change relative to manure problems can be traced to a non-agricultural cause. Urban sprawl or suburban encroachment is bringing more people into closer geographical contact with manure problems. Even without an increase in manure production and in the absence of intense confinement, there would be an increase in the significance or the impact of manure upon the environment. It does little good to argue the point that the dairy may have been in the area first, or that the problem only arises because of neighborhood encroachment. The new neighbor is there, and he doesn't wish to be subjected to odors, flies or unsightly aesthetic conditions.

Manure, whether from dairies or other livestock operations, probably is about as rich in fertilizer nutrients as it has ever been in the past. In spite of this, the demand for manure for soil fertilization is greatly reduced. Commercial chemically-produced fertilizer formulations can be mass produced and blended to exacting specifications, are easily stored or transported, and can often be applied by modern methods more economically than can livestock manures. This results in manure being potentially more available as an environmental pollutant than in the past. Fertilization with manures can also introduce weed seeds to fields.

The final change that should be recognized is one of attitude. The population is becoming increasingly more aware of the ecological or environmental consequences of pollutants. What may have been either an acceptable or unnoticed environmental situation in the past is scrutinized more closely and accepted less readily today.

Not associated with any change in dairying but still of significance to dairy manure's impact upon environmental quality is the matter of climatic conditions. In many of the regions of the nation that are noted for a significant dairy industry, one can find a seasonal variation that is significant. Wet winter seasons with a high potential for surface runoff are characteristics of Western Washington, Western Oregon, and Northern California. Frozen ground that prevents infiltration and incorporation of manure can be expected for long periods of the winter in Wisconsin, Minnesota and up-state New York where dairying is practiced quite extensively.

Precipitation is not only significant because of the increased likelihood of runoff from fields where manure may be applied, but also because it can add materially to the waste volume to be collected and managed at the cattle confinement area of modern dairies. If the precipitation is allowed to contact manure accumulated on the confinement area or in storage, it is then contaminated to the point that it must be managed as a part of the manure.

PROJECT DEMONSTRATION SITE AND PREPROJECT MANURE MANAGEMENT PROBLEMS

The State of Washington has operated a dairy farm near Monroe, Washington for several years in connection with the Reformatory located nearby. This Honor Farm constitutes one element of Farm Industries, an agency of the Office of Institutional Industries in the State Department of Institutions. (Recent reorganization has changed the Department to the Division of Institutions of the Washington State Department of Social and Health Services.) The Farm is operated to provide vocational training and experience to between 30 and 50 honor inmates of the nearby Washington State Reformatory.

The Farm entails approximately 250 acres of land on the flood plain of the Snoqualmie River. About 35 acres of the area are devoted to inmate housing, farm administration, shops and related facilities, feed storage, cattle confinement and milk processing plant leaving a little over 200 acres of tillable or crop-producing land. Figure 1 shows the Project site location and general layout of the Farm. Figure 2 shows the general arrangement of buildings. Silage corn and grass-clover mixtures for summer green-chop forage are the crops utilized in a planned field rotation scheme, for five fields of approximately equal size.

All of the crop land is subject to flooding quite infrequently. Perhaps as much as 25% of the fields are flooded almost every winter for varying durations. The area devoted to buildings has not been flooded within the memory of present residents of the area. It is generally assumed that between 40 and 50 inches of precipitation will occur in the immediate vicinity, and that 80 percent of this rainfall will occur between October 15 and April 15 of the following year.

The dairy cattle herd on the Farm fluctuates somewhat, but at the time of the initial meeting the herd size was approximately 485 animals, including about 225 milking cows. Some of the dry cows were maintained at other locations. The possibility existed that the herd might increase to as many as 800 cows within a few years. The cows were housed, fed, and milked in what might be called typical loose stall, partially roofed, confinement facilities. All confinement area, except for bedded stalls, was concrete surfaced. Most roof drainage was discharged to the confinement slab.

Manure was handled by various means. Some was handled as solids by tractor loading into a truck-mounted, mechanical-beater-type manure spreader. Urine, some feces, and a significant amount of rain water either drained or was scraped into an agitated manure sump. The manure wastes were pumped from the sump into a truck-mounted liquid spreader tank. A significant amount of rainfall escaped from the confinement slab

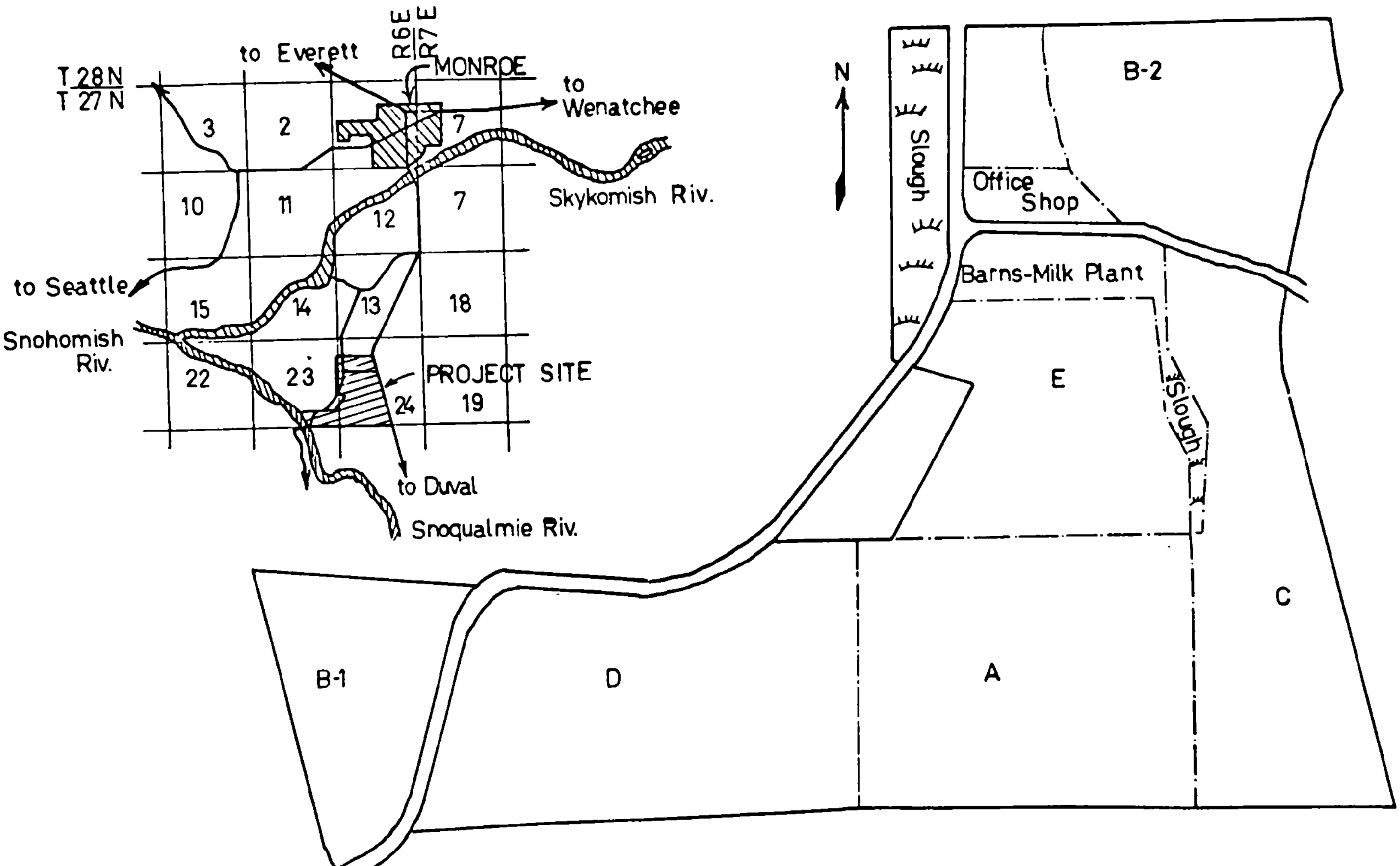

Figure 1. Location and Arrangement of the Monroe Honor Farm

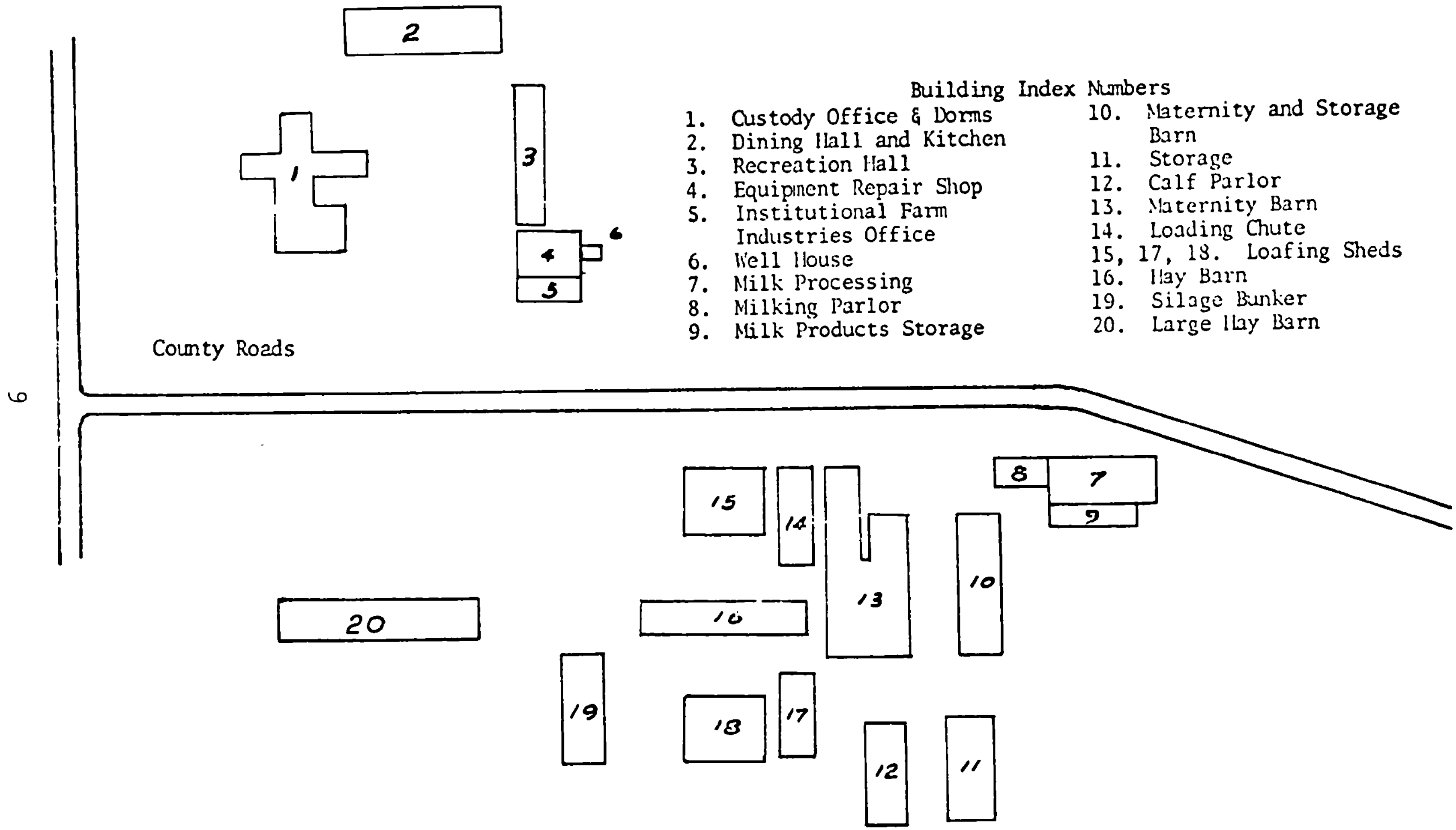

Figure 2. Building Facilities at Start of Project Development

as runoff to farm land and to an old slough extending through the Farm. Some manure produced in the milking parlor and most wash water and liquid waste from the processing plant went directly to the old slough system. The slough varied from 10 to 40 feet in width and was about 1,300 feet long. The slough banks were heavily vegetated with rushes and other weedy plants but trees or shrubs were absent. While some mosquitoes were noted, fly breeding along the slough did not appear to be significant.

The milking parlor provided two udder washing stations and eight milking stations. Five elevated stations in each of two milking lines are on either side of the central operator floor. A walk-through arrangement allows cows to enter either line for udder washing before proceeding to any vacant milking station. A measured amount of grain-based feed is mechanically charged to a feed cup as each cow enters a milking station. Milking machines are attached and initiated with the milk being collected in calibrated glass receivers. This milk is transferred through glass lines to the milk processing plant coolers after each cow is milked. Each cow is in the milking parlor between three to eight minutes at each of two daily milkings with an average time around four minutes per milking. Thus a relatively small amount of the manure is produced at the milking parlor. This is flushed away in liquid slurry form.

The milk processing plant contains milk cooling and raw milk storage, transfer pumps, pasteurizing and homogenizing equipment, separators, packaging equipment, ice cream and cottage cheese facilities, a bulk processed storage tank and cold storage rooms for ice cream and other packaged products. In addition, there are such supporting facilities as boilers, refrigeration equipment, loading facilities, cleaning facilities and other miscellaneous support facilities.

After analyzing the site it was generally resolved that: (1) the problem of dairy manure disposal at the Farm was both serious and expensive; (2) wintertime runoff from confinement slabs, fields, or the old slough could result in significant stream pollution; (3) an increase in herd size would magnify the problem; and (4) other farms of Western Washington were faced with similar, if not identical, problems.

Several schemes or processes for improvement were considered including: (1) conventional sewage treatment practices such as activated sludge treatment of liquified wastes, (2) anaerobic - aerobic lagoons in series, (3) land spreading of liquified manure, (4) dewatering and incineration, (5) land fill or burying, and (6) combinations of such processes. In all such consideration, the volumetric problem associated with precipitation on confinement areas appeared most troublesome. The incomplete destruction of manure solids by all means other than incineration appeared to limit the practicality of all disposal techniques considered.

After critical review of the problem, the following ideas seemed most promising:

1. The disposal of manure, manure solids, or liquid produced during the drier months could almost certainly be accomplished by immediate application to crop land without excessive cost or significant risk of water pollution.

2. In the case of manure produced in the colder winter months, by the time any lagoon effluent quality was sufficiently treated to be discharged, it could alternatively be applied as needed irrigation water for crops on the Farm.

3. The lagoon volume required for treatment of wintertime manure production would be equal to or larger than the volume needed to store the same manure production.

4. Periodic removal of non-degraded manure solid residues from a treatment lagoon system would not be easier or cheaper than would removal of the total manure volume from deep storage lagoons. In all likelihood, in fact, removal of the total manure slurry could probably be more readily accomplished from a planned storage facility than from any conceivable treatment lagoon.

5. Whether volumetric requirements were for treatment, storage, or a combination of both, any possible reduction in the amount of precipitation being added to the manure would be advantageous.

6. Because of the widespread need for solutions to similar problems, any development of manure management facilities at the Honor Farm should be followed and observed by the various agencies or institutions concerned with the problem.

After further consideration of the problem, the only logical step indicated was to try to develop facilities for winter storage and summertime field application of all manure and that wherever possible the manure should be handled in liquid form. It also seemed that this management scheme, if practical, should be applicable in nearly all areas of the country. Therefore, the circumstances seem to fit the criteria of widespread applicability necessary for a Solid Waste Disposal Demonstration Project.

An intensive period of preliminary planning and investigation resulted in a proposal to the Office of Solid Wastes of the U.S. Public Health Service which was submitted on March 6, 1967. A special request was made for a prompt review and funding decision in order that detailed planning and construction of facilities could be initiated to take advantage of the 1967 summer weather and in order to meet scheduled Farm needs for facilities.

After certain requested proposal revisions were made and submitted in May, notice of approval and funding was made on June 19, 1967 with an effective starting date of June 1, 1967.

PROJECT OBJECTIVES

The objectives of the Dairy Manure Management Methods Demonstration Project as proposed and funded were:

1. To demonstrate that both the recovered fertilizer values and the pollutional effect upon surface and local groundwater are significantly influenced by the season and method of application of dairy manure in areas that have seasonally high rainfall and land runoff problems. The advantages of properly scheduled application of dairy manure to farm lands in such areas would be demonstrated. Soil properties and field productivity would be evaluated.

2. To demonstrate that properly constructed and operated anaerobic dairy manure lagoons can provide the necessary method of low-cost storage so that ultimate disposal on farm lands can be scheduled during the most favorable seasons. The ability of dairy manure lagoons to stabilize the putrescible constituents of dairy manure was also to be demonstrated as was the ability of such lagoons to operate without significant problems from odor release, fly propogation or appreciable nutrient loss.

3. To demonstrate the relative economic and aesthetic advantages of an initially planned system for hydraulically flushing and transporting manure as compared to a system using tractor mounted scrapers for confinement yard cleaning. The compatibility of hydraulic flushing and transport to lagoon storage, lagoon treatment and ultimate field spreading would also be demonstrated.

4. To demonstrate the advantages of total roof coverage of the confinement areas so that the manure slurry volume would not be increased by rainfall which in turn would greatly increase the required lagoon volume and also increase the required capacity of aerobic treatment facilities. The effects of totally roofed confinement upon the health, cleanliness, production and milk quality of the confined herd was to be observed to determine whether such confinement offers advantages over and above the primary benefit of better manure management.

5. To investigate the feasibility of using anaerobic lagoons and a compact secondary aerobic process for partial destruction of manure on farms that do not have land available near at hand for manure disposal by land spreading. Under such conditions, now frequently found around large metropolitan areas, the putrescible organics of the manure would be biologically destroyed in the anaerobic lagoon and secondary aerobic process.

The non-degradable solids residue would be dewatered by draining, and possibly by pressing, and then trucked to acceptable sites for land spreading or burial. The liquid fraction could either be completely treated for final discharge or reuse, or partially treated for discharge to a municipal sewer system.

The last mentioned objective was not considered to be of paramount importance to the successful operation of the Honor Farm. It was included in the proposal because it was felt at that time that the necessary facilities could be provided and the necessary tests conducted at very low additional cost to the project. Any information gained as result of objective five would be of some value to dairy farms other than the Honor Farm.

SECTION IV

ORGANIZATION, FACILITY DESIGN AND CONSTRUCTION

PROJECT ORGANIZATION

Even before the Project was approved and funded, it was recognized by the administration of both the Department of Institutions and Washington State University that the success of the Project would be dependent upon a great deal of mutual coordination and cooperation. The conduct of the Project would necessarily interfere to some extent with normal operation of the Honor Farm. Also, operational requirements of the Farm could not always be adjusted to accommodate purposes or needs of the Project. To a very large extent, the required non-Federal matching expenditures or costs would have to be borne by the Department of Institutions. Ultimately the facilities developed by the Project would become assets of the Farm and the Farm would assume responsibility for the continued operation of such facilities as proved to be practical.

A Demonstration Grant Project Agreement was developed by the Assistant Attorneys General acting for both institutions, reviewed by the fiscal officers of each institution, and approved. This Agreement, which covered the initial year of Project activities, committed each institution to compliance with the actions proposed by the Project application and by the U.S. Department of Health, Education and Welfare document "Solid Waste Disposal Demonstration or Study and Investigation Project Grant Terms and Conditions." The Agreement provided that Dr. Donald E. Proctor, Associate Sanitary Engineer and Howard Magnuson, Supervisor of Institutional Farm Industries would act as responsible coordinators of activities for Washington State University and the Department of Institutions, respectively.

The Agreement further set forth the procedures and policies for expenditures, for records of expenditures, for reimbursements to Farm Industries by Washington State University from Grant funds, for amending the Agreement, and for Agreement renewal during subsequent Project years. The spirit of this document continued to guide the relationship between, and activities of, the two institutions throughout the life of the Project.

A Consultant Agreement was negotiated between Washington State University and Sleavin-Kors Inc. calling for that firm to: (1) conduct necessary on-site surveying work, (2) act in collaboration with the Project Director, the Co-Director and other advisors, in developing preliminary designs for collection sumps, pump installations, pipelines, storage lagoons, the activated sludge system, and the field distribution system, (3) develop detailed plans and specifications for the facilities just indicated, (4) obtain price quotations for mechanical components, and (5) stake out construction control points. This agreement stipulated payments for such services based upon unit costs for time spent surveying, designing, drafting, and typing plus actual costs for printing and travel.

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A subsequent addendum to the contract provided for Sleavin-Kors, Inc. to review plans and specifications for the foundations and main structural elements of the cattle housing and to recommend remedial measures to correct a defect in one structural steel span in that facility.

PROJECT STAFFING

As indicated in the Project grant application and in an earlier section of this report, the successful conduct of the Project required cooperation and coordination between the Department of Institutions and Washington State University. The scope of the Project involved many different technical disciplines. The personnel actually employed on Project funds were either drawn from the existing staff of the Sanitary Engineering Section at Washington State University, from the Farm Industries staff, or were new people hired specifically for this Project. In addition, several individuals from the College of Agriculture or from the Cooperative Extension Service contributed valuable time, effort and advice to the Project without payroll support. Several dairy farm owner-operators were also invited to visit the Project and offer advice or suggestions regarding cattle housing arrangements and manure handling techniques.

The Project Director was Dr. Donald E. Proctor from the Sanitary Engineering Section of the College of Engineering Research Division of Washington State University. The Co-Director initially was Mr. Howard Magnuson, Supervisor of Institutional Farm Industries of the Department of Institutions. He terminated employment with the Department of Institutions in April of 1969 and Mr. Harry Ingersoll was appointed to assume similar responsibilities. Both the Director and Co-Director retained some of their earlier duties and responsibilities while assigned on a fractional time basis to the Project.

The Project Director was primarily responsible for supervising the planning and/or operation of manure transport and storage facilities, for laboratory facilities and results, for runoff pollution studies, for fiscal control of grant funds, and for preparing Project continuation applications and reports. The Co-Director assumed supervisory responsibility for planning the new cattle housing facilities, for overall direction of construction on the Farm, for matching fund expenditures, and for all operations directly affecting the dairy herd or crop lands. The Director and Co-Director met quite frequently to coordinate all activities and expenditures.

Additional Farm Industries personnel worked on the Project on a less than full-time basis. This included the Farm manager, some of the office management and accounting staff, a mechanical repair shop foreman, general operation and maintenance personnel, and construction crew members. Regular full-time Project staff employed by Washington State University included a Resident Engineer, a Senior Experimental Aide for dairy herd studies, a Senior Experimental Aide for agronomy studies, and a Laboratory Assistant at the Project site. The agronomy aide terminated in the summer of 1968 and a suitable replacement could not be found. Other Washington State University personnel were utilized on the Project on a less than full-time effort or support basis. These included an Aquatic Biologist, a Bacteriologist, Chemists, a photographer, secretarial-clerical help, and laboratory assistants. The College of Agriculture and the Western Washington Research and Extension Centers contributed non-Project-supported assistance by Dairy Scientists, Agronomists and Soil Scientists, and Agricultural Engineers.

Some inmates from the Reformatory at Monroe are normally assigned and domiciled at the Honor Farm. This provides a mechanism for vocational training and experience in such areas as farm equipment operation and maintenance, milking machine operation, dairy product processing, herd management and office operations. In addition to work of this type, the Project enabled a few inmates to gain some experience in drafting work and construction while working with the Project staff.

FACILITIES

For the sake of organization of reporting on planning and design decisions, the list of all new facilities that were developed for the project is subdivided into six different categories. Many decisions involved consideration of functions that overlapped several of these categories. For example, one pump served both for slurry transport into the storage lagoon and for the application of stored manure slurry to crop lands via the field distribution system.

1. Cattle Confinement or Housing. This included site preparation, footings, the roof structure, internal pen arrangement and provisions for the feeding and care of the dairy cattle in the new barn. Roof drainage lines to dispose of precipitation was also included in this category.

2. Manure Flushing, Transport and Storage Facilities. This category included provisions for hydraulic cleaning of the new cattle pens, flushing water supply lines, pumps and controls, collection sumps and manure slurry transfer pump, a central sump for metering and sampling all manure slurries, the deep anaerobic storage lagoons and mixing equipment, and provisions for withdrawal of either stratified water or resuspended slurries from the lagoon.

3. Aerobic Treatment Facilities. This category included an equalizing tank for liquors to be treated, an aeration tank with turbine aerator, a final clarifier, raw waste and return activated sludge pumps, a chlorine contact chamber, and a lagoon to collect or accumulate the final treated effluent.

4. Field Distribution System. Facilities of this category included a high pressure pump, a buried pipeline with strategically located valves and risers, portable aluminum irrigation pipe and an application nozzle capable of distributing manure slurry on the fields.

5. Laboratory-Office Building. There was no vacant space available in any of the existing farm buildings suitable for either lab or office space. It was necessary to construct an office and laboratory facility. Provisions for heat, lights, and water at least were necessary.

6. Miscellaneous. This category included sumps, pumps and pipelines to intercept some of the wastes from the existing cattle confinement spaces and wastes from the milking parlor and milk processing plant. It also included protective fencing, some new roadways, water and electrical power service and other minor or related facilities.

A detailed account of planning and implementation for each of the above categories is given in Appendix D.

CONSTRUCTION

Establishing a set of priorities and a construction schedule for the several different facilities was a complex problem and one that necessarily involved considerable guess work. Many different factors had to be considered. It was recognized that the actual demonstration operations could not be significantly initiated until it was possible to: (1) have cattle housed in the new barn, (2) collect, transfer and store manure slurry in the storage lagoons, (3) apply manure slurry to at least some crop lands, and (4) collect and analyze manure slurry samples. This dictated that a first order construction priority had to be assigned to: (1) the new barn structure, (2) completion of at least one pen in the barns, (3) slurry transfer lines and the central manure slurry tank, (4) the deep manure storage lagoons, (5) the field distribution system, and (6) the laboratory-office building and furnishings. Only the aerobic treatment facilities, additional pens in the new barn, and a few miscellaneous items could be temporarily postponed without significantly shortening the time for Project operation and observation.

There was a series of sequential operations involved in construction of each group of facilities. For example, the construction of the deep storage lagoons could not progress very far before the 12-inch diameter ductile iron pipe or slurry withdraw line would need to be installed. Requests for bid quotations and purchase orders for this pipe and other materials could not be submitted until rather complete design details were established. Such design details were dependent upon site surveys and this survey work had to await development and approval of a contract for consulting engineering services. A different but equally complicated series of sequential steps was also involved in the construction of the new barn, the laboratory-office building, and the field distribution system.

Availability of both labor and materials was another factor to be considered. Snohomish County and the Puget Sound region was, in 1967, in a pronounced construction and development boom period. Development of extensive new aircraft manufacturing facilities for the Boeing Company at Everett drew heavily upon contract capabilities, the labor pool, and materials supplies. This development had also sparked a further demand for commercial and residential buildings, for highway construction, for new schools, etc., which also reduced the availability of men and materials. It seemed essential, therefore, to try to develop a construction plan or program that would involve a rather stable crew rather than to risk critical periods of manpower shortage associated with the fluctuating construction intensity.

Weather had to be regarded as another important factor in scheduling construction effort on the various elements or facilities. The onset of winter and its typical wet climate was almost certain to cause difficulties for any earth work not completed before the end of November. Work involving the local soils of the valley floor would be more seriously affected than would work on or with fill material hauled to the project site from a barrow pit at a nearby hillside location.

The detail account of construction progress and problems is given in Appendix E.

SECTION V

OPERATIONS AND OBSERVATIONS

The reporting of Project operations and observations could conceivably be organized either (a) in a somewhat chronological narration of all Project activities, or (b) in a series of narrative subsections, each dealing with a specific aspect within the overall scope of Project objectives. The latter seems to be the more appropriate of the two alternatives even though significant interrelationships exist between several such specific subject areas. For example, activities and observations involving crop response will be discussed as a specific and separate aspect of the Project even though it is directly related to the amounts of manure applied at various times and by various techniques to specific portions of the farm.

The subsections of this section of the report are organized according to the following defined scopes and headings:

A. Barn-Related Operations - such as confinement slab flushing or cleaning, livestock feeding and watering, rainfall diversion, manure slurry collection and pumping, etc. One significant aspect of feeding--the test feeding of high nitrate corn silage--will be reported along with a subsection on crop response to applied manure.

B. Manure Transport, Storage, and Treatment - will cover the operations and observations related to the central manure slurry tank; the input, mixing, and withdrawal from the deep anaerobic manure storage lagoons; and the results of attempts to treat anaerobic lagoon supernatant in the aerobic treatment facilities.

C. Land Application of Manure - will cover the application of either fresh manure or manure removed from the storage lagoons to crop lands.

D. Field Assimilation and Runoff - will summarize the available data and observations related to the more immediate fate of manure slurry applied to the fields. This section will include the results of chemical and bacteriological tests of field soils as well as water quality observations on the small stream which forms the east and south boundary of the farm.

E. Crop Growth Response and Nitrate Feeding Experiment - will cover the limited amount of data and observations on test plot and field performance under the influence of applied manure. A specific experiment related to the feeding of silage with an unusually high nitrate content will also be included in this section.

F. Miscellaneous - any observations or results not appropriate to other specific subsections will be reported under this heading.

BARN-RELATED OPERATIONS

Rainfall Diversion

One of the Project objectives was to demonstrate any advantages of a totally roofed confinement or holding area for dairy cattle. The principal expected advantage was a reduction in the volume of manure slurry to be collected, transported, stored, and ultimately disposed by excluding rainfall from the slurry. Other potential advantages included a reduction of weather stress on the cattle, possible reduction of cattle diseases, an improved milk-output to feed-consumption ratio, and improved herd cleanliness.

It is not possible to precisely determine the extent to which manure slurry volumes were reduced at the Project by the provision of the roof. A reasonable estimation of roof-effect on manure slurry volumes can be made, however.

For purposes of comparison, consider the following assumptions and computations:

Assumptions:

1. The cattle confinement, manure collection, and rainfall catchment areas are identical and amount to the new barn roof area of 65,424 sq. ft. for the equivalent of 6 pens of 63 cows each (378 total cows). This is 173 sq. ft./cow.

2. Assume that the necessary storage period for manure slurry is the six continuous wettest months of a year, or 182 days. This is a reasonable expected duration of potential runoff conditions during which manure slurry should not be applied to the fields.

3. The required manure storage lagoon volume is dictated not by the average year but by the abnormally high years of record. Examination of Table I of Appendix A indicates that 38.41 inches of precipitation occurred during the months of October 1968 through March 1969 to represent the "wettest six continuous months" during the period of Project activity. Examination of 30 years of records for the nearby Monroe Climatological Station indicates that the rainfall for the "wettest six continuous months" will be about 40 inches or more in about one year in five. The design precipitation value is thus taken as 40 inches = 3.33 feet.

4. Effective evaporation of rainfall on a confinement slab is negligible. Because urine, feces, and water trough spillage keep a large part of the slab damp for a large part of the time, it is assumed that little more water would evaporate even if the rainfall was added to the slab.

5. Actual excrement removal from the slab amounts to approximately 10 gal./cow-day.

6. Water used for flushing or cleaning the slab amounts to 20 gal./cow-day.

7. The maximum practical liquid depth for storage lagoons is assumed to be 15 feet. Direct precipitation of 40 inches = 3.33 feet reduces the "effective storage" depth to 11.67 feet.

Computations:

a. Excrement to be stored during "wet-season" = 378 cows x 10 gal./cow-day x 182 days x 1 cu. ft./7.5 gal. = 91,700 cu. ft.

b. Flushing water to be stored during "wet-season" = 378 cows x 20 gal./cow-day x 182 days x 1 cu. ft./7.5 gal. = 183,400 cu. ft.

c. Combined manure slurry to be stored if confinement area is roofed = 91,700 cu. ft. + 183,400 cu. ft. = 275,100 cu. ft.

d. Precipitation to be added to slurry if confinement area is not roofed = 173 sq. ft./cow x 378 cows x 3.33 ft. = 218,100 cu. ft.

e. Total slurry to be sent to lagoons if confinement area is not roofed = 275,100 cu. ft. + 218,100 cu. ft. = 493,200 cu. ft.

f. Lagoon area required with roofed confinement = 275,100 cu. ft./11.67 ft. effective depth = 23,570 sq. ft.

g. Lagoon area required without roofed confinement = 493,200 cu. ft./11.67 ft. effective depth = 42,260 sq. ft.

h. Direct rainfall into lagoon designed for roofed confinement = 23,570 sq. ft. x 3.33 ft. = 78,570 cu. ft.

i. Direct rainfall into lagoon designed for non-roofed confinement = 42,260 sq. ft. x 3.33 ft. = 140,870 cu. ft.

j. Total slurry at end of "wet-season"

	Roofed Confinement Case	Non-Roofed Confinement Case
Excrement	91,700 cu. ft.	91,700 cu. ft.
Flushing Water	183,400 cu. ft.	183,400 cu. ft.
Confinement Area Rainfall	-0-	218,100 cu. ft.
Total Slurry Sent to Lagoons	275,100 cu. ft.	493,200 cu. ft.
Lagoon Surface Rainfall	78,570 cu. ft.	140,870 cu. ft.
Totals	353,670 cu. ft.	634,070 cu. ft.

From these computations it appears that the provision of covered confinement areas must have a very significant influence upon: (1) the amount of land area devoted to storage lagoons, (2) the cost of constructing the lagoons, (3) the amount of manure slurry to be transported into the lagoons, and (4) the volume of slurry that must be reclaimed and applied to crop lands during the dry season.

Several additional factors should also be recognized. If the confinement area is not covered to exclude rainfall, then that rainfall will be added to the slurry whether the holding pens are stocked to cow-holding capacity or not. In other words, a reduction of the number of cows in an open confinement pen will not result in a significant reduction in the amount of manure slurry to be pumped, stored or applied to the fields.

In the above example, a lagoon depth limitation of 15 feet was assumed. If greater depths were assumed, the roof-effect differences would be smaller. In areas with less "wet-season" rainfall expectancy, the differences would also have been smaller. With shallower depth limitations or greater rainfall expectancy, the storage and pumping differentials would naturally be greater. If the allocation of confinement area per cow was reduced, the differential in storage volume requirements and in annual pumpage requirements would be smaller; but, the roof area costs per cow would also be reduced.

It is recognized that the above computations do not indicate whether or not the cost of providing a roof over the confinement pens is economically justified by reduced land utilization for manure storage lagoons, reduced lagoon construction costs, and reduction in annual manure slurry pumping and field application costs. Such an analysis depends upon many factors including the method and cost of roofing, "wet-season" duration and accumulative rainfall expectancy, land availability and value, lagoon depth limitations, earthwork costs, availability and adequacy of fields for dry weather application of manure slurry and the methods and costs for field application.

New Barn Environment - Cattle Health

Some observations were made relative to the affect of the roof over the confinement area upon the environment for the cattle. Table 1 of Appendix A shows spot check data on temperatures and humidity in the new barn, in one of the older loafing sheds, and outside of all buildings. Other data, obtained on recording thermometers, was also obtained but is too voluminous for inclusion in a report. In general, the new barn was from 1 to 5°F cooler than the outside during warm sunny summer days and from 2 to 5°F warmer on cold winter days. Wind or air velocity measurements were not made but there seldom was any apparent lack of air ventilation in the barn. In fact, the barn seemed to be excessively drafty even on quiet days prior to the time that the south wall or prevailing wind face of the barn was enclosed. On a few days of cold humid weather, there was some moisture condensation and dripping from the metal roof, but this did not appear to have great significance. In summary then, the effect of the roof or the confinement pens seems to be a slight but significant trend towards a warmer environment during cold weather and towards a cooler environment during warm summer days. Obviously, the cattle under the roof had little exposure to direct sunshine in either winter or summer, but they also had a greatly reduced exposure to rainfall and snowfall.

It was initially planned that records of incidence of all diseases for cattle housed in the new barn would be compared with similar records for cows housed or confined in the old facilities. In order for such comparison to provide a valid objective assessment of the disease impact of the totally roofed confinement, there would need to be a high degree of isolation between the two groups of cows. It did not prove to be practical to achieve such isolation. First, all cows from both groups had to go through some common alleys and pens and the same milking parlor twice each day. Secondly, farm operations and herd management plans had to be considered in terms of production objectives as well as research objectives. It was not practical to avoid transfers of individual cows from one group to the other. Finally, the actual maintenance of separate group health or disease records proved to be too complicated for achievement under the circumstances at the Project. Quite properly, other necessary operations and objectives had to be assigned a higher priority than did maintenance of research health records.

Assessment of the impact of covered confinement on cattle health at this Project must, for the above reasons, be subjective rather than objective. The supervisor of the Honor Farm, in commenting on his observations of the facilities up to November, 1971, attributes an "appreciable reduction of disease in the herd" to the sheltering effect of the roofed confinement including the wind-blocking effect of enclosing the total south wall of the new barn. (See Appendices A and B).

A very comprehensive program was initiated to evaluate the impact of the Project facilities and operations on one rather specific aspect of cattle health, namely mastitis. This disease (or, more properly, grouping of several disease or injury conditions) is characterized by inflammation in one or more quarters of the udder, high leucocyte counts in the milk from the infected or afflicted mammary quarters, and other varying symptoms of distress or abnormality in the cow. Milk production and quality may be expected to drop anywhere from slightly to drastically. Productivity may or may not be restored after, and if, a cure is effected. There are apparently several species of causitive organisms and several possible methods of transmission for infection. In short, mastitis can and does have a very significant impact on the economic success of a dairy farm operation.

It was generally speculated that the confinement environment of the new barn, as contrasted to the existing facilities, would probably favorably alter the incidence of mastitis. S ch favorable response could develop because of improved confinement area sanitation, reduced physical injuries to cows, reduced weather stress, or other unrecognized factors.

Though a great number of mastitis screening tests were conducted and several hundred pages of data were assembled and analyzed, a positive quantitative assessment of the relationship of mastitis incidence to the new Project facilities has not been accomplished. The number of uncontrolled or uncontrollable variables and factors that were associated with the operations of both the new and existing facilities preclude any subjective evaluation of the data. It is entirely possible that a significant actual reduction in mastitis did result simply because the testing program increased the attention and awareness of all personnel to the problem. Subtle and even unrecognized changes in herd management practices must be assumed to have occurred. In any event, there is no indication that the frequency or severity of cases of mastitis has been adversely altered by the Project facilities or operations.

Manure Cleaning or Collection

Several methods or procedures for removing the manure from confinement areas were considered. As mentioned in Section VIII, Appendix D, some previous pilot scale tests (1) had been conducted at Washington State University. These tests indicated that hydraulic washing of urine and feces might be practical. In those initial test series, orifices of various sizes and spacings were drilled into 2-inch diameter pipe sections. These test sections were then mounted in adjustable brackets on old bicycle wheels in such manner that the height above the confinement slab and the angle of jet impingement on the slab could be adjusted as desired. Figure 3 shows one such test in progress. Cleaning effectiveness was observed with variations in such factors as water pressure, orifice size, orifice spacing, impingement angle, orifice height, rate of travel, degree of dryness or fluidity of on-slab manure, slab roughness and slope of the slab.

As a result of the above tests, a second generation series of tests were initiated using a somewhat more elaborate pilot model of "hydraulic broom". This model was equipped with special nozzles that delivered a flat, fan-shaped, jet. Figure 4 shows this second model in operation. Though only a limited amount of testing was done with this pilot model, the results were quite encouraging.

Operating with the special nozzles spaced at 12-inch centers, an angle of slab impingement of about 15 to 20 degrees, just enough height above the slab so that the fanned jets just merged at the point of impingement, and with 200 psi pressure; the "broom" could thoroughly clean a heavily laden slab at rates of 2 to 2 1/2 feet of travel per second. This hand-propelled test unit was supplied by a heavy walled, 1 1/2-inch diameter hose from a stationary pump, so the length of runs were limited to

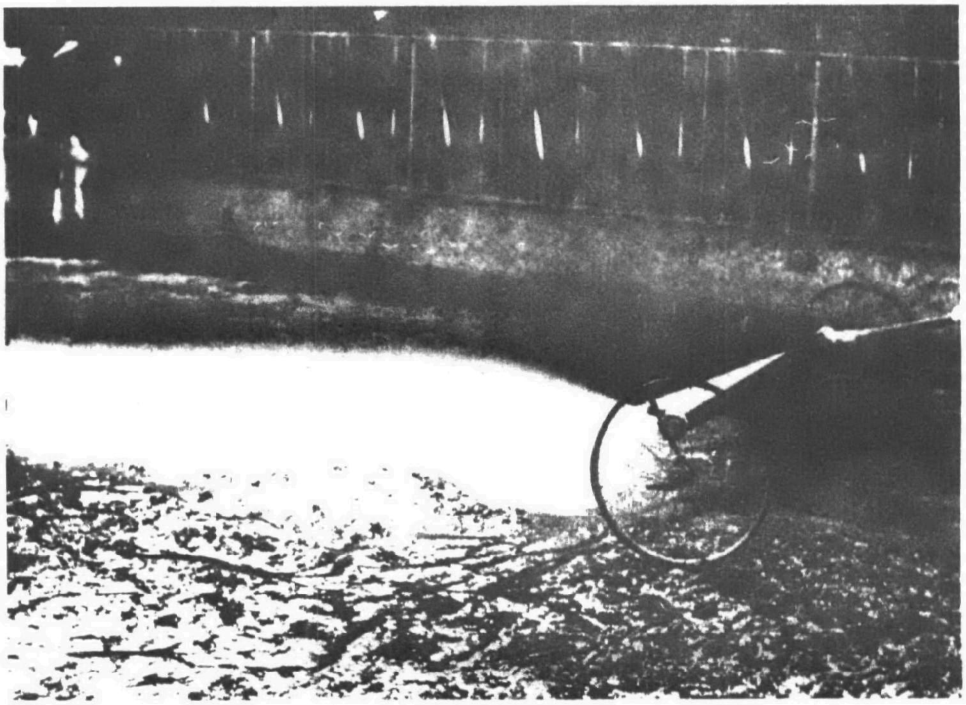


Figure 3. Drilled Orifice "Hydraulic Broom" During Early Manure Flushing Experiments

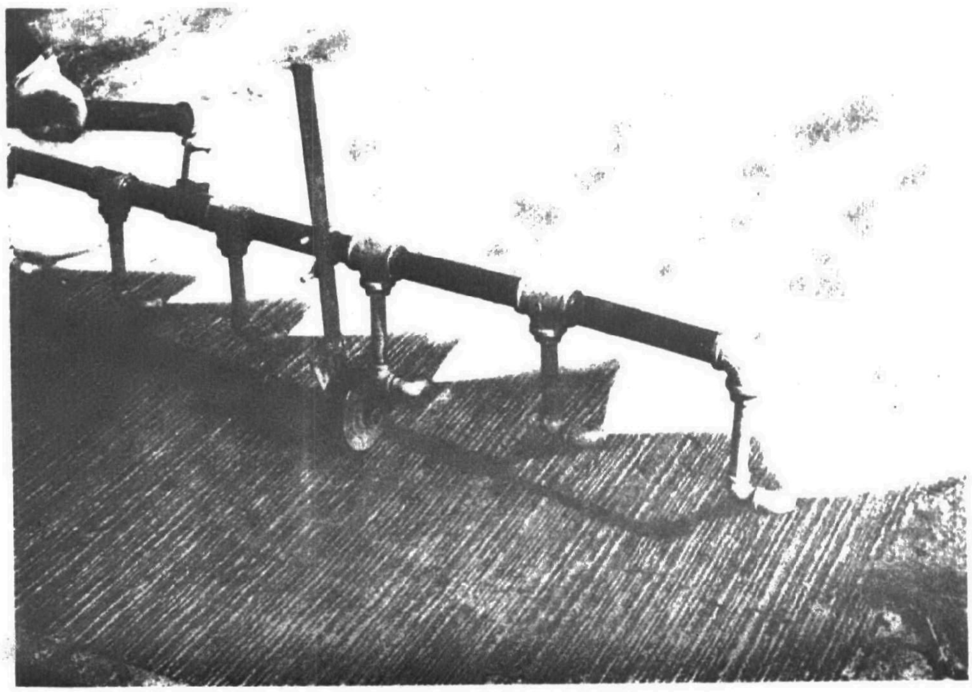


Figure 4. Second Generation "Hydraulic Broom" Pilot Model During Manure Flushing Experiments

about 15 to 20 feet. It appeared that it would be possible to flush off manure with considerably less than 20 gallons of water per cow-day. Both cleaning speed and effectiveness were so encouraging that construction of a full scale, truck-mounted, model was immediately initiated.

The development and results of the tank-truck-mounted "hydraulic broom" were briefly described on pages 92 and 93 of Section VIII of this report. The first problem that developed was the failure of a military surplus pump-engine unit to deliver the combination of flow and pressure necessary. Using a different pump, it was possible to achieve the necessary 200 psi of pressure. It was then possible to hydraulically clean the manure laden slab for a travel distance of 20 or 30 feet. The problem then was that a slurry mass would build up ahead of the "broom" after about 20 to 30 feet. This thick slurry mass was not able to flow away ahead of the "broom" at anything approaching the speed of travel of the "broom". While the hydraulic energy of the jets was sufficient to suspend the manure solids and push the resultant slurry into a 3- to 4-inch deep sloppy "puddle", the jets could not continue pushing the "puddle". A hydraulic jump would form where the high velocity fan-shaped spray encountered the viscous "puddle". The "puddle" would then soon build up and flood back past the jets in a mess of no small proportions. Unfortunately, two rolls of film which contained all pictures of the full scale truck-mounted hydraulic flushing rig or "broom" were lost so no photographs of the unit now exist.

It was speculated that hydraulic flushing might still be possible if conditions were changed to avoid the limitations imposed by the "unpushable puddle". Obviously, the mobile "broom" could not flush the ever-increasing puddle of manure slurry along the full 115-foot length of a confinement pen. It might be possible, though, to set the spray booms at an angle oblique to the direction of travel and thus "windrow" the slurry aside as the "broom" moved forward. It was with this possibility in mind, along with other considerations, that the design layout of pens C and D were altered to include grate-covered longitudinal gutters as shown in Figure 27 on page 97. With these longitudinal gutters, the manure slurry would only need to be flushed laterally a distance of 22 feet maximum. Available time on the Project ran out before the mobile "hydraulic broom" could be modified and tested, however. The idea still has sufficient merit to justify further exploration and may yet be attempted someday.

A second provision that was made for cleaning manure from the slab in pen A was the installation of drilled-orifice plastic pipe headers around the perimeter of the pen. In forming the pen-side base of the concrete mangers and the base for pen perimeter walls, recessed slots were provided for installing the drilled-orifice headers. (See page 92 of Section VIII. The multiple jets from these headers were directed to impinge on the concrete pen floor and spread out into a sheet flow across the slab.

Though several different sizes and spacings of orifices were tried in pen A, flushing success was limited. Near the point of impingement, the manure was flushed away from the perimeter walls, but the water tended to establish, and concentrate in, flow channels which did not carry much manure to the collection sump at the end of the pen. Any hay spilled from the mangers tended to resist being flushed away. Actually, the slab surface immediately in front of the mangers had somewhat less manure accumulation than did areas approximately 1 cow-length or more away from the mangers.

The insufficiency of success with hydraulic flushing made it necessary to resort to mechanical means for excrement removal from the confinement slabs. Two modifications of tractor-mounted slab cleaning equipment were used. One was a conventional metal scraper blade mounted on the rear of a farm tractor. The second modification involved replacing the metal scraper blade with a nylon-bristle broom as shown in Figures 5 through 8.

With either device, slab cleaning was scheduled for each pen at the time the cattle of that pen were removed for one of two daily milkings. Gates at either end of the pen could thus be left open and cattle did not interfere with equipment movement. The manure from the short stub alleys between bedded stalls was first either bladed or broomed out onto the main 30-foot wide (22-foot wide in pen C) pen area. The tractor then made repeated longitudinal passes from the outside end of the pen to the drop slot (into the manure collection sump) at the central alleyway gate at the other end of the pen.

In some instances, the perimeter spray headers were turned on before cleaning started to increase the fluidity of the accumulated manure. In other cases the water was turned on after the manure was partially removed. In still other cases, the perimeter water sprays were not used at all.

In the case of pen C, which was only 22 feet wide and had the longitudinal grate-covered gutter to convey manure to the collection sump, the manure could be deflected laterally to the gutter by either a metal blade or the nylon broom. There was some problem with hay stems and other fibrous solids fouling up the grates but the system seemed to function well, otherwise. The perimeter spray system seemed to be especially helpful in cleaning this pen. The circulating slurry flow in the gutter was adequate to flush solids through the Fiberglas-lined circular-cross-sectioned gutter without plugging up.

The metal scraper blade seemed to be the preferred choice for some of the farm personnel while the nylon broom seemed better to others. The blade seemed to be slightly faster, but the broom seemed to leave a slightly cleaner pen surface. Considering that the cows would be back

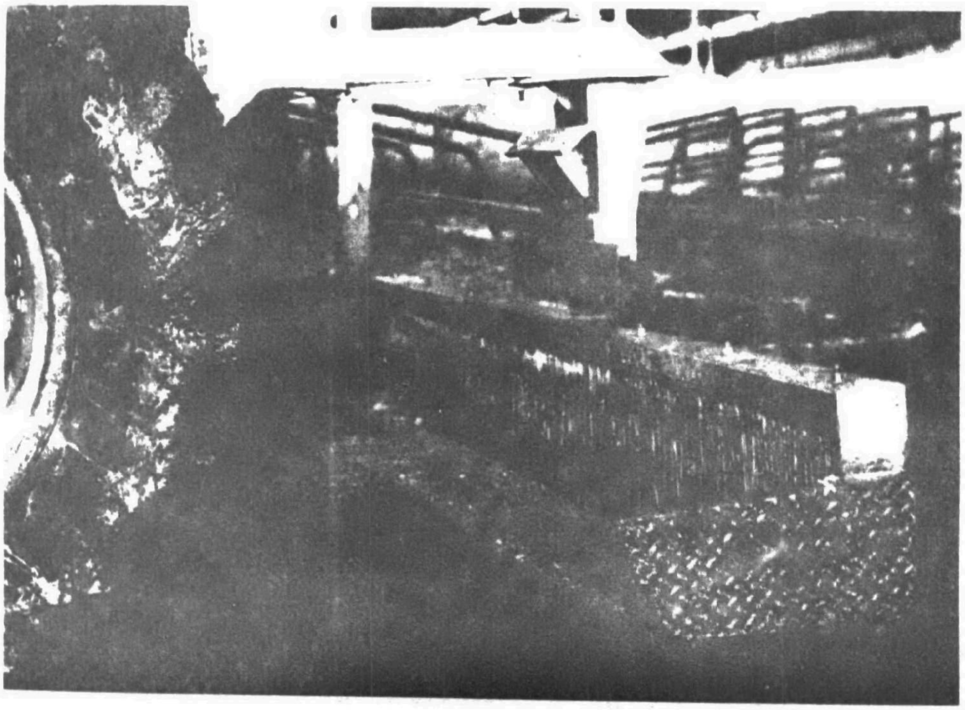


Figure 5. Nylon-Bristled Manure "Scraper" Mounted on Tractor

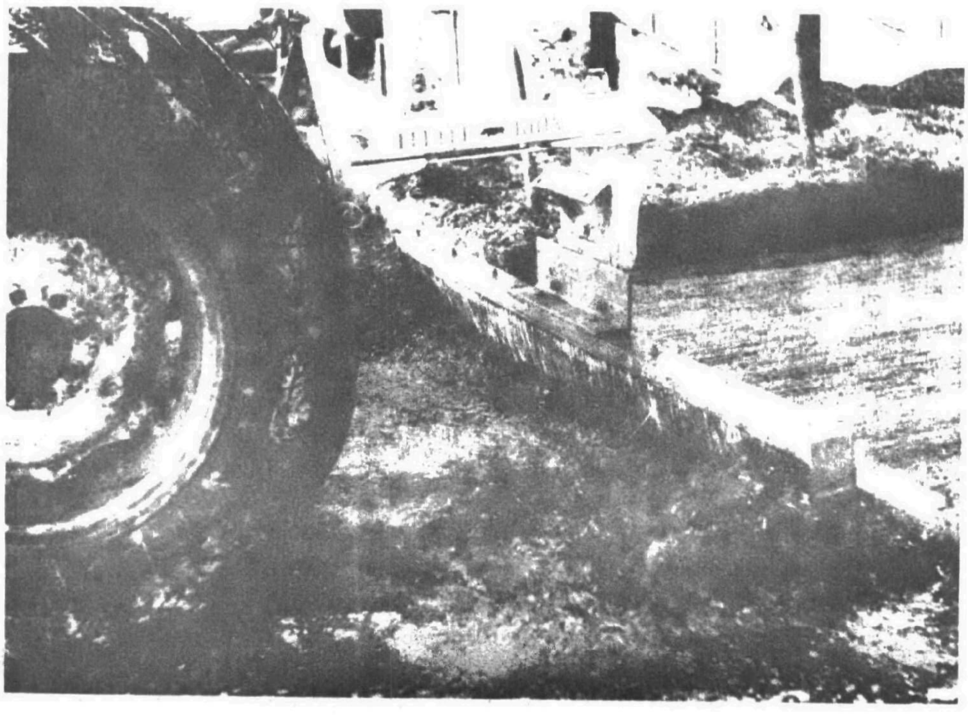


Figure 6. Nylon-Bristled Manure "Scraper" Operating in Alleyway Between Bedded Stalls

Figure 7. Nylon-Bristled Manure "Scraper" Operating on Main Surface of Holding Pen A

Figure 8. Nylon-Bristled Manure "Scraper" Discharging a Pushed "Load" into Drop Slot of Manure Collection Sump

defecating on the slab within 20 minutes anyway, perhaps the degree of surface cleanliness was of minor importance. It is logical to assume that the metal blade would wear away the roughness of the confinement slab, intentionally provided by brooming the wet concrete when placed, much faster than would the nylon broom device. This rough surface was needed to prevent the cows from slipping and injuring themselves. Also, any concrete derived "grit" in the manure slurry would either increase the wear on manure slurry pumps or would accumulate to reduce capacity in the collection sumps. The wear rate on the bristles of the nylon broom seemed to be essentially zero.

A limited amount of excrement was defecated inside the bedded stall areas. The cattle, almost without exception, would enter head-first into the 4 1/2-foot wide by 7-foot long-bedded stalls. This placed the defacating-urinating end towards the stub alleyways. Apparently, cows usually stand up for these functions so very little manure and urine was deposited in or on the wood shavings used for bedding of the stalls. The bedded stall areas were not paved so urine could soak through the bedding, the sand fill under the bedding, and on down into the gravelly fill material under the barn. The stalls were periodically "policed up" by a man with a fork who manually tossed the droppings out into the stub alleys just prior to the daily mechanical cleaning operation. Some wood shavings and chips got mixed into the manure in this manner. A far greater amount of shavings and chips got into the on-slab manure by being tracked or kicked out of the stalls by the cows. One or two inches of new bedding was added periodically and occasionally the old bedding was removed and replaced. The removed bedding was hauled out for field disposal rather than being added to the liquid manure slurry system.

Cattle Feeding and Watering

The system and procedure for feeding the cattle was probably not significantly different than at many other Pacific Northwest dairies. The cattle were fed what the writer (not a livestock nutritionist, certainly) would regard as a high roughage diet at the confinement areas and some grain or grain-based feed while in the milking parlor. During the growing season, freshly cut forage was the basic feed with some hay supplement. During the remainder of the year, the cattle were feed locally grown and stored silage plus either baled or cubed hay imported to the farm.

The pens, mangers, and service alleys were arranged so that freshly cut green chopped forage could be mechanically discharged directly from the field forage wagons to the manger along the entire length of a pen. When baled hay was fed, it could also be hauled on a truck in the service alley, broken open, and placed directly into the mangers. The cubed hay from bulk storage or silage from the large bunker-type silo were loaded into a mechanical forage box and mechanically discharged to the manger. An inclined grill of pipe work along the pen-side of the mangers (visible to the left in Figure 7) reduced the amount of hay or silage that might either spill out on the confinement slab while the mangers were being filled or be rooted out by the cows while they were eating. This grill also prevented bossy-dispositioned cows from driving other cows away from her immediate feeding area at a manger. Essentially then, feeding in the new barn facility was quite efficient but not particularly different than at many other dairies. Though initially included in plans, time and motion studies on feeding operations were never undertaken to quantitatively measure feeding time requirements because of time demands for other Project needs.

The watering of cattle in the first pens of the new barn was initially accomplished by an overhead float-controlled reservoir and a distribution system as discussed on page 90. Three troughs or drinking cups were installed in each pen. The level in each trough was float-controlled and supplied by exposed gravity PVC lines extending from the overhead reservoir. It was planned that the tank and lines would be drained if in-barn temperatures indicated a possibility of freeze-up. The first such occurrence, however, was quite fast and severe resulting in almost total loss of the entire watering system. Concrete watering troughs were then built into sections of the manger and supplied through float valves from underground pressure lines. This method of watering the cattle proved to be satisfactory. Except for maintenance of the float valves and periodic cleaning of the troughs, watering was totally automatic.

Manure Collection Sumps

The consistency of manure or manure slurry that was bladed, broomed, or flushed into the collection sumps varied quite appreciably depending upon several factors. When the perimeter flushing system in pen A was used, the resulting slurry that entered the sump through the drop slot was quite fluid. Without such water usage, the accumulated mass was of a stiff-paste consistency. Spilled hay and silage tended to further reduce the fluidity. Even with flushing water usage, however, the slurry tended to separate into a settled solids deposit on the bottom of the collection sump, a very dirty water layer, and a thin floating layer of shavings, chips, and hay stems. An appreciable amount of inert sand and grit, from the bedded stalls or from erosion of the roughened concrete, settled to form a very dense layer on the extreme bottom of the sump. Some baling wire, rocks, and other "junk" found its way into the sumps and also settled to the extreme bottom layer.

The central manure slurry tank was not yet functional when cattle were first permanently installed in pen A in July, 1968. From that time until December, 1968, all generated slurry had to be pumped through a temporary portable line into a truck-mounted liquid spreader tank for field application. No attempt was made to monitor or sample this manure slurry for several reasons. Representative samples could have been obtained only while the mobile chopper pump rig was operating as an in-sump agitator. The loading and hauling of liquid manure was done sporadically. The young non-producing heifers in pen F contributed an unknown quality and quantity of manure to the first or south collection sump. Manure from this pen was not routinely scraped into the sump but was hauled out as solid material. Some urine and spilled water from this pen did drain to the sump, however. Meaningful data could only have been obtained by being continuously present to sample each 500-gallon tankful of liquid manure and by running innumerable analyses. All Project personnel were too busily engaged in other activities related to getting other facilities finished to devote the required time to sampling and analyses.

When manure slurry was to be removed from one of the collection sumps, the mobile chopper pump rig was driven down the central alleyway and positioned adjacent to the 2-foot by 4-foot hatch in the sump roof. (See Figure 26 on page 95). With the hatch removed, the pump itself could be lowered into the sump. The gear head of the pump was then connected by a splined drive shaft to the rear axle drive of the pump rig chassis. Initially, the pump was connected to the temporary spreader tank-loading line but after December, 1968, the connection was to the 4-inch PVC slurry transfer line extending to the central manure slurry tank. An internal flap valve on the pump proper was then set to recirculate and agitate the contents of the sump. On some occasions it was felt necessary to add some water to the sump to dilute the slurry. The pump was operated for about one or two minutes to resuspend and blend the sump contents. The agitation nozzle of the pump could be swivelled through about 180 degrees of horizontal arc and angled down to sweep over essentially any part of the sump floor.

It was eventually discovered that the pump was not being used sufficiently long as an agitator. This allowed a heavy sand-manure "pack" to accumulate at the corners and bottom of the end walls. The sand was presumably largely derived from the bedded stalls. The sand level in the stalls was lowered to reduce this problem but not before a very large amount of sand had accumulated in the central manure slurry tank.

Several problems did develop with the mobile chopper pump rig. These problems led to a modification of the collection sump arrangement and elimination of the mobile pump rig as discussed on pages 94 through 96 in Section VIII. The electrically powered stationary pump installed in the third sump and 15-inch concrete slurry line connecting all of the sumps did prove to be satisfactory. This arrangement was significantly less prone to damage and trouble than had been the mobile pump rig. Some problems with chips contained in the bedding material did occur, but without serious or lasting consequence.

MANURE TRANSPORT, STORAGE, AND TREATMENT

Transfer and Storage

The first operation of the central manure slurry tank was in December, 1968. It was filled to various depths with water to test the turbine agitator and the high pressure chopper pump in the adjacent 4-foot diameter sump. It did appear that the central manure slurry tank agitator would be adequate to produce a uniform suspension of manure slurry. Subsequent operation with actual manure slurry revealed that the turbine was incapable of resuspending the bottom deposit in the tank when it contained an appreciable amount of sand. Two auxiliary 1/2-inch diameter mixing jets, operating on the discharge of the high pressure chopper pump, were subsequently installed for supplemental agitation. With such added mixing power, all but the coarsest sand was resuspended. After achieving resuspension of a tankful of slurry, it appeared that the central turbine alone could maintain a reasonable degree of homogeneity during the period required for sampling and for pumping the tankful on to its next destination. This destination was either one of the anaerobic storage lagoons or one of the fields via the field distribution system.

The slurry line from the high pressure chopper pump to the anaerobic storage lagoons was not completed until March, 1969. All manure slurry derived from the barn between December, 1968, and March, 1969, was pumped to the central manure slurry tank and then applied directly to the northwest corner of field E by way of the field distribution system. This manure slurry was not volumetrically measured or sampled.

It was intended that all batches of slurry transferred through the central manure slurry tank would be thoroughly mixed to establish homogeneity, measured for volume, and sampled for constituent analysis before being transferred on to its next destination. This, it was felt, would provide a record of the amount and composition of all manure applied to designated areas in the fields. It would also make it possible to run an accumulative mass balance on the constituents in the lagoons so that destruction, conversion, and loss could be evaluated. Table 1 presents the recorded data on transfers through the central manure slurry tank from March, 1969, through July, 1970.

If one takes the amounts of total volume, total solids, volatile solids, ammonia nitrogen, organic nitrogen, and total nitrogen that came from the barn between March 3, 1969, and June 25, 1969 (excluding the period from June 5 to June 28 when solid results are not available) and divides these amounts by 66 days x 126 cows = 8,316 cow-days, the following unit values are obtained:

Slurry Volume	44.04	gal./cow-day
Total Solids	13.28	lbs./cow-day
Volatile Solids	11.10	lbs./cow-day
Ammonia Nitrogen	0.245	lbs./cow-day

Table 1
Manure Transferred Through Central Manure Slurry Tank

Date	Volume (gal.)	Source *	Destination **	Concentrations (grams/liter): Total Solids	Vol. Solids	COD	BOD 5-day 20°C	Ammonia Nitrogen as N	Organic Nitrogen as N	Total Nitrogen as N	Mass Quantities (pounds): Total Solids	Vol. Solids	Ammonia Nitrogen as N	Organic Nitrogen as N	Total Nitrogen as N
03-28-69	46,000	B	L-1	24.3	19.0	-	7.2	0.69	0.75	1.44	9322	7289	265	288	552
04-07-69	46,000	B	L-1	36.3	27.0	-	7.5	0.82	0.93	1.75	13926	10358	315	357	671
04-16-69	50,000	B	L-1	44.0	33.2	-	10.0	0.87	0.95	1.82	18348	13844	363	396	759
04-25-69	53,400	B	L-1	40.0	32.0	37.7	9.9	0.79	0.82	1.61	17814	14251	352	365	717
05-05-69	56,000	B	L-1	44.9	37.3	36.1	10.4	0.66	0.79	1.45	20970	17420	308	369	677
05-28-69	61,000	B	L-1	-	-	42.0	10.0	0.90	0.94	1.84	-	-	458	478	936
06-02-69	41,500	B	L-1	29.7	24.8	30.4	-	0.47	0.65	1.11	10279	8584	163	225	388
06-03-69	58,500	L-1	E-0	15.4	11.3	17.3	-	0.53	0.46	0.99	7514	5513	259	224	483
06-04-69	58,500	L-1	E-0	23.0	18.6	24.8	-	0.50	0.52	1.02	11221	9075	244	254	493
06-05-69	56,200	L-1	E-0	23.0	17.2	24.3	-	0.67	0.57	1.24	10780	8062	314	267	581
06-16-69	69,300	B	L-1	32.3	27.1	36.9	-	0.41	0.79	1.20	18668	15663	237	457	693
06-25-69	50,000	B	A-1	37.1	29.3	35.0	-	0.73	0.58	1.31	15471	12218	304	242	546
06-26-69	61,200	L-1	A-2	36.2	30.1	43.4	-	0.67	0.74	1.41	18478	15363	342	378	720
06-27-69	39,500	L-1	A-2	35.4	29.4	31.9	-	0.61	0.73	1.34	11662	9685	201	240	441
06-30-69	25,000	L-1	A-3	31.8	26.2	36.6	-	0.49	0.63	1.12	6630	5463	102	131	233
07-10-69	51,000	B	L-1	41.4	34.3	42.0	-	0.68	0.66	1.34	17609	14589	289	281	570
07-17-69	56,100	B	L-1	65.7	55.3	80.8	-	0.95	1.02	1.97	30739	25873	444	477	922
07-24-69	40,800	B	L-1	69.2	58.0	86.0	-	1.09	1.16	2.25	23547	19736	371	395	766
08-04-69	48,500	B	L-1	63.8	53.7	77.2	-	0.95	1.15	2.10	25806	21721	384	465	849
08-11-69	61,200	B	L-1	78.4	66.6	77.2	-	1.05	1.29	2.34	40016	33993	536	658	1194
08-20-69	33,800	B	L-1	66.0	55.1	79.2	-	1.06	1.24	2.30	18605	15532	299	350	648
08-22-69	53,000	B	L-1	71.3	61.1	76.5	-	0.92	1.13	2.05	31516	27007	407	513	920
08-28-69	25,000	B	A-6	60.3	50.6	69.7	-	0.96	1.04	2.00	12572	10550	200	217	417
08-29-69	25,000	L-1	A-5	59.7	50.4	62.4	-	0.90	0.92	1.82	12447	10508	188	192	380
09-02-69	25,000	M	A-4	66.4	55.2	80.4	-	1.11	1.16	2.27	13844	11509	231	242	473
09-03-69	25,000	M	A-7	65.2	53.4	73.9	8.2	0.88	1.09	1.97	13594	11134	183	227	411
09-04-69	50,000	L-1	E-1	68.1	57.0	71.3	7.3	0.96	1.07	2.03	28398	23769	400	446	846
09-05-69	46,000	L-1	E-2	70.6	59.8	76.1	7.1	0.93	1.00	1.93	27085	22942	357	384	740
09-09-69	40,000	M	E-3	68.0	58.4	64.5	7.7	0.96	1.09	2.05	22685	19482	320	364	684
09-10-69	35,000	M	E-4	71.8	61.5	83.4	7.3	0.76	1.24	2.00	20958	17592	222	362	584
09-11-69	30,000	M	E-5	69.2	58.4	64.6	6.7	0.94	1.14	2.08	17314	14612	235	285	520
09-12-69	20,000	M	E-6	53.2	44.5	54.4	4.8	0.76	0.95	1.71	8874	7423	127	158	285
09-18-69	40,000	M	E-7	50.8	42.8	54.6	6.7	0.79	0.95	1.74	16947	14278	264	317	580
09-19-69	40,000	M	E-8	63.4	54.1	66.5	5.4	0.86	0.99	1.85	21150	18048	287	330	617

Table 1-cont.
Manure Transferred Through Central Manure Slurry Tank

Date	Volume (gal.)	Source *	Destination **	Concentrations (grams/liter) Total Solids	Vol. Solids	COD	BOD 5-day 20°C	Ammonia Nitrogen as N	Organic Nitrogen as N	Total Nitrogen as N	Mass Quantities (pounds) Total Solids	Vol. Solids	Ammonia Nitrogen as N	Organic Nitrogen as N	Total Nitrogen as N
09-22-69	35,000	M	E-9	61.3	52.4	68.9	5.4	0.90	1.02	1.92	17893	15296	263	298	560
09-24-69	45,000	M	E-10	48.8	41.4	56.2	5.0	0.75	0.91	1.65	18315	15537	281	342	623
09-24-69	52,000	M	E-11	50.2	42.8	57.4	5.2	0.80	0.90	1.70	21771	18562	347	390	737
09-26-69	30,000	M	E-12	35.2	28.6	45.5	4.9	0.67	0.69	1.37	8807	7156	168	173	340
09-30-69	35,000	M	A-8	46.4	38.3	54.2	6.3	0.91	0.86	1.77	13544	11180	266	251	517
10-06-69	12,000	M	L-1	52.6	43.2	57.0	7.0	1.08	0.98	2.06	5264	4323	108	98	206
10-06-69	50,000	M	A-9	52.6	43.2	57.0	7.0	1.08	0.98	2.06	21934	18014	450	409	859
10-09-69	50,000	M	A-10	40.2	32.7	51.8	5.2	0.78	1.05	1.83	16763	13636	325	438	763
10-10-69	40,000	M	A-11	30.5	24.6	33.2	4.4	0.66	0.51	1.17	10175	8207	220	170	390
10-15-69	61,200	B	L-1	51.8	42.4	56.0	5.4	0.95	0.83	1.78	26439	21641	485	424	909
10-23-69	66,300	B	L-1	65.4	54.2	71.4	7.4	1.18	1.04	2.22	36162	29970	652	577	1230
10-30-69	50,000	B	L-1	58.4	48.4	63.0	7.3	1.29	0.98	2.27	24369	20183	538	409	947
11-05-69	66,000	M	L-1	48.1	39.9	53.0	6.3	0.99	0.95	1.94	26476	21963	545	523	1068
11-13-69	66,000	M	L-1	45.6	38.8	38.7	5.9	0.97	0.89	1.86	25100	21357	534	490	1024
11-21-69	45,000	M	L-1	53.6	45.3	56.6	6.9	1.11	1.03	2.14	20116	17001	417	387	803
11-26-69	51,000	M	L-1	54.9	48.3	54.7	5.9	1.00	0.90	1.90	23351	20544	425	383	808
12-03-69	43,400	M	L-1	36.1	29.8	40.6	6.0	1.11	0.87	1.98	13067	10786	402	315	717
12-09-69	63,500	M	L-1	41.0	34.9	42.5	6.2	1.01	0.90	1.91	21713	18483	535	477	1012
12-17-69	81,000	M	D-1	44.2	37.4	50.0	6.2	1.06	0.91	1.97	29859	25265	716	615	1331
12-23-69	66,000	M	D-2	35.1	29.4	42.6	5.4	0.97	0.83	1.80	19320	16183	534	457	991
12-30-69	74,000	M	D-3	51.3	43.8	63.0	6.4	1.14	0.93	2.07	31660	27032	704	574	1278
01-08-70	65,000	M	D-4	54.9	47.3	64.2	6.7	1.36	1.04	2.40	29761	25641	737	564	1301
01-15-70	61,000	M	D-4	57.2	49.7	28.8	8.9	1.35	0.99	2.34	29100	25284	687	504	1190
01-21-70	56,000	M	D-4	44.1	38.0	40.6	7.4	1.15	0.92	2.07	20596	17748	537	430	967
01-28-70	61,000	M	D-5	33.3	27.5	42.5	2.7	0.97	0.76	1.73	16941	13990	493	387	880
02-02-70	66,400	M	D-5	55.3	48.7	53.8	6.4	0.96	0.85	1.81	30624	26969	532	471	1002
02-11-70	77,000	M	D-6	43.1	36.2	61.0	7.1	1.04	1.01	2.05	27678	23247	668	649	1316
02-19-70	62,000	M	D-6	51.1	45.0	49.4	8.2	1.13	0.97	2.10	26423	23269	584	502	1086
02-27-70	65,000	M	D-7	62.3	55.6	52.4	8.3	1.20	1.02	2.22	33773	30141	651	553	1203
03-06-70	73,000	M	D-7	48.8	41.8	57.2	7.8	1.23	1.16	2.39	29710	25449	749	706	1455
03-13-70	71,000	M	D-8	30.3	25.4	34.2	5.9	0.65	0.79	1.44	17942	15040	385	468	853
03-19-70	55,000	M	D-9	35.5	28.3	35.0	6.0	0.68	0.90	1.58	16284	12981	312	413	725
03-23-70	70,000	M	L-2	49.2	42.1	46.6	6.9	0.83	0.93	1.76	28723	24578	485	543	1027

Table 1-cont.
Manure Transferred Through Central Manure Slurry Tank

Date	Volume (gal.)	Source *	Destination **	Concentrations (grams/liter): Total Solids	Vol. Solids	COD	BOD 5-day 20°C	Ammonia Nitrogen as N	Organic Nitrogen as N	Total Nitrogen as N	Mass Quantities (pounds): Total Solids	Vol. Solids	Ammonia Nitrogen as N	Organic Nitrogen as N	Total Nitrogen as N
04-03-70	67,808	M	L-2	40.0	33.1	49.8	7.0	1.12	1.09	2.21	22618	18716	633	616	1250
04-10-70	51,000	M	L-2	81.3	70.6	89.1	9.4	1.57	1.18	2.75	34580	30029	668	502	1170
04-17-70	45,000	M	L-2	73.1	62.7	70.8	7.9	1.41	1.03	2.44	27434	23531	529	387	916
04-27-70	68,400	M	L-2	77.3	70.4	76.2	15.7	1.38	1.49	2.87	44096	40160	782	850	1637
05-08-70	60,500	M	L-2	36.8	31.2	85.2	8.7	0.69	0.78	1.47	18568	15743	348	394	742
05-15-70	51,000	M	L-2	53.2	45.4	66.6	11.8	0.84	1.06	1.90	22628	19310	357	451	808
05-21-70	41,000	M	E-TP	64.1	56.2	54.0	8.2	1.00	1.15	2.15	21918	19217	342	393	735
05-27-70	46,000	M	E-TP	53.8	44.8	59.1	10.2	0.96	1.19	2.15	20640	17187	368	457	825
06-02-70	64,000	M	E-TP	62.4	53.0	64.4	4.9	1.00	1.22	2.22	33307	28289	534	651	1185
06-16-70	61,000	M	L-2	68.5	57.6	57.8	7.4	0.96	1.24	2.20	34849	29303	458	631	1119
06-23-70	57,000	M	L-2	56.8	47.9	76.5	9.5	0.79	0.95	1.74	27001	22771	376	452	827
07-01-70	51,000	M	L-2	46.6	40.2	40.8	4.8	0.73	0.90	1.63	19821	17099	310	383	693
07-08-70	56,100	M	L-2	59.6	51.3	56.7	5.3	0.89	1.18	2.07	27885	24002	416	552	968
07-21-70	56,000	M	A-12	33.4	27.0	43.0	4.9	0.69	0.71	1.40	15599	12610	322	332	654
07-22-70	30,000	L-?	A-11	38.3	31.9	49.4	6.1	0.72	0.77	1.49	9583	7981	180	193	373
07-22-70	35,000	L-?	A-10	49.3	41.1	55.3	6.1	0.77	0.88	1.65	14391	11997	225	257	482
07-24-70	25,000	L-?	A-9	62.9	53.4	63.5	7.9	0.92	1.00	1.92	13115	11114	192	208	400
07-24-70	40,000	L-?	A-8	39.1	31.0	53.5	8.0	0.93	0.95	1.88	13044	10342	310	317	627

* Source Codes

B = Manure from the New Barn
L-1 = Manure Removed from Anaerobic Storage Lagoon #1
L-? = Manure Removed from an Anaerobic Storage Lagoon But the Records Don't Reveal Which One
M = Manure Accumulated as a Mixture from a Combination of Sources: New Barn, Tank Trucked from Old Barns, or Removed from Either of Anaerobic Lagoons

** Destination Codes

L-1 = Anaerobic Storage Lagoon #1
L-2 = Anaerobic Storage Lagoon #2
A to E + Number = The Field Designated by the Letter and a Specific Plot Designated by the Number

Organic Nitrogen	0.289 lbs./cow-day
Total Kjeldahl Nitrogen	0.534 lbs./cow-day

These data, in all respects but one, appear to be about as expected. The volume of slurry was higher than anticipated, indicating either that more flushing water was being used or that more water was being added to the collection sumps when they were agitated for transfer than was planned. To a very minor extent, the unit values may have been slightly increased because of the slight amount of feces, urine, and spilled trough water that was entering the south collection sump from pen F, which held 50 or 60 young heifers at this time. That pen was not being scraped or flushed into the collection sumps but, undoubtedly, some liquids and solids did reach the collection sump.

Because of several considerations, the mass balance determination of destruction, conversion, and loss of constituents in the anaerobic storage lagoons could not be made. On at least two occasions, a partial tankful of manure slurry was pumped to the lagoons without first being measured or sampled. On another occasion, the agitator motor for the central manure slurry tank cut out on the thermal overload switches just after starting to pump a large batch to the lagoons. This allowed an unknown amount of the solids to be deposited and left behind before the volume was completely transferred. These solids then were mixed with another batch from the barn so that an appreciable amount of solids was thus sampled twice. During one period, the records indicate inputs to the anaerobic storage lagoons but do not indicate to which of the two lagoons. BOD data for a series of 19 batches (879,000 gallons) was missed when the temperature control relay on the BOD bath malfunctioned. Finally, evaluation of destruction or conversion in the lagoons depends on a computation of the balance between total input, total withdrawal, and residual, if any, that remains at the time of balance. The slurry recirculation system for agitating the large lagoons was not capable of achieving homogeneity of the lagoon contents to allow representative sampling of the residual material.

The process of transferring slurry to the anaerobic lagoons seemed adequate. On one occasion, the valve to Lagoon No. 1 was left partially open while slurry was being transferred to Lagoon No. 2. This allowed a slight flow to the valve constriction with the result that the influent line was solidly plugged with fibrous solids. It was necessary to cut out and replace the plugged section since the solids were too impacted to be removed.

The anaerobic storage lagoons appeared to be quite satisfactory in terms of liquid retention or absence of exfiltration. No additions or withdrawals were made to Lagoon No. 1 for the period from June 1 to July 15 of 1970. There was approximately 1 1/4 inches of rainfall input during this period, less an unknown output loss by evaporation. The lagoon level dropped only about 3/4 inches during this same period. Assuming that the total 2 inches was indeed exfiltration (i.e. no evaporation), exfiltration would only be 0.0445 inches per day. It appears more likely that evaporation, even from the floating crust on the lagoon surface, would account for most of the observed loss in liquid volume.

The system for agitating and withdrawing storage slurry from the anaerobic storage lagoons proved to be usable but certainly not entirely satisfactory. The intake end of the aluminum decanting line was easy to lift out of the slurry to stop gravity flow of slurry to the deep withdrawal pump sump. It was quite difficult, however, to submerge the pipe when the lagoon was nearly full and the sump and pipe were empty. Occasionally a large chunk of the floating crust would block the inlet end of the withdrawal line while recirculating and agitating the contents of the lagoon. The two jets on the inlet line to a lagoon would break up the rafts of floating crust but only after several hours of operation. It was necessary to change the horizontal and vertical alignment or "aim" of the jets quite frequently while breaking up the floating crust. The bottom deposits were considerably easier to agitate but, again, the jet "aim" had to be altered quite frequently. The solids would tend to restratify (float and/or sink) in some areas of the lagoon while the jets were agitating other sections.

The covering of the lagoon embankment surfaces with a surcharge of rock prevented sloughing and erosion almost completely. A very small amount of rock was disturbed when one of the agitating or mixing jets was inadvertently directed to impinge on the lagoon embankment. Even then, no damage was done. A slight amount of the floating crust was "beached" on the rock surface as the level was drawn down, but this crust was quite dry and caused no problems. After observing the storage lagoon operations, it is suggested that a much better system of withdrawal for field application is needed and could be developed. It seems probable that a floating dredge concept, utilizing a chopper pump as the dredge unit, would be quite satisfactory. The dredge intake could be moved to the deposited solids rather than to try to move the solids to a fixed withdrawal point in the lagoon. The dredge discharge could be conveyed by heavy-duty hose to a booster pump permanently mounted on the lagoon embankment. The permanently mounted pump would then deliver the slurry to the field distribution system.

The absence of odors around the lagoons was especially worthy of note. Even when the lagoons were being agitated after several months without agitation, there was no particularly noticeable odor problems. It cannot be said that there was never a detectable odor, but odor around the lagoons was always within quite acceptable limits. The complete absence of any detectable fly problem associated with the lagoons was also noteworthy. A few rat-tailed maggots were noted but birds (mostly starlings and some other small birds like killdeers) grazed over the floating crust almost continuously, especially during the summer, with the result that almost no insects ever migrated from the lagoons.

In all, between March 28, 1969, and July 24, 1970, some 1.9 million gallons of slurry had been added to the lagoons and slightly more had been reclaimed for field application. Direct precipitation into the lagoons accounted for a residual volume of about 330,000 gallons in the two lagoons combined. A very slight fraction of the liquor had been withdrawn as settled anaerobic lagoon effluent or supernatant for experimental treatment in the small activated sludge treatment system.

Aerobic Treatment

As discussed in Section III - INTRODUCTION--Project Objectives, the successful treatment of supernatant drawn from the anaerobic storage lagoons was not critical to the overall success of the Project but would be a subject of interest to some dairymen.

The first attempt to operate the activated sludge treatment facilities started on April 19, 1970. No manure slurry had been added to Lagoon No. 1 since December 9, 1969, nor had the lagoon been disturbed by any recirculating flow. The aluminum withdrawal pipe in Lagoon No. 1 was lowered to approximately the midpoint between the top of the bottom sludge layer and the bottom of the floating crust layer in order to obtain supernatant of the lowest possible suspended solids concentration. The supernatant withdrawal flow was wasted into Lagoon No. 2 for about 30 minutes to clear the withdrawal line and the deep sump of chips and other debris. Then the equalization tank was filled with the lagoon supernatant.

Even after the long quiescent period in the anaerobic storage lagoon, the supernatant that was withdrawn contained a significant amount of wood chips and other fibrous material. It subsequently became apparent that this supernatant had to be passed through a 1/4-inch mesh screen in order to avoid constant problems of coarse suspended material plugging up the feed pumps, constant head tank, pipelines, and ball check valves on the activated sludge return pump.

The supernatant, as withdrawn from the anaerobic lagoon and after coarse screening, had an organic strength varying from 3,500 up to 4,500 mg. of 5-day BOD/liter. Total solids ranged from 7,000 to 12,000 mg./liter and volatile solids from 5,000 to 8,500 mg./liter. The supernatant was extremely turbid and very highly colored.

The activated sludge aeration basin was filled with the supernatant but continuous feed was not attempted at first. When the aerator turbine was started, it immediately generated about 500 cu. ft. of thick persistent foam which overflowed the aeration basin and oozed away in all directions. This foam completely covered the turbine and it must be presumed to have completely blocked the introduction of air and thus oxygen by the turbine. Figure 9 shows the aeration tank after 6 days without further addition of lagoon supernatant. Any attempt to skim, shovel, or pump the foam just allowed the turbine to get more air to generate more foam. Water was added to flush out some of the supernatant liquor and dilute the remainder.

Eventually, through dilution and a slow build-up of an activated sludge biomass, the foaming problem was reduced to the point that the surface turbine was exposed and effective as shown in Figure 10. The initial build-up of the mixed liquor suspended solids (MLSS) was a slow process, however, and it was several weeks before an attempt was made to operate on a continuous flow basis. Sludge synthesis or build-up rates appeared to be quite erratic but actually this was caused by variations in the amount of sludge solids lost over the effluent weirs of the final clarifier. The rate of intentional sludge wastage had to be varied quite frequently in order to achieve any degree of control over the concentration of mixed liquor volatile suspended solids (MLVSS). Sludge settling characteristics, which affected the return sludge concentration and thus the MLVSS concentration, appeared to worsen quite rapidly whenever the applied biomass loading had exceeded about 0.4 lbs. of BOD/day/lb. of MLVSS. The result was an extremely unstable control situation which was intensified by the small size of the treatment plant. If at any time the sludge settling characteristics got poorer; the rate of solids return to the aerator, as controlled by the sludge pump adjustments, was reduced. This allowed a decrease in the MLVSS concentration which in turn increased the BOD to MLVSS loading. This would then cause even poorer sludge settling and the cycle continued to spiral downward towards poorer and poorer treatment. Since the BOD strengths of the supernatant feed liquor was not known until 5 days after it was pumped to the equalization tank, control of biomass loading was a matter of guesswork.

When almost constant attention could be directed to the operation of the activated sludge plant, it was capable of reaching a high degree of BOD removal. For example, at one point it was being feed 2.7 gal./min. of slightly diluted supernatant having 2,960 mg. BOD/l. With an aeration volume of 3,200 gallons and a MLVSS concentration of 9,600 mg./l., the solids loading was 0.37 lbs. BOD/day/lb. MLVSS. The effluent BOD was 80 mg./l. which represented a 97.3 percent reduction. This was certainly not a typical performance for treatment of the anaerobic lagoon supernatant nor was it considered a safe treatment. With 3,200 gallons of mixed liquor at 9,600 mg./l. of MLVSS followed by a deterioration of settling characteristics so that the solids could only concentrate to 5,000 mg./l. in the return sludge, one could expect the next 3,000 gallons of effluent to also contain at least 5,000 mg./l. of volatile suspended solids. By operating with such a high solids concentration in the mixed liquor, one invites a period of serious trouble.

Perhaps a more typical performance was 85 to 90 percent BOD removal from 1 to 2 gal./min. of supernatant feed when operating with 5,000 to 6,000 mg./l. of MLVSS. This also required almost constant attention to the feed rate, sludge return pump, sludge settling characteristics, and mixed liquor concentration. Even assuming that the plant

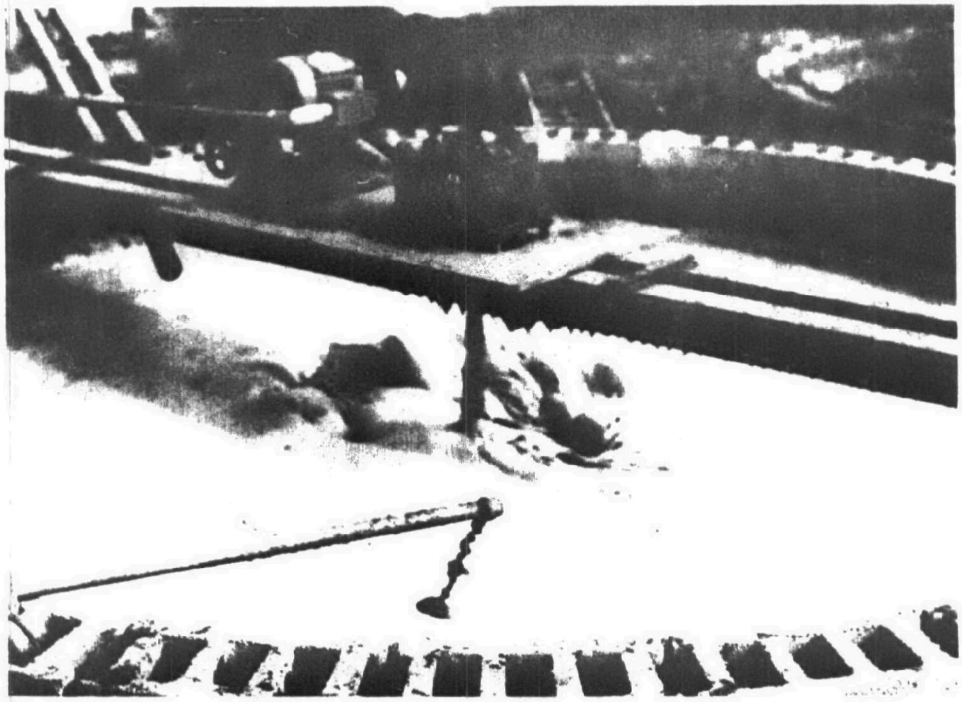


Figure 9. Activated Sludge Aeration Basin with Foam Blanket at Initial Start-up

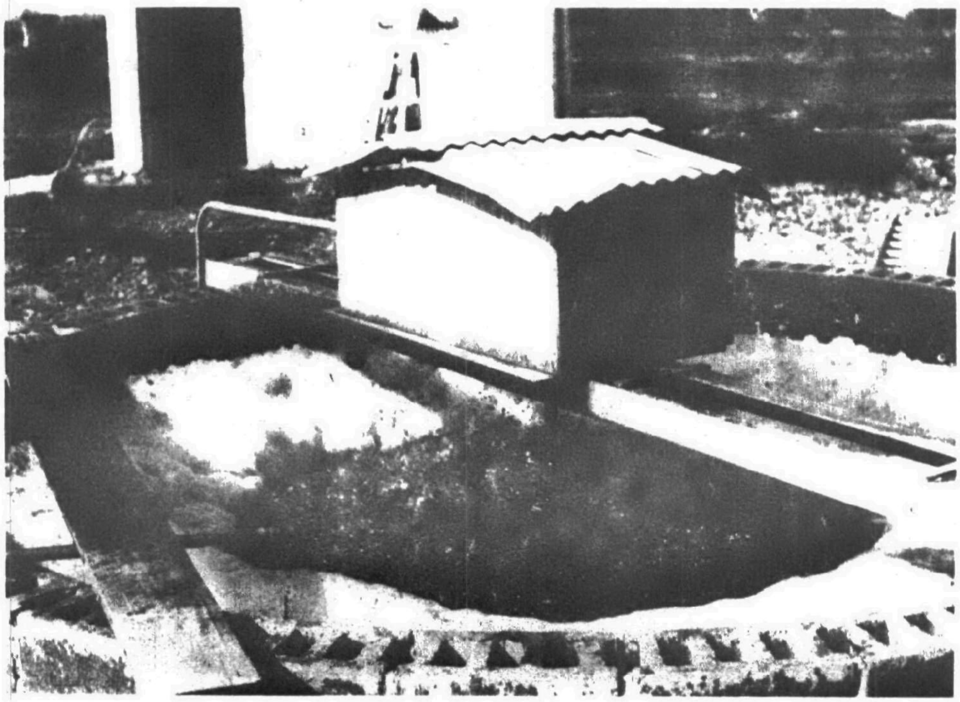


Figure 10. Diminished Foaming in Aerator after Biomass Development

could operate with much less operating attention, however, it is difficult to see much advantage offered to a typical dairy farmer. With 90 percent BOD removal, the effluent would still contain from 300 to 400 mg./l. of BOD which would hardly be acceptable for discharge to any watercourse. It could be used for irrigation water but probably the lagoon supernatant could have been used for that purpose without the expense or trouble of aerobic treatment.

Even with the activated sludge plant operating at the 97.3 percent removal efficiency, the effluent was highly colored. Figure 11 shows the surface of the final clarifier during a period of operation with about 90 percent BOD removal.

In August, the treatment of anaerobic lagoon supernatant alone was discontinued. Wastewater from the milk processing plant was hauled to the equalization tank in an 800-gallon tank truck. This wastewater also contained some of the clean-up water from the milking parlor so it was actually a mixture of milk processing waste and dilute manure

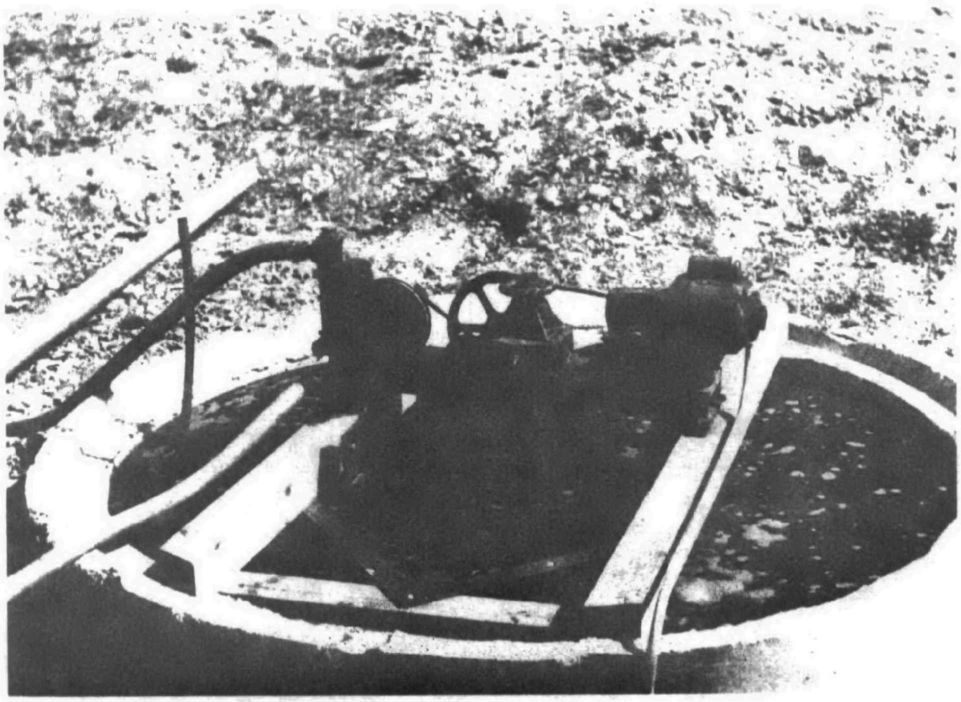


Figure 11. Final Clarifier, Scraper Drive, and Sludge Return Pump. The Effluent Was Always Highly Colored

slurry. It was also screened to remove bits of paper, swabs, etc., and any very coarse solids that might have been in the manure. The strength of the waste batches accumulated in the equalization tank varied from a low of 770 to a high of 2,900 mg. BOD/l. It was difficult to intercept much of this wastewater because the predominant flow was of short duration, occurring mostly during the periods of clean-up of the milking parlor and the processing plant. The same tank truck was also used for field spreading manure slurry from the older cattle housing facilities. This made it difficult to schedule truck availability to coincide with wastewater availability. Because of this problem, the treatment of milk processing wastewater was continued for only 11 days.

The activated sludge biomass, which was acclimated to the anaerobic lagoon supernatant, seemed to show no lag period for acclimation to the process wastewater. In fact, the first 900 gallons of process wastewater was fed at 20 gal./min. in order to refill the final clarifier which had been pumped out to inspect the sludge hopper and scrapers.

The feed rate was varied each day depending upon how much wastewater could be collected and trucked to the activated sludge facilities. Problems with the feed pumps or activated sludge return pump occurred during two nights and this caused some process upsets but performance was reasonably good in spite of this. BOD removals of around 80 percent were achieved with sludge loadings as high as 0.6 lbs. BOD/day/lb. MLVSS. This did not result in a high quality effluent, of course, but there is little reason to doubt that a good effluent quality could be achieved with lower biomass loadings and better process control. The effluent was slightly colored because of the presence of some manure slurry in the wastewater but not nearly as colored as when the anaerobic lagoon supernatant was being treated.

No further testing or operation of the activated sludge treatment facilities was undertaken after the 11 days of operation on the milk processing waste. It seemed rather pointless to attempt to reduce the organic strength of the lagoon supernatant to the point that it could be discharged to any stream because this would require a consistent dependable removal efficiency of at least 98 or 99 percent.

LAND APPLICATION OF MANURE

Table I on pages 36 through 38 presented the dates, amounts, and composition of nearly all batches of manure slurry transferred through the central manure slurry tank. Not included in that table was the slurry pumped from the collection sumps in the new barn to the central manure slurry tank between December, 1968, and March, 1969. This slurry was applied to the northwest corner of field E whenever the central manure slurry tank was about half full.

Figure 12 shows the location of each of the tabulated applications of slurry. When the fourth column of Table 1, headed Destination, contains the letter A, D, or E, it indicates to which of those fields the slurry was applied. The number following the field designation indicates the numbered circle within that field on Figure 12 to which that batch of slurry was applied. There were 16 batch applications (counting the 6-26-69 and 6-27-69 applications as a single batch) to field A, 14 applications to field D, and 18 applications to field E. This amounted to a total slurry volume of 2,421,000 gallons in the 14-month period from June, 1969, through July, 1970. The application to D-1 indicated on December 17, 1969, was more than one tankful but both portions were pumped on the same day and the composition was determined from a proportionally composited sample.

In delivering the slurry from the high pressure chopper pump to a selected application site, the 3-way valves of the underground PVC pipeline were set to pressurize only the pipeline portions conveying flow to the appropriate riser station. This greatly reduced any opportunity for solids to be pumped into a plug in any section of the pipeline. No one can say how many "plug-ups" might have occurred if Tees and gate valves had been used instead of 3-way valves, but it is important to note that no "plug-ups" did occur in the underground line.

Portable 4-inch diameter aluminum pipe was coupled to the selected riser station and strung out to the manure gun set at the center of the desired application circle. The manure gun was capable of "kicking around" in either direction, and was also capable of reversing its direction of rotation at any two selected points of the circle. This made it possible to apply slurry to either a complete circle or to any desired fraction of a circle. Applications E-6 and E-9 are examples of such part circle applications.

The diameter of an application circle and the rate of application were dependent upon the residual pressure at the gun which in turn was governed by the pipeline head loss between the high pressure chopper pump and the manure gun. The high pressure chopper pump and the manure gun were supposedly designed to deliver about 200 gal./min. to a circle of about 200-foot diameter. A venturi constriction in the pump discharge was intended to prevent excessive discharge in the event that a line should rupture or that an aluminum pipe joint accidentally uncoupled while pumping. By observing draw down rates in the central manure slurry tank during field applications, it was determined that the system was delivering about 220 to 230 gal./min. when pumping to points as remote as circle D-1. The diameter of the application circle varied from about 230 feet for a circle as remote as D-1 to as much as 300 feet for circle E-0 close to the pump.

Assuming an approximate 235-foot diameter (one acre of area) for the circles of application in fields A and D, each 10,000 gallons of

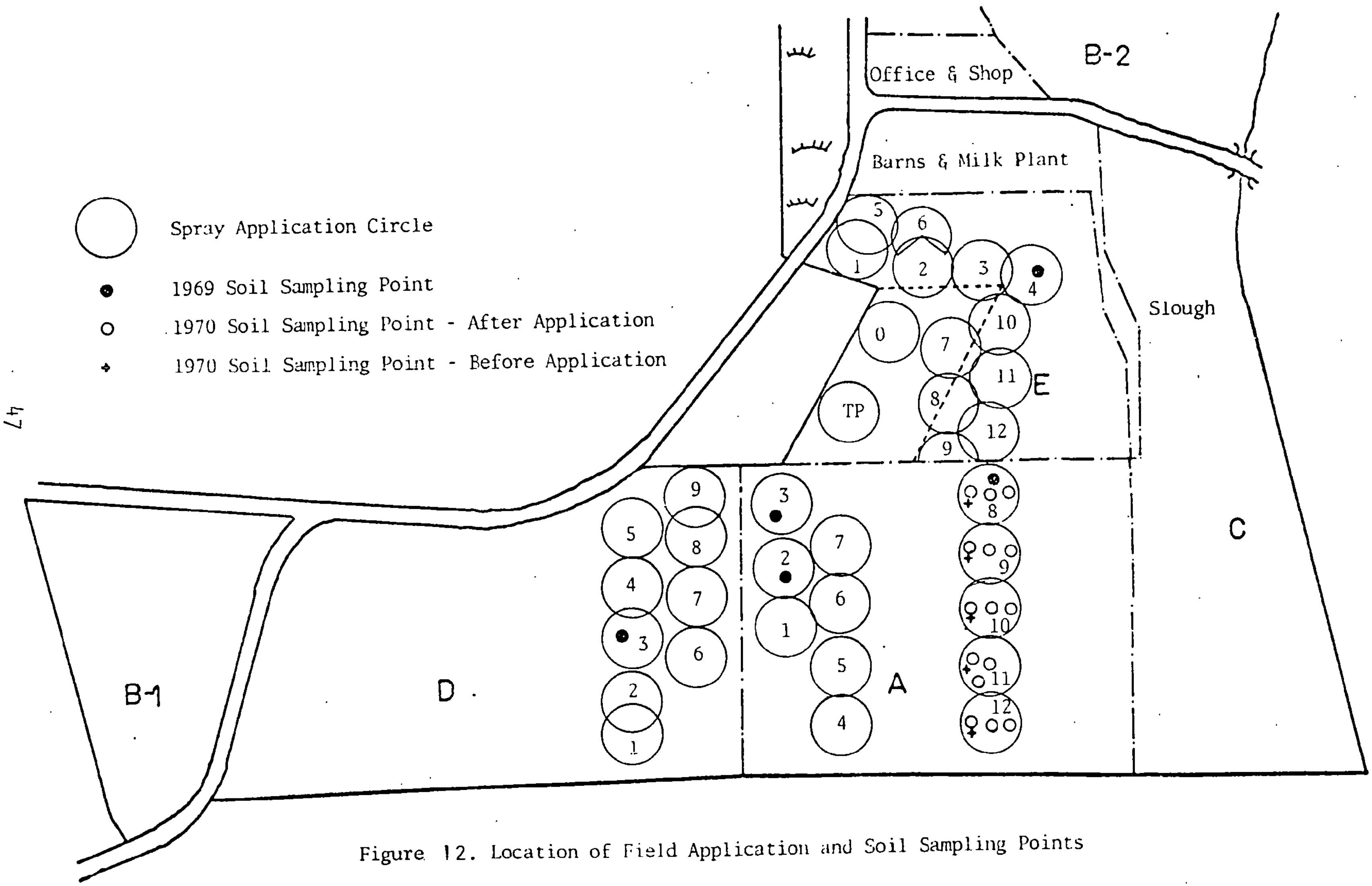


Figure 12. Location of Field Application and Soil Sampling Points

applied slurry would represent an applied liquid depth of 0.367 inches and the mass quantities of solids or nitrogen would represent actual loadings in pounds per acre. Assuming an average diameter of 270 feet for circles of application in field E, each 10,000 gallons of slurry would result in a liquid depth of 0.280 inches. Mass quantities should be divided by 1.31 to obtain mass loadings in pounds per acre for field E.

Figure 13 shows the manure gun in operation. About 12,000 gallons of slurry had been applied at this setting when the picture was taken. Two perpendicular lines of catch pans were strung out on 20-foot centers across circle E-0 on the second day (6-4-69) of application. This was done to evaluate the degree of uniformity of the slurry application within the circle. Comparing the measured volumes caught in the various pans revealed no appreciable difference in the applied volume per unit area except for a sharp decrease to zero application in the outside 15 feet of the circle. There appeared to be a few more large particles of wood shavings in the circular band between 20 to 60 feet out from the gun but no other non-uniformity in solids distribution over the circle could be detected by visual inspection of either the catch pans or the ground surface. The circles were shifted downwind on windy days but still appeared to distribute both liquid volume and solids quite uniformly over the circle.

Figure 13. Manure Gun in Operation. 12,000 Gallons Applied At This Point

Figure 13. Manure Gun in Operation. 12,000 Gallons Applied at This Point

There was a "drift" of fine mist that was detectable some 100 feet beyond the edge of the application circle on still days. You could feel this invisible mist as much as 300 feet away and downwind on windy days. This mist was insignificant so far as slurry distribution was concerned, but it may well be significant in terms of bacterial dispersion. The significance of possible bacterial dispersion needs to be investigated and evaluated.

The almost complete absence of odors around the anaerobic storage lagoons was noted earlier in this report. When manure slurry that had been removed from the anaerobic storage lagoons was being sprayed on the fields, there was usually a noticeable, though not especially objectionable, odor. Because descriptions of the type and intensity of odor are so completely subjective, not everyone agrees on the seriousness of the odor problem. In this writer's opinion, the odors associated with spray application of the dairy manure slurry, even when the slurry was drawn from the lagoons, were well within reasonable limits of acceptability. On quiet, wind-free days, the odors did not seem to persist long enough to be detected at 200 yards from the circle. On windy days, the odors were usually dispersed below detectable limits within 200 to 300 yards. Whenever the manure gun was turned off, the on-ground slurry deposit seemed to be instantly odor free. Admittedly, this is a subjective evaluation and it is not intended to apply to more than this Project and its particular circumstances. Beyond question, some fresh dairy manure can stink and might be expected to smell worse after anaerobic storage, but this did not seem to be true in this case.

FIELD ASSIMILATION AND RUNOFF

The ability of agricultural lands to assimilate or retain an application of manure slurry, and thus prevent a problem of a polluted runoff, will depend upon a multitude of factors. The absence or presence and abundance of vegetation, the amount of soil moisture, the amount of slurry applied, the slope and roughness of the land surface, the particle sizes and characteristics of the top soil and underlying soil profiles, and the prevailing weather are but a few of the probable factors governing the likelihood of polluted runoff during or following the slurry application. Figure 13 showed an application on well tilled soil after about 12,000 gallons (0.34 inches) had been applied. Figure 14 shows the same circle after about 50,000 gallons (1.4 inches) had been applied. Figure 15, on the other hand, shows a similar circle in plowed, but otherwise untilled, land after about 75,000 gallons (2.1 inches) had been applied. When surface puddling and surface flow occurs, the suspended and dissolved solids can flow to low spots to cause uneven distribution of the slurry constituents.

If the water of the slurry can soak into the ground, the residual mat of suspended solids may drain and air dry. Once partially dried, the solids tend to cling or bond to the supporting soil or vegetative

Figure 14. Same Application as in Figure 13 but after 50,000 Gallons

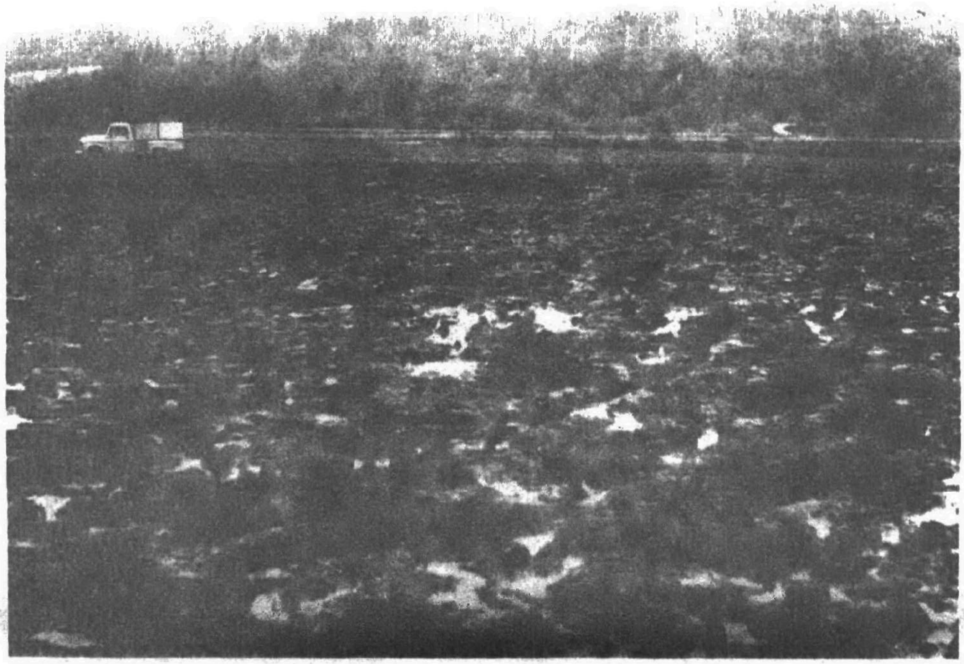


Figure 15, Effect of Rough Plowed Ground on Retention. This Circle Has Received about 75,000 Gallons surfaces even if they are subsequently moistened or even washed by rain. If so much slurry is applied that slow drying puddles form, or if the weather doesn't permit even partial drying, the suspended and colloidal solids are more easily resuspended in surface flows of rain water.

The upper soil profile of the Honor Farm fields is an extremely fine grained clay silt as indicated by the sieve analysis results on soil samples taken from field A and shown in Table 1 of Appendix C. The rate of water percolation or soak-in is quite low even in dry weather, so low volume applications of slurry are desirable to prevent possible runoff either at the time of application or during a heavy rainfall soon after slurry application.

The application of 176,000 gallons (5.0 inches) of slurry to circle E-0 on June 3, 4, and 5, 1969, and of 100,000 gallons (3.7 inches) to circle A-2 on June 26 and 27, resulted in standing puddles and uneven slurry distribution. Circle A-2 required several weeks to dry. Circle E-0 had to be disked in order to dry out early enough to allow seeding of test plots of silage corn and forage grasses. Certainly, any rainfall that would have caused runoff from these areas would have resulted in a loss of manure nutrients and a significant pollutant addition to receiving waters.

A small stream in a man-made channel forms the east and south boundaries of the Honor Farm. This stream flows through other pasture land before it arrives at the northeast corner of field B-2 (identified as inlet). It then flows along the east edge of field B-2, passes through a culvert under the county road, flows southward along the full east edge of field C, then flows westward to form the south boundary of fields C, A, and D, and finally enters the Snoqualmie River at the extreme southwest corner of the Honor Farm. Chlorinated effluent from an aerobic domestic waste lagoon for the Farm began entering the stream at the county road culvert during November or December 1969. A smaller stream, carrying drainage from the area south of the Farm, enters the perimeter stream at the southeast corner of the Farm. One tile drain discharges to the perimeter stream from the east at about the middle of the field C boundary and another enters from the south at about the boundary between fields A and D.

The bacteriological and chemical quality of the perimeter streams were monitored during the Project period. Table 2 of Appendix C presents the periodic bacteriological data. Table 3 of Appendix C summarizes the chemical data. Figures 16, 17 and 18 graphically indicate the fluctuations of COD, nitrates, and orthophosphates for the stream. Table 4 of Appendix C is a tabulation of data on the algae populations found in the stream.

The water of the perimeter stream during all of the summer of 1969 was of higher chemical quality at its point of discharge to the

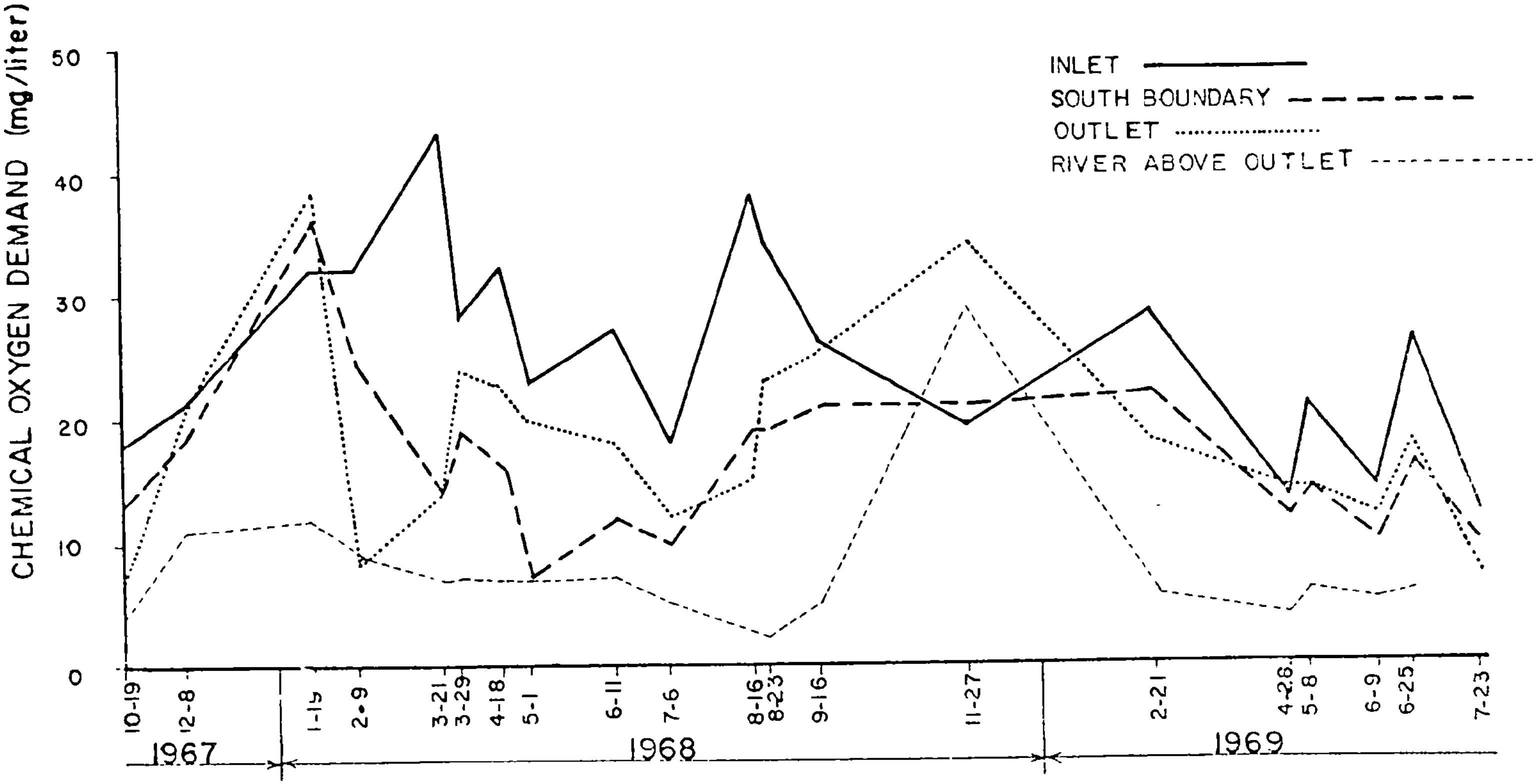


FIGURE 16. CHEMICAL OXYGEN DEMAND IN STREAM DRAINING STATE FARM

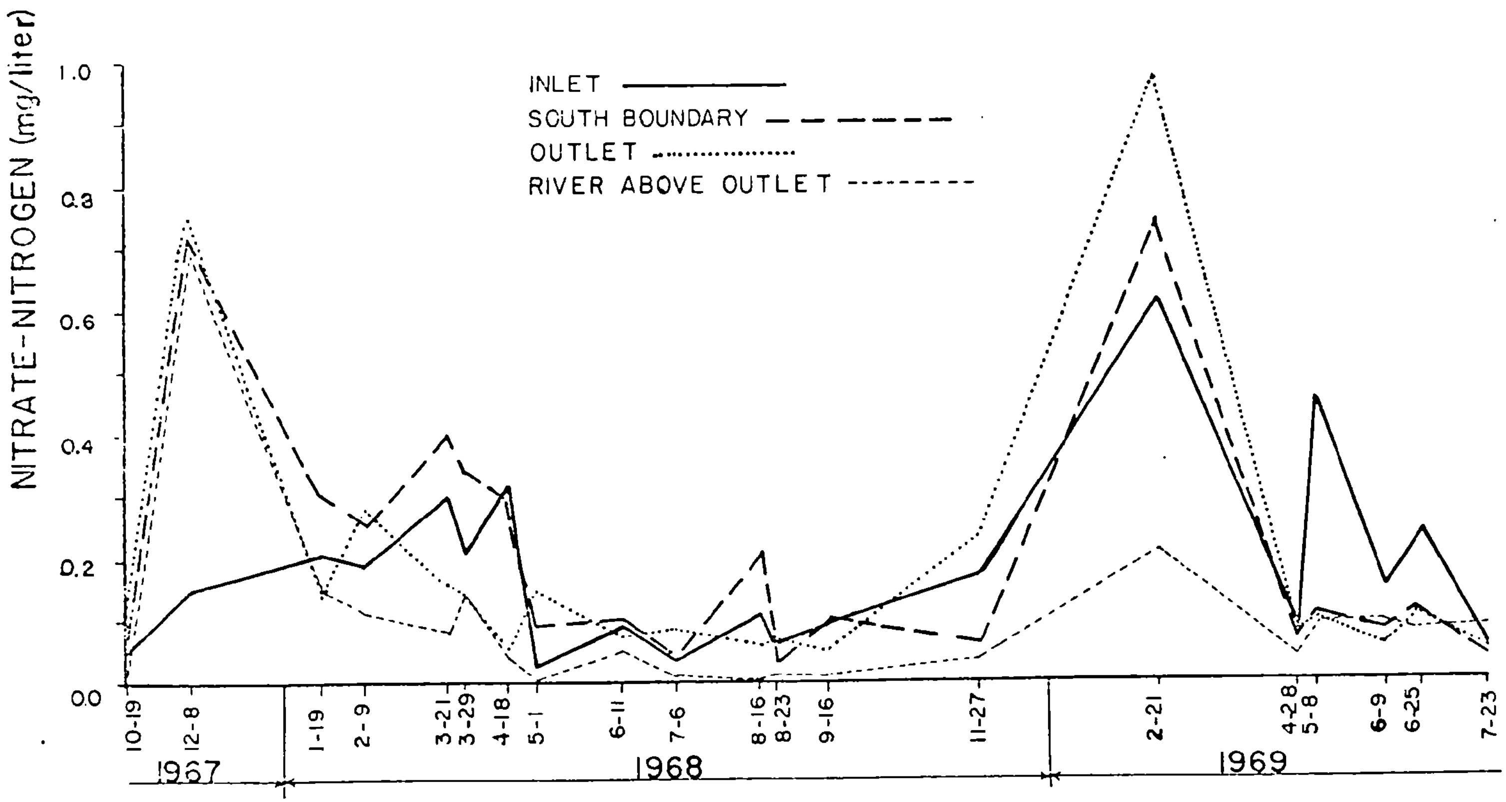


FIGURE 17. NITRATE-NITROGEN IN STREAM DRAINING STATE FARM

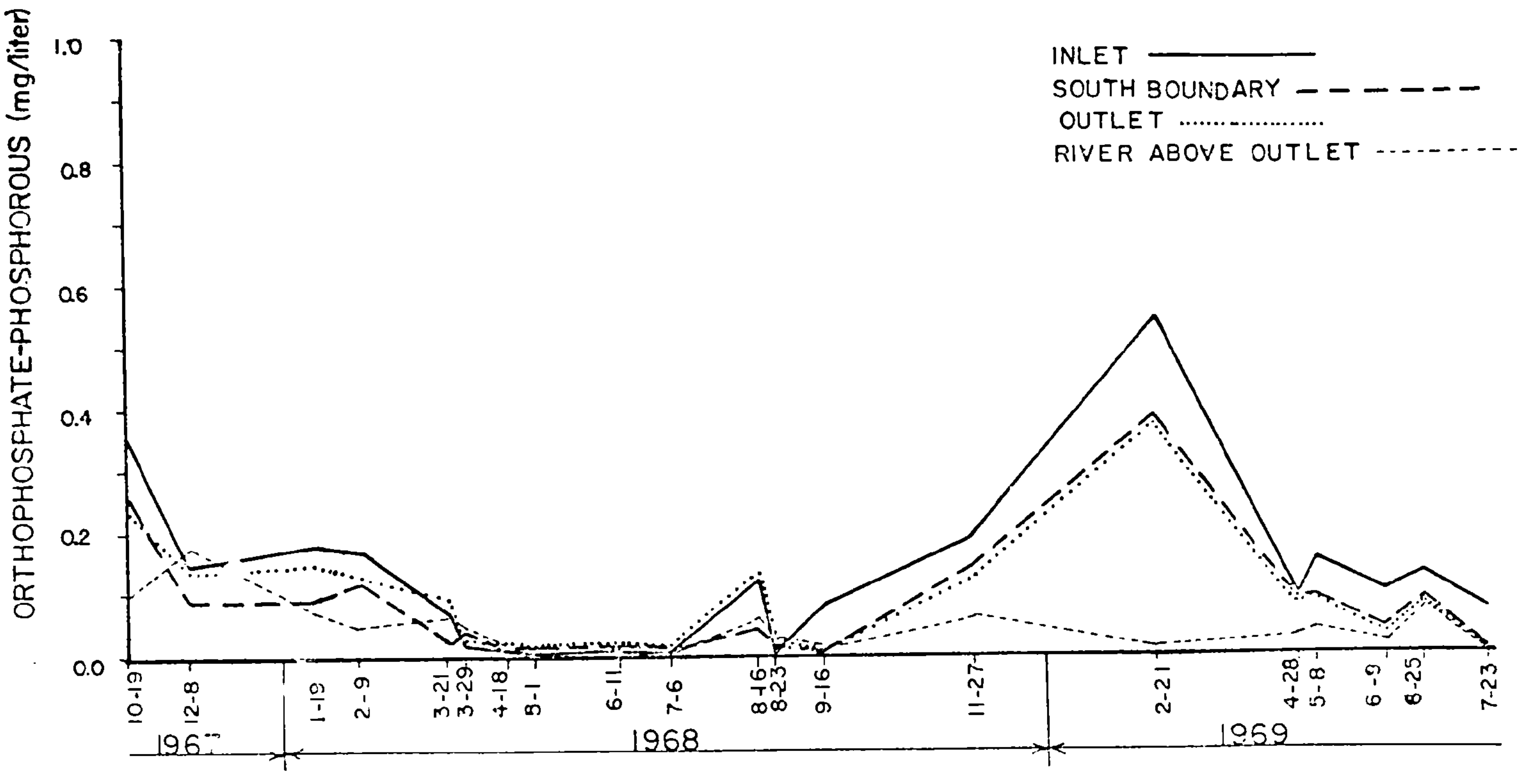


FIGURE 18. ORTHOPHOSPHATE-PHOSPHOROUS IN STREAM DRAINING STATE FARM

Snoqualmie River than at the inlet to the Farm. This had not always been true for nitrates or orthophosphates during the previous summer.

The bacteriological data tend to confirm the adverse effect to be expected from heavy manure applications during the wet winter months. Even though field D was rough surfaced from plowing without further tilling, it was not capable of retaining the heavy slurry applications imposed on it starting on December 17, 1969. The count for total coliforms, fecal coliforms, and fecal streptococci were all high on December 18, 1969, following the 81,500 gallon application to circle D-1 on December 17. These counts remained generally higher than for upstream points throughout the winter months indicating a runoff contribution from field D.

In contrast to this, a great amount of slurry was applied to field A in the summer and early fall months of 1969 without such continuous and dramatic impact. The stream quality data are not sufficiently extensive to prove the environmental superiority of summer time slurry application to crop land, as compared to winter applications, but they do support that contention.

Data was collected to determine vertical distribution of some pollutants following summer spray applications of manure slurry to field A. A single test hole was dug in five different circles on July 15, 1970, prior to test applications of manure slurry. Samples were collected at depths of 0, 0.5, 1, 2, and 3 feet and were then analyzed for soil particle size, soil moisture, chloride ion concentration, total coliforms, fecal coliforms, and fecal streptococci. Following the applications of various amounts of manure slurry, three test holes were made in each circle to obtain soil samples for similar determinations (except particle size). The tabulation below shows the amounts of slurry applied plus the elapsed time between slurry application and post-application soil sampling.

Circle	Date Slurry Applied	Date Soil Sampled	Elapsed Time (Days)	Slurry Amount Applied (Gallons)	(Inches)
A-11	7-22-70	7-23-70	1	30,000	1.10
A-10	7-22-70	7-24-70	2	35,000	1.28
A-9	7-24-70	7-27-70	3	25,000	0.92
A-8	7-24-70	7-28-70	4	40,000	1.47
A-12	7-21-70	7-28-70	7	56,000	2.06

All of these circles had received manure slurry applications in September or October of 1969. The pre-application tests revealed from 2,000 to 100,000 non-fecal coliforms per gram of soil at the surface, not more than 400 non-fecal coliforms per gram at the 0.5-foot depth, and no coliforms at greater depths. Fecal coliforms and fecal streptococci were not detected at any depth before the test slurry applications. Table 5 of Appendix C shows the numbers of organisms detected at the various depths in the various test holes following the test slurry applications. The applied slurry had contained an average of 650,000 total coliforms and 330,000 fecal coliforms per 100 milliliters. Table 6 of Appendix C indicates the pre- and post-application chloride concentrations of the soil. The results of sieve analyses (as mentioned earlier) are to be found in Table 1 of Appendix C. Soil moisture levels ranged from 13 to 40 percent (average 27%) before the test applications and were not significantly changed after the slurry applications.

The chloride data indicates that moisture, carrying soluble chloride ions, did penetrate as far as 3 feet down in the soil profile even though the highest chloride increase was at the surface.

Only hole 3 in circle A-10 indicated penetration of fecal streptococci as far down as 3 feet. Hole 1 of circle A-9 showed fecal streptococci penetration to the 2-foot depth but the much lower count at the 1-foot depth makes the data for the 2-foot depth seem questionable. With these two exceptions, fecal streptococci appear to be totally filtered out in the top 2-foot layer of soil. The penetration of both fecal and non-fecal coliforms was only slightly greater. Certainly, the data suggests that the tight clay-silt soil does strongly filter out the indicator organisms.

Another point of interest is the apparent rapid rate of die-off of organisms even at the surface as indicated in Table 5 of Appendic C. Both circles A-10 and A-11 received the slurry applications on the same day. Circle A-10 probably received an average of 137,000 coliforms and 70,000 fecal coliforms per square inch while circle A-11 received only 117,000 and 60,000, respectively. The extra day of elapsed time before sampling for circle A-10, however, appears to account for a significant reduction in all organisms at the surface. Several other observations of die-off rate after summer applications of slurry indicated that less than 10% of the organism survive for even as long as one day after the application unless standing puddles are created.

CROP GROWTH RESPONSE AND NITRATE FEEDING EXPERIMENT

In considering the disposal of dairy manure on crop land, there are many factors that should be considered. The environmental impact on air, ground water or surface water are important to all, including the dairyman. In addition to these factors, the dairyman must also consider the response of the crop--whether it be pasture, harvested forage, or grain--to the manure application. There is concern for both quantity and quality of the crop or crops. He may have a situation where he either wants the maximum crop yield from a limited amount of manure or where he wants the maximum manure disposal per unit area without unacceptably adverse crop response. High crop yields hopefully would also give high nutrient extraction and thus leave fewer nutrients to be leached to ground water or flushed to surface waters in the non-growth seasons.

One serious concern that has been expressed is that heavily fertilized or manured land may yield back feed or forage that is toxic to livestock because of abnormally high nitrate-nitrogen concentrations. Some have felt that this "nitrate-poisoning" can cause a decline in milk production, loss of appetite, abortion, and generally poor health in dairy herds.

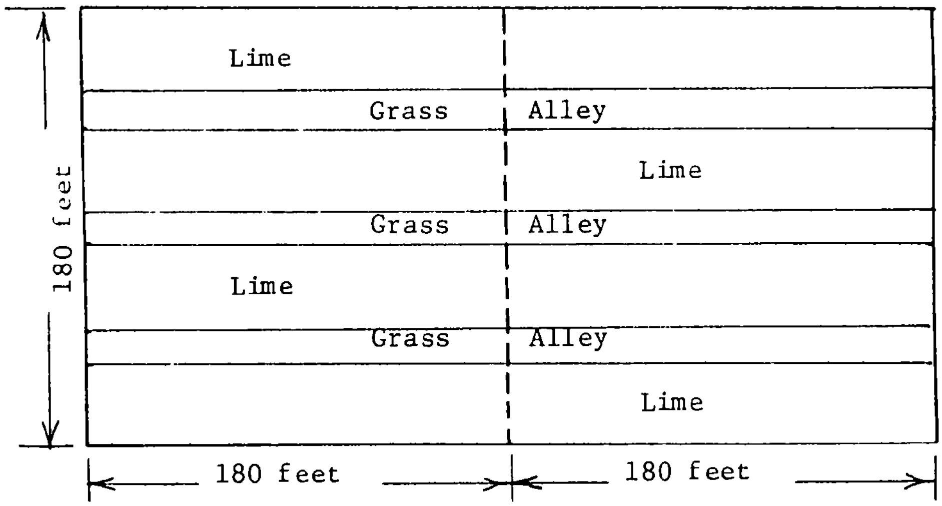
Construction of the main demonstration facilities at the Honor Farm were not far enough advanced to allow controlled manure applications for the 1968 growing season. As a prelude to full-scale investigation of the impact of dairy cattle waste on forage production and soil properties, variable commercial nitrogen treatments were applied to test plots of silage corn. (See Figure 19). Corn was grown at 20, 30, and 40 thousand plants per acre. Nitrogen (N) rates used were 50, 100, 200, and 400 pounds per acre with two levels of phosphorus (P) and potassium (K) fertilization. All N-P-K combinations and population variables were established with zero and 3-ton lime applications. The treatments were replicated four times.

Plant samples from the test plots and from the regularly grown silage corn fields were taken at 2-week intervals commencing August 20 and continuing until mid-October when the corn was harvested. Five sets of values were obtained for each sampling period. The stalk was divided at the ear position and samples taken as: 1. lower stalk, 2. lower leaves, 3. upper stalk, 4. upper leaves, and 5. whole plant. The corn was in the early tassel stage at the time of the first sampling and in the early dent stage when last sampled. All samples were analyzed for nitrate-nitrogen concentrations.

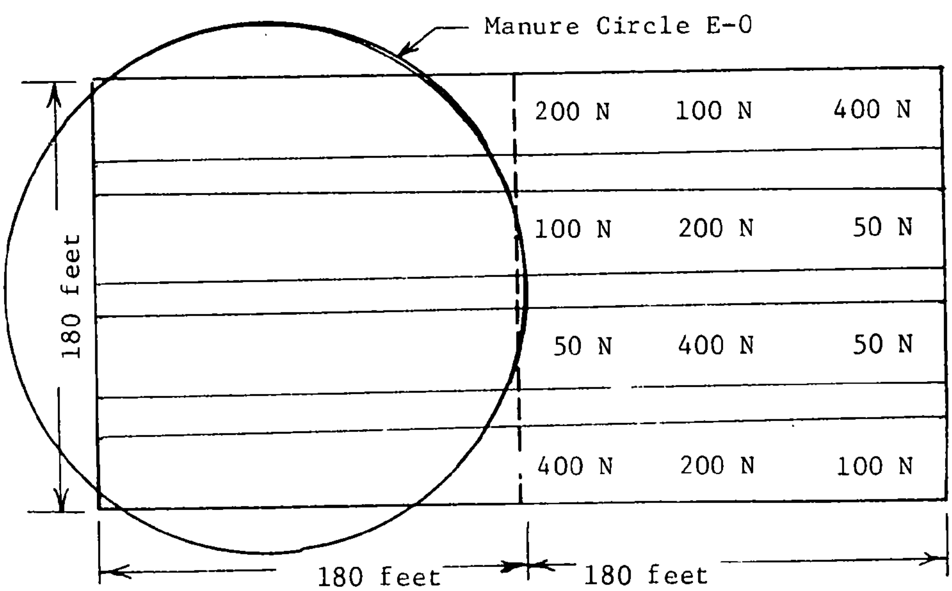
The nitrate-nitrogen concentrations were low for all plant sections with the 50 pound nitrogen treatment. Values were higher for the intermediate rates and highest with the 400 pound nitrogen treatment. The lower stalk section of the 400 pound nitrogen treatment was the only position to show nitrate-nitrogen values above the so-called "critical" level of 0.21% by the time for normal harvest. Whole plant values were only 0.10%. Higher population corn had higher nitrate values than did low population corn.

Prior to the usual time for harvesting and storing corn silage, however, samples of the immature corn from both test plots and regular corn fields showed very high nitrate-nitrogen concentrations. Values as high as 0.59% (dry weight basis) nitrate-nitrogen concentrations were found. This presented an opportunity to examine the possible response of dairy cattle to suspected "nitrate-poisoning" conditions.

Three groups of dairy cows, one group of pregnant heifers, and a set



1968 Test Plot Layout
Only Commercial Fertilizer Was Applied



1969 Test Plot Layout

Figure 19. Lay-Out of Test Plots for 1968 and 1969 Agrinomic Studies

of steers were assigned to a feeding trial to challenge them with the high nitrate corn silage. Field conditions permitted the freshly cut silage trial to continue for 32 days. Periodic sampling for nitrates in the green-chopped silage throughout the trial indicated that nitrate levels decreased as the corn matured. Milk production was maintained at a high level throughout the 32-day period with a minimum of fluctuation. No signs of stress were noted in any group and the steers made normal weight gains. The group of heifers did not exhibit any abnormalities during the trial during which two of them calved normally. It was concluded that the levels of nitrate fed were not high enough to reduce animal growth, lower milk production, or influence reproduction.

Although nitrate-nitrogen concentrations did increase in the corn as the amount of fertilizer nitrogen was increased, the levels achieved did not remain above the "critical level" as the corn advanced toward maturity. In terms of total nitrogen removal per acre by the crop, the largest removal occurred with the 40 thousand corn plants per acre which had received 400 pounds of nitrogen and the high phosphorus and potassium levels. The use of lime did not influence nitrogen removal in this trial.

In 1969, a heavy manure application was made to circle E-0 in the test plot area (circle E-0 in Figure 12 or on Table 1) as shown in the lower diagram of Figure 19. The soil was moderately dry when the 176,000 gallons (5 inches) of slurry was applied on June 3, 4, and 5.

The objective was to evaluate the application of heavy manure loading on the previous year's non-tilled corn land and also on the ryegrass-New Zealand white clover seeding present in the alleys. The undigested, ligneous material in the manure load provided a sealing effect and stopped infiltration so that excessive surface run-off became a problem. There was no effective difference in infiltration between the bare soil from the previous year's corn crop and the alleyways with the grass-clover stand. Small depressions accumulated manure slurry and became in effect "micro anaerobic lagoons." These small ponds of manure encrusted at the surface and dried out very slowly.

In order to proceed with any test planting operation in 1969, it became necessary to till through these manure ponds. A large tractor-driven rotovator was used to mix the manure slurry with the soil. During the mixing operation, dry soil particles would frequently be thrown out, even though pond depth overhead may have been 8 to 10 inches.

The delay in planting caused by these problems made it doubtful that corn could mature during the remainder of the season. Planting was made anyway as there was some doubt that germinating plants would survive the heavy manure load that had been applied. The total application of manure slurry would be equivalent to about 150 tons per acre of fresh excrement. The even distribution achieved by the manure gun was negated to some extent by the surface flow and ponding.

The crop of Idahybrid 216 silage corn germinated rapidly and grew well throughout the remaining portion of the season. There were no skips in rows due to poor germination or subsequent burning by excessive salts. The half of the plot area not covered by manure received commercial nitrogen rotovated into the soil at rates as indicated in Figure 19. Corn growth was much faster and the total obtained was substantially greater with manure than with 400 pounds per acre of nitrogen. Phosphorus and potassium were applied in ample amounts to remove them as variables. Quality of the feed as measured by nitrate-nitrogen concentration was satisfactory, and was not substantially different than that experienced with 200 and 400 pound applications of commercial nitrogen. It is assumed that the "available" nitrogen rate as applied by manure was about 400 pounds per acre. The rate of nitrogen transformation from organic and ammonia forms to nitrate is not known, however, and the actual amount could have been more or less than the 400 pounds assumed. No yield differences were obtained with commercial nitrogen rates above 100 pounds.

The fiber content in the manure created problems when applied to grass-legume forages. It formed a coating over the foliage and effectively stifled growth. The heavier applications selectively removed clover and broad-leaved weeds from the stand. Ryegrass, with its narrow leaves and upright growth habits, performed well under heavy loading. The upper limit that can be applied to established forage stands including clover appears to be about 25,000 gallons per acre, or just under one acre-inch. This is best applied to stubble soon after harvest.

Crop production experience in 1970 was similar to that of 1969. Corn fertilized with manure produced one-third more silage corn and matured 2 weeks earlier than did corn grown with commercial fertilizer. No stand loss was experienced from the heavy loadings which were rotovated into the soil ahead of planting.

Figure 20 shows a typical corn stalk from the manured circle on the left side and one from the commercially fertilized test plot on the right. In Figure 21, the larger ears show the earlier maturity achieved on the manured plot as compared to the small slow maturing ears from the commercial fertilizer plots.

Figure 20. Comparison of Whole Corn Stalks.
Left=Manured Test Plots, Right=Commercial Fertilizer

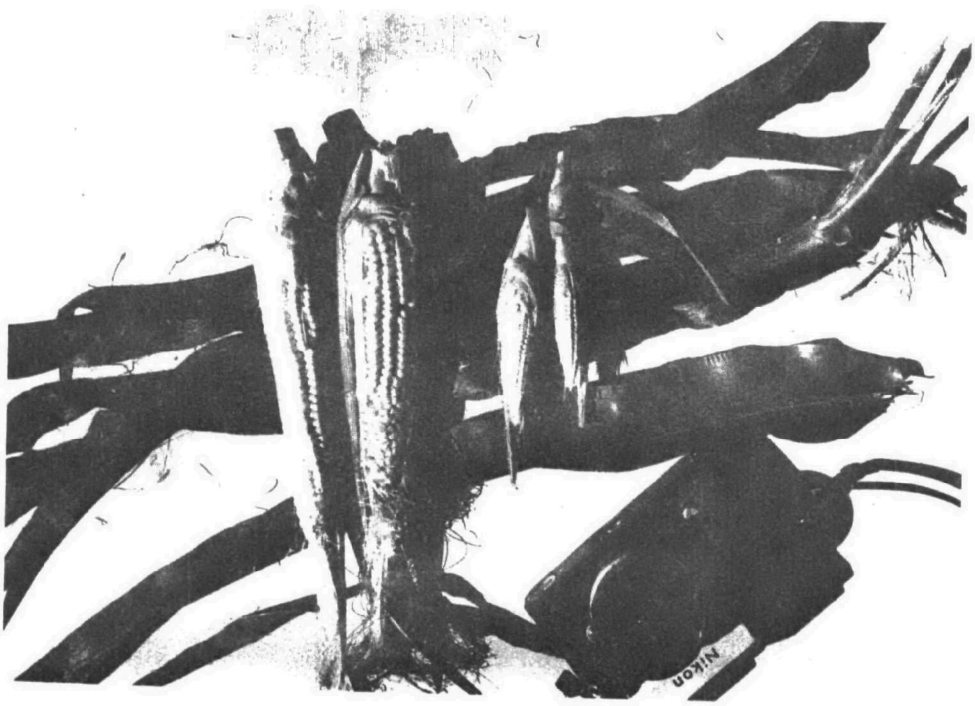


Figure 21. Maturity Comparison. Large Ears from Manured Test Plots, Small Ears from Commercial Fertilizer Plots

SECTION VI

ACKNOWLEDGMENTS

The cooperation and participation of the Farm Industries section of the Washington State Department of Social and Health Services (formerly in the Washington State Department of Institutions) in establishing, supporting and conducting this Project has been sincerely appreciated. Mr. Howard Magnuson, Mr. Richard Englund, and Mr. Harry Ingersol have contributed much time, talent, and patience to the Project Director during and following the conduct of the Project. The efforts of Mr. Ross Smith of Farm Industries to accomplish construction progress under conditions of bad weather, labor and materials shortages, and repeated changes in plans is also gratefully acknowledged.

The tireless efforts of Mr. James Hudson and Mr. Koorosh (Danny) Fouladpour, while acting as Resident Project Engineer, is acknowledged with this writer's sincere thanks. Thanks also go to Mr. Sid French for his conduct of mastitis tests at milking time whether that time be morning, noon or night and for his willingness to tackle any other task requested. Special gratitude is extended to Marge, Sharon and Kay, respective wives of these men, for their tolerance and understanding.

Mr. August Mueller of the Washington State University Albrook Hydraulics Laboratory devised the pilot models and conducted the tests for the hydraulic "brooms" as reported here. What he can't build from the junk yard probably isn't needed anyway.

Dr. Grady Williams, Extension Dairy Specialist, and Mr. Darrell Turner, Extension Soil Scientist, (both with the Western Washington Research and Extension Center at Puyallup) provided leadership and much effort for the high nitrate forage feeding experiment reported here. Mr. Turner planned and supervised the agronomic test plot studies. Both men contributed guidance and advice relative to their areas of expertise throughout the life of the Project and during preparation of this manuscript.

The monitoring of water quality in the perimeter stream and the sampling and analysis of soil surfaces and profiles for chemical and bacteriological penetration was conducted by Dr. William Funk and Dr. Donald Johnstone. Their assistance in developing this manuscript is also deeply appreciated.

The cooperation and patience of Dr. Surinder Bhagat, Head of the Sanitary Engineering Section, and of Professor Leon Luck, Chairman of the Department of Civil Engineering, during this long and late period of manuscript preparation is sincerely appreciated. The skill

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and dedication of Miss Susan Taylor, who typed this manuscript, merits this writer's sincerest thanks.

The significant financial support of this Demonstration Project initially provided by the Office of Solid Wastes, Public Health Service, Department of Health, Education, and Welfare, and by successor Federal Agencies is hereby gratefully acknowledged by the writer on behalf of Washington State University.

SECTION VII

LIST OF PATENTS AND PUBLICATIONS

PATENTS

No patents resulted from this Demonstration Project.

PUBLICATIONS

Proctor, Donald E., "The Management and Disposal of Dairy Manure," Proceedings of the 23rd Purdue Industrial Waste Conference, Lafayette, Indiana, May 1968.

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Turner, Darrell O., "Disposing of Animal Wastes," Crops and Soils Magazine, February-March, 1971.

Mueller, August C., "An Investigation to Develop Dairy Manure Flushing Methods," A Special Problem Report to the Faculty of Civil Engineering, Washington State University, May 1968. (Available from the Department of Civil and Environmental Engineering, Washington State University, Pullman, Washington 99163.)

SECTION VIII

APPENDICES

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Table A-1

Summary of Recent Rainfall and Temperature Data in the Project Vicinity*

Range No./Yr.	Number of Days of Rainfall Within Indicated Range (inches) 0.01/0.05	0.05/0.25	0.25/0.50	0.50/0.75	0.75/1.00	1.00/1.25	1.25/1.50	Over 1.50	Total for Month (in.)	Temperature Range Data Maximum	Average Maximum	Degree Days (Base = 65°F)	Minimum	Average Minimum
9/66	4	1	1	2	-	-	-	-	1.83	82	71.9	111	41	50.4
10/66	5	7	1	3	-	1	-	-	4.13	80	61.3	393	32	42.8
11/66	5	9	4	2	1	2	-	-	7.20	64	51.1	605	26	38.1
12/66	4	7	11	3	1	-	-	1	9.31	55	47.8	652	29	39.6
1/67	1	10	10	4	-	-	1	1	10.78	57	46.9	714	26	36.5
2/67	2	9	2	1	1	1	-	-	4.06	60	50.2	607	25	43.1
3/67	8	5	4	2	1	-	-	-	4.06	57	50.4	691	24	34.6
4/67	4	12	1	-	1	-	-	-	3.19	66	56.0	555	29	36.5
5/67	3	3	2	-	-	-	-	-	1.26	82	65.1	303	38	44.9
6/67	2	2	1	1	-	-	-	-	1.09	90	75.5	69	44	50.8
7/67	1	2	-	-	-	-	-	-	0.27	87	77.6	41	44	50.5
8/67	1	-	-	-	-	-	-	-	0.02	94	83.6	13	43	51.6
9/67	3	5	1	1	-	-	-	-	1.63	91	76.3	82	40	49.2
10/67	5	8	6	5	1	1	-	-	8.44	73	61.3	352	34	45.4
11/67	9	6	4	1	-	-	-	-	3.10	62	52.8	588	25	37.4
12/67	4	10	4	2	1	-	-	2	9.03	54	44.2	791	19	34.3
Yr. Total	43	72	35	17	5	2	1	3	46.93					
1/68	9	7	3	2	1	1	1	-	6.95	58	45.2	779	19	33.9
2/68	2	4	6	1	-	-	-	-	3.46	74	55.9	580	22	33.6
3/68	- - - - - - - - - - - - - - Data not Available - - - - - - - - - - - - - - -								5.74	- - - - - - - Data not Available - - - - - - -				
4/68	4	9	3	3	-	-	-	-	3.82	76	57.6	511	27	37.9
5/68	3	6	-	1	1	-	-	-	2.22	78	66.3	296	34	44.1
6/68	4	4	1	1	-	1	-	1	4.35	82	69.6	170	41	48.7
7/68	1	1	2	1	-	-	-	-	1.46	89	78.9	35	47	51.7
8/68	5	4	1	-	3	1	-	-	4.78	89	73.2	98	45	51.6
9/68	5	4	4	-	-	-	-	1	3.97	81	68.4	183	40	49.2
10/68	7	9	6	3	-	-	-	1	6.77	76	59.1	454	32	41.3
11/68	5	10	4	1	1	-	2	-	7.00	60	51.2	618	27	37.1
12/68	2	5	7	4	4	1	-	1	11.44	51	40.3	943	1	28.4
Yr. Total	- - - - - - - - - - - - March Data not Available - - - - - - - - - - - - - - -								61.96	- -				

Table A-1 (Cont.)

Summary of Recent Rainfall and Temperature Data in the Project Vicinity*

Range	Number of Days of Rainfall Within Indicated Range (inches)								Total for Month (in.)	Temperature Range Data				
	0.01/0.05	0.05/0.25	0.25/0.50	0.50/0.75	0.75/1.00	1.00/1.25	1.25/1.50	Over 1.50		Maximum	Average Maximum	Degree Days (Base = 65°F)	Minimum	Average Minimum
Mo./Yr.														
1/69	1	15	6	3	-	-	-	-	6.48	54	36.6	1,041	7	25.6
2/69	6	5	3	-	1	-	-	1	4.08	56	48.0	712	19	30.8
3/69	4	6	-	1	1	-	-	-	2.64	70	56.6	602	23	34.1
4/69	6	9	2	3	-	-	-	-	4.08	74	58.8	479	30	38.8
5/69	2	2	2	1	-	1	-	-	2.61	92	70.2	248	34	44.3
6/69	4	2	2	-	1	-	-	-	2.19	90	75.4	71	45	53.5
7/69	4	3	1	-	-	-	-	-	0.79	85	75.9	83	43	49.4
8/69	5	3	-	-	-	-	-	-	0.39	83	72.8	128	40	48.9
9/69	4	7	1	4	1	2	-	-	6.82	80	68.2	187	35	49.1
10/69	5	4	3	1	1	-	-	-	2.98	77	61.3	432	25	40.4
11/69	9	5	2	1	-	-	-	1	4.00	65	51.6	606	21	37.6
12/69	6	7	3	3	2	2	-	-	7.70	57	47.7	714	25	35.6
Yr. Total	56	68	25	17	7	5	0	2	44.76	-	-	-	-	-
1/70	3	5	4	5	3	-	1	-	8.67	58	45.3	793	20	33.2
2/70	3	4	1	1	1	-	-	-	2.23	69	54.7	558	26	35.0
3/70	10	6	3	1	1	-	-	-	3.84	64	55.2	612	23	34.9
4/70	6	11	2	1	1	-	-	-	4.13	65	55.3	545	28	37.9
5/70	4	6	1	1	-	-	-	-	1.86	82	64.9	350	35	42.0
6/70	3	4	-	-	-	-	-	-	0.64	93	73.7	141	40	48.2
7/70	1	-	1	1	1	-	-	-	1.78	89	76.5	85	43	49.5
8/70	1	1	1	-	-	-	-	-	0.57	85	75.4	82	42	49.[illegible]
9/70	2	5	2	3	-	-	-	-	3.55	83	66.7	268	30	44.8

*This data derived from Climatological Data, U.S. Department of Commerce, for the Washington State Reformatory Station near Monroe, Washington. This station is approximately 3 miles north of the Project site and 90 feet higher in elevation. Rainfall at the Project site is probably slightly higher than at this weather station. Also, the extreme maximum (and minimum) temperatures at the Project site may usually be expected to be as much as 5°F higher (and 5°F lower) than at this weather station.

Table A-2

Thirty-Year Summary of Means and Extremes of Rainfall and Temperature Data in the Project Vicinity*

(1931-1960)

Month	Precipitation (inches)		Temperatures (°F)					
			Extremes		Means			
	Monthly Means	Maximum Days	Record High	Record Low	Daily High	Daily Low	Daily Mean	Degree Days (Base = 65°F)
Jan.	6.03	2.02	72	-3	44.0	31.9	38.0	843
Feb.	5.01	2.45	73	-2	48.2	33.6	40.9	678
Mar.	4.59	1.48	77	13	53.2	36.1	44.7	632
Apr.	3.21	1.23	85	24	60.9	39.8	50.3	444
May	3.01	1.72	92	29	67.2	44.5	55.9	295
June	2.53	2.10	96	34	71.3	49.1	60.2	159
July	1.04	1.62	99	33	76.7	51.5	64.1	74
Aug.	1.34	1.70	101	39	75.8	51.5	63.6	71
Sept.	2.49	2.20	94	31	70.3	48.2	59.2	186
Oct.	4.65	1.90	84	23	60.9	43.4	52.2	387
Nov.	6.32	2.15	72	5	51.1	37.4	44.2	642
Dec.	6.54	2.60	66	10	46.3	35.0	40.7	763

Maximum Annual Rainfall = 62.07 inches (1950)
Minimum Annual Rainfall = 25.71 inches (1952)

*This data derived from Climatological Data, U.S. Department of Commerce, for the Washington State Reformatory Station near Monroe, Washington. This station is approximately 3 miles north of the Project site and 90 feet higher in elevation. Rainfall at the Project site is probably slightly higher than at this weather station. Also, the extreme maximum (and minimum) temperatures at the Project site may usually be expected to be as much as 5°F higher (and 5°F lower) than at this weather station.

Table A-3

Spot Observations of Temperatures and Humidity
Effects of Totally Roofed Confinement Area

Dates	Time of Observation A=AM, P=PM	Weather	Temperatures (°F)(1) Inside New Barn	Inside Old Barn	Outside	Relative Humidity (%)(1) Inside New Barn	Outside	Approx. Number of Cows
7/11/68	9 A	Fog	64	-	67	69	70	60
7/12/68	10 A	Rain	59	-	54	80	90	60
7/15/68	10 A	Cloudy	60	-	64	74	70	60
7/16/68	1 P	Sunny	69	-	72	59	59	60
7/17/68	10 A	Sunny	60	-	60	66	60	60
7/18/68	10 A	-	65	-	63	76	76	60
7/24/68	10 A	Fog	71	-	64	76	62	100
7/25/68	4 P	Sunny	74	-	74	74	34	100
7/26/68	1 P	-	72	-	74	61	42	100
7/29/68	10 A	Sunny	73	-	72	60	56	100
7/30/68	2 P	Sunny	74	-	78	56	49	100
8/1/68	4 P	Sunny	80	-	86	48	39	100
8/2/68	2 P	Sunny	70	-	76	63	31	100
8/5/68	3 P	Cloudy	64	-	60	70	66	100
8/6/68	2 P	Sunny	67	-	74	50	42	100
8/8/68	4 P	Sunny	70	-	78	53	54	100
8/13/68	2 P	Cloudy	62	-	66	69	58	100
10/2/68	8 A	Fog	43	43	44	90	94	160
10/3/68	9 A	Fog	48	50	52	96	94	160
10/4/68	9 A	Rain	54	54	52	88	90	160
10/7/68	8 A	Cloudy	50	50	54	70	76	160
10/8/68	8 A	Fog	39	41	37	94	96	160
10/9/68	8 A	Cloudy	44	44	41	86	94	160
10/10/68	8 A	Rain	48	50	48	-	-	160
10/14/68	9 A	Cloudy	48	44	44	96	96	160
10/15/68	9 A	Rain	52	52	48	88	78	160
10/16/68	9 A	Cloudy	44	43	41	86	94	160
10/17/68	9 A	Cloudy	48	48	46	80	94	160
10/18/68	9 A	Fog	43	44	41	96	96	160
10/21/68	9 A	Fog	43	43	41	88	96	160
10/22/68	8 A	Fog	55	54	48	94	96	160
10/23/68	8 A	Rain	55	57	55	88	88	160
10/25/68	10 A	Rain	59	59	57	90	90	160
10/28/68	8 A	Cloudy	55	54	54	82	82	160
10/29/68	8 A	Rain	54	55	52	90	92	160
11/4/68	9 A	Fog	37	37	34	94	98	160
11/6/68	9 A	Fog	36	36	32	94	98	160
11/7/68	8 A	-	52	48	48	80	80	160
11/8/68	8 A	Rain	52	50	48	88	88	160
11/12/68	2 P	Cloudy	54	57	50	82	76	160
11/14/68	8 A	-	50	46	43	94	88	160
11/15/68	10 A	Rain	43	41	39	84	86	160
11/18/68	10 A	Rain	52	50	48	88	88	160
11/19/68	9 A	Cloudy	54	52	50	94	88	160
11/20/68	9 A	-	57	57	54	76	82	160
11/21/68	9 A	Rain	48	48	44	80	80	160
11/22/68	8 A	Rain	50	50	48	86	88	160
11/25/68	8 A	Rain	48	52	46	94	94	160
11/26/68	8 A	Cloudy	46	48	46	86	80	160
11/27/68	8 A	Rain	52	52	50	80	76	160
12/2/68	9 A	Rain	41	41	41	88	94	160
12/4/68	9 A	Fog	39	37	36	94	100	160
12/5/68	8 A	Cloudy	39	41	39	78	72	160
12/6/68	8 A	Clear	32	34	30	92	92	160
12/21/68	8 A	Fog	27	27	25	-	-	160
1/2/69	8 A	Cloudy	36	38	37	94	94	160
1/3/69	9 A	Rain	39	39	37	52	92	160
1/6/69	8 A	Rain	43	43	41	94	100	160
1/9/69	8 A	Rain	41	41	39	86	100	160
1/10/69	8 A	Rain	37	39	37	86	92	160
1/13/69	9 A	Snow	37	39	36	94	94	160
1/14/69	8 A	Snow	36	36	34	86	92	160
1/15/69	9 A	Cloudy	36	37	36	82	86	160
1/23/69	9 A	Cloudy	19	21	17	-	-	160

(1) All spot observations on temperature and humidity were obtained at approximately four feet above ground level.

APPENDIX B

A REPORT ON THE POST-EXPERIMENTAL OPERATIONS

DAIRY MANURE MANAGEMENT SYSTEM MONROE STATE DAIRY FARM

Introduction

This report is being written approximately one year after the completion of experimentation and data collection on the Manure Management System. During this year the final system configuration has been in "normal operation," under the management of the regular Farm Industries staff. This report is intended to record the significant operating experiences related to the Manure Management System.

I. Cattle Confinement Facility

The physical arrangement of the redesigned pens, e.g. Pen C, proved to be much better than the earlier design, e.g. Pen B. Rather than scraping the manure the full length of the pen, it was merely necessary to windrow it over to the longitudinal gutter.

The flushing arrangement in Pen C was moderately effective in cleaning the pen floor. It was naturally most effective at the location of the spray impingement on the floor, however, it also carries most surface materials into the longitudinal gutter, and down the gutter to the sump.

The total hydraulic system has functioned satisfactorily, although the wood shavings used as bedding can be a cause of plugging the pump. As a result, the level of the shavings was reduced to minimize mixing them with the manure.

The concrete block half-walls used in the stall and service alley areas have not proved to be entirely satisfactory. Both equipment and cows have caused cracking of the mortar and damage to the walls. A solid poured, filled block or pipe dividers are suggested as superior considerations.

An exterior wall (corrugated sheet) was constructed on the south side of the confinement facility. That is the direction of the prevailing winds. This wall greatly reduced drafts in the barn, and is felt to be responsible for the appreciable reduction of disease in the herd.

II. Central Slurry Tank and Chopper Pump

The slurry tank is a system component which was fundamental to the demonstration and experimental phase of the Project, but is not a necessary component of the operating system. It is used as a part of the operating system, however, since the high pressure chopper pump is installed in conjunction with it, its primary advantage now is the agitation performed on the slurry which is pumped to the fields.

The subsystem associated with the central slurry tank has functioned satisfactorily.

III. Aerobic Treatment Facility

The subsystem which comprises the aerobic treatment facility is not used in the normal operations. The one exception is the use of the effluent storage lagoon as a water storage lagoon for water which flushes the field distribution system.

IV. Manure Storage Lagoons

Lagoon storage of the manure slurry has proved to be entirely satisfactory. The surface layer of solids, or crust, effectively minimizes the problems of odors and flies. There has been no apparent leakage from the lagoon.

The one recommendation related to the lagoon design is in regard to agitation. The installed design does not afford complete agitation throughout the lagoon since the agitation jets cannot be directed toward the area beneath the pier.

During the past year, a heavy crust, approximately three feet thick, formed on the top of the lagoon. This problem, however, was not due to a design deficiency in the lagoon. It was due to a failure to sufficiently agitate the slurry and was complicated by the damaging of the discharge pipe. This heavy crust was removed by mechanical means. A repeat of such a crust formation is not expected.

V. Field Distribution

The field distribution or irrigation system has proved to be reliable and entirely satisfactory. The most important caution, as is the case in the total manure handling system, is to thoroughly flush the system to prevent a build-up of solids which might plug a line.

NOTE: This report (Appendix B) was provided by Mr. Richard Englund and Mr. Harry Ingersol of the Washington State Department of Social and Health Services.

Table C-1

Soil Profile Sieve Analysis Results
(Values are percentage by weight passing the designated sieves)

Hole Location (Field Circle)	Depth (Ft.)	# 200 0.075 mm	# 100 0.15 mm	# 50 0.30 mm	# 30 0.60 mm	# 10 1.50 mm
A-8	0	98.2	100	100	100	100
	1	94.4	100	100	100	100
	2	92.1	99.5	100	100	100
	3	7.6	29.5	73.9	96.6	99.97
A-9	0	98.7	98.8	99.0	99.3	99.8
	1	99.3	100	100	100	100
	2	68.2	88.6	98.2	99.8	100
	3	78.8	96.9	99.7	99.9	100
A-10	0	92.9	95.8	98.5	99.6	100
	1	98.3	100	100	100	100
	2	97.3	98.4	99.8	100	100
	3	8.0	18.4	47.0	89.1	100
A-11	0	98.0	100	100	100	100
	1	97.0	100	100	100	100
	2	99.0	100	100	100	100
	3	4.1	11.5	47.9	79.7	99.5
A-12	0	96.0	97.2	?	99.4	99.6
	1	98.7	100	100	100	100
	2	98.9	100	100	100	100
	3	86.2	95.1	97.9	100	100

TABLE C-2

BACTERIOLOGICAL PROFILE OF THE STREAM WHICH DRAINS THE MONROE DAIRY FARM

Sampling Period from October 1967 to May 1970

STATION	10-18(19)-67	12-8-67	1-19-68	2-9-68	3-21-68	3-29-68	4-8-68	5-1-68	4-28-69	5-8-69	6-9-69
Inlet											
TC[a]	20,000[b]		9,000	580,000	9,000	7,000	5,500	3,000	430,000	9,300	910
South Boundary											
TC	21,000	500	5,500	750,000	3,000	3,000	2,000	3,000	430,000	93,000	2,300
Outlet to River											
TC	28,000	2,000	9,000	900,000	6,000	1,000	900	7,000			2,100
River Above Outlet[c]											
TC	d	3,000									120

STATION	6-16-69	6-25-69	7-23-69	10-7-69	10-8-69	10-20-69	10-31-69	11-5-69	11-24-69	12-4-69	12-18-69
Inlet											
TC	300	9,300	1,400	400[i]	2,300	900	700	9,200	2,700	2,700	3,400
FC[e]				400		400	700		700	700	1,100
FS[f]				200	400	100	300	1,010	180	210,000	4,000
Below Tile #1[g]											
TC				400	2,300	<300	1,300	940	800	800	
FC				400		<300	1,300		200	500	
FS				300	200	50	120	210	10	20,000	
Southeast Corner[h,n]											
TC	720	3,900		2,300	400	1,500	800	3,500	17,000	11,000	110,000[j]
FC				900		900	500		400	2,200	
FS				100	1,000	440	500	8,200	710	480,000	
South Boundary											
TC					400		200				54,000[k]
FC							<200				
FS					200		70				
Outlet to River											
TC	2,300	15,000	910	1,100	900	2,300	700	7,900	13,000	200	92,000
FC				400		900	400	1,700	3,300	200	92,000
FS				200	1,100	50	180	600	3,300	130,000	58,000
River Above Outlet											
TC		2,800	200								

Superscripts refer to footnotes on second page of table.

TABLE C-2 (Cont.)

STATION	1-20-70	1-27-70	2-3-70	2-10-70	2-13-70	4-2-70	4-7-70	4-15-70	4-28-70	5-1-70
Inlet										
TC	<2,000	200	<200	200	2,800					
FC	<2,000	<200	<200	200						
FS	100		<10	10						
Southeast Corner[n]										
TC	13,000[j]	14,000[j]	46,000[l]	46,000[l]	11,300[m]	7,000[m]	800[m]	200	7,900	5,900
FC	13,000[j]	7,000[j]	17,000[l]	33,000[l]		<2,000[m]	<200[m]	<200	800	
FS	3,000[j]		2,100[l]	1,100[l]		<100[m]	<100[m]	100	300	1,500
South Boundary										
TC				110,000						
FC				110,000						
FS				300						
Outlet to River										
TC	46,000[k]	79,000[k]	33,000[m]	33,000[m]	22,700[m]	8,000[m]	13,000[m]	400	11,000	4,100
FC	33,000[k]	49,000[k]	33,000[m]	11,000[m]		8,000[m]	13,000[m]	200	600	
FS	5,000[k]		2,400[m]	200[m]		500[m]	300[m]	<100	1,000	1,100

[a] Most Probable Number of Total Coliforms /100 ml of sample
[b] Approximate Total Coliforms (not confirmed) inclusive dates 10-18-67 thru 7-23-69
[c] Snoqualmie River Upstream of Stream Draining Farm
[d] No data available
[e] Most Probable Numbers of Fecal Coliforms /100 ml of sample
[f] Fecal Streptococci /100 ml of a sample
[g] Station located downstream of drain tile which drained area east of farm
[h] Station located downstream of drainage ditch from farm adjacent to Monroe Farm
[i] Samples for Total Coliforms were confirmed in brilliant green bile lactose broth (Difco) from this date onward
[j] Sample taken upstream of manure spray field D, 81,500 gallons applied on 12-17-69, spillage into creek was observed
[k] Sample taken downstream of field D, refer to footnote j
[l] Sample taken upstream of manure spray applications on 2-2-70
[m] Sample taken downstream of manure spray applications on 2-2-70
[n] As of 12-18-69 the Southeast Corner station was relocated downstream of milk waste drainage ditch

TABLE C-3

Water Quality Chemical Data for Stream Draining State Farm
(1967-68-69)
(mg/1)

	NO_3-N	NH_4-N	Organic N	PO_4	Total PO_4	SO_4	Cl	COD	pH	Cond
October 18-19, 1967										
Inlet	0.05			0.355	0.95	13.0	3.5	18.0		36
South Boundary	0.07			0.255	0.98	13.0	3.5	13.0		
Outlet to River	0.09			0.235	0.90	14.5	4.1	7.0		
River above Outlet	0.02			0.100	0.20	5.0		4.0		
December 8, 1967										
Inlet	0.15	Tr		0.145	1.24	8.9		21.19	6.62	36
South Boundary	0.72	0.0		0.090	1.46	9.5		18.4	6.67	89
Outlet to River	0.75	Tr		0.138	1.46	10.5		21.7	6.53	123
River above Outlet	0.70	-		0.175	1.01	5.5		10.85	7.07	36
January 19, 1968										
Inlet	0.21			0.180		10.0	5.41	32.0	6.5	
South Boundary	0.35			0.90		11.0	2.25	36.0	6.8	
Outlet to River	0.14			0.150		14.0	4.50	38.0	7.0	
River above Outlet	0.15			0.07		6.2	5.86	11.8	7.2	
February 9, 1968										
Inlet	0.19	Tr	1.40	0.17	0.95	14.0		32.0	6.6	
South Boundary	0.26	Tr	2.24	0.118	0.91	16.4		24.2	5.8	
Outlet to River	0.28	Tr	1.56	0.125	1.10	18.2		8.4	6.0	
River above Outlet	0.11	-	0.84	0.0	0.50	5.8		8.9	7.1	

Note: Column headings explained on page 132.

TABLE C-3 Cont.

	NO_3-N	NH_4-N	Organic N	PO_4	Total PO_4	SO_4	Cl	COD	pH	Cond	DO	Temp °C
March 21, 1968												
Inlet	0.30	Tr	1.54	0.07		10.2		43.0	6.15	58		
South Boundary	0.40	Tr	1.40	0.01		6.4		14.0	6.7	110		
Outlet to River	0.16	-	0.98	0.09		12.0		14.0	6.8	95		
River above Outlet	0.08	-	0.21	0.06		6.0		6.6	7.0	<50		
March 29, 1968												
Inlet	0.21	Tr		0.017	1.2	10.0	9.5	28.0	6.5	82		
South Boundary	0.34			0.033	1.3	13.0	2.5	19.0	6.4	96		
Outlet to River	0.14			0.025	0.93	13.0	3.25	24.0	6.6	117		
River above Outlet	0.14			0.039	0.35	6.8	0.5	7.0	7.2	<50		
April 18, 1968												
Inlet	0.32	-		0.01	0.94	5.0		32.0	7.3		8.2	11
South Boundary	0.30	Tr		0.01	1.10	6.4		17.0	6.8		8.1	12
Outlet to River	0.055	0.01	-	0.02	0.35	16.2		22.9	6.7		8.2	12
River above Outlet	0.04	-		0.01	0.1	8.0		11.0	7.1		9.0	9
May 1, 1968												
Inlet	0.026	-	-	0.005	0.85		2.25	22.6	7.4	97		14
South Boundary	0.093			0.011	0.96		4.0	7.4	7.4			14
Outlet to River	0.150			0.013	1.38		6.0	20.0	7.1	115		15.5
River above Outlet	0.008			0.010	0.65		1.0	3.4	7.0			11
June 11, 1968												
Inlet	0.09			0.009	1.2		2.6	27.0	6.7			15
South Boundary	0.1			0.015	1.32		4.8	12.0	6.9			17.5
Outlet to River	0.075			0.021	0.98		5.2	18.0	7.1			18
River above Outlet	0.05			0.008	0.11		2.3	7.0	7.2			14.6

TABLE C-3 Cont.

	NO_3-N	NH_4-N	Organic N	PO_4	Total PO_4	SO_4	Cl	COD	pH	Cond	DO	Temp °C
July 6, 1968												
Inlet	0.038	-	1.96	0.006	0.144		3.5	18.0	7.75	75		22
South Boundary	0.035		1.77	0.008	0.180		6.5	10.0	6.9		9.0	22
Outlet to River	0.082		1.98	0.012	0.360		6.8	12.0	7.2		10.0	24
River above Outlet	0.01		1.11	0.005	0.084		2.21	5.0	7.25	<50	8.0	18
August 16, 1968												
Inlet	0.11	Tr	0.8	0.12	0.15		4.2	37.7	6.2	150		21
South Boundary	0.21	Tr	0.30	0.04	0.18		3.8	19.0	7.48	120		22
Outlet to River	0.06		0.34	0.132	0.21		3.2	15.0	7.60	110		22
River above Outlet	0.004		ND	0.06	0.20		2.0	14.0	6.75	62		20
August 23, 1968												
Inlet	0.06		0.65	0.006	0.052		4.0	34.0	6.6	145		19
South Boundary	0.03		0.56	0.012	0.088		2.0	19.0	7.4	120		19
Outlet to River	0.065		0.37	0.019	0.100		2.5	23.0	7.5	110		19
River above Outlet	0.01		0.19	0.021	0.188		1.5	2.2	7.3	60		17
September 16, 1968												
Inlet	0.09			0.08				26.0	6.1	132	9.2	12
South Boundary	0.10			0.003				21.0	7.3	106	8.4	12.4
Outlet to River	0.05			0.005				25.0	7.0	140	8.6	13.1
River above Outlet	0.01							5.0	6.9	71	9.8	10.9
November 27, 1968												
Inlet	0.175	Tr	2.88	0.19	0.54		3.1	19.2	6.85	150	10.0	8
South Boundary	0.062		1.19	0.14	0.71		2.4	21.0	6.6	150	10.0	8
Outlet to River	0.244	Tr	0.92	0.12	0.825		2.6	34.0	6.5	130	8.0	8.75
River above Outlet	0.032		0.32	0.06	0.11		1.5	28.8	6.9	125	10.0	7.0

TABLE C-3 Cont.

	NO_3-N	NH_4-N	Organic N	PO_4	Cl	COD	pH	Cond	DO	Temp °C
February 21, 1969										
Inlet	0.61	Tr	1.93	0.54	0.8	28.4	6.6		8.0	8
South Boundary	0.74	Tr	0.84	0.38	1.13	22.0	6.8		10.0	8
Outlet to River	0.97		0.54	0.42	1.6	18.2	6.8		10.0	8
River above Outlet	0.21		0.18	0.01	1.33	5.6	6.9	120	10.0	8
April 28, 1969										
Inlet	0.084		0.20	0.09	1.65	13.4			9.6	10
South Boundary	0.07		0.14	0.085	1.13	12.0			10.0	11
Outlet to River	0.08		-	0.08	2.0	14.0			10.0	
River above Outlet	0.04		-	0.03	1.33	4.0			10.0	
May 8, 1969										
Inlet	0.45	Tr	1.61	0.15		21.0			10.0	11
South Boundary	0.11		0.22	0.09		14.0			9.9	11.2
Outlet to River	0.10		0.41	0.09		14.0			9.4	11.2
River above Outlet	0.09		0.14	0.04		6.0			9.2	11
June 9, 1969										
Inlet	0.15	Tr	1.42	0.10		14.0			9.9	14
South Boundary	0.08	Tr	0.80	0.04		10.0			9.5	15
Outlet to River	0.06	Tr	0.74	0.035		12.0			8.5	14
River above Outlet	0.09		-	0.02		5.2			9.9	14
June 25, 1969										
Inlet	0.24	Tr	0.91	0.13		26.0			8.75	11.5
South Boundary	0.12		0.24	0.09		16.0			8.8	12
Outlet to River	0.11		0.20	0.09		18.0			8.3	13
River above Outlet	0.08		0.14	0.09		6.0			9.0	11

TABLE C-3 Cont.

	NO_3-N	NH_4-N	Organic N	PO_4	Cl	COD	pH	Cond	DO	Temp °C
July 23, 1969										
Inlet	0.06		0.57	0.07		12.0			9.25	11
South Boundary	0.04		0.18	<0.01		9.8			9.61	12
Outlet to River	0.05		0.18	<0.01		7.0			8.5	12
River above Outlet	0.09		0.11	<0.01					9.0	11

NO_3-N is Nitrate Nitrogen

NH_4-N is Ammonia Nitrogen

Organic N is Organic Nitrogen

PO_4 is Orthophosphate

Total PO_4 is Total Phosphate

SO_4 is Dissolved Sulfates

Cl is Cloride Ion

COD is Chemical Oxygen Demand

pH is a Measure of Hydrogen Ion Activity in Standard pH Units

Cond is Specific Conductivity

DO is Dissolved Oxygen

Temp ^oC is Temperature on the Centigrade Scale

TABLE C-4

ALGAE COMPOSITION OF STREAM DRAINING STATE FARM 1967-68.
(Algae are shown as number of cells/ml except where noted.)

*Stream Inlet N.E. Corner Farm

	Oct	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov
DIATOMS												
Synedra sp.												
Nitzschia sp.	62	20	16	94			210	36	6		2	
Diatoma sp.									6			
Fragilaria sp.									4		20	
Eunotia sp.												
Stauroneis sp.												
Navicula sp.												
Melosira sp.												
Pinnularia sp.												
Stephanodiscus												
Cymbella sp.												
Gomphonema sp.											12	
Phacus curvicauda												
Achnanthes sp.												
YELLOW GREEN												
Tribonema sp.									4	6		
GREENS												
Pandorina morum sp.			6	293	1128	130	2	6				
Ankistrodesmus sp.				224		150	60					
Closterium parvulum							8	2				
Pediastrum sp.					2							
Scenedesmus quadricauda						6	70				8	22
Stigeoclonium sp.							.2					
Spirogyra sp.								96				
Coelastrum sp.									20			
BLUE GREENS (trichomes/ml)												
Spirulina sp.												
Anabaena sp.										28		
Oscillatoria sp.								12	24	24		
Flagellates												
Euglena sp.	12			2	6			20	60			
Euglena elastica						45		28				
Chlamydomonas sp.						2344	12				8	218

South Farm Boundary

	Oct	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov
DIATOMS												
Synedra sp.											4	54
Nitzschia sp.	16	11					54	34				10
Diatoma sp.				12	90	70						
Fragilaria sp.												
Eunotia sp.												
Stauroneis sp.											2	
Navicula sp.									16	2	140	
Melosira sp.		10										
Pinnularia sp.												
Stephanodiscus								62				
Cymbella sp.												
Gomphonema sp.										10		
Phacus curvicauda												
Achnanthes sp.												
YELLOW GREEN												
Tribonema sp.												
GREENS												
Pandorina morum sp.		10	6	11		19				8		
Ankistrodesmus sp.		4							8			10
Closterium parvulum					4		34	6	2			
Pediastrum sp.												
Scenedesmus quadricauda							4					
Stigeoclonium sp.												
Spirogyra sp.												
Coelastrum sp.												
BLUE GREENS (trichomes/ml)												
Spirulina sp.												
Anabaena sp.										28		
Oscillatoria sp.								38		16		
Flagellates												
Euglena sp.	8	28	2				2			16		
Euglena elastica					4				4	18		
Chlamydomonas sp.					400	229	18					

Outlet

	Oct	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov
DIATOMS												
Synedra sp.						2		2	2	14		
Nitzschia sp.							200	12	4			
Diatoma sp.			2	6		26						
Fragilaria sp.						2						
Eunotia sp.			2									
Stauroneis sp.												
Navicula sp.				2						6		
Melosira sp.												
Pinnularia sp.												
Stephanodiscus										18		
Cymbella sp.												
Gomphonema sp.											24	2
Phacus curvicauda												6
Achnanthes sp.												
YELLOW GREEN												
Tribonema sp.						4						
GREENS												
Pandorina morum sp.			18	17								
Ankistrodesmus sp.												
Closterium parvulum				8			38	8	12	6		
Pediastrum sp.												
Scenedesmus quadricauda												
Stigeoclonium sp.												
Spirogyra sp.							8	16	10			
Coelastrum sp.										4		
BLUE GREENS (trichomes/ml)												
Spirulina sp.												
Anabaena sp.												
Oscillatoria sp.										16		
Flagellates												
Euglena sp.		12		4								
Euglena elastica												
Chlamydomonas sp.					38	20		2	2			

Snoqualmie River

	Oct	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov
DIATOMS												
Synedra sp.						2		36	10	10	2	1
Nitzschia sp.		4	1		15	2	4					
Diatoma sp.	2	1				4	20					
Fragilaria sp.	20	8	8	6				4				2
Eunotia sp.	2	2	2									
Stauroneis sp.												
Navicula sp.			1	2				6	5			
Melosira sp.												
Pinnularia sp.	2	2				2						
Stephanodiscus												
Cymbella sp.										18		2
Gomphonema sp.												
Phacus curvicauda												
Achnanthes sp.									4	10	4	2
YELLOW GREEN												
Tribonema sp.												
GREENS												
Pandorina morum sp.												
Ankistrodesmus sp.										2		2
Closterium parvulum					2		38					2
Pediastrum sp.												
Scenedesmus quadricauda									8	2		
Stigeoclonium sp.												
Spirogyra sp.							8	1				
Coelastrum sp.												
BLUE GREENS (trichomes/ml)												
Spirulina sp.												
Anabaena sp.												
Oscillatoria sp.												
Flagellates												
Euglena sp.												
Euglena elastica							6					
Chlamydomonas sp.					3	20		2	2			

*For sampling locations see Figure 1.

Table C-5

Vertical Distribution of Intestinal Bacteria in Soil Collected from Test Holes after Application of Manure Slurry to Test Plots

	Depth Feet	Test Hole Number A8-1	A8-2	A8-3	A9-1	A9-2	A9-3	Test Hole Number A10-1	A10-2	A10-3	A11-1	A11-2	A11-3	Depth Feet
Total Coliforms MPN/10 grams soil	0.0	1,100,000	1,000,000	240,000	240,000	--	240,000	24,000	>1,100,000	210,000	1,100,000	460,000	1,100,000	0.0
	0.5	>110,000	230	24,000	>110,000	--	24,000	4,600	24,000	>110,000	9,300	110,000	700	0.5
	1.0	43	>1,100	>1,000	>1,100	--	>1,100	<3	<3	>1,100	<3	<3	4	1.0
	2.0	7	7	7	>1,100	--	4	<3	4	>1,100	4	<3	<3	2.0
	3.0	<3	<3	<3	<3	--	--	<3	23	>1,100	<3	<3	11	3.0
Fecal Coliforms MPN/10 grams soil	0.0	1,100,000	1,100,000	240,000	240,000	--	240,000	24,000	>1,100,000	221,000	1,100,000	460,000	1,100,000	0.0
	0.5	>110,000	230	24,000	>110,000	--	24,000	4,600	24,000	>110,000	9,300	930	<30	0.5
	1.0	23	>1,100	>1,100	>1,100	--	>1,100	<3	<3	>1,100	<3	<3	<3	1.0
	2.0	<3	<3	<3	>1,100	--	4	<3	4	>1,000	<3	<3	<3	2.0
	3.0	<3	<3	<3	<3	--	--	<3	23	>1,100	<3	<3	<3	3.0
Fecal Streptococci per 10 grams soil	0.0	3,000,000	1,600,000	86,000	65,000	7,000	80,000	28,000	440,000	15,000	340,000	360,000	310,000	0.0
	0.5	9,500	<100	1,100	9,800	900	10,000	4,900	<100	8,800	3,400	<100	<100	0.5
	1.0	<100	2,000	9,000	1,700	5,600	6,300	<100	<100	900	<100	<100	<100	1.0
	2.0	<100	<100	<100	10,600	<100	<100	<100	<100	700	<100	<100	<100	2.0
	3.0	<100	<100	<100	<100	<100	<100	<100	<100	300	<100	<100	<100	3.0

MPN indicates most probably number of organisms.

Table C-6

Concentration of chloride in soil taken from test holes prior to and after application of manure slurry to test plots. Concentration of chloride is expressed in mg/kg of dry soil.

Depth Feet	Prior	----------After----------			Prior	----------After----------		
	A8	A8-1	A8-2	A8-3	A9	A9-1	A9-2	A9-3
0.0	18.0	870.0	290.0	570.0	37.0	300.0	129.0	360.0
0.5	2.7	69.0	21.0	19.0	2.6	33.0	30.0	78.0
1.0	2.7	7.2	60.0	58.0	15.8	39.0	160.0	49.0
2.0	2.0	5.4	3.3	23.0	8.8	56.0	21.0	20.0
3.0	1.4	6.0	8.6	12.3	8.3	4.6	13.6	11.5
	A10	A10-1	A10-2	A10-3	A11	A11-1	A11-2	A11-3
0.0	78.0	340.0	340.0	250.0	5.0	340.0	129.0	670.0
0.5	7.9	19.0	12.9	50.0	3.3	20.0	31.0	7.7
1.0	3.5	20.0	9.4	123.0	3.4	12.4	29.0	5.2
2.0	7.3	14.0	12.5	38.0	5.2	5.6	12.4	3.8
3.0	4.1	8.2	14.4	14.3	1.9	4.1	17.0	12.9

APPENDIX D

PLANNING AND IMPLEMENTATION OF REQUIRED FACILITIES AND EQUIPMENT

CATTLE CONFINEMENT OR HOUSING PLANS

Tentative plans at the time of writing the Project grant application called for developing new housing for 348 cows. (See Figures 22 and 23) The existing confinement facilities were to be retained and utilized so that it would be possible to make comparisons between the new totally covered cattle environment and the more typical environment of dairies of the Northwest.

A new confinement area totaling about 65,000 square feet was to be completely roofed and paved but without enclosing walls. As initially proposed, this area would be divided with about half of the area on either side of an existing large baled hay storage barn (180 feet long by 36 feet wide by about 30 feet high). Six separate pens for 59 cows each was to have been provided. Each pen was to be 115 feet long by 64 feet wide and contain mangers, watering troughs, bedded stalls, and loafing area. Manure slurry collection channels would extend across each pen and run to one of two slurry collection and pumping sumps. The plan provided for further expansion at some future date which would then place all cows in the new type of housing and utilize the new manure handling methods.

Several problems appeared as detailed plans were being developed. Integrating low and flat pitched roof structures with the tall steep roofed hay barn presented difficult, but not insurmountable, problems. There would be significant conflicts, however, between the routing of cows to and from the milking parlor, the movement of feed and forage wagons through the pen service alleys, and the placement of trucks during storage and removal of hay in the storage barn. Gravity flow in the manure collection channels would have made it necessary to locate one sump inside the hay barn and the other at the truck entryway to the barn. This would also conflict with cattle and vehicle traffic flow.

The possibility of moving the hay barn was investigated and found to be both feasible and reasonable in cost. The cost of moving the hay barn appeared to be more than offset by savings associated with the simplified new housing structure. By relocating the hay barn it was possible to place fill material to elevate the floor level of the new housing facility. Fill depths of two to six feet set the floor elevation of the new barn above any known previous flood elevations. The surcharge of fill material also increased footing stability for the silty river bottom soil.

A new layout for the cattle housing facility was developed. This layout provided for six paved pens but now all under one continuous roof. (See Figures 24 and 25). No side walls were needed. Each pen was to be

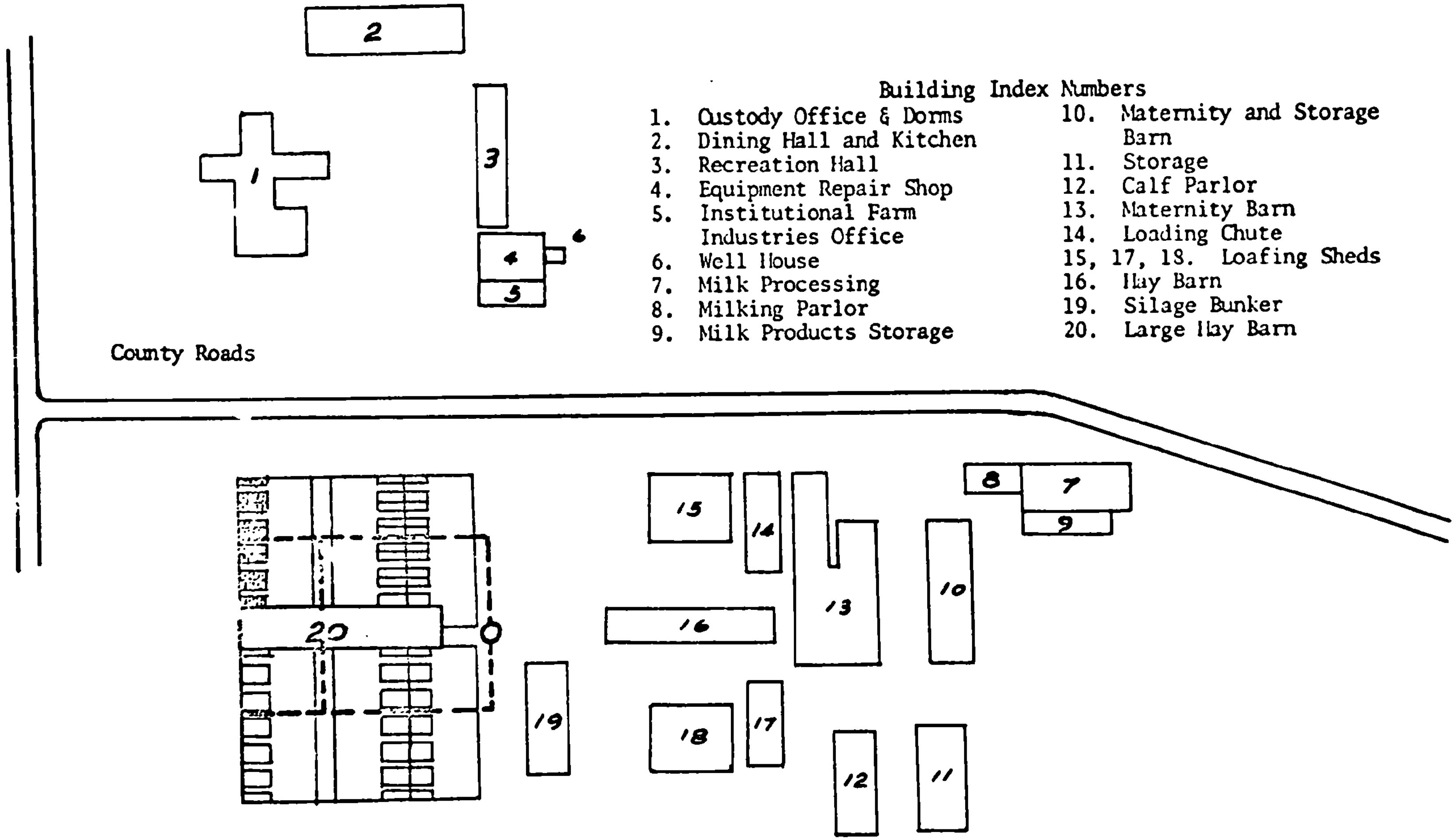

Figure 22. Initially Proposed New Cattle Housing

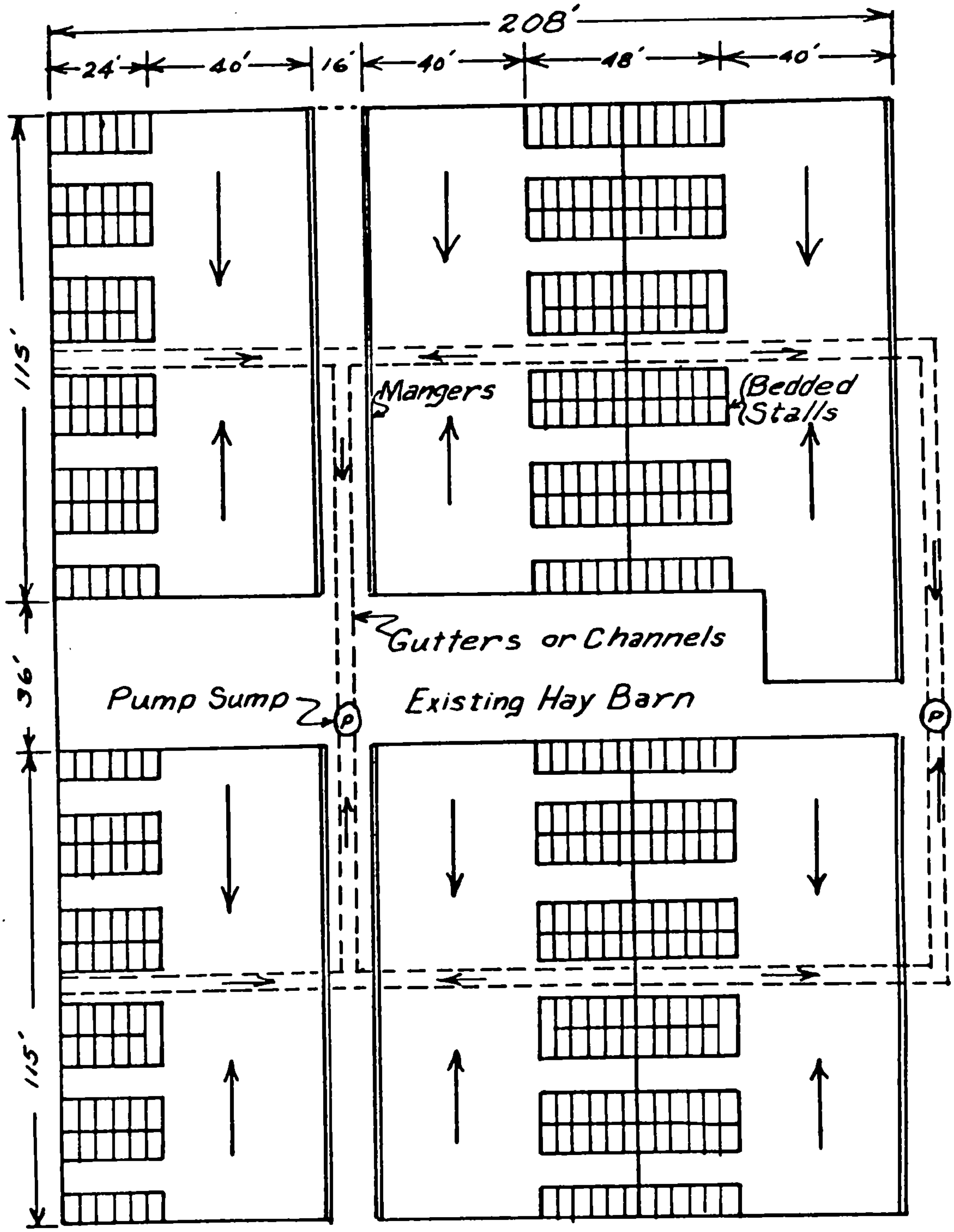

Figure 23. General Arrangement of Pens, Stalls, Gutters and Mangers of Initially Proposed New Cattle Housing. (Totally Roofed but without Walls.)

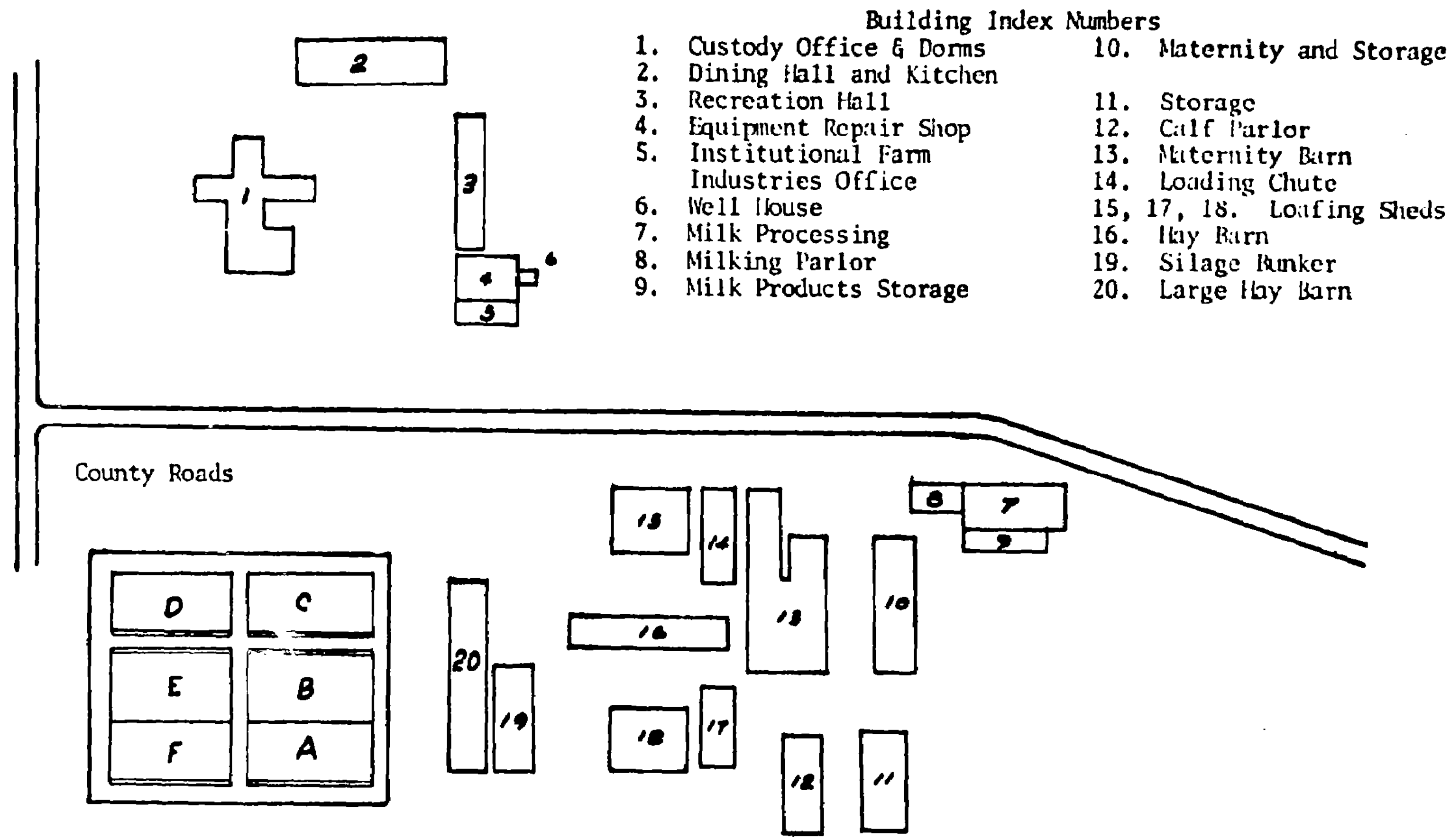

Figure 24. New Cattle Housing Location After Haybarn Relocation

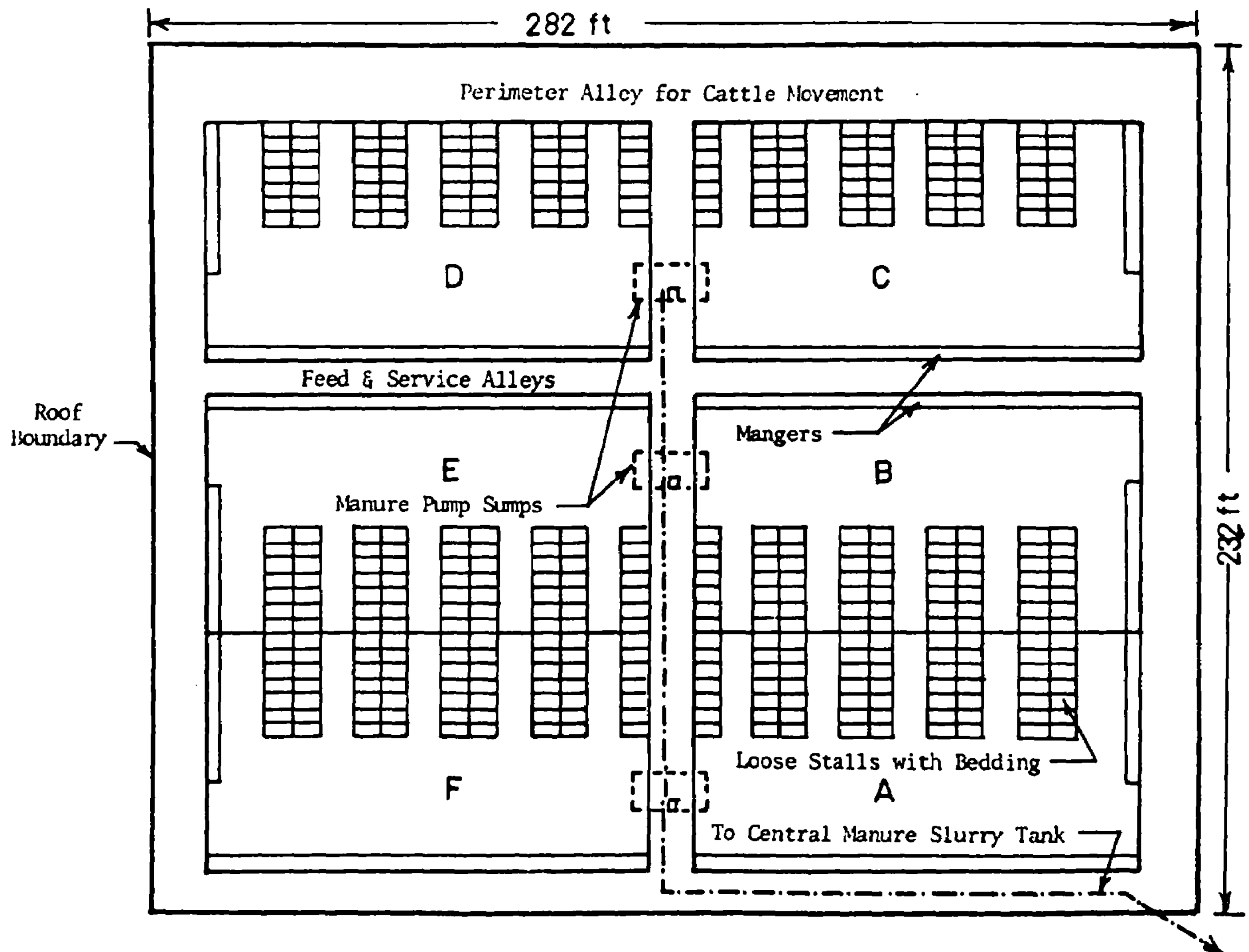

Figure 25. Pen Arrangement for New Cattle Housing Facility

60 feet wide by 115 feet long providing 110 square feet of area for each of 63 cows.

After space layout of the pens, mangers, cattle and vehicle service alleys, and manure sumps was completed; three steel building erection firms were each invited to propose a structure to cover the area. They were informed of the limitations on column location or more specifically where columns could not be placed. Each was permitted to vary the spacing of columns, rafters, or purlins within limits in their individual proposals and bids.

The submitted structural plans and accompanying bids of the two lowest bidders were then reviewed by Sleavin-Kors (Project consultants) for adequacy and structural safety. Both were approved and a contract was completed with Parrott-Kauffman of Tacoma, Washington to erect the 65,000 square foot steel building for $82,890. This contract included all framing, the roof itself, guttering and downspouts, and walls from the roof downward to an elevation 14 feet above ground level but did not include column footings or any interior facilities other than the supporting columns.

With footing locations, elevations, and dimensions fixed by the building plans and contract, interior facility designing could proceed to the construction detail stage. It was decided that cattle should be placed in each pen as soon as it was completed to allow a brief period of observation. If any serious faults were noted, modifications could be made in subsequent pens.

Concrete block walls were called for along the stall area side and central service alley side of the pens. These walls varied from four to five feet high. They served to break up wind patterns over the cattle when lying in the stalls as well as to divide the whole area into separate pens. Concrete mangers were designed along the side of lateral service alleys to allow direct mechanical discharge of silage from forage wagons. Baled or cubed hay could also be fed in the same mangers. Concrete curbs extended around each block of fourteen bedded stalls. The stall areas were not paved but were partially filled with sandy soil and dressed over with two to three inches of wood shavings.

A drinking water supply distribution system of PVC pipe was to be suspended from the steel roof structure with gravity drop lines going to each of three drinking cups in each pen An elevated and float controlled reserve tank was designed for the head of the water distribution system. This eliminated any possible cross connections between watering cups and the farm water supply. This system was almost completely destroyed by an extremely rapid and severe drop in temperature. Though there was no known precedent for such severe weather, it was decided that the drinking water supply had to be placed underground by extending it through the unpaved stall areas to avoid possible future destruction by freezing.

The floor surface of all but the bedded stall areas was to be of non-reinforced concrete poured directly on well-compacted fill gravel. The floor surfaces were not to be in direct contact with the column footings. The main open spaces of each pen were designed to slope 1/8 inch per foot from the exterior ends of the pens toward the central service alley. The surfaces were to be heavily broomed or roughened to prevent hoof slippage and injury to the cattle. The short paved alleys between blocks of stalls sloped 1/4 inch per foot toward the open ends of the alleys.

Some changes in plans were made for subsequent pens after observing operations with cattle in the first completed pens. Most of such changes were minor. One significant change made for pens C and D was a reduction in area. It appeared that 110 square foot of area per cow, including the bedded stalls, was more area than necessary or desirable. For pens C and D the width of the open loafing area was reduced from 30 to 22 feet so that only 95 square feet of total pen area was provided for each of 63 cows.

It was necessary to provide for storm water disposal from the 65,000 square feet of new roofing. Concrete pipe was installed along both 282 foot long ends of the building to intercept the downspouts. These pipes discharged into a new culvert which extended under the county road just west of the building and discharged into an old slough.

MANURE FLUSHING AND COLLECTION

A principle objective of the Project was to develop and demonstrate a system of manure collection, transport, storage, and field application that was economically attractive and which offered little or no potential for water pollution. Comparisons of operating costs and aesthetics were to be made between the new manure management techniques and the more conventional methods of scraping, loading, and hauling. For comparison purposes, it was planned that the existing cattle housing facilities would continue to be operated for one or two years as they had before initiation of the project.

It was felt that handling manure by hydraulic methods and in slurry form at all stages was the key to economic success. Some previous brief pilot scale tests at Washington State University had indicated that manure and urine from dairy cattle confinement areas could be removed and collected in slurry form by hydraulic flushing. By using simple drilled-pipe orifices at pressures around 200 psi, it had been possible to flush small areas quite clean when a "hydraulic broom" traveled at speeds of two feet per second. Water consumption rates of not more than 20 gallons per cow per day seemed possible.

Two schemes of flushing manure from the confinement area of the new cattle housing were planned. One scheme involved stationary pipes with drilled orifices installed just above floor level around the perimeter of each pen. High pressure jets from the orifices would be directed against the floor to flush away the manure accumulation once or twice each day. The other scheme involved a high pressure spray header or "hydraulic broom" mounted on a tank truck. This mobile "hydraulic broom" would proceed along the length of each pen flushing accumulated manure ahead of it to a collection sump at the downstream end.

As detailed plans were being developed for the first cattle pens, provisions were made for the stationary drilled-orifice pipes at the bases of the mangers and at the ends of the short alleys between bedded stalls. Recessed slots were provided to house the pipes to prevent damage by cows or equipment. Manually operated valves were located to allow all or only portions of the stationary jet system to be operated as desired. Couplings were located to allow tests with different orifice diameters and spacings.

Initially the water supply for the stationary flushing system was to come from the Farm water supply system with a temporary and removable connection to prevent cross connections and contamination. Ultimately it was planned that treated anaerobic lagoon effluent could be pumped and used for flushing if the flushing system proved to be effective. This would not only reduce water consumption, but would also reduce the storage volume required in the deep anaerobic lagoons and reduce the volume of slurry to be applied to fields later on.

Additional work was initiated to develop the mobile "hydraulic broom". Special V-Jet nozzles were obtained which produced a fan shaped, high velocity jet. A small, wheel mounted, hand propelled "hydraulic broom" model was built which allowed variations in nozzle spacing, nozzle height, and angle of jet impact with the slab. For development test purposes, the jets were powered by a stationary centrifugal pump connected to the model by high pressure hose. With the nozzles set about ten to twelve inches above the slab, spaced on twelve or fourteen inch centers, inclined at about 20° from the slab, and operating at 200 psig; the model broom seemed to operate quite satisfactorily. It was difficult to overcome the jet reaction and to drag the supply hose but the device did clean the manure laden slab quite thoroughly at travel speeds of up to two feet per second.

It was then decided to proceed with the development of a full scale truck mounted "hydraulic broom". A 550 gallon tank truck and a large, gasoline engine powered, 2-stage centrifugal pump was purchased from a military surplus equipment and supply depot Specifications accompanying the pump-engine combination indicated that it should deliver 450 gallons per minute at 290 psig.

The pump-engine was mounted above the 550 gallon tank on the truck. The pump discharge was piped to a three valve manifold at the front of the truck. Three nozzle headers were fabricated. One 7-foot long header was mounted across the front of the truck and an 11-foot long header was mounted to swivel down as an extended outrigger from either side of the front of the truck. Each pipe and nozzle header was connected by high pressure hose to the valve manifold. With the side booms extended, the mobile "hydraulic broom" rig would cover a lateral span of thirty feet or the width of the open area of the new cattle pens.

In spite of specifications, the pump-engine combination did not provide sufficient flow or pressure. Even after shutting off the flow to both side booms, the pressure in thc remaining 7-foot header was only about 150 psig. At this pressure, the short "broom" would clean manure from the slab but for only a distance of 20 to 30 feet. After that much forward travel, the generated manure slurry would form a hydraulic jump ahead of the jets but would not flow on down the slab. The "broom" could loosen manure from the slab and generate a liquid slurry but the slurry was too thick to flow away down the 1/8 inch per foot slope. A positive displacement pump was substituted for the centrifugal pump to obtain higher pressures at the jets. The results were essentially the same. It had to be assumed that it was not possible to hydraulically flush manure for the full 115-foot length of a pen unless a much larger volume of water was used. This would increase the resulting manure slurry volume to the point that long term storage was impractical. The goal of hydraulic flushing by mobile "hydraulic broom" had to be abandoned. There was an indication at least that if the broom was set at an angle of about 45° to the direction of travel, it might be possible to flush the resulting slurry into a longitudinal gutter extending down the length of the pens. Time did not permit exploration of this possibility.

Three rectangular manure collection sumps were designed to be located beneath the floor slab of the central service alley in the new barn. (See locations on Figure 25). Each pair of pens opposite of each other along the central alley would be serviced by a common collection sump. The sumps were designed to have inside dimensions of 20 feet by 10 feet by 7 feet effective liquid depth. Assuming 20 gallons of manure slurry per cow per day and 126 cows in each pair of pens, each 10,400 gallon sump could handle about four days of manure production.

The 20-foot dimension of the sump was set perpendicular to the length of the 12-foot wide alley so that the sumps would extend about three feet outward under each pen floor. A 10-foot long by 8-inch wide slot through the pen floors was located immediately beneath gates opening each pen to the central service alley. Manure could then be flushed or scraped towards the central alley to drop through the slots into the collection sumps. Metal covers for the slots prevented injury to cows as they went through these gates on their way to or from the milking parlor. These covers were removed during pen clean-up operations which were scheduled while the cows were away for milking.

A 2-foot by 4-foot covered hatch in each sump roof was located in the center of the service alley and near one wall of each sump. This allowed for placement of a mobile chopper pump. A 2-foot by 4-foot by 1 1/2-foot deep depression was cast in each sump floor immediately below these hatches. This allowed placement of the chopper pump intake at a low enough elevation so that the main sump floor could be dewatered.

A single mobile pump rig was designed and built to service all three sumps. A gear-head manure chopper pump was mounted in hoisting guides on the rear end of a surplus military 4 x 4 truck chassis. A reversible electric winch was provided to raise or lower the pump. The rear axle drive shaft of the truck was disconnected from the truck and splined to engage the shaft of the gearhead pump when it was lowered into any sump. The front end drive of the truck was left intact for self-propelled mobility of the pumping rig.

The chopper pump had an internal flap-valve which could be set to either recirculate slurry through a doubly-swivelled agitator nozzle or to discharge slurry. The accumulated slurry in the sump could be resuspended, blended, and chopped. A quick coupling connection from the pump discharge port to an underground 4-inch diameter PVC line allowed the pump to transfer the homogenized slurry to a large receiving tank near the main storage lagoons. Nearby water connections provided for diluting the slurry, if necessary. Figure 26 shows the pump in position in a sump hatch but without the connection to the slurry transfer line.

Though operations and results will generally be discussed in a later section of this report, operational problems which made it necessary to redesign the manure collection and transfer system need to be mentioned at this point. The mobile chopper pump rig did meet its intended objectives of homogenizing and transferring slurry, but difficulties were encountered. Inmates were probably not as conscientious about their efforts and equipment care as normal farm owners or employees would have been. Considerable damage to the pump rig resulted when it was hoisted from a sump without first disengaging the power shaft and when they attempted to drive away from the sump without first hoisting the pump from the sump. Safety chains to hold the pump in the hoisted position were not always secured with the result that the pump was occasionally dropped to the concrete slab while in motion. Baling wire and other hardware got into the sumps to cause damage to the cutters and centrifugal blades of the chopper pump. Also, the pump manufacturer had ceased operations so that repair parts were in questionable supply for the future.

After considerable experience with such pump damage in connection with the first two sumps to be constructed and operated, a decision was made to redesign the collection sump and pumping system. Construction of the third sump and of pens C and D had been started at this time. Instead of another rectangular sump to accommodate the mobile chopper pump rig, the third sump was designed as a round, concrete block walled, sump. It was 10 feet in diameter by 10 feet deep and placed on a poured concrete base. It was designed to accommodate a stationary, electrically powered, chopper pump. In order to eliminate recurrent damage problems with the

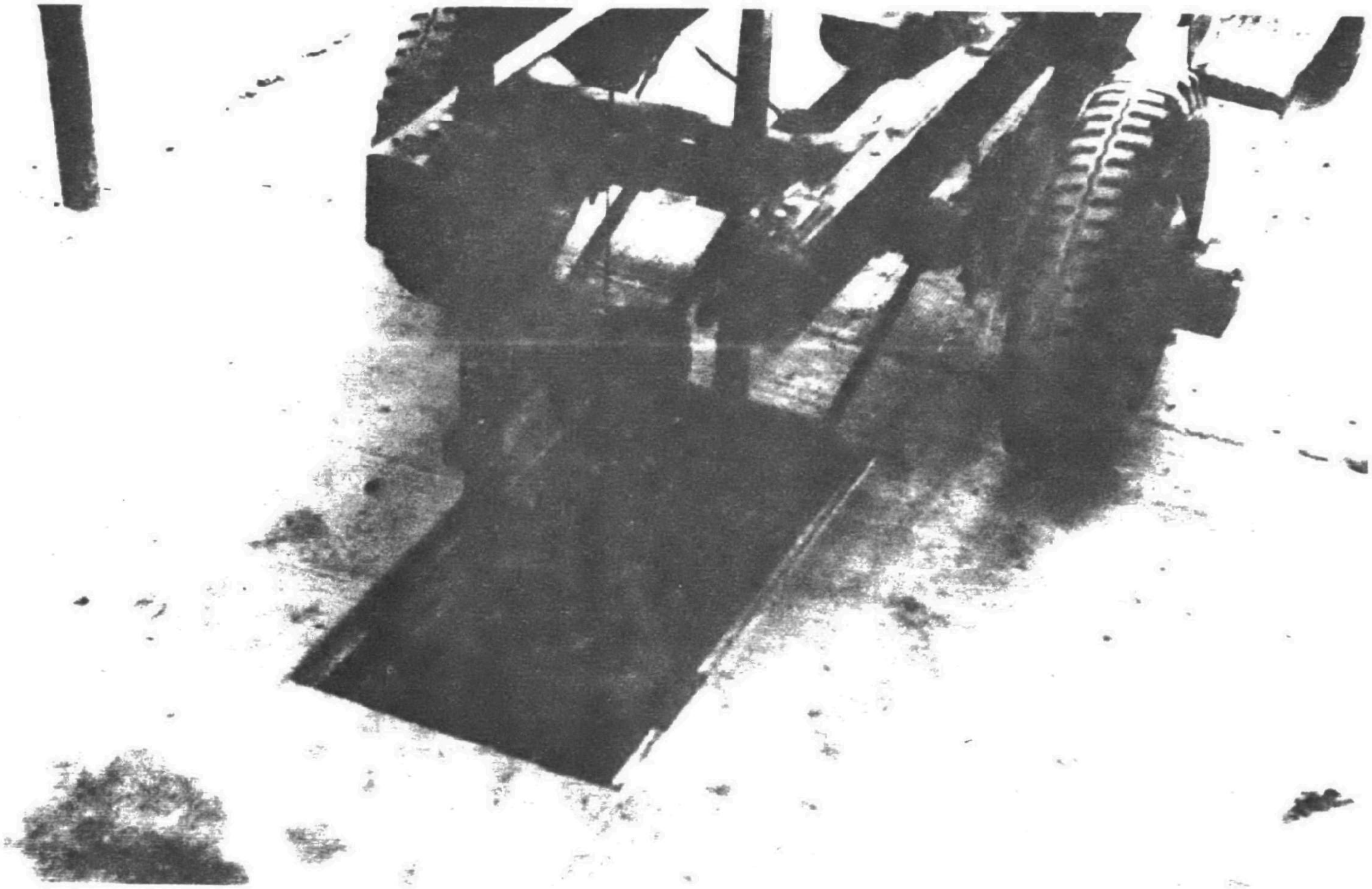

Figure 26. Mobile Chopper Pump Rig Shown in Place in Collection Sump. Discharge Connection not Installed.

mobile pump rig, it was decided that gravity slurry lines (See Figure 27) would be installed to deliver all slurry to this one round sump.

Heavy steel troughs were fabricated to fit into the manure drop slots for pens A and F. These troughs discharged to a single 15-inch diameter concrete gravity line (slope 1/4-inch per foot) extending to the second rectangular sump. A 15-inch concrete line (slope 1/2-inch per foot) connected the second rectangular sump to the third round sump. The original 4-inch diameter PVC slurry transfer line was modified to allow several alternative functions or discharges for the stationary pump. It could be set or valved to: (1) resuspend and homogenize the content of the round sump, (2) discharge to the steel troughs of pen A and F to flush the troughs and concrete lines, (3) discharge into the second rectangular tank through nozzles to resuspend and flush its contents on to the round sump, (4) transfer homogenized slurry to the large central receiving tank near the storage lagoons, or (5) flush out collection gutters being designed to run longitudinally through pens C and D.

Failure of the "hydraulic broom" to clean the full 115-foot length of the previous pens had prompted a decision to try an angled "hydraulic broom" to flush the manure laterally into a longitudinal gutter in pens C and D. It was felt that this revision could overcome the problem of slurry build-up in front of the "broom". The floor slab design of pens C and D was altered to slope 1/8-inch per foot towards the central alley and also 1/4-inch per foot laterally towards a grate-covered gutter running the full length of each pen (pens C and D). This resulted in a diagonally directed slope of 0.265 inches per horizontal foot as opposed to 0.125 inches per foot in the first four pens completed. The width of the open pen area of pens C and D had been reduced from 30 feet to 22 feet which further reduced the distance over which slurry needed to be flushed by the "hydraulic broom".

Flow in the longitudinal gutters discharged directly into the third or round sump. The fifth listed alternative discharge mentioned for the stationary chopper pump was to the upper end of the longitudinal gutters to provide a flushing flow and avoid solids build-up. Figure 27 shows the arrangement of the round sump, the 15-inch gravity line and the longitudinal gutters.

MANURE TRANSPORT AND STORAGE

The pipeline to carry the manure slurry from the collection sumps to the storage lagoon area had to be located beneath the floor level of the new barn in order to avoid obstructing either cattle or vehicle traffic. Steel pipe was considered but would have been subject to corrosive attack and also would have necessitated large diameter pipe-threading machinery. PVC pipe was selected as being more permanent and easier to install. It was also felt that the internal smoothness of both pipe and fittings would offer less resistance to flow and less likelihood of solids plugging

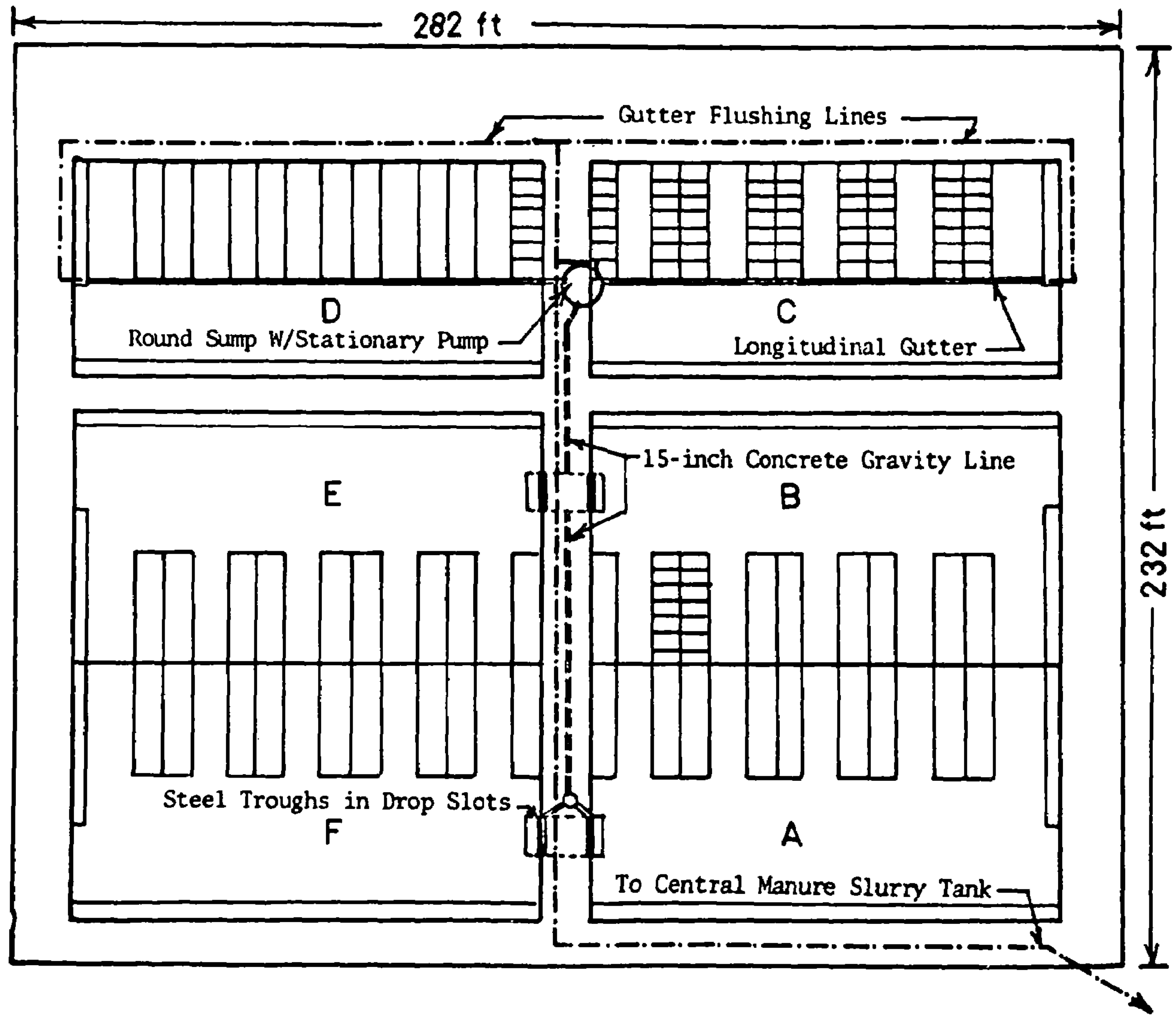

Figure 27. Modified Manure Handling System in New Cattle Housing Facility

the line. A 4-inch diameter line was considered to be adequate since the rate of transfer from the barn to the storage area was not especially critical.

The transfer line was designed to permit the entry of clean-out rods or tapes at each collection sump (via the pump connection) and at the main change in line direction at the end of the central service alley. The transfer line extended down the central service alley, turned east and ran along the lateral service alley across the south end of the barn and then extended southeasterly to a large central manure slurry tank in the storage-treatment facilities area. The line length required was about 420 feet overall or 300 feet beyond the last sump connection.

A 2-foot wide strip of the lateral service alley floor was to be left unpaved to allow excavation and repair of the slurry transfer line if it should prove necessary. The main water supply line and the flushing water supply line were also to be installed under this unpaved strip. As initially planned, the slurry transfer line was to contain no valves. Plugs would be inserted in any quick-coupling connections for the mobile chopper pump that were not in use at any given time. Subsequent changes in plans to use only a stationary pump in the round sump made it necessary to install recirculation control valves at the two rectangular sumps.

It was intentionally planned that the transfer of slurry from the new barn could only be to a large central manure slurry tank. This central tank would provide for batch accumulation of slurry, volumetric measurement, blending and sampling of manure slurry before it was either placed in the storage lagoons or applied to crop land. Any slurry removed from lagoon storage could also be batch accumulated in this tank, measured and sampled before being applied to the fields. The function of the central manure slurry tank was, therefore, dictated by research needs. Such a tank would not be necessary in the manure handling scheme of a normal farm operation. Near the end of the Project operations, a bypass line was installed to allow slurry transfer directly from the barn to the anaerobic storage lagoons.

The central manure slurry tank was located as near as possible to the center of all related facilities. It was placed between the barn and the storage lagoons and at the input end of the field distribution system. Figure 28 shows the location of the central manure storage tank relative to the storage lagoons and other facilities. Because it would be filled and emptied quite frequently, it was placed in a gravel filled area at such elevation that neither flooding nor high ground water level would impose a problem of hydraulic lift when the tank was empty.

The central manure slurry tank was designed as a 36-foot diameter by 10-foot deep, flat bottomed, concrete block walled, uncovered basin. With a resulting maximum capacity of 75,000 gallons, it could accumulate almost 3,800 cow-days of manure production assuming 20 gallons of slurry

1. Central Manure Slurry Tank
2. High Pressure Chopper Pump & Sump
3,4. Manure Storage Lagoons
5. Deep Lagoon withdrawal Sump & Pump
6. Treated Effluent Storage Lagoon
7. Activated Sludge Feed Storage Tank
8. Activated Sludge Aeration Basin
9. Sedimentation Tank
10. Line to Field Distribution System
11. Lagoon Inlet Mixing Jets
12. Aluminum Decanting Pipe

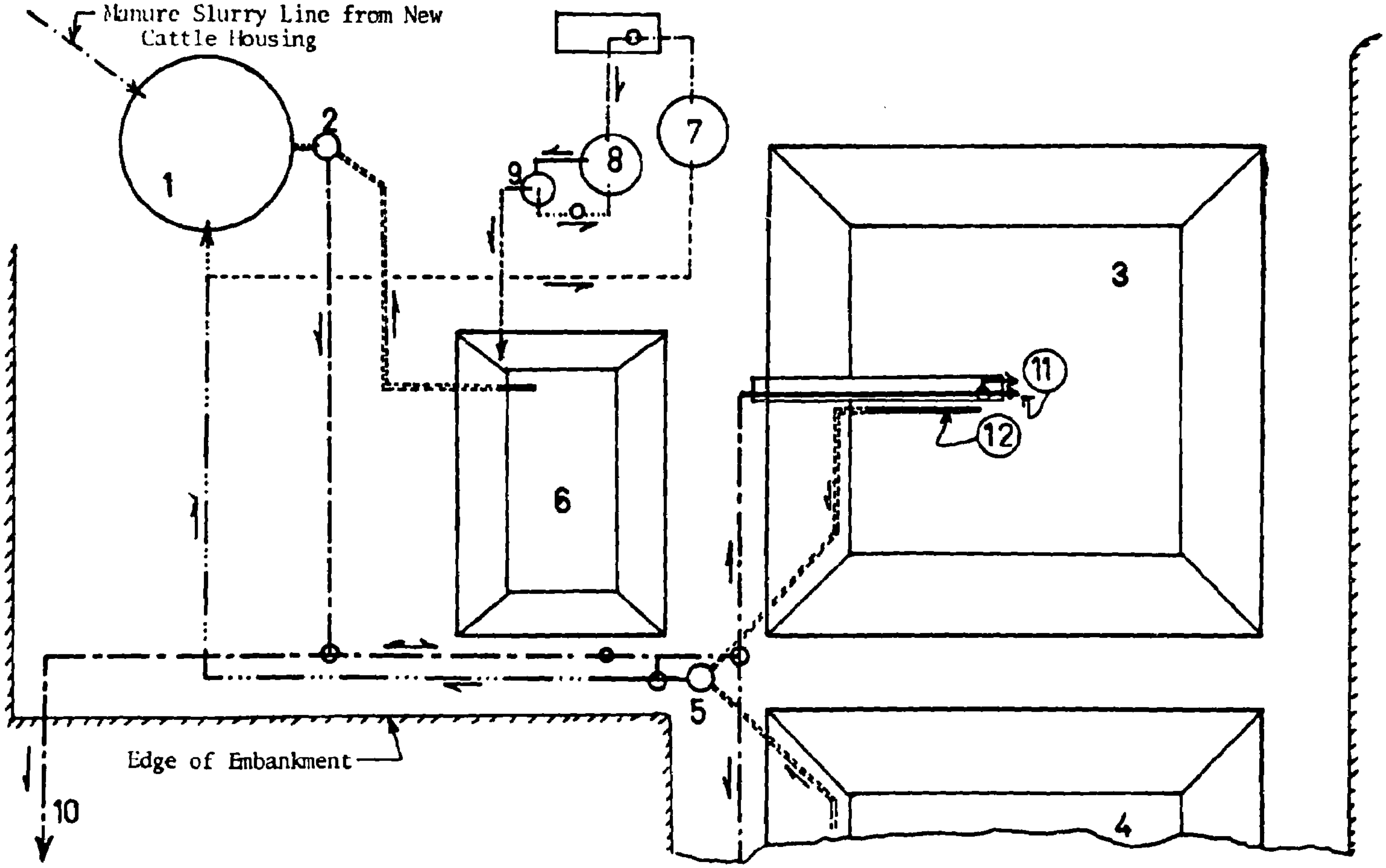

Figure 28. Schematic Layout of Manure Storage, Treatment and Distribution Area

per cow-day. This would equal about ten days of production from the new barn at capacity occupancy.

As initially designed, the central slurry manure tank was equipped with a 5 HP, 24-inch diameter, flat bladed, mixing turbine installed near the basin floor. The mixer motor and gear reducer were mounted on a column supported bridge extending to the tank center. A vertical shaft, suspended from the gear reducer and equipped with a water lubricated bottom steady bearing, supported and powered the turbine. A great deal of sand in the initial manure slurries from the barn presented sediment problems near the slurry tank walls. To promote resuspension of the sand, two high velocity slurry jets were installed near the tank floor perimeter to assist in mixing the tank contents.

The manure slurry transfer line from the collection sumps in the barn and a slurry return line from the storage lagoons discharged independently over the wall into the central manure slurry tank. Provision was also made to allow a truck mounted liquid manure spreader tank to empty into the slurry tank. This provided for receiving slurry from the older cattle confinement areas during periods when the spreader tank could not operate in the fields because of bad weather or likelihood of runoff.

A 4-foot diameter pump sump was located about 8 feet away from the central manure slurry tank. The sump and slurry tank were connected by a 24-inch diameter corrugated metal pipe. A manually operated sluice gate in the slurry tank controlled flow to the pump sump. The pump sump was about one foot deeper than the slurry tank to allow nearly complete emptying of the slurry tank. (Actual experience indicated that it should have been still deeper.)

A high pressure manure chopper pump was selected for installation in the 4-foot diameter sump. It was rated to deliver about 200 gpm of slurry at slightly more than 100 psig, but it was found that it would actually deliver nearly 250 gpm at such pressure. The pump was equipped with a recirculating jet discharging immediately beneath the intake cutters of the pump to break up any suspended chunky materials in the slurry. As installed, this pump was additionally valved to discharge back: (1) to the central manure slurry tank through the supplemental mixer jets, (2) to the anaerobic manure storage lagoons, or (3) to the field distribution system.

At the time of writing the initial Project proposal, it was planned that three anaerobic storage lagoons would be constructed in a line along the old slough area of the Farm. Subsequent consideration and exploration indicated that dewatering problems at that location would be severe and that gravely strata would present problems of infiltration and exfiltration. A location closer to the existing and proposed barns would shorten manure slurry transfer lines and utility lines. Protection against seasonal flooding by the Snoqualmie River would also be easier at a site adjacent to the farm buildings.

Three separate lagoons were designed with construction of the third lagoon to be deferred until storage needs could be better evaluated. Storage capacity requirements could range from as low as 1,080,000 gallons (300 cows x 180 days x 20 gallons/cow-day) to 4,520,000 gallons (800 cows x 180 days x 30 gallons/cow-day). Multiple lagoons instead of one single large lagoon were chosen so that some variation in loading or operation could be practiced during any year of operation.

The lagoons were each designed to have 18-foot total depth with 65-foot by 65-foot square bottoms and 110-foot by 110-foot top dimensions. Each lagoon could hold 600,000 gallons to the 16-foot depth or 645,000 gallons to the 17-foot depth. Direct precipitation into the lagoon, assuming 36 inches of precipitation during a single storage season, would reduce the 17-foot effective slurry storage capacity to only 373,000 gallons per lagoon.

The lagoons were to be partially below and partially above original ground level. Soil removed in the central excavation would be compacted in superimposed banks. Most of the soil in the location area was a river silt with a trace of sand so permeability or exfiltration was not considered to be a problem. It later developed that though the soil was of low permeability, it would not hold a stable slope when wet. The interior slopes had to be surcharged with a layer of fractured shale to prevent the banks from sloughing back into the lagoon.

Manure slurry placed in the lagoons was expected to stratify into three distinct zones: (1) a floating surface crust, (2) an intermediate strata of liquor that was high in dissolved and colloidal solids but low in suspended solids, and (3) a bottom deposit of settleable solid material. The previous passage of input slurry through manure chopper pumps in the collection sumps in the barn and in the central manure slurry pump sump was expected to eliminate coarse or long and fiberous material that would tend to impart rigidity to either the crust or bottom deposits. The formation of a floating crust was considered to be desirable. It would tend to become a porous aerobic barrier to the escape of volatile, odor producing gases and would also insulate the lagoon contents against heat loss.

When withdrawal of slurry for field application was desired, some mechanism of resuspending the bottom deposits and of breaking up the surface crust was needed. Initially, it was planned that a manure chopper pump would be installed on a pier near the center of each lagoon. The pumps would be equipped with jets that could be rotated about a vertical axis and swivelled to angle upwards or downwards and, therefore, be aimed in almost any direction. This plan was discarded for four reasons: (1) it would require one such pump for each lagoon, (2) it would provide for only one elevation of withdrawal in each lagoon, (3) it would require electrical service extending to the center of each lagoon, and (4) each supporting pier and pier-to-bank service bridge would have to be designed to resist the starting torque of the chopper pumps and also to allow for hoisting and removing the heavy pumps for maintenance or repair work. Turbine type mixers in each lagoon would have presented similar problems. Neither chopper pumps nor turbines located in the lagoons could have provided for withdrawal from the stratified liquor zone for feed to the aerobic treatment facilities.

As an alternative scheme for lagoon mixing and withdrawal, light bridges and piers were designed to extend to the center of each lagoon. A 4-inch diameter PVC pipe, suspended from the bridge, branched to either of two mixing jets in each lagoon. One of these jets was located four feet from the lagoon bottom and the other at ten feet above the bottom. Each jet mechanism could be horizontally rotated through 360° and swivelled from about 45° above horizontal to about 30° below horizontal. Either or both jets could thus be directed towards any bottom deposit or floating crust.

The jets and bridge supported pipe of each lagoon were designed and valved to receive new manure slurry from the central manure slurry tank or recirculated slurry drawn from any lagoon. The jets, therefore, served as the inlet connections to the lagoons.

Though construction of a third lagoon was deferred, all three lagoons were designed to form an L-shape having a common corner. A single withdrawal or recirculation sump and pump was designed to be located in that common corner. Any withdrawal from any sump would be via a 12-inch diameter ductile iron pipe extending from near the bottom of each lagoon to this single sump. The ductile iron pipe for each lagoon was reduced to a stub section of 8-inch pipe at lagoon floor level. The stub pipe extended just into the lagoon adjacent and parallel to the length of the bridge. A 5-foot section of reinforced Neoprene dredge hose coupled this 8-inch diameter stub pipe to a 21-foot long section of 8-inch diameter aluminum pipe extending on out into the lagoon. With the hose section in the line, the aluminum pipe could be swung through any angle from horizontal to vertical. These pipes allowed gravity flow withdrawal from any level within the lagoon before, after, or during mixing. It was not necessary to install valves in either the ductile iron or aluminum pipes since the open end of the aluminum pipe could be raised out of the liquid to provide flow shut-off.

A small hand winch from each bridge to the corresponding free end of the aluminum pipe provided for hoisting it to the desired withdrawal elevation. Unfortunately, it was subsequently found that hoisting the aluminum pipes was not difficult but getting them to sink and flood when empty did pose a problem.

The withdrawal sump was 21-feet deep with a bottom floor elevation about 2-feet lower than the floor of the lagoons. A poured concrete base supported 4-foot diameter concrete pipe which served as the vertical sump walls. A 40-HP manure chopper pump was modified to incorporate a 19-foot long vertical enclosed pump shaft. The motor was mounted above the top of the sump to drive the pump located just above the sump floor.

The discharge connection of this deep sump pump was designed to be valved to flow: (1) back into any lagoon through the mixer jets, (2) to the central manure slurry tank and thus to the field distribution system, (3) directly to the field distribution system without additional pumping (for possibly loading liquid manure spreader tanks at remote locations), or (4) to a feed storage-equalization tank for an activated sludge treatment process.

AEROBIC TREATMENT FACILITIES

When the Project plans were initially being developed, it was felt that some effort should be directed towards destructive treatment of manure slurry as an alternative to only storage and field application. It was not felt that such treatment would be essential to future Honor Farm operations although they might prove helpful. If stratified liquor could be withdrawn from the lagoons and upgraded in quality by aerobic treatment, such water could either be reused as flushing water or discharged. This would reduce the required lagoon storage capacity. Such aerobic treatment could also be useful in disposing of liquid wastes from the milk processing plant. More importantly, success of such treatment might prove valuable to dairies having insufficient land suitable for field application of manure. Since the anaerobic lagoons would be in operation anyway, it was considered appropriate to attempt such treatment in connection with the Project.

For the sake of simplicity of facilities, a completely mixed activated sludge process was chosen. In order to avoid the additional maintenance problems associated with air cleaners, blowers, and air diffusers, a surface turbine was selected as the means of aeration and mixing.

Certain assumptions were made to establish a design basis for the activated sludge process. The maximum volume of lagoon liquor to be treated was assumed to be equal to the amount of rainwater that could be expected to fall directly into the storage lagoons. The 36 inches of anticipated precipitation over 180 days of wet storage season would average 600 $ft.^3$ (4500 gal) per day of liquor to be treated. The anticipated strength of 3000 to 4000 mg BOD/l would represent an organic loading of 110 to 150 lb. BOD/day. Liquid wastes from milk processing, after some reductions in water usage and segregation of uncontaminated cooling water, were anticipated to be around 12,000 gallons/day at an average strength of 1000 mg BOD/l. This would impose a loading of 100 lb. BOD/day on the experimental activated sludge plant.

The stratified liquor from the lagoons could be withdrawn through the aluminum pipes and the deep sump but the rate of such withdrawal was far in excess of the activated sludge process rate. Also, the milk waste flow was highly variable and occurred during only a fraction of each day. An equalization tank was designed to accumulate and blend at least a 1-day supply of feed liquor (lagoon supernatant and/or milk processing waste). This tank was 14 ft.-10 in. in diameter by 10 feet deep (12,900 gallons). A concrete block wall on a poured concrete base formed the tank which was set below ground level in a fill area where hydraulic lift on the empty tank constituted no problem.

A smaller, but similarly constructed, tank was designed for the activated sludge aeration basin (11 ft.-9 in. diameter by 6 feet deep). At a maximum liquor depth of 4 ft.-2 in., it would hold 450 $ft.^3$ (3350 gallons) of mixed liquor or 112 lbs. of mixed liquor suspended solids (MLSS) at a solids concentration of 4000 mg/l.

The surface aeration turbine was a simple 24-inch diameter x 3/16-inch thick steel disk to the bottom of which eight radial flat blades (4-inch long sections of 1 1/2 x 1 1/2 inch angle) were bolted. Holes in the circular disk were drilled to admit air to the trailing side of the blades when rotated. The turbine was suspended from, and rotated by, a vertical shaft which was in turn suspended from the vertical output shaft of a gear reducer. The gear reducer was belt driven through a Reeves-type variable speed pulley by a 2-HP motor. The drive assembly was mounted on a fixed bridge spanning the aeration basin. The turbine disk could be raised or lowered on the vertical shaft to optimize aeration at any liquid depth desired in the basin. Mixed liquor depth, and thus volume, could be altered by an adjustable overflow weir which discharged mixed liquor to a final clarifier.

Input feed flow to the aerator was regulated by a float controlled constant head tank and valve. A 1 1/2 inch diameter line from near the bottom of the equalization tank extended to the suction side of parallel feed pumps. The pump discharge maintained the level in the constant head tank. Any excess flow was returned to the equalization tank through a mixing jet to keep the tank contents mixed and prevent any suspended solids from precipitating.

The final clarifier for separating the mixed liquor into final effluent and return activated sludge was 6 feet in diameter by 6 ft.-6 in. deep. It consisted of rings of concrete sewer pipe stacked vertically upon a poured concrete base. A steel cone in the base formed a sludge hopper and suction connection for the return activated sludge pump. Inflow to the clarifier entered a central stilling well at mid-depth. A bottom sludge scraper was rotated at 3/4 RPM by a bridge-mounted worm gear reducer. A common motor powered the scraper and a diaphragm-type sludge return pump. Clarified effluent was collected at two weir cups at the surface and conveyed by gravity to a small effluent storage lagoon. It was initially planned that a chlorine contact tank would be installed in the effluent line, but it was later assumed that if chlorination was necessary, it could be done in the effluent storage lagoon.

No provision was made for either thickening excess activated sludge or for controlling a constant split between returned and wasted sludge from the clarifier. With an anticipated high rate of sludge synthesis at the high organic loading, such provisions should have been made.

FIELD DISTRIBUTION SYSTEM

Several dairies in the Pacific Northwest and elsewhere had previously constructed pits to accumulate manure in liquid slurry form over short periods of time. Some dairymen pumped this slurry into tank spreaders and hauled it for crop land application on a year round schedule. Others had installed high pressure chopper pumps which delivered slurry through portable aluminum pipe to a single manure "gun" or spreading nozzle for field application. Such pump and pipeline application was also practiced on a year round basis. In some instances for either of these spreading techniques, there could be little doubt that water and/or solids could flow away to contaminate surface waters during the wetter winter seasons. Problems of field compaction and rutting by wheeled tractors and tank wagons was at least logically reduced by the pump, pipeline and nozzle system. The pump, pipeline and nozzle equipment was commercially available and appeared to be quite reliable.

In planning for long-term storage of manure during the wet seasons of high runoff potential, it was recognized that the subsequent field application technique would be vitally significant. The cost of field application had to be minimal. The timing of application to most crops or fields could be critical. Any labor requirements for field spreading operations during the summer would be superimposed upon labor needs for seeding, maintaining and harvesting crops during the growing season. All such consideration indicated that manure slurry application could best be accomplished by pump, pipeline and nozzle technique. While portable aluminum pipe offered flexibility of operation, labor for moving and reconnecting long strings of pipe represented a significant problem. Surface lines crossing fields and roads would interfere with movement of cultivating, harvesting, and hauling equipment. Aluminum pipe can be damaged rather easily. For these reasons, a primary distribution system of underground pipeline was designed to reach within 1500 feet or less of any point on approximately 175 acres of crop land on the Farm. Six riser stations for connecting portable pipe were strategically located so that spreading manure on any one field would not block vehicular traffic in or from any other field. Figure 29 indicates the location of the underground pipeline, valves and risers. An additional 1500 feet of portable secondary line was needed to connect the buried line to the manure gun at any desired point on the Farm.

The flow in the field distribution system would be pumped by the high pressure chopper pump in the sump adjacent to the central manure slurry tank. This pump was rated to match the desired flow and pressure rating of the field distribution "gun" or nozzle. (i.e. 200 gpm at 100 psig). Friction losses in the distribution system would vary, of course, depending upon how far the flow was conveyed in the underground line and how much portable pipe was needed to reach a selected point of application.

PVC pipe and fittings were selected for the underground pipeline because of its smooth interior surface and the ease of assembly of the cemented

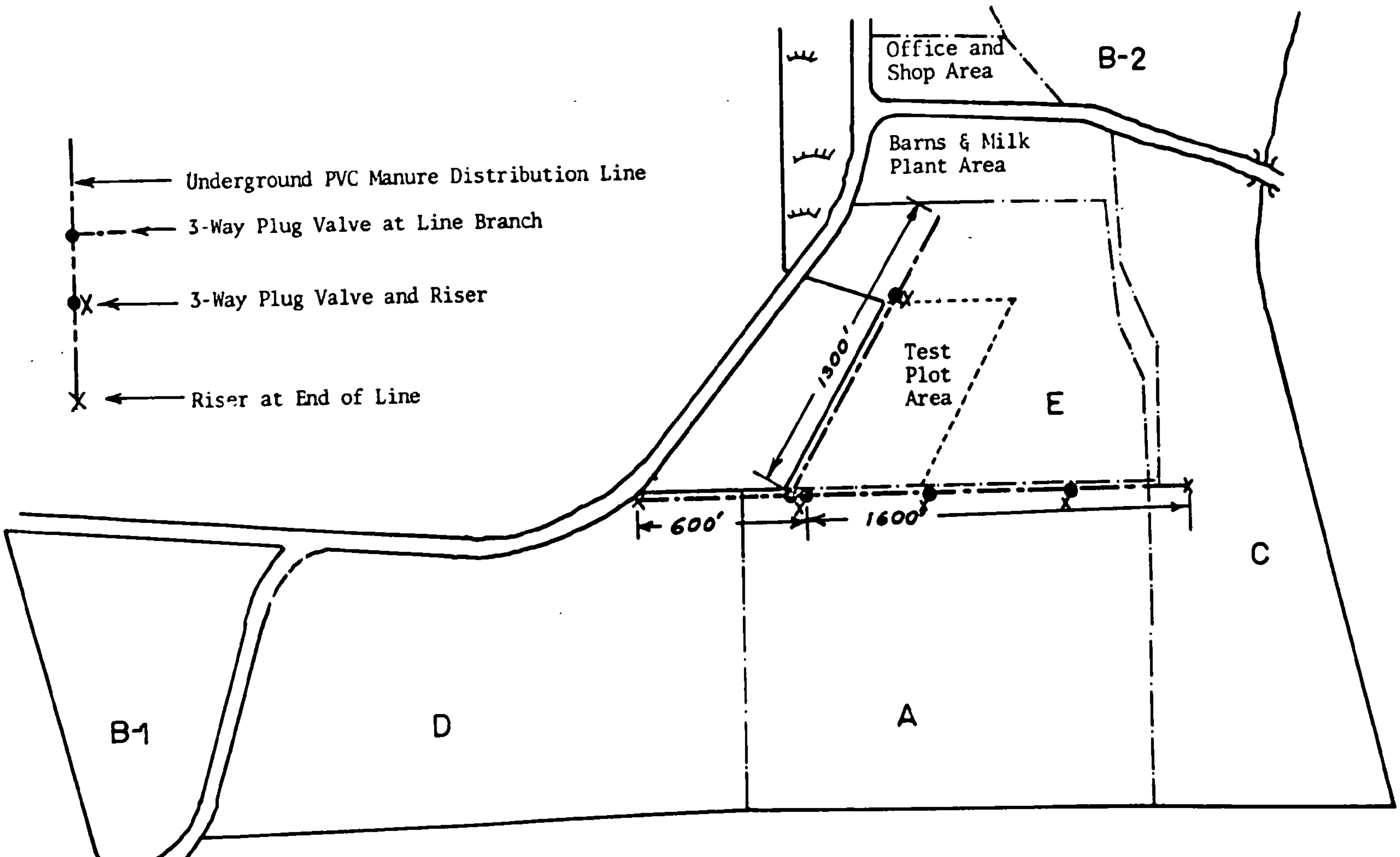

Figure 29. Farm Plan Showing Location of Underground Pipe, Valves and Risers of Field Distribution System.

joints. Approximately 1830 feet of 5-inch diameter and 1670 feet of 4-inch diameter line were to be laid at depths of 4 feet. Larger pipe would have allowed lower head losses but both the pump manufacturer and the pipe vendor felt that at flows of 200 to 230 gpm, the velocity could be low enough to permit solids segregation and deposition in lines of any size greater than 5 inches.

It was recognized that if the line should become plugged with solids at any point, it would constitute a major expense to excavate the line, cut out the plugged section, and splice in new pipe. The suspended solids of manure slurries tend to be strained out and tightly compacted if a slurry line is partially obstructed. The lines, whether aluminum or PVC, tend to stretch slightly under pressure and fill with tightly packed solids. Then when the hydrostatic pressure is released, the pipe contracts to solidly grip the plug of solids which can build up to several feet in length. Efforts to rod or ream out the solids are usually futile. For this reason, a three-way plug valve instead of a Tee was installed at every branch or riser location in the buried line. Thus no dead-end section would be left under pressure except when actual flow was occurring. Operational plans called for flushing the pipeline with solids-free water whenever use of any section would be discontinued for more than a few hours. This was intended to, and did, prevent solids deposition and consolidation anywhere in the line.

Each of the six riser stations consisted of a three-way valve installed in the main underground line with the side port connected to an elbow and a vertical riser extending above ground level. Each riser terminated with a quick-coupling connection for 4-inch diameter aluminum irrigation pipe. Aluminum pipe in 30-foot lengths with irrigation-type couplings was provided to reach any selected point of application.

The manure "gun" discharged through a 15/16-inch diameter nozzle. The "gun" nozzle was mounted on a vertical-axis swivel joint and discharged at an angle of about 40° above horizontal. Gun rotation was accomplished by a jet deflecting blade on a counter weighted kicker arm that swung up into the jet about once every two seconds. The gun assembly was wheel mounted for portability.

LABORATORY - OFFICE BUILDING

Institutional Farm Industries did have some office space at the Honor Farm but such space was already utilized to full capacity before the Project was initiated. Space suitable for establishment of a laboratory was not available. Initially, it was planned that a temporary laboratory-office building would be constructed in the proximity of the manure storage and treatment facilities. This would have necessitated the extension of potable water lines and other utilities, however. There was also a serious question about inmate security and safety if the laboratory was situated beyond the immediate view of the security office. It was decided that the new laboratory-office space could best be added on to the existing Honor Farm offices where water, telephone, and other utilities were already available and where items such as copy machines could be shared. The new space would then have utility after conclusion of the Project instead of requiring expenditures for removal.

A 20-foot by 59-foot concrete block walled addition was planned to extend across the front of the existing Institutional Farm Industries offices. As shown in Figure 30, the laboratory would occupy 260 square feet of the new space plus 140 square feet of the existing building space. The remaining new area would provide: (1) office space for the technical staff of the Project, (2) enlarged office space for the Project Co-Director, (3) a conference area, and (4) a clerical and switchboard office. Some Project accounting work would be conducted in the older existing office space.

MISCELLANEOUS

It was initially planned that wastes from the milk processing plant would be intercepted in a pump sump. From this sump the waste would either be pumped to the aerobic treatment facilities for lagoon supernate or to a new lagoon to be built to handle sanitary sewage associated with inmate housing and food service. The sanitary sewage lagoons did not represent a portion of this Project, but it was contemplated that they would be constructed at about the same time. Plans were developed for interceptor sumps for both the milk processing waste flow and for the waste from the milking parlor. Subsequent changes in plans for the sanitary waste problems prevented actual development of these planned facilities.

Approximately ten acres of farm land was set aside for experimental agronomy test plots. This was staked out for tests with varied amounts of manure applied in accordance with several application schedules for several different crops. The area selected was situated so that it could either be served by the field distribution system or by more conventional methods of manure application.

Some trial sections of concrete gutters were designed to be constructed by a local concrete products firm. These gutters were built to permit installation of high velocity jets of flushing water so that heavy or thick manure slurry could be conveyed to collection sumps. Though the gutter sections were found to be capable of manure slurry transmission, they were not found to be economically attractive. Actually, it was found that rather thick manure slurry could be conveyed through gravity concrete or plastic lines rather easily anyway so that special gutters were not necessary.

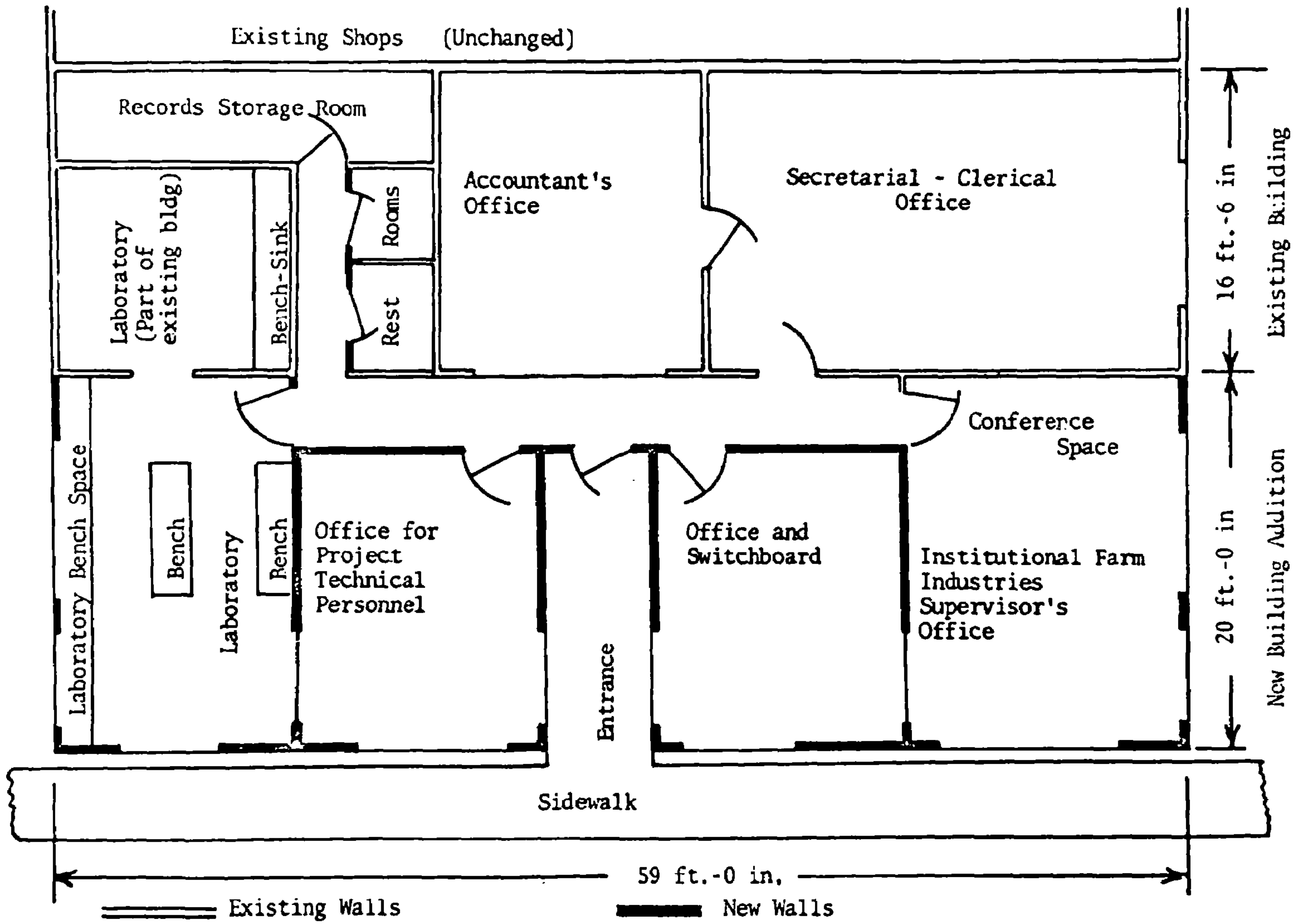

Figure 30. Plan of Laboratory - Office Addition

APPENDIX E

CONSTRUCTION--PROGRESS AND PROBLEMS

ANAEROBIC STORAGE LAGOONS

Recognition of the probable impact of the approaching winter climate dictated that earth work for the deep anaerobic storage lagoons should start at the earliest possible time. Design details and layout surveying could not be completed until mid-September, however. This coincided in time with both the height of the regional construction boom and the highest seasonal labor demands for crop harvesting in the local area. It was actually late September before lagoon construction could be initiated.

By mid-October, the deep lagoon withdrawal sump was installed and much of the earth work for the lagoons had been done. An occasional light rain had occurred without consequence but on October 18 there was an estimated 1 1/2 inches of precipitation. This gave the first real indication of how difficult it actually would be to work with the river bottom soils during the wet winter months. It became obvious by the end of October, rather than at the end of November, that the lagoons simply could not be finished until the following summer. Water was standing to depths as great as 2 1/2 feet in lagoon areas already excavated. Embankment slopes on both the inside and outside of the lagoons were sloughing badly. Any attempt to compact the lagoon walls resulted only in deep ruts and more mud.

The Farm is located near the confluence of the Snoqualmie and the Skykomish Rivers, both of which have large drainage areas in the Cascade Mountain Range. An above normal snow pack had accumulated by late December when warm weather and heavy rains started rapid melting and runoff. A near-record flood resulted to further plague construction efforts. Figures 31 and 32 show the sloughing and the nearness of flood waters as of late December, 1967. Had the initially planned location of the storage lagoons along the old slough been maintained, they would probably have been overtopped and certainly would have been encircled by the flood waters.

Portable pumps were used to dewater the previously excavated portions of the lagoons in early April, only to be filled again by more rainfall. Only after repeated pumping was it possible to resume lagoon earth work in June, 1968.

Several design changes were required. A previously unsuspected thin gravel lens was encountered just below the planned lagoon floor level. It was necessary to elevate all levels about 1 foot to avoid the probable exfiltration problem. This decreased the amount of excavated material and increased the amount of dike fill material required in order to maintain the same storage capacity. The excess required fill was hauled by truck from a hillside barrow pit. It was also necessary to

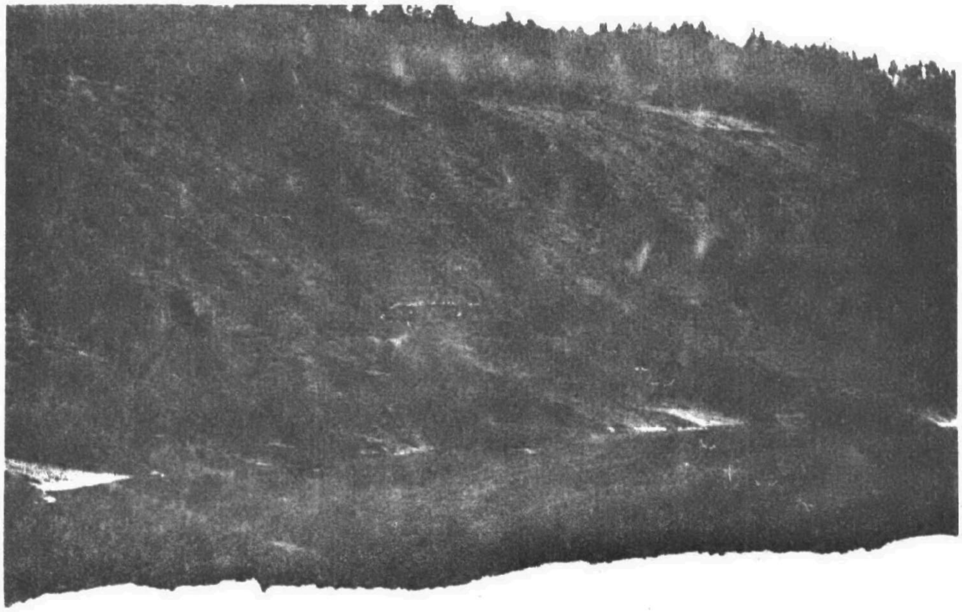

Figure 31. Deterioration of Anaerobic Storage Lagoon Embankments (December 1967)

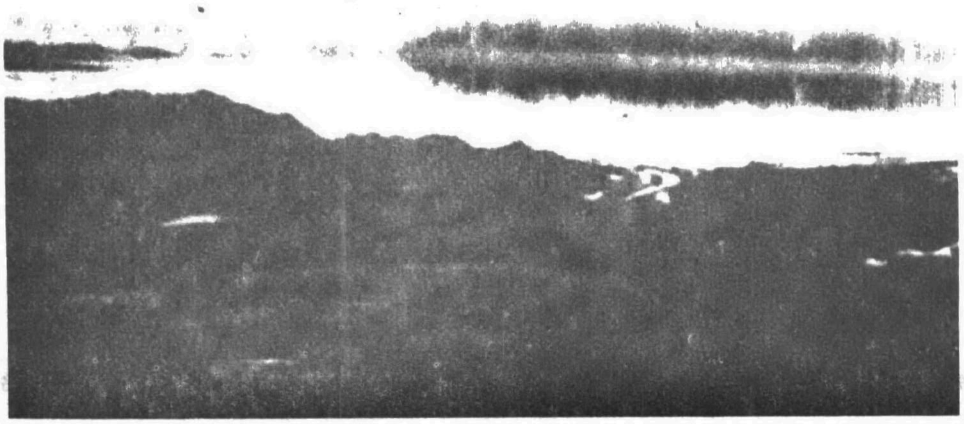

Figure 32. Flood Conditions Adjacent to Lagoon Construction Area. Cropland in Background (December 1967)

cover all exposed embankment surfaces with a rock surcharge to stabilize the slopes and prevent additional sloughing or erosion.

Placement of the 12-inch ductile iron slurry withdrawal connections to the deep withdrawal sump, completion of earth work, and hauling of the rock surcharge material was completed in mid-August.

Concrete footings were formed and poured in each lagoon at: (1) the top of the west bank slope, (2) near the bottom of the west bank, and (3) six feet towards the west bank from the center. These concrete footings were to support the service bridges for the lagoons. Used or surplus 4-inch by 4-inch galvanized steel angles were used to fabricate an intermediate and center pier for each bridge. Enough surplus structural aluminum beam was acquired to form the deck beams of one bridge. Timber beams were used for the second bridge. Each bridge extended approximately f feet beyond the central support pier to allow placement and rotation of the influent slurry nozzles. Decking planks were secured directly to the service bridge beams.

The 4-inch diameter PVC influent slurry lines for each bridge were suspended below and immediately adjacent to the bridge decking. These lines were then branched, valved, and reduced to form parallel 3-inch diameter steel lines near the central pier of each bridge. (See Figure 33). Both 3-inch lines extended on to the center of the lagoon and turned down through elbows to vertical drop pipes. A union was placed immediately below each of these elbows to allow rotation of the drop pipes about a vertical axis. One drop pipe in each lagoon extended to within four feet of the lagoon bottom with the other dropping to 10 feet above the bottom. A nozzle arrangement, fabricated from standard pipe fittings, was installed on the terminal end of each drop pipe. This nozzle could be swivelled from about 45° above horizontal to 30° below horizontal by an operating handle extending up to the pipe unions. The combination of horizontal rotation at the unions and vertical swivelling at the nozzles allowed the influent flow to be directed in essentially any direction from either or both influent lines in either lagoon. The nozzle diameters could be changed to any size between 1 inch and 2 1/2 inch nominal pipe size. A steady bearing to resist the reaction of the nozzles was placed immediately below each nozzle and braced to the central bridge support tower.

Five-foot long sections of 8-inch diameter Neoprene dredge hose was coupled to the buried ductile iron gravity withdrawal pipes for each lagoon. A 21-foot long section of 8-inch diameter aluminum pipe was coupled to the free end of the dredge hose to serve as a variable level decanting line.

Figure 34 shows the service bridge and decanting line of one lagoon. The vertical influent slurry lines, bridge safety rails, and winch to operate the decanting lines had not been installed when this picture was taken. The naturally fractured shale used as stabilizing surcharge was in place at that time.

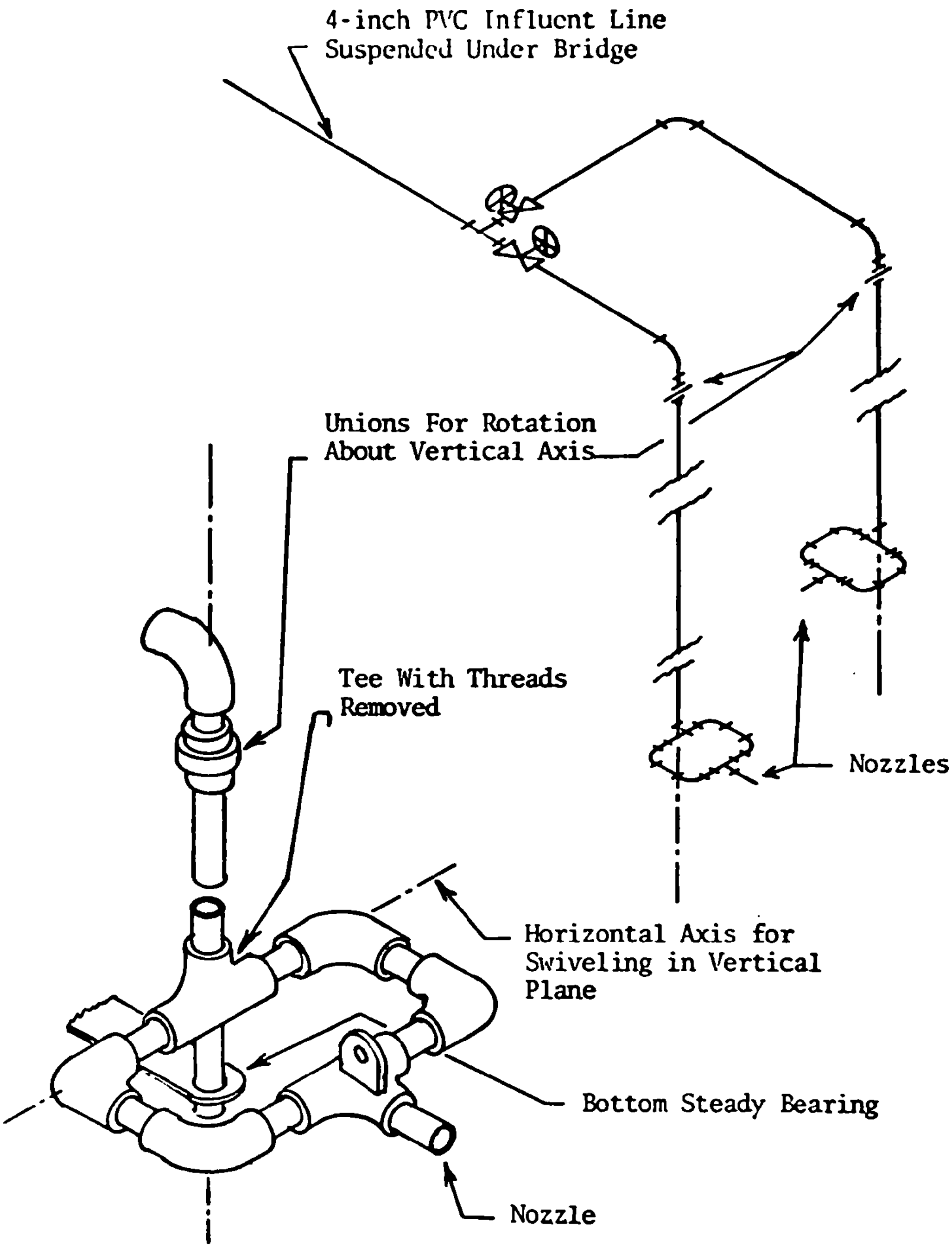

Figure 33. Schematics of Influent Piping to Anaerobic Storage Lagoons

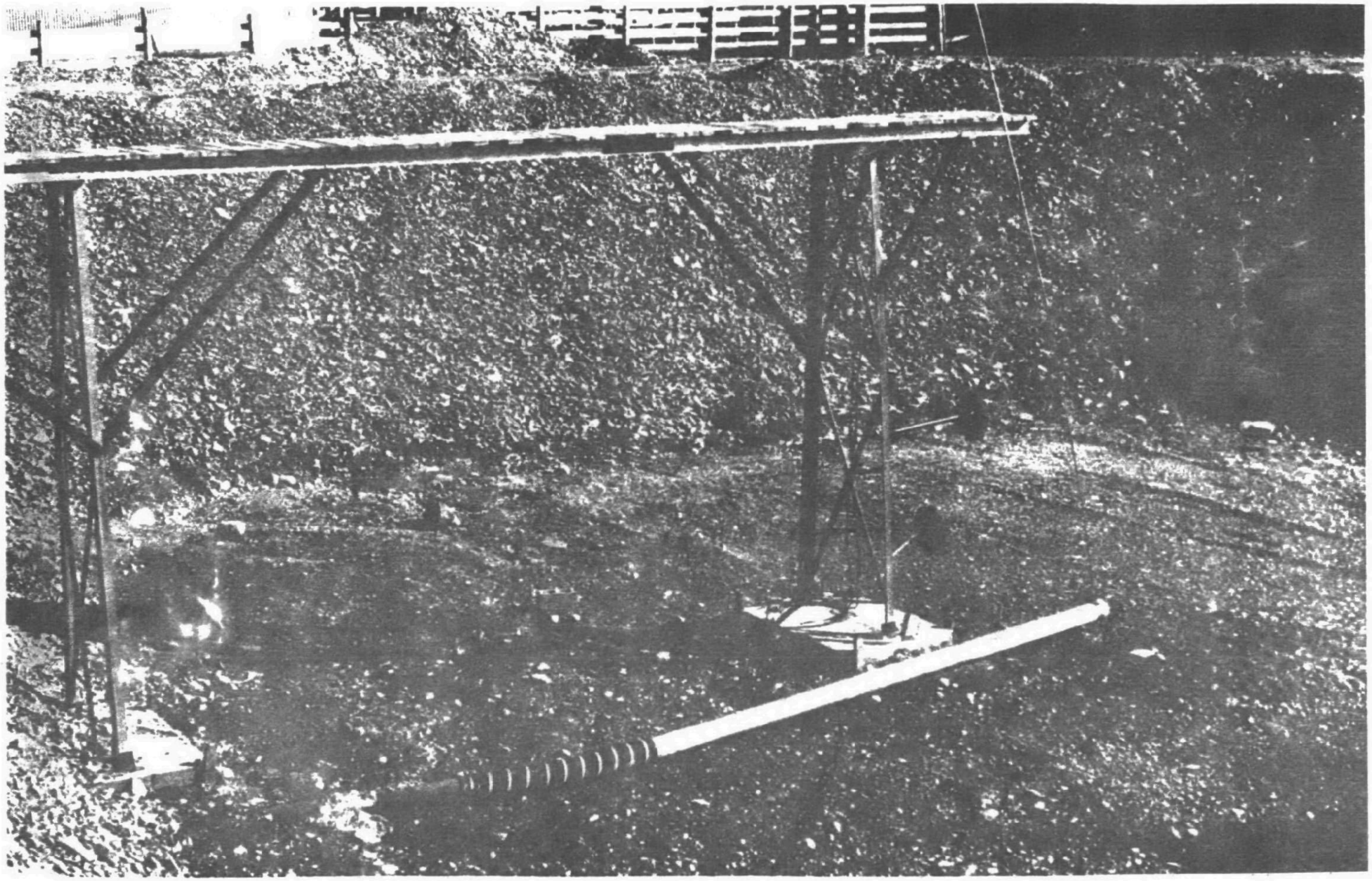

Figure 34. Anaerobic Storage Lagoon Showing Bridge, Withdrawal Pipe and Neoprene Hose Connection

Slurry was first stored in the first lagoon in early March, 1969. The second lagoon was completed and ready for use in June, 1969.

CATTLE HOUSING

While design and layout work for the anaerobic storage lagoons was progressing, site preparation for the new barn or confinement structure was underway. Even before a decision to move the hay barn had been made, placement of fill dirt to elevate the new barn site above the floodable land surface had started. Concrete footings for the new location of the hay barn were formed and poured and the movement itself completed during the last week of August 1967.

The hauling of fill dirt for the new barn site was pursued only whenever either men or equipment were not committed to lagoon construction or to critical farm operations. By early November, 1967, the estimated 8500 cubic yards of fill was sufficiently near completion to allow surveying and staking for the location of all column footings for the new structure. Considerable difficulty, associated with rainy or freezing weather, was encountered before all the forming and pouring of the 72 concrete footings could be completed in mid-December.

The prefabricated structural steel elements for the new barn arrived via rail from Texas in early January, 1968. The erecting contractor had all structural elements erected by the end of January and had the building roof and upper wall sheeting completed by mid-February. By this time, plans for the interior details of pens, mangers, walls, and manure sumps were complete allowing such construction work to be undertaken under roof.

The first manure collection sump to service 2 cattle pens, the main loafing area pavement of pen A, and most of the footings for the divider walls of pen A were formed, poured, and completed by late March, 1968. Freezing weather and labor shortages had significantly delayed progress on the interior details for the barn. Late delivery on purchase orders for PVC pipe and fittings and on control valves further delayed the completion of the first pen and the pavement of the central alleyway, since some pipe fittings and valves had to be installed under the concrete mangers and alley floor slab. Work on other facilities such as the laboratory-office building and some service water lines was underway while awaiting receipt of critical construction materials for the barn. Construction of a second manure collection sump and a start on the second and third cattle pens were worked into the schedule during the delay of work on the first pen. The storm water collection and removal system, consisting of 10-inch and 15-inch concrete pipe was also installed during March and April.

The PVC pipe and fittings began arriving in April. Hydraulic flushing water supply lines, perforated flushing lines, the elevated tank and distribution lines for stock watering, and the manure slurry transfer lines could then be installed allowing completion of the first pen. The mangers, stanchions, curbs around the bedded stalls, and other details of the first pen were completed in late May. The first 63 head of cows were transferred to pen A on May 27, 1968. Some minor changes in the flushing water lines and in the bedding arrangement of stalls were needed. It was June 7, 1968, when cattle were permanently installed in pen A.

According to the initial plan, cattle would be observed in the first completed pen for a few days before starting construction of additional pens. The late receipt of pipe and valves had made it necessary to proceed with construction of the second manure collection sump plus significant portions of pens B and F before such observations were possible, however. Pen F, to house young stock and pregnant heifers, was being completed as a subdividable holding pen without any individual bedded stalls.

While construction work on the interior facilities was progressing at the Project site, the mobile chopper pump rig to operate with the manure collection sumps was being developed in the shops at the Washington State Penitentiary at Walla Walla. This rig, described on page 94, was completed and ready for use by June 7, 1968, when cattle were permanently installed in pen A. Though the transfer line to convey manure slurry to the central manure slurry tank was complete at that time, the central manure slurry tank itself was not. It was necessary, therefore, to construct a temporary slurry line from the first collection sump to a point just outside the barn. The mobile chopper pump rig could then be used to load a truck-mounted tank-type manure spreader for application of the manure to fields.

Pen F was completed in July and pen B in early September. The only significant differences between pens A and B were: (1) the perimeter flushing lines under the concrete manger and at the end of the alleys between stalls were omitted in pen B, (2) a different orientation to the brooming or roughening of the concrete floor slab surface was used, and (3) the dividers between bedded stalls was modified. Construction activity inside the barn was then slowed down in order to divert both men and equipment to the completion of other facilities such as the lagoons, the central manure slurry tank and its adjacent pump sump, the field distribution system piping, and repairs to water service lines.

In September, 1968, the truck-mounted "hydraulic broom" was subjected to its first full scale test. (See Pages 92 and 93). It was apparent that the "broom" would never be able to flush away one day's manure accumulation along the full 115 foot length of a pen. It did appear that it could, after modification, flush the manure laterally across the width of the loafing area of a pen. By this time, observation of the cattle in pens A and B had indicated that the width of the loafing area could and should be significantly reduced which would also reduce the distance over which manure needed to be flushed. Construction of pens C and D had to be delayed, therefore, until revised detail plans could be developed and necessary materials acquired.

A problem with the PVC pipe and fittings started to show up at about this time. The total significance of pipe failures developed later, but in September it was necessary to break out one section of the alley floor to repair a high pressure PVC water service line. Several more critical breaks occurred both inside the barn and elsewhere to cause serious interruptions in construction efforts. This problem will be more fully discussed in a subsequent part of this report.

The temperature dropped to about freezing in late December. Then, on December 30, 1968, a very rapid and severe further drop in temperature to about 0°F occurred. Although emergency plans had been established to drain the overhead stock watering supply tank and distribution lines to prevent freezing damage; the speed and severity of the temperature drop was too great. By the time it was realized that such emergency action was necessary, it was too late. Essentially every section of the pipe in the distribution system had already ruptured. Some float valves in the drinking cups for the cows had also broken. After considering the extent of damage and the possibility of similar occurrences in the future, it was decided that the stock watering system had to be changed. Sections of the concrete mangers were blocked off and converted to watering troughs or tanks. New underground supply lines were installed to avoid future freeze-up problems. The overhead supply system was drained, disconnected, and abandoned.

By January, 1969, the construction details for pens C and D were essentially complete. The arrangement of bedded stalls and mangers would be essentially the same as they had been for pens A and B. The loafing area width was to be reduced from 30 feet to 22 feet and would slope 1/8 inch per foot longitudinally and 1/4 inch per foot laterally. A grate-covered longitudinal gutter would run the full length of each pen sloping 1/4 inch per foot towards a common manure collection sump in the central alleyway. The gutter itself would have a 10-inch diameter circular cross section formed by pouring concrete around a Fiberglas liner. The common collection sump to serve pens C and D was to be a 10-foot diameter by 10-foot deep sump having concrete block walls on a poured concrete base. The sump was to be offset from the alley center far enough to allow an electrically powered chopper pump to be permanently installed in a small blocked off section of pen C.

The location of the new third collection sump presented a serious construction problem. The excavation required to pour the concrete would have to be about 11-feet deep and only about 8-feet away from the foundation pier for one building column and 12-feet from a second adjacent pier. While the excavation was open, the banks sloughed or caved in to the extent that both footings and columns were in jeopardy. To further compound the problem, one of the heaviest snowfalls of record for the area occurred while the footings were partially undercut. Thus a very heavy deadload (14 inches of wet saturated snow) was superimposed on the structure while two adjacent footing blocks (4 foot by 4 foot by 2 foot concrete) were suspended from the roof rather than supporting it.

Probably it was more a matter of good luck rather than good planning that permitted the sump base to be poured, the block walls to be laid, and the back filling to be completed without roof collapse.

The necessary 10-inch diameter Fiberglas liner sections for the gutters were fabricated in Seattle and available by the first of March. The intricate form work for the longitudinal gutter was completed, the Fiberglas liner sections assembled and placed, and the gutter concrete poured for pen C by the end of March, 1969. It had been decided that pen D construction would be postponed indefinitely since pens A, B, C, E, and F were adequate, in conjunction with pre-Project housing facilities, to handle the then existing herd size. Pens A, B, C, and E, when completed, would provide housing or confinement for 250 head of producing cows and pen F was already completed for housing young stock and pregnant heifers.

Even with the gutter installed for pen C, it seemed that completion of pen E, to be similar to pens A and B, could be achieved more quickly than for pen C. To the extent that men and equipment could be spared from construction of other project facilities and operations, they were assigned to completion work on pen E. This pen was completed and put in use in August, 1969.

Work on pen C then resumed but utilizing only the men and equipment to the extent that they were not completely engaged in other more critical work. Grading, forming, and pouring for the 22-foot wide slab of the loafing area, for the footings for pen walls, and for the alley between bedded stall areas moved quite slowly on this basis and was not completed until early March, 1970. Rather intricate form work and false work was required for pouring the alley floor slab over the new round manure collection sump and the beam to carry the wall of pen C across the top of the sump. The form work was ready for concrete pouring on March 12, 1970 when a significant change in plans became necessary.

As discussed on page 94, the mobile chopper pump was damaged repeatedly while in service on the two previously constructed rectangular manure collection sumps. It was then discovered that the manufacturer of the chopper pump had discontinued manufacturing and sales operations. Spare parts were no longer going to be available until, and unless, some other company acquired the patent and/or manufacturing rights. Since the pump had repeatedly sustained damage while being hoisted or moved, it was decided that a stationary pump system was needed that could handle the manure slurry from all of the cattle pens. The revised design for manure collection for pens A, B, E, and F is described on page 96 through 98 and is shown in Figure 27. The plan essentially called for installation of a 15-inch diameter line connecting the second and third (round) collection sumps and extending on to intercept the slurry flow from pens A and F.

The altered design called for a series of difficult construction steps which were further complicated by the fact that cattle were already housed in pens A, B, E, and F. These cattle had to be fed, watered, and moved to and from the milking parlor. Also, manure had to be removed while the alteration work was progressing in the central alleyway. The water supply lines and manure slurry transfer line was already installed under the alleyway floor slab and had to be protected while the excavation for, and placement of, the 15-inch concrete line was under way. Because of the critical need to coordinate the construction work with cattle operations, a higher priority was assigned to the alleyway construction work.

The heavy steel troughs to be inserted into the manure receiving slots in the sump for pens A and F were fabricated in the machine shops of the College of Engineering at Washington State University. While this was under way, the excavation was made to lay the 15-inch line from the round manure collection sump to the middle (pens B and E) collection sump. The central alleyway had already been paved between pens A, B, E, and F so it was necessary to break out a 6-foot wide by 40-foot long strip of concrete in order to excavate that portion. While this was not reinforced concrete, it was discovered to be from 6 to 8 inches thick instead of the planned 4-inch thickness. Three-inch deep cuts were sawed along both sides of the breakout strip in order to avoid cracking the remainder of the alley slab or the footings for the pen walls. A pavement breaker was then used to fracture the strip of floor slab.

The middle collection sump had to be pumped and cleaned in order to open holes through the heavily reinforced sump walls to connect the 15-inch concrete pipe. It was discovered that the forms had slipped when the south wall of the manure sump had been poured with the result that the wall was actually 16-inches thick at the point of breakthrough rather than the 8-inch designed thickness.

As soon as the section of new line from the round sump to the middle sump was completed and back filled, the remaining section to connect pens A and B to the middle sump was started. The strip of alley floor slab was broken out and the trench excavated. A manhole was constructed near the north wall of the south sump to form a transition from the steel troughs, installed in the manure slots, to the 15-inch concrete line. A portion of the high pressure water service line had to be relocated in order to allow placement of the lines connecting the steel troughs to the manhole. Both the water line and the manure slurry line (both 4-inch diameter PVC) were found to be under a severe strain because of differential settlement of the barn site fill material. The lines were uncovered and realigned before back filling and repaving the central alleyway.

Connections were provided in the south sump (between pens A and F) to allow recirculated slurry to be flushed through the troughs and concrete line. A high pressure water outlet near the sump could also be used for flushing in the event that there was not enough slurry on hand for recirculated flushing. An outlet was also cut into the manure slurry transfer line in the middle sump. A mainline valve, a branch valve, and a nozzle were installed in the middle sump so that the discharge from the stationary chopper pump could be directed to agitate the contents of the middle sump and thus assure flow on to the round sump.

The pouring of the slab over the round sump and the beam to carry the pen wall across the top of the sump was accomplished while the alterations in the alleyway were progressing. By the end of June, 1970, all the alteration work in the alleyway was completed except for the actual installation of the stationary chopper pump in the round sump and the installation of a slurry line to the outside end of the longitudinal gutter in pen C. This line would provide for recirculation through the gutter for flushing purposes. Provision was also made to flush the gutter with fresh water if necessary at any time. The pump was installed and operational by mid-July. The mangers, watering troughs, stall dividers, grate covers for the longitudinal gutter, and other details of pen C were completed by the end of July, 1970. Cows were installed in this pen on August 6, 1970. This essentially completed all construction work on the new barn.

One additional detail of construction has not been previously discussed. The barn structure proper had initially not included any enclosing walls between the ground level and an elevation of 14-feet above ground. During the 68-69 winter season, it was observed that the predominant southerly winds were driving rain and snow well into the barn. It was decided that closing in the south wall would significantly reduce the winds in the barn and would protect the mangers of pens A and F from the wind blown precipitation. This was accomplished sometime during that winter season.

MANURE TRANSPORT AND AEROBIC TREATMENT FACILITIES

The central manure slurry tank, the high pressure chopper pump sump, the aerobic treatment facilities, and the treated effluent storage lagoon were all to be located in a common area adjacent to the anaerobic storage lagoons. These facilities were all to be constructed as open-topped vessels or pits recessed below grade. It was necessary that they neither be subjected to inundation during flooding situations nor to hydrostatic lift should they be empty when groundwater levels might be high.

The three initially planned anaerobic storage lagoons were to be constructed in an L-shaped configuration so that they would occupy three quadrants of a large square. The central manure slurry tank and aerobic treatment facilities were to be constructed in the fourth or remaining quadrant of the square. The ground level of the facilities quadrant was to be elevated to approximately the same elevation as the top of the storage lagoon embankments using fill dirt acquired during the excavation and construction of the anaerobic lagoons.

Construction surveying and staking started in September, 1967, for the anaerobic storage lagoons and the above facilities. A combination of earthwork efforts and rainy weather had reduced the facilities quadrant to a bottomless mud bog by late October, 1967, when further earthwork was halted. By the time work could resume in the following spring, a decision had been made to defer construction of the third storage lagoon. This reduced the amount of available fill material. Also, encountering a gravel strata at the planned lagoon floor elevation made it necessary to raise all lagoon elevations. This further reduced the yield of fill material from lagoon construction. It was necessary, therefore, to haul in some 2,000 cubic yards of additional fill material in order to elevate the facilities quadrant and to complete the lagoon embankments. A gravelly glacial till material from a hillside site was selected that would add stability to the fine textured soil at the lagoon site. The filling and rough grading of the area was completed by early June, 1968.

The general layout of the central manure slurry tank and aerobic treatment facilities is shown in Figure 28 on page 99. The designed details for the central manure slurry tank are discussed on page 100, and the remaining facilities details are given on pages 103 through 105.

The excavation for the various tanks was started on June 28, 1968. The concrete bases for the central manure slurry tank and the high pressure chopper pump sump were poured first. The first ring of 4-foot diameter sewer pipe to form the walls of the pump sump had been provided with an opening for the 24-inch diameter corrugated pipe connection between these two tanks. As soon as the bottom ring of the pump sump and the corrugated connection were in place, the concrete block and mortar walls of the central manure slurry tank could be placed. The remaining section of the pump sump walls were then placed and grouted allowing the placement of backfill around both tanks.

The equalization tank and aeration basin were the next tanks to be constructed. The excavations were made and the bases poured simultaneously. The block walls of these two tanks plus the earthwork for the treated effluent storage lagoon had just been completed when a nearby major waterline broke. The resulting flood washed soil and gravel into all of the completed tanks and caused significant sloughing of the effluent lagoon banks. It was necessary to clean out the tanks and reshape the effluent lagoon before any further work could proceed. Rock surcharge was placed to stabilize the interior embankment slopes of the lagoon against further sloughing. The final clarifier basin was then constructed. Before the concrete bottom of this tank was poured, a conical steel sludge hopper and sludge withdrawal pipe had to be placed in the concrete form. The construction of all of the basins, less all internal hardward and plumbing, plus the treated effluent storage lagoon was completed by the end of August, 1968.

A 6-inch diameter gravity flow PVC line with a gate valve was installed to connect the treated effluent storage lagoon with the high pressure chopper pump sump. This was to make it possible to use treated effluent for flushing solids out of the lines of the field distribution system when desired or for rinsing manure solids off of field vegetation following the application of manure slurry to growing crops.

A tower or column was erected at the center of the central manure slurry tank to support the turbine type mixer and one end of a service bridge. The bridge itself was then constructed. A wooden steady bearing for the mixing turbine was mounted in a recessed hole in the floor at the center of the central manure slurry tank. The turbine and its supporting drive shaft were then installed.

Because of late receipt of the vertical output shaft worm gear reducer for the central manure slurry tank mixer, it was December, 1968, before the mixer turbine drive and high pressure chopper pump could be installed, wired, and ready for operation. The lines to transport manure slurry to the anaerobic storage lagoons were purposely being delayed at that time while causes of PVC line failures were being investigated. The manure slurry transport line from the new barn was ready for use, however, as was the piping to the field distribution system. The central manure slurry tank was filled with water to a depth of 7 feet to test the mixer and pump. Both the mixer and the pump appeared to perform satisfactorily. Subsequent operation with actual manure slurries, however, revealed that the mixer or agitator was not capable of resuspending deposits of heavy solids that settled out of the manure slurry. It was necessary to supplement the agitation of the turbine with a pair of 1/2-inch diameter hydraulic nozzles mounted near the bottom perimeter of the central manure slurry tank. These nozzles were installed on opposite sides of the central manure slurry tank and directed to oppose the rotational flow established by the turbine agitator.

The flow to the above nozzles was taken from the valved discharge of the high pressure chopper pump. The piping was valved so that either nozzle could be selected or both nozzles could be turned on simultaneously. The combination of the turbine and hydraulic agitation was capable of resuspending all settled solids except for some coarse sand that found its way into the manure slurry. Once resuspended, the turbine alone could maintain the suspension.

Though only a relatively small amount of pipe installation was needed to start transferring manure slurry on to the storage lagoons, it was felt that no more PVC pipe should be installed until there was a better understanding of repeated serious failures and breaks in already existing PVC lines. Since this matter will be discussed in a subsequent section of the report, it may suffice at this point to say that the breakage was understood and the transfer piping completed to the first lagoon in March, 1969. Manure slurry was applied on an adjacent field through the field distribution system until such lagoon storage started in March.

A higher priority on other work prevented further development of the aerobic treatment facilities for some time. The chopper pump for the deep withdrawal sump (see Item 5, Figure 28, Page 99) had to be specifically developed for the Project. A commercially available chopper pump head, identical to the one used on the mobile chopper pump rig, was purchased. This was then modified in the machine shops of the College of Engineering at Washington State University to allow a 40-HP motor at the top of the sump to drive the chopper pump at the bottom using a 19-foot long totally enclosed, oil lubricated, vertical shaft. The pump and motor were installed in June, 1969. Because of a defective magnetic motor starter, it was necessary to use a direct manual switch for operation of the pump during the first month in order to agitate the contents of an aerobic lagoon and transfer the slurry back to the central manure slurry tank for field application.

In November, 1969, work resumed on completion of the aerobic treatment facilities. A steel bridge to span the 11 3/4-foot diameter of the aeration basin was constructed. This was to support the surface turbine aerator and drive assembly. A variable speed turbine drive assembly which had been developed in the College of Engineering machine shops was mounted on the bridge. It consisted of a 10:1 ratio vertical shaft gear reducer which was belt driven through a variable speed pulley by a 2-HP electric motor. This provided an available speed range of 70 to 210 RPM for the turbine shaft. The elevation of the 8-bladed, 24-inch diameter turbine could be changed by raising or lowering it on the vertical turbine shaft. This permitted optimum aeration as the liquid level, and therefore the mixed liquor volume, was changed by adjustment of an overflow weir that discharged the mixed liquor flow to the final clarifier.

A raw feed line was installed to convey liquid from the bottom of the equalization tank to the suction side of two parallel feed pumps. Initially, two flexible-impeller vane-type pumps with variable speed pulley drives were installed as feed pumps. These pumps subsequently proved not to be reliable in self-priming and were replaced by more conventional centrifugal pumps. The feed pumps were piped to a constant level feed tank. All excess flow was piped back to a nozzle discharge in the equalization tank to prevent sedimentation or stratification in that tank. The rate of feed from the constant head tank to the activated sludge aeration basin was adjusted or regulated by a gate valve in the feed line. The suction pumps, constant head feed tank, and regulating valve were placed in a small wooden building which also housed the manual disconnects and magnetic contactors for all motors of the aerobic treatment facilities, the central manure slurry tank agitator, the high pressure chopper pump, and the deep sump pump. The sludge scraper assembly and drive shaft for the final clarifier was installed and coupled to a common drive which operated both the scraper and a diaphragm-type activated sludge return pump. The scraper was then used to screed in a concrete grout bottom for the final clarifier. The effluent weirs and influent stilling well were then installed. A clarifier effluent line was then installed to convey the treated effluent to the effluent storage lagoon. The electrical wiring to the turbine drive, the final clarifier drive, and the feed pumps was accomplished on January 14, 1970, to render the aerobic treatment facilities ready for operation.

FIELD DISTRIBUTION SYSTEM

The layout planning and staking for the field distribution system was established in November, 1967, according to the arrangement shown in Figure 29 on page 106. Floating debris during flooding in December removed or disrupted most of the stakes. The line and valve locations and grades were reestablished in June, 1968. The necessary PVC pipe and 3-way plug valves for the system did not start arriving until April, 1968.

A wheel-type trencher was brought in on June 9, 1968, to excavate for the pipe installation. Only 11 hours were required to excavate the necessary 3,500 lineal feet of trench. The trencher was able to cut a 24-inch wide trench to a precise continuous grade line varying from 40 to 48 inches below the uneven ground surface. The resulting ditch had a semicircular smooth bottom in the silty soil which simplified placement and bedding of the pipe.

The PVC pipe (1,830 feet of 5-inch and 1,670 feet of 4-inch) had an integrally formed bell on each length for a solvent-weld joint with the downstream end of the preceding length. PVC reducers and flanges were used to adapt to 3-way plug valves at each riser or take-off station and at the point where the line branched at the southwest corner of field E. (See Figure 29, page 106). All five of the 3-way plug valves were 4-inch diameter valves except for the first riser station where a 6-inch valve was used.

A cast iron flange, threaded for 4-inch pipe, was attached to the side port of the 3-way plug valve at each riser station. A close nipple and elbow from this flange provided for a vertical steel riser pipe extending above the ground surface where a quick-coupling connection for 4-inch aluminum irrigation pipe was installed. The quick-coupling also permitted the aluminum surface string of pipe to be swivelled to extend in any horizontal direction. For valve protection and valve-key operation, a section of 8-inch diameter concrete sewer pipe was installed over each plug valve.

The upstream end of the field distribution system was connected to a 6-inch 3-way plug valve in the line from the high pressure chopper pump. This valve could be set to discharge either to the field distribution system or to the anaerobic storage lagoons.

Both 4-inch diameter irrigation pipe without nozzle headers and 3-inch diameter pipe with conventional rotating impulse irrigation nozzles were purchased. The 4-inch aluminum pipe provided for conveying manure slurry to the manure "gun" while the 3-inch pipe and nozzles provided for conventional irrigation of crops. This provision allowed for the application of an amount of water to control plots to match the water applied in manure slurries. In this manner, it was felt that the crop response to manure nutrients could be identified separately from any beneficial crop response to the water content of the manure slurries.

The manure "gun" was described earlier on page 107. The overall field distribution system was completed in August, 1968, but it was December, 1968, before the high pressure chopper pump and central manure slurry tank were completed to allow testing of the installation. One solvent-welded joint failed during the first hour of operation using water rather than manure slurry. No further pipe or joint failures developed in the underground pipe system. Occasionally, the connecting latch joining sections of aluminum pipe for surface distribution would slip allowing the pipe joint to come apart. This did not result in any serious damage except possibly to the appearance or pride of anyone in the immediate vicinity.

LABORATORY-OFFICE BUILDING

It was mid-September before detailed plans could be developed and approved for the addition to the existing Farm Office building. The necessary concrete blocks, windows, doors, plumbing materials and fixtures, heating and lighting fixtures, and other miscellaneous items were then ordered. Actual construction started with layout staking on September 21, 1967, and with the installation of the septic tank and drain field to serve the addition.

The foundations, floor slab, concrete block walls, interior wall framing, roof joists, and roofing were completed by mid-October. The window assemblies were not received until November, however, to complete the "closing-up" of the building. Interior finishing could then get underway.

The necessary electrical space heaters and light fixtures were slow to arrive. Also, all electrical contractors in the region were already committed to more work than they could handle on schedule with the result that it was mid-December before much wiring was installed. The installation of some office lighting and heating fixtures was not completed before mid-January, 1968.

The laboratory benches, sinks, and cabinets were sufficiently complete by January to permit the laboratory equipment and supply vendors to start shipments on orders. It was soon discovered that the river bottom soil profiles were such that vibrations from trucks on the county road (75 feet away) would disturb the analytical balance. A special heavy concrete pillar mounted on a vibration damping pad was built to support the balance.

Both the Project office space and the laboratory were essentially complete and usable by the end of January, 1968. Installation of laboratory equipment items such as the Kjeldahl digestion-distillation apparatus, a constant temperature water bath for BOD tests, an autoclave, a small still, and other installed equipment was accomplished on an as-time-permits basis and were not completed until about July, 1968.

MISCELLANEOUS CONSTRUCTION

Several items of construction were involved that were either general in nature or that did not relate specifically to any single major aspect of the Project. This included some minor fencing, extension of the electrical power lines to serve the new pumps and treatment facilities, yard and barn lighting, and some minor relocation of roadways. These tasks did not represent a significant construction involvement nor did they present serious problems. One effort, however, that presented a long series of most significant problems was the extension of water service lines.

The farm water supply system consisted of a turbine-pump equipped well near the farm office and an elevated reservoir located approximately 1/2 mile away on the sloping valley wall. The reservoir "floated" on the farm distribution system providing about 200 to 250 feet of head at the various farm buildings depending upon whether the well pump was running or not and also depending upon the rate of water usage. The distribution piping was mostly composed of steel pipe with some sections of asbestos cement pipe. There was no existing water service immediately adjacent to the new barn structure that could provide water in sufficient quantity for livestock watering, flushing purposes, or fire protection.

After considering several possibilities, it was decided that the existing water mains should be tapped near the farm office and again near the milk processing plant. A high pressure supply loop would be extended from the first mentioned tap, south across the county road and along the full length of the east side of the new barn, then along the south side of the existing farm buildings, and then back to the second tap near the milk processing plant. Since pressures were not excessive and the possibility of severe water hammer impulses were considered remote; 4-inch diameter, 200 psi rated, PVC pipe with solvent-weld fittings were selected for the loop with the exception of the two road crossings. PVC piping was also selected for extending service lines into the new barn and to other points of need.

Based upon the ease and speed of installation, the choice of PVC lines and fittings seemed wise indeed, at first. No one involved in the Project, however, had previous experience in making PVC joints, but all accepted the idea that one advantage of PVC piping was the ease and simplicity of PVC plumbing. The necessary materials for essentially all Project piping needs were ordered at one time including needs for the distribution loop, all water service and slurry lines in the new barn, the field distribution system, and lines for the storage and treatment facilities. Both PVC joint cleaner and cement were also included in the order. Joint making instructions, provided with the joint cement and solvent, suggested that the outer surface of the male end and the inner surface of the famale end at each joint should be "cleaned" with the joint cleaner before applying the joint cement and joining the two elements. All of the pipe and fittings were from new shipments and appeared to be extremely clean. In making joints, the appropriate surfaces were lightly wiped with a cloth dampened with the cleaner. The joint cement was then applied and allowed to stand unjointed for a few seconds. Then the joint was pressed together, rotated slightly, and held firmly in place. This all appeared to be in compliance with the instruction as provided by the vendors.

By mid-July, 1968, some minor joint separations had occurred, but a serious problem of pipe failure was not yet apparent. A major break occurred in the high pressure supply loop along the east side of the new barn in late July. In August, 1968, the supply loop ruptured close to the area where the equalization tank and activated sludge aeration basins were under construction. This not only disrupted water service but also caused a significant set-back in construction of those facilities. A third major break in the supply loop developed along the east side of the new barn in September and the supply line under the concrete alley floor of the new barn also failed.

The vendors of both the PVC pipe and the cleaning and jointing solvents were contacted. They expressed the belief that the joints were failing because: (1) the jointing cement was not being applied uniformly, (2) the joined pieces were not being rotated after being "stabbed" together, or (3) bedding and backfilling for the pipes were not being done properly. They did provide a different brand of cement for further PVC pipe work.

Failure of PVC joints continued. In December, 1968, still another failure occurred under the alleyway floor slab in the new barn. Again it was necessary to break out concrete in order to make repairs. It was obvious that something had to be done or the Project crew would be spending full time on repairs, leaving no time for further construction or for Project operations.

A meeting between the pipe vendors, the solvent vendors, the Washington State University purchasing agent, the Project Director and Co-Director, and the Resident Project Engineer was held on December 19, 1968. In the course of the discussion, it was learned that the joint cleaner was possibly mis-named. The "cleaner" was actually intended as a surface softening or preparation solvent as well as a cleaner. While the construction crew had been carefully wiping the matching surfaces of joints with a "cleaner-dampened" cloth, the vendors indicated that the surfaces should be liberally wetted or saturated with the cleaner. The matching surfaces should then be allowed to stand for a moment to soften before applying the cement that would solvent-weld the surfaces.

Test joints were made following the more explicit instructions. These joints were than sawed open and examined to reveal a much more continuous and vastly superior bond or solvent-weld.

Eventually, confidence in the PVC piping was restored to the point that the lines conveying manure slurry to and from the anaerobic storage lagoons and additional piping for subsequent pens in the new barn could proceed. It is unfortunate that such a high price had to be paid for a small bit of knowledge. No PVC joint formed subsequent to that meeting failed by virtue of joint slippage or bond failure. Records of man-hours of effort expended and materials costs for pipe repairs were not maintained, but it is estimated that pipeline repairs probably cost about twice as much as the initial installation of the pipe systems.

Another construction item not discussed elsewhere and not included in the discussion of Project Planning and Design was the development of a shallow well in the area of the storage and treatment facilities. While construction of the central manure slurry tank and treatment facilities was underway, it was recognized that a significant amount of water would probably be needed. This water would be needed for: (1) flushing residual solids from the field distribution system lines, (2) for flushing solids off of growing vegetation after applications of manure slurry, and (3) for applying matching amounts of manure-free water to control plots so that it would be possible to differentiate between crop response attributable to manure nutrients and crop response attributable to the carriage water in applied manure slurries.

A 32-inch diameter by 30-foot long by 3/8-inch wall thickness section of used steel pipe was purchased from a salvage yard. Fifty-six lineal feet of 1/2-inch wide slots were cut out in the bottom 7 feet of the pipe. A drag line and clam shell bucket were used to excavate a hole into which the homemade well casing was then installed. The hole was then backfilled with clean gravel to complete the shallow well.

Though a permanent pump installation was never made, the well was tested for capacity in August, 1968. The suction hose of a gasoline engine powered dredge pump was lowered into the water level approximately 16 feet below ground level. During approximately 90 minutes of operation at 450 gallons per minute, a steady-state drawdown of less than 4 feet was observed.

Unfortunately, other Project construction or operation needs always continued to be more pressing or more urgent than installation of a well pump. Such installation was never accomplished. Such water as was needed for the above mentioned purposes continued to be drawn from the high pressure farm supply system.