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canada animal manure management guide

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CANADA ANIMAL MANURE MANAGEMENT GUIDE

This publication has been revised by the Animal Manure Management Committee under the authority of the Canada Committee on Agricultural Engineering Services. The Canada Department of Agriculture has agreed to publish the Guide, in accordance with the terms of reference of the Federal-Provincial Cooperative Committee on Agricultural Communications.

The Guide Committee

E.M. Barber (Chairman), British Columbia Ministry of Agriculture
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M. Pascua, Newfoundland Department of Forestry and Agriculture
A. Raad, Prince Edward Island Department of Agriculture and Forestry
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D. Hogkinson, Manitoba Department of Agriculture
M. Wrubleski, Saskatchewan Department of Agriculture
B.S. West, Alberta Department of Agriculture
W.M. Carson, Nova Scotia Technical College
J.B. McQuitty, University of Alberta
J. Pos, University of Guelph
J.B. Robinson, University of Guelph
D.D. Schulte, University of Manitoba

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CAUTION TO BE OBSERVED IN USING THIS GUIDE

Information presented in this guide is based on maintaining an ecological balance between nutrients supplied by animal manure and fertilizer and nutrients used by crops, without undue nuisance from other properties of manure. Individuals not trained or experienced in animal manure management should not extract portions of the guide, nor draw inferences, without considering all aspects of the problem from the source of the manure through to its reutilization by crops.

Information is also presented on the nitrogen content of farm-animal manure. To avoid any misunderstanding, the amount of nitrogen excreted by an animal is not the same amount available when the manure is applied to the crop. The amount of nitrogen available depends on the method of handling and processing, and should be assessed for each different type of management system.

INTRODUCTION

Public concern continues about all forms of pollution. At the same time, intensive animal operations, some on limited land areas, have increased in number and size. This trend toward increased scale of animal confinement for production of meat, milk and eggs magnifies the problems of manure management and increases the possibility of causing pollution.

Furthermore, the number of animal operations with little or no cropland available for manure utilization and the number of residential dwellings on or near farmland is increasing. This often results in pollution-related disputes between urban residents and animal producers, particularly in the densely populated areas of Canada. Thus, there is a need for properly designed and managed animal facilities, and for control of the number of residential dwellings on or near farmland. Land-use policies must be developed that take into account the special requirements of animal production.

The fundamental basis for sound manure management practices is an appreciation of the natural role that animal manure plays in unmanaged soil-plant systems. This leads to the realization that the most appropriate management of manure is to return it to soil, thus using it as a nutrient in crop production. The guiding principle is that nutrients returned to the soil should be matched to specific crop requirements. Even so, special precautions may be required to prevent air and water pollution before, during or after land application of the manure.

Unlike many facets of animal production, the technology related to manure handling still is developing rapidly. Extension personnel, regulatory officials, producers and research workers must realize this, so that problems may be minimized through up-to-date management practices.

The purpose of this guide is to focus attention on those practices that provide a reasonable yet environmentally sound basis for manure management. It gives descriptions of alternate practices which, though not yet commonly employed, may prove useful to both the agricultural community and to those who plan, regulate or assess animal manure management systems. However, the guide is not a detailed design manual; rather it provides a common basis for understanding manure management practices across Canada. It is a place to start and should be used with that in mind.

Finally, this publication is intended as a common foundation for new or revised national, provincial and other jurisdictional regulations, codes or guidelines on animal manure management, that eventually can be made consistent with one another.

REGULATORY PROGRAMS COVERING MANAGEMENT PRACTICES

Federal

At the federal government level, the Fisheries Act has implications in all parts of Canada since this legislation covers the control of pollution in water frequented by fish. Also, the Canada Water Act provides for the conduct of cooperative federal-provincial watershed studies. The results of these studies can be used to establish water-quality standards for the watershed.

Provincial

Major responsibility for the regulation of farm nuisance and pollution problems continues to be at the provincial level. After early experimental approaches to this tough regulatory problem, there is now a tendency to regulate farm pollution problems through guidelines and education programs as opposed to the use of specific and detailed regulations. A growing number of provinces are adopting a certificate of compliance program wherein written approvals are given to operations that comply with recognized standards. More animal producers sit on advisory and inspection committees. Several provinces are giving new emphasis to land-use planning in an attempt to prevent problems before they occur.

British Columbia — British Columbia has adopted a system of agricultural pollution control whereby the livestock and poultry industries regulate their own sanitation and pollution problems. The B.C. Agricultural Environmental Control Program is administered by the B.C. Federation of Agriculture. Producer sanitation committees investigate complaints and make recommendations specific to each farm, based on defined environmental guidelines. The full force of the Pollution Control Act is brought to bear on farmers who refuse to comply with the recommendations.

To supplement this program, British Columbia now is experimenting with the application of Minimum Distance Separation Formulas, administered at the municipal level, to control the siting of livestock and poultry buildings.

Regulatory agencies with authority to control waste management on British Columbia farms are:

- Pollution Control Branch, Ministry of Environment — Pollution Control Act, 1967
- Ministry of Health — Health Act
- Ministry of Municipal Affairs and municipal governments — Municipal Act
- Ministry of Lands and Forests — B.C. Water Act
- Environment Canada — Fisheries Act
- Ministry of Agriculture — Milk Industry Act

Alberta — The agricultural environmental control program in Alberta is based on voluntary guidelines and is administered jointly by Alberta Agriculture and Alberta Environment. The program educates farmers on good manure management methods and coordinates the various regulatory agencies listed below. This program has avoided a tough regulatory approach to the problem of agricultural pollution. Operations meeting the guidelines are issued a certificate of compliance.

Complaints made to Alberta Environment are initially turned over to Alberta Agriculture where an amiable solution is attempted. When a solution is not obtained by negotiation, the matter reverts to the agency whose jurisdiction is involved. Recent increased involvement by the agricultural industry itself indicates the possibility of greater self-policing by producer groups.

Formulas are being developed to aid in the orderly siting of agricultural and non-agricultural developments. These formulas may be used to implement land-use plans at the local level.

Regulatory agencies with authority to control waste management on Alberta farms are:

- Local governments — Building permits, development bylaws, set backs, etc.
- Regional Planning Commission or Provincial Planning Director — Municipal Planning Act
- Alberta Transportation — Developments on provincial highways
- Local boards of health — Provincial Board of Health Regulations under the Public Health Act
- Alberta Environment — Water Resources Act
  — Clean Air and Clean Water Acts
  — Joint administration of certificate of compliance program
- Alberta Agriculture — Regulations under the Alberta Dairyman's Act
  — Joint administration of certificate of compliance program

Saskatchewan — The Family Farm Improvement Branch of Saskatchewan Agriculture administers The Pollution (By Live Stock) Control Act, 1971. This act empowers the Minister of \griculture to issue permits for the construction of facilities for intensive livestock operations. Failure to apply for a permit may constitute an offence under the act.

Before the Minister issues a permit, approval must be received from the Ministers of Health, Tourism and Renewable Resources, and Environment. Copies of the applications are also sent for comments to rural municipalities, nearby urban municipalities, and other affected agencies.

Complaints against intensive livestock operations are investigated by Branch farmstead-engineering specialists who recommend corrective measures. Generally speaking, cooperation from farmers is excellent. If necessary, the Minister may issue orders under the act to clean up operations. Failure to comply with a Minister's order constitutes an offence under the act.

The Saskatchewan Intensive Livestock Operations Code of Good Practice recommends isolation distances and other practices for locating and operating intensive livestock operations. The Department of Agriculture has shared in the costs of relocating facilities to more desirable locations when there are no other alternatives for pollution control.

The Minister of Agriculture has appointed a committee representing livestock producers to advise him on the administration of this act.

Manitoba—The management of animal wastes is provincially regulated under the Clean Environment Act and the Public Health Act. The livestock waste regulation under the Clean Environment Act outlines the basic requirements for the storage and disposal of animal wastes and the disposal of dead animals. Certain livestock operations in locations of potential concern are further required to register with the Department of Mines, Resources and Environmental Management, which administers the act.

Regulations under the Public Health Act administered by the Department of Health and Social Development deal with the protection of water sources and the location of, and sanitation in, facilities for the keeping of animals. There is overlap between the two acts in this regard with the latter being very antiquated in the area of livestock production.

To date, prosecutions under any of these regulations have been few. Education and persuasion have been used in lieu of force to change waste management practices. Particular cases where it is difficult to apply or interpret the legislation are handled individually with cooperation between Agriculture, Environmental Management and the client. Hopefully the forthcoming review and revision of regulations pertaining to the management of livestock wastes will eliminate much of the ambiguity and redundancy of the current legislation.

Ontario—Ontario attempts to prevent pollution from animal manure by means of manure management information and guidelines in the form of an Agricultural Code of Practice. Minimum Distance Separation Formulas are used for siting livestock buildings and manure storages. These formulas are also used to site rural residences, both farm and non-farm, in relation to neighboring livestock operations.

Certificates of compliance are issued jointly by the Ministries of Environment and Agriculture and Food to farmers who can meet the siting distances and who agree to specific conditions of manure management appropriate to their operations. Municipalities are required to include reference to the Agricultural Code of Practice in official plans and thus in zoning bylaws.

Air or water pollution violations by livestock operations are dealt with initially by the Ministry of the Environment which then consults with Ministry of Agriculture and Food engineers on recommendations for abatement. Continued violation is referred to a Farm Pollution Advisory Committee composed of farmers representing each of the major livestock and poultry groups. Failure to follow the recommendations of this group results in a violator being subjected to legal action under the Environmental Protection Act.

Ministries of Agriculture and Food, Environment and Housing participated in and sponsored the third revision of the code published in 1976.

Relevant legislation is:

- The Environmental Protection Act, 1971, administered by the Ministry of The Environment
- The Ontario Water Resources Act, administered by the Ministry of The Environment
- The Milk Act, administered by the Ministry of Agriculture and Food
- Fisheries Act, administered by Environment Canada

Quebec—Farming comes under the Environment Quality Act (December 1972) which states that contaminants emitted by these operations must not affect the life, health, safety, welfare or comfort of human beings, nor cause damage to the quality of the soil, vegetation, wildlife or property. Farming operations are subject, moreover, to the Provincial Health Regulations (1944) concerning fox farms, pigpens, barns, stables, yards and manure.

A draft regulation under the Environment Quality Act concerning animal farming operations is presently being prepared. This will regulate the location of animal production sites, and the storage and disposal of manure from animal operations.

New Brunswick — The Agricultural Environmental Control Program in New Brunswick is administered jointly by the Provincial Departments of Agriculture and Environment. Under this program every livestock farmer is requested to obtain a certificate of compliance. Farmers who borrow money through either the federal or provincial loaning agencies for construction of their livestock facilities are required to have a certificate of compliance before a loan is approved. These certificates are issued jointly by the two Departments. Farmers who cause a pollution hazard can be forced to comply with pollution control regulations under the Clean Environment Act.

Regulatory agencies with authority to control livestock manure and waste management in New Brunswick are:

• Department of Environment	— Clean Environment Act — Unsightly Premises Act
• Department of Health	— Health Act
• Department of Municipal Affairs	— Community Planning Act
• Environment Canada	— Fisheries Act

Nova Scotia—The proper use and storage of animal manure on livestock farms in Nova Scotia comes under the Environmental Protection Act as enacted in 1973. This act is administered by the Nova Scotia Department of Environment which has complete authority to control manure management. As yet, no regulations have been established under the act that give specific requirements for storage and handling of manure.

A set of guidelines covering the storage and handling of manure was established by personnel representing the departments of agriculture of the four Atlantic Provinces. Later, another set of guidelines for Nova Scotia was developed by a committee representing the Departments of Environment, Health, and Municipal Affairs, and the Federation of Agriculture.

Regulatory agencies with authority to control animal manure and waste management in Nova Scotia are:

• Department of the Environment	— The Environmental Protection Act — Water Act
• Department of Health	— Health Act
• Department of Municipal Affairs	— Municipal Act

Prince Edward Island — With the exception of newly established piggeries and poultry operations, Prince Edward Island has opted for guidelines and extension education programs to promote and upgrade sound animal waste management on farms. New piggeries and poultry operations which have benefited from public funds in their establishment under provincial capital grants programs, such as the Family Farm Development and New Farmer Programs, have to meet animal waste management guidelines before they are approved for public funding. This is usually done through inspection and the issuing of a certificate of compliance to these guidelines by the P.E.I. Department of Environment.

Usually, complaints attributed to animal waste pollution are referred by the P.E.I. Department of Environment to the P.E.I. Department of Agriculture and Forestry for action and follow-up. In resolving these complaints, staff of the P.E.I. Department of Agriculture and Forestry usually resort to nothing more than good public relations augmented by whatever technical engineering and financial assistance is available and warranted in each specific case.

The only acts which could be used to enforce acceptable standards of pollution abatement are The Act to Establish the Environmental Control Commission administered by the P.E.I. Department of Environment and The Public Health Act administered by the P.E.I. Department of Health.

Newfoundland — The Newfoundland Agricultural Environmental Control Program is administered by the Department of Consumer Affairs and Environment and the Department of Forestry and Agriculture.

Complaints are investigated by the environment officers of the Department of Consumer Affairs and Environment and the agricultural representatives of the Department of Forestry and Agriculture. They submit their corresponding reports to an interdepartmental Livestock Waste Management Committee for evaluation and appropriate action. The same procedure is applied to both new and existing livestock or poultry producers. Decisions made by this committee are based on guidelines recently legislated by Council and on the existing acts of other regulatory agencies concerned.

The regulatory agencies with authority to control waste management in Newfoundland are:

• Department of Consumer Affairs and Environment	— The Waste Material (Disposal) Act — The Environmental Management and Control (Water and Sewage) Regulations — Prevention and Control of Air Pollution — Soil Regulations — Legislated Livestock Waste Management Guidelines
• Department of Health	— Milk and Its Product Act — Meat and Meat Product Act
• Environment Canada	— Fisheries Act

Other agencies involved in the issuance of permits to build are:

- Development Control Division, Department of Municipal Affairs and Housing
- Provincial Planning Office
- Department of Transportation and Communications
- Public Health Inspection Services Division, Department of Health
- Environmental Management and Control Division, Department of Consumer Affairs and Environment
- Agriculture Division, Department of Forestry and Agriculture
- Municipal or Community Council Authority (if applicable)

Importance

Manure resulting from animal production can be detrimental to the environment and a hazard to the health and safety of both humans and animals. Even if adequate facilities for manure handling and storage are provided, difficulties still may occur. Hence an awareness of the potential hazards or problems associated with animal manures and an understanding of the circumstances involved can minimize the risks and lead to the development of sound manure management practices. The solution to many of the potential hazards or problems is first to recognize their existence and second to exercise care and common sense to avoid them. Some of the more important considerations follow.

Water Pollution

A characteristic of animal manures is their high water pollution potential. Hence a major objective of efficient manure management must be to ensure that manure or its constituents cannot gain access to rivers, streams, lakes or water supplies.

Manure contamination of water can occur in a number of ways, some of which are more obvious than others. Obvious examples are direct dumping of manure into surface water, providing animals direct access to streams for drinking, runoff from feedlots and manure stockpiles, and overflow from manure storages of inadequate capacity. The less obvious ways include spring surface runoff following winter application of manure on frozen ground sloping towards a stream, seepage from excessively high application rates on land and from lagoons and detention ponds constructed in porous soils. Under certain conditions, various manure constituents may be carried downwards by water percolating into the groundwater. There is also a possibility of absorption of air-borne manure constituents by nearby bodies of water downwind from the operation.

There are several consequences of water pollution by animal manures. Oxygen in the water is depleted because the bacteria demand it to decompose the organic matter in the manure. This demand is known as the biochemical oxygen demand (BOD) of the manure. If dissolved oxygen concentrations are seriously depleted, the water may no longer support desirable aquatic life such as fish but instead becomes septic and unpleasant. The addition of manure constituents such as nitrates and phosphates to water also may cause or contribute to eutrophication and the resultant unsightly growth of algae.

Contamination of water by manure poses a serious health hazard to humans and animals, water acting as the carrier of numerous disease pathogens from infected animals. In addition, contaminated water can be responsible for nitrate poisoning in both animals and humans, particularly infants. Manure also can impart taints and odors to drinking water.

Manure Gases

Manure undergoes microbial decomposition after it is voided by the animal. The organic matter is broken down to simpler compounds, the process being characterised by the production and evolution of numerous gases. If the decomposition takes place in the presence of oxygen (O_2), the process is said to be aerobic and, when it occurs in the absence of O_2, the process is called anaerobic. In practice, most manure storages are anaerobic. Anaerobic decomposition is typical of liquid manure handling systems and characteristic of collection pits, holding tanks and storage lagoons.

Aerobic decomposition is essentially an odorless process whereas anaerobic decomposition is characterised by bad odors. In addition, the latter can produce gases, in considerable quantities, which are potentially hazardous to man and animals. These include carbon dioxide (CO_2), methane (CH_4), ammonia (NH_3) and hydrogen sulfide (H_2S). Some of the properties and physiological effects on humans of these gases are given in Appendix 1.

Manure gases have caused fatalities and near fatalities, involving both humans and animals, and property damage and loss. Such accidents are the result of high concentrations accumulating under certain conditions. These conditions occur infrequently and are largely recognizable.

Carbon dioxide is seldom a critical problem in animal housing. Instances have occurred where failure of the mechanical ventilation system in a tightly constructed barn has resulted in animal deaths, probably due to a combination of heat stress and O_2 deficiency rather than CO_2 asphyxiation. An alarm system to warn the operator in the event of such a failure would be a prudent investment.

Methane also is unlikely to be a factor in animal health and performance in normally ventilated buildings. Its significance lies in its flammable and explosive nature. At low concentrations, it burns with a pale blue flame, but at higher concentrations there is a real danger of an explosion. The head space of a covered manure storage is an example of where explosive concentrations may collect. To minimize the risks from CH_4 in and around manure handling and storage facilities, prohibit smoking or use of naked flames, use explosion-proof electric motors on fans and equipment, adequately vent covered storages to outside air, use U-bends or gas traps in all sewage channels connecting a barn to outside storage tanks so gases in the tank cannot back up into the barn, and ensure that a barn with inside manure storage is continuously ventilated (if unventilated for even a short period, thoroughly vent before use).

Ammonia, with its sharp pungent odor, acts as an irritant to moist tissues such as eyes and the respiratory tract even at relatively low concentrations. High or even moderate concentrations in the animal environment are not a concern, as these have not been found. Rather, quite low concentrations, readily detectable to humans, appear to decrease animal health and performance in the presence of other atmospheric contaminants such as dust and H_2S. Rapid manure removal from the barn, adequate floor slopes to ensure good drainage, liberal use of bedding and increased ventilation rates (particularly during emptying of storages) are possible methods of reducing concentrations.

Hydrogen sulfide is potentially the most dangerous of the manure gases and has killed both humans and animals in Canada and many other countries. Constant exposures to concentrations of only a few parts per million or short exposures to intermediate concentrations also are suspected of being detrimental to animal well-being. Normally, H_2S is barely detectable in animal housing as long as the liquid manure remains undisturbed. Even slight agitation of storages or disturbance of gutters will release H_2S to the atmosphere. Concentrations appear to be largely a function of the length of time the manure is stored and the degree of agitation or disturbance. The greatest risks are during emptying of tanks and pits, when concentrations in the pithead space and above slats can reach lethal levels within a few minutes. To minimize risks from this gas, do not agitate when emptying pits located within a building and at the same time provide maximum ventilation, remove stock from a building when agitation is necessary (or, if stock cannot be moved, make use of a windy day to ensure a maximum air exchange through open doors and windows), use gas traps in sewage channels between covered outside pits and barns to prevent gas back-up, and empty pits frequently, particularly in warm weather.

Entering manure storages at any time is extremely dangerous, especially during or following emptying of the storage. Consequently, never enter such a facility without being properly equipped with air-breathing apparatus and safety harness. Omit the air-breathing apparatus only when positive ventilation has been provided by fans of sufficient capacity to ensure that manure gases are purged from the storage head space and a constant supply of fresh air is available.

Odors

Possibly the most common complaint directed at animal production facilities is about the bad odors they produce. Many of these complaints occur at the time manure storages are being emptied and the manure field-spread. The odors are the result of the biological breakdown of the manure under anaerobic conditions within storages, whether these be piles, lagoons or indoor pits.

Many compounds are involved in manure smells. Some, such as NH_3 and H_2S are produced in easily detected quantities. Others, such as mercaptans and amines, are present in concentrations measured in parts per billion, that are only detectable by highly sophisticated analytical techniques and equipment. Even at such concentrations, a number of these compounds can be perceived as offensive by the human nose. Consequently, consider the odor nuisance of animal manures to minimize the risks of complaints.

In recent years, manure odors have been the subject of extensive research around the world. Two basic approaches have been used: preventing the production of malodors in the first instance, or attempting to eliminate the odor after it has been produced. Unfortunately, neither approach has found a practical low-cost solution to the problem, for a variety of reasons. As a result, the animal producer is left with sound planning and management as the most effective means of minimizing the odor nuisance. Planning authorities as well as operators must recognize, however, that malodors cannot be eliminated even with the best possible planning and management.

Minimizing odor nuisance is basically common sense and a respect for the rights of others. Locate animal facilities so that prevailing winds blow away from nearby residences. Local municipalities frequently have regulations governing minimum distances between them. Avoid spreading manure on land adjacent to residences or main roads unless the manure is either injected directly into the soil or incorporated immediately into it by cultivation. Either method not only reduces offensive odors during spreading but also minimizes the high nitrogen losses to the atmosphere that normally occur when manure lies on the soil surface.

Local weather reports provide a valuable management tool in minimizing odor nuisance. Field spread manure on cool windy mornings when the wind is blowing away from nearby residences, as this is least likely to cause offense. Odors from manure applied to fields late in the day tend to be trapped near the ground because the air is cooling and falling. Again, don't field spread on weekends and during holidays as neighbors are more likely to object at such times.

A high standard of hygiene within barns will minimize the indoor odor problem. Thorough cleaning and frequent manure removal to storage, coupled with good drainage and liberal use of bedding where appropriate all contribute, since the breakdown of feces and urine requires, among other things, time and moisture. Good hygiene also will reduce atmospheric dust concentrations and, since dust is a carrier of odors, the exhaut air from barns will be less offensive.

Other Concerns

Animal production raises other concerns that may require consideration. Manure, for example, makes an ideal breeding ground for various insects, including flies, and tends to attract birds and even rodents. All of these can be a nuisance and possible carriers of disease.

The noise generated by animals in confinement can be another annoyance to nearby residents. Aesthetics are also a legitimate concern for, although an animal production unit can be an asset in one setting, it may detract from another unless suitably screened.

Dust, to a varying degree, is a feature of animal production units. Not only a physical nuisance, it also carries odors and could transmit certain disease pathogens. Dust is more likely to be a problem in total confinement of poultry (particularly deep litter), and pigs. Blowing dust from feedlot operations can be a nuisance to nearby residents.

Management Principles

To think that an animal production operation can be maintained without some impact on the natural environment is unrealistic. However, the extent to which it may be detrimental depends primarily on its management. The uniqueness of each animal production unit must be stressed; no two situations are identical. Although different operations may have several common features, the best way to minimize the environmental hazard from animal manure is to examine the management options available in each case. Consider the following:

Is adequate land available for crop utilization of manure, having regard to the rate and time of application to avoid water pollution and to make most efficient use of the plant nutrients contained in the manure? If the land base is insufficient, investigate alternative means of manure disposal to arrive at an environmentally satisfactory solution.

Ensure sufficient manure-storage capacity to eliminate uncontrolled release of manure into the environment, avoid land application of manure during winter, and permit most effective crop use of nutrients. Storage must be of a type that will eliminate seepage to groundwater.

Locate animal production facilities to avoid nuisance complaints about odors, dust, flies, noise and aesthetics, by providing adequate separation and suitable screening.

Use weather conditions to best advantage to minimize odor nuisance during field spreading of manure. Better still, use soil injection or rapid soil cover of manure, and gain the additional benefits of greatly reduced nitrogen losses and control of possible pollution arising from surface runoff.

Control manure gases, particularly from stored liquid manure, to ensure the safety and health of both humans and animals, either by frequent transfer of manure from animal facilities to separate storages or by exhausting enough air from the headspace in indoor storages to prevent gas build-up.

Provide drinking water facilities for animals on pasture so they won't drink from, and contaminate, streams or lakes.

In any given situation most or all of the above principles may require examination in detail to achieve an environmentally and economically acceptable animal manure management system. The manure handling and storage alternatives outlined in the following sections offer the opportunity to make management decisions, based as closely as possible on the requirements of these principles.

USE OF MANURE IN CROP PRODUCTION

General Information

The nutrients contained in manure have their origin in animal feed and, by measuring intake, excretion and weight gain it is possible to prepare, for each class of animals, a nutrient budget as shown in Table 1. While the numbers differ for different animals and for different diets, the recovery in the manure for each of the three principal plant nutrients is generally 65 to 90%. When animals are on range, these nutrients are returned directly to the soil from which they were derived and the net loss from the soil of most nutrients, including phosphorus (P) and potassium (K), is relatively small. In the case of nitrogen (N), the loss may be greater but is made up partly by natural fixation. In recent years, management has changed from essentially pastoral to a more intense system in which the animals are continuously housed or occupy only small land areas. Feed grown elsewhere must be imported to such animal concentrations and, as manure accumulates in these feeding areas, so do plant nutrients. To ensure these nutrients do not threaten the quality of groundwater or surface water, they must be applied to cropland in a rational way. *Therefore blocks of productive agricultural land must be maintained close to animal production enterprises. This should be a major consideration of all land-use planning.*

Fate of Manure Nutrients Applied to Cropped Soils

Table 2 shows the approximate major nutrient content of manure from different types of animals. The nitrogen in freshly excreted manure is in the organic form, which is converted to ammonium-nitrogen during storage or after application to soil. Since ammonium is firmly held to the surfaces of soil particles, it does not leach easily, but under some conditions may be converted to ammonia gas which volatilizes. Large quantities of N may be lost in this way from manure lying on the soil surface, particularly in dry, warm and windy weather.

Certain soil microbes convert ammonium-nitrogen to nitrate-nitrogen. This form of N is not adsorbed to soil and may be leached from the root zone depending on the amount of water movement in the soil. Nitrate-nitrogen may also be lost when other microorganisms convert it to gaseous compounds such as nitrous oxide, or to free nitrogen (denitrification) when oxygen is in short supply in soils. Thus, when soils are very wet, nitrate may be leached out of the root zone with percolating water or it may volatilize as a result of denitrification.

Crops generally have higher requirements for N than for the other major elements. Both ammonium-nitrogen and nitrate-nitrogen are taken up by plants.

Table 1 — Nutrients Ingested and Excreted by 15 Feeder Pigs (18-90 kg)

	Ingest (kg)	Excrete (kg)	(%)
Nitrogen	105	68	65
Phosphate	59	41	69
Potash	32	27	84

Table 2 — Nitrogen, Phosphorus and Potassium Excreted by Animals over a 365-day Period*

	Nitrogen (kg of N)	Phosphorus (kg of P_2O_5)	Potash (kg of K_2O)
1 dairy cow (545 kg)	64	30	80
2 beef cows (182-500 kg)	64	30	80
6 pigs (14-90 kg)	64	36	22
120 hens (2.3 kg)	64	51	28
180 broilers (0-1.8 kg)	64	29	25

*Adapted from Land Requirements for Utilization of Liquid Manure in Crop Production by G.E. Jones, T.H. Lanes, and L.R. Webber, Ont. Dept. of Agr. and Food Information Leaflet, June 1968

Note: Figures refer to freshly voided manure and include feces and urine. The kind of manure management system has a very large influence on actual nutrient content at time of land application

Phosphorus is taken up by plants in the form of mineral phosphates which normally arise in soil from the weathering of the soil's parent material, from the addition of fertilizer P or from mineralization of organic P. The P in manure may be inorganic or organic; the organic component mineralizes rather slowly in soils and so not all of it is immediately available for crop uptake. Phosphates, unlike nitrates, are virtually immobile in mineral soils because, if not used by plants, they form insoluble compounds in combination with calcium, iron or aluminium. At normal soil pH an equilibrium exists between the insoluble complexes and the plant-available phosphate so that, at any time, a small proportion of the soil P will be available to plants.

Soils generally have large stores of potassium, up to 10 times as much as either N or P. While much of this K is unavailable at any one time, some release brings this element into the soil solution, from which it may either leach or be taken up by plants. Most of the K added to soils in manure is readily available, and during the first season, is either taken up by the crop or adsorbed on the soil to become available later. In the soil, K is not subject to conversions and losses like N, nor is it fixed as firmly in insoluble compounds as is P.

Manure Nutrients as Potential Environmental Contaminants

Manure applied to soils may influence water quality in a number of ways, the extent depending on such factors as cropping practices, local topography, soil type, precipitation and season. The most direct contamination occurs when manure, applied to sloping frozen land on top of snow, is washed directly to a watercourse when the snow melts. Occasionally, similar effects may result when heavy rain occurs immediately after manure application to unfrozen soil. Addition of manure to water enhances algal and/or submerged plant growth because of the increased nutrients, creates a demand on the dissolved oxygen as organic matter decomposes, and introduces potentially pathogenic bacteria to the water.

Over-application of manure to any soil over a long term will build up the nutrient content of the soil (the P content is of particular concern) far beyond crop requirements. Sediments eroded from this heavily enriched soil will cause greater water pollution with P, the critical nutrient in aquatic systems, than sediments from normal productive soil.

Over-application of manure may also result in nitrate contamination of groundwater. Nitrate should be kept from entering groundwater or surface water because of its potential toxicity to animals and infants when consumed in the water supply. While the tolerance for nitrate is moderately high (regulatory agencies generally accept a limit of 10 milligrams of nitrate-nitrogen per litre of drinking water), cases are on record of groundwater supplies far exceeding acceptable levels. High concentrations have often been traced to mismanagement of animal manure.

High concentrations of nitrate in forages and in corn plants may occur when nitrate levels far exceed the crop requirements. High nitrate forages have occasionally been implicated in illness or death of cattle. In silage corn it may lead to dangerous accumulations of gas in the newly-filled silo when the nitrate is reduced to nitrogen oxides.

Manure Application Rate

In estimating the best application rate of manure to a particular soil, consider:

- the texture and fertility level of the soil;
- the nutrient requirements of the crop to be grown;
- the nutrient contents of the manure;
- local climatic factors which will affect the fate of each of the major nutrients (as described above); and
- the objective of safe, pollution-free recycling of manure nutrients.

The nutrient balance in manure (i.e., the N:P:K ratio) may not be ideal for the specific soil-plant requirements. For example, if sufficient manure is applied to meet the annual requirement for N, the P application may be excessive. On the other hand, just meeting the phosphorus requirement would in that case require a nitrogen supplement. The actual application rate may represent a compromise; the kind of compromise reached should consider local requirements and conditions. For that reason, consult the appropriate provincial agency and, with as much information as can be gained from soil tests, crop requirements, and manure analyses, plan your manure utilization system according to provincial recommendations.

SITE SELECTION, LAND-USE PLANNING AND BUILDING CONSTRUCTION

Site Selection

Selection of a barn or feedlot location on an animal production farm is most important. You must have essential services, enough area, and suitable surroundings.

Essential services are:
- feed and water;
- electricity; and
- transportation and traffic routes.

Sufficient area for:
- animal pens or buildings;
- feed and manure storage;
- control of snow, wind and runoff;
- manure application on productive land; and
- expansion.

Suitable surroundings concern:
- topography and drainage;
- natural shelters and screening;
- proximity to operator's residence;
- compatibility with adjacent land uses;
- adequate separation from neighbors and residential and recreational areas;
- location and uses of nearby bodies of water and water courses; and
- environmental and zoning regulations.

Each farm needs individual consideration and some points discussed may be covered by provincial or local legislation. Consult local authorities before construction.

Use prevailing winds to advantage to carry unavoidable odors away from neighbors and the farmhouse. Also, locate the site as far as possible from neighboring dwellings to allow dilution of odors and minimize nuisance from noise and flies. Consult the appropriate local authorities about required separation distances.

Avoid low areas subject to flooding. The site should have a natural slope to provide drainage away from the barn or feedlot. A natural slope allows gravity flow of liquid manure to a storage or feedlot runoff to a detention basin. Site a feedlot at the top of a ridge, or construct a ditch or terrace above the lot to intercept and divert unpolluted runoff water.

A uniform slope of 2 to 5% and a relatively impervious soil (loam to clay loam) is desirable for unpaved feedlots. However, sand or gravelly soil is better beneath paved areas to promote good natural or artificial drainage, minimizing the risk of heaving and cracking of the pavement.

Select an impervious clay site for below-ground storages. If any sand or gravel is found in the excavation, provide an impervious lining to protect against groundwater pollution.

As a further precaution, locate animal facilities and manure storages far enough from surface bodies of water to permit the construction of additional pollution control works if necessary.

The accumulation of some snow, which gets mixed with manure on open confinement areas, is practically unavoidable in most parts of Canada. To minimize snowdrifts, select a site about 30 to 60 m downwind from a porous windbreak such as a shelterbelt of trees or shrubs. Alternatively, build a windbreak 3 to 3.5 m high of boards spaced to provide about 20% porosity, to allow a large part of drifting snow to settle before it reaches the feedlot.

Land-use Planning

Land-use planning, proximity to proposed or existing residences, and prevailing-wind direction must be evaluated before constructing or modifying an animal operation. Good relationships between farmers, neighbors and regulatory bodies are absolutely necessary. It is impossible to control all odors from an animal operation, particularly at manure-spreading time, as existing technology cannot cope fully with a little 'country atmosphere' from time to time. Residents and regulatory officials must be made aware of manure management from an agricultural point of view.

Land-use planning officials hopefully will avoid direct zoning of residential areas into predominately agricultural areas and thus minimize future conflicts between residents and farmers. An earlier statement in this publication is repeated for emphasis: *Therefore blocks of productive agricultural land must be maintained close to animal production enterprises. This should be a major consideration of all land-use planning.* An agricultural operation in an area zoned for agriculture is expected to represent reasonable land use.

Provincial agricultural advisors, representatives of regulatory agencies and farmers are working together with municipal authorities to plan and develop guidelines for rational land use. For example, in Ontario an Agricultural Code of Practice has been developed featuring Minimum Distance Separation Formulas. These formulas are applied to both farming and non-farming land uses to assess the environmental commitment as compared to other alternatives. A similar system, based on the Ontario formulas, is being developed in British Columbia and Alberta with the express purpose of maintaining buffer zones between non-compatible land uses.

Farm Building Construction

Farm buildings should be designed and constructed in accordance with the Canadian Farm Building Code.[1] They also should meet local health and sanitation requirements.

The Canada Plan Service (CPS) Design Center prepares detailed large-scale plans for Canadian agriculture. Prepared in cooperation with the provinces, the plans are available at provincial department of agriculture distribution centers or from local extension advisers.

In areas where the climate is humid and mild, the installation of eavestroughs on buildings to divert roof drainage away from the site is recommended. In colder climates with deep snow, eavestroughing requires too much maintenance; therefore provide a gravel splash pad at the base of the wall to control erosion from roof runoff, and slope roofs away from open lots. It is important to divert uncontaminated runoff, including roof runoff, away from open-lot areas to lessen the manure washed away and the volume of waste to be handled.

While management systems should be employed that reduce dust and dust-borne odors from barn ventilation systems, the problem cannot be completely eliminated. Hence, exhaust the air away and downwind (if possible) from residences. Tall stacks help dilute dust and odors, but are not always practical, because of the high cost of stacks large enough for summer ventilation, stack freezing, and icing of fans that operate intermittently.

[1] Issued by the Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

Introduction

Most manure handling systems for confined animal operations have common parts that function in the following sequence: collection (temporary storage); transfer to storage; storage; removal from storage; transportation to land; land application and incorporation. Some of the basic requirements for these parts are discussed under "Parts of the System".

Although manure handling systems are functionally similar and some pieces of equipment are common, there is in practice no single system. Because the methods of animal management and the properties of manure are not the same for all animals, different systems have been developed for each kind of animal. Those for beef cattle, dairy cattle, swine and poultry are outlined in detail later in this section and where necessary, the effect of climatic differences across Canada have been taken into account. Some of the alternate systems shown for each kind of animal differ simply in the provision of more or less automation. Other alternatives are tied specifically to given methods of animal management and particularly to the way fresh manure is modified in its consistency (its resistance to movement or separation). The consistency of fresh manure always is changed, more or less, somewhere within the handling system.

Although other factors are involved, the moisture content of manure has an important effect on its consistency and hence on the selection of handling equipment and facilities. Based on consistency, manure is handled generally as a *liquid, solid* or *semisolid*. For example, where animal management practices exclude or restrict the use of bedding, *liquid manure* with a thin consistency is produced by adding water (intentionally, or from leaky waterers). Some liquefaction also takes place when liquid manure is stored anaerobically. At 85% moisture content or greater, liquid manure will flow by gravity from deep horizontal gutters, and, at 90% or greater, it can be pumped readily. Appendix 2 contains a useful graph to determine the amount of dilution water required to change the moisture content. Where ample bedding is used or manure is subjected to natural or induced air drying, *solid manure* is usually produced. It has a stiff, nonflowing consistency and can be handled by an established line of solid manure equipment. An example is manure with 8% bedding or greater. There are, however, existing management practices where the amount of bedding or drying is limited, and thick *semisolid manure* is produced that may flow slowly or hardly at all. For instance, when about 2% long straw bedding is added to fresh dairy cattle manure, the mixture will likely flow slowly, whereas very little flow will occur with additions of about 4%. Some modifications to conventional solid manure facilities and equipment are required to handle semisolid manure.

In each of the alternate systems outlined later, manure consistency is taken into account by specifying the type of handling facilities and equipment required.

Parts of the System

Collection and Transfer

Odor production in confinement barns can be minimized when collection facilities are small and manure is transferred at frequent intervals to separate storage; the in-barn environment, is subjected only to the unavoidable odors of animals and fresh manure. On the other hand, large collection facilities for liquid manure become anaerobic manure storages. Where collection and storage are combined within a barn, you need special precautions to minimize risks from hazardous gases released during agitation and/or emptying, as discussed earlier under "Manure Gases".

Transfer equipment must be suited to the consistency of the manure. For solid manure, mechanical equipment is readily available to scrape (or load), convey and stockpile the manure. Tractor scoops, box-type manure spreaders and pumps can be used to transfer semisolid manure. If tractor scoops are used, the manure must be pushed against a substantial buck-wall to load the scoop. Also, where box-type manure spreaders are used, end-gate attachments will be needed to contain the manure in the spreader. Enclosed-chain conveyors are a low-cost alternative to more expensive pumps.

Liquid manure can be transferred horizontally from the collection area by gravity flow in deep gutters, hydraulically in shallow trenches, or by mechanical scrapers. Where site conditions allow storage below the level of the collection area, collected manure may be delivered directly into a separate large storage. However, transfer pumps or elevators are required where the storage is above the collection area. Conventional open impeller sewage pumps are used successfully, although they do clog occasionally. Helical rotor pumps also are used but the synthetic rubber stator can be damaged by small rocks or by operating the pump dry. More costly non-clog pumps, used successfully for years in municipal sewage treatment plants, are available; these have smooth-vaned recessed impellers that will pass any solids that can enter the pump inlet. Piston pumps with large pistons that push manure through 8- to 16-in. PVC pipe recently have been gaining acceptance by animal producers. These pumps can move manure horizontally 45 m or more, depending on the consistency.

Where manure enters directly into a separate large storage from the collection area, precautionary measures are needed to protect the barn from dangerous gases from the storage. Gas traps involving baffles and/or intermediate chambers are acceptable. Alternatively, if the openings between the barn and the storage are small and the storage tank is completely enclosed, a continuous-running fan exhausting from the storage to the outside air will give similar protection plus some barn ventilation.

Storage

Storage structures are required to hold manure, wastewater and feedlot runoff between periods of land application. Although different farms have different storage needs, several general points related to storage location, size, construction and operation should be observed. Specific requirements differ for solid, semisolid and liquid manure. Detailed plans for several types of storages, prepared by the Canada Plan Service (CPS), are available through extension engineers at provincial ministries or departments of agriculture.

Location — Locate the storage convenient to the barn or feedlot but at a site that will allow expansion of the animal facilities and the storage. It should be accessible by firm farm roads to allow easy transport of manure and equipment to and from the storage. For below-ground storages, avoid areas with a high water table and choose a site where surface-water runoff may be diverted. The soil should be compacted well to prevent differential settlement of the storage structure and, where an earthen storage is considered, should be sufficiently impervious to contain manure liquids.

Sizes — The size of manure storage depends on the type and number of animals, the length of time that manure is stored and, with liquid manure, the volume of dilution water added. The daily volumes of fresh manure produced by different animals are shown in Table 3. The number of animals is the average number confined during the storage period, not the number of animals produced. The storage time period should be sufficient to avoid having to spread manure on snow, frozen ground or sensitive crops. Fall and spring applications are best, requiring up to six months storage capacity for most farm situations. In regions with a long winter, storage capacity for 200 days or greater may be required. To minimize the space required in a liquid manure storage, avoid excessive amounts of dilution water. Unless land application through an irrigation system is planned, add only enough water to bring the moisture content to about 90% for easy agitation and pumping.

To determine the size of manure storage, use the following formula:

$$V_s = \frac{(N_a \times V_m \times T)}{1000} + V_w$$

where V_s = volume of storage, in cubic metres
N_a = number of animals confined during storage period
V_m = volume of manure produced, in litres per animal per day (see Table 3)
T = storage time in days
V_w = volume of dilution water required for liquid manure storages, in cubic metres (see Table 3 for moisture contents of fresh manure and Appendix 2 for dilution water needed to change moisture contents)

The size of detention basins (usually earthen) to store contaminated runoff from open feedlot and manure storage areas depends on the size of the runoff area and the amount of runoff that occurs during the critical time that storage is required. Under most Canadian conditions, this critical period is the winter 6 months or greater, to avoid application of the runoff on snow or frozen ground. To obtain a design value for the amount of runoff, there are estimating formulas. A local hydrologist can use these, taking into account the conditions familiar to him. To obtain a first approximation for design, use the following formulas as a guide:

For paved feedlots
$V = A \times (0.48\ P_m + 0.65\ P_s)$
For unpaved feedlots
$V = A \times (0.22\ P_m + 0.45\ P_s)$
For solid manure storages
$V = A \times (0.25\ P_m + 0.65\ P_s)$

where (in any consistent units),
V = volume of storage
A = area contributing to runoff
P_m = sum of the November to April (6 months) mean monthly total precipitation (rainfall plus equivalent water depth of snowfall)[2]
P_s = the 24-hour precipitation from a storm expected once in 25 years[3]

These formulas suggest that the design storage capacity be based on the detention of winter runoff plus the storm runoff that may occur before emptying the storage in the spring. At that time, and at times following major runoff events between May and October, the runoff is applied to crop land for utilization of the fertilizer nutrients in the runoff.

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[2]Available from publications by the Atmospheric Environment Service, Environment Canada, Downsview, Ontario.
[3]Available from "Short duration rainfall intensity — duration — frequency" data prepared by Atmospheric Environment Service, Environment Canada, Downsview, Ontario.

Table 3 — Animal Manure Characteristics (Nominal Values for Urine and Feces as Voided)

Animal	Volume of manure /animal* (L/day)	Volume of manure and bedding /animal* (L/day)	Undiluted manure moisture (%)	Urine in manure (%)	BOD/ animal (g/day)	Nutrients/animal**		
						N (g/day)	P_2O_5 (g/day)	K_2O (g/day)
Cattle								
Beef or dairy calf (0-3 mo)	5.4							
Beef or dairy calf (3-6 mo)	7.1							
Beef feeder or dairy heifer (6-15 mo)	14.2	17.0		35		77	36	91
Beef feeder or dairy heifer (15-24 mo)	21.2	22.6						
Beef cow (545 kg)	28.3	34.0						
Dairy cow (545 kg)	45.3		87	30	900	172	82	204
Open pen loose housing		56.6						
Free stall loose housing		48.1						
Tie stall		50.9						
Swine								
20-90 kg (8-22 wk)	5.1		91	45	135	32	18	11
5-10 kg (3-6 wk)	1.1							
11-20 kg (6-9 wk)	2.3							
21-35 kg (9-12 wk)	3.4							
36-55 kg (12-16 wk)	5.1							
56-80 (16-20 wk)	7.4							
81-90 kg (20-22 wk)	9.1							
Sow	11.3	13.6						
Chicken				0				
Broiler (0-1.8 kg)	0.08	0.14	litter-25					
Laying hen (1.8 kg)	0.14		77		9	1.45	1.1	0.6
Turkey			75	0				
Broiler (0-14 wk)	0.13							
Growing hen (0-22 wk)	0.18							
Growing tom (0-24 wk)	0.28							
Breeder	0.34							
Rabbit (doe and litter)	0.71							
Ewe sheep	2.8	4.2	75	50	40	20	7	17
Horses	26.0	56.6	80	20		122	50	91
Mink (female and kits)	0.20							

*Adapted from Canadian Farm Building Code, Associate Committee on the National Building Code, National Research Council of Canada, Ottawa
**Manure analyses by an appropriate laboratory are advisable since the actual nutrient contents can vary in practice

Although a settling basin is not always installed between the feedlot and the detention basin to remove some of the solids from the runoff, its use is recommended. As a guide to design, the surface area of the settling basin should be about 1/40th of the feedlot area that contributes runoff, and the basin should be 0.6 m in depth or greater, but not exceeding 1.2 m. An earthen settling basin should have a paved ramp and pad if the solids are to be removed with a tractor scraper.

Construction — Storage facilities for manure or runoff should be manure-tight to avoid water pollution. Although most storages are constructed as single units, multiple units may be required where it would be uneconomical to build beyond a particular capacity, or where agitation equipment has limited capacity.

Solid manure storages require a slab to provide footing for the operation of loading equipment and a perimeter curb to contain the liquid runoff (Figure 1). In areas of heavy precipitation, it may be economical to either add a roof, or to drain the runoff to an adjacent holding basin to provide increased liquid storage. The floor of the storage should slope to a low corner, preferably that corner diagnonally opposite to the paved entrance ramp. The crown of the ramp and the top of the perimeter curb should all be at the same level for maximum liquid retention.

Semisolid manure storages require a slab surrounded by either a concrete wall (Figure 2) or a low curb surrounded by an earthen embankment to contain both the liquid runoff and the sloppy manure (Figure 3). A ramp entrance provides access for manure removal equipment. The entrance ramp is crowned to exclude drainage water from the yard. The floor slab slopes to a low point at the corner opposite the entrance ramp to facilitate complete removal of the liquid fraction by a vacuum tanker or an irrigation system. An optional drain or porous wall at the low corner may be installed to allow liquids to pass into a separate storage basin.

In areas of heavy precipitation, it may be economical to use a roof over a rectangular walled storage as in Figure 4.

Liquid manure storages are either below or above the collection facilities. Storages below gutters or alleys can be either rectangular (Figure

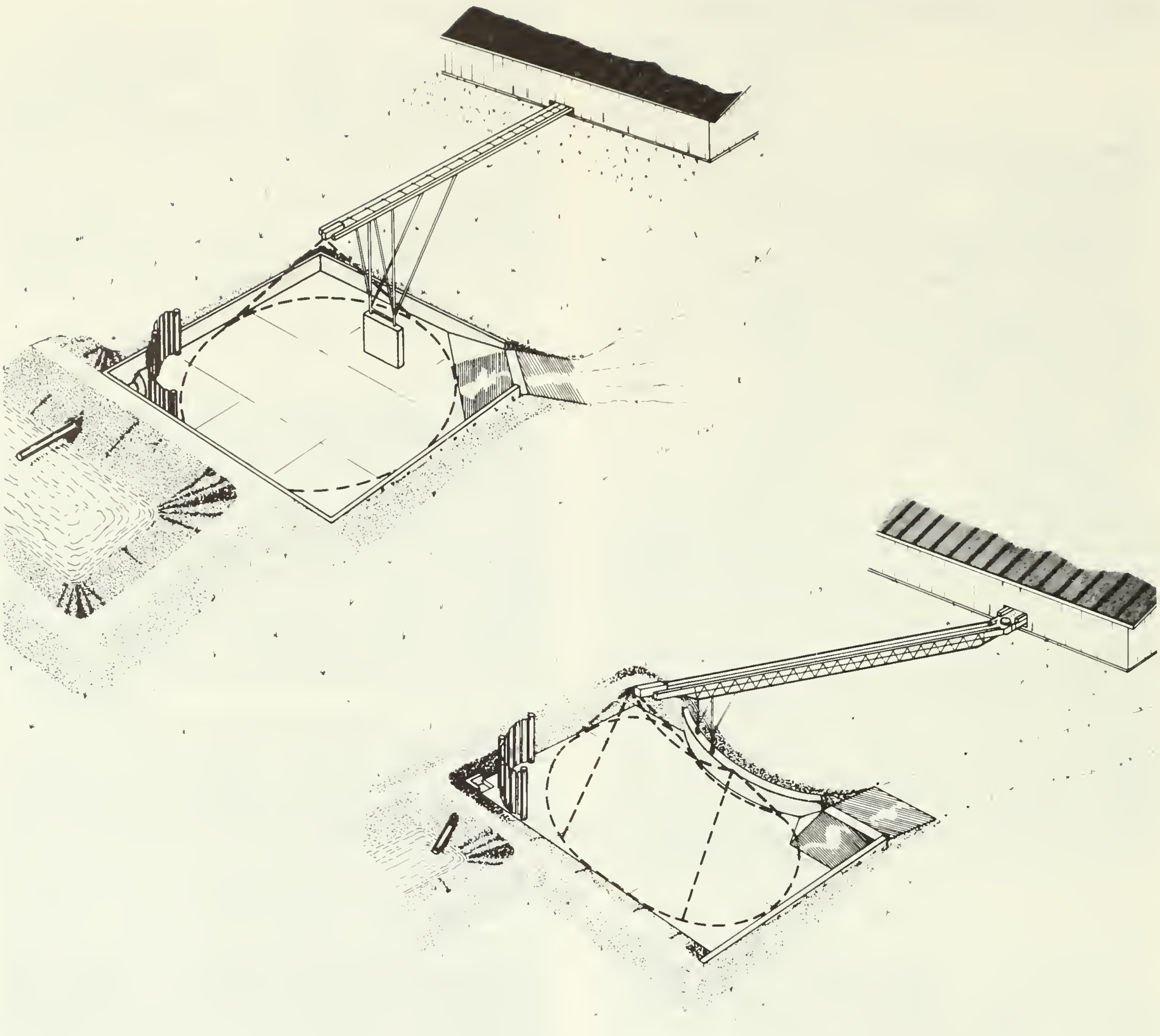


Figure 1 — Curbed storage slab for stacked manure (CPS plan M-2703)

5) or circular (Figure 6) reinforced concrete structures to accommodate gravity transfer from the barn. Agitation is necessary and commonly is done hydraulically with a tractor pto-powered liquid manure pump. The effective agitation radius using this method is limited to about 7 to 9 m; therefore, large circular storages should be limited to 15 m in diameter with tractor accesses at two opposite sides. Rectangular storages work best if divided into compartments no larger than 7 by 9 m with the pump access opening located centrally along one long side. Where odors from storages will create a nuisance, rectangular storages can be covered at less cost than circular storages. Inexpensive earthen manure storages can be used but they require a suitable dock to place a tractor and a pump agitator near the deepest part of the storage for manure removal (Figure 7). A slab of pavement is recommended under the pump location to prevent erosion while pumping. Unless manure is pumped under pressure to earthen storages, the inlet pipe should be above the liquid level in the storage; submerged inlets under gravity flow may plug. Earthen storages also are limited to manure-tight soil conditions (otherwise a waterproof lining will be required), and to locations where odors will not create a nuisance.

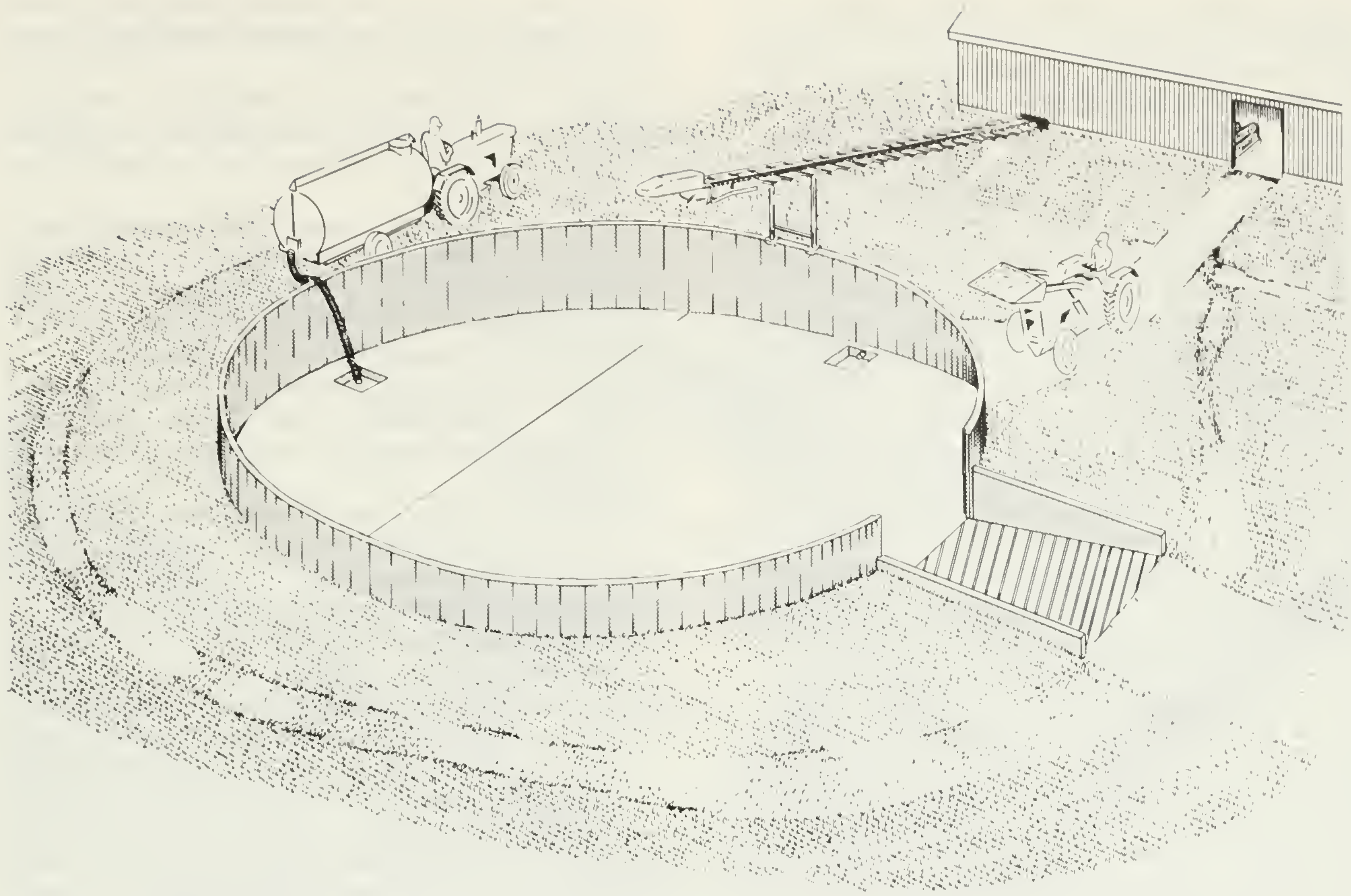


Figure 2 — Open circular manure storage with tractor access
(CPS plan M-2701)

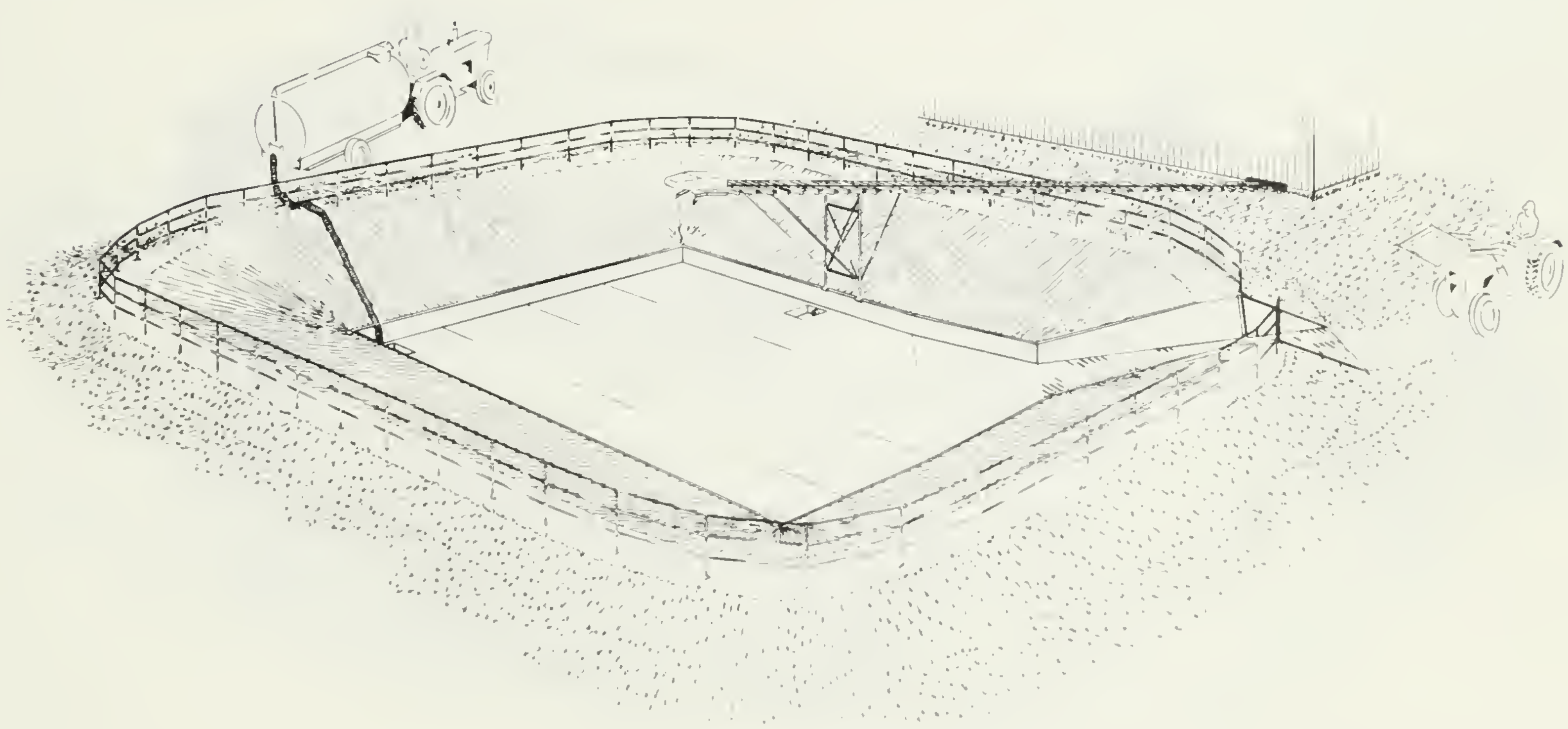


Figure 3 — Curbed slab manure storage with earth banks
(CPS plan M-2704)

Liquid manure storages located above the collection facilities can be circular concrete structures built mostly above ground. These storages have been traditionally of a silo type, 9 m in diameter by up to 9 m high (Figure 8). Larger diameter silos, including some up to 18 m and occasionally up to 24 m, recently have been gaining acceptance as agitator pumps improve. Above-ground storages must be manure-tight. For poured concrete structures, this can be achieved by using good quality concrete, with special reinforcement to resist liquid pressures. For concrete stave structures, a waterproof plaster coating is required. The sump pump and plumbing system is a most important part of above-ground storages. It must be able to transfer manure into the storage at convenient intervals, agitate the manure before removal from storage and remove manure from the storage and fill a tanker. A suitable sump pump and plumbing arrangement is shown in Figure 8, but other arrangements may be used. Above-ground storages overcome construction problems in high water-table areas and provide a degree of safety due to the height of access. Although the concrete construction costs are generally less than for below-ground structures with roof or cover in areas where there are experienced silo contractors, the overall cost due to the required pump and plumbing is about the same. Liquid manure forms a crust more readily in silo-type storage, so odors are negligible except when pumping out.

Operation of liquid manure storage—Some of the measures you can take to minimize operating problems are:

Disturb liquid manure in storage as little as possible, to minimize the emission of odors. Odors are further reduced by covering the storage.

Add only enough dilution water to allow agitation and pumping. Excess water increases storage requirements (or reduces the length of storage period for existing structures) and increases the quantities to be handled.

Avoid coarsely ground feeds, particularly with swine. These feeds can create flow and settlement problems in conduits, gutters and storages.

Avoid additions of hay and bedding; where hay is fed, chopped hay creates fewer pumping problems than long hay.

Provide adequate agitation before removing manure from storage. Avoid agitation when the wind is toward neighbors.

When manure enters a separate covered storage through barn openings, exhaust ventilate from the storage or provide a gas trap, to prevent back-flow of odorous and dangerous gases into the barn.

Remove animals and open all doors for maximum ventilation when agitating open storages within the barn, to avoid gas hazards.

Fence open-top outdoor storages to exclude children and domestic animals.

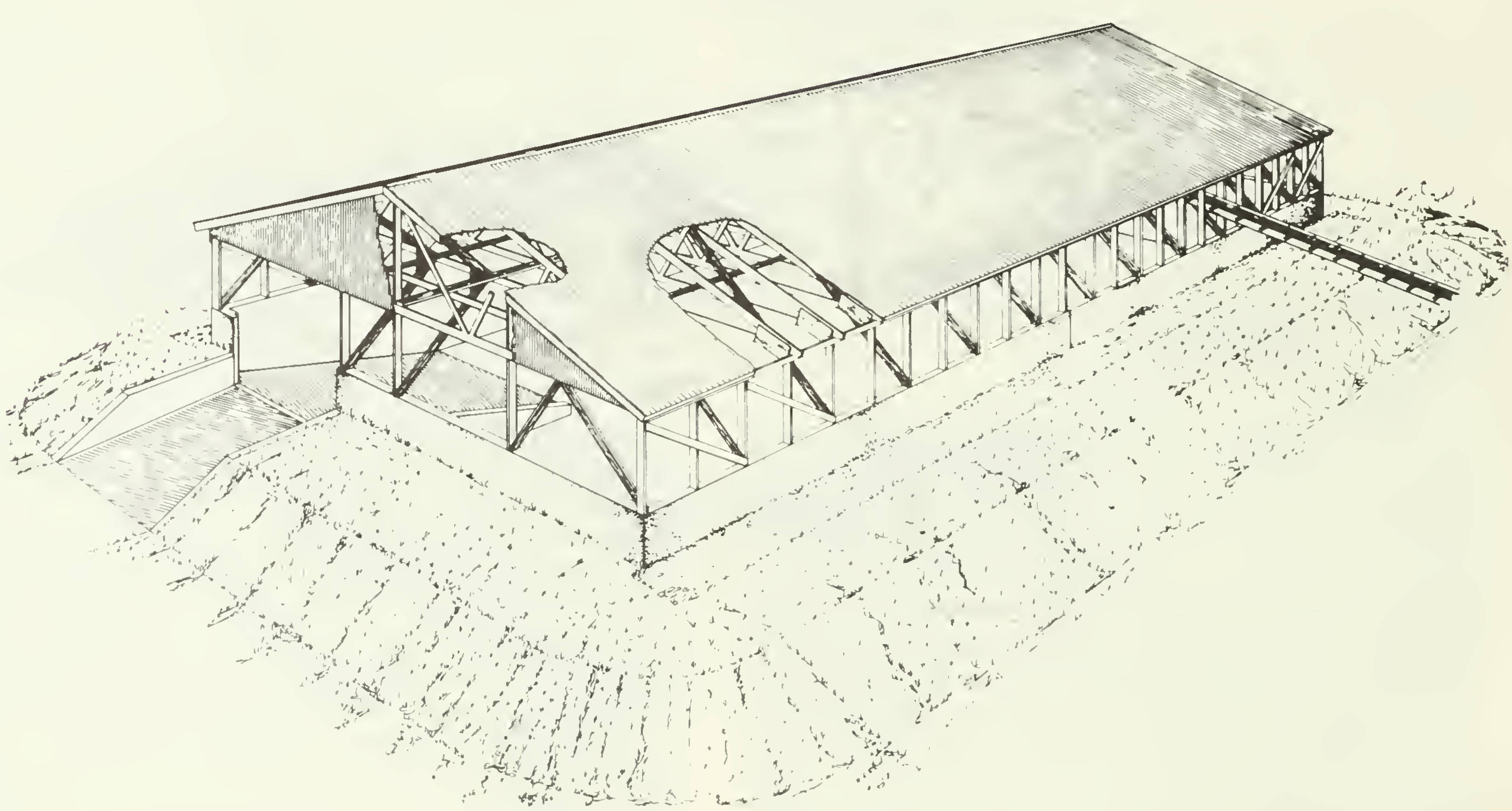


Figure 4 — Rectangular roofed storage for semisolid manure (CPS plan M-2705)

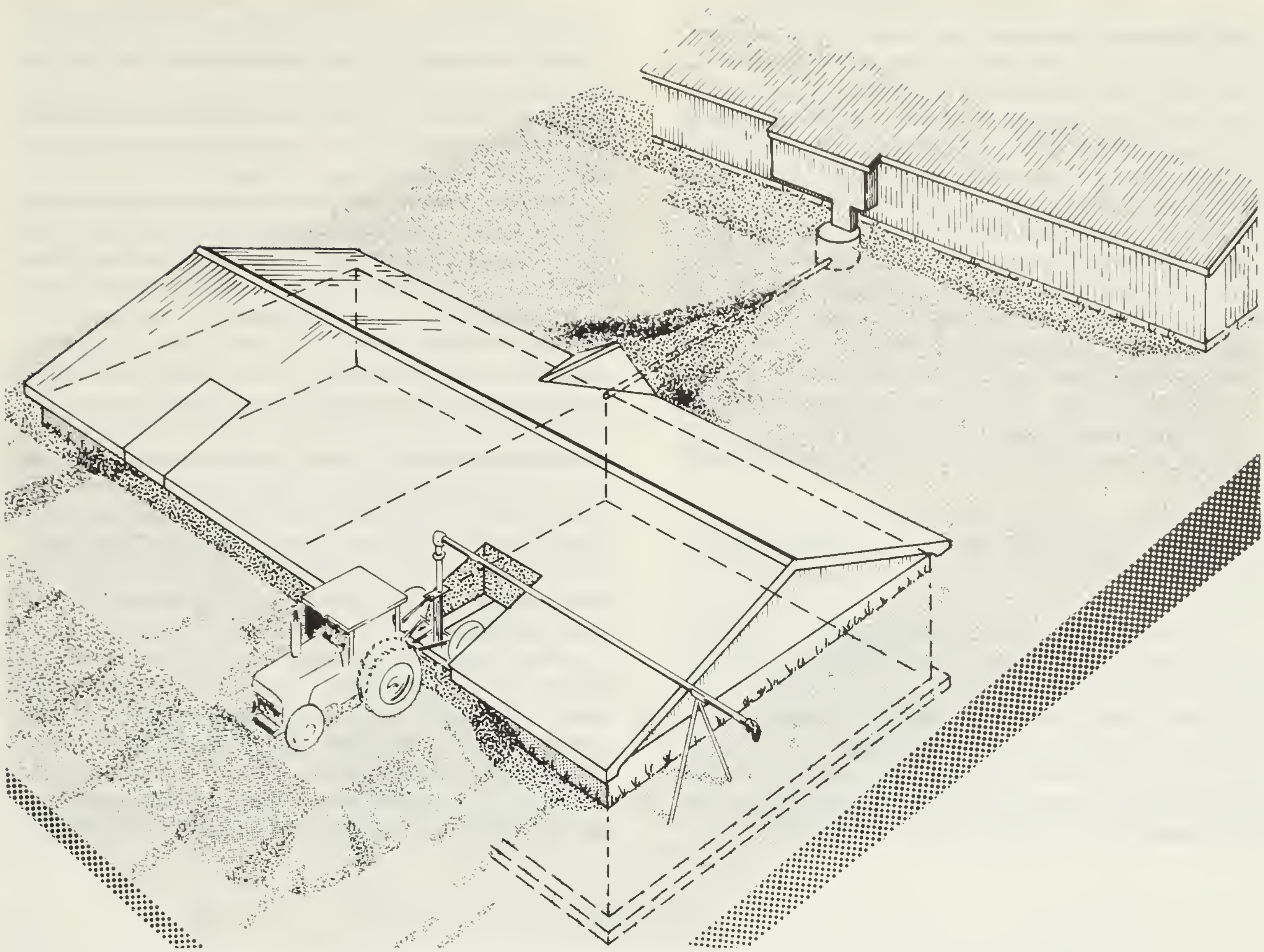


Figure 5 — Rectangular roofed manure tank (CPS plan M-3753)

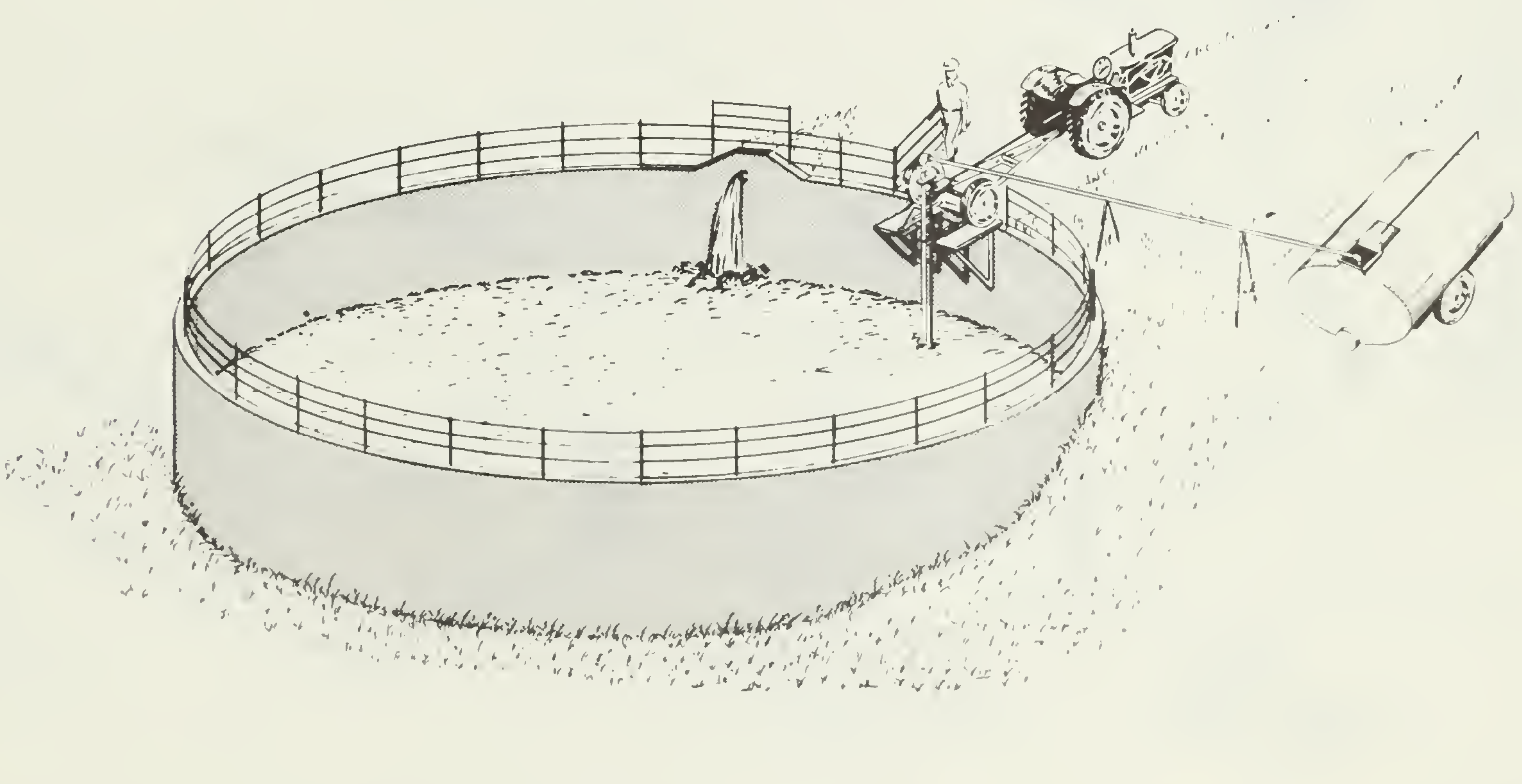


Figure 6 — Below-ground open circular manure tank (CPS plan M-3752)

Keep covers for equipment-access openings into covered storages securely in place when not in use. Covers should weigh 20 kg, should not float, and should either be larger than their openings or be secured with a safety chain so they can't fall into the storage.

Do not enter an indoor or covered storage without taking special precautions. Make sure it is well ventilated and wear a rope safety harness. Have at least two men standing by on the rope outside the storage in case of emergency. As an additional precaution, wear a self-contained breathing apparatus.

Do not smoke or use matches or an open flame while inspecting an unventilated storage tank. Some manure gases, particularly methane, can be explosive when mixed with air (see Appendix 1).

Removal, Transport and Land Incorporation

Conventional handling equipment is available to remove, transport, and spread solid and liquid manure on the land. Special equipment (that is available) and special facilities are required to handle semisolid manure. These include a buck-wall for a scoop loader to work against and either a box spreader with end-gate or an open-top, flail-type tank spreader.

Application of manure onto cropland via sprinkler irrigation has not proven acceptable to many farmers because of problems with labor, equipment and odors; where irrigation is planned, manure must be diluted to about 95% moisture content to make a mixture liquid enough for successful pumping and sprinkling.

An alternative to storing liquid and solid fractions of manure in a single storage and handling them together is to use suitable drains that let the liquid collect in a separate basin. From here it can be readily pumped through an irrigation system onto adjacent fields. The semisolid manure remaining then can be handled more easily with sludge pumps or tractor scoops.

To minimize the odor nuisance when field spreading, manure should be applied downwind from neighbors and during periods of the day when air movement favors odor dispersal. Covering manure by plowing or disking as soon as possible after spreading greatly reduces odor and keeps manure from washing off fields with the surface runoff.

Although not widely practiced, two methods for incorporating liquid manure into the land have been developed. In the plowdown method, inexpensive hoods are fitted to tanker outlets to divert manure downward into a 1.8 m swath; a second tractor, with wheels set wide apart and pulling a plow slightly wider than the swath, follows the

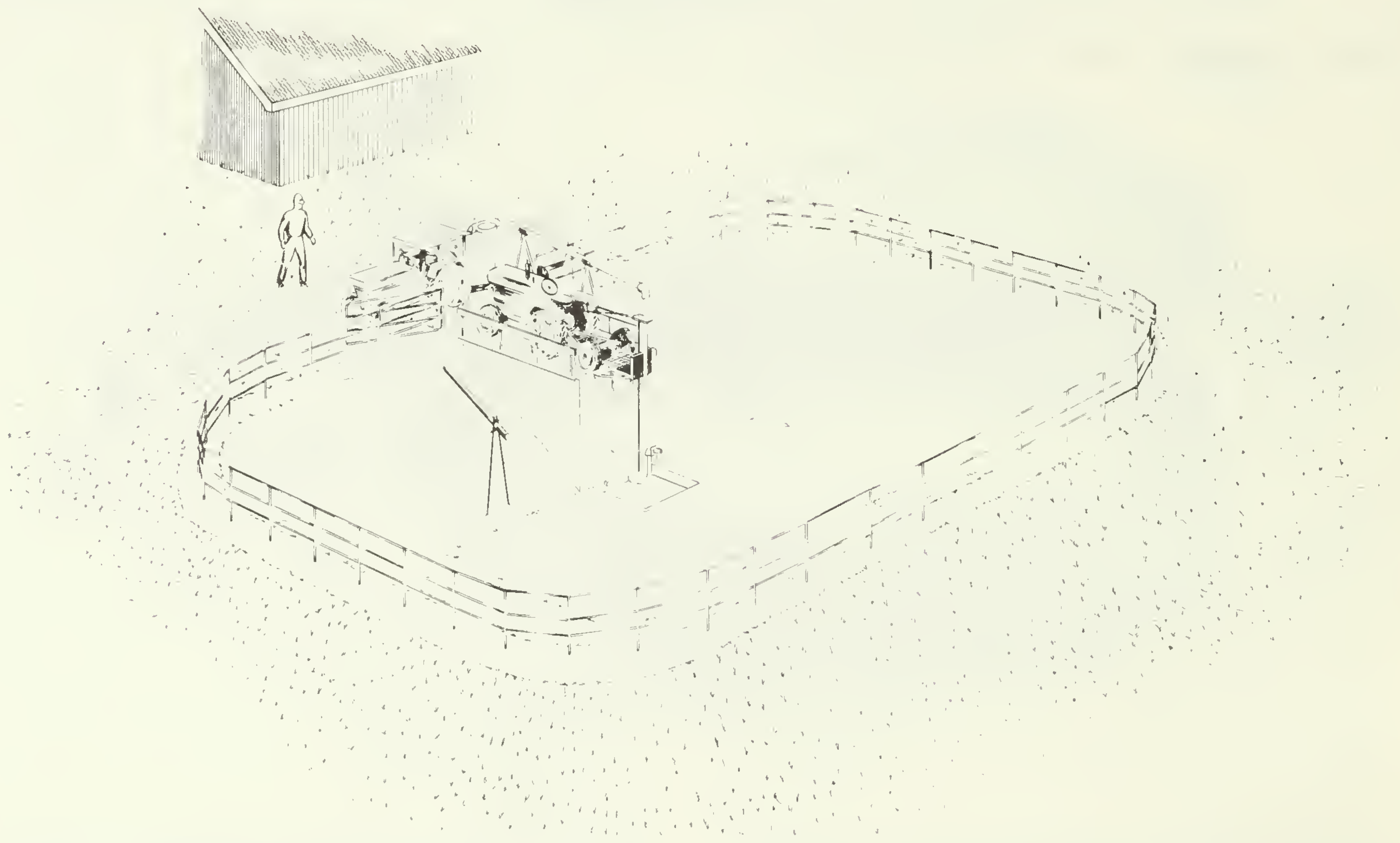


Figure 7 — Clay-lined manure storage pond with pumping dock (CPS plan M-2702)

tanker and covers the swath within seconds. This method is not efficient for most farm operations with only one tanker, but it can be used if neighbors pool equipment. Concentrating manure in a relatively narrow swath results in application rates higher than those obtained with conventional spreading equipment. However, by reducing the tanker outlet to 75 mm in diameter, reducing the discharge pressure at the outlet, and travelling at 5 to 6 km/h, the application rate can be kept below 100 t/ha.

The second method for land incorporation of liquid manure is soil injection. This holds the greatest potential for odor control, for lengthening the time manure can be applied in the spring, for incorporating manure into hay and pasture without completely destroying the crop, and for achieving an acceptable rate of application. Soil injectors now available lead liquid manure under pressure from the tanker through tubes located behind deep cultivator teeth. Some refinements are still needed to avoid buildup ahead of the injector unit, to ensure adequate coverage behind the unit, and to make injectors suitable for row-crop application under a wide range of soil conditions. For the corn producer, injection may extend the time he can apply manure between rows by a few weeks during the critical work period in the spring; for the hay and pasture producer, manure may be incorporated without plowing and unnecessary loss of crop.

Existing rapid cover plow-down and soil injection equipment is designed for liquid manure and is not suitable for producers who have an odor problem with solid and semisolid manure. Where rapid cover techniques cannot be used, an alternative is precise placement of manure on the ground surface. Manure is forced out of the spreader and drops to the ground between two curtains or through flexible drop tubes trailing just above the ground. This technology has been developed recently in Europe; it likely will find application on Canadian farms where odors and spray drift from field spreading have become a problem.

Beef Cattle

Five alternate manure handling systems are shown in Table 4. The first two require minimum capital invested in housing, but need a relatively large feedlot, for example, 18 to 28 m² per feeder. Careful management is important to control the high runoff and odor pollution possible with open-dirt feedlots. Good drainage combined with the regular mounding of manure is essential to maintain high levels of sanitation and minimize odor nuisance. Drainage, however, must be controlled in leak-proof storage to avoid surface and groundwater contamination. To minimize the

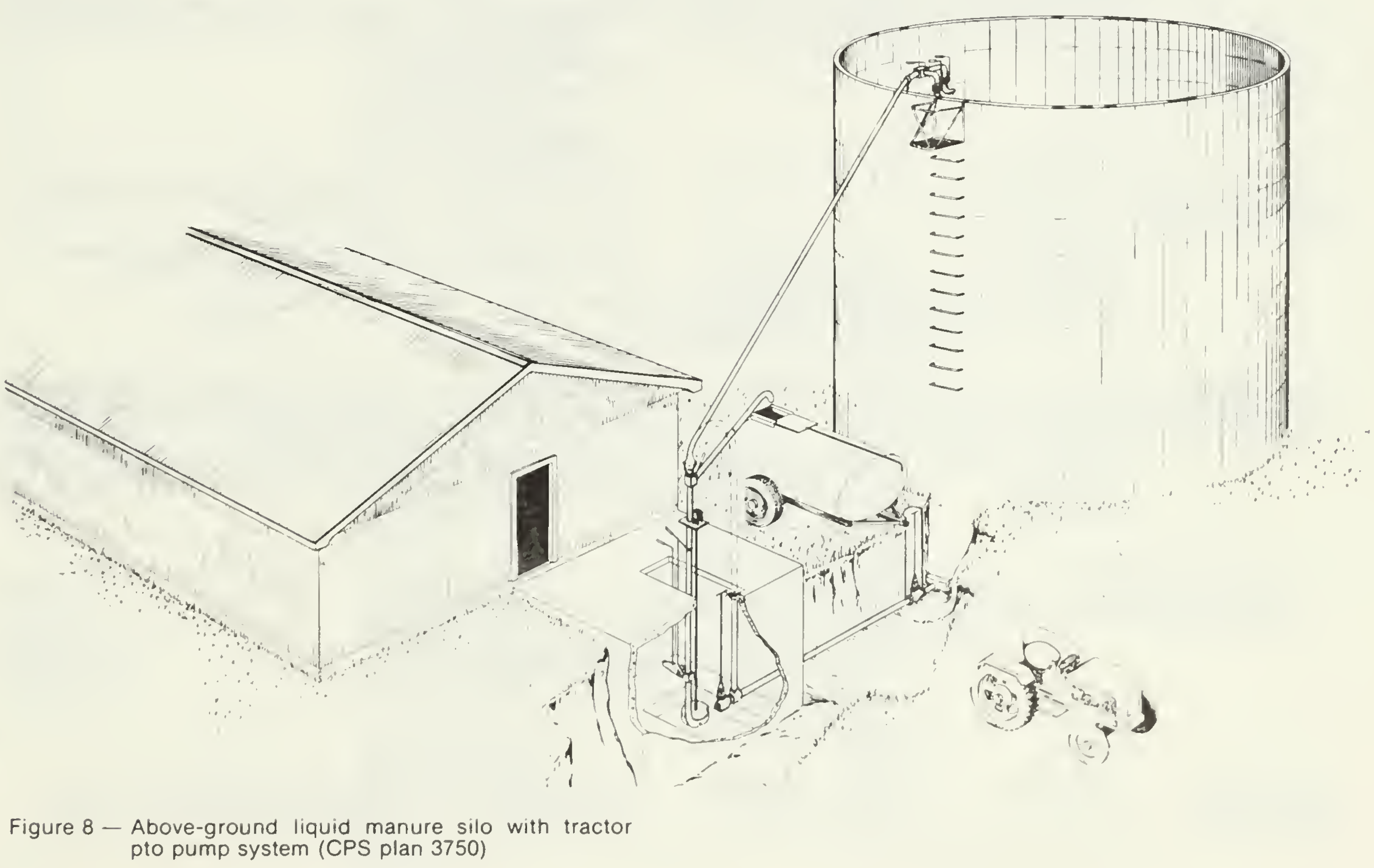


Figure 8 — Above-ground liquid manure silo with tractor pto pump system (CPS plan 3750)

groundwater pollution hazard presented by infiltration and deep percolation of nitrates beneath active feedlot surfaces, an undisturbed soil-manure interface should be maintained when manure is either mounded on the lot or removed during the clean-out operation. Snow control around the feedlot is important, as well as provision of diversion ditches to prevent outside water from entering the lot.

The third system, which combines open feedlot and covered shelter, is more suitable for humid regions. Less area is required, for example, 5 to 6.5 m² per feeder. A paved feedlot facilitates easy and frequent cleaning.

The last two systems are totally covered feedlots which allow the lowest area per animal, for example, 2 to 3 m² per feeder. Confinement housing for beef cattle requires considerable engineering input relating to proper ventilation, slat design, manure tank design and access for manure removal. Operators considering the extremely high investment for a fully confined facility should obtain agricultural engineering assistance far beyond what this guide provides.

Dairy Cattle

Table 5 shows manure handling systems for the two common types of animal management, tie stall and free stall. For tie stall management, manure can be handled as a solid, semisolid or liquid. The three alternate systems for free stall management take advantage of the lesser bedding requirements and provide for handling manure as either a liquid or semisolid.

Milk Center Wastes

Where manure is handled as a liquid, all milk center wastes are best used to dilute the liquid manure in storage. Depending on the location of

Table 4 — Manure Handling Systems for Beef Cattle

Type of animal management	Type of manure	Collection, transfer and storage	Removal and transport to land	Comments
Open field and woodlot	Field droppings		Spread by cattle	If slab not used at feed and water site, change site locations periodically to minimize large concentrations of manure. Avoid sites where pollution of natural bodies of water will occur
	Manure near feeding-watering sites	On slab or ground	Tractor loader to spreader to land	
Open dirt feedlot (dry climate)	Lot manure with bedding added	Tractor scraper to mounds on lot	Tractor loader to spreader to land	Mound seldom needs to be removed if it can be maintained firm and dry. Divert outside water away from feedlot.
	Wet manure near feed bunks and waterers	Tractor scoop to curbed storage slab	Liquids drain to settling basin, solids loaded to spreader to land	Storage slab may be upper part of settling basin
	Lot and storage slab runoff	Surface drains to settling basin. Overflow stored in detention basin	Settling basin sludge: Tractor loader to spreader to land Detention basin liquid: Vacuum tanker to land OR Pump to irrigation system to land	Obtain local advice regarding size of settling and detention basins
Open paved feedlot and covered bedded area (humid climate)	Solid manure in covered bedded area	On paved or dirt floor	Tractor loader to spreader to land	Provide sufficient headroom in bedded area for bedding pack plus cattle space (3-3.7 m typical)
	Semisolid manure on paved lot	Tractor scraper to stock pile on curbed slab	Tractor loader to spreader to land	Let snow and ice mixed with manure melt and drain before handling
	Lot and stock pile runoff	Surface drains and/or sewers to earth detention basin or concrete tank	Vacuum tanker to land OR Pump to irrigation system to land	
Covered feedlot with solid floor	Solid manure in bedded area	On paved or dirt floor	Tractor loader to spreader to land	Provide sufficient headroom in bedded area for bedding pack plus cattle space (3-3.7 m typical)
	Unbedded manure at feeding-watering area	To handle as semisolid manure, tractor scraper to stockpile on outdoor curbed slab. (see CPS plans M-2701, M-2703, M-2704, or M-2705). Retain runoff on slab, or drain to earth detention basin or concrete tank	Tractor loader to spreader to land	Use box spreader with endgate or open-top flail-type tanker
		To handle as liquid manure, tractor scraper to storage tank (see CPS plans M-3752 or M-3753) or earthen storage (see CPS plan M-2702)	Pump-agitator to tanker to land	
Covered feedlot with fully slotted floor	Liquid manure	Manure through slotted floor to tank storage below	Pump-agitator to tanker to land	When agitating liquid manure, remove cattle and open all doors to avoid gas hazard

Table 5 — Manure Handling Systems for Dairy Cattle

Type of animal management	Type of manure	Collection and transfer	Storage	Removal and transport to land	Comments
Tie stall with bedding (see CPS plan 2220)	Solid manure	Shallow gutter, gutter cleaner to elevator	Stack on curbed slab (CPS plan M-2703)	Tractor loader to spreader	In cold climates, manure dropped from a stacker will freeze into a very steep cone and will interfere with stacker operation
	Manure stack runoff	Surface drain and/or sewer	Retain within storage, or drain to detention tank or earthen basin (CPS plan M-2703)	Vacuum tanker, or pump-filled tanker, or irrigation	
Tie stall with limited bedding (see CPS plan 2220)	Semisolid manure	Shallow gutter, gutter cleaner to storage, or gutter cleaner to short term holding tank and by plunger pump through pipe to storage OR Grate-covered deep gutter, continuous gravity flow to storage, or gravity flow to short term holding tank and by plunger pump through pipe to storage	Stockpile in walled storage (CPS plans M-2701, M-2704, M-2705)	Tractor loader to spreader, or tractor scraper and ramp to spreader, or sludge pump to spreader	Semisolid handling recommended with uncut hay or bedding In high precipitation areas, consider draining storage with separate storage and handling of liquid fraction
	Liquid fraction in storage		Retain within storage or drain to detention tank or earthen basin	Vacuum tanker, or pump-filled tanker, or irrigation	
Tie stall with restricted chopped bedding (see CPS plan 2220)	Liquid manure	Grate-covered shallow gutter, gutter cleaner to storage; or gutter cleaner to short term holding tank and pump to long term storage OR Grate-covered deep gutter, continuous gravity flow to storage, or gravity flow to short-term holding tank and pump to long-term storage	Above-grade silo type storage (CPS plan 3750), or concrete storage tank (CPS plans M-3752, M-3753) or earthen storage (CPS plan M-2702)	Agitation, then by gravity or pump to open-top tanker, or by vacuum tanker	Where storage is in direct contact with collection area, continuous tan exhaust to prevent gas entry and cold drafts into barn
Free stall with paved passages; limited bedding (CPS plans 2101, 2104, 2106, 2112)	Semisolid manure	Tractor scraper to buck-wall to storage OR Tractor or shuttle scraper to opening into storage or to elevator into storage, or to short-term holding tank and plunger pump to long-term storage, or to cross gutter with continuous gravity flow to storage OR Tractor scraper to buck-wall or ramp to truck or spreader to distant storage	Stockpile in walled storage (CPS plans M-2701, M-2704, M-2705)	Tractor loader to spreader, or tractor scraper and ramp to spreader, or sludge pump to spreader	Semisolid handling re-commended with uncut hay or bedding In high precipitation areas, consider draining storage with separate storage and handling of liquid fraction
	Liquid fraction in storage		Retain within storage or drain to detention tank or earthen basin	Vacuum tanker, or pump-filled tanker, or irrigation	
Free stall with paved passages; restricted chopped bedding (CPS plans 2101, 2104, 2112)	Liquid manure	Tractor or shuttle scraper to opening into storage, or to short-term holding tank with pump to storage, or to cross gutter with continuous gravity flow or gutter cleaner to storage	Above grade silo-type storage, (CPS plan 3750), or concrete storage tank (CPS plans M-3752, M-3753) or earthen storage (CPS plan M-2702)	Agitation, then by gravity or pump to open-top tanker, or by vacuum tanker	Close floor openings from barn into storage when agitating holding tank
Free stall with slotted floor passages, re-stricted chopped bedding (CPS plan 2102)	Liquid manure	Manure through slotted floor to trench below, flush trench with pump recirculation system, pump-agitator to long-term storage OR Manure through slotted floor to deep gutter below, continuous gravity flow to storage, or gravity flow to short-term holding tank and pump to long-term storage	Above grade silo-type storage (CPS plan 3750), or concrete storage tank (CPS plans M-3752, M-3753), or earthen storage (CPS plan M-2702)	Agitation, then by gravity or pump to top loading tanker, or by vacuum tanker	When flushing trenches, remove cattle and open all doors to avoid gas hazard

the storage, they can either flow to the storage through a pipe and gas trap, or collect in a sump from which they are pumped by a float-operated, sewage-type sump pump (CPS Plan 2102 shows such a system). However, the addition of milk center wastes to a manure storage will reduce the effective capacity of the storage by 25% or more.

Where liquid manure storage is not available, solid manure preferably should be removed from the milking parlor floor and placed in the manure storage. Milk center wash water may be delivered through a pipe and gas trap to a lagoon, a collection tank or a sediment tank and underground disposal field. Lagoons may be suitable in some areas but Canadian field experience is limited and prior approval from local authorities should be obtained. Follow recommendations contained in Part 2 of the *Canadian Farm Building Code*[4] for the construction of aerobic lagoons, but the lagoon effluent unlikely will be acceptable for discharge into surface waters. Therefore, provide for periodic application of the lagoon contents to cropland. The recommended loading rate is based on providing 4.5 to 5.5 m^2 of lagoon surface area per cow milked.

[4] Issued by the Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

Particularly in milder climates, milk center wastes may be collected in a concrete tank and applied to adjacent cropland via a pump and sprinkler system on a regular basis, usually every 2 to 4 weeks. Never apply milk center wastes in this manner onto snow covered or frozen fields, and take care to prevent surface runoff to a watercourse.

For the sediment tank and disposal field system, recommended tank sizes are shown in Table 6 and recommended sizes of disposal field are shown in Table 7. However, where manure gratings or floor drains collect manure solids in the milking parlor and these solids are added to the milk center wastes, the sediment tank sizes in Table 6 should be doubled. Construct sediment tanks to permit easy inspection and removal of sediment. Individual practice determines the rate of sediment accumulation in the tank and depends on the amount of manure and waste feed washed to the tank and the sanitizers used. Regular removal and land application of sediment is required to avoid carry-over of solids that may prematurely plug the disposal field. To determine the cleaning frequency, check the depth of sediment every few months after you begin operation.

Table 6 — Sediment Tank Capacities for Milk Center Wastes*

No. of cows	Volume (L)	Settling compartment		
		Length (mm)	Width (mm)	Water depth (mm)
Up to 25	2250	2060	915	1220
26 to 45	2700	2440	915	1220
46 to 65	3250	2740	990	1220
66 to 100	4100	2740	1065	1370

*Adapted from Canadian Farm Building Code, Associate Committee on the National Building Code, National Research Council of Canada, Ottawa

Table 7 — Size of Underground Disposal Field for Milk Center Wastes*

No. of cows	Length of tile trench (m)		
	Good subsoil drainage (Sand and gravel)	Medium subsoil drainage (Sandy loam soil)	Poor subsoil drainage (Silt & clay loam soil)
Up to 25	30	30	45
26 to 45	30	55	80
46 to 65	40	80	120
66 to 100	60	120	180

*Adapted from Canadian Farm Building Code, Associate Committee on the National Building Code, National Research Council of Canada, Ottawa

Swine

As shown in Table 8, swine manure can be handled as either a solid, semisolid or liquid. However, the high cost and general scarcity of bedding materials for solid manure handling systems has led to the wide use of the generally more efficient liquid manure handling systems.

Several alternate facilities to collect and transfer liquid manure are shown. The hand scrape to deep narrow gutter system, with sluice gates to regulate gravity flow through a gas trap into storage, was a popular trend in certain areas of the country; however, a new trend of gutter flushing systems seems to be developing. Some use tipping buckets or syphon tanks with fresh water or clear effluent for flushing, while others use the pump-agitator to recycle flush water. In the latter case, aeration devices may be used in the surge tanks to control odors, or a floating intake may be used to remove relatively clear effluent from the surface of detention ponds. For breeding herds, an optional system is shown using open paved runs and a covered bedded area. If these facilities are placed on a sloping site, gravity flow can be provided from the paved runs via surface drains or channels to storage. However, extra storage must be provided to allow for the added precipitation on the exposed manure collecting and transfer areas.

Table 8 — Manure Handling Systems for Swine

Type of animal management	Type of manure	Collection and transfer	Storage	Removal and transport to land	Comments
Bedded pens: see CPS plans	Solid manure	Shallow gutter, gutter cleaner to elevator	Stack on curbed slab (see CPS plan M-2703)	Tractor loader to spreader to land	Only practical where bedding is abundant and inexpensive
3025 3036 3302 3311 3312 3426 3801 3802	Manure stack runoff	Surface drains and/or sewer	Retain within storage or drain to detention tank or earthen basin	Vacuum tanker to land	Leaching can be reduced by providing covered storage (see CPS plan M-2705, and add features for handling liquid fraction)
Little or no bedding: see CPS plans 3025 3035 3036 3301 3302 3311 3312 3428 3448 3449 3801 3802	Liquid manure	Hand scrape to shallow gutter, shovel (or gutter cleaner) to opening into storage OR Hand scrape to deep narrow gutter, gravity flow from gutter through valve and gas trap into storage OR Hydraulic flushing using fresh water or recycled liquid manure OR Through partially slotted floor to either: trench below, gravity flow from trench through gas trap into storage OR trench below, removal and transfer by vacuum tanker to long-term storage OR continuous loop trench below for oxidation ditch. Effluent overflow into storage (see Oxidation Ditches, page 00)	If storage site below level of collection facilities, gravity flow to large tank (see CPS plans M-3752, M-3753) or earthen storage (CPS plan M-2702) If storage site above level of collection facilities, gravity flow to short-term holding tank, pump to large above-ground circular tank (see CPS plan 3750)	Pump-agitator to tanker to land OR Vacuum tanker to land	To exclude long-term storage gases from barn, provide a gas trap where manure enters storage OR provide a continuous-running fan exhausting from storage. This fan should be selected to give the first stage ventilation rate required by the swine
Open paved runs and covered bedded area (optional for breeding herds)	Solid manure	Hand scrape to gutter or open trench, tractor scrape to storage	Stack on curbed slab	Tractor loader to spreader to land	
	Semisolid manure and runoff from paved runs and from manure stack	Hand or tractor scrape to surface drains, open channels or sewer	Retain within storage or drain to detention tank or earthen basin	Pump-agitator to tanker to land OR Vacuum tanker to land	

Poultry

Two manure handling systems for chicken broilers and heavy breeders and three systems for layers are shown in Table 9. This table includes comments on management.

Dead Bird Disposal

A number of choices are available to the poultryman for disposal of dead birds.

- burial pits and disposal pits;
- refrigerated holding and regular delivery to a rendering plant;
- incineration; and
- storage in long-term holding tanks for land disposal.

Disposal facilities should be adequate to handle normal mortality rates, estimated to be 1% each month. A large loss due to disease or power failure should not be considered in the design of these facilities. Such a loss can better be handled by arranging to bury the birds or, preferably, by delivering them to a rendering plant.

In order to decide which of the four methods to adopt, a number of factors must be considered.

Burial Pits and Disposal Pits—These must be located and constructed to avoid polluting water supplies. They must not be a hazard to people in the area. This means that burial pits are less desirable for continual use than disposal pits that are enclosed.

Although local water table and soil conditions must be considered, pits should generally be located at least 45 m from any well or spring used as a water supply.

Disposal pits can be made of metal, concrete or other locally approved material that is waterproof, and should be constructed to exclude insects and rodents. The addition of lime helps control odors. For safety, cover pits with tight-fitting lids equipped with a locking device.

Refrigerated Holding—Some poultrymen have developed a satisfactory method to tem-

Table 9 — Manure Handling Systems for Poultry

Type of animal management	Type of manure	Collection and transfer	Storage	Removal and transport to land	Comments
Floor housing with bedding (broilers, replacement pullets, breeders)	Dry litter	On floor, tractor loader to truck or spreader to storage	On floor (current broiler batch); interim storage in stockpile on curbed slab	Tractor loader to spreader to land	Stockpile storage required only if housing must be cleaned and repopulated during period when manure cannot be spread
Heated floor housing, no bedding (broilers)	Dry droppings	On concrete or wood floor	On floor (current broiler batch); interim storage in weatherproof shed	Tractor loader to spreader to land	Floor slab heated by circulating hot water in steel or plastic piping
Ceiling suspended or floor supported cages (layers)	Liquid manure	Shallow trench, tractor shuttle scraper (for ceiling-suspended cages) or cable shuttle scraper (for floor-supported cages) to opening into storage, OR cross conveyor to storage	Storage tank (see CPS plans M-3752, M-3753 and 3750) or earthen storage (see CPS plan M-2702)	Pump-agitator to tank to land OR Vacuum tanker to land	Add dilution water during agitation, as required for pumping
	Semisolid manure	Shallow trench, tractor shuttle scraper (for ceiling-suspended cages) or cable shuttle scraper (for floor-supported cages) to cross conveyor to storage	Stockpile in walled storage (see CPS plans M-2701, M-2704, M-2705)	Tractor loader to spreader to land	Avoid adding excess water
	Semisolid manure	Droppings directly into deep pit below (see CPS plan 5211)		Tractor loader to spreader to land	Avoid adding dilution water to minimize odor. Maximum ventilation in pit area to assist drying of manure
Tiered cages (layers)	Semisolid manure	Moveable belt to cross conveyor. Dropping boards, mechanical scraper to cross conveyor	Stockpile in walled storage	Tractor loader to spreader to land	Avoid adding excess water
Wire or wood slat floor. Partial or total floor area (breeders)	Semisolid manure	On floor, tractor loader to truck to storage or spreader to land	On floor (current flock); interim storage in stockpile on curbed slab	Tractor loader to spreader to land	Stockpile storage required only if housing must be cleaned and repopulated during period when manure cannot be spread
	Stockpile runoff	Surface drain and/or sewer	Retain in storage or drain to detention tank or earthen basin	Vacuum tanker to land	Avoid dilution water

porarily store dead birds in a milk-can cooler. A refrigerator or freezer of adequate capacity for the flock also could be used. This method is limited to smaller flocks.

Incineration—Incinerators should be designed to consume all material and should meet National Fire Protection Association standards for Type 4 wastes. In addition, they must meet any local requirements. Some provinces require licensing. In these cases, the incinerator must be of an approved or licensed design, and each installation must be approved individually as well.

Incinerators must be operated and maintained correctly. They should be fire safe and located so that prevailing winds carry exhaust fumes away from neighbors.

Long-term Storage and Land Disposal—Poultrymen who have chosen this method of disposal install precast concrete cisterns sized to be filled over 3 to 5 years. When one tank is filled, a second tank is used, allowing an additional 3 to 5 years for complete digestion before the first tank is pumped out for land disposal. Digestion is by enzymes or natural decay. Water is added to aid decomposition.

A good, tight-fitting and child-proof lid can be made by cementing a milk can with the bottom removed into the top of the cistern.

A holding tank sized to provide 550 L of tank capacity per 1 000 broilers or 2850 L per 1 000 layers (same as for disposal pits) should provide 5 years filling time and allow water equal to one-half of the tank capacity to be added.

Before making any final decision on method of disposal and starting construction, check with local authorities to make certain the proposed method of disposal meets all requirements.

Animal manure may be processed in a variety of ways to control odors, reduce water pollution potential, improve fertilizer value, permit energy recovery, or reduce volume. Although manure processing systems are available commercially, most are not widely used. However, because these systems may be valuable in certain circumstances, they are discussed in this section to indicate what is involved.

Anaerobic Processes

Most manure management systems involve an anaerobic process of one kind or another. In fact, virtually all manure storage piles, pits and ponds are basically anaerobic; that is, the organic material decomposes in the absence of free oxygen. Depending on the nature of the manure and other environmental conditions, many complex reactions can occur. The difference between an ordinary manure storage pit, for example, and a process defined as anaerobic is that in the latter, one attempts to control the process and consequently the reactions that occur within its environment.

Anaerobic processes for manure management generally rely on bacteria for degradation of the organic matter. Although millions of these bacteria may be present in as little as a thimblefull of manure, there are normally only two types of microorganisms involved. The first type converts the fats, carbohydrates and proteins in the manure to simpler compounds, including simple organic acids such as acetic and propionic acid. These so-called acid-forming bacteria reproduce rapidly and are not sensitive to changes in their environment. By themselves, they and others combine to produce the highly odorous gases and volatile compounds associated with ordinary manure storage units.

Processes such as anaerobic lagoons and anaerobic digesters rely on a second type of bacteria, the methane-formers, to control odors and produce energy. The methane-producing bacteria are relatively few and do not reproduce rapidly. They are extremely sensitive to the presence of oxygen and, in general, require a special environment to function properly.

The end products of a properly functioning anaerobic process are methane (CH_4), carbon dioxide (CO_2), water, new bacterial cells, inert solids, small amounts of hydrogen (H_2) and traces of hydrogen sulfide (H_2S), ammonia (NH_3), water vapor and other gases. Anaerobic lagoons and anaerobic digesters are the two most widely used anaerobic processes for manure management.

Anaerobic Lagoons

Because of low initial cost and ease of operation, anaerobic lagoons have been adopted widely for treatment of animal manure in the United States. In Canada, anaerobic lagoons have not been successful because of low temperatures for much of the year. Under these conditions, the decomposition rate is low. Consequently, lagoons fill rapidly with solids that do not stabilize and obnoxious odors are produced.

Anaerobic lagoons should not be confused with manure storage ponds or feedlot runoff detention ponds. Unfortunately, many anaerobic lagoons are underdesigned or poorly managed. When this happens, they cease to function as a lagoon and simply serve as a holding basin. In spite of the drawbacks, situations may exist where neighbors do not object and the lagoon is not a surface or groundwater pollution hazard. In such instances, anaerobic lagoons may provide valuable flexibility in manure management systems.

If construction of an anaerobic lagoon is being considered, there are several basic requirements. It should be placed far enough away and downwind from living areas to avoid being a nuisance, be located where there is enough space for expansion and slope is sufficient to prevent surface drainage from entering, and be built to permit biological action during as much of the year as possible. This means the lagoon should be as deep as possible and of sufficient volume to handle the manure and waste water from the entire herd at a recommended loading rate. Recommendations for loading rates and lagoon construction are contained in the Canadian Farm Building Code[5]. Consult local authorities for approval of design before starting construction.

Anaerobic Digester

Anaerobic digesters are widely used to process dilute organic materials resulting from municipal and industrial sewage treatment. This process has been used successfully in warmer climates for solids stabilization and methane gas production from animal manure. *However, as of 1979, the economic feasibility of producing methane gas from animal manure in North America has yet to be demonstrated.* Most animal manures have potential for methane production, depending on the amount and condition of manure available and the development of a suitable farm-size system of anaerobic digestion in Canada.

[5]Issued by the Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

Most digesters are circular, airtight structures of varying depth. They are equipped with mixing devices and heat exchangers to keep manure at approximately 35° C. Anaerobic digestion occurs from 0 to 60° C, but gas production is severely limited in the upper and lower ends of this range. Temperature, loading rate, mixing, retention time, alkalinity and toxicity of feed additives all affect methane production. Other facts to consider before investing in an anaerobic digestion system include the high cost of properly designed structures, the mixing equipment and gas-control devices needed, the continual care necessary to avoid explosions, the need to regularly feed liquid manure to the digester and supervise the digester operation, the storage and use of the biogas produced, and the storage and use of the digested liquid manure.

A successfully operated anaerobic digester produces gas consisting of about 60 to 70% methane and 40 to 30% carbon dioxide. This mixture is sometimes called biogas. Research at the University of Manitoba and elsewhere has shown it is possible to produce heating energy equivalent to 1 to 2.4 L of fuel oil per day, from each 1 000 kg of animal liveweight, depending on the species. The potential for electricity generated from biogas is somewhat less, about 2.6 to 6.2 kWh per day for each 1 000 kg of liveweight, again depending on the species. Research also has shown that poultry manure normally will produce more biogas per unit liveweight than manure from swine, dairy or beef. However, because of the dilution needed to guard against ammonium inhibition of the bacteria, more digester capacity is necessary. The result is that biogas from poultry manure per unit digester capacity is about the same as for other species. Manure that lies for more than a few hours on open feedlots or concrete aprons, or that has bedding or other debris mixed with it, will not be as effective as liquid manure collected under cages or slotted floors, or by flushing gutters.

In anaerobic digestion, approximately 1% of the original nitrogen in the manure is lost while virtually all of the phosphorus and potassium are retained. Reports that digested manure is better fertilizer than regular liquid manure are based on digested manure having a larger percentage of inorganic nitrogen that is readily available to plants. However, digested manure must be incorporated quickly during land application to prevent large losses of ammonia nitrogen. Therefore, we can only say for certain that, with proper management, anaerobically digested manure is at least as good as regular manure.

Of the volume of manure that enters a digester, 97 to 98% will leave the digester and presumably must be hauled to the field. However, depending on the dilution necessary for digestion, more may have to be hauled. Poultry manure, for example, needs no dilution if hauled as a solid manure, but if digested, the dilution water would increase the original volume about four times.

Studies in Canada have shown that, on an annual basis, about 35% of the gross energy produced by a well-insulated and properly-operated anaerobic digester is used to heat and mix the incoming manure, and replace heat losses. The percentage of gross energy that must be returned to the digester depends on the time of year. During January about 46% is used to run the digester while in July and August less than 27% is needed.

Three realistic options exist for using biogas on animal production farms: use it directly for cooking, lighting, space heating, water heating, grain drying or gas-fired refrigerating and air conditioning; transform it into electricity by burning it in an engine that turns a generator; or vent it to the atmosphere. The best use depends on the amount and type of seasonal energy needed by a particular farm and the comparative cost of each form of energy from other sources. *At present, the use of biogas as a fuel for cars, trucks and tractors is impractical because of its low energy per unit volume.* This low energy content reduces the distance that can be travelled or the work that can be done with the biogas contained in a reasonably-sized tank.

The cost of an anaerobic digestion system on a farm will depend partly on the degree of automation desired and thus the complexity of the system, the amount of dilution necessary and therefore the size of the digester, the investment in addition to the normal manure handling costs, and the intended use of the biogas. Other factors that influence costs are the structural materials used for the digester, the amount of insulation necessary, the bearing capacity of the soil, the location of the water table and the location of the digester with respect to the barn. Some farmers may be able to reduce costs by obtaining various components of the system through sales and salvage yards. They also may choose to build the system themselves and avoid direct labor costs. Some may prefer to use additional labor to operate the system instead of purchasing automatic controls, decreasing the initial cost but increasing the operating cost. Therefore, each situation must be examined to determine its economic justification. Much progress has been made in research and development of anaerobic digesters for farms. *However, anaerobic digestion cannot be recommended at present for use with normal animal operations.*

Aerobic Processes

Aerobic decomposition occurs when a dilute mixture of organic wastes and water is supplied with dissolved oxygen. Under these conditions, aerobic bacteria use the organic matter as a food source in biochemical and oxidation reactions to produce new bacterial cells, carbon dioxide and water as the primary end products. In practical systems, all of the organic matter will not be decomposed aerobically and accumulation of these stable solids along with fixed solids will result.

Compared to domestic sewage, animal manure contains extremely high amounts of carbonaceous material and nutrients. Consequently, treatment of animal manures with the hope of obtaining effluent suitable for disposal in a stream or lake is not economically feasible today. However, in many instances partial treatment of liquid animal manures may be used to control odors or to reduce the nitrogen content of the material. Oxidation ditches and aerated lagoons have been the most successful methods of treating liquid animal manures. Composting (an aerobic process) can be used to stabilize solid manure.

Oxidation Ditches

An oxidation ditch is an open channel pit shapped like a racetrack in which a paddle, brush-type rotor or an air pump supplies oxygen to the liquid manure and keeps the liquid contents of the ditch in circulation. Oxidation ditches have been employed under slotted floors in swine, beef, and dairy confinement buildings and under caged layer systems for poultry. The principal advantage of the oxidation ditch is its capability to minimize odors. Construction and installation costs can be high and maintenance may be a problem.

Foaming of the ditch contents is sometimes encountered during start-up or when the ditch is overloaded. Antifoam agents, water spray, or small amounts of oil may be used to combat foaming. An oxidation ditch should be started gradually by initially filling the ditch with tap water. A rotor should not be started in a ditch that contains liquid manure more than a few days old. The oxidation ditch works well in cold climates provided the majority of the ditch is within the confinement facility.

A properly designed, installed, and operated oxidation ditch can reduce odor production dramatically. However, it does not eliminate the need for manure management. In most cases a relatively odor free effluent still must be stored and returned to the land. In some cases the volume of liquid effluent may be reduced; in others it may be increased depending upon the type of manure, water use, and evaporation within the facility. Engineering advice on the design of an oxidation ditch should be sought prior to investment so that loading rates and rotor capacity, etc., can be matched to the individual operation.

Aerated Lagoons

There are two types of aerated lagoons: the naturally-aerated lagoon (sometimes called an aerobic lagoon or an oxidation pond) and the mechanically-aerated lagoon.

Naturally-aerated lagoons are generally shallow (1 m) basins in which bacteria and algae are expected to purify the organic matter of the manure. Lack of a long, warm summer in Canada and the ease with which it is possible to overload naturally aerated lagoons has limited their success for animal manure management. Mechanically-aerated lagoons operate on the same biological principles as the oxidation ditch. However, the aerator is generally a pump or a blower that is often designed to float in place on the lagoon.

Several disadvantages exist with mechanically-aerated lagoons when compared to an oxidation ditch. Manure must be moved to the lagoon, the lagoon will require more space, if not maintained it will be an eyesore, and it is subject to freezing. Advantages usually include flexibility with respect to existing buildings, lower initial costs, and less concern for foaming or equipment failure. If properly designed and operated, a mechanically-aerated lagoon will control odors. Liquid and solids will have to be removed periodically and measures would have to be taken to start the aerator as soon as possible in the spring to prevent growth of odor-producing bacteria. As is the case with the oxidation ditch, engineering advice should be sought before purchasing a fixed or floating aerator.

Composting

Composting is a relatively fast aerobic process in which organic matter is broken down by bacteria and fungi to produce a dark-colored humus. Aeration is accomplished by mixing solid or semisolid manure with a mechanical scraper, windrower, or rotary drum. This process is self-heating to about 60° C and with moderate shelter can be operated year-round. Stable compost can be produced in about 10 days provided a carbon to nitrogen ratio of approximately 25:1 and a moisture content of around 50% are maintained in the heap. Since fresh animal manure contains more nitrogen and moisture than is desirable for good composting, chopped straw may be used to improve the compost. Good composting requires daily mixing and should not be tried without adequate labor, time, and equipment. Commercial compost markets are limited and, as with dried manure, relatively few animal operations in North America have successfully sold these as by-products.

Dehydration

Moisture removal by the addition of heat is more applicable to undiluted poultry manure than to other types. It is the highest in nutrients, the driest to begin with, and can be dried further in the poultry house by ventilation using surplus heat produced by the flock or heat from outside air.

Dehydration is desirable for odor control, improved handling characteristics and weight reduction. Manure dried to 15% moisture content or less stores well with little odor and doesn't attract many flies. Commercial manure drying for marketing has had limited success in North America because demand in any given area is small.

Incineration

Incineration of animal manure has failed as a feasible manure management alternative. Air pollution due to odors and particulate matter, the fact that 10 to 30% of the initial dry matter remains as ash, and high costs are the primary reasons for this failure.

Appendix 1 Properties of the Principal Manure Gases and their Physiological Response on Adult Humans[1]

Gas	Specific gravity[2]	Odor	Color	Affinity for water	Limits of inflammability[3] (% by volume)		Threshold limit value[4] (ppm)[5]	Excursion factor[6]	Time-weighed average limit[7] (ppm)	Gas concentration (ppm) and physiological response
					Lower	Upper				
Ammonia (NH_3)	0.6	Sharp, pungent	None	Highly soluble	15.5	27.0	25	1.5	37.5	IRRITANT 5-50 — least detectable odor 100-500 — irritations to mucous surfaces in 1 hour 400-700 — immediate irritation of eyes, nose and throat 2 000-3 000 — severe eye irritation, coughing, frothing at mouth, could be fatal 5 000 — respiratory spasm, rapid asphyxia, may be fatal 10 000 — rapidly fatal
Carbon dioxide (CO_2)	1.5	None	None	Moderately soluble	—	—	5 000	1.25	6 250	ASPHYXIANT 20 000 — safe 30 000 — increased breathing 40 000 — drowsiness, headaches 60 000 — heavy, asphyxiated breathing 300 000 — could be fatal (30 minute exposure)
Hydrogen sulfide H_2S)	1.2	Offensive, rotten egg smell	None	Highly soluble	4.3	45.5	10	2	20	POISON 0.01-0.7 — least detectable odor 3-5 — offensive odor 10 — eye irritation 20 — irritation to mucous membranes and lungs 50-100 — irritation to eyes and respiratory tract (1 hour exposure) 150 — olfactory-nerve paralysis, fatal in 8-48 hours 200 — dizziness (1 hour), nervous system depression 500-600 — nausea, excitement, unconsciousness, possible death, (30 minutes) 700-2 000 — rapidly fatal
Methane (CH_4)	0.6	None	None	Slightly soluble	5.0	15.0	—	—	—	ASPHYXIANT 500 000 — headache, nontoxic

[1]Source. Nordstrom, G.A. and J.B. McQuitty 1976. Manure gases in the animal environment — a literature review. Research Bulletin 76-1, Department of Agricultural Engineering, University of Alberta, Edmonton, Alberta. 80 pp. 115 ref.

[2]Specific gravity: the ratio of the weight of pure gas to standard atmospheric air, per unit volume. If value is less than 1.0, the gas is less dense than air; if greater than 1.0, it is more dense than air.

[3]The range within which a mixture of the gas with atmosphere air can ignite or explode in contact with a flame or spark. Source: R.C. Weast (Ed.). 1973-74. Handbook of Physics and Chemistry, 54th Edition. CRC Press, Cleveland.

[4]Threshold limit value (TLV) represents conditions under which nearly all workers may be repeatedly exposed for an 8-hour day and 40-hour work week without apparent adverse effects.

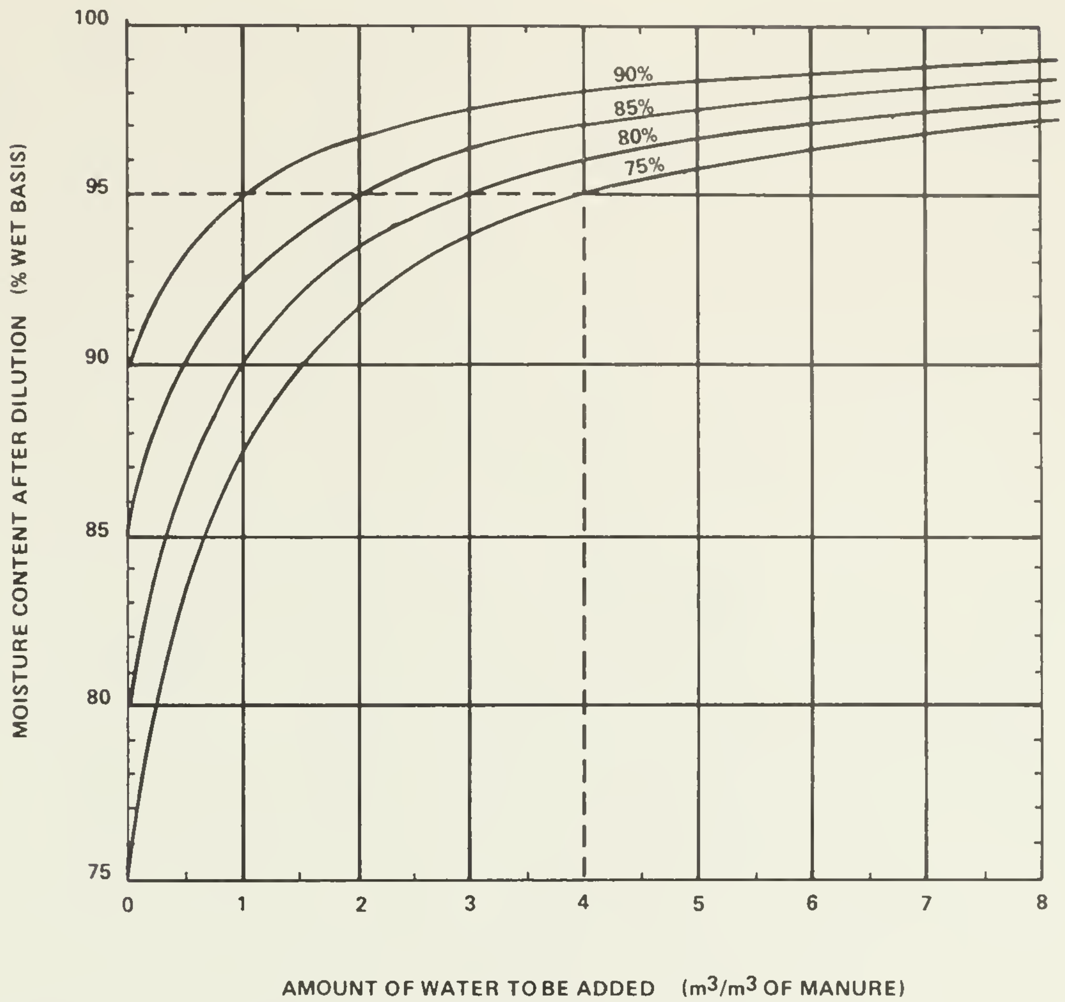
[5]Parts per million of gas in atmospheric air; to convert gas concentration to percent by volume, divide ppm by 10 000.

[6]Excursion factor defines the magnitude of the permissible excursion above the TLV.

[7]Time-weighed average (TWA) limit defines the maximum concentration permitted for a short period. TLV multiplied by the excursion factor equals TWA.

NOTE: When two or more hazardous gases are present, and in the absence of information to the contrary, the effects of the different gases should be considered as additive; that is, if the sum of $\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots + \frac{C_n}{T_n}$ exceeds unity, then the TLV of the mixture should be considered as being exceeded. C = observed atmospheric concentration and T = corresponding TLV for each gas,n

Appendix 2 — Volume of Dilution Water Required to Change the Moisture Content of Manure



EXAMPLE: To bring manure that has 75% moisture content up to 95% moisture, 4 m^3 of water must be added to each m^3 of manure.