MICHIGAN RIGHT TO FARM ACT
Act 93 of 1981

AN ACT to define certain farm uses, operations, practices, and products; to provide certain disclosures; to provide for circumstances under which a farm shall not be found to be a public or private nuisance; to provide for certain powers and duties for certain state agencies and departments; and to provide for certain remedies for certain persons.

286.471 Short title.

Sec. 1. This act shall be known and may be cited as the "Michigan right to farm act".

286.472 Definitions.

Sec. 2. As used in this act:

(a) "Farm" means the land, plants, animals, buildings, structures, including ponds used for agricultural or aquacultural activities, machinery, equipment, and other appurtenances used in the commercial production of farm products.

(b) "Farm operation" means the operation and management of a farm or a condition or activity that occurs at any time as necessary on a farm in connection with the commercial production, harvesting, and storage of farm products, and includes, but is not limited to:

(i) Marketing produce at roadside stands or farm markets.

(ii) The generation of noise, odors, dust, fumes, and other associated conditions.

(iii) The operation of machinery and equipment necessary for a farm including, but not limited to, irrigation and drainage systems and pumps and on-farm grain dryers, and the movement of vehicles, machinery, equipment, and farm products and associated inputs necessary for farm operations on the roadway as authorized by the Michigan vehicle code, Act No. 300 of the Public Acts of 1949, being sections 257.1 to 257.923 of the Michigan Compiled Laws.

(iv) Field preparation and ground and aerial seeding and spraying.

(v) The application of chemical fertilizers or organic materials, conditioners, liming materials, or pesticides.

(vi) Use of alternative pest management techniques.

(vii) The fencing, feeding, watering, sheltering, transportation, treatment, use, handling and care of farm animals.

(viii) The management, storage, transport, utilization, and application of farm by-products, including manure or agricultural wastes.

(ix) The conversion from a farm operation activity to other farm operation activities.
(x) The employment and use of labor.

(c) "Farm product" means those plants and animals useful to human beings produced by agriculture and includes, but is not limited to, forages and sod crops, grains and feed crops, field crops, dairy and dairy products, poultry and poultry products, cervidae, livestock, including breeding and grazing, equine, fish, and other aquacultural products, bees and bee products, berries, herbs, fruits, vegetables, flowers, seeds, grasses, nursery stock, trees and tree products, mushrooms, and other similar products, or any other product which incorporates the use of food, feed, fiber, or fur, as determined by the Michigan commission of agriculture.

(d) "Generally accepted agricultural and management practices" means those practices as defined by the Michigan commission of agriculture. The commission shall give due consideration to available Michigan department of agriculture information and written recommendations from the Michigan state university college of agriculture and natural resources extension and the agricultural experiment station in cooperation with the United States department of agriculture natural resources conservation service and the consolidated farm service agency, the Michigan department of natural resources, and other professional and industry organizations.

(e) "Person" means an individual, corporation, partnership, association, or other legal entity.

286.473 Farm or farm operation as public or private nuisance; review and revision of practices; finding; conditions.

Sec. 3. (1) A farm or farm operation shall not be found to be a public or private nuisance if the farm or farm operation alleged to be a nuisance conforms to generally accepted agricultural and management practices according to policy determined by the Michigan commission of agriculture. Generally accepted agricultural and management practices shall be reviewed annually by the Michigan commission of agriculture and revised as considered necessary.

(2) A farm or farm operation shall not be found to be a public or private nuisance if the farm or farm operation existed before a change in the land use or occupancy of land within 1 mile of the boundaries of the farm land, and if before that change in land use or occupancy of land, the farm or farm operation would not have been a nuisance.

(3) A farm or farm operation that is in conformance with subsection (1) shall not be found to be a public or private nuisance as a result of any of the following:
(a) A change in ownership or size.
(b) Temporary cessation or interruption of farming.

(c) Enrollment in governmental programs.
(d) Adoption of new technology.
(e) A change in type of farm product being produced.

286.473a Request to investigate complaints; memorandum of understanding; conduct and procedures for investigation and resolution; notice of finding; determination of implemented changes; conditions requiring payment of costs; "unverified complaint" defined.

Sec. 3a. (1) The Michigan commission of agriculture shall request the director of the Michigan department of agriculture or his or her designee to investigate all complaints involving a farm or farm operation, including, but not limited to, complaints involving the use of manure and other nutrients, agricultural waste products, dust, noise, odor, fumes, air pollution, surface- or ground-water pollution, food and agricultural processing by-products, care of farm animals and pest infestations.

(2) The Michigan commission of agriculture and the director of the Michigan department of agriculture shall enter into a memorandum of understanding with the Michigan natural resources commission and the director of the Michigan department of natural resources. The investigation and resolution of environmental complaints shall be conducted in accordance with the memorandum of understanding. The Michigan commission of agriculture and the director of the Michigan department of agriculture shall develop procedures for the investigation and resolution for other farm-related complaints.

(3) If the director of the Michigan department of agriculture or his or her designee finds upon investigation that the person responsible for the farm or farm operation is using generally accepted agricultural and management practices, the director of the Michigan department of agriculture or his or her designee shall notify that person and the complainant of this finding in writing. If the director of the Michigan department of agriculture or his or her designee identifies the source or potential sources of the problem caused by the use of other than generally accepted agricultural and management practices, the director of the Michigan department of agriculture or his or her designee shall advise the person responsible for the farm or farm operation that necessary changes should be made to resolve or abate the problem and to conform with generally accepted agricultural and management practices. The director of the Michigan department of agriculture or his or her designee shall determine if those changes are implemented and shall notify the person responsible for the farm or farm operation and the complainant of this determination in writing.

(4) A complainant who brings more than 3 unverified complaints against the same farm or farm operation within 3 years may be ordered, by the director, to pay to the Michigan department of agriculture the full costs of investigation of any fourth or subsequent unverified complaint against the same farm or farm operation. As used in this subsection, "unverified complaint" means a complaint in which the director of the department of agriculture or his or her designee

determines that the farm or farm operation is using generally accepted agricultural and management practices.

286.473b Recovery of costs and expenses.

Sec. 3b. In any nuisance action brought in which a farm or farm operation is alleged to be a nuisance, if the defendant farm or farm operation prevails, the farm or farm operation may recover from the plaintiff the actual amount of costs and expenses determined by the court to have been reasonably incurred by the farm or farm operation in connection with the defense of the action, together with reasonable and actual attorney fees.

286.473c Property subject to disclosure; contents of statement.

Sec. 3c. (1) Certain real property is subject to those disclosures described in section 7 of the seller disclosure act, Act No. 92 of the Public Acts of 1993, being section 565.957 of the Michigan Compiled Laws. A seller of real property located within 1 mile of the property boundary of a farm or farm operation may voluntarily make available to the buyer the following statement: "This notice is to inform prospective residents that the real property they are about to acquire lies within 1 mile of the property boundary of a farm or farm operation. Generally accepted agricultural and management practices may be utilized by the farm or farm operation and may generate usual and ordinary noise, dust, odors, and other associated conditions, and these practices are protected by the Michigan right to farm act.".

(2) Certain subdivided land is subject to those disclosures described in section 8 of the land sales act, Act No. 286 of the Public Acts of 1972, being section 565.808 of the Michigan Compiled Laws.

286.474 Application of state and federal statutes.

Sec. 4. (1) This act does not affect the application of state statutes and federal statutes.

(2) For purposes of this section, "state statutes" includes, but is not limited to, any of the following:

(a) The county rural zoning enabling act, Act No. 183 of the Public Acts of 1943, being sections 125.201 to 125.232 of the Michigan Compiled Laws.

(b) The township rural zoning act, Act No. 184 of the Public Acts of 1943, being sections 125.271 to 125.301 of the Michigan Compiled Laws.

(c) Act No. 207 of the Public Acts of 1921, being sections 125.581 to 125.592 of the Michigan Compiled Laws.

GENERALLY ACCEPTED AGRICULTURAL AND MANAGEMENT PRACTICES FOR MANURE MANAGEMENT AND UTILIZATION

ADOPTED BY
MICHIGAN AGRICULTURE COMMISSION
LANSING, MICHIGAN

November 1998

In the event of an agricultural pollution emergency such as a chemical/fertilizer spill, manure lagoon breach, etc., the Michigan Department of Agriculture and/or the Michigan Department of Natural Resources should be contacted at the following emergency telephone numbers:

Michigan Department of Agriculture:	**800/405/0101**
Michigan Department of Natural Resources:	**800/292-4706**

If there is not an emergency, but you have questions on the Michigan Right To Farm Act or items concerning a farm operation, please contact the Michigan Department of Agriculture, Right To Farm Program, P. O. Box 30017, Lansing, Michigan 48909, (517) 373-1087.

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Section I. INTRODUCTION

Like all other segments of our economy, agriculture has changed significantly during the past fifty years and will continue to change in the future. The trend toward larger facilities (the overwhelming majority being family owned) has resulted in farm operations being more capital intensive and less labor intensive. Larger farm size offers marketing advantages and generally lower unit cost of production compared to smaller-sized operations. However, increased numbers of animals in livestock operations bring new management challenges dealing with manure and odors generated.

Animal agriculture in Michigan must have the flexibility and opportunity to change agricultural enterprises and to adopt new technology as it becomes available to remain viable and competitive in the market place. If a healthy, growing livestock industry in Michigan is to be assured, efforts must continue to address the concerns of livestock producers and their neighbors, particularly in two areas: (1) producers who use generally accepted manure management practices in their livestock operations should be protected from harassment and nuisance complaints and (2) persons living near livestock operations which do not follow generally accepted agricultural and management practices need to have concerns addressed when odor nuisance or water quality problems occur.

Technical recommendations for livestock manure and wastewater management practices have been consolidated in two major sources of information. These are the Natural Resources Conservation Service (NRCS) Field Office Technical Guide, or (NRCS-FOTG) (see USDA-NRCS in the References section) and the Midwest Plan Service Livestock Waste Facilities Handbook, or MWPS-18 (Midwest Plan Service, 1985). Each has published waste management specifications and management guides that are a consensus of agricultural engineers and professionals working in the waste management field. Because these documents are dynamic and periodically reviewed and updated, they contain current state-of-knowledge guidance on generally accepted management practices for livestock operations which will not be duplicated here. These documents provide more in-depth information about the manure management practices which are presented in this document. Other documents that specifically relate to recommendations contained in this paper are the National Pork Industry Handbook and Fertilizer Recommendations for Field Crops (Christenson et al, 1992) and Vegetable Crops (Warncke et al, 1992) in Michigan, each available from Michigan State University Extension (MSUE).

Manure Management System Plan

A manure management system plan describes the practices, equipment, and structures utilized in the management of manure, barnyard runoff, and milk parlor wastewater. This type of plan can assist producers to minimize the potential for the degradation of soil, water, air, plant, and animal resources, and maximize the beneficial utilization of nutrients from manure. A manure management plan is most effective when a total system approach is used. A total system accounts

for all the by-products associated with an agricultural enterprise throughout the year from manure production to nutrient utilization.

A manure management system plan is a coordinated combination of structural components and management practices necessary to control and use manure and other by-products from livestock production in a manner that minimizes adverse impacts on the environment.

A manure management plan will include most, but probably not all, of the following components:

1) Production refers to the amount or volume of manure and any other agricultural by-products produced and the associated nutrient content. This amount of manure depends on the type of animals, their average weight, and the time they are in confinement. The volume of barnyard runoff depends on the lot size and precipitation . The volume of milk parlor wastewater depends on the herd size and milking practices used.

2) Collection refers to how manure and any other by-products will be gathered for management. This includes collection points, method and scheduling of collection, and structural facilities needed. Examples include: solid stacking, a scraping system, flushing system, slotted floors, etc.

3) Storage facilities include underground holding tanks, above-ground storage tanks, solid stacking facilities and earthen storage facilities. The storage time, facility size, holding capacity and site location should be identified.

4) Transfer occurs throughout the system and may take different forms at different steps in the system. Transfer includes movement between production and collection points, storage facilities, treatment facilities, and land application. The plan may specify the method, distance, frequency and equipment needs for transfer.

5) Treatment of manure and any other by-products may occur either before of after storage, depending on the system, and can be physical, biological, and/or chemical. Common forms of treatment include solids separation, anaerobic and aerobic lagoons, composting and methane digesters. Treatment usually involves more intensive management and may require specialized equipment, but it is not a necessary component for all systems.

6 Utilization refers to the end-use of the manure and other livestock operation by-products. A use needs to be identified for the full quantity of manure and other by-products, as described in the Production section. For most livestock operations, manure and other by-products are used as a nutrient source for crops. Soil test information, manure and by-product nutrient content, crops to be grown, realistic yield goals, and availability of crop fields are key

elements in scheduling land applications and utilizing manure and other by-products for nutrients. Other end-uses may include, but are not limited to, use as a feed supplement and use of composted manure as a mulch, soil amendment or as bedding material.

7) Recordkeeping refers to the information maintained and organized to document that activities performed on the farm are consistent with the system plan. Manure management records are an integral part of crop production records and should include individual field items such as crop to be grown, amount of fertilizer applied, and additional information as recommended in Section V, Management Practice 12. Any data or supporting calculations used to develop the system should also be maintained.

An up-to-date manure management system plan and current records will help demonstrate good management practices. Sound planning, design, construction, operation and maintenance of a manure management system will help ensure the success of a sustainable livestock operation.

The recommendations described in the above references and these practices reflect the best judgment of professional livestock producers and professionals who assist livestock producers with designing and managing their operations to be good stewards of the environment. An important aspect of generally accepted agricultural and management practices requires that the producer manage the manure and wastewater handling system in a manner that minimizes any negative effect on the environment. This requires that the producer consider the total management aspects of the manure handling system rather than only parts of the system. A good recordkeeping system helps the producer record the past history of manure management, so that future management of the system will be enhanced and can provide a factual basis for documenting sound environmental stewardship. The generally accepted agricultural and management practices which follow are those that should be incorporated in most situations. However, adverse weather conditions may, in part, prevent responsible livestock operators from adhering to these practices for a short duration of time.

Also, no two livestock operations in Michigan can be expected to be the same due to the large number of variables which, together, determine the nature of a particular operation. These variables include such items as the kind and number of livestock, type of housing and manure handling system, feed rations used, type of manure application equipment, soil types and landscape features on the farm, crops grown, etc. These manure management practices are reasonable and accomplishable for the majority of livestock producers without creating a competitive disadvantage to the Michigan livestock industry.

Section II. RUNOFF CONTROL AND WASTEWATER MANAGEMENT

Rainfall and snowfall-induced runoff from uncovered livestock facilities requires control to protect neighboring land areas and prevent direct discharge to surface waters. Livestock facilities

which require runoff control include all holding areas where livestock density precludes sustaining vegetative growth on the soil surface.

1. **Facilities may be paved, partially paved around waterers and feed bunks, or unpaved.**

2. **Runoff control is required for any facility if runoff from the lot leaves the owner's own property. This would include runoff to a neighbor's land, a roadside ditch, a drain ditch, stream or lake.**

3. **Milk parlor and milk house wastewater shall be managed in a manner to prevent direct discharge into surface water.**

Storage Ponds for Runoff Control

Runoff control can be achieved by providing facilities to collect and store the runoff for later application to cropland. The quantity of water to be handled in the runoff control facility can be minimized by diverting roof runoff and offsite runoff away from livestock areas to a drainage system independent of the manure management system.

4. **Runoff storage ponds should be designed, dependent upon the utilization plan, plus contain the runoff from the maximum 25-year, 24-hour storm event rainfall for the area. Storage ponds must be constructed to reduce seepage loss to acceptable levels.**

The NRCS-FOTG or MWPS-18 can be consulted for detailed design information. See Section IV "Construction Design for Manure Storage Systems" for more information.

Land Application of Runoff

Equipment must be available for land application of stored runoff water. Land application should be done when the soil is dry enough to accept the water.

5. **Application rates should be determined based upon the ability of the soil to accept and store the water and the ability of plants growing in the application area to utilize nutrients. Land application should be done when the water can be beneficially used by a growing crop. Sprinkler irrigation methods will provide uniform application of liquid with minimum labor requirements. Directing lot runoff through a structure for settling solids can reduce odor from the liquid during storage and application to the land (see NRCS-FOTG & MWPS-18).** See Section III for "Odor Management" Practices.

Infiltration Areas

6. **An alternative to a storage pond is a structure for settling solids and an infiltration area (or vegetative filter) for handling lot runoff. The vegetated area may be either a long, grassed, slightly sloping channel, or a broad, flat area with little or no slope surrounded by a berm or dike. All outside surface water should be excluded from the infiltration area so that the only water applied is lot runoff and direct precipitation. Vegetation should be maintained and harvested at least once per year to prevent excessive nutrient buildup in the soil of the infiltration area.**

Design information about infiltration areas (such as sizing, establishment, and maintenance) is available in the NRCS-FOTG, MWPS-18, or the Pork Industry Handbook (MSU Extension Bulletin E-1132 by Vanderholm and Nye, 1987). These systems are not practical for every situation.

Pasture Systems

Pasture land is land that is primarily used for the production of forage upon which livestock graze. Pasture land is characterized by a predominance of vegetation consisting of desirable forage species (see Moline et al, 1991; Moline and Plummer, 1991a, 1991b). Sites such as loafing areas, confinement areas or feedlots which have excessive livestock densities that preclude a predominance of desirable forage species are not considered pasture land.

7. **Stocking densities and management systems should be employed which ensure that desirable forage species are present with an intensity of stand sufficient to slow the movement of runoff water and control soil erosion and movement of manure nutrients from the pasture land (NRCS-FOTG).**

8. **Livestock should be excluded from actual contact with streams or water courses except for controlled crossings and accesses for water (NRCS-FOTG).**

As authorized by the Riparian Doctrine, producers are entitled to utilize surface waters traversing their property. However, this use is limited to activities which do not result in water quality degradation. The goal for controlling livestock access to surface waters is to prevent water quality degradation. Livestock impact water quality by the erosion of sediment and nutrients from stream banks and by the direct deposition of manure nutrients, organic matter and pathogens.

Direct deposition is effectively prevented by restricting livestock to controlled access locations. Banks are effectively stabilized by maintaining vegetation or, as in the case of controlled watering accesses and crossings, stream banks and beds may be stabilized with appropriate protective cover such as concrete, rocks, crushed rock, gravel or other suitable cover. In addition

to addressing environmental and public health aspects, controlling livestock access to surface water and providing alternate drinking water sources may improve herd health by reducing exposure to water and soil borne pathogens.

9. **Runoff from pasture feeding and watering areas should travel through a designed vegetated buffer (NRCS-FOTG) or a vegetated area of at least 66 feet before it travels into a surface water course.**

Section III. ODOR MANAGEMENT

Odor perception is a subjective response to what people detect, through their sense of smell, in the air they breathe. While there is no scientific evidence that odorous gases that escape from livestock operations are toxic at the concentrations experienced by neighbors, they can become an annoyance or a nuisance to neighbors.

1. **Livestock producers should plan, design, construct and manage their operations in a manner that minimizes odor impacts upon neighbors.**

The goal for effective odor management is to reduce the frequency, intensity, duration, and offensiveness of odors, and to manage the operation in a way that tends to create a positive attitude toward the operation. Because of the subjective nature of human responses to certain odors, recommendations for appropriate technology and management practices is not an exact science. The recommendations in this section represent the best professional judgement available.

The proximity of livestock operations to neighbors and populated areas is usually the most critical factor in determining the level of technology and management needed to minimize odor impacts upon neighbors. Therefore site selection is an important factor in minimizing odor impacts for and upon neighbors. The more remote the livestock operation, the better the likelihood that odors will not become an annoyance for neighbors; and therefore a lower level of technology and management will adequately manage odors at the livestock facility. However, the distance which a livestock operation should be located from neighboring land uses to effectively control odors is not easily established. No scientific basis exists for determining such distances quantitatively, nor is there any commonly held community consensus in Michigan at this time for what these distances should be.

The principles, upon which the most common and effective techniques for odor control are based, include: (a) reducing the formation of odor causing gases and (b) reducing the release of odorous gases into the atmosphere. The degree to which these principles can be applied to the various odor sources found in livestock operations depends on the level of technology and management which can be utilized. The following subsections discuss the most common and predominant odor sources which are feed materials and manure.

Feed Materials

Using fermented feeds such as corn or hay silage is an acceptable animal husbandry practice throughout Michigan for dairy and beef cattle, horses, sheep and goats. Some odors associated with the storage and feeding of these materials are normal for these livestock operations.

2. The odor of these fermented feed materials such as corn or hay silage can be minimized by harvesting and storing them at an appropriate dry matter content (generally greater than 33 percent dry matter).

The practice of feeding food processing by-products (e.g. cull potato, dairy whey, pastry by-products, sugar beet pulp and sweet corn husks) to livestock is a generally accepted practice. This is especially common where livestock operations exist within close proximity to food processing facilities. Using these materials for livestock feed diverts useful by-products (that can pose a substantial load on local sewage treatment plants and a major problem for food processing plants) from the waste stream and converts them into a valuable resource. Properly handled in a livestock operation, these feeds pose no threat to the environment. These products may require special feed handling systems and may substantially increase or change the manure generated by the animals to which they are fed. Some of these by-products, and the manure produced from their consumption by livestock, can generate rather offensive and intense odors. In these situations, feed handling and manure management practices should be used to control and minimize the frequency and duration of such odors. Human garbage can only be fed under permit in Michigan (See P.A. 173 of 953 as amended).

Manure

Fresh manure is usually considered to be less odorous than anaerobically decomposing manure. Fresh manure emits ammonia but in general is not accompanied by other products of decomposition which contribute to odors.

3. Frequent (daily or every few days) removal of manure from animal space coupled with storage or stacking and followed by application to crop land at agronomic rates is an acceptable practice throughout Michigan.

Manure odors are generally those associated with the anaerobic (in the absence of oxygen) decomposition of organic material by microorganisms. The intensity of odors depends upon the biological reactions that take place within the material, the nature of the excreted material (which is dependent upon the species of animal and its diet), the type of bedding material used and the surface area of the odor source. Sources of decomposing manure can include stacked solid manure, outside lots when manure is allowed to accumulate, uncovered manure storages, manure treatment systems, and land application areas.

Stacked Solid Manure

4. **Solid manure that may contain bedding materials and/or is dried sufficiently, such as that from poultry, cattle, sheep, swine, horse and fur-bearing animal facilities can be temporarily stacked outside the livestock building.**

Odors from such manure storages are minimal except when disturbed, such as during removal for land application. Provisions to control leachate and runoff from surrounding areas need to be in place to protect groundwater and surface waters. (See Section II and Chapter 6 of MWPS-18 for alternative design concepts and details). Livestock operations may utilize a variety of bedding materials as part of their manure management system. The use of straw, hay, sand, sawdust, wood shavings, waste paper, or other suitable materials, either individually or in combination, as livestock or poultry bedding is a common generally accepted practice. Bedding materials should be of an appropriate size to maximize absorptive properties and to prevent blowing and dispersion when subsequently applied to crop land. Waxed paper, aluminum foil and plastics should not be present in bedding materials.

Outside Lots

Outside open lots with or without shelters are acceptable for raising livestock in Michigan. In these systems manure is deposited over a relatively large surface area per animal (compared to a roofed confinement system for example) and begins to decompose in place. The soil compaction that occurs on outside lots limits movement of water and nutrients from the lot toward groundwater. Odor impacts can be mitigated by keeping the lot surface as dry as possible, thus limiting the microbiological activity that generates odors. Providing adequate slopes, orientation that takes advantage of sunlight, diverting up-slope runoff water away from the lot, and using recommended stocking densities will enhance drying of the lot surface. The MWPS-18, National Pork Industry Handbook, and Michigan Beef Production Notebook provide details and alternatives to accomplish this. Most feed additives and odor control chemicals applied to feedlot surfaces have not been demonstrated to be effective in reducing odors from feedlots in humid areas such as Michigan.

In spite of good facilities design and management, odors may be generated from outside livestock lot systems. The intensity of these odors is somewhat proportional to the surface area of the odor producing sources. The frequency of impact and offensiveness to neighbors is often related to the distance to neighbors' houses and their location relative to prevailing winds.

5. **New outside lot systems should not be located in close proximity to residences and other odor-sensitive land uses. They should not be**

located uphill along a confining valley leading toward residences. New residences or other sensitive land uses should not be located within close proximity to existing outside lot facilities.

Manure Storages and Acceptable Covers

6. **Use covered manure tanks if technically and economically feasible.**

7. **Where possible, do not locate manure storage in close proximity to residential areas.**

The primary objective of storage is to temporarily store the manure before application to land. However some biological activity occurs in these storages and the gases generated can be a source of odors. If storage facilities are left uncovered, the potential for manure odors to be carried away by air movement will increase. Various types of covers can be used to prevent wind driven air from coming into direct contact with a liquid manure surface and incorporating odors.

Acceptable covers that can retard odor escape from manure storages include the following:

a) **Natural fibrous mats similar to those which develop on liquid manure storages receiving manure from beef and dairy cattle fed a high roughage diet.**

b) **Slotted flooring or other underbuilding tanks. Ventilation must be provided in the building to prevent accumulation of noxious and flammable gases.**

c) **A flexible plastic or similar material that covers the liquid surface and is of such strength, anchorage and design that the covering will not tear or pull loose when subjected to normal winds that have an average recurrence interval of 25 years. Gas escape ports should be provided which allow any gas that may evolve to escape.**

d) **A solid covering such as concrete, wood, plastic or similar materials that covers the entire liquid surface and is of such strength, anchorage and design that they will withstand winds and expected vertical loads. Adequate air exchange should be provided which will prevent the occurrence of explosive concentrations of flammable gases.**

Manure Treatment Systems

A biological treatment system is designed to convert organic matter (feed, bedding, manure) in animal manure and other by-products to more stable end products. Anaerobic processes occur without free oxygen and liquefy or degrade high BOD (biochemical oxygen demand) manure and other by-products. They can decompose more organic matter per unit volume than aerobic treatment processes. Aerobic processes require free oxygen and are helpful in reducing odor, but are generally considered uneconomical for livestock operations. Extreme environmental changes alter microbial activity. When microorganisms are stressed by the environment, waste treatment processes can malfunction and odors may become more intense.

Treatment Lagoons and Storage Ponds

Anaerobic treatment lagoons are generally earthen basins containing diluted manure and are designed to provide degradation of the organic material. Well-designed and managed, anaerobic lagoons can be short-term odor sources. The occurrence of purple sulfur-fixing bacteria can significantly reduce odors from an anaerobic treatment lagoon. The intensity of odors is usually greatest during the early spring and occasionally in the fall.

Aerobic treatment of manure liquids can be accomplished by natural or mechanical aeration. In a naturally-aerated system, such as a facultative oxidation pond, an aquatic environment occurs in which photosyntheses from algae and surface aeration from the atmosphere provide an aerobic zone in the upper regions of the pond. A transition zone occurs below this aerobic zone that has a limited amount of oxygen. This is the facultative zone where facultative bacteria can live either with or without oxygen. At the bottom there may be a sludge layer that is anaerobic. The processes that occur in the aerobic zone have a low odor potential. The odorous compounds that are created in the facultative and anaerobic zones are converted to low odor forms in the aerobic zone. For a naturally-aerated system to function properly, design specifications and quantities of manure solids to be treated must be closely followed.

An aerobic lagoon should be loaded at a rate no higher than 44 pounds of ultimate BOD/ day/acre. The material in the pond should be dilute enough to allow light to penetrate 3 to 4 feet into the water. The lagoon should be a minimum of 4 feet deep (or deeper to allow for accumulation of sludge) to prevent rooted vegetation from growing from the bottom of the lagoon.

Mechanically aerated systems can be used to treat animal manures to control odors, decompose organic material, remove nitrogen, conserve nitrogen or a combination of these functions. When adequate oxygen is supplied, a community of aerobic bacteria grow that produce materials with low odor potential. Alternative treatment systems to accomplish mechanical aeration include facultative lagoons, oxidation ditches, or completely-mixed lagoons.

Effluent from treatment lagoons and storage ponds should be land applied to avoid long-term and extensive ponding and to utilize manure nutrients at agronomic rates (see Section V). Construction design for treatment lagoons and storage ponds should conform to the recommendations in Section IV.

Composting

Composting is a self-heating process carried on by bacteria, actinomycetes and fungi that decompose organic material in the presence of oxygen. Composting of organic material including livestock manures can result in a rather stable end product that does not support extensive microbial or insect activity, if the process and systems are properly designed and managed. The potential for odors during the composting process depends upon the moisture content of the organic material, the carbon-nitrogen ratio, the presence of adequate nutrients, the absence of toxic levels of materials that can limit microbial growth, and adequate porosity to allow diffusion of oxygen into the organic material for aerobic decomposition of the organic material. Stability of the end product and its potential to produce nuisance odors, and/or be a breeding area for flies, depends upon the degree of organic material decomposition and the final moisture content. Additional information and guidance about alternatives for composting manures are available in the "On-Farm Composting Handbook" (Rynk, 1992).

The occurrence of leachate from the composting material can be minimized by controlling the initial moisture content of the composting mixture to less than 70% and controlling water additions to the composting material from rainfall. Either a fleece blanket[1] or a roofed structure can be used as a cover to control rainfall additions or leachate from composting windows. If the composting process is conducted without a cover, provisions must be made to collect the surface runoff and either be temporarily stored (see Section IV) and applied to land (see Section V), added to composting material for moisture control during the composting process, or applied to grassed infiltration areas (see Section II).

Methane Digestors

Methane can be produced from animal wastes by anaerobic digestion. This process converts the biodegradable organic portion of animal wastes into biogas (a combination of methane and carbon dioxide). The remaining semi-solid is relatively odor free but still contains all the nitrogen, phosphorus, and potassium originally present in the animal manure, although some of the nitrogen can be lost after storage in a holding pond.

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[1] A fleece blanket is a non-woven textile material made from synthetic fibers such as polypropylene. The non-woven texture of a fleece blanket prevents rainfall from penetrating into the composting material, but allows the necessary exchange of carbon dioxide and oxygen.

Anaerobic digestion is a stable and reliable process, as long as the digestor is loaded daily with a uniform quantity of waste, digestor temperature does not fluctuate widely, and antibiotics in the waste do not slow biological activity.

Application of Manure to Land

The following list of practices may be used to reduce odor in the application of manure to land. Appropriate implementation will help reduce complaints of odors.

8. **Avoid spreading when the wind is blowing toward populated areas.**

9. **Avoid spreading on weekends/holidays when people are likely to be engaged in nearby outdoor and recreational activities.**

10. **Spread in the morning when air begins to warm and is rising, rather than in late afternoon.**

11. **Use available weather information to best advantage. Turbulent breezes will dissipate and dilute odors. Hot and humid weather tends to concentrate and intensify odors, particularly in the absence of breezes.**

12. **Take advantage of natural vegetation barriers, such as woodlots or windbreaks, to help filter and dissipate odors.**

13. **Establish vegetated air filters by planting conifers and shrubs as windbreaks and visual screens between cropland and residential developments.**

14. **Incorporate manure into soil during, or as soon as possible after, application. This can be done by (a) soil injection or (b) incorporation within 48 hours after application. However, incorporation may not be feasible where manures are applied to pastures or forage crops, such as alfalfa, or where no-till practices are used (see Section V).**

Irrigation of manure to land can be an effective land application method for delivering manure to land in a short period of time without the potential damage to soil structure that can occur with other methods. However, the process can be odorous for a short period of time.

Section IV. CONSTRUCTION DESIGN FOR MANURE STORAGE AND TREATMENT FACILITIES

Construction Design

1. **Construction design for manure storage and treatment facilities should meet specifications and guidelines found in the NRCS-FOTG. Additional publications that can be used are the National Pork Industry Handbook fact sheets E-1341 (Safley et al, 1993) and E-1399 (Melvin et al, 1987) from MSU Extension and the Concrete Manure Storages Handbook, MWPS-36 (Midwest Plan Service, 1994) and Circular Concrete Manure Tanks publication (Midwest Plan Service, 1998).**

Seepage Control for Earthen Basins

2. **To protect groundwater from possible contamination, utilize liners that meet specifications and guidelines in the NRCS-FOTG. Liners include natural existing soil (Barrington and Jutras, 1985; Barrington et al, 1987a, 1987b), bentonite or similar high swell clay materials, compacted earthen liners, and flexible membranes.**

Section V. MANURE APPLICATION TO LAND

One of the best uses of animal manure is as a fertilizer for crop production. Recycling plant nutrients from the crop to animals and back to the soil for growth of crops again is an age-old tradition. Depending on the species of animal, 70-80% of the nitrogen (N), 60-85% of the phosphorus (P), and 80-90% of the potassium (K) fed to animals as feed will be excreted in the manure and potentially available for recycling to soils.

Livestock operations can generate large amounts of manure and increase the challenge of recycling manure nutrients for crop production. Good management is the key to ensure that the emphasis is on manure utilization rather than on waste disposal. Utilizing manure nutrients to supply the needs of crops and avoiding excessive loadings achieves two desirable goals. First, efficient use of manure nutrients for crop production will accrue economic benefits by reducing the amounts of commercial fertilizers needed. Second, water quality concerns for potential contamination of surface waters and groundwater can best be addressed when nutrients are applied at agronomic rates.

The following management practices are suggested for livestock producers to help them achieve the type of management that will accomplish these two goals. However, adverse weather conditions may, in part, prevent responsible livestock producers from adhering to these practices for a short duration of time. In addition to effective nutrient management and water quality

protection, applying manure to land warrants close attention to management practices so potential odor problems can be minimized or avoided. Section III contains odor control measures which should be implemented as part of the land application program.

Soil Fertility Testing

1. All fields should be sampled at least every three years, and the soils tested to determine where manure nutrients can best be utilized.

One goal of a well-managed land application program is to utilize soil testing and fertilizer recommendations as a guide for applying manures. This will allow as much of the manure nutrients as possible to be used for supplying crop nutrient requirements; then any additional nutrients needed can be provided by commercial fertilizers. Therefore, soil testing and manure analysis information can assist the producer in using manure nutrients for the greatest economic benefit. Additional information on soil sampling and soil testing can be found in MSUE bulletins (Christenson et al, 1992; Meints and Robertson, 1983; Warncke, 1988; and Warncke et al, 1992).

Fertilizer Recommendations

2. Use fertilizer recommendations, consistent with those of Michigan State University, to determine the total nutrient needs for crops to be grown on each field that could have manure applied.

Fertilizer recommendations made by MSUE are based on the soil fertility test, soil texture, crop to be grown, a realistic yield goal (average for past 3-5 yrs.), and past crop management. (See Christenson et al, 1992; Vitosh, 1996; Vitosh et al, 1995; and Warncke et al, 1992.) Fertilizer recommendations can then be utilized by the livestock producer to help identify on which fields manure nutrients will have the greatest value in reducing the amounts of commercial fertilizers needed, thereby returning the greatest economic benefit.

Manure Analysis

3. To determine the nutrient content of manure, analyze it for percent dry matter (solids), ammonium N (NH_4-N), and total N, P and K.

Several factors which will determine the nutrient content of manures prior to land application are: (a) type of animal species, (b) composition of the feed ration, (c) amount of feed, bedding, and/or water added to manure, (d) method of manure collection and storage, and (e) climate. Because of the large variation in manure nutrient content due to these factors, it is not advisable to use average nutrient contents provided in publications when determining manure nutrient loadings for crop production. The best way to determine the nutrient content of manure and provide farm-specific information is to obtain a representative sample(s) of that manure and then have a

laboratory analyze the sample(s). In order to establish "baseline" information about the nutrient content of each manure type on the farm, sample and test manures for at least a two year period. MSUE can provide information on collecting representative manure samples and where to send samples for analysis.

Manure Nutrient Loadings

4. **The agronomic (fertilizer) rate of N recommended for crops (consistent with Michigan State University N fertilizer recommendations), should not be exceeded by the amount of available N added, either by manure applied or by manure plus fertilizer N applied and/or other sources. The available N per ton or per 1000 gallons of manure should be determined by using a manure analysis and the appropriate mineralization factors (see Manure Management Sheet #2, MSUE Bulletin E-2344 by Jacobs et al, 1992b) for organic N released during the first growing season following application and the three succeeding growing seasons.**

Excessive manure applications to soils can: (a) result in excess nitrate-N (NO_3-N) not being used by plants or the soil biology and increase the risk of NO_3-N being leached down through the soil and into groundwater; (b) cause P to accumulate in the upper soil profile and increase the risk of contaminating surface waters with P where runoff/erosion occurs; and (c) create nutrient imbalances in soils which may cause poor plant growth or animal nutrition disorders for grazing livestock. The greatest water quality concern from excessive manure loadings, where soil erosion and runoff is controlled, is NO_3-N losses to groundwater. Therefore, the agronomic fertilizer N recommendation should never be exceeded.

The availability of N in manure for plant uptake will not be the same as highly soluble, fertilizer N. Therefore, total manure N cannot be substituted for those in fertilizers on a pound-for-pound basis, because a portion of the N is present in manure organic matter which must be decomposed, before mineral (inorganic) forms of N are available for plant uptake.

The rate of decomposition (or mineralization) of manure organic matter will be less than 100% during the first year and will vary depending on the type of manure and the method of manure handling. Therefore, in order to estimate how much of the total manure N in each ton or 1000 gallons of manure will be available for crops (and a credit against the N fertilizer recommendation), some calculations are needed. The total N and NH_4-N content from the manure analysis can be used with the appropriate mineralization factors to calculate this value. Management tools to assist with these calculations include (a) Manure Management Sheet #2, MSUE Bulletin E-2344 (Jacobs et al., 1992b), (b) bulletins MM-2 and MM-3 from the Animal Manure Management Resource Notebook (Jacobs, 1995a, 1995b), or (c) the MSU Nutrient Management computer program (MacKellar et al, 1996).

In addition to the amount of plant available N provided during the first year after a manure application, more N will be released from the residual organic matter not decomposed the first year. This additional decomposition and release of N will occur during the second, third and fourth years and should be estimated and included as a N credit against the fertilizer recommendation to avoid excessive N additions to the soil-plant system. At the present time, organic N released (mineralized) during the second, third and fourth cropping years is estimated to be 50%, 25%, and 12.5%, respectively, of the amount released the first year. To assist with the calculations for estimating this carryover N from previous manure applications, the same management tools listed in the preceding paragraph can be used.

5. **If the soil test level for P reaches 150 lb/acre (Bray P1), manure applications should be reduced to a rate where manure P added does not exceed the P removed by the harvested crop. (If this manure rate is impractical due to manure spreading equipment or crop production management, a quantity of manure P equal to the amount of P removed by two crop years can be used for the first crop year, if no additional fertilizer or manure P is applied for the second crop year.) If the Bray P1 test reaches 300 lb/acre or higher, manure applications should be discontinued until nutrient harvest by crops reduces P test levels to less than 300 lb/acre. To protect surface water quality against discharges of P, adequate soil and water conservation practices should be used to control runoff and erosion from fields where manure is applied.**

While the availability of N and P in manure may be considerably less than 100%, the availability of K in manure is normally considered to be close to 100%. Periodic soil testing can be used to monitor the contribution made by manure P and K to soil fertility levels, but soil tests have not been very effective to determine the amount of N a soil can provide for plant growth.

When manures are applied to supply all the N needs of crops, the P needs of crops will usually be exceeded, and soil test levels for P will increase over time. If soil test P levels reach 300 lb/acre (Bray P1), the risk of losing soluble P and sediment-bound P by runoff and erosion (i.e., nonpoint source pollution) increases. Therefore, adequate soil and water conservation practices to control runoff and erosion should be implemented. For example, conservation tillage can enhance infiltration of water into soils, thereby reducing runoff, soil erosion, and associated P loadings to surface waters. Nevertheless, if soil test P levels reach 300 lb/acre (Bray P1), no more manure (or fertilizer) P should be applied until nutrient harvest by crops reduces P test levels to less than 300 lb/acre.

To avoid reaching the 300 lb/acre Bray P1 test level, manure application rates should be reduced to provide the P needs of crops rather than providing all of the N needs of crops and adding excess P. Therefore, if the soil test level for P reaches 150 lb/acre (Bray P1), manure applications should be reduced to a rate where manure P added does not exceed the P removed

by the harvested crop. The quantity of manure P_2O_5 [2] that should be added can be estimated from Tables 1 and 2, using a realistic yield goal for the crop to be grown. For example, if a yield of 120 bu/acre for corn grain is anticipated, the amount of manure P_2O_5 added to this field should be limited to no more than 42 lb/acre (120 bu/acre X 0.35 lb P_2O_5/bu nutrient removal rate).

If the rate of manure application based on P_2O_5 removal by the crop is lower than the manure spreader can physically apply, or is not realistic when planning for crop production management, the rate of manure application can be increased. The higher rate of manure application can be the P_2O_5 removal for two crop years, as long as this rate does not exceed the N fertilizer recommendation for the first crop grown after the manure is applied. If this higher rate of manure application is used, no fertilizer or manure P_2O_5 should be applied the following crop year.

Manure Nutrient Loadings on Pasture Land

In pasture systems where the grazed forage is the sole feed source for livestock, nutrients from manure deposited by the grazing livestock will not exceed the nutrient requirement of the pasture forage. These types of pasture systems may require supplemental nutrient applications to maintain forage quality and growth.

Pasture systems utilizing supplemental feed (e.g., swine farrow/finish) often result in manure nutrient deposition in excess of pasture forage requirements. Therefore, nutrient management with rotation to harvested forage or row crops is necessary. Available nutrient deposition should be quantified based on livestock density and nutrient mineralization factors. Manure nutrient loadings should be based on the rotational crop nutrient requirement consistent with those recommended by Michigan State University, as noted above.

Method of Manure Application

6. Manures should be uniformly applied to soils. The amount of manure applied per acre (gallons/acre or tons/acre) should be known, so manure nutrients can be effectively managed.

As is true with fertilizers, lime and pesticides, animal manures should be spread uniformly for best results in crop production. Also, in order to know the quantity of manure nutrients applied, the amount of manure applied must be known. Determining the gallons/acre or tons/acre applied by manure spreading equipment can be accomplished by a variety of ways. One method is to measure the area of land covered by one manure spreader load or one tank wagon of manure. A second method is to record the total number of spreader loads or tank wagons applied to a field of known acreage. With either approach, the capacity of the spreader (in tons) or the tank wagon (in gallons) must be known, and some way to vary the rate of application will be needed such as

[2] Fertilizer P recommendations are given in, and fertilizer P is sold as, pounds of phosphate (P_2O_5).

adjusting the speed of travel or changing the discharge settings on the manure spreading equipment. Guidance is available from the MSUE to help determine the rates of manure application that a livestock producer's equipment can deliver.

Incorporating manure immediately (i.e., within 48 hours following surface application) will minimize odors and ammonia (NH_3) loss. When manures are surface applied, available N can be lost by volatilization of NH_3. These losses will increase with time and temperature and will be further increased by higher wind speeds and lower humidities. Therefore, injecting manures directly into the soil or immediately incorporating surface-applied manure will minimize NH_3 volatilization losses and provide the greatest N value for crop production. Table 3 shows potential volatilization losses when manures are applied to the soil and allowed to dry on the surface before incorporation. When dilute effluents from lagoons that contain low solids (<2%) are applied/irrigated at rates that do not cause ponding, most of the NH_4-N will likely be absorbed into the soil and retained (see Jacobs, 1995a, 1995b, or Jacobs et al, 1992a, for additional information). Surface application of manures via irrigation or other methods without incorporation provides alternatives to producers using reduced or no-till soil management, supplemental irrigation of crops, application to land with established pasture or other forages, etc.

7. **Manures should not be applied to soils within 150 feet of surface waters or to areas subject to flooding unless: (a) manures are injected or surface-applied with immediate incorporation (i.e., within 48 hours after application) and/or (b) conservation practices are used to protect against runoff and erosion losses to surface waters.**

8. **Liquid manures should be applied in a manner that will not result in ponding or runoff to adjacent property, drainage ditches, or surface water. Ultimately, a goal of manure application is to prevent runoff and erosion losses to surface waters.**

To reduce the risk of runoff/erosion losses of manure nutrients, manures should not be applied and left on the soil surface within 150 feet of surface waters. Manures that are injected or surface applied with immediate incorporation can be closer than 150 feet as long as conservation practices are used to protect against runoff and erosion. A vegetative buffer between the application area and any surface water is a desirable conservation practice. Manure should not be applied to grassed waterways or other areas where there may be a concentration of water flow, unless used to fertilize and/or mulch new seedlings following waterway construction.

Manure should not be applied to areas subject to flooding unless injected or immediately incorporated. Liquid manures should not be applied in a manner that will result in ponding or runoff to adjacent property, drainage ditches or surface water. Therefore, application to saturated soils, such as during or after a rainfall, should be avoided.

9. **As land slopes increase from zero percent, the risk of runoff and erosion also increases, particularly for liquid manure. Adequate soil and water conservation practices should be used which will control runoff and erosion for a particular site, taking into consideration such factors as type of manure, bedding material used, surface residue or vegetative conditions, soil type, slope, etc.**

As land slopes increase, the risk of runoff and erosion losses to drainage ways, and eventually to surface waters, also increases. Soil and water conservation practices should be used to control and minimize the risk of non-point source pollution to surface waters, particularly where manures are applied. Injection or surface application of manure with immediate incorporation should generally be used when the land slope is greater than 6%. However, a number of factors such as liquid vs. solid or semi-solid manures, rate of application amount of surface residues, soil texture, drainage, etc. can influence the degree of runoff and erosion associated with surface water pollution. Therefore, adequate soil and water conservation practices to control runoff and erosion at any particular site are more critical than the degree of slope itself.

Timing of Manure Application

10. **Where application of manure is necessary in the fall rather than spring or summer, using as many of the following practices as possible will help to minimize potential loss of NO_3-N by leaching: (a) apply to medium or fine rather than to coarse textured soils; (b) delay applications until soil temperatures fall below 50 °F; and/or (c) establish cover crops before or after manure application to help remove NO_3-N by plant uptake.**

Ideally, manure (or fertilizer/other source) nutrients should be applied as close as possible to, or during, periods of maximum crop nutrient uptake to minimize nutrient loss from the soil-plant system. Therefore, spring or early summer application is best for conserving nutrients, whereas fall application generally results in greater nutrient loss, particularly for NO_3-N on coarse textured soils (i.e., sands, loamy sands, sandy loams).

11. **Application of manure to frozen or snow-covered soils should be avoided, but where necessary, (a) solid manures should only be applied to areas where slopes are six (6) percent or less and (b) liquid manures should only be applied to soils where slopes are three (3) percent or less. In either situation, provisions must be made to control runoff and erosion with soil and water conservation practices such as vegetative buffer strips between surface waters and soils where manure is applied.**

Winter application of manure is the least desirable in terms of nutrient utilization and prevention of nonpoint pollution. Frozen soils and snow cover will limit nutrient movement into the soil and greatly increase the risk of manure being lost to surface waters by runoff and erosion

during thaws or early spring rains. When winter application is necessary, appropriately-sized buffer strips should be established and maintained between surface waters and frozen soils where manure is applied to minimize any runoff and erosion of manure from reaching surface waters. Particular attention to soil slopes and manure application rates can help prevent runoff and erosion from frozen and/or snow covered soils where manure is applied.

Management of Manure Applications to Land

12. Records should be kept of manure analyses, soil test reports, and rates of manure application for individual fields.

Good recordkeeping demonstrates good management and will be beneficial for the producer. **Records should include manure analysis reports and the following information for individual fields:**

a) soil fertility test reports;

b) date(s) of manure application(s);

c) rate of manure applied (e.g., gallons or wet tons per acre);

d) previous crops grown on the field; and

e) yields of past harvested crops.

An important ingredient of a successful program for managing the animal manure generated by a livestock operation is "planning ahead". An early step of a manure application plan is to determine whether enough acres of cropland are available for utilizing manure nutrients without resulting in excess nutrient application to soils.

Tables 4 and 5 from MWPS-18 can help in making preliminary estimates of manure quantities and manure nutrients produced by different types of livestock and N losses during handling and storage of manures before they are applied. This information (or preferably manure analyses and actual quantities of manure for a particular farm) can be used to compare the quantity of available manure nutrients against the quantity of nutrients removed by the crops to be grown in the livestock operation. Manure Management Sheet #1, MSUE Bulletin E-2344 (Jacobs et al, 1992b), and the MSU Nutrient Management computer program (MacKellar et al, 1996) can assist with this type of inventory. If the quantity of manure nutrients being generated greatly exceeds the annual crop nutrient needs, then alternative methods for manure utilization should be identified. For example, cooperative agreements with neighboring landowners to provide additional land areas to properly utilize all of the manure nutrients may be necessary.

Another consideration is to use good judgment when planning manure applications in conjunction with normal weather patterns, the availability of land at different times during the growing season for different crops, and the availability of manpower and equipment relative to other activities on the farm which compete for these resources. Having adequate storage capacity to temporarily hold manures can add flexibility to a management plan when unanticipated weather occurs, preventing timely applications. Nevertheless, unusual weather conditions do occur and can create problems for the best of management plans.

Finally, good recordkeeping is the foundation of a good management plan. Past manure analysis results will be good predictors of the nutrient content in manures being applied today. Records of past manure application rates for individual fields will be helpful for estimating the amount of residual N that will be available for crops to use this coming growing season. Changes in the P test levels of soils with time due to manure P additions can be determined from good records, and that information can be helpful in anticipating where manure rates may need to be reduced and when additional land areas may be needed. Recordkeeping systems, such as that described in MSUE Bulletin E-2340 (Jacobs et al, 1992a), or available as a microcomputer program called MSU Nutrient Management (MacKellar et al, 1996), may be helpful in accomplishing this goal. The Nutrient Management program can easily calculate manure application rates for individual fields that follow the nutrient application criteria recommended in these manure management Generally Accepted Agricultural and Management Practices.

Table 1. Nutrient removal (lb/unit of yield) by several Michigan field crops.[1]

Crop		Unit	N	P_2O_5	K_2O
			---- lb per unit ----		
Alfalfa	Hay	ton	45[2]	10	45
	Haylage	ton	14	3.2	12
Barley	Grain	bushel	0.88	0.38	0.25
	Straw	ton	13	3.2	52
Birdsfoot Trefoil	Hay	ton	48[2]	12	42
Bromegrass	Hay	ton	33	13	51
Canola	Grain	bushel	1.9	0.91	0.46
	Straw	ton	15	5.3	25
Clover-grass	Hay	ton	41	13	39
Corn	Grain	bushel	0.90	0.35	0.27
	Grain[3]	ton	26	12	6.5
	Stover	ton	22	8.2	32
	Silage	ton	9.4	3.6	7.8
Dry Edible Beans	Grain	cwt	3.6	1.2	1.6
Oats	Grain	bushel	0.62	0.25	0.19
	Straw	ton	13	2.8	57
Orchardgrass	Hay	ton	50	17	62
Potatoes	Tubers	cwt	0.33	0.13	0.63
Red Clover	Hay	ton	40[2]	10	40
Rye	Grain	bushel	1.1	0.41	0.31
	Straw	ton	8.6	3.7	21
Sorghum-Sudangrass (Sudax)	Hay	ton	40	15	58
	Haylage	ton	12	4.6	18
Soybeans	Grain	bushel	3.8	0.88	1.4
Sugar Beets	Roots	ton	4.0	1.3	3.3
Wheat	Grain	bushel	1.2	0.62	0.38
	Straw	ton	13	3.3	23

[1] Source: Fertilizer Recommendations for Field Crops in Michigan (Christenson et al, 1992).
[2] Legumes get most of their nitrogen from air.
[3] High moisture grain.

Table 2. Approximate nutrient removal (lb/unit of yield) in the harvested portion of several Michigan vegetable crops.[1]

Crop	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	--- lb/cwt[2] ---			--- lb/ton[2] ---		
Asparagus	0.67	0.20	0.50	13	4.0	10
Beans, snap	1.2	0.12	0.55	24	2.4	11
Broccoli	0.20	0.05	0.55	4.0	1.0	11
Cabbage	0.35	0.08	0.35	7.0	1.6	7.0
Carrots	0.17	0.09	0.34	3.4	1.8	6.8
Cauliflower	0.33	0.13	0.33	6.6	2.6	6.6
Celery	0.25	0.10	0.80	5.0	2.0	16
Cucumbers	0.10	0.06	0.18	2.0	1.2	3.6
Lettuce	0.24	0.10	0.45	4.8	2.0	9.0
Muskmelon	0.42	0.10	0.55	8.4	2.0	11
Onions	0.25	0.13	0.24	5.0	2.6	4.8
Peas, shelled	1.0	0.23	0.50	20	4.6	10
Peppers	0.20	0.07	0.28	4.0	1.4	5.6
Pumpkins	0.20	0.06	0.34	4.0	1.2	6.8
Sweet Corn	0.42	0.14	0.28	8.4	2.8	5.6
Squash	0.18	0.08	0.33	3.6	1.6	6.6
Tomatoes	0.20	0.04	0.35	4.0	0.8	7.0

[1] Source: Fertilizer Recommendations for Vegetable Crops in Michigan (Warncke et al, 1992).

[2] 1 ton = 20 cwt

Table 3. Ammonium nitrogen volatilization losses for surface application of solid and semi-solid manures.[1]

Days Before Incorporation	Retention Factor (RF)	Loss Factor (LF)
0-1 day	0.70	0.30
2-3 days	0.40	0.60
4-7 days	0.20	0.80
>7 days	0.10	0.90

[1] Source: Recordkeeping System for Crop Production (Jacobs et al, 1992a).

Table 4. Manure and manure nutrients produced by different livestock species.[1]

Animal Species	Type and Average Size (lb)	Production (per day)			
		Manure (ft^3)	Nutrients (lb)		
			N	P_2O_5	K_2O
Dairy Cattle	150	0.19	0.06	0.023	0.048
	250	0.32	0.10	0.045	0.084
	500	0.66	0.20	0.082	0.169
	1,000	1.32	0.41	0.166	0.325
	1,400	1.85	0.57	0.232	0.458
Beef Cattle	500	0.50	0.17	0.127	0.145
	750	0.75	0.26	0.191	0.229
	1,000	1.00	0.34	0.250	0.289
	1,250	1.20	0.43	0.318	0.373
	Beef Cow	1.05	0.36	0.273	0.313
Swine	Nursing Pig 35	0.038	0.016	0.0118	0.012
	Growing Pig 65	0.070	0.029	0.0223	0.024
	Finishing Pig 150	0.16	0.068	0.050	0.054
	Finishing Pig 200	0.22	0.090	0.068	0.071
	Gestating Sow 275	0.15	0.062	0.048	0.048
	Sow and Litter 375	0.54	0.230	0.173	0.181
	Boar 350	0.19	0.078	0.059	0.061
Sheep	100	0.062	0.045	0.015	0.039
Horse	1,000	0.75	0.27	0.105	0.205
Poultry (per 100 birds)	Chicken Broilers 2	0.24	0.24	0.123	0.09
	Chicken Layers 4	0.35	0.29	0.250	0.14
	Turkey[2] 16	1.40	1.16	1.00	0.56

[1]Source: Livestock Waste Facilities Handbook (Midwest Plan Service, 1985).
[2]Values for turkeys estimated by multiplying the "Chicken Layers" values times four.

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