Approved: 2-17-97
Date

MINUTES OF THE HOUSE COMMITTEE ON ENVIRONMENT.

The meeting was called to order by Chairperson Steve Lloyd at 3:30 p.m. on February 4, 1997 in Room 526-S of the Capitol.

All members were present except: Rep. Kent Glasscock - excused

Committee staff present: Raney Gilliland, Legislative Research Department
Hank Avila, Legislative Research Department
Mary Ann Graham, Committee Secretary

Conferees appearing before the committee: Gary Hall, President Kansas Farm Bureau
Rich McKee, Executive Secretary Feedlot Division
Kansas Livestock Association
Mike Jensen, Executive Vice President Kansas Pork
Producers Council

Others attending: See attached list

Chairman Steve Lloyd called the meeting to order at 3:30 p.m. He reviewed the agenda for next week, the week of February 10, he mentioned that the Wednesday meeting will address the deer population issue.

The Chairman welcomed the president of the Kansas Farm Bureau, Gary Hall, to the committee. Mr. Hall spoke in response to the Performance Audit Report on the KDHE Confined Livestock Feeding Operations Program. He distributed a Public Policy Statement (See Attachment 1) for review. Mr. Hall owns and operated a crop and livestock farm in Dickinson county and feels the protection of water quality and our environment is important to all citizens. He briefed the committee on the role and responsibilities of the Kansas Farm Bureau. Discussion and questions followed.

The Chairman welcomed Rich McKee, Executive Secretary, Feedlot Division, Kansas Livestock Association, to the committee. Mr. McKee distributed copies of testimony, (See Attachment 2) regarding the Post Audit Report of the KDHE Livestock Program. He briefed the committee in behalf of the Kansas Livestock Association which is a trade association representing over 7300 members on legislative and regulatory issues. Discussion and questions by the committee followed.

Chairman Lloyd introduced Rep. Joann Flowers and former Rep. Marvin Smith, attending today's meeting, to the committee and guests.

The Chairman welcomed Mike Jensen, Executive Vice President, Kansas Pork Producers Council. Mr. Jensen presented testimony, (See Attachment 3) to the committee. Also a Participants Manual on the National Pork Producers Council Environmental Assurance Program.(See Attachment 4) He gave a quick overview of numerous projects ongoing and in the planning stages for the producers in the state. After the briefing, discussion and questions followed. He introduced Tim Stroda, Director of Communications, Kansas Pork Producers Council, in the audience.

The Chairman called on Karl Mueldener,Director, Bureau of Water, Division of Environment and Ellyn Sipp, Principal Auditor, Legislative Division of Post Audit, in the audience, to answer questions concerning permit and registration fees. Discussion and questions followed.

Chairman Lloyd thanked all of the conferees and guests for attending today's meeting. Tomorrow's committee meeting will be a hearing on **HB 2061**, concerning drainage districts.

The meeting adjourned at 5:00 p.m.

The next meeting is scheduled for February 5, 1997

Unless specifically noted, the individual remarks recorded herein have not been transcribed verbatim. Individual remarks as reported herein have not been submitted to the individuals appearing before the committee for editing or corrections.

HOUSE ENVIRONMENT COMMITTEE COMMITTEE
GUEST LIST

DATE: 2-4-97

NAME	REPRESENTING
Howard H Woodbury	FB
Rodger Wilson	FB
Carol Cowen	FB
Virgil Cowen	FB
Bill Kaun	FB
Roy TAYLOR	KFB
Dan Culvan	KDHE
Melinda Barrett	Chase Co. Farm Bureau
Denise Breitenman	" "
Janice Fuller	KFB
Kathleen Sexpene	KFB
Carissa McKenzie	KFB
EDWARD ROWE	LEAGUE OF WOMAN VOTERS / KS
Paul Johnson	PACK

HOUSE ENVIRONMENT COMMITTEE COMMITTEE
GUEST LIST

DATE: 2-4-97

NAME	REPRESENTING
Mike Jensen	Ks Pork Council
Francis Kelsey	Ks Farm Bureau
Teresa Huffin	Ks Farm Bureau
Tim Stroda	KS Pork Producers Council
Carl Reimer	KS Farm Bureau (Meade Co)
Ivan W. Wyatt	Ks Farmers Union
Chris Wilson	KS Ag Aviation Ass'n
Carolyn Michael	Crawford Co. Farm Bureau
RONALD Schriner	KFB (PRATT Co)
Lester Goyen	KFB Pratt Co.
Kay Hall	Kansas Farm Bureau
Ellyn Sipp	Legislative Post Audit
Frank Van Fleet	Wy Co. Farm Bureau
Gwen Wiehe	Wyandotte Cty. Farm Bureau
Orland Stephen	KFB
Dennis C. McKee	KFB
Donna Bates	Kansas Farm Bureau Jeff. Co
David Reisig	Russell Co Farm Bureau
CAROLYNN BURNS	CHEROKEE Co. FARM BUREAU

..nsas Farm Bureau

PUBLIC POLICY STATEMENT

HOUSE COMMITTEE ON THE ENVIROMENT

Re: Industry Response to the Performance Audit Report on the KDHE Confined Livestock Feeding Operations Program.

February 4, 1997
Topeka, Kansas

Presented by
Gary Hall, President
Kansas Farm Bureau

Chairman Lloyd and members of the House Committee on the Environment, I am Gary Hall, President of the Kansas Farm Bureau. I own and operate a crop and livestock farm in Dickinson County.

Farm Bureau is a voluntary, general farm organization of farmers and ranchers who are members of the 105 county Farm Bureaus across Kansas.

The livestock industry is a major agricultural enterprise on the farms and ranches of Kansas and is a cornerstone of the strong Kansas economy. It is important not to pass legislation or adopt regulations that would threaten or destroy this industry. Farm Bureau policy adopted by membership emphasizes, "Rules and regulations promulgated by any Kansas agency should not put Kansas producers or businesses at a competitive disadvantage with any other state."

House Environment
2-4-97
Attachment 1

The protection of water quality and our environment is important to all citizens, rural and urban, east to west. The high priority our farm and ranch members place on protecting our natural resources and the environment is the reason Kansas Farm Bureau created the Natural and Environmental Resources (NER) Advisory Committee nine years ago. The 10-member Committee examines issues and makes recommendations to the KFB Board of Directors on programs, projects and activities. Additionally, all 105 county Farm Bureaus have local NER Committees. Most are conducting watershed protection programs with our recently acquired EnviroScape Unit, plugging abandoned water wells, testing water and presenting Wetland Conservation Awards to deserving landowners.

Farm Bureau membership on the Wildscape Foundation, the Kansas Wetlands and Riparians Areas Alliance, the Kaw Valley Heritage Alliance and participation on the Governor's Water Quality Initiative and the NRCS Technical Advisory Committee demonstrates our commitment to working with others to protect the State's natural resources. Yes, we all have responsibilities and we are trying to do our part!

We certainly appreciate your scheduling of industry response to the Performance Audit Report recently conducted by the Legislative Division of Post Audit on KDHE's Confined Livestock Feeding Operations Program.

Some concern has been expressed about the Department's design standards. While we have no reason to believe they are not adequate, we applaud KDHE for requesting researchers and soil scientist at Kansas State

University, the nation's first Land Grant institution, to review and recommend any adjustments that may be needed to adequately protect water quality.

Another section of the Farm Bureau "Environmental Standards" resolution states, "We believe any legislation that is enacted, or any environmental regulations which are proposed for promulgation must be based on:

1. Factual information;
2. Scientific Knowledge; and
3. Economic impact studies."

Yes, our livestock producers will accept changes in design standards as long they are based upon good research and sound science.

The audit indicated the agency did not always complete all paper work or complete the documentation of actions. We have been critical of and continue to be concerned by the slowness of processing permits. The agency faces a large backlog of permit renewals. The expansion of swine and dairy facilities in southwest Kansas presents an even larger challenge for KDHE. The registration requirement in SB 800 approved by the 1994 Legislature surfaced more than 1300 facilities for the agency to visit and examine, many resulting in new permits.

For these reasons, we applaud Governor Graves' supplemental request to open a satellite office in Dodge City and his plan to add a technician to each of the 7 District Offices and 2 to the Central Office. While we generally support restraint in increasing the size of government, we believe this investment is appropriate to assure the protection of the State's natural resources.

We acknowledge the administration of the livestock program needs improvement, but we ask you not to "throw the baby out with the bath water." We remind the legislature SB 800 only recently became law. The new program changes a number processes and increases fees. The fee increases in SB 800 are beginning to generate significant increases in State General Fund revenues for Kansas. We encourage increased appropriations of these new fees for enhancing the Livestock Feeding Operations Program at KDHE.

We ask this new and improved program be given a chance to work before major changes are made in the statutes or regulations. We suggest building on the many successful and sound provisions of this regulatory program.

In closing, we agree with the report that the Department does not have enough staff to adequately administer the program in a manner expected by all Kansans. Adequate funding and a clear legislative message that calls for improvement in administering the program will cure many of the problems.

Thank you for this opportunity to speak on behalf of the farm and ranch members of Kansas Farm Bureau.

KANSAS LIVESTOCK ASSOCIATION

Since 1894

Testimony

presented by

Rich McKee
Executive Secretary, Feedlot Division

regarding

Post Audit Report of the KDHE Livestock Program

before the

House Environment Committee

February 4, 1997

The Kansas Livestock Association (KLA), formed in 1894, is a trade association representing over 7,300 members on legislative and regulatory issues. KLA members are involved in all segments of the livestock industry including cow-calf, feedlot, seedstock, swine, dairy and sheep. In 1996 cash receipts from agriculture products totaled over $7.5 billion, with sixty percent of that coming from the sale of livestock. Cattle represent the largest share of cash receipts, representing ninety percent of the livestock and poultry marketings.

House Environment
2-4-97
Attachment 2

6031 SW 37th Street Topeka, KS 66614-5129 (913) 273-5115 Fax (913) 273-3399 E-MAIL: kla@kla.org

2-4

DESIGN STANDARDS FOR CONFINED LIVESTOCK FEEDING OPERATIONS

I. SITE CONSIDERATIONS

A. SITE SELECTION

1. General

The site selected for confined livestock feeding operations should be located such that animal waste and runoff can be controlled, stored, handled, and disposed of in a manner that does not result in degradation of land, air, or water resources. The site should be located as far as practical from nearby residential dwellings, communities, streams and intermittent waterways, and water supplies. The topography, geology, climate, and terrain must be carefully considered to evaluate subsurface and surface drainage characteristics, land application requirements for waste disposal, and odor dispersal by prevailing winds. Adequate non-inhabited areas should be located adjacent to the feedlot for the dispersal of odors and the disposal of livestock runoff and waste accumulations. Careful selection and evaluation of proposed sites for confined livestock operations and associated waste disposal areas can prevent potential environmental problems, reduce construction costs, and minimize operational expenses.

2. Site Evaluation

All proposed sites for confined livestock feeding operations will be evaluated and appraised by Departmental personnel. Sites are not to be developed for proposed confined livestock feeding activities prior to being reviewed and evaluated by Department personnel.

3. Registration Applications

Registration applications are to include a sketch depicting the location of all residential dwellings, businesses, or other facilities frequented by the public which are located within one mile of the proposed feedlot site. The name, address, and phone number of residents and property owners and their approximately distance from the proposed operation shall be included upon the sketch.

4. Plans and Specifications

Plans and specifications for proposed water pollution control facilities shall include a location map showing the distance to nearby property lines and non-owed residential dwellings or places frequented by the public. Additionally, the separation provided from water supplies and nearby intermittent waterways or streams shall be identified.

5. Construction

Construction of confined livestock feeding facilities shall not be initiated until Department approval has been obtained for the proposed water pollution control provisions to be utilized by the livestock operation.

B. LOCATION AND SEPARATION REQUIREMENTS

Department approval of sites for proposed confined livestock feeding operations and water pollution control facilities is contingent upon compliance with the following:

1. Building Permits and Zoning Ordinances

   The site selected for the proposed livestock feeding operation shall conform with all existing city, township, county or other building and zoning permit and ordinance requirements. Upon request, the feedlot operator shall furnish assurance that these requirements have been fulfilled.

2. Property Lines

   A minimum separation distance of 100 feet shall be provided between property lines and the perimeter of the confined livestock feeding operation including all associated waste storage and water pollution control facilities. Separation distances may include roadway and railroad right-of-ways as long as a minimum of 100 feet from the property lines is observed.

3. Water Supplies

   All potential water pollution sources associated with the livestock operation shall be located a minimum of 100 feet from water supply wells and reservoirs. A minimum of 50 feet separation shall be provided from rural water district lines. Water supplies should be located up hill from livestock facilities or adequate provisions provided to prevent contamination from either surface or subsurface drainage from the livestock facilities.

4. Floor Protection

   Confined livestock feeding facilities, waste storage areas, water pollution control facilities, and other facilities containing potential water pollutants shall not be located in flood plains subject to inundation more frequently than once in ten years.

5. Groundwater Protection

   The lowest elevation of the feedlot or associated water pollution control structures shall be located a minimum of 10 feet above groundwater aquifers or seasonal perched water tables. Feedlots should not be located directly over limestone outcropping, gravel deposits, or other porous subsurface strata without provisions to prevent groundwater contamination.

6. Land Requirements

   A minimum of 40 acres shall be under the direct control or ownership of the livestock operation. For open lot feeding facilities a minimum of one acre of land per acre of lot shall be under the direct control or ownership of the livestock operation for the disposal of stormwater runoff accumulations.

7. Surface Drainage

Confined livestock operations should be located upon land with slopes less than 5%. The proposed site should permit the diversion of surface drainage from adjacent upslope land not used for confined livestock feeding facilities to minimize control requirements.

8. Disposal Land

A minimum of one half of the property owned by or under the direct control of the livestock operation or one acre/100 head capacity shall be readily available for disposal of either runoff or dilute wastewater accumulations. Additionally, for each 20 tons, on a dry weight basis, of livestock wastes (slurries and lot scrapings) annually generated by the confined livestock feeding facilities, a minimum of one acre of agricultural land shall be readily available for land application. Application rates utilized for the disposal of liquid and solid waste accumulations should be based upon the nutrient requirements of both the land and crops.

9. Residential Separation and Odor Control

A potential significant problem with livestock waste facilities is odor. Odor is defined as an air pollutant under Kansas statutes. Control of odor from animal feeding operations frequently involves the waste and wastewater handling facilities. The responsibility for enforcing the statutes and regulations in both of these environmental areas, air and water, has been charged to the Department of Health and Environment. In light of these potential odor problems KDHEs animal waste permits contain odor control provisions.

Odor potential and problems from livestock facilities will be handled by the Bureau of Water Quality, Agricultural Waste Unit, within the air pollution control statutes and regulations. The standard odor clause will offer a coordinated enforcement approach through the water pollution control permit, in essence, an enforcement of permit conditions.

The Department of Health and Environment will conduct site appraisals of proposed livestock feeding facilities for the purpose of reviewing proposed water pollution control facilities as well as odor control capabilities. Confined livestock feeding facilities, including waste storage and water pollution control facilities, are to be located a minimum of 1/4 mile (1320) from the nearest habitation. Guidelines for minimum site separation provisions for various types and capacities of confined livestock facilities are provided in the table below.

CAPACITY[1]	SEPARATION DISTANCE[2]
1,000 head or less	1,320 feet
1,000 to 5,000 head	4,000 feet
5,000 or more	5,280 feet

[1]Capacity is given for swine and beef organizations. For dairy operations multiply herd size by 10 for capacity to determine separation

distance. For poultry operations divide flock size by 10 for capacity to determine separation distances.

[2]Separation distances may be reduced with the written permission of affected property owners with residential dwellings or facilities frequented by the public. The permission should be a written statement from the affected individuals stating that there are no objections to the establishment and construction of the livestock operation. The statement shall not waive any future rights with respect to future action due to inadequate operation and maintenance of the facility to prevent degradation of air, water, or land sources. A copy of the statement is to be furnished to this office, the property owners, and the owner of the livestock operation.

The recommended minimum separation distances in the table above are meant for use as a general guideline. Depending upon topographic features, prevalent wind directions, type of livestock operation, wastewater or runoff control considerations and other general operating considerations, the Department may approve exceptions when justified.

II. RUNOFF CONTROL FACILITIES

A. RUNOFF CONTROL SYSTEMS

1. General

Runoff control systems are designed to retain surface drainage resulting from precipitation falling upon open lots, concrete feeding floors, and other open exposed facilities which contain livestock wastes. Livestock wastes entering runoff retention structures shall be restricted to those directly transported by runoff occurrences. Dry weather wastewater flows entering the runoff control facilities should be minimized and restricted to wash water, water system overflows or other dilute liquids. Additional control capabilities are required for contributing dry weather wastewater flows.

2. Location

Runoff control structures must be located at a lower elevation than the confined livestock facilities which contributes surface drainage that requires control provisions. When possible, the drainage characteristics of the proposed confined feeding facilities should be selected or altered to permit the installation of a single runoff retention facility. (See Site Selection I, Site Considerations.)

3. Extraneous Drainage

The quantity of runoff requiring control provisions is directly related to the area contributing surface drainage. Extraneous drainage from adjacent land area not utilized by the confined livestock operation should be diverted in a manner that prevents this drainage from contacting animal wastes or other potential water pollutants. All channels, terraces, diversions, and other structures utilized to exclude extraneous drainage shall not be subject to inundation or failure more frequently than once in ten years. Careful site selection can minimize or eliminate the provisions needed to exclude extraneous drainage.

4. Collection System

Collection systems shall be designed to control and convey surface drainage from the open lots and facilities containing livestock waste or other water pollutants to appropriate runoff retention structures. The channels, ditches, berms, culverts, dikes, terraces, and other devices used by the collection system to control feedlot runoff shall be designed to convey the peak hourly flow expected once in five years. The collection system is to be designed to permit the removal of sediment and waste accumulations to maintain convenience capabilities for future runoff occurrences. When possible, collection channels and ditches should be located outside the feedlot so a vegetation cover can be established to minimize erosion problems and to more readily facilitate maintenance and repair work.

5. Sedimentation Structures

Sedimentation structures preceding runoff retention ponds are normally required to intercept feedlot drainage. Relief, slope, drainage characteristics, and other site specific considerations will influence the selection of appropriate sedimentation control provisions. These structures shall be designed to reduce runoff flow velocities, partially settle out suspended silt and wastes, store sludge deposits, and facilitate the routine removal of sludge accumulations.

Sedimentation control structures shall be designed so they are not subject to failure of inundation more frequently than once in ten years. Where closed conduits are utilized to interconnect sedimentation control structures with runoff storage basins, an emergency open channel spillway shall be provided. The minimum storage for sludges and liquids provided within the sedimentation structure and/or runoff retention pond shall be 1/2 acre-inch per acre of controlled surface drainage.

Sedimentation control and storage provisions shall be provided in accordance with the following:

a. Shud ponds are required for all controlled feedlot drainage areas which are greater than 15 acres. For each acre of controlled surface drainage, the shud pond shall provide a minimum of 1/2 acre-inch of storage capacity. Shallow average depths and gradually sloping bottoms for shud ponds are recommended to facilitate solid deposition and cleanout.

b. Debris basins which temporarily detain and subsequently release runoff to holding ponds are acceptable for controlled drainage acres less than 15 acres. The debris basin shall provide a minimum volume of one acre-inch per acre of controlled feedlot drainage to detain runoff flows.

c. Channels, diversions, and terraces that collect and convey runoff to holding ponds may be utilized as sedimentation structures for controlled drainage areas which are less than 10 acres. These conveyance facilities shall be designed with average slopes less than 1/2 foot/100 feet for flow velocities less than 2 fps, and with flat broad bottom channels which can support vegetation and be easily maintained. Inlet structures to runoff holding ponds are to be designed to reduce flow velocities and channel scouring to minimize conveyance of silt and livestock wastes. A minimum volume of 1 acre-inch per acre of controlled feedlot drainage area shall be provided within the runoff retention pond for sludge accumulations.

d. Sedimentation structures are recommended but not required for controlled feedlot drainage areas which are less than five acres. If sedimentation structures are not utilized, a minimum volume of 1-1/2 acre-inches per acre of controlled feedlot drainage area shall be provided within the runoff retention pond for storage.

6. <u>Runoff Retention Structures</u>

Runoff retention structures shall be designed to control, store, and facilitate the timely disposal of feedlot drainage resulting from a 25-year 24-hour rainfall occurrence. The minimum volume required for runoff storage shall provide capacity to retain a 10-year 24-hour rainfall event from the confined feeding facilities and all other contributing drainage areas assuming no infiltration losses. Additional storage shall be provided to retain a minimum of four months of dry weather flows which are controlled by the runoff retention structure. Dry weather flows shall not contain appreciable amounts of animal wastes or other readily settleable solids. The selection of sedimentation control provisions will determine volume requirements for sludge accumulations to be provided by runoff retention structures.

The large volumes of surface drainage requiring control provisions normally dictates the use of diked or excavated earthen impoundments. The maximum depth of runoff retention ponds shall not exceed 20 feet and emergency spillways shall be provided if overflow would likely result in structural failure. A minimum of two feet of freeboard shall be provided between the minimum design water level required to control runoff, dry weather flows, and sludge accumulations and the lowest elevation of the runoff retention pond's berms or its emergency spillway outlet. Closed conduits and/or open channels used to interconnect runoff retention structures shall be designed to convey flows without bypassing or overflowing more frequently than once in ten years. Staff gauges are to be installed to facilitate the measurement of water levels to determine the available storage capacity (as feet of depth) remaining in the runoff retention structure.

Staff gauges are to be clearly marked at the level which the minimum Required Storage Volume remains available above in the runoff retention structure.

B. RUNOFF DISPOSAL SYSTEMS

1. <u>General</u>

Disposal provisions must be capable of maintaining runoff retention structures so storage is available for future runoff occurrences. Normally, irrigation equipment is employed to apply runoff accumulations upon agricultural land. Design of runoff disposal facilities should facilitate operation without degradation of land, air, and water resources.

2. Disposal Capabilities

Irrigation equipment or other suitable facilities are required to dewater and apply upon agricultural land surface drainage retained by runoff retention structures. Runoff control facilities which rely primarily upon evaporation for disposal shall provide dewatering and land application capabilities for standby use. The equipment and land utilized for runoff dewatering and disposal activities shall be owned or under the direct control of the livestock operation. The runoff disposal system shall be capable of applying runoff accumulations upon agricultural land whenever storage capabilities are not adequate to retain the 10-year 24-hour rainfall quantity. The runoff disposal system shall be designed so it is capable of applying 1/10 of the required runoff storage volume each day of operation. Days suitable for dewatering and disposal activities are those which are preceded by three days with less than 0.05 of an inch of precipitation per day; average temperature above 32°F, and on which there is no snow cover and the ground is not frozen. With favorable weather conditions, it should normally be possible to empty full runoff retention structures within two weeks following rainfall. Runoff retention structures, evaporation ponds, and storage reservoirs that provide storage capabilities in excess of that necessary to retain the 10-year 24-hour rainfall volume shall be dewatered whenever the water level infringes upon the storage capabilities to retain a future runoff occurrence from a 25-year 24-hour rainfall event.

3. Irrigation Equipment

Irrigation equipment normally consists of pumping, delivery, and application equipment. Consideration will be given to gravity withdrawal, conveyance, and application systems provided they are capable of conducting disposal activities in a timely and environmentally acceptable manner. The irrigation disposal equipment shall be in conformance with the following:

a. Irrigation equipment shall be selected so it is capable of applying 1/10 of the required runoff volume within 12 hours of operation. For each acre-foot of required runoff storage capacity, the irrigation system shall provide a minimum pumping rate of 50 gpm.

b. Irrigation equipment shall be capable of handling a limited amount of solids 1 to 2 inches in diameter and should be designed to prevent damage from freezing weather. Conventional centrifugal and turbine irrigation pumps are normally acceptable. Gated pipes are capable of handling a limited amount of solids. Sprinkler systems should be selected with orifice openings at least 1/2 inch in diameter. Inlets should be screened to minimize plugging problems.

c. Normally, a minimum of two pumps shall be provided for operational capability and reliability. A single pump with twice the required pumping capacity may be used in lieu of two pumps. At least one pump or dewatering method shall be available for each independent runoff control structure so they can be dewatered simultaneously.

d. Irrigation systems should be designed to deliver lower application rates during winter months or when field conditions are relatively wet. Additionally, the system should be portable or designed to deliver and apply runoff upon more than one field.

4. Application Rates

Application of runoff accumulations upon agricultural land is to be conducted in a manner that prevents surface runoff, detriment to land and crops, or nuisance conditions such as odors. When possible, application rates should be determined by crop moisture and nutrient needs. The irrigation system and disposal land shall facilitate the following application rates:

a. Sprinkler irrigation systems shall be designed so application rates do not exceed the soil infiltration rates. For furrow, flood, or high rate sprinkler systems where application rates exceed soil infiltration rates, tailwater control provisions shall be provided. Tailwater control pits must be capable of retaining 20% of the daily applied runoff quantity and pump back or direct land application provisions shall be provided.

b. The daily application of runoff shall be restricted to a maximum of three acre-inches per acre. A pumping rate of 120 gpm will deliver three acre-inches in 12 hours upon one acre.

c. The annual application of runoff should not apply nutrients or moisture in excess of that required for crop production. Normally, the total annual application of nitrogen should be restricted to 250 pounds per acre. The annual application of 6 to 12 acre-inches per acre should not normally result in the buildup of excessive nutrient accumulations. Normally, separate land should be utilized for the application of concentrated livestock wastes. Soil testing should be routinely conducted on land receiving runoff accumulations and/or livestock wastes and the application of commercial fertilizer adjusted accordingly.

d. Fresh water and runoff accumulations may be blended prior to application. Cross-connections between runoff, irrigation, disposal systems and water supply systems shall be prohibited. Disconnect irrigation lines from wells prior to use for runoff disposal. Irrigation reservoirs or runoff retention structures should be used for blending runoff accumulations prior to application.

5. Land Requirements

The amount of land required for disposal activities is dependent upon volume of runoff controlled and the application rates which can be utilized for disposal purposes. Additionally, the crops produced will influence appropriate application rates and will restrict application when planting, harvesting, and field work activities are conducted. The following are minimum land requirements for runoff disposal:

a. A minimum of three acres of land shall be readily available for each acre-foot of required runoff storage volume to control a 25-year 24-hour runoff event. With no reserve runoff storage capacity and three acres per acre-foot of disposal land, an application of four acre-inches per acre, the equivalent of two acre-inches per acre applications, would be required. Normally, at least twice this amount of land should be available for runoff disposal to avoid conflicts with plating, harvesting, and field work activities.

b. Land utilized for the disposal of runoff accumulations should not be adjacent to neighboring residences or near areas which would adversely effect adjoining property owners. The disposal land shall not be subject to flooding more frequently than once in five years. Additionally, disposal sites should not be immediately adjacent to intermittent watercourses or streams which would carry runoff from the property. Prior to utilizing property that has well defined drainage characteristics, appropriate tailwater control structures will normally be required.

c. For each 12 inches of average annual rainfall, a minimum of one acre of disposal land per acre of controlled drainage area shall be provided. Land not owned or leased by the feedlot operation which will be used for runoff disposal activities shall be under written agreement. Additional disposal land will be required if adequate land cannot normally be available to conduct disposal activities.

6. Monitoring and Reporting Requirements

Div of Water Quality

The ~~Division of Environment~~ is to be notified immediately by telephone of all overflow occurrences from runoff retention structures or discharges from runoff disposal practices. Within five days following the incident, a report of duration, approximately volume or flow, corrective action undertaken, and resulting water pollution problems, is to be submitted to the department.

Monthly monitoring reports are normally required for runoff control facilities controlling more than five (5) acres of drainage. Department personnel will determine on a case by case basis whether monitoring requirements, as outlined below, will be implemented.

a. An operational log is to be maintained by the operation, at the operation, which will be subject to periodic review and inspection by Department personnel. Monthly operation log forms will be provided by the Department. In the event of a discharge occurrence, reports for a two monthly period prior to the discharge are to be submitted to the Department to verify prudent and proper management of the runoff control system. As outlined on the second page of a permit for a runoff control system, the permittee is to have storage volume available which is equivalent to the volume of a 10-year 24-hour rainfall event over the specified drainage area. The permittee is to monitor and record the depth representing this available storage capacity within the wastewater retention structures on Monday each week. Whenever the storage capacity to be maintained (10-year 24-hour rainfall volume) specified within the second page of the issued permit is not available, the storage capacity present in the lagoons shall be monitored and recorded daily. The quantity of precipitation received shall be monitored and recorded each day rainfall or other precipitation events occur. A reliable and accurate rain gauge shall be obtained and located at a convenient and unobstructed site to measure moisture accumulations. The permittee shall indicate on the operation log form the days disposal is conducted, the quantity dewatered, and the areas used for the disposal of wastewater accumulations.

III. WASTEWATER CONTROL FACILITIES

A. WASTEWATER STORAGE AND DISPOSAL SYSTEMS

1. General

Wastewater storage systems consist of structures and equipment to retain dry weather wastewater accumulations for subsequent application upon agricultural land. The control structures are primarily used to store livestock wastes, washwaters, and other wastewater flows. Common storage structures employed are manure pits or tanks and/or earthen holding ponds. Normally, wastewater accumulations are removed by slurry hauling equipment for subsequent application upon cropland.

2. Location

Wastewater storage structures are to be located and constructed in a manner that prevents surface or groundwater pollution. The control structures are normally designed to collect and control wastewater by gravity. The structures should be designed and located to exclude surface drainage from adjacent fields.

Surface drainage retained by wastewater control structures should be minimized by installing roof gutters and diversions to direct surface drainage away from buildings and control structures. Surface drainage from exposed concrete feeding floors normally will require control provisions. (See Section I - Site Considerations)

3. Collection System

Paved floors are to be sloped to control wastewater flows. Drains and pipes are to be designed to facilitate cleanout. Conduits used for gravity conveyance of wastewater flows to control structures shall be a minimum of 6 inches in diameter. Cleanout provisions shall be located every 200 feet, change in grade, or change in direction. Collection lines shall be laid on a minimum slope of 0.5%.

4. Wastewater Storage Structures

All wastewater storage structures are to be designed to facilitate pump-out and removal of wastewater accumulations. Wastewater storage systems shall not provide less than four months of storage capacity. Storage capacity to be provided shall be in conformance with the following:

a. Liquid manure pits and tanks shall provide a minimum of 120 days storage for average dry weather wastewater flows. Additional storage shall be provided for surface drainage from exposed contributing surface areas to retain the 10-year 24-hour rainfall occurrence assuming no infiltration.

b. Earthen holding ponds shall provide a minimum of 120 days storage for average dry weather wastewater flows. Additionally, storage shall be provided for surface drainage and rainfall entering the earthen holding pond from a 10-year 24-hour rainfall occurrence assuming no infiltration. Earthen holding ponds shall provide a minimum of 2 feet of freeboard above the design water level providing the required storage capacity. A minimum of 3 to 1 side slopes shall be used and earthen holding ponds are to be constructed without an emergency spillway. Berms and dikes are to be seeded and inlet structures designed to minimize erosion problems.

c. Concrete manure pits shall provide a minimum of 30 days storage from average dry weather wastewater flows when interconnected with earthen holding ponds. The earthen holding pond shall provide a minimum of 120 days storage for average dry weather wastewater flows. The earthen holding pond shall provide additional storage to retain surface drainage and rainfall entering the structure from a 10-year 24-hour rainfall occurrence assuming no infiltration losses. The earthen retention pond shall be constructed with a minimum of 2 feet of freeboard above the design water level. A minimum of 3 to 1 side slopes are to be utilized on the inside slope and a minimum of 2½ to 1 side slopes on the backslope and the structure is to be designed without an emergency spillway. The dikes and berms are to be seeded and splash pads provided for inlet structures to minimize soil erosion problems. Wastewater control systems are to be designed to permit the pump-out and removal of liquid and solid waste accumulations. Pump-out ports are to be located a minimum of every 40 feet along the side wall of concrete manure pits. Earthen holding ponds shall not be wider than 100 feet at the design water level to facilitate the removal of the majority of solid accumulations and deposits in the bottom of these structures. The maximum depth for concrete manure pits and earthen holding ponds shall be 10 feet unless specifically designed for removal of liquid wastes and accumulations at the bottom of the structures.

5. <u>Wastewater Disposal Equipment</u>

Equipment to dewater and apply wastewater accumulations upon cropland shall be owned or readily available. The equipment shall be capable of removing both liquid and solid accumulations from the wastewater control structures. The disposal equipment shall be capable of dewatering and applying 60 days of wastewater accumulations and the surface drainage from a 10-year 24-hour rainfall occurrence within 5-12 hour days with favorable weather conditions. Cropping practices should be compatible with required wastewater disposal practices. Wastewater accumulations are to be applied upon land not subject to erosion and in a manner that prevents surface runoff problems. Consideration will be given to other disposal methods provided they can be conducted in an environmentally acceptable manner. Wastewater disposal equipment shall be in conformance with the following:

a. Liquid manure pumps should be capable of agitating wastewater accumulations. Irrigation equipment is acceptable for disposal of dilute wastewater concentrations such as washwater from milk parlors, or the liquid overflow from concrete manure pits.

b. Liquid manure wagons used to pump, haul, and apply wastewater accumulations shall be of water-tight construction and designed to prevent spillage.

c. Nutrients applied annually through the application of liquid and solids wastes from wastewater control structures shall be restricted to that level required by the specific crops or crops under production. Normally, the total applications of nitrogen should be restricted to 250 pounds per acre. A yearly application rate of 5000 to 10,000 gallons of slurry wastes per acre will normally supply 250 pounds of nitrogen.

d. Concentrated wastewater accumulations are to be incorporated at the time of application. Soil injectors may be used with tank wagon hauling equipment. If wastewater accumulations are surface applied, the land should be tilled within 12 hours following the application. Dilute wastewaters applied with irrigation equipment will not require incorporation unless odor or nuisance problems develop.

B. ANAEROBIC LAGOON SYSTEMS

1. General

Anaerobic lagoon systems consist of an impoundment(s), the primary function of which is to store and stabilize organic wastes. Their design must be based both upon hydraulic and organic loading parameters. Ultimate disposal of wastewater effluents is either by land application or by evaporation within a secondary cell. These systems require regular loading rates, flows that exceed livestock waste production, and continuous water levels to function properly. Consequently, they are applicable primarily to livestock operations utilizing flush water, washwater, or similar methods to hydraulically remove, clean, and transport waste accumulations to the lagoon system.

Anaerobic lagoons do not include runoff, wastewater, or other control systems solely designed and operated to retain hydraulic flows without regard to organic loading rates.

2. Location

Anaerobic lagoons are to be located and constructed in a manner that prevents surface or groundwater pollution. Additionally, the site should be selected considering prevailing winds, land application areas, waste disposal methods, neighboring residences, and other related items to minimize odor and nuisance aspects. The lagoon system is normally located to permit gravity collection of wastewater flows and should be designed to exclude extraneous surface drainage from farmland. (See Section I - Site Considerations)

3. Collection Systems

The collection systems shall be designed to facilitate the daily removal and conveyance of livestock wastes to the lagoon system. All drains, channels, and conduits shall be designed to convey average daily maximum flows and shall readily facilitate cleanout. Gravity conduits shall be a minimum of 6 inches in diameter and shall be laid with a minimum slope of 0.5%. Cleanout provisions shall be located every 200 feet and flow velocities of at least 2.5 fps are to be maintained to minimize solid deposition.

4. Design Parameters

Anaerobic lagoons consist of single stage or two stage design. The structures shall utilize a minimum of 3:1 side slopes and shall be constructed without emergency spillways. A minimum of 2 feet of freeboard shall be provided above the maximum design water level, and the minimum berm width shall be 8 feet to permit the operation of a tractor and mower.

a. Organic Loading

Anaerobic lagoons shall be designed to receive livestock wastes for a daily loading rate not to exceed 6 pounds volatile solids (V.S.)/1000 ft^3. The lagoon shall provide storage in addition to this required volume for waste, wastewater, rainfall, and dilution water accumulations. For two-cell systems, the design of the secondary cell is designed upon organic waste loading rates. The first cell shall be a minimum of 8 feet deep and shall be maintained with a minimum water level of 5 feet. The minimum volume to be maintained in the first cell shall be based on the organic waste loading rate (6 lbs V.S./day per 1000 ft^3). Secondary cells shall be a minimum of 6 feet deep and shall be maintained with a minimum water level of 2½ feet. The construction of deep structures is preferred to reduce surface areas, maintain relatively constant water temperatures and thereby reduce system upsets, land requirements and obnoxious odor emissions.

b. Hydraulic Loading

Anaerobic lagoons shall be designed to detain waste, wastewater, rainfall, and other flows in a manner that prevents discharge and the buildup of sludge and mineral accumulations. Storage shall be provided for a minimum detention period of 180 days with a maximum detention time of 365 days prior to effluent disposal. The annual net inflow (wastes, rainfall, runoff, dilution water and other flows less evaporation, percolation and other system losses) shall equal or exceed 1000 ft^3/10 lbs V.S./day. Single stage systems shall be dewatered at least annually to withdraw sludges and reduce mineral concentrations. Two-stage systems may be designed to evaporate effluents in the secondary cell; however, the second cell shall be maintained with a minimum depth of 2½ feet and a minimum volume of 1000 ft^3/3 lbs V.S./day.

c. Inlets

Submerged inlets that outlet near the center of the lagoon are preferred. Surface inlets that discharge at the middle of the longest side are also acceptable. The inlet shall consist of a 6 inch or larger pipe and be designed with cleanout provisions. Cleanouts are recommended at the lagoon entrance and at 200 foot intervals. The minimum slope for drain lines should be 0.5% for surface inlets, or to maximum water elevation for submerged inlets. The drain lines should be designed to maintain a flow velocity of 2.5 feet per second or greater.

d. Water Balance

Anaerobic lagoon systems shall provide a supplement water source to maintain adequate lagoon volume and to dilute waste inflows. The supplemental water source may be either a surface or groundwater supply and should be capable of delivering a minimum of 3 gpd/lb V.S./day for the design waste loading rate.

Additionally, a water balance shall be calculated to estimate the supplement water required by the control system. Evaporation losses range from less than 1 ft^3/square foot of pond surface area to greater than 4 ft^3/ft^2 of pond surface area per year. Use average annual evaporation rates for estimates.

Anaerobic control structures are to be essentially water-tight with percolation rates less than ¼ inch/day. Seepage losses vary from essentially zero to 90 inches/year (¼ inch/day). For estimates, an average rate of 3 ft^3ft^2 of pond/year may be employed unless more specific soil information is available.

All plans for anaerobic lagoon systems shall include an operational section. The operational section shall identify supplemental water sources, requirements, and discuss the methods to be employed to initially establish and maintain the minimum water level, and the system to be utilized for wastewater effluent disposal.

IV. CONSTRUCTION DETAILS

Construction of water pollution control facilities shall be conducted in conformance with approved engineering practices. Materials and supplies shall be quality products that insure reasonable life of the control system and conform to ASAE, ASCE, ASME, SCS or other widely accepted standards. The Division of Environment limits its review to the functional capabilities and the adequacy of systems to control water pollutants.

A. EARTHEN IMPOUNDMENTS

1. Embankment Berms

Embankment berms shall be a minimum of five (5) feet wide and shall be constructed of compacted unconsolidated soils essentially void of rock, gravel, sand, or other porous media. All vegetation shall be removed when fill is placed above grade to construct embankments. Berms 10 to 12 feet in width are recommended to facilitate the operation of a tractor mounted mower and irrigation, pump and haul, or dragline equipment.

2. Dikes and Embankments

Side slopes shall be a minimum of 3 horizontal to 1 vertical (3:1) on the water side of impoundments. Back slopes shall be a minimum of 2½ horizontal to 1 (2½:1) vertical. The design of side slopes should be based on soil types, operational and maintenance requirements. Three to one (3:1) or flatter side slopes are recommended for ease of construction and for safe operation of equipment.

3. Emergency Spillways

When required, emergency spillways shall provide erosion protection to prevent washout of impoundment dikes and berms. Either tube or open channels may be utilized and shall be designed to convey flows resulting from 25-year 24-hour or greater runoff occurrences. A minimum of one foot of freeboard shall be provided above the inlet elevation of spillways.

4. Inlets

All inlets shall be designed to provide erosion protection of impoundment embankments. Splash pads, rip-rap, and conduits shall be provided as needed. Normally, submerged inlets will require little or no protection, whereas open channel inlets normally require splash pads.

5. Fencing

All earthen impoundments shall be fenced or adequately protected to prevent access by livestock or unauthorized personnel. Fencing shall consist of a minimum of five barb wires spaced on 10/12/12/12/12 inch centers from the ground. Woven fabric fencing (40 inches) with 3 or more strands of barb wire is recommended to further restrict access by family pets and children. The fencing should be located at the toe of the embankment backslope so sufficient room is present for the operation of mowing, dewatering, and maintenance equipment. A gate at least 14-16 feet wide is to be provided for access and shall normally be secured.

6. Seeding and Mowing

Sod shall be established on the side slopes above water levels, berm, and backslopes of embankments. Short-rooted grass such as Bermuda, Fescue, Switch Grass, Brome, Timothy, and native grasses are suitable. Precautions shall be taken to prevent the establishment of long rooted weeds or legumes and animal burrows, etc., that can result in seepage problems.

7. Impoundment Bottoms, Side Slopes

The impoundment bottom and side slopes shall provide a minimum cover of one foot of unconsolidated fill essentially void of sand, gravel, rocks or other porous media. Additional precautions shall be taken if rock is encountered to prevent seepage and inflow problems such as over excavating and back filling with clay, sealing with bentonite, or installing a plastic liner.

B. CONCRETE STRUCTURES

1. Concrete Pits

All concrete manure pits shall be constructed with reinforced concrete in a water tight manner. Side walls shall be a minimum of 6 inches thick and pit bottoms a minimum of 4 inches thick. It is recommended that professional design assistance be obtained to prevent structural failure due to flotation, inadequate reinforcement, unstable foundations, etc.

The design of pit covers requires careful evaluation of loading parameters (livestock, implements, etc.) and is not a do-it-yourself job.

2. Retain Walls

Retain walls are used to provide a vertical side for earthen impoundments to facilitate pumpout activities. The retaining walls should be reinforced, anchored, and designed for site specific conditions. It is recommended that professional design assistance be obtained.

3. Splash Pad, Open Channels

These facilities are less critical and more easily repaired if structural failure occurs. Channels require careful construction to provide proper slopes and flow capabilities. Normally, the minimum thickness for non-reinforced concrete should be four inches.

4. Metal, Fiberglass, and Other Storage Vessels

Several manufacturers provide prefabricated storage structures consisting of stave concrete silos, epoxy lined metal tanks, etc. These facilities shall be of water tight construction and of quality design. These and other designs will be individually evaluated.

C. OPEN CHANNELS AND CONDUITS

1. Diversions, Terraces, and Open Channels

These earthen collection devices shall be designed to convey the peak hourly flow expected to occur once in five years. The slopes shall be designed to minimize bed erosion and when possible the runoff collection channel should facilitate the deposition and subsequent removal of manure solids and silt. The recommended minimum channel width and depth is 10 feet and 2 feet respectively. When possible these facilities should be located outside of livestock confinement areas so a vegetative grass cover can be established and to simplify sludge removal and maintenance.

2. Closed Conduits, Drain Lines

Closed conduits are used primarily for gravity conveyance of dry weather wastewater flows. They shall be designed to provide adequate capacity for the average daily peak hourly flow rate and shall be capable of maintaining flow velocities that minimize solid deposition (2.5 gps or greater). The minimum acceptable conduit size shall be 6 inches and the minimum grade shall be 0.5% for gravity lines. Steeper grades (2% or more) are recommended to maintain higher flow velocities.

Conduits interconnecting control structures (sedimentation ponds, runoff holding ponds, etc.) must be designed to convey runoff flow in addition to dry weather wastewater flows. Flow capacity requirements are dependent on flood storage reserved and the pipe sizing should enable the complete control of a 24-hour 25-year storm without bypassing the control system.

V. ODOR ASSOCIATED WITH LIVESTOCK OPERATIONS

A. GENERAL

Odors associated with livestock operations are usually attributable to water pollution control and manure management practices. Other potential sources are related to feed storage, processing and distribution. Objectionable odors exist whenever odorous compounds are emitted and transported to an area where their presence is undesirable to people. The emission of odorous vapors and gases is related to the volatility of the compound, its chemical composition, temperature and air movement.

Principles of odor generation, release, transport, and detection are not thoroughly understood, and decisions regarding odor control must consequently reflect judgments based upon limited knowledge. Odor sensation is a personal response. Not all people are equally sensitive, nor is there general agreement as to the severity of odors once detected. The qualitative appraisal of odorous substances cannot be impartially measured by instrumentation to determine their degree of unpleasantness.

B. TREATMENT

Treatment processes involve methods to reduce, alter, or mask odor emission resulting primarily from anaerobic microbial metabolism of organic wastes. Economics have prevented wide acceptance and utilization of treatment techniques to control odors. The following are treatment methods which have been employed.

1. Drying-Dehydration

Manure is dried to reduce the moisture content thereby altering the decomposition process to inhibit anaerobic microbial metabolism. When the moisture content of manure is reduced to 50% or less, sufficient porosity can exist for air movement to prevent anaerobic decomposition. The additional of bedding or other dry material can partially reduce the moisture content.

2. Disinfection

Disinfection can be used to inhibit anaerobic decomposition. Lime, chlorine, formaldehyde, and other chemical disinfectants have been successfully used, however, the quantities required and associated costs may be unreasonable.

3. Odor Control Agents

A variety of chemicals or agents, designed to aid in odor reduction are marketed. The effectiveness of these products is difficult to measure, and an individual trial is recommended prior to purchase. These products may generally be classified as masking agents, conteractants, and deodorants. Masking agents are mixtures of volatile oils that may have a stronger more acceptable odor. Conteractants are based upon the characteristics of two properly selected odors which tend to cancel one another thereby resulting in total detectable intensities less than that of the individual constituents. Deodorants are based upon the principal of eliminating or transforming the odorous constituents so they are not emitted. They may inhibit or alter biological activity and decomposition processed by changing the enzyme balance.

4. Aeration

Aeration of wastes (usually in a liquid state) can result in aerobic decomposition which is nearly odorless. Equipment cost, maintenance requirements, and system complexities are the significant factors that prevent wide spread utilization.

C. WASTE MANAGEMENT

Although chemical control and treatment processes may have useful applications, effective long term solutions to odor problems are best achieved by selecting livestock production, manure collection, transport, storage, handling, and land application procedures that are technically feasible and compatible with adjacent environmental usages and the total livestock production system. Obnoxious manure odor emissions frequently are the result of poor housekeeping techniques as well as problems inherent to manure management.

The following managerial procedures have proven helpful to reduce odor emissions:

1. Location

Livestock operations should be located a reasonable distance from residential areas, places of employment, recreational facilities, and other areas frequented by the general public excluding the livestock owner's residence. Distances have not been established beyond which complaints are invalid, however providing separation as stipulated in Section 1 will be considered indicative of reasonable safeguards. Wind direction and velocity, humidity, topography, temperature, and unique meteorological conditions (inversion, etc.) affect odor transmission and detection.

2. Confined Livestock Feeding Areas

Confined livestock feeding areas should be kept as dry as practicable. Dirt lots are to be maintained such that surface water does not collect and remain in depressions or create prolonged muddy conditions following precipitation events. By keeping manure covered surfaces dry the primary source of odor, anaerobic decomposition of manure wastes, can be minimized in terms of quantity and concentration. Dirty, manure covered animals can result in accelerated anaerobic decomposition of wastes resulting in odorous by-products that are vaporized by the animals' body heat and emitted into the atmosphere. Related benefits of dry pens and lots are better control of potential water pollutants, improved control of flies and other insects, and greater animal comfort and productivity.

3. Waste Collection

Waste collection should be conducted such that livestock and feeding areas can be kept dry. The frequency of waste collection is dependent upon the makeup of the livestock production unit. For open lots units waste collection is intermittently conducted by scraping and removing solid accumulations. In general, dirt lots should be cleaned a minimum of twice a year or whenever excessive manure accumulations result in manure covered animals. For concrete lots and pens, cleaning operations should be conducted a minimum of once every two months or whenever excessive manure accumulations result in manure covered animals. Regular, routine removal of waste accumulations, the use of bedding, scraping, and mounding of waste accumulations should be employed to maintain confinement areas and livestock in a dry environment.

4. Waste Storage

Prolonged on-site storage of animal wastes can intensify odor emissions. Waste storage systems can be classified as interim solid, slurry, or liquid storage of wastes preceding land application and disposal. Very few livestock operations utilize satisfactory aerobic lagoons or waste storage treatment systems which are suitable for the total disposal of wastes.

Solid wastes (scraping from lots and pens) should be stored at a site with good drainage. Such wastes may require drying prior to stocking, however, when sufficiently dry it is recommended that they be stockpiled in a manner that minimized their total surface area. A dry crust or cover will form which will partially absorb odor from inner layers undergoing anaerobic decomposition.

Slurry includes a mixture of solid and liquids that cannot be handled with conventional liquid pumping or solid handling equipment. The contents of manure pits, bottom deposits in retention lagoons, and sludge accumulations in sedimentation ponds are examples of animal wastes slurries. These wastes are volatile and are undergoing anaerobic decomposition. It is recommended that slurry wastes be stored in structures that permit the use of a vacuum tanker, positive displacement pump, or other specialized equipment for subsequent removal and disposal activities. The surface area of manure pits and holding basins should be minimized to reduce odor emissions and left undisturbed except during periods of cleanout. Depending on waste characteristics, a crust may form, otherwise a liquid layer should cover the heavier slurries. Installing covers over these structures may prove beneficial in retarding the anaerobic decomposition process. As explosive gases are generated, adequate ventilation is mandatory.

Liquid storage structures are devices or facilities used to retain wastewater flows containing minor amounts of livestock wastes. To reduce odor emissions runoff control systems should normally be maintained dry except for short periods following rainfall-runoff occurrences. The solids entering such storage devices should be minimized by using settling devices or by using appropriate solid or slurry waste handling practices so the liquid effluents can be removed with conventional irrigation equipment.

5. Waste Disposal

Land application of livestock wastes is the predominant method of disposal associated with animal waste management systems. It is an integral part of nearly every manure handling system. Liquids, solids and slurries are amenable to land application and properly conducted the contained nutrients and water are beneficially utilized by vegetation.

Solid wastes and runoff accumulations should be applied upon farmland as frequently as possible to reduce on-site accumulations. Slurry wastes should be handled less frequently and when removed, rapidly handled to minimize their time of transport and application. If possible, slurry wastes or other similar wastes (such as lagoon sludges, putrefied solid wastes, etc.) should be applied at times when temperatures are cool and field tillage activities can be conducted.

The following are general recommendations which reflect good management practices:

a. Avoid spreading wastes when the wind would blow odors toward populated areas or toward sensitive neighboring residential dwellings.

b. Avoid spreading wastes immediately before weekends and holidays and other times when nearby people are likely to be engaged in outdoor and recreational activities. If possible become familiar with the social commitments of nearby neighbors and adjust waste disposal schedules accordingly.

c. Avoid spreading wastes near heavily traveled highways and upon properties immediately adjacent to neighboring residential dwellings.

d. When possible spread wastes in the morning when the air is warming and raising rather than late afternoon. Spreading at night may be helpful provided the weather is clear and some breeze is present. Avoid spreading on foggy, damp days. Use the available weather information to best advantage; i.e. turbulent breezes dissipate and dilute odors and rains will remove odors from the atmosphere.

e. If possible, incorporate solid and slurry wastes into the soil during or immediately after application. Most slurry tank wagons have soil injector attachments available, otherwise plow or disc fields shortly following slurry or solid waste applications. These practices minimize odor emissions and also preserve nutrients and reduce the potential for water pollution. If wastes cannot be incorporated, apply then in a thin uniform layer to ensure drying in five days or less.

6. Miscellaneous

Other related items in reducing and minimizing odor emission problems include:

a. A clean, orderly appearing livestock operation is effective in suggesting a non-offensive situation. This consideration may warrant the installation of vegetative screening or other similar items to improve the operation's appearance.

b. Dead animals should be disposed of in a timely manner. They should be removed from the site within 24 hours. Picked up by rendering workers is preferred, otherwise burial or incineration may be used.

c. Open communication with neighbors can be helpful in determining their concerns and to explain your operation and the practices used to minimize odor and nuisance concerns.

Expected Runoff From 25 Year—24 Hour Rainfall on Livestock Confinement Lots

County	25 Yr Rainfall (inches)	Bare Earth Lot CN=90	Paved Lot CN=97
ALLEN	6.6	5.43	6.24
ANDERSON	6.5	5.33	6.14
ATCHISON	6.0	4.85	5.64
BARBER	5.8	4.65	5.44
BARTON	5.3	4.17	4.95
BOURBON	6.6	5.43	6.24
BROWN	5.9	4.75	5.54
BUTLER	6.3	5.14	5.94
CHASE	6.2	5.04	5.84
CHAUTAUQUA	6.7	5.53	6.34
CHEROKEE	6.8	5.63	6.44
CHEYENNE	4.1	3.01	3.75
CLARK	5.2	4.07	4.85
CLAY	5.7	4.55	5.34
CLOUD	5.5	4.36	5.15
COFFEY	6.4	5.24	6.04
COMANCHE	5.5	4.36	5.15
COWLEY	6.4	5.24	6.04
CRAWFORD	6.7	5.53	6.34
DECATUR	4.5	3.40	4.15
DICKINSON	5.8	4.65	5.44
DONIPHAN	5.9	4.75	5.54
DOUGLAS	6.2	5.04	5.84
EDWARDS	5.2	4.07	4.85
ELK	6.6	5.43	6.24
ELLIS	4.9	3.78	4.55
ELLSWORTH	5.5	4.36	5.15
FINNEY	4.7	3.59	4.35
FORD	5.0	3.88	4.65
FRANKLIN	6.4	5.24	6.04
GEARY	5.9	4.75	5.54
GOVE	4.6	3.49	4.25
GRAHAM	4.7	3.59	4.35
GRANT	4.6	3.49	4.25
GRAY	4.8	3.68	4.45
GREELEY	4.3	3.20	3.95
GREENWOOD	6.4	5.24	6.04
HAMILTON	4.4	3.30	4.05
HARPER	6.1	4.94	5.74
HARVEY	6.0	4.85	5.64
HASKELL	4.7	3.59	4.35

County	25 Yr Rainfall (inches)	Bare Earth Lot CN=90	Paved Lot CN=97
HODGEMAN	4.9	3.78	4.55
JACKSON	6.0	4.85	5.64
JEFFERSON	6.1	4.94	5.74
JEWELL	5.2	4.07	4.85
JOHNSON	6.3	5.14	5.94
KEARNY	4.5	3.40	4.15
KINGMAN	5.9	4.75	5.54
KIOWA	5.4	4.26	5.05
LABETTE	6.8	5.63	6.44
LANE	4.7	3.59	4.35
LEAVENWORTH	6.1	4.94	5.74
LINCOLN	5.4	4.26	5.05
LINN	6.5	5.33	6.14
LOGAN	4.4	3.30	4.05
LYON	6.3	5.14	5.94
MARION	6.1	4.94	5.74
MARSHALL	5.7	4.55	5.34
MCPHERSON	5.8	4.65	5.44
MEADE	5.0	3.88	4.65
MIAMI	6.4	5.24	6.04
MITCHELL	5.3	4.17	4.95
MONTGOMERY	6.8	5.63	6.44
MORRIS	6.1	4.94	5.74
MORTON	4.6	3.49	4.25
NEMAHA	5.8	4.65	5.44
NEOSHO	6.7	5.53	6.34
NESS	4.8	3.68	4.45
NORTON	4.6	3.49	4.25
OSAGE	6.3	5.14	5.94
OSBORNE	5.1	3.97	4.75
OTTAWA	5.6	4.46	5.25
PAWNEE	5.2	4.07	4.85
PHILLIPS	4.8	3.68	4.45
POTTAWATOMIE	5.9	4.75	5.54
PRATT	5.6	4.46	5.25
RAWLINS	4.3	3.20	3.95
RENO	5.8	4.65	5.44
REPUBLIC	5.4	4.26	5.05
RICE	5.6	4.46	5.25
RILEY	5.8	4.65	5.44
ROOKS	4.9	3.78	4.55

Expected Runoff From 25 Year–24 Hour Rainfall on Livestock Waste Confinement Lots

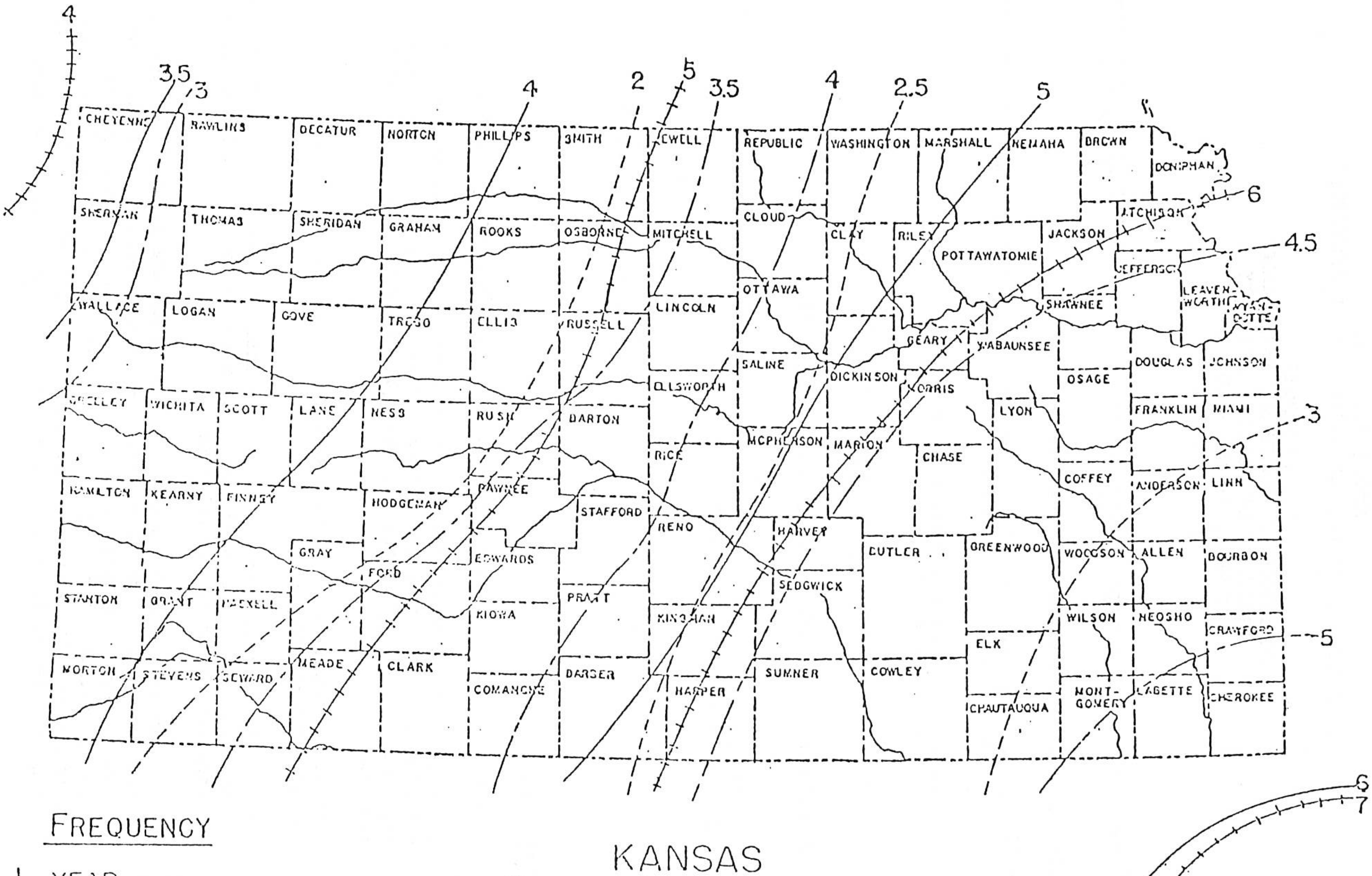
County	25 Yr Rainfall (inches)	Bare Earth Lot CN=90	Paved Lot CN=97
RUSH	5.0	3.88	4.65
RUSSELL	5.2	4.07	4.85
SALINE	5.7	4.55	5.34
SCOTT	4.5	3.40	4.15
SEDGWICK	6.1	4.94	5.74
SEWARD	4.8	3.68	4.45
SHAWNEE	6.1	4.94	5.74
SHERIDAN	4.5	3.40	4.15
SHERMAN	4.2	3.11	3.85
SMITH	5.0	3.88	4.65
STAFFORD	5.5	4.36	5.15
STANTON	4.5	3.40	4.15
STEVENS	4.7	3.59	4.35
SUMNER	6.2	5.04	5.84
THOMAS	4.4	3.30	4.05
TREGO	4.8	3.68	4.45
WABAUNSEE	6.1	4.94	5.74
WALLACE	4.2	3.11	3.85
WASHINGTON	5.5	4.36	5.15
WICHITA	4.4	3.30	4.05
WILSON	6.6	5.43	6.24
WOODSON	6.5	5.33	6.14
WYANDOTTE	6.2	5.04	5.84

SCS RUNOFF EQUATION:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$S = (1000/CN) - 10$$

WHERE: P = RAINFALL (INCHES)
Q = RUNOFF (INCHES)
S = POTENTIAL MAXIMUM RETENTION (INCHES)



FREQUENCY

1 YEAR - - - - - - -
5 YEAR — — — — —
0 YEAR ————————
'5 YEAR —+—+—+—+—

KANSAS

RAINFALL PROBABILITIES
24 HOUR (INCHES)

ENVIRONMENTAL HEALTH SERVICES
KANS. STATE DEPT. OF HEALTH

2-25
27

New

OPERATIONAL REPORT OF AGRICULTURAL AND RELATED WASTE CONTROL FACILITIES

STATE OF KANSAS
DEPARTMENT OF HEALTH AND ENVIRONMENT
BUREAU OF ENVIRONMENTAL QUALITY
TOPEKA, KANSAS 66620-0001
(913) 296-5521

NAME ______________________________ A-______________
Permitted Facility Name — Permit Number

MANAGER ______________________________

ADDRESS ______________________________ ______________
P.O. Box, Street Address — County

____
City, State, and Zip Code

STATUS ______________________________
Number of Animals Confined

REPORT PERIOD FOR THE MONTH OF ______________, 19____.

I HEREBY CERTIFY THAT THE INFORMATION SUBMITTED HEREIN IS TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF:

______________ ______________________________
Date Signed — Signature of Manager or Owner

INSTRUCTIONS:

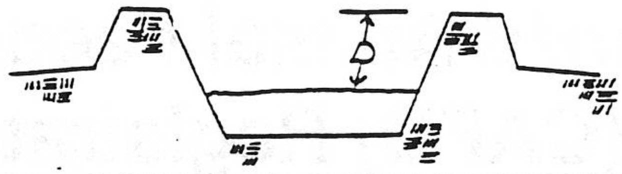
The following minimum data shall be recorded on the back of this form:

1. Daily precipitation amounts in inches and tenths. Facilities with no runoff containment structures need only report precipitation starting three days before land application of waste and continuing until all waste is applied.

2. Available storage depth in each wastewater impoundment on the 1st, 15th, and last day of the month.

3. Whenever the minimum required wastewater storage capacity is not available in any impoundment, the available depth shall be recorded daily until the required storage is again available.

4. On everyday when either solid or liquid wastes are applied to land, the following information shall be recorded: soil condition (frozen, thawed, or snow covered), average daytime air temperature, quantity of waste applied in gallons, tons, or cubic yards whichever is most appropriate, size of the area (in acres) to which waste is applied, and crop(s) either growing or intended to be grown next season on the application area.



DATE	PRECIP (INCHES)	WASTE DISPOSAL DAYS: SOIL COND (T,F,S)*	AIR TEMP (°F)	QUANTITY APPLIED (gal, tons, yd^3)	AREA APPLIED (ac)	CROP APPLIED TO	AVAILABLE DEPTH (D) FROM TOP OF BERM TO WATER SURFACE (see drawing) — STRUCTURE NUMBER: 1 (FT)	2 (FT)	3 (FT)	4 (FT)	5 (FT)	6 (FT)	7 (FT)	8 (FT)
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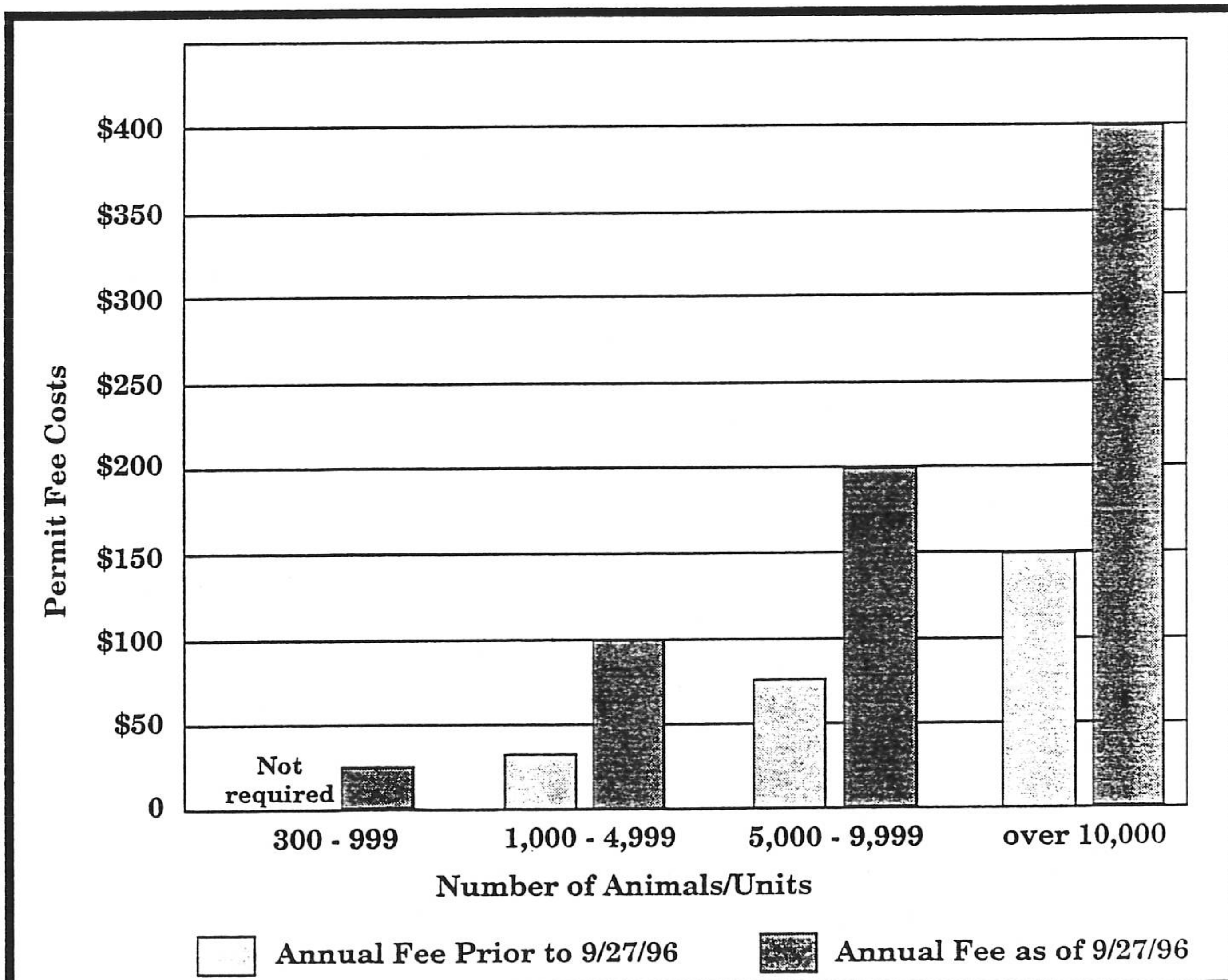
* F=Frozen, T=Thawed, and S=Snow Covered

Confined Animal Feeding Operation (CAFO) Registration Fees

Number of animals/units	Fee Prior to 9/27/96	Fee as of 9/27/96	% Increase
300 - 999 animals/units	NA	$25	NA
1,000 - 4,999	$30	$100	333%
5,000 - 9,999	$75	$200	266%
over 10,000	$150	$400	266%



Permits required for a 20,000 head cattle feedlot in Kansas.

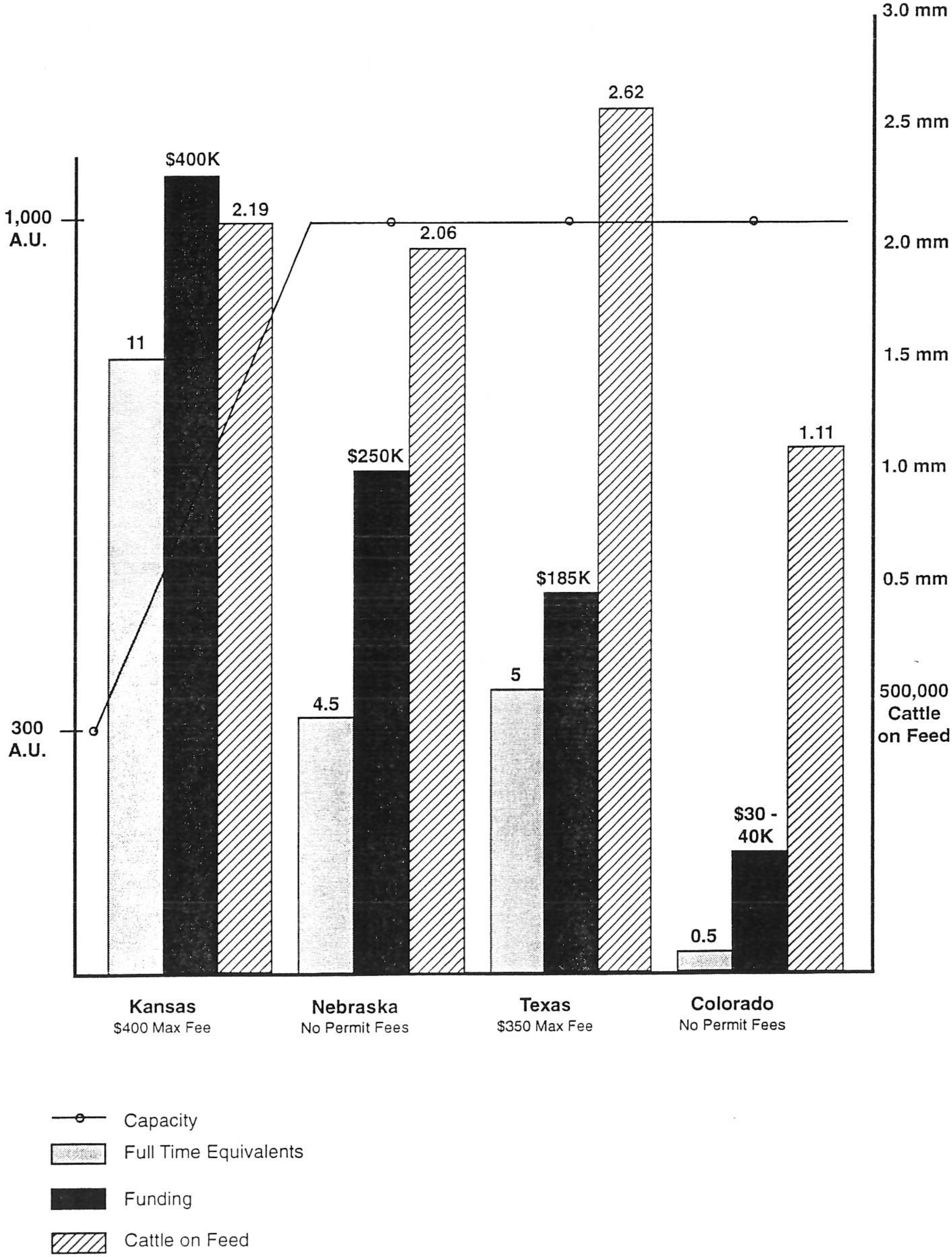
KDHE/NPDES permit - (threshold 300 a.u.)	$ 400
Stockwatering permit - (threshold 1,000 hd.)	$3,285
Animal Health Dept. license - (threshold 1,000 hd.)	$ 750
Chemigation permit -	$ 100

$4,535 in annual permit fees*

Most feedlots must be in compliance with other state and federal regulations not listed above including: boiler permit, commercial drivers license, fuel storage tanks and scale certification.

* These annual fees do not include the cost of compliance.

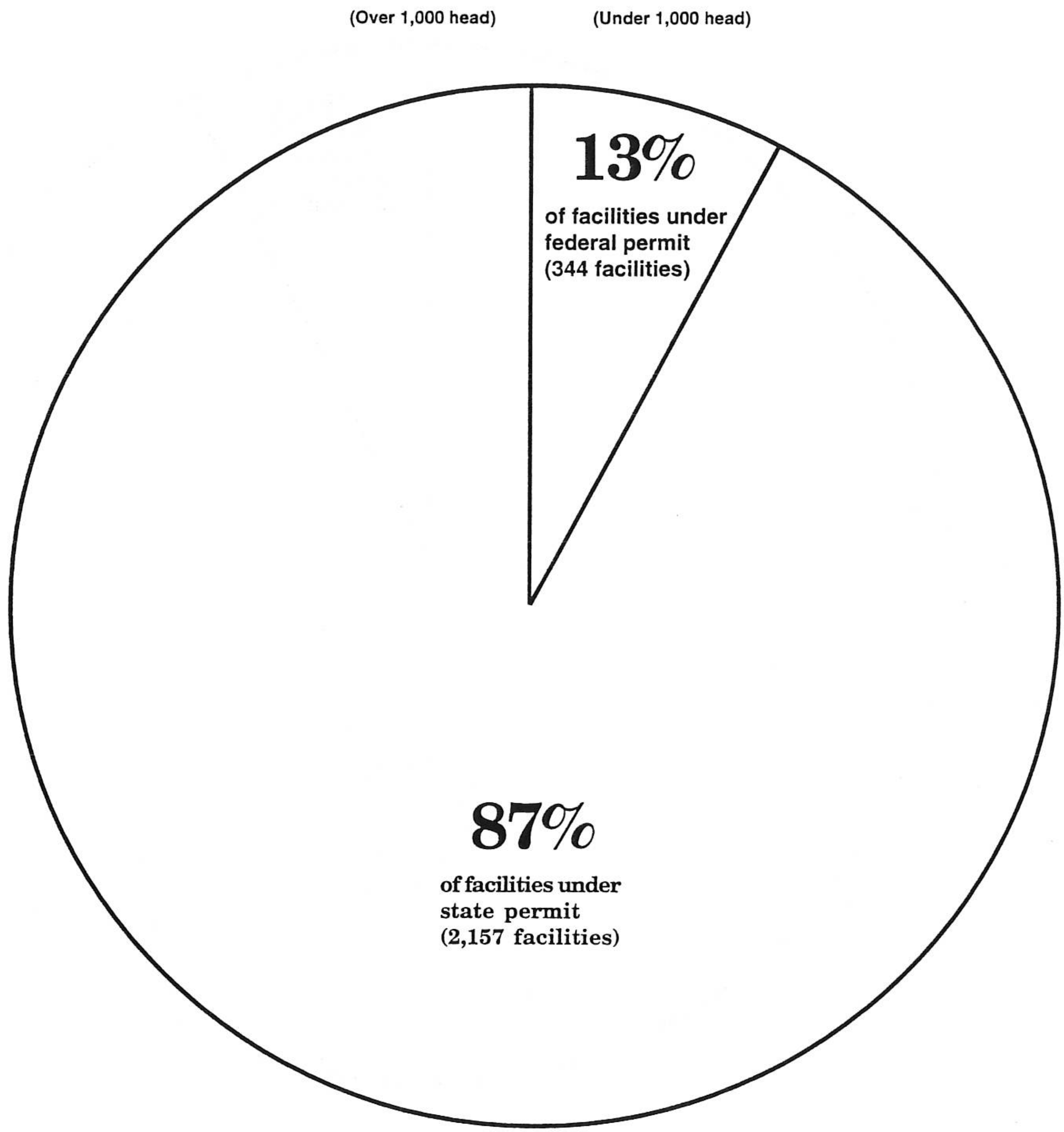
Capacity Permitted



Data current as of November 1996

All Confined Feeding Facilities

Federal vs. State*



Total Permitted Facilities in State - 2,501

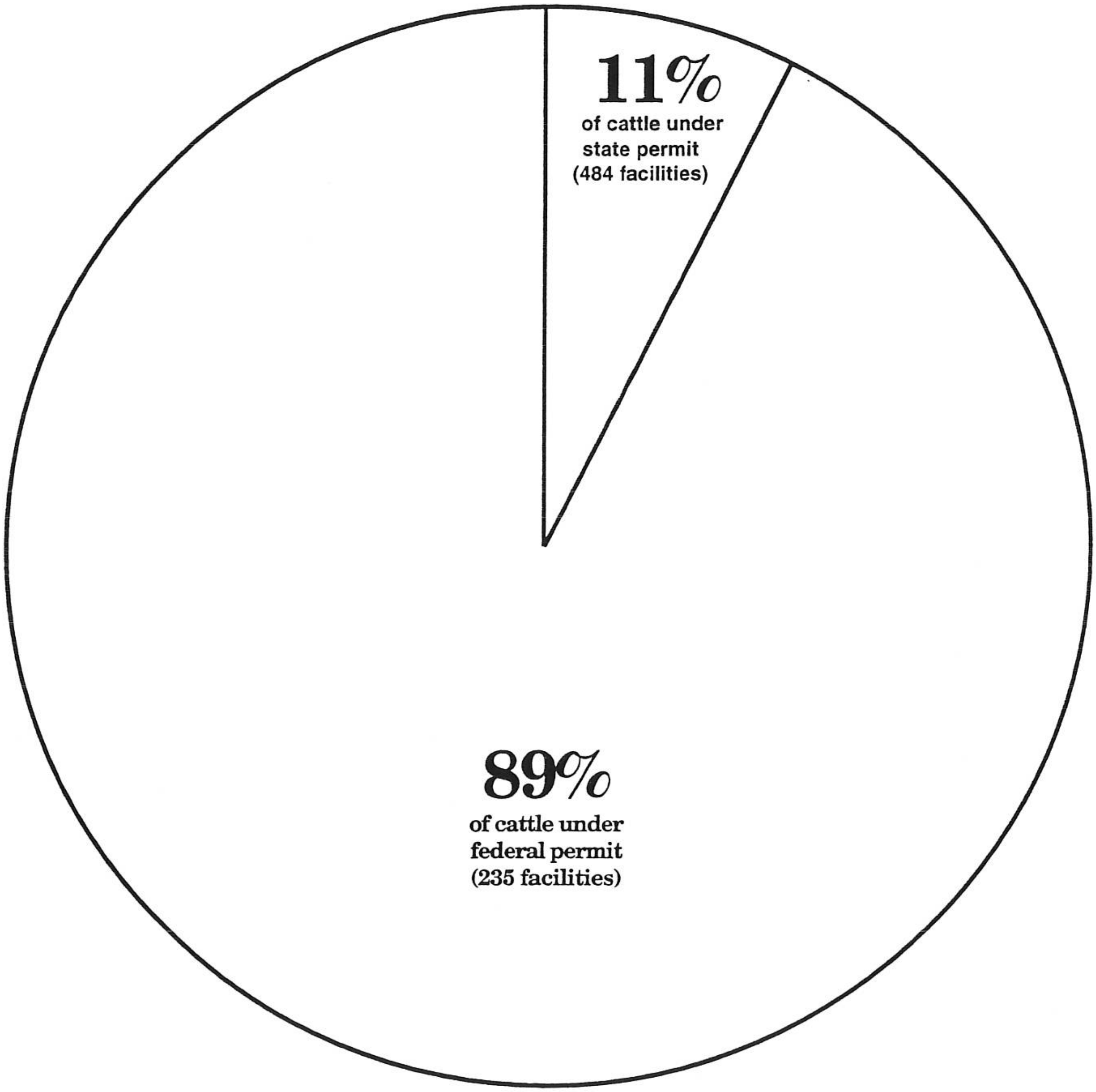
* Note: State facilities include:
484 cattle
923 swine
673 dairy

Data current as of November 1996

Feedlot Cattle In Kansas

Federal vs. State

(Over 1,000 head) (Under 1,000 head)



Number of cattle in Kansas feedlots	3,369,113
Number of cattle under federal regulation	3,004,290
Number of cattle under state regulation	364,823

Data current as of November 1996

Separation Distance Requirements
by State

ANIMAL UNITS	KANSAS	MISSOURI	COLORADO	NEBRASKA	OKLAHOMA	TEXAS
300 - 999	1,320 feet	NONE	NONE	NONE	NONE	NONE
1,000 +	4,000 feet	——	NONE	NONE	NONE	1,320 feet
1,000 - 2,999	4,000 feet	1,000 feet	NONE	NONE	NONE	1,320 feet
3,000 - 6,999	4,000 feet	2,000 feet	NONE	NONE	NONE	1,320 feet
7,000 +	4,000 feet	3,000 feet	NONE	NONE	NONE	1,320 feet

*** The separation distance applies to dwellings and public buildings.**

Data current as of November 1996

RELEASE FORM

I, ______________________________, owner of the residential dwelling in close proximity of property owned by ______________________ hereby give my permission to the same to construct confined livestock feeding and associated water pollution control facilities which will be no less than __________ feet from my residence.

Further, I understand the livestock operation will be designed to provide facilities for ____________________________________, and will operate and maintain them within the conditions of their Water Pollution Control Permit.

Further, I reserve the right to seek relief from all personal or property damages resulting from the subsequent operation of these facilities.

________________________ ________________________

Signature of Owner Date

________________________ ________________________

Address Phone

____

City, State, Zip

________________________ ________________________

Signature of Witness Date

See c... at end of paper.

Self-Sealing of Earthen Liquid Manure Storage Ponds: I. A Case Study[1]

M. H. MILLER, J. B. ROBINSON, AND R. W. GILLHAM[2]

ABSTRACT

A monitoring system was established on an unlined, earthen storage pond near Kitchener, ON prior to the addition of liquid manure from a 4500-head beef (*Bos taurus*) feeding operation. The bottom of the pond, which had a surface area when full of 2 ha, was a coarse textured sand. This material, with some gravel layers, extended below the water table, which was initially at 13.7 m below the ground surface. A platform, at which soil moisture measurement and groundwater sampling tubes were installed, was constructed within the pond. Additional groundwater sampling tubes were installed at several points surrounding the pond. Moisture content of the soil immediately below the pond reached saturation when liquid manure was first added but began to decrease within 2 weeks and reached a steady state at a water potential of about −0.03 MPa within 90 d. The infiltration rate at this time was estimated to be less than 10^{-4} m s^{-1}, a value considered to indicate that the bottom was effectively sealed. There was a rapid increase in Cl content of the groundwater within 2 weeks of manure addition but the concentration declined to initial values within 12 weeks. There was no evidence of elevated Cl concentrations in groundwater outside the boundaries of the pond. The NO_3-N content of groundwater below the pond decreased to non-detectable values very shortly after addition of manure but returned to background values within 12 weeks except in the upper portions of the groundwater. A similar depression of NO_3-N was observed at one sampling position within a few meters of the pond but not at more distant points. It was concluded that the NO_3-N depression was due primarily to denitrification in the groundwater as it passed below the pond. It is concluded that, with some limitations, unlined earthen manure ponds are environmentally acceptable, even in sandy material.

Additional Index Words: groundwater contamination, nitrate-nitrogen, chloride.

Miller, M. H., J. B. Robinson, and R. W. Gillham. 1985. Self-sealing of earthen liquid manure storage ponds: I. A case study. J. Environ. Qual. 14:533-538.

Storage of liquid manure presents serious problems to animal producers in Ontario. Due to the potential for run off and pollution of surface water from winter spreading, the Agricultural Code of Practice for Ontario requires that a 26-week storage capability be provided before an operation can be certified. Because of the prohibitive construction costs of concrete storage reservoirs or tanks for this volume, producers are using earthen storage reservoirs which may or may not be lined. Considerable concern exists for the potential of groundwater pollution, particularly with unlined ponds.

Studies on the degree of sealing of soils when liquid manure is infiltrated have been summarized by Hills (1976) and DeTar (1979). Two general approaches have been used in these studies; (i) the determination of infiltration rates in reconstituted columns (Chang et al., 1974; Hart and Turner, 1965; Hills, 1976) or in natural soils (Baier et al., 1974; DeTar, 1979; Meyer, 1973) from direct measurement or from measurement of hydraulic gradients below the floor of the pond and (ii) the measurement of concentrations of pollutants in the soil (Clark, 1975; Meyer, 1973; Miller et al., 1976) below the floor of the pond.

Results of infiltration studies have indicated that ponds become "effectively" sealed on infiltration of liquid manure for time periods ranging from a few days on clay soils to as much as 100 d on loamy sands and sands (Baier et al., 1974; Chang et al., 1974; Davis et al., 1973; Hills, 1976; Meyer, 1973). One exception was the study of Hart and Turner (1965) in which infiltration rates into a sandy loam remained relatively high (1.9 to 3.6 × 10^{-7} m s^{-1}) after 2 yr and depended on solids concentration. The authors state that the expected biological sealing of the lagoon did not appear to be very effective. DeTar (1979) found that the reduction in infiltration rate after 1 week increased several fold as the total solids content increased from about 1 to 15 g kg^{-1}. The effect was similar for both clay and sandy loam soils. He concluded that total solids content was more important than the rate of water infiltration.

Miller et al. (1976) reported NH_4-N concentrations in soil in excess of 35 mmol kg^{-1} 0.9 m below the floor of two 8- to 10-yr old swine (*Sus scrofa domesticus*) manure ponds in sandy loam to silt loam soil, indicating that large quantities of manure had infiltrated. The NH_4-N concentrations below two ponds in clay soils were much lower with little evidence of accumulation at depths > 0.4 m. These latter ponds had been in use only 2 yr. The authors were unable to separate the effects of age and soil texture nor were they able to determine whether infiltration was continuing.

An opportunity arose in the fall of 1975 to establish monitoring systems on a large liquid manure storage pond prior to addition of liquid manure from a 4500-head beef (*Bos taurus*) finishing operation located west of Kitchener, ON. This pond was constructed by diking one end of a natural small valley using surface material from within the valley. The excavation exposed a sand subsoil over most of the floor of the pond. The liquid manure from the pits below the slotted pens was centrifuged to remove a portion of the solids and the effluent from the centrifuge was pumped into the pond. Considerable dilution occurred in the pond due to runoff from the surrounding area.

Because of the sand material and the relatively dilute manure, the probability of this system self-sealing was not considered to be high. A study was conducted to determine the extent to which materials from this pond infiltrated into the soil and the effect of the pond on the quality of groundwater in adjacent areas.

MATERIALS AND METHODS

Establishment of Study Site

The storage pond is located in Wilmot Township, Waterloo County on a glacial outwash material. The pond was formed in the fall of 1975

[1] Contribution from Dep. of Land Resource Science, Univ. of Guelph, and Dep. of Earth Science University of Waterloo, ON, Canada. This research was supported by Ontario Ministry of Agriculture and Food and by Agriculture Canada. Received 2 Feb. 1984.

[2] Professor of Soil Science, professor of Environmental Biology (now deceased) Univ. of Guelph, associate professor, Dep. of Earth Science, Univ. of Waterloo, respectively.

2-35

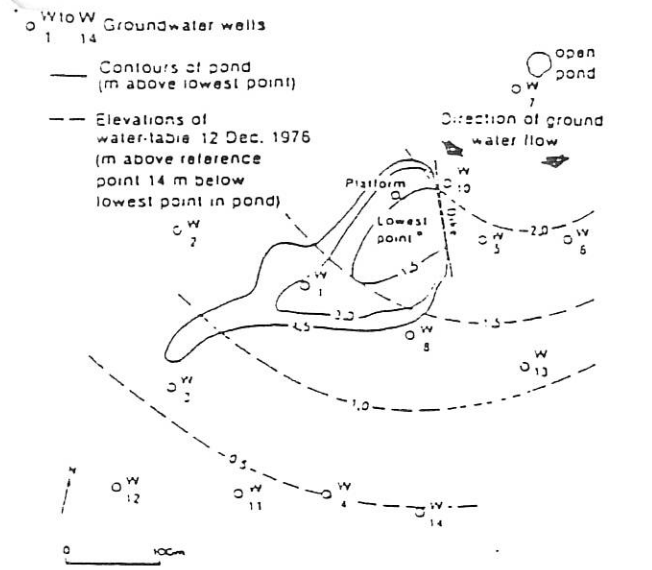


Fig. 1. Map of pond area showing sampling points and water table elevations.

by constructing an earthen dike approximately 5 m high and 100 m long across a natural valley (Fig. 1). The material for the dike was obtained from two kame-like mounds within the pond area as well as from the pond floor. Hence all of the surficial material was removed from the bottom of about half of the pond exposing the unweathered material which consisted of a coarse sand with occasional gravel layers or lenses (Table 1). This material constituted most of the bottom of the pond within the 3.0-m contour (Fig. 1). The pond, when filled to the 4.5-m contour, would have a surface area of about 2 ha and a volume of approximately 15 000 m^3.

A platform (Fig. 2) was constructed in December 1975 at a point approximately 1.5 m above the lowest point in the pond (Fig. 1). This platform was set in concrete and extended to about 5 m above the soil level, which was above the highest anticipated liquid level. A ladder was attached to the platform and a rowboat was used to reach the platform when the liquid level was above the base.

A neutron-probe access tube, and several groundwater and soil moisture sampling tubes were installed at the platform in December 1975. The neutron-probe access tube (40 mm i.d. aluminum) extended into the soil to a depth of 1.6 m. The groundwater sampling tubes (P3 to P9) consisted of 45-mm i.d. PVC pipe sealed at the bottom and with slots covered with nylon mesh extending 300 mm from the base. These tubes were placed so the center of the slotted region was at 1.5-m intervals beginning 3 m above and extending to 3 m below the initial position of the water table (13.7 m below ground surface). The soil-moisture sampling tubes consisted of porous cups (0.1 MPa air-entry value) attached to a 44-mm i.d., 330-mm long plastic tube (Soil Moisture Equipment Co., Soil Water Sampler #1900). This unit was sealed into a PVC pipe in the top of which was sealed a 2-hole stopper. A glass tube was inserted in one hole to permit evacuation of the system. A 1.9-mm i.d. nylon tube was sealed into the second hole and extended to close to the bottom of the porous cup to permit withdrawal of a sample. The porous cups were placed at depths of 0.15, 0.45, 0.90, 1.5 and 3.0 m below the soil surface. The PVC pipe extended to the top of the platform as did the neutron access tube and all groundwater sampling tubes.

A water table level and sampling well (W1) was installed in December 1975 within the pond approximately 100 m from the platform. This well was similar to those used at the platform with the exception that the tube was slotted for a distance of 1 m and the well was placed so that the center of the slotted region was at the water table at the time of installation. Similar water table wells were installed in the region surrounding the pond in July (W2 to W7) and September (W8, W10) of 1976. Additional wells (W11 to W14) were installed at later stages in the study.

The level of the top of all tubes was determined relative to a bench mark using standard survey methods.

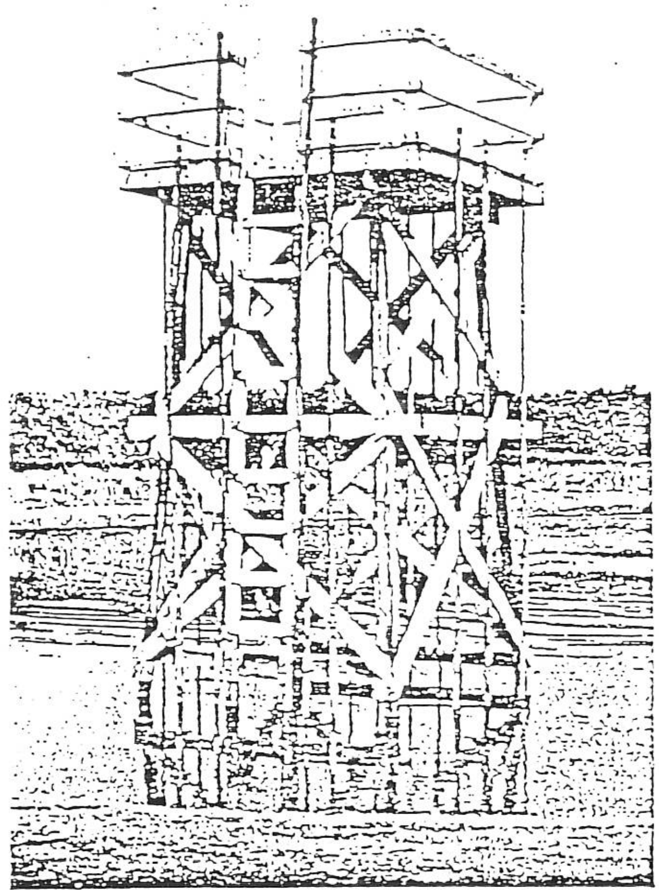


Fig. 2. Sampling platform in manure storage pond.

Sampling Procedures

Water levels were determined using a two-pronged probe embedded in a short length of 25-mm o.d. PVC pipe and connected to a 1.5-volt battery through an ammeter so that when the prongs contacted the water, a current was registered. The depth was determined by measuring the distance from the tip of the probe to the top of the well.

After measuring the depth to water, the well was flushed using a 28-mm i.d. by 450-mm long aluminum baler to remove at least 2 times the initial volume of water in the well. A 50-mL sample was then taken by submersing a glass tube inserted into a stainless steel tube holder. A clean tube was used for each sample and the sample was refrigerated in a polyethylene bottle until analyzed.

Moisture content of the soil below the pond was determined using a Troxler depth probe (Model 1257) connected to a scaler-ratemeter (Model 2651) with a 20-m cable. Measurements were taken at 0.1-m increments beginning 0.1 m below the soil surface and extending to a depth of 1.5 m.

To collect soil moisture samples, the porous cup systems were evacuated using a hand pump and held under negative pressure for approximately 20 min. Water was withdrawn from the cup through the small diameter nylon tubing by applying suction through a collecting vessel.

Analytical Methods

All water samples were analyzed for chloride, nitrate and ammonium using automated colorimetric methods. Chloride was determined using a method in which thiocyanate is liberated from mercuric thiocyanate by the formation of non-ionized but soluble mercuric chloride. In the presence of ferric ions the thiocyanate liberated forms highly colored ferric thiocyanate (Anon., 1974). Nitrate (plus nitrite) was determined following reduction to nitrite in a cadmium column.

2-36

Table 1. Particle size distribution of material beneath storage pond at platform.

Depth†	Gravel >2 mm	Sand 2-0.05 mm	Silt 0.05-0.002 mm	Clay <0.002 mm
m		$g\ kg^{-1}$		
0-0.6	0	960	20	20
0.6-1.2	0	960	20	20
1.2-1.8	0	980	10	10
1.8-2.4	17	938	25	20
2.4-3.0	17	938	25	20
4.5-5.1	756	222	17	05
6.0-6.6	23	904	54	19
7.5-8.1	10	940	30	20
9.0-9.6	287	645	53	15
10.5-10.6	104	820	58	18
12.0-12.6	78	839	64	19
13.5-14.1	12	909	69	10
15.0-15.4	183	752	49	16
15.4-15.5	11	860	109	20
16.5-17.1	10	931	40	19
18.0-18.3	95	810	57	08

† Sampled continuously to 3.0 m and thereafter when change in material was apparent.

The nitrite reacts with sulfanilamide under acid conditions to form a diazo compound which couples with N-1-naphthylethylenediamine dihydrochloride to form a reddish purple azo dye (Anon., 1977). Ammonium was determined using the automated distillation method of Steckel and Hanawalt (1967).

Loading of Pond

Liquid manure was first added to the pond on 16 Feb. 1976. Some characteristics of the liquid manure pumped into the pond and of the liquid in the pond are presented in Table 2. The depth of liquid at the platform throughout 1976 is shown in Table 3. Runoff from the surrounding area resulted in variable dilutions of the liquid manure in the pond.

RESULTS AND DISCUSSION

Water-table Elevation

Water levels were measured in all functional wells periodically from December 1975 to April 1981. These values were used to establish isopleths of the water table in the vicinity of the pond. These isopleths are presented in Fig. 1 for 12 Dec. 1976, relative to a reference point 14 m below the lowest point in the pond. As indicated, the principal direction of groundwater flow is from north-northeast towards the south and southwest. The apparent divergence in the flow direction may be the result of greater amounts of infiltration and recharge in the topographically low area in the vicinity of the open pond.

Unfortunately, the platform was shifted by ice pressure during the winter of 1977 so watertable measurements and samples were not obtained from below the pond after December 1976. Water table elevations at the platform during 1976 are presented in Table 3. Also presented are the differences between the levels at the platform and at W1 at each time of measurement. The difference in water table elevation between the platform and W1 increased by about 0.1 m within a week of the time the liquid level reached the platform on 17 Feb. This difference was maintained until early April and subsequently declined to the initial value by early June. During this interval the liquid level did not approach the base of W1 which was 1.35 m above the base of the platform. This suggests that there was a rapid input of water to the water table when manure was first added to the pond but that this input was markedly reduced after about 8 weeks. The liquid level was above the base of W1 during two periods; mid-July to mid-August and from mid-November to the end of the sampling period. During these two intervals the difference in water table level between the platform and W1 was reduced relative to the initial measurement suggesting that the input at W1 was considerably greater than that at the platform at these times. The pond was partially emptied beginning on 23 August and the difference in elevation increased again, approaching the initial value. These data suggest an initial rapid infiltration of liquid to the ground water some 13 m below the bottom of the pond. This reflects the highly permeable nature of the soil materials. There appeared to be a marked reduction in input, however, after about 8 weeks.

Table 2. Some characteristics of liquid manure pumped into pond and of liquid in pond.

	Liquid manure	Liquid in pond† Mean	Liquid in pond† Range
Total solids, $g\ kg^{-1}$	50	nd‡	
NH_4^+, mmol L^{-1}	145	58	42-82
NO_3^-, mmol L^{-1}	0	0	
K^+, mmol L^{-1}	72	nd	
Na^+, mmol L^{-1}	141	nd	
Ca^{2+}, mmol L^{-1}	12	nd	
Mg^{2+}, mmol L^{-1}	10	nd	
Cl^-, mmol L^{-1}	nd‡	43	28-68
pH	8.4	nd	

† Determined periodically during 1976.
‡ Not determined.

Table 3. Depth of liquid at platform and water table elevations during 1976.

	Depth of liquid at platform†	Water table elevation at platform‡	Difference in water table elevation between platform and W1
		m	
11 Dec. 1975	0	2.09	0.61
16 Dec. 1975	0	2.08	0.60
11 Feb. 1976	0	1.85	0.57
17 Feb. 1976	0.05	1.97	0.64
24 Feb. 1976	0.12	2.18	0.71
10 Mar. 1976	0.33	2.32	0.65
24 Mar. 1976	0.33	2.53	0.72
7 Apr. 1976	0.45	2.56	0.69
12 May 1976	0.58	2.62	0.66
2 June 1976	0.60	2.64	0.62
23 June 1976	0.53	2.66	0.61
30 June 1976	0.97	2.66	0.60
7 July 1976	1.27	2.65	0.59
28 July 1976	1.52	2.66	0.54
11 Aug. 1976	1.52	2.63	0.56
31 Aug. 1976	0.64	2.67	0.57
21 Sept. 1976	0.70	2.64	0.58
19 Oct. 1976	1.07	2.57	0.59
16 Nov. 1976	1.38	2.50	0.55
14 Dec. 1976	1.60	2.35	0.48

† Soil level at W1 was 1.35 m above that at platform.
‡ Distance above reference point 14 m below lowest point in pond.

Soil Moisture Content

Moisture contents ($m^3\ m^{-3}$) in the soil below the sand at the platform site are presented in Fig. 3. The moisture

2-37

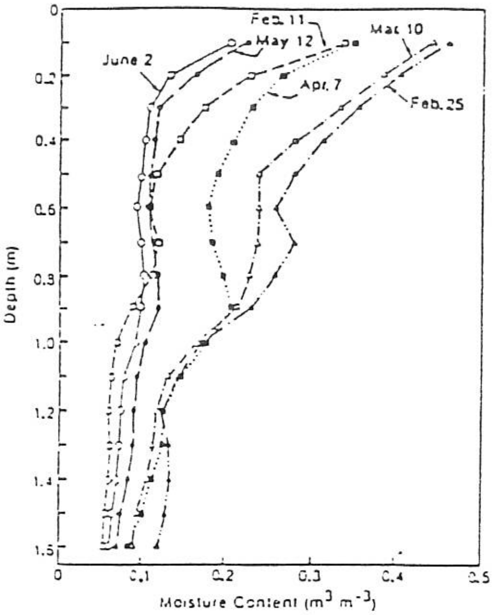


Fig. 3. Moisture content of soil beneath floor of pond before and after addition of manure.

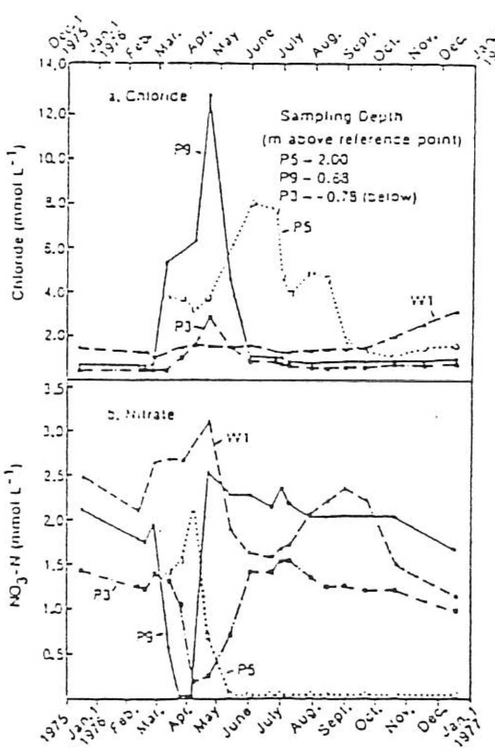


Fig. 4. Chloride and NO_3-N concentrations in groundwater below manure storage pond.

content in the upper layers was high on 11 Feb. due to recent snowmelt but was close to the estimated field capacity at depths of 0.4 m or greater. There was a major increase in moisture content on 25 February, 1 week after the liquid had reached the platform. This increase was evident at all depths measured. The moisture content on 10 March was less than that on 25 February particularly in the upper layers. This trend was further evident on 7 April and by 12 May the moisture content was markedly reduced at all depths. There was a small decrease in moisture content between 12 May and 2 June but no further change after 2 June. The somewhat higher content at the 0.1-m depth may have been due to inclusion of water in the pond within the sphere of influence of the moisture gauge. This instrument is not normally used for measurements at less than 0.2-m depth below the soil surface.

The moisture content profiles indicate a marked reduction in infiltration rate within 4 weeks of manure addition. Within 12 weeks the infiltration rate was reduced to less than the hydraulic conductivity of the soil at a volumetric moisture content of about 0.1 m m^{-3}. Using a model developed by McBride and MacIntosh (1984), the soil water potential for this soil at a volumetric moisture content of 0.1 m m^{-3} is approximately −30 kPa. Assuming a saturated hydraulic conductivity for the soil material of 4×10^{-4} m s^{-1} (a very high value), the unsaturated hydraulic conductivity at −30 kPa estimated by the method of Campbell (1974) would be less than 10^{-9} m s^{-1}. According to DeTar (1979), a pond can be considered sealed if the infiltration rate is less than 10^{-8} m s^{-1}. Thus according to this calculation, which we consider to be conservative, it can be concluded that this pond became effectively sealed within 12 weeks of initial liquid manure addition.

Elemental Content of Water

SOIL WATER

Samples of soil water were obtained from points 0.15 and 0.45 m below the bottom of the pond on 25 February. Samples could not be obtained at greater depths or at later times due to the lower soil moisture content. The NH_4-N, Cl and NO_3-N contents of the samples obtained averaged 93.8, 66.2 and 0 mmol L^{-1} respectively. These values are close to the maximum concentrations in samples taken periodically from the pond (Table 2).

GROUNDWATER BELOW POND

Chloride and nitrate concentrations in the groundwater directly below the platform (P 3, P 5 and P 9) and at W1 during 1976 are presented in Fig. 4a and b. The depth of sampling relative to the reference point (14 m below lowest point in pond) for each of the three wells is shown in Fig. 4. When liquid manure was first added to the pond, P5 was slightly above the water table whereas P9 and P3 were approximately 1.25 and 2.75 m below respectively.

The Cl concentrations at P9 increased rapidly within 3 weeks of manure addition, reached a peak 9 weeks later and then declined to close to the initial concentration by 14 weeks. A similar but less pronounced increase occurred at P3, 2.75 m below the water table.

The first sample was obtained from P5 on 10 Mar. 1976 when the water table rose due to input from the pond. The Cl concentration at this point was lower than that at P9 at this time (Fig. 4a). It remained relatively constant as the concentration at P9 reached a peak, but subsequently increased reaching a peak on 2 June when the concentration at P9 had declined to the initial value.

The concentration at P5 declined slowly, returning to value of P9 in October. This behavior would seem anomalous since P5 is a shallower sampling point than P9. The probable explanation is that lateral flow of ground water was occurring more rapidly than the vertical infiltration of the manure. The platform was located about 1.5 m above the lowest point of the pond. Thus infiltration of liquid would occur first some distance from the platform. When this reached the groundwater, lateral flow would occur toward the platform. This lateral flow would raise the water table at P5 to a level that allowed samples to be taken. The water being sampled, however, would be primarily that which had been in the capillary fringe rather than that from vertical infiltration. Only after sufficient mixing time would the Cl increase at P5. This hypothesis is supported by the presence of a gravel layer at about the same depth as P9 (Table 1).

The Cl concentration at W1 was initially somewhat higher than that at the platform and remained reasonably constant until October when an increase was evident (Fig. 4a). This increase may have been due to groundwater movement, which was generally in the direction of W1 (Fig. 1) or to direct input in the area of W1.

The NO_3-N concentration in the groundwater in the region of the pond is generally high, probably due to the application of high rates of manure to surrounding fields in previous years. The NO_3-N concentration in the groundwater at P9 decreased rapidly following addition of manure, and was below detection limits from 24 March to 7 April, following which it increased to the initial values on 22 April where it remained for the duration of the sampling (Fig. 4b). The concentration at P3 followed a similar pattern although the decline was delayed and did not reach nondetectable values. As with Cl, there was a delay in the effect at P5 where the NO_3-N concentration did not decrease until 7 April. The concentration became non-detectable by 12 May and remained so for the duration of the sampling period (Fig. 4b).

The reduction in NO_3-N may have occurred due to dilution with incoming liquid from the pond or to denitrification arising from an input of readily available carbon. The latter is considered more likely because of the very high inputs that would be required to reduce the concentration to a nondetectable value by dilution alone. The occurrence of denitrification is also suggested by the fact that NO_3-N concentrations at P5 remained low for at least 26 weeks. While some delay in reestablishment of initial levels would be expected if the main groundwater flow was below the depth of P5, the Cl concentrations at this depth decreased to initial values within 16 weeks. This suggests that a NO_3-N sink, probably denitrification, was present in the upper few centimeters of the groundwater.

The NO_3-N concentration at W1 decreased in May, increased again in July, then declined towards the end of the sampling period. The decline in May could be due to movement of NO_3-depleted groundwater from beneath the pond. As this supply of depleted groundwater diminished (due to reduced infiltration of manure) the concentration increased again. Towards the end of the sampling period there would be direct input of manure at W1 resulting in a decline due to dilution and/or denitrification.

Table 4. NH_4-N concentrations (mmol L^{-1}) in groundwater below manure storage pond.

Date	Sampling position†		
	P5	P9	W8
11 Feb. 1976	ns	nd	ns
24 Feb. 1976	ns	0.02	ns
24 Mar. 1976	nd	0.02	ns
22 Apr. 1976	nd	nd	ns
12 May 1976	nd	nd	ns
2 June 1976	6.8	nd	ns
23 June 1976	7.1	nd	ns
30 June 1976	5.0	nd	ns
7 July 1976	4.3	nd	ns
28 July 1976	6.4	nd	ns
11 Aug. 1976	4.8	nd	ns
31 Aug. 1976	3.4	nd	ns
21 Sept. 1976	2.8	nd	0.4
19 Oct. 1976	1.5	nd	0.6
16 Nov. 1976	0.6	nd	0.5
14 Dec. 1976	0.4	nd	0.3
17 Mar. 1977	ns	ns	0.6
27 June 1977	ns	ns	0.6
9 May 1978	ns	ns	0.1
14 July 1978	ns	ns	0.1
24 Nov. 1978	ns	ns	nd

† ns = not sampled; nd = not detectable <0.02.

The NH_4-N concentration in groundwater was below the detection level for the method used prior to manure addition but was detectable at P9 on 24 February (Table 4) and 24 March after which it declined again. At no time was NH_4-N detectable at P3 or W1. At P5 NH_4-N was first detectable on 2 June, remained reasonably constant until September when it declined again. This pattern is similar to that for Cl although less marked due likely to adsorption of NH_4^+ ions on the limited exchange sites present.

GROUNDWATER ADJACENT TO POND

Chloride and NO_3-N concentrations in ground water at five sampling positions surrounding the pond during 1976 through 1980 are shown in Fig. 5. As shown in Fig. 1, positions W2, W5 and W10 are upstream from the pond in terms of groundwater flow whereas W8 and W3 are downstream. The pipe at W3 was broken in the summer of 1978 so no further samples could be obtained from that position.

The Cl concentration at W8 on the downstream edge of the pond was very similar to that at W5 and W10 on the upstream edge throughout the sampling period (Fig. 5a). This indicated that the elevated concentration of Cl observed at the platform was diluted to essentially background values before reaching this position. Likewise, there was no evidence of elevated Cl concentrations at W3; the values at this position were very similar to those at W2.

The NO_3-N concentrations at W8 were similar to those at W5 and W10 at the first two sampling times, declined to very low values in late 1976, remained low until July 1978 and then increased again to values similar to W5 and W10 (Fig. 5b). Because there was no apparent elevation of Cl at W8, this decreased NO_3-N can not be explained by direct input of liquid from the

2-39

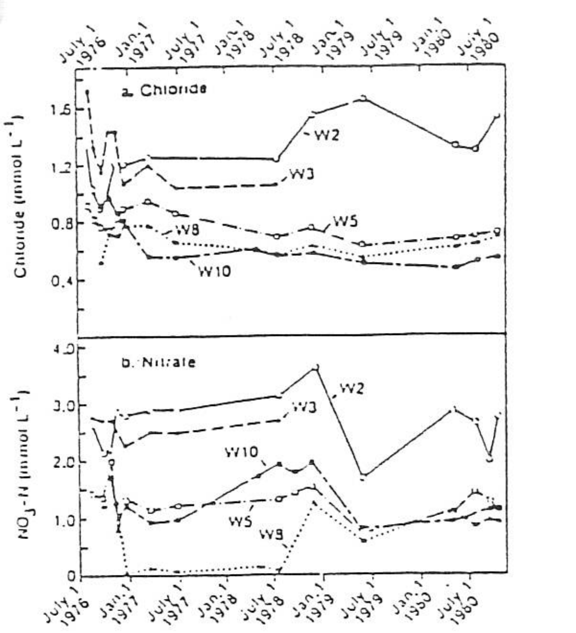


Fig. 5. Chloride and NO_3-N concentrations in groundwater at several points adjacent to manure storage pond.

pond. It is apparent that NO_3-N was being removed from the groundwater as it flowed under the pond during this period, most probably by denitrification. The NO_3-N depression persisted for about 2 yr at W8 (Fig. 5b) but only 8 to 12 weeks at the platform (Fig. 4b). Since the platform was upstream from the major portion of the pond, the NO_3-N concentrations would be expected to return to background values much more quickly than would downstream points such as at W8. There was no depression of NO_3-N concentrations at W3 where the values were similar to those at W2.

CONCLUSION

Based on the soil moisture measurements and elemental analyses of groundwater, it can be concluded that this pond became effectively sealed to infiltration within 12 weeks of the addition of manure. There was an initial rapid flush of liquid but some sealing effect was evident within 2 weeks. This initial rapid flush caused marked elevations of Cl in the groundwater directly below the pond for a short period. The input of Cl was not sufficient, however, to result in any evident contamination of groundwater beyond the edges of the pond.

There is evidence that input of readily oxidizable carbon to the groundwater resulted in denitrification which effectively depleted the NO_3-N from the groundwater flowing under the pond. This effect, which disappeared after about 2 yr, was evident only in very close proximity to the pond. Thus it appears that the input from this pond had no effect on the downstream groundwater quality.

We consider that this pond was a severe test of the suitability of unlined earthen manure storage facilities because of the coarse nature of the soil material and the relatively dilute manure. The initial flush observed here would be of concern only if groundwater was being withdrawn for consumption from a point very close to the pond, in which case elevated Cl concentrations might be present. It is very unlikely that NO_3-N contamination of groundwater would occur from such ponds while they are in use. There would be a considerable accumulation of NH_4-N in the soil below the pond. If this soil was allowed to become aerobic, high concentrations of NO_3-N could occur.

ACKNOWLEDGMENT

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2-40

Self-Sealing of Earthen Liquid Manure Storage Ponds: II. Rate and Mechanism of Sealing[1]

See Conclusion at end of paper

J. G. ROWSELL, M. H. MILLER, AND P. H. GROENEVELT[2]

ABSTRACT

A laboratory study was conducted to determine the degree and rate of sealing of the soil surface where liquid beef (*Bos taurus*) manure with solids content of 50 g kg^{-1} was infiltrated into cores of a sandy loam, a loam, and a clay soil under hydraulic heads of 1 and 5 m. A second experiment explored the mechanism of sealing. The infiltration rate was expressed in the logarithmic form of the Kostiakov equation: $\log q = A + b \log t$ where q = infiltration rate (m s^{-1}) and t = time (s). In this relation A represents the log of the initial infiltration rate (at 1.0 s) and b is the rate of change in rate with time on a logarithmic scale. The infiltration rate decreased rapidly with time and reached a value of 10^{-8} m s^{-1} or less within 30 d on all soils at 1-m hydraulic head. This rate is considered to indicate an essentially impermeable system. At a 5-m head the infiltration rate reached 10^{-8} m s^{-1} within 10 d on the clay soil but required periods > 30 d on the other two soils. A physical blocking of pores was the major mechanism of sealing. The rate of reduction of infiltration into the loam soil was similar for sterilized manure indicating that in this study biological activity was not a factor. Infiltration of a salt solution having similar cationic constituents as the manure remained constant over time indicating that dispersion of soil particles was not a factor.

Additional Index Words: soil texture, hydraulic head, groundwater contamination.

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In Ontario, 26-week manure storage capacity is recommended to avoid environmental contamination resulting from winter spreading. Unlined earthen ponds are a low cost alternative to concrete and metal manure storage structures but they are suspect because of the possibility of seepage of pond contents. The subsequent contamination of groundwater could render it unsafe for human or livestock consumption.

The infiltration of pond contents into underlying soil materials has been measured at full-sized ponds (Clark, 1975; Davis et al., 1973; Loehr and Ruf, 1968; Robinson, 1973; Miller et al., 1976, 1984), in pilot scale lagoons (Hart and Turner, 1965; Hills, 1976) and in soil columns in the laboratory (Travis et al., 1971). The hydraulic conductivity of soil columns recovered from the bottom of a manure storage pond has also been measured (Chang et al., 1974). Substantial decreases in infiltration rate with time occurred in all cases but the magnitude of the decrease and the time required to achieve such a decrease has been inconsistent between investigations.

Monitoring of pond constituents in groundwater beneath manure storage ponds also lead researchers (Oliver et al., 1974; Robinson, 1973; Sewell et al., 1975) to conclude that the infiltration rate of pond contents decreased with time but there is little consensus as to the rate or degree of this decrease. Studies undertaken to determine the effects of soil type (Chang et al., 1974; DeTar, 1979; Hills, 1976; Travis et al., 1971) and the hydraulic head of the infiltrant (Hills, 1976) on the infiltration rate have also produced contradicting results.

Physical, chemical, and biological mechanisms have been proposed to explain the reduction in infiltration rates. Infiltration studies which did not involve manure have indicated that dispersion of soil particles by Na^+ (Matthew and Harms, 1969) and biological activity (Allison, 1947; Avnimelech and Nevo, 1964; McCalla, 1950) affect infiltration rate in soils. Mechanisms suggested for sealing manure ponds included blockage of pores by organic particles followed by further blockage with microbial products (Chang et al., 1974; Tollner et al., 1983). These workers attributed little importance to the chemical effect, i.e. dispersion of soil particles. Travis et al. (1971) reported that infiltration of a lagoon-water simulant caused sealing in a silty clay loam soil (300 g kg^{-1} clay, 500 g kg^{-1} silt), presumably by dispersion, but not in a loam soil (200 g kg^{-1} clay, 440 g kg^{-1} silt). Hills (1976) suggested that chemical effects were important in soils with more than 75 g kg^{-1} clay and 305 g kg^{-1} silt. He indicated that the initial sealing was due to physical blocking of pores while the final sealing was caused by excretions from anaerobic microorganisms.

This paper describes two laboratory experiments which were conducted in conjunction with a subfloor groundwater quality monitoring study at an existing unlined earthen manure storage pond (Miller et al., 1985). The objectives of these laboratory investigations were to determine the effects of hydraulic head and type of soil material on the infiltration of liquid manure into soil materials and to determine the mechanism by which the reduction of the infiltration rate occurs with time.

EXPERIMENTAL PROCEDURE

Effects of Soil Type and Hydraulic Head

Samples of three different soils materials were collected from separate soil profiles at depths where pedogenic processes had not altered the material significantly (Table 1). All soils effervesced vigorously when tested with HCl indicating the presence of carbonates. The sandy loam and loam soils were collected in bulk lots. Cores of the clay soil were taken by pressing sections of ABS plastic pipe (150-mm diam by 150-mm long) 110 mm into the massive clay with the aid of a truck-mounted hydraulic press. All soils were stone-free; the clay soil exhibited no evidence of varying and was assumed to be a clay till.

The sandy loam and loam soils were packed into sections of ABS plastic pipe (45-mm diam by 150-mm long) to bulk densities of 1.4 and 1.3 Mg m^{-3} respectively and a depth of 110 mm.

The inner sidewalls of the sections of ABS pipe used to contain the sandy loam and loam soils were coated with high-vacuum silicon-based grease to fill gaps between the soil and the sidewall. All columns were allowed to absorb water from their base for 24 h and were then allowed to drain under gravity for another 24 h prior to the beginning of infiltration. Inspection of trial columns following infiltration of manure spiked with the fluorescent dye uranine and inspection of experimental columns at the conclusion of infiltration studies indicated

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Table 1. Properties of soil materials used for infiltration studies.

Soil	Sand	Silt	Clay	Bulk density	pH	CEC	Volumetric moisture content at water pressures, kPa of −33.3	−10	−5
	g kg⁻¹			Mg m⁻³		mmol (+) kg⁻¹	m³ m⁻³		
Sandy loam	524	426	50	1.4	8.2	101.3	0.095	0.342	0.380
Loam	370	479	151	1.3	7.5	184.7	0.269	0.370	0.419
Clay	80	258	662	1.3	8.0	265.6	ND†	ND	ND

† ND — No data.

that there were no gaps between the soil and sidewall to bias infiltration rates.

The manure came from a beef (*Bos taurus*) feedlot where animals are fed a diet which includes a high proportion of wastes from a potato (*Solanum tuberosum*) processing plant. "Peeling" of potatoes at the plant is accomplished using sodium hydroxide. The resultant wastes, and hence the feed, and manure, contain abnormally high levels of sodium. Manure is collected at the feedlot below slatted floors as a slurry. It is then centrifuged, the solids are removed to another site for composting and the supernatant is held in a pond until land application. The manure used in this experiment was the supernatant following centrifugation and contained 14.5, 7.2, 14.2, 1.2, and 1.0 mmol L⁻¹ of NH_4^+, K^+, Na^+, Ca^{2+}, and Mg^{2+}, respectively. It had a pH of 8.4 and a solids content of 50 g kg⁻¹. The manure was held at approximately 4°C until used.

The apparatus consisted of paired graduated 50-mL constant-head burettes which could be operated independently to allow filling of empty burettes with minimal relief of head (Fig. 1). Regulated air pressure was applied at the air inlets to give the desired hydraulic head. Three sets of this apparatus delivered manure at a 1-m head and three sets at a 5-m head at the soil surface. A 40-mm space above the soil ensured that the pressure was distributed evenly over the soil surface.

Six sets (three soil types and two hydraulic heads for a total of six treatments) were operated simultaneously to form a replicate. The experiment included three replicates. Infiltration was allowed to continue over an approximately 31-d period in each replicate. Infiltration was terminated when accumulating gases (presumably methane and carbon dioxide) interrupted the continuity of the manure in the

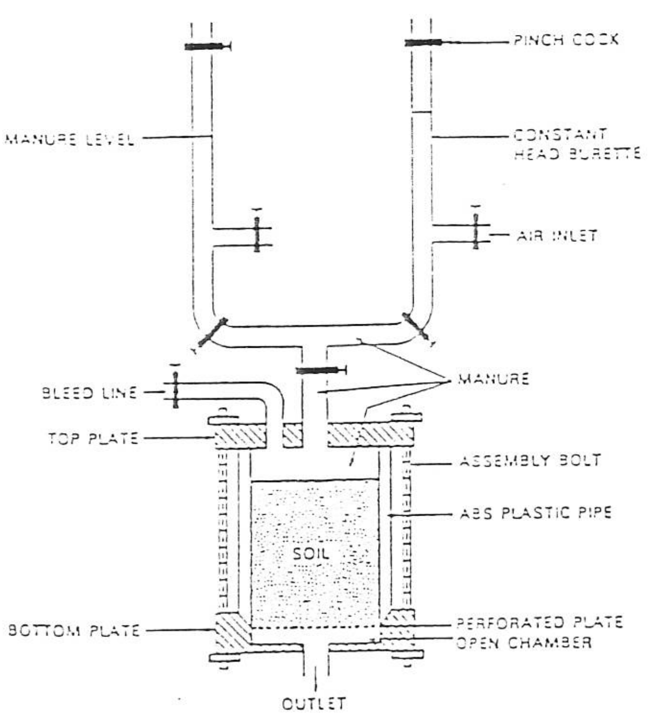

Fig. 1. Diagram of apparatus for infiltration of manure into soil columns under constant head.

apparatus at an unacceptable frequency. The quantity of manure that had infiltrated was measured at irregular intervals governed by the rate of decrease of the manure in the burettes. Infiltration rates were calculated using the relation $q = Q/Zt$ where q = infiltration rate (m s⁻¹), Q = quantity infiltrated (m³), Z = cross-sectional area of column (m²), and t = time (s).

The infiltration rate was related to time using the Kostiakov infiltration equation $q = at^b$ where a and b are constants. This equation yields a linear relation when log q is plotted against log t.

$$\log_{10} q = A + b \log_{10} t$$

The value of A (= log a), the intercept, represents the infiltration rate at t = 1.0 s while b, the slope, represents the rate of decrease in infiltration rate with time (on log scale).

Regression equations were developed for each core and analysis of variance was performed on the slopes and the intercepts of the regression equations. Tukey's honestly significant difference technique (Steel and Torrie, 1960) was used to compare means when significant differences (P = 0.05) were indicated by the analysis of variance.

The Mechanism of Sealing and Location of the Seal

The mechanism of sealing was investigated by measuring the infiltration rates of several liquids into either loam soil or glass beads. The treatments were: manure at 1-m hydraulic head into loam soil; sterilized manure at 1-m head into loam soil; sterilized, clarified manure at 0.25-m head into loam soil; sterilized manure at 1-m head into glass beads; a salt solution containing similar quantities of cations (as chloride salts) as the manure at 0.25-m head into loam soil; and 0.005 M $CaSO_4$ into loam soil at 0.25-m head.

The apparatus used was the same as described previously but with the following exceptions. The sterilized clarified manure was delivered from paired 500-mL burettes with a fixed height air inlet. The hydraulic head was set by the height of the air inlet above the soil surface. The salt and 0.005 M $CaSO_4$ solutions were delivered from glass carboys with the hydraulic head set in the same manner as for the sterilized clarified manure. Efflux was calculated for these columns rather than influx because of the lack of a graduated constant head

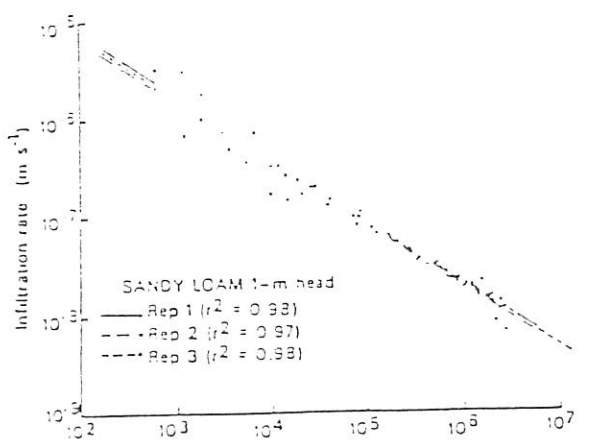

Fig. 2. Infiltration-time relationship for infiltration of liquid manure into sandy loam soil at 1-m head.

2-42

Table 2. Influence of soil material and hydraulic head on infiltration rate constants.

Soil	Intercept (A)†		Slope (b)†	
	Hydraulic head		Hydraulic head	
	1 m	5 m	1 m	5 m
Sandy loam	−4.012b‡	−3.559b	−0.615bc‡	−0.613bc
Loam	−3.624ab	−2.954a	−0.685c	−0.759c
Clay	−5.681c	−5.056c	−0.425a	−0.492ab

† Intercept and slope refer to A and b respectively in equation $\log_{10} q = A + b \log_{10} t$ where q = infiltration rate (m s^{-1}) and t = time (s).
‡ Values for each parameter followed by same letter are not significantly different at $P = 0.05$ using Tukey's honestly significant difference (Steel and Torrie, 1960).

vessel of sufficient volume. Glass beads with a mean diameter of 300 μm were used instead of the loam soil in one treatment. Columns were prepared in the same manner as in the previously described experiment.

Manure was "sterilized" by addition of a formaldehyde solution (0.4 L L^{-1}) to constitute 2% of the total volume. A separate microbial oxygen uptake study indicated that the formaldehyde solution must comprise 2% of the final volume to ensure that microbial oxygen uptake in the manure was less than 1 mL kg^{-1} h^{-1} at 25°C. Both the soil and the 0.005 M $CaSO_4$ solution contained 0.2% of the formaldehyde solution to prevent possible changes in permeability due to microbial activity.

Sterilized, clarified manure was prepared by centrifuging sterilized manure at 20 000 g for 30 min and passing the supernatant through a no. 2 filter paper to remove floating solids. The sterilized clarified manure appeared clear but yellowish brown in color.

Infiltration rates were calculated and regression equations developed as described previously.

RESULTS AND DISCUSSION

Effects of Soil Type and Hydraulic Head

Regression analysis demonstrated an excellent fit of the infiltration rate of liquid cattle manure into soil over time to the model

$$\log_{10} q = A + b \log_{10} t$$

where q is the infiltration rate (m s^{-1}) at time t (s). Of the 18 regressions developed (six treatments and three replicates), eight had r^2 values of 0.97 or higher, seven had values between 0.90 and 0.97, and none was < 0.77. The relations for the sandy loam soil at 1-m and 5-m heads are shown in Fig. 2 and 3, respectively.

Analysis of variance indicated that there was a significant increase in initial infiltration rate (less negative intercept value) with increased hydraulic head as would be expected. Comparison of individual means (Table 2) indicated that none of the within-soil comparisons of intercept and slope were significant ($P = 0.05$) although the differences for the loam and clay soils were significant at $P = 0.10$. The intercept values for the clay soil are significantly lower (more negative) than those for the other two soils indicating a much lower early infiltration rate.

The rate of decrease of the infiltration rate, b, was not significantly affected by hyraulic head even at $P = 0.10$. One might expect that the higher early infiltration rate with the higher head would result in a more rapid sealing, particularly if the mechanism is a physical blocking of pores. The slope of the regression was somewhat greater for the 5-m than the 1-m head but the difference did not approach significance. The rate of decrease in infiltration on the clay soil was considerably less than in the other two soils (Table 2) probably reflecting the much lower early infiltration rate.

Table 3. Infiltration rates of manure into three soil materials at three times.

	Hydraulic head	Time		
		10 min	1 d	30 d
		m s^{-1}		
Sandy loam	1 m	1.90 ± 0.16 × 10[illegible]	8.91 ± 0.44 × 10[illegible]	1.10 ± 0.04 × 10[illegible]
	5 m	2.68 ± 1.04 × 10[illegible]	1.23 ± 0.20 × 10[illegible]	1.51 ± 0.12 × 10[illegible]
Loam	1 m	3.24 ± 1.65 × 10[illegible]	10.0 ± 0.31 × 10[illegible]	9.94 ± 2.06 × 10[illegible]
	5 m	1.15 ± 1.04 × 10[illegible]	2.21 ± 1.27 × 10[illegible]	1.57 ± 0.52 × 10[illegible]
Clay	1 m	1.52 ± 0.91 × 10[illegible]	1.75 ± 0.75 × 10[illegible]	4.08 ± 1.54 × 10[illegible]
	5 m	4.03 ± 2.74 × 10[illegible]	4.20 ± 2.00 × 10[illegible]	6.25 ± 3.27 × 10[illegible]

The actual infiltration rates (m s^{-1}) as calculated from the equations are presented in Table 3 for three times: 10 min, the earliest measurement time; 1 d; and 30 d. DeTar (1979) has suggested that material with an infiltration rate of 10^{-8} m s^{-1} can be considered impermeable. Infiltration rates of all three soils at 1-m head and the clay soil at 5-m head were very close to or less than this value after 30 d of infiltration. The infiltration rate on the clay soil reached this value after 3 and 10 d for the 1-m and 5-m heads respectively. If the same rate of decrease in infiltration rate occurred beyond the 30-d period of measurement, the loam and sandy loam soils exposed to a 5-m head would reach a value of 10^{-8} m s^{-1} after 51 and 59 d, respectively. It must be emphasized that the latter two values represent extrapolations beyond the measured times.

Mechanism of Sealing and Location of the Seal

Relationships between infiltration rate and time similar to those in the previous section were developed for the infiltration of manure into loam soil at 1-m head, sterilized manure into loam soil at 1-m head, sterilized clarified manure into loam soil at 0.25-m head and sterilized manure into glass beads at 1-m head. Of the 12 regressions (four treatments and three replicates) performed using $\log_{10}$ of infiltration rate and $\log_{10}$ of

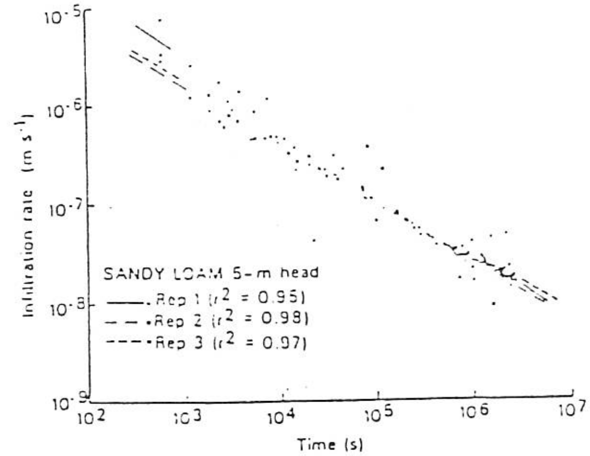

Fig. 3. Infiltration-time relationship for infiltration of liquid manure into sandy loam soil at 5-m head.

2-43

Table 4. Effect of infiltrant on infiltration rate constants.

Infiltrant	Intercept (*A*)	Slope (*b*)
Manure into loam soil at 1-m head	−3.502a†	−0.596a
Sterilized manure into loam soil at 1-m head	−3.871ab	−0.620a
Sterilized clarified manure into loam soil at 0.25-m head	−3.347a	−0.657a
Sterilized manure into glass beads at 1-m head	−4.195b	−0.567a
0.005 *M* $CaSO_4$ into loam soil at 0.25-m head	−5.157‡	0.0003
Salt solution into loam soil at 0.25-m head	−5.161	−0.0103

† Values within a column followed by the same letter are not significantly different ($P = 0.05$) using Tukey's honestly significant difference (Steel & Torrey, 1960).

‡ Salt solution experiments performed separately so statistical comparison cannot be made.

time, 10 had r^2 values better than 0.95 and the remainder were better than 0.83.

There were no significant differences among either the slopes or the intercepts of the regression equations for the infiltration of manure or sterilized manure into the loam soil at 1-m head (Table 4). This is strong evidence that microbial activity did not significantly influence the formation of the partial seal within the 31-d duration of this experiment. It cannot be concluded that microbial activity would not be a significant factor in manure storage pond sealing beyond 31 d.

The coefficients of the regression equations for the sterilized clarified manure were not significantly different from those for the unamended manure (Table 4). It is unclear why the sterilized clarified manure passed readily through a no. 2 filter paper but caused a partial seal in the loam soil. A probable explanation is that dispersed organic colloids which passed through the filter paper flocculated upon entering the calcareous soil due to a change in pH and/or cationic constituents, particularly Ca^{2+} and Na^{+}. The flocculated colloids may then have blocked the pores of the soil.

The initial infiltration rate into the glass beads was significantly lower than into the soil. The rate of decrease was somewhat, but not significantly, lower. This suggests that deflocculation of soil particles or absorption of manure on soil particles was not a significant factor because these processes would not occur with the glass beads.

The slopes of the infiltration rate-time relations for the 0.005 *M* $CaSO_4$ and the solution containing similar cationic constituents as the manure did not differ significantly from zero (Table 4), indicating that there was no tendency for either of these solutions to cause sealing. Likewise there was no difference in initial infiltration rates (Table 4). This suggests that in this loam soil (150 g kg^{-1} clay, 480 g kg^{-1} silt) there was no dispersive effect of the salt constituents.

Post-infiltration reflected-light microscopy of longitudinal cross sections of columns from the soil type-hydraulic head experiment revealed little color change over depths > 5 mm. Cross sectioned columns of sandy loam soil used in the 1-m and 5-m hydraulic head treatments showed a surface mat of organic material. In the 5-m hydraulic head treatments, the top 2-mm layer of soil exhibited little enrichment of organic matter. An approximately 3-mm layer immediately below that was considerably darker than the soil above and below. The darkness was attributed to organic matter enrichment. Fine particles may have entered the sandy loam soil during the initial stages of infiltration. Development of the surface mat may then have prevented further entry of particulates. Water and other soluble manure components may have carried the particulates which had already entered the soil downward slowly resulting in the light layer immediately below the surface. This layer was not found in columns of the other soil types presumably because the pores were too small to transmit the appropriate particles. Why this separation of organic layers did not occur in the 1-m hydraulic head-sandy loam soil treatments is unknown.

The zone of darkening immediately below the surface was approximately 6-mm thick in the loam soil treatments and 3-mm thick in the clay soil treatments.

Considerable difference was found among soil types in the thickness and consistency of the mat that formed over the soil surface. A firm mat approximately 10-mm thick was found in the sandy loam soil treatments whereas a thickened slurry of only a few millimeters covered the clay soil after infiltration. This slurry was readily poured off of the clay soil surface. The mat over the loam soil was intermediate between these extremes.

Physical blockage of pores both at the surface and in the mat on the surface appears to be the principle mechanism by which the seal formed when manure infiltrated into the sandy loam and loam soil materials. Rapid blocking of soil pores in the surface may have reduced infiltration rates into the clay soil sufficiently so that a surface mat of excluded particles could not accumulate.

CONCLUSION

The results of this study support the conclusions of Miller et al., (1985) that a liquid manure storage pond will effectively self-seal even with sandy materials. The initial infiltration rate and the length of time required for the seal to develop will be greater for coarser-textured materials. Because the total amount of material escaping from the pond before the seal forms will be greater, more care needs to be exercised in establishing ponds on these materials to ensure that contaminants do not reach water supplies.

The mechanism of sealing in these studies was a physical blocking of pores by the particulate material in the manure. Neither biological activity nor dispersion of soil particles appeared to be important. While biological activity will probably further decrease the permeability with time, the physical mechanism appears to be sufficient to reduce the infiltration to an acceptable rate.

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BIOLOGICAL SEALING of LAGOONS and PONDS

BIOLOGICAL SEALING

McCalla[1/] discovered the phenomenon of biological sealing in 1950 in the San Joaquin Valley while attempting to recharge ground water through wells. He attributed the sealing to biological activity. His theory was proved when he used sterile water and sealing did not occur. Sealing is also known to occur in soils beneath feedlots even though the feedlots may be located on gravelly material. This organic seal is due primarily to the activity of micro-organisms under anaerobic conditions.

Sealing is caused by both physical and biological processes. The physical process is one of filtration and sedimentation of suspended particles that clog the soil pores. Physical sealing occurs during the initial filling of a lagoon or waste storage pond, but it contributes less to the ultimate sealing than the biological processes. It is important, however, in the storage of solid and slurry manure in which the total solids content is very high and often the proportion of fibrous solids is large.

It is generally agreed that biological sealing is the more important process. In the absence of oxygen when a food source is present, anaerobic micro-organisms multiply rapidly and fill the soil voids. They excrete polysaccharides and polyuronides in the form of gums, waxes, and jells. These byproducts of their metabolism seal the voids very effectively.

Whether a soil is considered sealed and impermeable depends on how the terms are defined. Some states require that permeability not exceed 0.0036 centimeters (cm) per hour or 1 ft per year. Most states do not have such restrictive regulations.

A number of research projects have been conducted in recent years on the sealing effects of animal wastes. Hills[2/] found a final infiltration rate of 0.0032 cm/hour (0.9 ft/year) for loams, silt loams,

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[1/] McCalla, T.M. The influence of micro-organisms and some organic substances on water percolation through a layer of Peorian loess. Soil Sci. 10:175-179. 1945.

[2/] Hills, D.J. Infiltration characteristics from anaerobic lagoons. Water Poll. Control Fed. 48(4):695. 1976.

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NOTES ON LIVESTOCK LAGOON SEALING [1]/

A. Proc of Int Symp on Livestock Wastes, 1971.

1. Nordstedt <u>et al</u>. (U of Florida)
   3-stage dairy lagoon system in coastal plains soil (sandy).
   Depths of lagoons: 12, 3, 4 ft.
   Watertable 1-4 ft below ground surface during sampling.
   Receives 20% of manure from 800 milk cows.
   Some seepage from anaerobic first lagoon at observation wells 15 and 50 ft. away. (NO_3 and salts)
   No seepage 100 ft away and 10 ft deep.
   Lagoon and test wells are above a clay layer which stops vertical seepage.

B. Proc of 3rd Int Symp on Livestock Wastes, 1975.

1. Sewell <u>et al</u>. (U of Tennessee)
   Dairy lagoon overflowing to holding pound in silt loam and sandy loam (lagoon) and silt loam (pond), both with sand below.
   Test wells to at least 18 ft deep and 15-45 ft from lagoon or pond.
   Lagoon seepage reduced markedly after two months. Initially Cl and NO_3 increased in test wells, and reduced to normal levels later.
   Continuous operation did not reduce groundwater quality.

2. Collins <u>et al</u>. (VPI)
   Three swine manure lagoons in sandy loam.
   High watertable at times into lagoon.
   No significant seepage 9 ft from lagoon.

C. Trans. ASAE, 1973.

1. Davis <u>et al</u>. (U of Calif, Riverside)
   Dairy waste pond in soil with infiltration rate of 48 in./day.
   After four months of manure water, infiltration rate reduced to 0.2 in./day.
   Manure slime and biological sludge effectively blocked exfiltration from pond.

D. Proc 4th Int Symp on Livestock Wastes, 1980.

1. Ritter <u>et al</u>. (U of Delaware)
   Swine manure lagoon.
   Some localized seeping (NH_3)
   Self sealing occured.
   Minimum impact on groundwater.

E. Proc of 1974 Cornell Ag. Waste Management Conference.

[1]/ Prepared by R. E. Hermanson, Extension Agricultural Engineer, Washington State University.

1. Baier et al. (Coop. Ext., U of California)
   Studied 17 manure holding ponds with respect to sealing
   Soils: sands, loamy sands, sandy loam, fine sandy loam, loam, clay loam. Used tensionmeters, etc. to determine hydraulic gradient. Analyzed for NO_3, salts, pH, TDS. One poultry, remainder dairy manure ponds. Hydraulic gradient vs. time. At zero no water leached from ponds.
   Ponds normally filled slowly. In more than six months, not enough water leached to wet soil at 60 cm.
   Loam and clay loam - sealed in 3-5 days.
   Fine sandy loam - 10 days.
   Sandy Loam - 33-43 days.
   Loamy sand - 48 days.
   Sand - 53 days.

F. Proc of 1977 Cornell Ag. Waste Management Conference

1. White et al. (Ohio State U)
   Anaerobic lagoons for swine manure.
   Two stages - 12 and 9 ft deep.
   Microbial analysis and EC measurements from wells on each side of facility indicate seepage initially. At end of second year coliform and streptococcus dropped to nearly zero, as did conductivity.

G. Loehr, R.C. 1974. Agricultural Waste Management-Problems, Processes, and Approaches. Academic Press, N.Y.
   "At present groundwater contamination from agricultural sources, is for the most part, below levels that have been demonstrated to cause disease, excessive removal cost, or aesthetic nuisance."

H. Meyer et al. 1973. (U of California, Ag. Extenision - Stanislous, San Joaquin, and Merced Counties)
   Dairy and poultry manure ponds. (lightly loaded)
   Virtually no salt was lost from pond through leaching.
   Manure ponds seal under all soil conditions.
   Sandy loam, loams, and clay loams in less than 30 days.
   Loamy sands in 30-60 days - at high loading rate, sealed in 30 days.
   Seepage in order of 1 mm per day, after 30 days.
   No observable changes in nearby wells and groundwater.
   Not necessary to recommend an artificial pond seal.

I. ASAE Winter Meeting Papers, Dec. 1983.

1. Reese and Loudon. (Michigan State U)
   Conducted a literature study of 22 references on lagoon sealing.
   Important to sealing are soil type and manure total solids concentration. Soil type affects initial sealing time, but all soils sealed.

2. Dalen et al. (Minnesota - SCS, State)
   Investigated a swine and a dairy manure lagoon. (15 ft deep)

No groundwater quality impact
Ammonia and soluble phosphorus in seepage greatly reduced below pond at depth of 5 ft.

3. Barrington and Jutros. (McGill U, Canada)
Four lagoons - clay, loam, fine sand, sand over clay.
Dairy, swine.
Soil sealing by dairy manure was instantaneous and effective.
Swine manure, because of particles rather than short fibers and being more biodegradable, requires finer soil than does dairy manure to seal.
Infiltration rates 10 to 20 x 10^7 cm/sec (0.034 - 0.068 in./day).

Hegg et al. 1979. WRRI Report 78, Clemson U.
Three swine manure lagoons in coastal plain soils.
Lagoons 5-6 ft deep.
Observation wells: 16 to 26 ft deep.
Most wells have no change in water quality. One or two wells show marked change, suggesting nonheterogenous soil.

Observations and conclusions. Years of observation confirm the natural sealability of lagoons receiving livestock manure. The bioseal occurs by growth of microorganism in soil pores. The colloidal slimes plug passageways. Even coarse soils plug in a two-phase process: mechanical, by deposition of fibers and small particles; and microbial as decribed above.

Dairy manure fibers improve the sealing ability of dairy cattle manure and can seal the surface of crop or pastureland if the manure is not incorporated into the soil.

If there is any evidence that a soil will not seal, a compacted clay layer or soil-sealing soil ammendment such as sodium carbonate can be used. Need should be documented, however, by extensive soil borings.

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AN ASAE MEETING PRESENTATION

GROUND WATER QUALITY BENEATH CATTLE FEEDLOTS IN TEXAS

by

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SUMMARY:

At two 40,000 head cattle feedlots, ground water was sampled from the Ogallala Aquifer at 14 or 15 water wells supplying cattle drinking water and irrigation water. Nitrate-nitrogen (NO_3-N) concentrations averaged less than 1.2 mg/L and 5.21 mg/L at Feedlots A and B (maximum value of 9.54 mg/L). Other nutrient and salinity values were also low.

KEYWORDS:

livestock, manure, animal waste, water quality, aquifer, feedyards, playas, nitrate, contaminants, agriculture

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Ground Water Quality Beneath Cattle Feedlots in Texas

by
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Summary

A ground water sampling study was conducted at two cattle feedlots with capacities of 45,000 (Feedlot A) and 42,500 head (Feedlot B), respectively, in Castro and Parmer Counties in the Southern High Plains of Texas. At both feedlots, ground water was sampled from the Ogallala Aquifer at 4 water wells supplying cattle drinking water and from 10 or 11 irrigation wells within a distance of 2/3 to 7/8 mile from the feed pens or playas (natural depressions) used for collection of feedlot runoff. Nitrate-nitrogen (NO_3-N) concentrations averaged less than 1.2 mg/L at Feedlot A (maximum value of 2.23 mg/L) and 5.21 mg/L at Feedlot B (maximum value of 9.54 mg/L). These are below the USEPA primary drinking water standard of 10.0 mg/L NO_3-N. Other nutrient and salinity values were low. The well water in all feedlot wells and in farm irrigation wells appears to be suitable for irrigation, livestock watering and human consumption. There is no evidence of ground water contamination from these two feedyards, built in the late 1960's.

Introduction

The Ogallala Aquifer is a large water-table aquifer that contained approximately 417 million acre feet of fresh ground water in 1990 in the State of Texas. It supports the major irrigated agricultural production base in the state as well as the region's municipal water needs. Water quality in the Ogallala is generally excellent. For example, nitrate-nitrogen concentrations averaged 3.2 ppm and total dissolved solids averaged 591 ppm in 449 public and private water supply wells, according to testing reported by the Texas Department of Health (Anderson and Bernstein, 1983).

The Texas High Plains area which overlies the Ogallala Aquifer accounts for over two-thirds of the irrigated cropland in Texas or nearly 4 million acres. Most of the large commercial feedlots in Texas, including 87 feedlots with over 5,000 head capacity, are located in 26 counties of the Texas High Plains. More than 5 million head of cattle are marketed annually from cattle feedlots on the Texas High Plains. There are also 10 major meat packing plants in the area with a combined annual kill of 4.7 million head, representing nearly one-fourth of the beef cattle slaughter capacity in the nation.

Feedlots were constructed to drain feedlot runoff into playa lakes, which are large, circular natural depressions with clay bottom soil, or into man-made holding ponds. Most of the feedlots have operated under Texas Water Commission (TWC) permits requiring no-discharge of wastewater since the early 1970's. The TWC is currently requiring revised permits for many cattle feedlots under rules adopted in 1987 for all livestock and poultry feeding facilities (TWC, 1987). These rules involve stringent requirements for ground water quality protection, including soil of low permeability for lining of holding ponds and lagoons.

Previous research at cattle feedlots in the High Plains showed that leaching of potential contaminants was retarded by clay soils that form the bottom of playa lakes (Clark, 1975 and Lehman et al., 1970). Miller (1971) measured groundwater quality in the Ogallala Aquifer beneath 80 cattle feedlots in the Texas High Plains. He determined that about one-fourth may have contributed to nitrate levels that approached or exceeded the U.S. Environmental Protection Agency's drinking water standard of 10 mg/L NO_3-N in the immediate vicinity of the feedlots.

The Texas Cattle Feeders Association (TCFA) sponsored a study in January-February, 1990 in which well water from 26 feedlots (total of 730,000 head capacity) in a four-county area of the

Texas High Plains (Randall, Castro, Deaf Smith, and Parmer Counties) was sampled (Sweeten et al., 1990). Cooperating agencies in that study included the Texas Agricultural Extension Service (TAEX) and the High Plains Underground Water Conservation District No. 1 (HPUWCD). One operating well for cattle drinking water supply at each feedlot was sampled. Samples were delivered by airplane to the TAEX Soil and Water Testing Laboratory at Texas A&M University, College Station, on the same day they were collected. Analyses were begun the following day, with priority given to nitrate analysis. The nitrate-nitrogen concentrations ranged from 0.25 to 9.10 mg/L and the mean value was 2.81 $\pm$ 2.37 mg/L (Sweeten et al., 1990). By comparison, the U.S. Environmental Protection Agency standard for public drinking water is 10 mg/L nitrate-nitrogen. Average concentrations of the other constituents were reported in Sweeten et al., 1990.

The present field study was conducted in 1991 using producing water wells within and around two typical feedyards in Castro and Parmer Counties. This field study was designed to determine whether the mineral content of the ground water from the Ogallala Aquifer in the vicinity of the two feedlots has been elevated as a result of possible percolation of the lower quality water held in runoff holding ponds or playas and/or infiltration through the feedlot surface. The main purpose was to determine if these typical cattle feeding operations may have affected the quality of the ground water in the Ogallala Aquifer in the vicinity of the feedlots. Other purposes were to extend the data base of ground water quality data as a reference for any future assessments of feedlot impact, and finally to disseminate the information to cattle feedlot operators, agricultural producers, agency officials and others with a vested interest in preserving the quality of ground water beneath the High Plains.

Materials and Methods

Feedlot Selection

Several criteria were used to select the two cattle feeding operations involved in this study, including feedlot capacity of 5,000 head or more; in operation for at least 20 years; operated under a permit from the Texas Water Commission; surrounded by irrigated farmland with access to operating irrigation wells; and participation in the 1990 feedlot ground water sampling study mentioned previously.

Personnel of the Texas Cattle Feeders Association performed the initial screening of cattle feedlots and identified 13 feedlots that tentatively met most of the criteria. Texas Agricultural Experiment Station (TAES) personnel then visited these feedlots and narrowed the list of candidates to 6 feedlots. Also, surrounding well locations were identified and the suitability of the wells for sampling purposes was determined at the 6 locations. A subsequent field visit was made by TAEX, TAES, TCFA and HPUWCD personnel to each of the feedlots. The following two feedlots were selected:

a. Feedlot A -- Castro County; 45,000 head capacity average; constructed in 1966; located on a playa lake with slightly modified clay bottom for improved channelization and pumping.

b. Feedlot B -- Parmer County; 42,500 head capacity; constructed in 1969; located on a playa that had not been modified.

The volume of ground water in storage in each county in 1990 was estimated at 11.74 and 9.64 million acre-feet, respectively (HPUWCD, 1991). The depth to water table in the vicinities of both feedlots ranges from 270 to 320 feet and the aquifer thickness ranges from 100 to 120 feet.

At Feedlot A, 4 wells were sampled on-site while 10 irrigation wells were sampled off site to determine if water quality was similar to the feedlot production wells. The direction of ground water flow was estimated to be from northeast to southwest, based on previous data of water surface elevations in District observation wells measured on a routine basis. Accordingly, 3 irrigation wells were considered to be essentially upgradient and 7 wells were considered to be downgradient from the playa lake on the feedlot. The distance of each off-site (farm irrigation) well from the center of the feedlot was estimated cartographically.

At Feedlot B, the estimated direction of ground water flow was southwest to northeast. Four (4) feedlot wells were sampled along with 4 farm irrigation wells that were considered upgradient and 7 irrigation wells that were considered downgradient. Two wells were designated as "upgradient" or "downgradient" in relation to the off-site playa southeast of the feedlot used for feedlot runoff storage.

Each well to be sampled was identified according to legal description and well number. A permission form was completed for each well by the well owner or operator, under the coordination of the County Extension Agent-Agriculture, TAEX. Locations of wells were reported by Sweeten et al. (1991).

Sample Collection Methods for Well Water

All sampling was conducted by two technicians with HPUWCD in accordance with a quality assurance/quality control (QA/QC) plan of that agency. They were assisted in the sampling program by an agricultural engineer with TAES. Special care and attention was given to the collection of water samples to assure that the wells were properly purged, so that the water samples were truly representative of the quality of water in the Ogallala Aquifer. In addition to ground water samples, wastewater (feedlot runoff) samples were collected from the playas used for runoff collection and storage during the sampling period. At Feedlot B, another playa basin southeast of the feedlot that was used for supplemental storage and irrigation of feedlot runoff was sampled also.

All samples taken were from wells operating in excess of 6 hours with the exception of the on-demand wells at Feedlot A and one irrigation well at Feedlot A. In these cases, the wells were in manual operation for approximately 20 minutes before tests for sampling stability were initiated.

Before the water samples were collected for analysis, a water stream from the well was tested at 5 minute intervals, for pH, conductance and temperature. These tests were conducted to assure that the wells had been properly purged and that steady state conditions were reached. Alkalinity was measured in the field by titration of a 50 milliliter (mL) sample with 0.02 N sulfuric acid. A fecal coliform test was also initiated.

Three one-liter (1 L) water samples were taken and two were acidified in the field to stabilize selected elements prior to packing in ice for preservation and transportation to the Environmental Science Laboratory (ESL) at Texas Tech University within 12 hours after collection. The 3 one-liter samples were analyzed by the ESL within 48 hours after collection in accordance with USEPA-approved standard QA/QC procedures. The water samples from the feedlot production wells, irrigation wells and playas were analyzed in the laboratory for 8 constituents, according to USEPA-approved standard methods.

Sampling Period

The sampling study of ground water from the Ogallala Aquifer from beneath the two feedlots and the immediately surrounding irrigation wells was conducted during a 30-day period (June 24 through July 23, 1991). The feedlot wells are operated almost continuously throughout the year. The sampling period coincided with the peak seasonal use of irrigation water. Consequently, aquifer drawdown and cones of depression should have been well-developed around each well, and it is expected this would draw any contaminant plumes (if present) from a substantial distance in all directions directly toward the well. Wastewater samples were taken from playas at the end of the study.

Results

Feedlot A--Castro County

Data from on-site field measurements of pH, temperature, conductance (EC), and total alkalinity (expressed as mg/L of calcium carbonate) for Feedlot A are presented in Table 1. The pH of ground water ranged from 6.83 to 7.54 and averaged 7.25 ± 0.19 (mean plus or minus one standard deviation) for all wells sampled. The mean pH values for the feedlot wells and all farm irrigation wells were identical.

Temperature of all ground water samples averaged 19.4 ± 1.0 degrees C. The feedlot wells and farm wells whether upgradient or downgradient averaged within one standard deviation of the overall mean value. The range of temperatures was 18.0 to 21.6 degrees C.

Conductance, a measure of total salinity that is usually correlated with total dissolved solids, ranged overall from 478 to 800 micromhos (μmhos)/cm, and had a mean value of 568 ± 110 μmhos/cm. The feedlot wells had slightly higher conductance than farm wells (means of 619 ± 127 vs. 548 ± 39 μmhos/cm, respectively). The highest conductance value occurred in feedlot well #2779, which also had the lowest pH and the highest total alkalinity.

The phenolphthalein alkalinity was negligible so that the total alkalinity was virtually all composed of bicarbonate alkalinity. Average values of total alkalinity averaged slightly higher for the feedlot wells as compared to the upgradient and downgradient farm wells. However, this difference was entirely due to a higher alkalinity reading in well #2779. The overall mean total alkalinity value was 248 ± 18 mg/L as $CaCO_3$.

Laboratory analysis of ground water samples by the Texas Tech Environmental Sciences Laboratory revealed very low concentrations of nutrients including nitrate, ammonia, nitrite, total Kjeldahl nitrogen (TKN), orthophosphate, potassium, and salt ions (sodium and chloride), as shown in Table 1. Most of these elements are mobile in terms of leaching potential. In many cases the values were below the limit of detection of <1.00 mg/L.

Nitrate concentrations ranged from <1.00 mg/L to a peak value of 2.23 mg/L. The highest value occurred in a farm well considered to be upgradient from the feedlot. Average nitrate concentration for the feedlot wells was 1.03 mg/L as compared to 0.82 mg/L for all farm irrigation wells.

All nitrite (NO_2-N) and orthophosphate (PO_4) values were below 1.00 mg/L. Ammonia averaged less than 0.07 mg/L, and the peak value of total Kjeldahl nitrogen was 0.88 mg/L--in an upgradient well. Potassium (K), sodium (Na) and chloride (Cl) were very low and averaged only 8.57 ± 0.88 mg/L, 42.1 ± 5.7 mg/L, and 21.0 ± 14.6 mg/L, respectively, for all wells. The highest values of K and Cl were found in one of the feedlot wells (#2779), but these values were still quite low.

By contrast, feedlot runoff stored in the playa lake had much higher conductance, total alkalinity, total Kjeldahl nitrogen, orthophosphate, potassium, sodium and chloride than the well water

(Table 2). However, concentrations of nitrate and nitrite were below 1.0 mg/L (the same as well water samples) probably due to anaerobic conditions in the wastewater stored in the playa.

Feedlot B--Parmer County

Field measurements of ground water temperature, pH and total alkalinity for wells sampled at or around Feedlot B (Table 3) were very similar to values obtained for Feedlot A. There did not appear to be any differences between the feedlot wells and the farm wells designated as either upgradient or downgradient. Average values for all wells were as follows: pH = 7.34 ± 0.25; temperature = 19.4 ± 0.8 degrees C; and total alkalinity = 216 ± 39 mg/L.

However, conductance values were generally higher for Feedlot B than for Feedlot A, especially in farm wells where the peak values of 1,000 and 1,150 μmhos/cm occurred (Sweeten et al., 1991). Overall, the conductance averaged 727 ± 164 μmhos/cm, and it was slightly greater in farm irrigation wells (762 ± 178 μmhos/cm) than in the feedlot wells (631 ± 109 μmhos/cm). The two wells with the highest conductance (wells #1600 and #4502) were in close proximity to the off-site playa (Playa #2), which is used to store pumped supernatant effluent from Playa #1 that serves as the primary runoff holding pond for the feedlot.

Laboratory-determined values of ammonia, total Kjeldahl nitrogen, nitrite, orthophosphate, potassium, and sodium (Table 3) were virtually the same for Feedlot B as for Feedlot A and were independent of location with respect to the feedlot or ground water direction. Mean values for these parameters for all wells (farm and feedlot) were as follows:

Ammonia -- 0.04 ± 0.03 mg/L
TKN -- 0.37 ± 0.27 mg/L
Nitrite -- <1.00 mg/L
O-Phosphate -- <1.00 mg/L
Potassium -- 7.75 ± 0.95 mg/L
Sodium -- 30.9 ± 5.1 mg/L

Nitrate and chloride were generally higher at and around Feedlot B than for Feedlot A (Table 2). Nitrate (NO_3-N) levels in all wells averaged 5.21 ± 1.85 mg/L with a range of 2.56-9.54 mg/L. All nitrate values were below the USEPA public drinking water standard of 10.0 mg/L NO_3-N. The 4 feedlot wells had lower nitrate concentrations (4.65 ± 1.63 mg/L) than did the farm irrigation wells believed to be either upgradient (5.72 ± 2.01 mg/L) or downgradient (5.23 ± 2.20 mg/L).

Similarly, chloride levels in feedlot wells were lower than in most of the farm irrigation wells. The overall range of chloride concentration was 29.5 mg/L to 143.0 mg/L, and averaged 69.0 ± 31.5 mg/L. All of these values are considered low both for irrigation and for drinking water purposes (humans and livestock). The highest values of both nitrate and chloride were found in farm irrigation wells #1600 and #4502 in the vicinity of Playa #2. This corresponds to the result for conductance as discussed previously. Further testing would be needed to determine if there was any relationship between this playa and the water quality in the two wells.

The two playa lakes used for storage of cattle feedlot runoff were sampled on one occasion (Table 2). Wastewater stored in Playa #1 used as the primary runoff holding pond had lower concentrations of alkalinity, total Kjeldahl nitrogen, orthophosphate, potassium, sodium and chloride than the playas at Feedlot A. Also, Playa #2 had higher values of conductance, alkalinity, K, Na and Cl than Playa #1, probably due to evaporation losses and concentration of salinity elements. However, both the TKN and orthophosphate levels were lower by a factor of five in

Playa #2 than in Playa #1, probably reflecting nutrient losses due to sedimentation in Playa #1. Nitrate and nitrite levels were below 1.0 mg/L in both playas.

Statistical Analysis and Discussion

Data used in the statistical analysis which the laboratory reported as less than a specific detection value were entered numerically into the data set(s) as a value corresponding to the midpoint of the range between the minimum detection level and a zero value. Interpretation of the data was not altered due to selection of this value, and values of standard deviations are more appropriate using these midpoint values.

To determine if contamination had occurred in the ground water, the data was initially analyzed to determine if there were differences among the three location groupings around each feedlot--upgradient, downgradient, and feedlot wells. (Statistically, these type comparisons are referred to as "within" comparisons.) The respective groupings from each feedlot (e.g. upgradient) were compared using an ANOVA (analysis of variance) with SAS[1] to determine if statistically significant differences existed. The ANOVA results of the comparisons between the two locations for the upgradient, downgradient and feedlot well groupings indicated there was no significant difference between the groupings at either of the two feedlot locations except for the following detection--the TKN (total Kjeldahl nitrogen) levels at feedlot A were significantly higher (mean value of 0.52 mg/L) in the upgradient wells than either in the feedlot or downgradient wells. This detection does not indicate any contamination in the ground water unless the ground water flow was determined incorrectly, which is unlikely considering the annually acquired data by HPUWCD personnel used to determine the flow direction. The means of each grouping and all farm wells are provided in Table 1 (for groupings at Feedlot A) and Table 2 (for groupings at Feedlot B).

The data was subsequently analyzed with the upgradient, downgradient and feedlot well data of the two feedlots to determine if differences were evident among the respective well groupings between the feedlots. The comparisons were to determine if the levels of the constituents at each feedlot differed significantly. (Statistically, these type comparisons are typically referred to as "among" comparisons.) If detected, this would indicate there could be possible geological influences or other factors which caused elemental differences in the ground water quality, not necessarily related to the feedlot operations. The analysis indicated that significant differences existed for a number of constituents among the respective groupings of the feedlots. The NO_3-N differed for all groupings between the feedlots. The upgradient groupings differed additionally in chloride levels with the feedlot wells differing in potassium and sodium. The downgradient grouping had the most differences additionally with EC, sodium and chlorides. While differences among the groups are evident, it should be recognized that the constituent levels for the groupings at both feedlot locations are acceptable for a variety of uses, including irrigation, and generally meet the primary and secondary EPA drinking water standards.

The mean data of the playa lake water samples for the individual and combined feedlots are presented in Table 3 to illustrate characteristics of runoff contained in the feedlot playas at the ground surface. The data from these samples were not included as a separate grouping in the ANOVA due to the short time interval represented by such grab samples in relation to potential percolate though the playa over the past two decades. There is no evidence from the data analysis to indicate that contaminated percolate has reached the ground water table.

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[1] SAS refers to Statistical Analysis Systems, SAS Institute, Cary, N.C.

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Table 1
Analytical Results of Ground Water Samples at Feedlot A and Neighboring Farm Irrigation Wells, Castro County, June-July, 1991

Constituent	Well Location (No. Wells)			
	Feedlot (4)	Farm Wells		
		Upgradient (3)	Downgradient (7)	All Farm Wells (10)
pH	7.25 ± 0.38	7.23 ± 0.16	7.25 ± 0.14	7.25 ± 0.14
Temperature (Deg. C)	19.3 ± 0.5	18.5 ± 0.4	19.5 ± 1.3	19.2 ± 1.2
Conductance (μmhos/cm)	619 ± 127	562 ± 13	543 ± 45	548 ± 39
Total Alkalinity (mg $CaCO_3$/L)	261 ± 34	237 ± 1	245 ± 4	242 ± 5
Ammonia (NH_3-N, mg/L)	0.03 ± 0.00	0.07 ± 0.07	0.04 ± 0.01	0.05 ± 0.04
Total Kjeldahl Nitrogen (TKN, mg/L)	0.14 ± 0.20	0.52 ± 0.31	0.20 ± 0.18	0.30 ± 0.26
Nitrate (NO_3-N, mg/L)	1.03 ± 0.37	1.31 ± 0.87	0.60 ± 0.28	0.82 ± 0.58
Nitrite (NO_2-N, mg/L)	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00
Ortho-Phosphorus (PO_4-P mg/L)	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00
Potassium (K, mg/L)	9.23 ± 0.94	8.27 ± 1.50	8.33 ± 0.47	8.31 ± 0.80
Sodium (Na, mg/L)	46.0 ± 7.7	40.2 ± 3.7	40.8 ± 5.4	40.6 ± 4.7
Chloride (Cl, mg/L)	31.8 ± 25.5	22.1 ± 6.4	14.3 ± 5.6	16.6 ± 6.6

All data are means and standard deviations. There were no statistically significant differences in means among the left three columns for any of the constituents $\alpha \leq 0.05$.

Table 2
Characteristics of Feedlot Runoff Stored in Playa Lakes, Feedlots A and B, June-July, 1991

Constituent	Feedlot A (2)	Feedlot B, Playas 1 & 2 (4)	Weighted Average, Both Feedlots (6)
pH	7.26 ± 0.26	8.29 ± 0.67	7.94 ± 0.75
Temperature, °C	21.6 ± 0.8	29.8 ± 1.2	27.0 ± 4.3
Conductants, EC, μmhos/cm	2360 ± 212	1481 ± 331	1771 ±525
Total Alkalinity, mg $CaCO_3$/L	511 ± 47	511 ± 33	511 ± 33
Ammonia-Nitrogen, NH_3-N, mg/L	50.4 ± 13.8	11.8 ± 13.1	24.7 ± 23.2
Total Kjeldahl Nitrogen, TKN, mg/L	71.9 ± 34.7	27.6 ± 21.8	42.3 ± 32.3
Nitrate, NO_3-N, mg/L	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00
Nitrite, NO_3-N, mg/L	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00
Orthophosphate, PO_4-P, mg/L	35.4 ± 2.4	6.2 ± 5.3	15.9 ± 15.7
Potassium, K, mg/L	352.2 ± 17.8	124.3 ± 68.8	200.3 ± 129.4
Sodium, Na, mg/L	120.5 ± 8.3	97.3 ± 42.8	105.0 ± 35.5
Chloride, Cl, mg/L	290.5 ± 37.5	196.9 ± 116.8	228.1 ± 103.9

Table 3
Analytical Results of Ground Water Samples at Feedlot B and Neighboring Farm Irrigation Wells, Parmer County, June-July, 1991

Constituent	Well Location (No. Wells)			
	Feedlot (4)	Farm Wells		
		Upgradient (3)	Downgradient (7)	All Farm Wells (10)
pH	7.40 ± 0.27	7.20 ± 0.35	7.40 ± 0.20	7.32 ± 0.26
Temperature (Deg. C)	20.1 ± 0.7	18.9 ± 0.4	19.4 ± 1.0	19.2 ± 0.8
Conductance (μmhos/cm)	631 ± 109	779 ± 164	753 ± 197	762 ± 178
Total Alkalinity (mg $CaCO_3$/L)	219 ± 40	218 ± 54	214 ± 40	215 ± 43
Ammonia (NH_3-N, mg/L)	0.03 ± 0.01	0.05 ± 0.02	0.05 ± 0.03	0.05 ± 0.03
Total Kjeldahl Nitrogen (TKN, mg/L)	0.39 ± 0.29	0.41 ± 0.29	0.34 ± 0.15	0.36 ± 0.19
Nitrate (NO_3-N, mg/L)	4.65 ± 1.63	5.72 ± 2.01	5.23 ± 2.20	5.41 ± 2.05
Nitrite (NO_2-N, mg/L)	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00
Ortho-Phosphorus (PO_4-P mg/L)	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00	<1.00 ± 0.00
Potassium (K, mg/L)	7.10 ± 0.50	7.88 ± 1.24	8.05 ± 0.99	7.99 ± 1.03
Sodium (Na, mg/L)	29.3 ± 1.8	33.7 ± 7.6	30.2 ± 5.1	31.5 ± 6.0
Chloride (Cl, mg/L)	41.7 ± 14.2	85.9 ± 29.8	75.0 ± 34.5	78.9 ± 31.3

All data are means and standard deviations. There were no statistically significant differences in means among the left three columns for any of the constituents $\alpha \leq 0.05$.

2-58

FEEDLOT BIOLOGICAL SEALING
and
RUNOFF REGULATIONS

BACKGROUND INFORMATION

The Beef Cattle industry has received much attention recently from the general public and environmentalists. Their concern with feedlots is mainly from the standpoint of pollution of surface waters from runoff and potential degradation of groundwater quality from nutrients accumulating in the soil profile. Mismanaged feedlots represent a great pollution potential, but the potential is far greater than the actual contribution to soil and water pollution.

GROUNDWATER POLLUTION CONTROL

Groundwater and soil profile contamination beneath a properly managed feedlot is virtually nonexistent. (1) On the feedlot surface, three layers develop on and in the soil profile as a result of organic accumulation. The first layer of manure soon helps to provide for the development of a second interface layer consisting of organic matter and mineral deposits. The third layer is formed by physical compaction from the cattle and the chemical reaction of the manure. Urine and solid manure have high sodium and potassium contents that influence the electrical charges of the soil particles and cause them to disperse. At the same time the trampling of the cattle on the surface compacts the dispersed soil particles into a dense, poorly aerated mass or hardpan. Original soil texture has little effect on water infiltration into the surface of an established feedlot. The organic matter serves as a food source for microorganisms. Microbial decomposition produces various byproducts, such as organic gels and polysaccharides that reduce water infiltration by plugging soil pores. The surface layer may absorb appreciable water, but actual infiltration into the soil is minimal to non-existent, and therefore becomes resistant to nitrate, potassium sodium and other nutrient contamination of groundwater.

REGULATIONS

According to Nebraska law any feedlot, regardless of size, that has the potential to discharge manure or runoff may be required to have a waste control facility, ie. runoff containment facility, holding ponds, lagoons, sediment basins, etc.

It is the responsibility of the owner or operator of the feedlot to request the Department of Environmental Control (DEC) to inspect the facility to determine if a runoff control structure is required. If such structure is required, the owner or operator must apply for a construction permit. This application must include submission of plans and specifications, designed by the Soil Conservation Service (SCS) or registered professional engineer or anyone demonstrating knowledge and experience in the design, operation and management of waste control facilities. A construction permit must be obtained from the DEC prior to construction. When construction is complete, the owner or operator must submit a "certification of completion" form to the DEC. The containment facility, if required, must be large enough to handle the runoff created by a 25 year - 24 hour rainfall. The amount of rain fall in a 25 year - 24 hour storm ranges from 3.4 inches in the west to 5.85 inches in eastern Nebraska. Your local SCS office will have this information for your area.

The containment facility can consist of any structure deemed appropriate by the DEC ranging from holding lagoons to sediment basins and filter strips. Water runoff should be diverted away from the feedlot to the maximum extent possible, allowing for a smaller containment facility.

Confinement Facilities

Semi or totally housed feeding facilities must have the capacity to hold all livestock wastes for a period of 120 days and must be compatible with the ability to apply manure for best crop management and utilization. The amount of disposal area should be based on the nutrient value of the manure, soil and site characteristics. Manure management and disposal will be discussed in a subsequent issue of CEEP Tips.

Locations

Runoff control facilities must be located at least 100 feet from any well used for domestic purposes or at least 1000 feet from any well used for public water supplies. Concurrently, these structures cannot be located in an area that impairs surface waters or groundwater.

NPDES Permit

A National Pollution Discharge Elimination System (NPDES) Permit is required when a facility has the potential to discharge into waters of the state. The NPDES permit program is a federal program administered by the DEC to control primarily surface water pollution.

A feedlot could be required to have a runoff containment structure and not an NPDES permit. For example, a feedlot located further away from waters of the state would not necessarily need an NPDES permit, but may be required to control runoff with some type of containment facility. All confinement facilities under roof are exempt from NPDES permit requirements. An NPDES permit is only required if the potential exists for effluent to discharge into waters of the state.

COST SHARING and ASSISTANCE PROGRAMS

The purpose of the ASCS cost sharing program is to reduce the existing pollution of water, land and air by agriculture wastes and to allow the recycling of nutrients to the land. Cost sharing is available from ASCS for waste storage facilities, lagoons, collection basins, settling basins, diversion channels, waterways, outlet structures, piping, land shaping as part of a system, leveling and filling to allow installation and permanently installed equipment, and conduits needed as an integral part of the system. Cost sharing is not available for pumps, screens, gated pipe, portable pipe, spreading or any type of application of manure to land, or storage sites to store solid manure. Liquid manure pits are eligible for cost share provided they contribute significantly to improving the quality of surface and groundwater. Cost share funds are limited to operations that are 5 years old or older. New operations are expected to ensure protection of the surface water and groundwater during construction. Cost sharing by ASCS carries certain obligations and specifications. These include normal cleaning and maintenance and removal of liquids from retention facilities within two or three weeks after a significant rainfall to restore adequate capacity required for a 25 year storm. Maximum cost shares are 65 percent of the county average cost for those items provided in the county program.

Assistance with design and construction criteria are available from local SCS and NRD offices. SCS will provide the technical support of designing and engineering runoff containment facilities for smaller sized operations. Although variable from county to county, SCS will usually provide assistance for facilities that cover less then 10 acres. Larger sized facilities are attractive to private business, therefore left open to competition.

Soil Profile Conditions of Cattle Feedlots[1]

Lloyd N. Mielke, Norris P. Swanson, and Thomas M. McCalla[2]

ABSTRACT

Characterization of the conditions that exist in the feedlot surface and soil profile is important to evaluation of the potentials for soil and water pollution. Cattle action and management activities create a dynamic condition in the feedlot. The organic matter surface causes physical and biochemical changes in the soil that are unlike natural or cultivated soils. The feedlot profile can be described as three layers: the organic matter, the interface, and the underlying soil. Measurable characteristics include bulk density, infiltration, and content of organic matter, water, and nitrate-N. Generally, the surface 15.2-cm depth of feedlot soils is compacted and has a high bulk density. Infiltration into the feedlot surface layers is essentially zero. There is no transpiration, and the soil-water content is more uniform through the profile than on cropped land.

Additional Index Words: infiltration, layered soils, organic content.

The beef cattle feeding industry recently has received much attention from the general public and the environmentalists. Their concern with feedlots is mainly from the standpoint of pollution of surface waters from runoff. Of equal, or possibly greater importance in some localities, is the potential for degrading the ground-water quality from nutrients accumulating in the feedlot soil profile.

Most of the beef cattle in the USA are fed in large, open, soil-surfaced feedlots in the Plains and Midwest. Confinement feeding, where cattle are highly concentrated, usually under a roof, is increasing rapidly but accounts for only a small portion of the total animals fed.

Beef animals account for nearly two-thirds of all the red meat consumed in the USA (4). In 20 years, 1950–1970, consumption of beef from grain-fed cattle has increased from about 50% to more than 70%, a fact that reflects the increase in numbers of cattle feedlots.

The availability of feed grain and cattle has influenced the concentration of cattle feeding operations in four major areas of the USA according to Viets (5). About three million head are fed annually in southern California and Arizona. The Texas and Oklahoma Panhandle areas have had spectacular growth with more than five million cattle fed annually. Eastern Colorado, Nebraska, and South Dakota feed about six million annually, twice as many as in 1962. Cattle on feed in the Central Corn Belt numbered almost eight million in 1969.

Agricultural Statistics report 13,911,000 cattle on feed as of January 1, 1972. The January inventory is usually the highest of any period of the year (1). Assuming that the lots are at capacity and using 37.1 m^2 per head as recommended by the Midwest Plan Service (2), about 53,000 ha are used for feedlots nationally. Higher cattle densities are common in commercial lots, particularly in drier regions. Assuming that 37.1 m^2 per head is a good estimate, the total feeding area would be less than 490 km^2 for the entire USA, an area much smaller than an average-size county. The feedlot involves intensive management and a high dollar value. Feedlots also represent a great pollution potential, but the potential is far greater than the actual contribution to soil and water pollution.

FEEDLOT SURFACES

Three layers develop on and in the top of the soil profile as a result of organic accumulation in a feedlot. A layer of manure soon accumulates on the soil surface of the feedlot. Under continuing use, an interface layer of mixed organic and mineral soil forms under the manure cover. A third layer is the top of the soil profile, which is affected physically by compaction of the animals and chemically by the manure. Mixing of organic matter and soil-mineral material is generally limited to the first few centimeters of soil. Depending on the feedlot management and history, the physical effects may be evident for several centimeters and the chemical effects for several centimters or meters in the soil profile.

Physical, chemical, and biochemical processes all contribute to formation of the layers in a feedlot surface. As manure is deposited and accumulates, decomposition is going on by physical and microbial processes. Urine and solid manure have high sodium and potassium contents that influence the electrical charges of the clay soil particles and cause them to disperse. At the same time, the trampling of the cattle on the soil surface compacts the dispersed soil particles into a dense, poorly aerated mass. A platy structure forms in some soils and, generally, structure tends to become massive. Observations suggest that after dispersion and compaction, the original soil texture has little effect on water infiltration into the surface of the established feedlot.

The manure containing organic matter serves as a food source for microorganisms. Microbial decomposition produces various byproducts, such as organic gels and polysaccharides that reduce water infiltration by plugging the soil pores. Infiltration of water is controlled by the most limiting layer which in feedlots is the combined effects of the surface and interface layer.

The hydrophilic substances in the manure swell and slow down water movement when the manure is kept wet. However, when the manure dries, these substances shrink and crack, and water may move rapidly through the surface. Water pollution of ground water by nitrate-N can be reduced by keeping the two surface layers moist enough to avoid cracking.

ORGANIC MATTER LAYER

The composition of the organic layer varies with depth and stage of decomposition, water content as affected by

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2-61

Table 1—Volatile solids by percent weight loss by ignition in surface 7.6 cm of four eastern Nebraska feedlots

Location of feedlot	Soil	No. of samples	Volatile solids	
			Average	Range
			%	
Gretna	Marshall silty clay loam	[illegible]	[illegible]	[illegible]
Springfield	Marshall silty clay loam	[illegible]	[illegible]	[illegible]
Omaha	Judson silt loam	[illegible]	[illegible]	[illegible]
Central City	Volin silt loam	[illegible]	[illegible]	[illegible]

* [illegible] recently cleaned lot and [illegible] manure mound; other values were [illegible]

feces, precipitation and evaporation, and the ration fed to the cattle. Feedlot management practices including cleaning and animal density affect the surface conditions and control development of the organic matter layer. Swanson et al. (3) report that changes in weather, coupled with cattle trampling, quickly alter the characteristics of the surface layer to greatly affect runoff characteristics and the quality of the runoff water.

Samples from three eastern Nebraska feedlots typify the organic matter layer. The average and range of volatile solids content, percent weight loss by ignition, for the three feedlots are shown in Table 1. Six areas were sampled on the Gretna feedlot. The volatile solid contents were highest near the upper end and near the top of the slope, and lowest along the side of the feedlot opposite the feedbunks.

One composite sample was taken from each of the four pens on the Springfield feedlot site. The pens differed in area, but had about the same number of cattle in each. After the first 2 years of feeding, the pens with the highest cattle densities had the highest surface volatile solids contents.

The Omaha feedlot has a 10 to 15% slope compared to the 6% slopes at the Springfield and Gretna sites. The low volatile solids content was from a recently cleaned lot. The high volatile was from a manure mound. Organic content in a mound decreases as decomposition progresses.

A typical bulk density of an organic matter layer ranges from 0.75 to 0.93 g cm^{-3}. The surface bulk density of a silty clay loam ranges from 1.4 to 1.6 g cm^{-3}, and that of a silt loam averages 1.2 g cm^{-3}. Solids transported from the feedlot surface by runoff are primarily organic, with bulk densities in the range of 0.36 to 0.53 g cm^{-3} and an average of 0.46 g cm^{-3}. Runoff can transport materials ranging from the small soil particles up to large aggregates and bits of undigested plant tissue.

Surface materials are removed by wind as well as water. In dry climates and during dry periods, cattle hoof action aids drying and destroys many existing aggregates formed by wetting and drying of the surface. The undigested cellulose fibers have a low density and are readily picked up and moved by wind. Dust in a feedlot also causes cattle health problems that commonly affect eyes and the respiratory system.

THE INTERFACE LAYER

The interface layer is of mixed organic matter and mineral soil of undefined thickness on top of the soil profile, forming as a result of weather, cattle action, and manure accumulation. It appears that the interface starts to form when cattle are first concentrated in an area. Hoof action is severe and the soil surface becomes compacted.

Table 2—Soil bulk density of the surface 7.6 cm of beef cattle feedlots and adjacent cropland

Location	Texture	Cropland adjacent to feedlot	Inside feedlot
		g cm^{-3}	
Central City	Silt loam	[illegible]	[illegible]
Omaha	Silty clay loam	[illegible]	[illegible]

As manure accumulates, the organic matter and interface, layers develop and the soil is protected.

The interface tends to be massive, without any definite soil structure. When dry, this layer may be hard like pavement. Bulk density, as an indicator of compaction in the feedlot, is shown in Table 2 for two soil types at Central City and Omaha. The top 7.6 cm of silt loam outside the feedlot has a bulk density of 0.4 g cm^{-3} less than the comparable depth inside the feedlot. There was 0.2 g cm^{-3} difference for the silty clay loam. At depths of 30.5 cm, bulk densities were essentially the same inside and outside the feedlot.

Volatile solids by percent weight loss through ignition in the organic layer interface and upper soil profile are shown in Fig. 1. Arbitrary boundaries were assumed for the interface and the samples were segmented by 1-cm depths above and below these boundaries. The values indicate that some mixing of soil and organic matter occurs near the top of the soil profile. The interface layer would be about 5 cm deep or ± 2.5 cm on either side of the assumed boundary (Fig. 1). Under cultivation, the organic matter content would be about 2-3% for this Volin silt loam soil.

Bulk densities through the organic layer, the interface layer, and the top of the soil profile for a silt loam soil are shown in Fig. 2. The bulk density of less than 0.80 g cm^{-3} at the surface increases to almost 1.7 g cm^{-3} in the interface and then decreases slightly. The increased density at 50 cm is attributed to increased clay content at that depth.

Infiltration measurements were attempted in a feedlot using the concentric cylinder technique. Expansion upon wetting of the surface layer was so great that a fixed gage could not be used to determine surface elevation, and infiltration was so slow that appreciable intakes could not

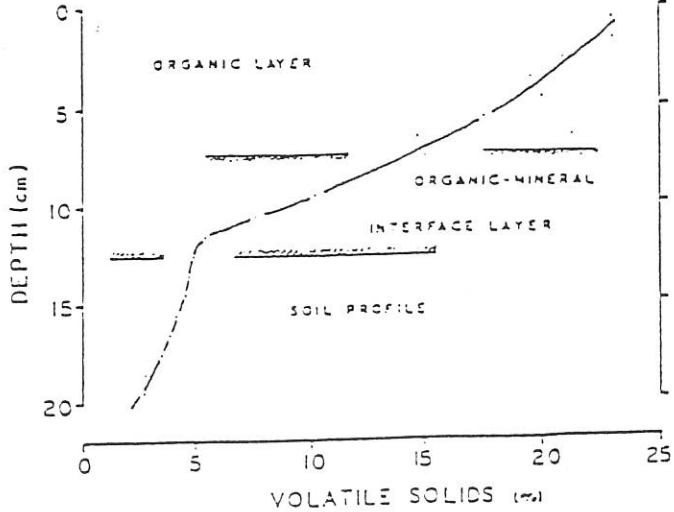

Fig. 1—Volatile solids by percent weight loss by ignition in surface layers of a beef cattle feedlot, Central City, Nebraska.

2-62

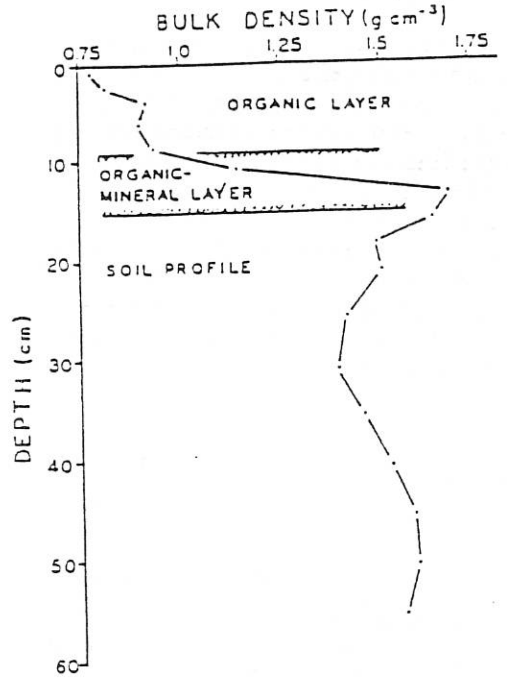

Fig. 2—Bulk density of undisturbed core from feedlot silt loam soil, Central City, Nebraska.

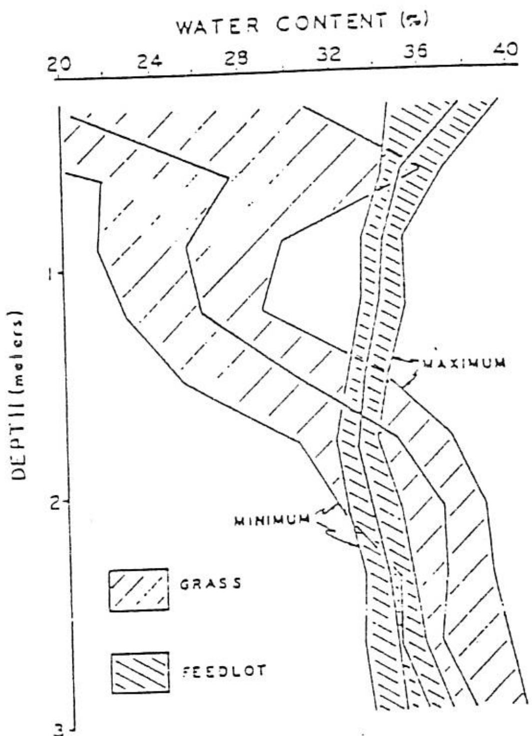

Fig. 3—Yearly range and average soil water content in Marshall silty clay loam soil profile under a feedlot and under grass, Gretna, Nebraska.

be measured even over several hours. The surface materials in a pack can adsorb great quantities of water. Only extremely low rates of actual infiltration into the soil have been observed in the field and in the laboratory using undisturbed soil columns. Unlike research investigations in cultivated fields, measurement equipment in a feedlot requires constant surveillance and protection to guard against destruction by cattle. An apparatus with a vertical

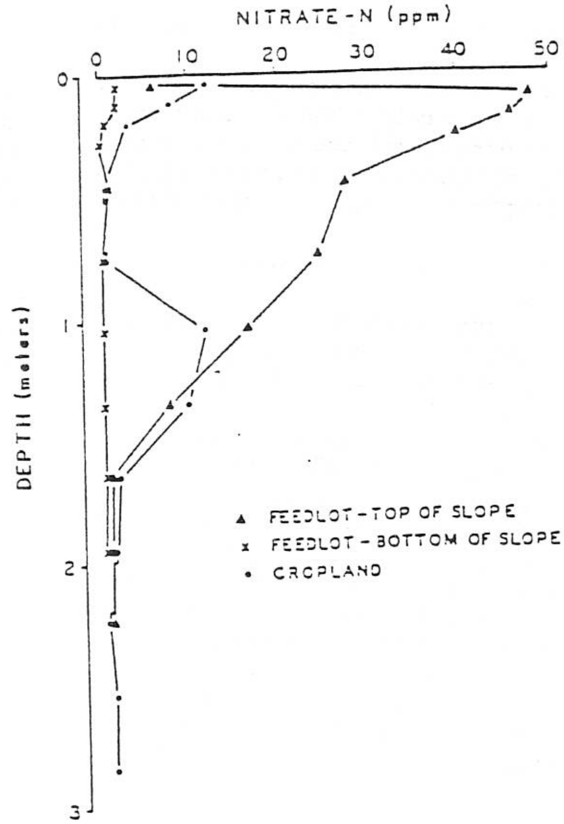

Fig. 4—Content of nitrate-N in Marshall silty clay loam for feedlot and cropland, Omaha, Nebraska.

supply tank, check valve and float, and concentric infiltration cylinders was used in the Gretna feedlot. The test was necessarily isolated from the animals, but no measurable infiltration was evident from the supply tank water elevation over a 20-day period. Most precipitation that falls on the feedlot either leaves as runoff or is adsorbed for later removal by evaporation or sublimation in the case of snow and ice.

SOIL PROFILE

The feedlot soil profile is unique in that there is no extraction of soil water by plant roots. The interface layer almost completely restricts water movement into or out of the profile. However, any water entering the profile could act as a transport medium to move chemicals in solution.

Access tubes 5.1 cm in diameter were installed in the Gretna feedlot and an adjacent grassed area. Soil-water contents were measured at monthly intervals for three seasons inside and immediately outside the feedlot on the Marshall silty clay loam site. Fig. 3 shows the range and average of soil-water contents at various soil depths for six access tubes inside the feedlot and for four access tubes under grass outside the feedlot in 1970. The range of soil-water content over the season was narrow for the feedlot profiles and remained relatively constant through the profile. In contrast, the seasonal soil-water content under the grass fluctuated widely, particularly in the root zone. The top 1.7-m depth of soil was wetter in the feedlot than under grass, but the feedlot soil tended to be drier below that depth. Patterns were similar during 1969, 1970, and 1971.

The narrow range of soil-water contents in the feedlot soil profile include, and may be essentially accounted for, by variation in equipment calibration. Lower values at deeper depths as compared with those under the grass indicates that wetting fronts do not move through the feedlot profile.

Nitrate-N levels in the soil profile under feedlots tend to vary widely among locations. Nitrate-N levels in three soil profiles, two under a feedlot and the other under alfalfa (*Medicago sativa* L.), are shown in Fig. 4. The two soil cores from the feedlot were taken from a selected pen. All portions of this pen had received the same management and had been used continuously for more than 30 years. The surface slope was 13%, except that it decreased toward the lower end of the pen. One core was taken from the profile on the steeper slope. The nitrate-N was high in the top 0.6 m of soil and then decreased to about the same as in the cropland at the 1.7-m depth. The second core was taken from the soil profile at the lower end of the slope where soil and manure had been deposited. Very little nitrate-N was found in this profile. This condition is similar to that found under manure mounds. Where manure is mounded or has naturally accumulated to several inches, conditions are favorable for denitrification.

CONCLUSIONS

The texture of the soil profiles under the feedlots investigated appears to have little effect on the water movement into the profile or runoff characteristics for a mature feedlot. The bulk density of the interface (organic-mineral) layer in the feedlot is greater than in the cropland at the same depth. Organic-matter content is higher in the interface layer and the combined effects of soil particle dispersion and compaction provide a barrier to water movement. The surface layer may adsorb appreciable water, but actual infiltration into the soil is minimal. Where an interface exists and a cover of manure is present, nitrate-N is less likely to accumulate in the profile.

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Infiltration of Water on a Cattle Feedlot

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ABSTRACT

INFILTRATION into a feedlot surface could not be measured on site because of extremely low infiltration rates. Four undisturbed soil cores from an active cattle feedlot, encased in heat-shrink plastic, were used in the laboratory to measure infiltration. Six undisturbed feedlot cores containing the manure surface, interface layer (2 cm manure and top of soil) and soil below were cut into sections 10 cm long. Air permeability, hydraulic conductivity, air-water permeability ratio, and bulk density were measured on each section. The interface layer of manure and soil develops as a result of hoof action and manure cover. It is the most restrictive layer to water and air movement in the feedlot soil profile. The hydraulic conductivity increased 28-fold from the interface layer to the next layer and was about the same as the comparable depth in adjacent cropland.

INTRODUCTION

Most of the effort in managing feedlot waste is concentrated on runoff control. Less noticeable, but very different to assess, are the accumulation and movement of nutrients through the soil profile under the feedlot. These nutrients are potential pollutants of the groundwater. The nitrate-nitrogen (NO_3-N) content is the most common single criterion used to indicate water pollution. Since NO_3-N is very soluble and mobile in water, it is often assumed that where water goes, NO_3-N goes, also. In this study, we determined some of the characteristics of infiltration of water into and water and gas movement through a feedlot profile. Physical soil characteristics indirectly affect nitrogen conversion and, therefore, directly influence the nitrogen status under the feedlot.

Published data indicate that animal wastes contribute to groundwater pollution. Gilham and Webber (1969) attributed the increased NO_3-N concentration in the groundwater near a dairy barnyard in Ontario, Canada, to the barnyard leachate that tended to move in the direction of groundwater flow. In Missouri, Smith (1967) found as much as 908 to 1816 kg/ha of NO_3-N in a 6.1- to 7.6-m soil profile under an area where livestock had been fed for more than 50 years.

Lorimor et al. (1972) found a very small amount or no increase in NO_3-N in groundwater downgradient from the feedlot as compared with upgradient. The feedlot had not been cleaned since 1956, and it was completely covered with manure. Soil water and soil gas were sampled under this feedlot and under adjacent, irrigated corn (Elliott et al. 1972, Elliott and McCalla 1972). They measured high concentrations of NO_3-N soil water near the feedlot surface but very little deeper than 15 cm. Below 15 cm, higher concentrations of NO_3-N were found in the profile under irrigated corn than under feedlots.

Miller (1971) found compacted layers in feedlots that had higher bulk densities and lower water permeabilities than other parts of the soil. These layers were generally near the surface and permeabilities were as low as or lower than in playa lake sediment. Mielke et al. (1970) reported very low infiltration in a feedlot established for several years with a high organic matter content in the interface layer. Interface formation was attributed to soil particle dispersion and compaction that provided a barrier to water movement (Mielke et al. 1974).

The chemical characteristics of the feedlot soil profile, with particular reference to the interface layer, were investigated by Schuman and McCalla (1975). High content of exchangeable K^+ in the top few centimeters caused some dispersion and contributed to the poor physical properties and low infiltration rate of water. While some of the results in the literature cited are specific for NO_3-N concentration, they also indicate a physical soil characteristic that influences water movement.

FIELD PROCEDURES

The feedlot was located in the Platte River Valley in east-central Nebraska on a Wann silt loam. Mielke et al. (1970) described the feedlot in detail. Infiltration of water in the feedlot was determined by the double-cylinder method. Two methods — the fixed hook and the float-controlled, calibrated supply tank — were used. A fence protected the equipment from cattle destruction.

Undisturbed feedlot soil cores, encased in heat-shrink plastic, 10.2 cm in diameter, were taken with a Giddings* hydraulic soil probe. Sampling technique and the equipment used to encase undisturbed soil cores in heat-shrink plastic were reported by Mielke (1973).

LABORATORY PROCEDURES

Field observations of the physical characteristics of the feedlot surface and soil profile were used to plan the laboratory investigations. Four undisturbed feedlot soil cores (75 to 88 cm long) were taken at random for measuring infiltration of water. All cores used in the laboratory were encased in heat-shrink plastic by the method described in "Field Procedures".

Six additional undisturbed feedlot soil cores and two cores from adja-

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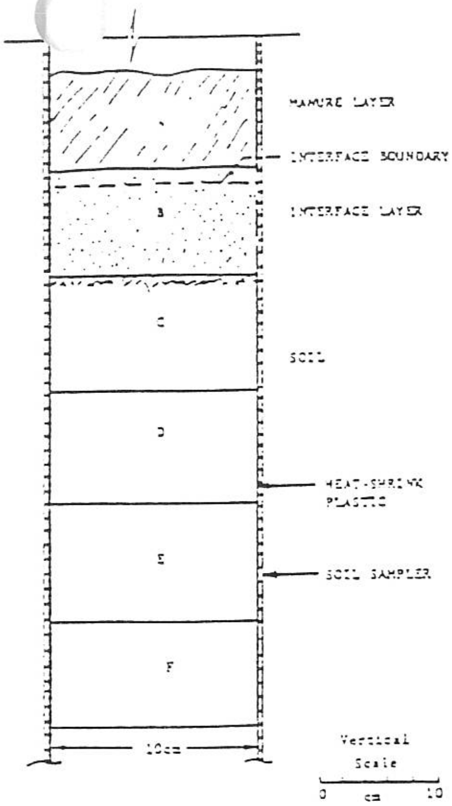

FIG. 1 Cross-section of soil sample with feedlot soil core sections A, B, C, D, E, and F. The interface layer includes the bottom of the manure layer and the top of the soil.

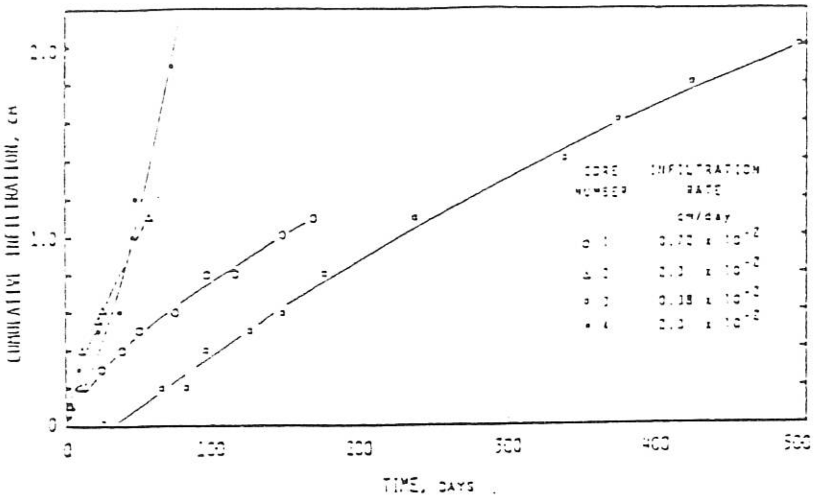

FIG. 2 Cumulative infiltration for undisturbed feedlot soil cores encased in heat-shrink plastic.

cent cropland were taken for measurements of air permeability, hydraulic conductivity, porosity, particle-size distribution, bulk density, and organic matter content. These cores ranged from 28 to 59 cm long. The dense interface layer was located, and each core was sectioned into A, B, C, D, etc., as shown in Fig. 1. The surface (Section A) included the organic matter layer. Section B contained the interface, i.e., the bottom of the organic matter layer and the top of the soil. Air permeability was determined on each core section with equipment described by Grover (1955) and modified by Tanner and Wengel (1957). The soil cores were kept at field moisture content to avoid shrinkage away from the plastic liner. Hydraulic conductivity on the cores was determined by the constant head method using tap water. All measurements were made in a constant temperature room at 25 C.

Compactibility was determined on soil material from the feedlot interface similar to that of Section B and on soil from an adjacent cornfield. The procedures used were for low compaction with a 2.5-kg rammer and 30.5-cm drop (Felt 1965). Hydraulic conductivity was determined on soil cores compacted at the water content for maximum compactibility.

FIELD RESULTS AND DISCUSSION

Early field observations of outdoor cattle feedlots showed that a dense layer exists near the soil surface that apparently decreases water intake. The feedlot we studied had manure accumulation of 15 to 30 cm, but it was not unlike other level farm feedlots in the Platte River Valley. Research results showed a low NO_3-N content in the groundwater (1 to 2-m depth) in the immediate vicinity of this feedlot in contrast with much higher NO_3-N content in wells under cropland (Mielke et al. 1970).

Other observations revealed low intake of water on the feedlot surface. On one occasion, water was pumped from a caisson (used for research) and spread on the feedlot surface. Ten days later, the pattern of the water still could be seen, and some free water remained on the surface.

The double-cylinder method of measuring infiltration of water failed to show any water intake over a 4-hr period of measurement in the feedlot used in our study. Another set of double cylinders, equipped with a float valve connected to a water-supply reservoir, measured the infiltration for 14 days. Less than 1.7 cm of water entered the feedlot surface after the initial period of absorption. The rate of water intake was 0.12 cm/day or 0.005 cm/hr, which is much less than very slow permeability (0.13 cm/hr) as classified by USDA (1951).

The layer containing the interface develops with time as a result of physical and chemical action and is better developed in level feedlots than in sloping feedlots. As long as the soil surface is covered by manure, Trampling by cattle has little direct physical influence and likelihood of breaking up the interface layer is less. On feedlots with steeper slopes, erosion by rainfall or snowmelt runoff, combined with sliding hoof action to remove or displace the manure, leaves the mineral soil surface exposed. With the disappearance of frost in the spring, snowmelt runoff on slopes can remove 1 cm or more of the interface layer. After a wet winter, a feedlot with 260 head/ha, on a silty clay loam soil with slopes of 6 percent, was very sloppy in the surface 7 to 10 cm; however, the hard interface layer was at the soil surface.

LABORATORY RESULTS AND DISCUSSION

Infiltration of water into four undisturbed feedlot cores in the laboratory was determined for 25 to 548 days (Fig. 2). The slowest rate was 0.38×10^{-2} cm/day for Core 3.

These curves would be typical if water were standing in the feedlot. Infiltration is a much smaller factor than evaporation in removing water from a feedlot surface.

The air permeability of the soil cores taken from feedlot and cropland is shown for each core section in Table 1. Air permeability was determined at field-water content. For the feedlot cores, average air permeability in Section B was about half that in Section A and 1/16 that in Section C. That for Section D was about three times greater than that for Section C. Air permeabilities were slightly higher for Sections E and F than for Section D in soil cores 3 and 4. Air permeability was higher in cropland cores than in feedlot cores owing to their greater porosity.

The average hydraulic conductivity

(... or the individual feedlot and cropland soil sections during a 24-hr period is shown in Table 2. Water did not percolate through two of the six B sections or through one A section. The results obtained on core 5 were difficult to interpret and were eliminated from the averages in Tables 2 and 3. Average HC was lowest (0.07 cm/hr) in Section B. On the average, water permeability increased 28-fold between the B layer and the C layer. The high sand content of Sections E and F accounted for their HC of 5.77 and 6.04 cm/hr, respectively.

The ratio of intrinsic air to water permeability (K'_a/K'_w) was 82 in the A layer and 56 in the B layer of the feedlot soil cores (Table 3). The ratios were lowest in the E and F layers of sandy loam and loamy sand soil. The ratios were 3 to 5 for the cropland that had a high sand content but were 30 to 50 in the cropland core with a higher silt content (data not shown). Since a ratio of 1 is indicative of completely stable soil structure, the feedlot soil cores are not water-stable.

Average bulk density was 1.42 g/cm^3 for the entire interface B sections, which included the bottom of the manure pack and soil below (Table 4). Bulk density of only the interface soil below the manure (determined by clod method) averaged 1.68 g/cm^3 and for individual samples ranged from 1.45 to 1.85 g/cm^3.

Bulk densities of material taken from the feedlot interface and adjacent cropland soil and compacted at different water content are shown in Fig. 3. The interface samples from the feedlot were air-dried. The manure shrinks upon drying and separates from the soil. The soil portion was designated as low organic matter, representative of the soil below the interface boundary (Fig. 1). The interface sample, high in organic matter, contained soil as well as about 2 cm of manure, which was representative of the entire B sections of the undisturbed soil cores. The maximum compaction was 1.70 g/cm^3 at 18 percent water content for the low organic matter interface material in Fig. 3. Compaction of the soil is a continuing process in the feedlot and, eventually, compaction by hoof action would occur at optimum water content. The bulk density data show cattle-hoof action can compact the first few centimeters of soil to about the same degree as standard methods for low compaction. The interface layer, high in organic matter, showed a maximum compaction of 1.61 g/m^3 at 20 percent water content. Maximum soil compaction in the cornfield was 1.81 g/cm^3 at 13.5 percent water content.

The cornfield soil contained 3.15 percent organic matter, based on the loss-on-ignition determination, compared with 4.71 and 7.27 percent for the interface with low and high organic matter, respectively. The greater organic matter content would

TABLE 1. INTRINSIC AIR PERMEABILITY (K'_a) OF UNDISTURBED FEEDLOT AND CROPLAND SOIL CORES BY SECTION

Section	Feedlot core 1	2	3	4	5	6	Average	Cropland core 1	2	Average
	$cm^2 \times 10^{-8}$									
A	0.40	2.82	0.82	0.42	0.77	2.08	1.22	7.68	3.20	5.44
B	0.39	0.22	0.67	0.66	1.34	0.16	0.66	11.98	5.92	8.95
C	22.00	3.90	15.80	2.19	1.01	20.40	10.88	17.09	6.67	11.88
D	34.30	77.10	29.00	15.60	4.40	36.60	32.92	—	14.72	—
E	—	—	38.88	24.83	—	—	31.85	—	7.58	—
F	—	—	43.46	34.69	—	—	39.07	—	—	—

TABLE 3. AVERAGE INTRINSIC AIR AND WATER PERMEABILITY AND RATIO OF AIR TO WATER PERMEABILITY BY LAYERS FOR UNDISTURBED FEEDLOT SOIL CORES

Section	Permeability: Water (K'_w)	Air (K'_a)	Ratio of air to water permeability (K'_a/K'_w)
	$cm^2 \times 10^{-8}$		
A	0.024*	1.53*†	82†‡
B	0.018*	0.52*	56‡
C	0.510*	12.8 *	41*
D	0.710*	38.6 *	53*
E	1.46	31.8	22
F	1.53	39.1	26

*excluding Core #5
†excluding Core #1
‡excluding Cores #2, 5, 6

TABLE 2. HYDRAULIC CONDUCTIVITY OF UNDISTURBED FEEDLOT AND CROPLAND SOIL CORES BY SECTIONS

Section	Feedlot core 1	2	3	4	5	6	Average	Cropland core 1	2	Average
	cm/hr									
A	0.00*	0.10	0.22	0.01	0.07†	0.13	0.09	6.26	0.58	3.42
B	0.03	0.00*	0.24	0.08	0.47†	0.00*	0.07	9.61	0.47	5.04
C	4.45	0.37	3.94	0.56	0.02†	0.71	2.01	21.06	0.56	10.81
D	2.66	4.66	3.18	1.36	0.43†	2.19	2.31	—	1.07	—
E	—	—	6.55	4.98	—	—	5.77	—	0.90†	—
F	—	—	5.48	6.60	—	—	6.04	—	—	—

*Based on water taken in—probably by absorption. No water percolated through; therefore, no hydraulic conductivity.
†Not included in average

TABLE 4. BULK DENSITY OF THE UNDISTURBED FEEDLOT CORES AND SOIL IN THE INTERFACE LAYER AND CROPLAND CORES

Section	Feedlot core 1	2	3	4	5	6	Average	Cropland core 1	2	Average
	g/cm^3									
A	1.10	0.99	1.09	0.99	1.14	0.92	1.04	1.66	1.60	1.63
B	1.48	1.35	1.57	1.46	1.26	1.38	1.42	1.76	1.54	1.65
C	1.32	1.48	1.44	1.54	1.54	1.36	1.45	1.72	1.46	1.59
D	1.32	1.36	1.44	1.48	1.41	1.40	1.40	—	1.38	—
E	—	—	1.45	1.59	—	—	1.52	—	1.44	—
F	—	—	1.57	1.68	—	—	1.62			
*	1.53	1.60	1.70	1.74	1.78	1.73	1.58			

*Average bulk density of 3 clods in one interface of Section B

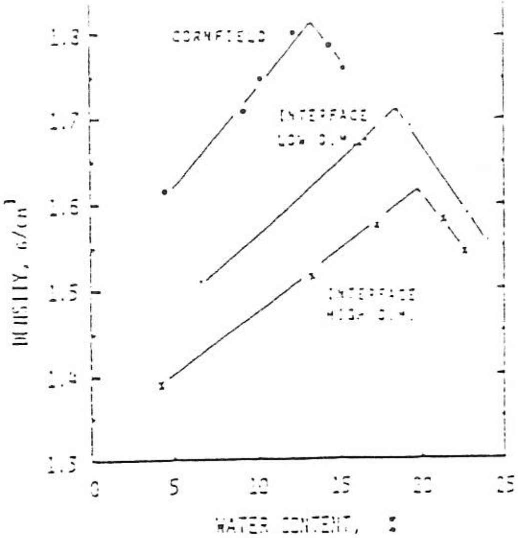

FIG. 3 Densities of feedlot interface materials of low and high organic matter content and adjacent cropland soil low in organic matter content compacted at different water contents.

account for the greater water content and the lower compaction of the high organic matter sample. Loss-on-ignition was 5.5 percent for soil below the interface layer in the B section of undisturbed soil cores. The loss-on-ignition averaged 11.2 percent for the entire interface layer (Section B), including organic matter, which was about 5 percent higher than the sample used for compaction test.

Hydraulic conductivity measurements were attempted on the interface material compacted to maximum density. The falling-head hydraulic conductivity method was used, and water was absorbed but did not pass through the core. The wetting front moved about 5 cm into the interface soil with low organic matter in 6 days, whereas in the core with high organic matter, the wetting front moved only 2 cm in 6 days.

Physical characteristics of the feedlot soil have a direct and indirect effect on NO_3-N content in the soil profile. This result is supported by the field observations and the laboratory results from undisturbed cores in this study. McCalla and Elliott (1971) and Elliott and McCalla (1972) found more CO_2 and less O_2 under feedlots than under cropped fields. They also found methane under feedlots, which is generally produced under anaerobic conditions when organic matter is present. Conditions are favorable for denitrification under feedlots. In a direct way, the interface layer, with high bulk density, low air and water permeability, and low infiltration capacity, limited the water movement and tended to maintain a stable soil-gas balance. Indirectly, the anaerobic condition undoubtedly controlled microbial metabolism, which was limited by the rate of gas exchange in the soil. The interface layer helped to maintain conditions favorable for denitrification and restricted movement of water through the soil. The feedlot surface and soil profile represent conditions uncommon to most soil environments. These results help to show why the soil and groundwater pollution is not as severe as the potential nutrient source would indicate.

SUMMARY

Physical soil condition on the feedlot was difficult to simulate or recreate in laboratory columns. An undisturbed-soil sampling technique was used to obtain soil cores representative of feedlot conditions. The feedlot interface layer forms when cattle are present and, as defined, includes about 2 cm at the bottom of the manure pack, the interface boundary, and about 10 cm of mineral soil.

Water intake in the feedlot and into undisturbed complete feedlot soil cores was extremely slow (range from 0.38×10^{-2} to 2.3×10^{-2} cm/day). Air and water permeabilities were lowest in the interface section and increased in the soil below. Water permeability increased 28-fold between the interface layer and the next layer 10 cm deeper. Bulk density was 1.42 g/cm³ of Section B, which was about the same as Sections C and D. However, the bulk density was 1.68 g/cm³ in the mineral soil in the interface layer. Interface soil material showed maximum compaction of 1.70 g/cm³ at 18 percent water content. No water moved through the interface material during 6 days. Undisturbed feedlot soil cores and feedlot interface material compacted at water content for maximum density are effective barriers to water movement. This fact is important in understanding feedlot hydrology and managing feedlots to protect groundwater quality.

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Texas Agricultural Extension Service

Groundwater Quality Protection for Livestock Feeding Operations

John M. Sweeten*

Introduction

The primary constituents of livestock and poultry manure that can contaminate groundwater include pathogenic organisms, nitrates and ammonia. Other constituents such as potassium, sodium, chloride and sulfate also may leach through the soil and impair the quality of an aquifer. Phosphorus and organic solids are not usually sources of groundwater pollution because of their limited leaching potential.

Potential point sources of groundwater contamination in livestock feeding operations include open, unpaved feedlots, runoff holding ponds, manure treatment and storage lagoons, silos and manure stockpiles. Insecticide spray equipment, dipping vats and disposal sites for waste pesticides, rinsates or containers also may contribute to localized groundwater contamination. This is especially true if pesticide use or disposal occurs near the well-head, because of the possibility of direct entry of runoff or infiltration around or through well casings or abandoned wells.

Nonpoint pollution sources include fields used for land application of manure and wastewater, manure accumulations around livestock watering locations, and intermittently-used stock pens. Livestock grazing operations, from sparse rangelands to intensively-stocked pastures, can influence the water quality of streams and aquifers. The nonpoint source pollution potential of pastured livestock depends in part upon the stocking density, length of grazing period, average manure loading rate, uniformity of manure spreading by grazing livestock, and disappearance of manure with time. Because livestock concentrations (animal density) vary widely across Texas, manure voided varies from less than 0.1 to more than 7 dry tons per acre per year. Nitrogen deposition from grazing cattle ranges from approximately 1 to 200 pounds per acre per year for sparse rangelands and intensively-grazed improved pastures, respectively.

This publication summarizes research results and management strategies for groundwater pollution control for open feedlots, holding ponds and lagoons, and land on which manure and wastewater are applied.

Feedlot Surfaces

Research in several states, in climates ranging from arid to humid, has determined that an active feedlot surface develops a compacted manure/soil interfacial layer (usually 2 to 4 inches thick) which provides an excellent moisture seal. This compacted manure/soil layer reduces the water infiltration rate to less than 0.002 inches per hour, or as little as 3 percent of the infiltration rate of the underlying soil (Mielke et al., 1974; Mielke and Mazurak, 1976). This zone of low infiltration restricts the leaching of salts, nitrates and ammonium into the subsoil and underlying groundwater (Schuman and McCalla, 1975A). This interfacial layer is usually dark brown or black, often resembling charcoal, perhaps because of its iron sulfide content (Norstadt et al., 1975). It is composed of bacterial cells, organic matter, degradation products and soil particles.

Self-Sealing of Soil Surface

If an undisturbed anaerobic layer of compacted manure is left above the manure/soil interfacial layer, formation and leaching of nitrate are retarded in favor of denitrification (Stewart et al., 1967; Chang el al., 1973). With this type of anaerobic condition, nitrate is converted to nitrogen gas which is released to the atmosphere rather than being leached to subsoil and

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2-69

groundwater. The soil profile which best retards nitrate and nitrite movement and retains salts near the soil surface was found to be sandy topsoil above a clay loam subsoil (Norstadt and Duke, 1982).

McCalla and Elliot (1971) found that reducing conditions are present 1 to 5 feet beneath a cattle feedlot, as evidenced by the presence of methane and carbon dioxide and the oxygen levels in the soil air beneath feedlots as compared to a cropped field. Reducing conditions, coupled with the presence of organic matter, promote denitrification and protect against nitrate leaching.

To avoid disrupting the surface seal provided by the manure/soil interfacial layer, feedlot personnel should be taught the correct use of manure collection machines (wheel loaders or elevating scrapers) to "harvest manure" rather than "cleaning pens." Leaving an undisturbed manure pack also will result in collecting the highest quality manure for crop fertilization or energy generation (Sweeten et al., 1985). Feedlots that have been abandoned without manure removal may be more likely to pollute groundwater than active feedlots (Madison and Brunett, 1984).

Nutrient Leaching

Concentrations of nitrate and ammonia decrease rapidly within the top foot (30 cm) of the feedlot soil layer (**Figure 1**) (Schuman and McCalla, 1975B). Soil water samples taken at about 3 feet beneath cattle feedlots showed concentrations of NO_3, P, Mg and salinity similar to those under adjacent cropland (Alego et al., 1972; Elliott et al., 1972; Schuman and McCalla, 1975B; Dantzman et al., 1983).

Miller (1971) measured groundwater quality in the Ogallala Aquifer beneath 80 cattle feedlots in the Texas High Plains. He determined that about one-fourth had contributed to nitrate levels that approached or exceeded the U.S. Environmental Protection Agency's drinking water standard of 10 ppm NO_3-N in the immediate vicinity of the feedlots. Seepage rates were estimated at 2 to 20 x 10^{-6} cm per second (0.003 to 0.03 inches per hour) under feedlot surfaces and playas used for runoff collection.

Borman (1981) monitored water quality in a shallow alluvial aquifer, by means of 19 observation wells placed around a 90,000 head feedlot, from feedlot startup through 4 years of operation. Chloride concentrations increased slightly in one well downgradient from a runoff retention pond. Leachate had percolated to 5 feet beneath the feedlot but not to 20 feet. The observed changes in groundwater quality were slight, which was attributable to an impermeable manure pack, soil clogging under the cattle pens, limited recharge, denitrification in the unsaturated zone, and soil clogging at the bottom and sides of an unlined runoff retention pond.

Kreitler (1975) has developed a technique for differentiating between the nitrate in soil and groundwater caused by animal wastes and that caused by commercial fertilizer or resulting from natural soil material. The method uses N-15 isotope as a tracer.

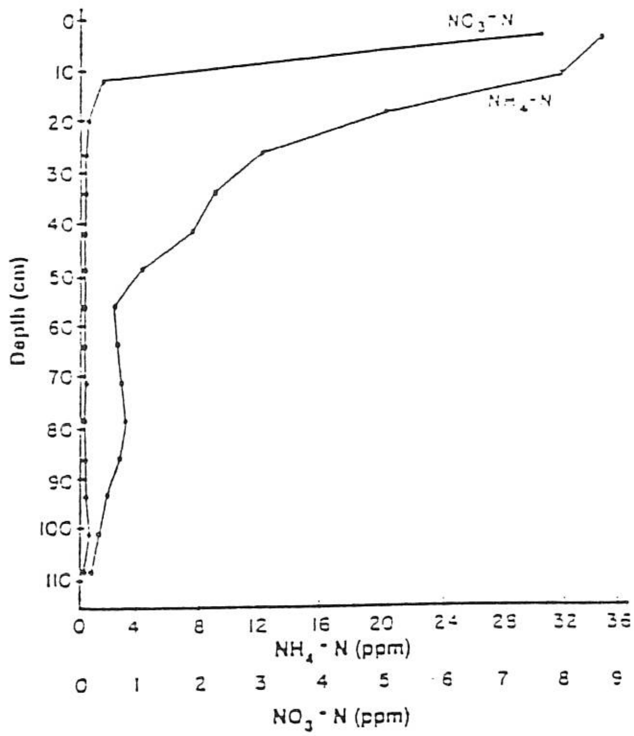


Figure 1. Ammonia and nitrate nitrogen present in a feedlot soil profile (Schuman and McCalla, USDA-ARS, 1975B).

Holding Ponds and Lagoons

Self-Sealing

Seepage from livestock waste treatment lagoons and runoff holding ponds has been studied by researchers for at least 2 decades. In essence, it has been determined that bacterial cells and fine organic matter generally clog soil pore spaces along the bottoms and sides of lagoons and holding ponds (Barrington and Jutras, 1985), making them effectively "self-sealing" (Davis et al., 1973).

After several months of storage, coefficients of permeability of the bottom soil of ponds storing liquid manure, wastewater and runoff from livestock operations have usually been from one to three orders of magnitude (i.e., 10 to 1000 times) lower with wastewater than with clean water (Robinson, 1973; Lehman and Clark, 1975; Barrington and Jutras, 1983). Where the bottoms and sides of manure storage ponds and lagoons have moderate to fine-textured soil (such as silt, clay loam or clay), the final permeability coefficient is usually of the order of magnitude of 10^{-6} centimeters per second (cm/sec), or 0.0014 inches per hour (in/hr) (Figure 2) (Barrington and Jutras, 1985). However, final permeabilities of a sand usually exceed 10^{-6} cm/sec (0.0014 in/hr) (Dye et al., 1984). Cattle manure has generally shown better self-sealing properties than swine manure (Barrington and Jutras, 1985).

Livestock manure and wastewater provide significant beneficial self-sealing on the bottoms and sides of lagoons and holding ponds. However, this phenomenon should not be counted on as the sole means of protecting groundwater, and lagoons and holding ponds should be placed in relatively impermeable subsoils (Dye et al., 1984).

Many feedlots in Texas are built on playa lakes, which have clay bottoms (Randall Clay) several feet thick underlain by much more permeable soil material (of Pleistocene origin) which resembles caliche. Lehman and Clark (1975) determined that undisturbed cores of the clay surface soil in playas had permeability values with clear water of 2.8×10^{-5} cm/sec (0.04 in/hr), as compared to 1.1×10^{-3} cm/sec (1.6 in/hr) for the buried Pleistocene materials. However, the addition of feedyard runoff reduced permeabilities to only 5.6×10^{-7} cm/sec (8.3×10^{-4} in/hr) for the Randall clay after 10 days, and to 1.7×10^{-6} cm/sec (0.0025 in/hr) for the underlying soil within 45 days.

Nutrient and Salt Leaching

Lehman et al. (1970) investigated the leaching of feedyard runoff contaminants below a playa lake bottom. Nitrogen compounds did not move

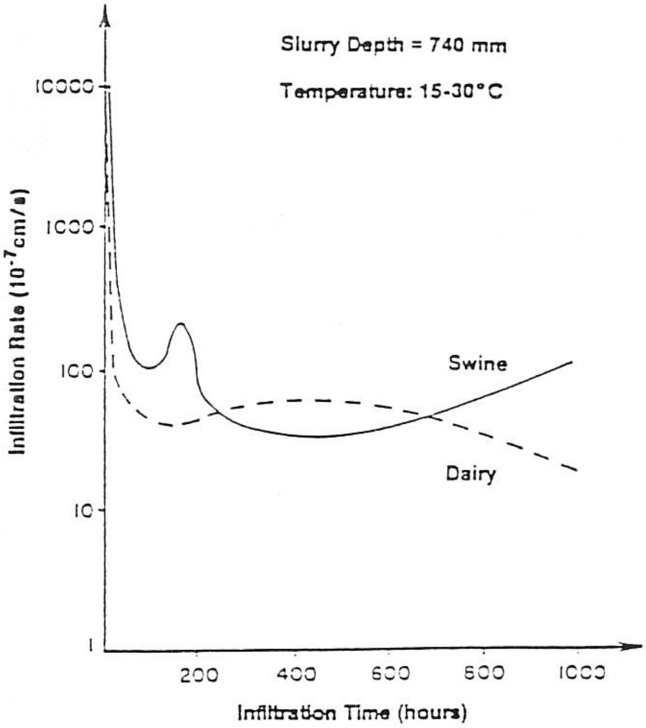


Figure 2. Infiltration rates for swine and dairy manure slurries over coarse sand (Barrington and Jutras, 1985).

below 3 feet. At 2 feet and below, the nitrate and nitrite concentrations were only slightly higher than for playas not receiving feedyard runoff (Table 1).

The feedlot playa study was repeated 5 years later by Clark (1975). Results in Figures 3 and 4 show that both nitrate and chloride concentrations decreased drastically within the top meter of soil. Below 1 meter (3.3 feet), nitrate concentrations were lower than the public drinking water standards of 10 mg/l nitrate-nitrogen.

The potential for groundwater contamination is increased (Lehman and Clark, 1975) when playa

Table 1. Nitrate, nitrite and ammonium-nitrogen concentrations beneath playa used for feedlot runoff collection (Lehman, Stewart and Mathers, 1970).

Depth Feet	Feedlot Playa* (3 obs. wells)			Non-Feedlot Playa (2 wells)	
	Nitrate	Ammonium	Nitrite	Nitrate	Nitrite
0	12.8	58.7	2.8	–	–
1	225	18.4	3.2	7.8	0.34
2	6.2	5.7	0.13	2.8	0.16
3	3.7	3.1	0.05	2.8	0.16
4	3.0	3.3	0.03	2.5	0.13
5	3.4	3.5	0.02		
6-13	0.3-2.7	1.1-2.8	0.02-0.12		

* Average of 3 center observation wells.

2-71

lake bottoms are excavated below the Randall clay layer. When excavation must be done, the clay should be stockpiled and reapplied to a compacted depth of 1 foot or more over the bottom and sides of the pond to serve as a clay liner (TWC, 1987).

Monitoring wells placed near livestock waste treatment lagoons and holding ponds have been used to determine the distribution of groundwater contaminants caused by lagoon seepage (Collins et al., 1975; Ciravolo et al., 1979; Sewell, 1978; Ritter et al., 1981; Phillips and Culley, 1985). Nutrient or salt concentrations in shallow groundwater sometimes increase in the immediate vicinity of lagoons or holding ponds. However, these initial increases usually diminish after several months. Results of studies with monitoring wells are reasonably consistent with the observed reductions in permeability caused by self-sealing.

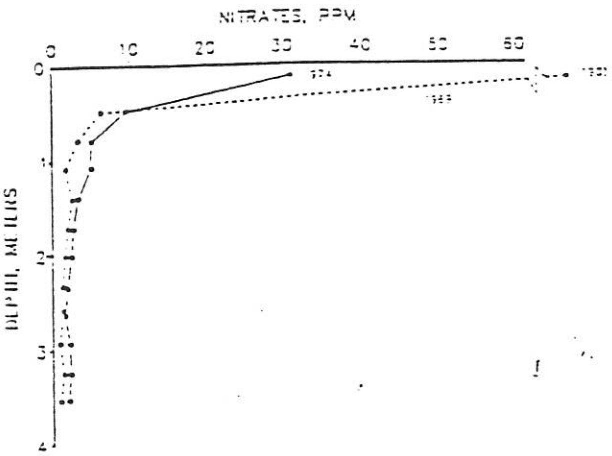


Figure 3. Nitrates (NO_3-N), dry-weight basis (110°C), beneath a feedyard playa, 1969 and 1974 (Clark, 1975).

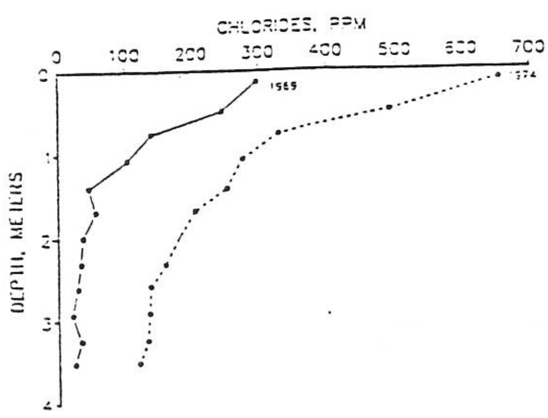


Figure 4. Chlorides, dry-weight basis (110°C), beneath a feedyard playa, 1969 and 1974 (Clark, 1975).

Regulatory Requirements for Soil Material

The Texas Water Commission (TWC, 1987) adopted a regulation that governs confined, concentrated livestock and poultry feeding operations. In order to protect groundwater from seepage from lagoons and holding ponds, the TWC regulation requires that all wastewater retention facilities be constructed of compacted or in-situ soil materials at least 12 inches thick and with low permeability. The soil material must meet or exceed the following criteria:

- liquid limit of 30 percent or more;
- plasticity index of 15 or more; and
- fraction passing a number 200 mesh sieve of 30 percent or more.

Many lagoons also are required by individual permits to have clay liners with a permeability coefficient of 1×10^{-7} cm/sec.

If these soil standards for lagoons and holding ponds are followed, combined with the benefit of self-sealing from stored manure and wastewater, groundwater should be adequately protected. And, cumbersome requirements such as monitoring wells or impermeable membrane liners should not be needed.

Land Application of Wastes

It is essential that livestock manure and wastewater be collected, stored and applied to land in such a way as to prevent discharge to surface water (TWC, 1987). The hourly application rate for wastewater should be uniformly less than the soil infiltration rate to prevent surface runoff. Also, manure and wastewater should be applied to soils at annual rates that match expected plant uptake of nutrients and crop yield goals to ensure that groundwater contamination will not occur.

Yields from Manure Application

With proper manure fertilization rates, such as 10 tons of feedlot manure per acre, crop yields usually equal or exceed the yields from commercial fertilizer, as shown in Table 2 (Mathers and Stewart, 1984). Yields with manure are often sustained for several years longer than with commercial fertilizer because of the slower release of residual nutrients and micronutrients (Lund et al., 1975; Lund and Doss, 1980).

Nutrient Accounting Balance

With proper manure application rates, most of the applied nutrients can be accounted for in increased crop harvest or increased weight gain of pastured cattle. Excessive manure application rates usually do not increase yields appreciably, but they do increase the soil nitrate levels to more than 10 ppm NO_3-N (Figures 5 and 6) (Reddell, 1974; Matthews and Stewart, 1984; Westerman et al., 1983).

Some research projects have documented crop nutrient uptake as a percent of applied nutrients. For example, Westerman et al. (1978) determined that the uptake of nitrogen, phosphorus and potassium (N-P-K) by coastal bermudagrass was 74, 41 and 74 percent, respectively, when swine lagoon effluent was applied at rates matching the recommended soil nitrogen (N) needs. But plant uptake of N-P-K was only 33, 17 and 32 percent when N application was four times the soil/plant requirements. The remaining 67 percent of the N applied remained in the soil and some had leached below the root zone (Figure 5). When manure applications greatly exceed crop nutrient requirements, nitrate-nitrogen accumulates in the root zone (Murphy et al., 1972; Manges et al., 1975; Reddell et al., 1974) and it may be subject to leaching. This soil accumulation of nitrate-nitrogen is illustrated in Figures 6 and 7 (Mathers and Stewart, 1971). Further research is needed on how nutrients in soils leach, volatilize, denitrify or are used by crops in typical livestock and crop production systems in Texas.

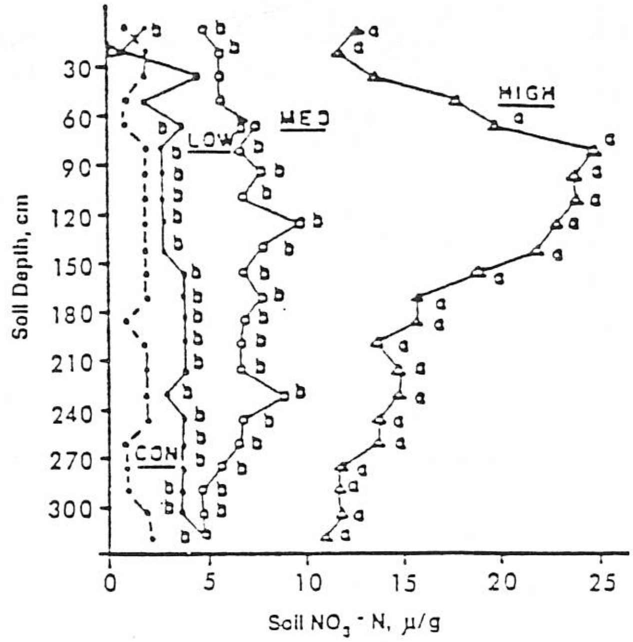


Figure 5. Effect on soil nitrate (NO_3-N) of lagoon effluent irrigation rates of 0, 4.7, 9.4 and 18.9 in/yr (control, low, medium and high, respectively) for 6 years (Westerman et al., 1983).

Table 2. Crop yields from feedlot manure application, Bushland, Texas 1969-80. USDA-ARS.

Manure Treatment	Number of Years: Manure Applied	Number of Years: Recovery No manure	Average Yields, lbs/acre/yr: Sorghum Grain 1969-'73	Average Yields, lbs/acre/yr: Corn 1975, '77, '79	Average Yields, lbs/acre/yr: Wheat 1976, '78, '80
0	11	0	4,490	8,350	1,400
0 (N)	11	0	6,440	13,390	4,050
0 (NPK)	11	0	6,410	13,560	4,290
10	11	0	6,640	13,920	3,430
30	11	0	6,490	13,400	4,530
60	5	6	6,360	14,340	4,000
120	5	6	5,120	13,950	4,260
240	3	8	900	15,260	4,330
240	1	10	330	12,100	2,810

Source: Mathers, A.C. and B.A. Stewart. 1984, *Transactions of the ASAE*, 27(4).

2-73

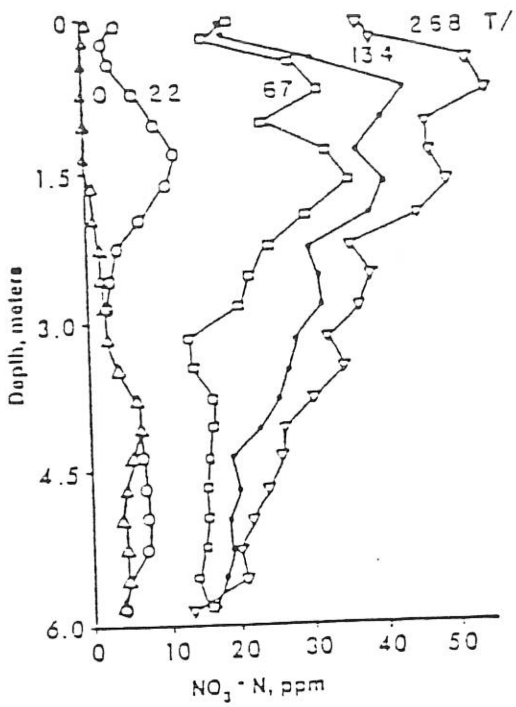


Figure 6. Total amount of nitrate-nitrogen accumulated in 20-foot soil profiles following two cropping seasons with the indicated amounts of manure applied each year (0, 10, 30, 60 and 120 tons/acre or 0, 22, 67, 134 and 258 metric tons/hectare) (Stewart and Mathers, 1971).

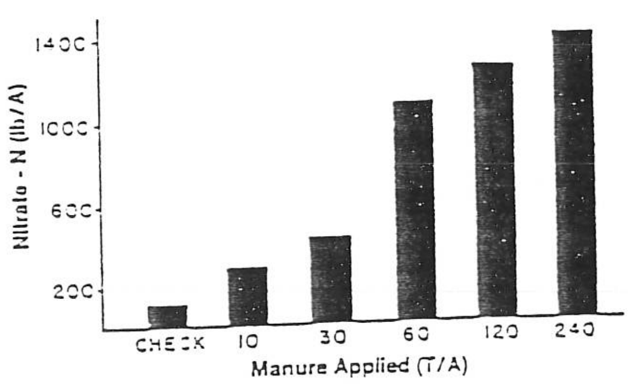


Figure 7. Nitrate-N in pullman clay loam soil after five annual applications of manure at indicated rates to irrigated grain sorghum (Mathers et al., 1975).

Soil Testing

Much of the agricultural soil in Texas is low in available nitrogen, organic matter and micronutrients and could benefit from manure application. Technical guides to proper manure application are readily available (Gilbertson et al., 1979). Fertilizer recommendations for specific crops are available from county Extension agents and agronomists (Table 3).

Producers should annually sample and test soils for nutrients. They should also measure the nutrient and salt concentrations in manure and wastewater in order to establish fertilization practices that both produce optimum crop yields and protect water quality. Soil testing is both a good agricultural practice and an excellent groundwater protection measure. Accurate soils analyses can be obtained at low cost from the Soil/Water/Plant Testing Laboratories of the Texas Agricultural Extension Service in College Station and Lubbock.

Summary

Feedlot surfaces should be managed to collect (harvest) manure frequently, yet to maintain an undisturbed layer of compacted manure and a manure/soil interfacial layer over the underlying soil surface. This will restrict leaching of nutrients and salts. When feedlots are closed, however, all manure should be removed.

A significant amount of self-sealing occurs in the soil at the bottoms and sides of storage lagoons and holding ponds as the soil is clogged with organic matter and bacterial cells. However, a complete seal is not formed. Therefore, compacted clay soils are needed to adequately control seepage, in accordance with state water pollution control regulations and permits.

Applying manure and wastewater according to crop nitrogen requirements will prevent groundwater contamination in most cases. However, excessive application rates can contaminate underlying aquifers with nitrate, ammonia, chloride and perhaps other substances.

2-74

regulations, and to provide the information it needs to regulate. That heavy reliance on the industry hasn't produced acceptable results, and the Department hasn't ensured that permitting requirements have been met, that feeding operations have operated with valid permits, and that operators submit required monitoring reports. The Department also hasn't established the types of procedures it needs to ensure that all these things happen. In addition, the Department appears to be slow to respond when it becomes aware of facilities that repeatedly violate its regulations. Water is one of the State's most valuable resources, and once polluted it can take many years to clean up. To-date, Kansas has been able to avoid some of the major lagoon failures experienced by Iowa and North Carolina. However, contamination problems that could be starting now won't show up for many years, particularly if groundwater deep below the surface is involved.

Recommendations

1. To ensure that all feeding facilities that represent a pollution threat to the State's water resources are identified and required to obtain a permit and operate within Department regulations, the Department should:

   a. Develop procedures for identifying facilities that haven't registered with the Department but that need to be evaluated for pollution potential.

   b. Develop a definition for the term "significant potential for pollution."

2. To ensure that confined-animal-feeding facilities are constructed in a manner consistent with State laws and regulations, and to help minimize the likelihood that these facilities will pollute the State's surface and groundwater, the Department should do the following:

   a. Incorporate its design standards for building animal-waste lagoons in the Kansas Administrative Regulations, and clarify with its staff that these are requirements, not guidelines. The Department also should require that the rationale for any deviations from those standards allowed by Department engineers is fully documented.

   b. Develop a formal system that requires its staff to review each facility's file and determine that all tests, inspections, certifications, and other requirements have been met by the operator before a permit is issued.

3. To ensure that confined-animal-feeding facilities continue to operate according to law and regulations after their initial permit has been issued, the Department should do the following:

   a. Develop a plan to identify and inspect all confined-feeding operations that are past due for inspections and ensure that in the future its staff inspect each facility at least as often as required by Department policies.

b. Ensure that staff promptly investigate all complaints about confined-feeding facilities, and inform the complainant of the outcome.

c. Develop a system for tracking complaints and violations to show which ones have been addressed, and which ones remain unaddressed.

d. Ensure that when regular inspections or complaint investigations uncover violations, there is either a visual inspection or adequate documentation submitted to the Department within a reasonable time to show that the violation has been corrected.

e. Ensure that applications for renewal permits are thoroughly investigated, and a site inspection has been recently made to identify any changes to the facility that might prompt the Department to place additional requirements (or remove existing requirements) from the facility's permit to operate. To accomplish this, the Department should determine how far in advance renewal applications need to be submitted so an investigation can be completed and the new permit issued before the facility's existing permit expires.

f. Ensure that feeding facilities submit monitoring logs when due, that Department staff understand the importance of reviewing those logs, and that staff follow up on a timely basis when the logs indicate potential problems at a facility.

g. Follow up on facilities shown in this audit to be operating contrary to Department standards or regulations, and take corrective action where needed.

4. To ensure that confined-feeding facilities that violate the Department's regulations have an incentive to take the required corrective action, the Department should apply penalties that are timely, consistent, and increasingly severe to fit the magnitude of the violation or the length of time it has gone uncorrected.

5. To ensure that neighbors and others potentially affected by the proposed construction of a confined-animal-feeding operation have adequate knowledge about the facility, and have an opportunity to voice any complaints or objections, the Department should reassess its public notification procedures to come up with a workable means of notifying affected citizens who aren't likely to be reached by its current procedures. As part of the notification process, the Department should consider providing a brochure that outlines the kinds of comments it can and can't consider.

Conclusion

The Department appears to have all the statutory authority it needs to regulate confined-feeding operations to prevent water pollution, and to control nuisances such as dust and odors. To-date, it has focused its efforts on controlling water pollution—rather than on trying to deal with problems of odor and dust—because of the difficulty involved in establishing standards and measuring the amount of dust created by a specific source. With the limited staff it has available for the Program, the Department has had to rely on the industry to police itself to a certain extent, and it can't adequately carry out the things it needs to do to make sure confined-feeding operations are operating according to laws and regulations. The Department may need to further study whether additional regulations governing dust and odors are warranted, and how it might be possible to implement them.

Recommendations

1. To ensure the Department's animal waste control program has enough staff to carry out the functions needed to adequately protect the State's water resources, the Senate Ways and Means Committee and the House Appropriations Committee should seriously consider the Department's request for additional Program staff in its fiscal year 1998 budget request.

2. To ensure that the cost of regulating confined-feeding operations doesn't become a burden on the State General Fund, the Department should determine the full cost of adding sufficient staff to the program, and seek the support of the Legislature to adjust registration and permit fees to the level needed to defray those costs.

3. The Department should further study whether it needs to issue regulations governing dust and odors generated by confined-feeding operations. In doing so, it should consider such things as the number of complaints it receives about these issues, lawsuits filed against confined-feeding operations in which dust and odors were an issue, and any other relevant issues. It should report its findings back to the Legislative Post Audit Committee before the start of the 1998 Legislature.

Should the feedlot registration threshold be modified from 300 to 1,000 animal units?

- The 1,000 a.u. threshold would be consistent with federal law.
- The 1,000 a.u. threshold would be consistent with all of the surrounding states and almost all other states.
- The change would be consistent with the precedent the legislature has set in other areas of state law by declaring that state regulations will be no more stringent than federal law.
- The 1,000 a.u. threshold would be consistent with the threshold the legislature has set for other permits required of feedlot operators (stockwatering permit, animal health department license).
- The state would maintain the authority to regulate any size of facility.
- As in other states, operators of facilities with less than 1,000 a.u. could be monitored through the non-point source program. Various educational and technical assistance support is available to operators in this category.
- Moving the threshold to 1,000 a.u. allows the state to focus more attention on the larger facilities which are responsible for the large majority of the animal waste.

KANSAS PORK PRODUCERS COUNCIL
KPPC
Serving Since 1956

Testimony to House of Representatives Environmental Committee

Mr. Chairman, and members of the Committee, I am Mike Jensen. I serve as the Executive Vice President of the Kansas Pork Producers Council. Our producer organization represents the majority of pork production units in this state. We have supplied you several reference materials for today's presentation.

We have numerous projects ongoing and in the planning stages for the producers in our state. A quick overview of them is as follows:

Environmental Stewardship Recognition Program

Over the past several years we have been recognizing operations in the state for their efforts in environmental activities. One of these operations progressed to be nationally honored for its environmental efforts.

Environmental Workshops

Our organization has sponsored several workshop sessions for our producers to interact with both regulatory (KDHE & DWR) and assistance sources (SCC, KSU Extension and NRCS) personnel. These sessions have provided a forum for producers to both keep current on statutory, regulatory and policy matters as well as interacting with service providers.

Environmental Guide and Producer Legal Guide

After the passage of SB 800 in 1994, the KPPC published a guide for producers in this state to inform them of the changes and encourage them to pursue registrations or permits. This proved to be the most-requested publication our organization has ever produced. We recently updated the guide to include a basic legal structure guide as well as the most current environmental information.

Environmental Assurance Program

I served on the National committee which established a program to assist our producers in keeping current with the "Best Management Practices" (B.M.P.'s) available to them. The result was the Environmental Assurance Program. Kansas was the first state in the nation to offer the completed program to our producers.

2601 Farm Bureau Road • Manhattan, Kansas 66502 • 913/776-0442 • FAX 913/776-9897

House Environment
2-4-97
Attachment 3

Environmental Demonstration Projects

Our organization recently approved a project to research and disseminate to producers the latest in innovative techniques in environmental management. This program will encompass numerous projects across the state. The goal of the program will be to evaluate new techniques in odor reduction and manure utilization. The culmination of this program will be field days and video presentations to producers and any interested parties.

Summary

In conclusion, I want to emphasize that our producers are actively working toward solutions to any actual or perceived problems. Our producers actively interact with KDHE, DWR, SCC, NRCS, KSU and other agencies that regulate or assist our industry. Recent environmental scrutiny has resulted in our producers, who also happen to be Kansas citizens and your neighbors, being unfairly branded as polluters. It has also painted state of Kansas employees as ineffective at their jobs. These are people who dedicated their careers to keeping the state's waters clean long before environmentalism was an issue.

Kansas was the first state to implement a livestock program in 1968. Our industry has been actively working with the agencies to do our part in protecting the environment for nearly 30 years. It's time to look at Kansas agriculture as a leader in both environmentalism and production. Please remember, **OUR** industry's future is also based on the availability of a quality water supply.

I want to finish with the old common sense saying "an ounce of prevention is worth a pound of cure." KDHE and Kansas livestock producers have been operating on the "ounce of prevention" theory for three decades. Before we abandon this common-sense approach, our organization's members believe there must be scientific evidence to justify having to bear the brunt of the "pound of cure" approach.

Thank you for your time.

Kansas Pork Industry Facts

Kansas recently rose to the number 8 state in hog and pig inventory

- In the last year, Kansas producers marketed:

2,103,833 market hogs
123,959 feeder pigs
26,953 seedstock
2,254,745 total

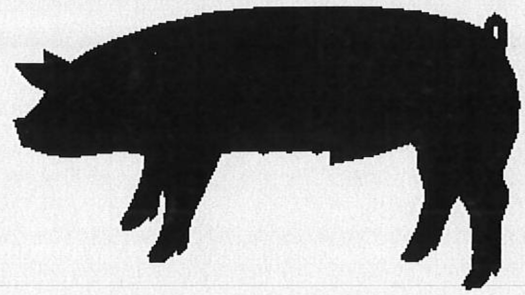
- 1995 gross market value was $291,138,681.47

- Kansas' sow inventory rose 27% in the last year to 190,000 head or 2.85% of the U.S total.

- Kansas swine consume over 24 million bushels of grain, primarily Kansas-grown dryland milo.

- Approximately 500 Kansas operations:
  - market 77.5% of our swine
  - have the equivalent of a 50-sow operation
  - average above $10,000 net income annually from swine

Symbol II



Symbol II is the pork industry's "perfect pig".
This hog will be marketed at 156 days of age weighing 260 pounds.
It will yield a 195-pound carcass.

* The Kansas swine industry annually spends about:

$170 million for feed grains
$6 million for veterinary care
$7 million for utilities (gas, propane & electric)
$7 million for trucking costs (hog marketing only, no grain)
$6 million in interest
$27 million in construction
$15 million in supplies

Geographically, the northcentral and northeast part of the state have the most hog operations. Washington county has the most hogs in the state with Nemaha in second and Clay in third. There are also some large operations in the southwest corner of the state.

Numbers as of January 1, 1997

KANSAS PORK PRODUCERS COUNCIL
KPPC
Serving Since 1956

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NPPC Environmental Assurance Program℠

Participants Manual

Produced by the National Pork Producers Council,
in cooperation with the National Pork Board

House Environment
2-4-97
Attachment 4

Table of Contents

Introduction
I. Why Do We Need an Environmental Assurance Program? 1

Environmental Audit
II. How Am I Doing? 6

Environmental Stewardship
III. Environmental Stewardship
Nutrient Management 9
Factors Affecting the Application of Manure 26

IV. Handling Manure to Protect the Environment
Manure Treatment and Utilization Considerations 29
Environmental Considerations of Manure Storage and Treatment Systems 30
Manure Treatment 32
Manure Reduction Strategies 33
Nutrient Application Plans 36
Nutrient Utilization Exercise 37
Air Quality 39
Air Quality and Human Health Considerations 42
Facilities Management 44
Techniques for Improving Management of Current Facilities 45
Aesthetics and Neighbor Relations 46
Community Relations Case Study 47

Key Regulations
V. Key Regulations
Federal Regulations 48
State and Local Regulations 50
Nuisance Laws 51

Environmental Assessment
VI. Environmental Assurance Action Plan
How to Use this Tool 57
Action Plan Instrument 58

Assurance Form
Environmental Assurance 73
Environmental Assurance Form 74

Appendix
Groundwater Protection 75
Surface Water Protection 77
Soil and Manure Sampling 80
Considerations for Setting Realistic Crop Yields 84

Resource Directory
Farm*A*Syst 85
State Contacts 86
Evaluation of NPPC Environmental Assurance Program 90

4-2

I. Why Do We Need An Environmental Assurance Program?

When you hear the term "environmentalist," what comes to mind? Some people think of extremists chaining themselves to trees or raising alarm about a certain pesticide or industrial chemical. For others, "environmentalist" means school children promoting recycling or planting trees in a community. However, probably few people immediately associate "environmentalist" with pork producers. Should they?

As we approach the next century, environmental concerns continue to be in the forefront of the public mind. This affects several key issues:

- as the population expands, food demands will continue to increase;
- regulations are likely to increase in both volume and complexity;
- traditional views of agriculture are changing;
- there will be greater demands for personal living space and resources like potable water

To fit into this new environmental world, pork producers must continue to improve their management of production inputs and outputs as they relate to the environment.

<u>Discussion Topic</u>

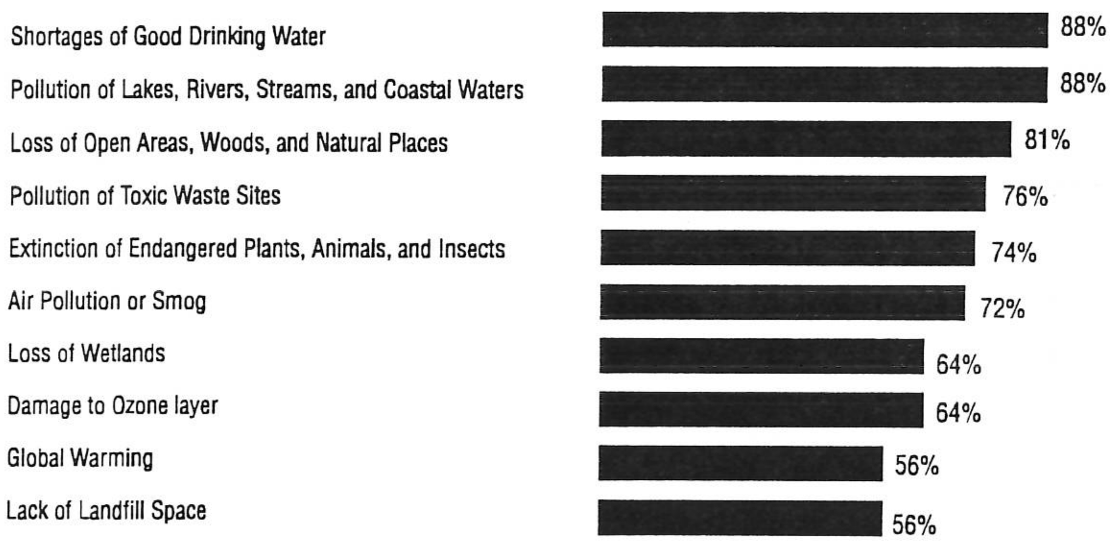
What are the "hot" environmental issues in your community?

In your opinion, what are the top sources of pollution in your community?

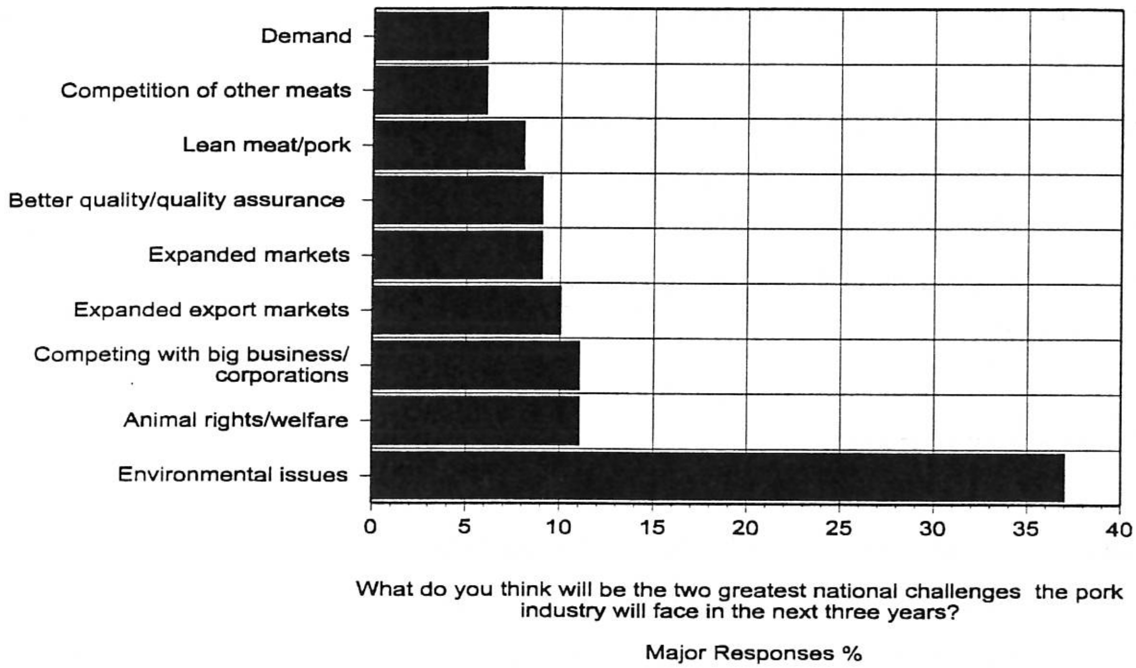
The General Public and the Environment

The good news is that the sky isn't falling: most Americans feel there can be balance between economic development and the environment. A Times/Mirror Magazine survey revealed that Americans are most concerned about water issues. Eighty-eight percent (88%) of the respondents felt that shortages of good drinking water and pollution of lakes, rivers and streams were the most pressing environmental issues facing the U.S. today.

Environmental Issues Americans Want to See Addressed



Pork producers were also asked what they think the two greatest national challenges the pork industry will face in the next three years are. Their responses included the following:



As you work through the information in the program today and complete your Environmental Assurance Plan, think beyond the immediate environmental concerns of family and neighbors.

- How does the rest of the public view your environmental actions?
- Are there any ways to get a financial premium for producing pork using environmentally sound practices? Will the public pay a premium for environmentally assured pork?
- What are the political implications of your environmental management?
- How would a regulator, a state legislator, or a Member of Congress view your farm?

The impression you leave on these individuals plays a critical role in shaping our future. NPPC and pork producers like you can use this program to help policy makers understand how you use sound environmental management. So, you may want to approach this program with three key considerations:

- keep an open mind about what you want from this program;
- be creative with how you use the information;
- take action on the information presented.

America's pork producers must be dedicated to conserving the environment. Our industry can only gain by having producers who are united in treating the environment with respect.

Environmental Assurance

The objectives for the workshop:

- to evaluate your current environmental management techniques;
- to review the impacts of manure management on water quality;
- to learn ways to reduce your manure management costs and increase manure nutrient utilization;
- to explore techniques for odor management;
- to discuss "environmentally sensitive" facility management;
- to share ideas on pork production; and
- to inform the general public about the pork industry's environmental assurance effort.

When you have completed the program, you will experience the benefits of being environmentally assured:

- confidence and security that you are a good environmental steward;
- improve profitability through better nutrient management;
- reduce the potential liability of a nuisance suit through good faith efforts and recordkeeping;
- build a positive environmental image for your farm, your family and your industry;
- join other Environmentally Assured Pork Producers in raising the awareness at local, state and national levels that we are dedicated to conserving the environment.

II. How Am I Doing? — A Personal Environmental Audit

Before diving into today's program, consider your current management techniques. Circle the answer that most closely fits your practices. Please answer honestly. This audit will not be seen by anyone else; it is simply a tool to help you focus on the possible environmental challenges of your operation.

1. I conduct manure nutrient analysis.

Annually	Every 5 years	Never

2. I know my manure application rate (tons, gallons/acre, or lbs of NPK/A).

Yes	No

3. I use soil samples to determine nutrient levels in fields to which manure is going to be applied.

Annually	Every 3 years	Never

4. I consider runoff potential before manure is applied to frozen or saturated ground.

Always	Once in a while	Never

5. When applying manure near rivers, streams, or other water bodies, I follow state and/or legal requirements or maintain at least a 50 ft. set back.

Always	Sometimes	Never

6. I consider wind direction before applying manure near populated areas.

Always	Once in a while	Never

7. When applicable, I incorporate or inject manure.

Within 0-24 hours	Within 24 hours to a week	Never

8. My facilities are inspected for possible environmental hazards.

Always	Once every couple years	Never

9. I consider the distance to a well when I load or apply manure.

Always	Sometimes	Never

10. I use odor management techniques.

Always	Sometimes	Never

11. I maintain detailed records on where and when I apply manure.

Always	Sometimes	Never

12. I know the total amount of nutrients produced on my farm operation.

Always	Sometimes	Never

13. I change my management practices to reduce potential environmental risk.

Regularly	Sometimes	Never

14 I have tested my well water for nitrates and bacteria.

Within 1 year	Within 5 years	Never

15 My manure system is designed for the ________________ of manure that is produced on my farm.

a.) treatment b.) utilization c.) disposal

III. Environmental Stewardship

A. Nutrient Management

Understanding water quality

We all depend on clean air and water. The water supply we use for both personal use and pork production comes from either surface water (lakes, streams, or rivers) or groundwater. Groundwater is the more important source for most pork producers; it provides drinking water for half the US population and nearly the entire rural population. Because groundwater is such a vital source, any type of contamination is viewed with concern.

The best way to protect ground and surface water is to understand and manage water quality. The following are several key terms associated with the hydrology and geology of water quality:

Groundwater:

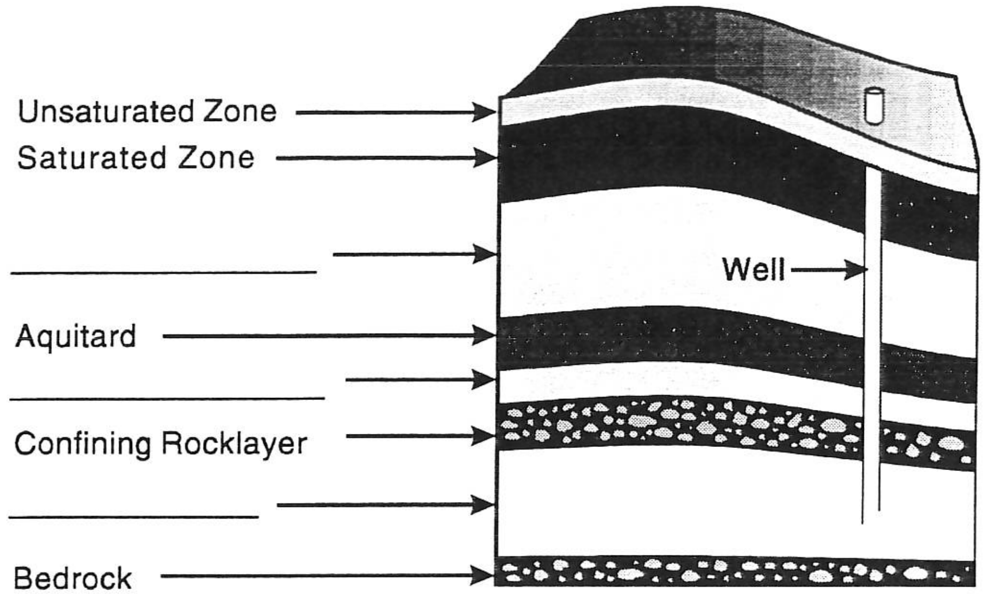
Surface water:

Aquifer:

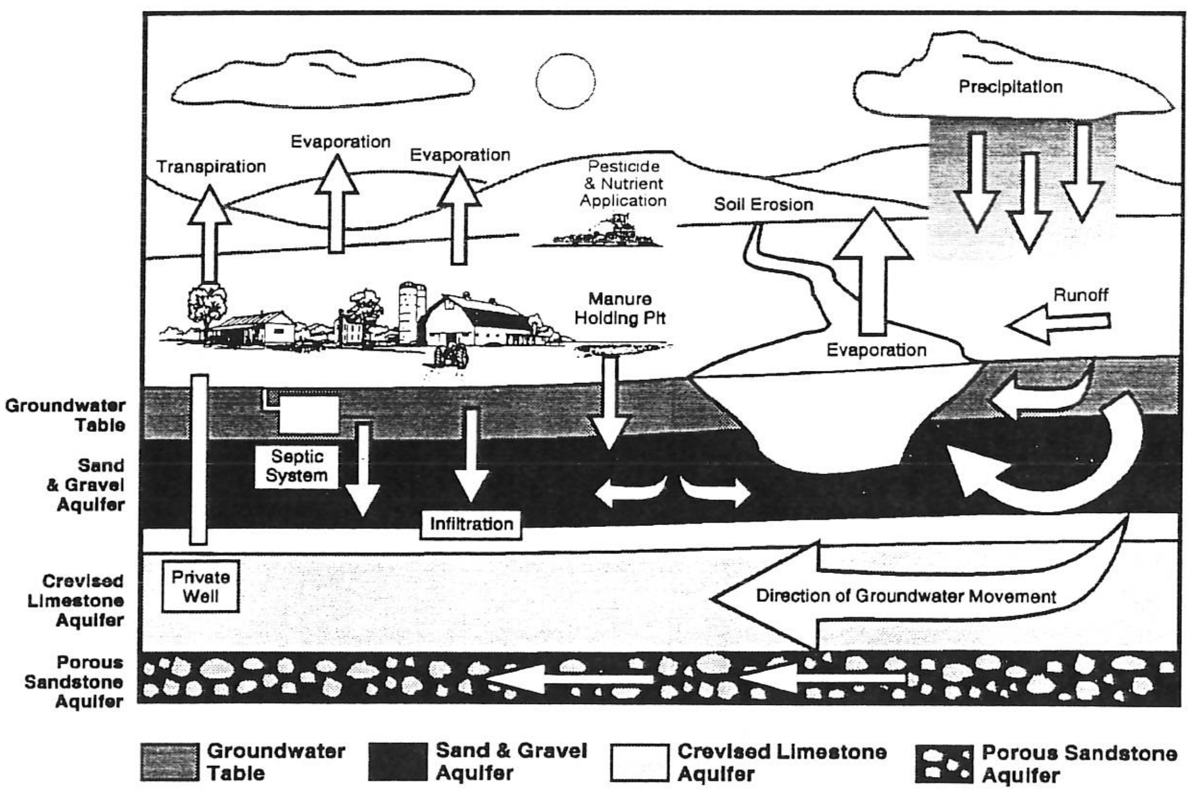
Leaching:

Runoff:

Groundwater flow:



Ground and Surface Water Flow



Based on the previous definitions, what land areas and bodies of water would be most susceptible to contamination due to manure? What are the possible routes of contamination to both ground and surface waters?

All water contaminants have a source. Municipal sewage treatment facilities, industries, and even some livestock operations are considered "point" sources because they directly discharge their effluent into waterways. Anything that is not a point source, is considered a non point source.

What are some other examples of point sources?

What are some examples of non point sources?

Are most of our agricultural water quality problems from *point sources* or *non point sources*?

Sources of Water Contaminants

There are many different sources of water quality contaminants. Industries, homeowners, mining, acid rain, air pollution and agriculture can all contribute to water quality contamination.

EPA and state regulatory agencies assess water quality by sampling rivers, lakes, streams and groundwater for pollutants. Below is a chart showing the EPA's assessment of the nation's water quality.

Five Leading Sources of Water Quality Impairment			
Rank	**Rivers**	**Lakes**	**Estuaries**
1	Agriculture	Agriculture	Municipal Point Sources
2	Municipal Point Sources	Urban Runoff/ Storm Sewers	Urban Runoff/ Storm Sewers
3	Urban Runoff/ Storm Sewers	Hydrologic/Habitat Modification	Agriculture
4	Resource Extraction	Municipal Point Sources	Industrial Point Sources
5	Industrial Point Sources	Onsite Wastewater Disposal	Resource Extraction

Source: EPA National Water Quality Inventory Report to Congress, 1993

This assessment of water quality may not reflect recent changes in farm management related to government farm program requirements. Additionally, we do not know what the background or natural levels of nutrients or sediments are within any given water system. Keep in mind that in order to get additional information, expensive studies would have to be conducted. This makes it difficult to gauge agriculture's relative contribution toward water quality impairment. However, these assessments do drive the attitudes and programs of both regulators and consumers. Understanding and responding to this concern should be an important consideration for pork producers.

Manure, Nutrients and Water

Much of the success of modern crop production can be attributed to the proper use of nutrients. Both synthetic fertilizers and manure have been used extensively to increase crop production and feed a growing world population. The negative side of nutrients is that, if they are not used properly, they can end up in ground and surface waters. When nutrients and manure move into water, what are some of the negative things that can happen?

The primary nutrients found in hog manure are nitrogen, phosphorus and potassium. Nitrate nitrogen (nitrate is NO_3^--N, a water soluble, negatively charged ion) in water can be harmful to humans. Doctors recommend using bottled drinking water to make formula when nitrate levels exceed the drinking water standard set by the Public Health Service [44 (ppm) of nitrate (NO_3^-)]. This level is equivalent to 10 ppm of nitrate-nitrogen (NO_3^--N). Swine rapidly eliminate nitrate and generally are not effected. Nitrate nitrogen (NO_3^-) and ammonium nitrogen (NH_4^+) are produced through the biological break-down of manure. Excessive nutrients and decomposing organic nutrients (N, P, K, S) can be responsible for algal blooms and weed growth in water, which can reduce available oxygen for aquatic species. Along with the nutrients, manure may increase salinity on some soils. This is especially true in western states.

The value of manure

We often don't think about the true "value" of manure in terms of N, P, and K. But as fertilizer costs rise and profit margins fall, producers need to look for new ways to get as much value as possible from manure. Different livestock produces manure with different nutrient values – some more concentrated than others. That's why manure testing and analysis is critical. Hog manure has a relatively good nutrient value compared to other livestock.

SWINE MANURE GENERATION WORKSHEET

(For estimating and preliminary planning purposes only -- consult more specific tables or a professional nutrient management advisor for detailed figures.)

Group	Number		Avg. Size (lbs/each)		Manure Production Factor	
Nursery pigs	_______ (a)	X	25 lb	X	1.6	= ____________ (d)
Grower/Finisher	_______ (b)	X	150 lb	X	1.0	= ____________ (e)
Sows/Boars	_______ (c)	X	300 lb	X	.6	= ____________ (f)

Total = ____________ (w) animal wgt. factor
(d+e+f)

Manure Volume:

Total animal weight factor (w) ________________ X .001 = ____________________ cu. ft./day (h)
cu. ft/day (h) X 7.5 = ____________________ gallons/day (i)
cu. ft/day (h) X 365 = ____________________ cu. ft./year (j)
gallons/day (i) X 365 = ____________________ gallons/year (k)

Add in waste water volume - if unknown, use .1 to .25 gallons/head/day as an estimate:

Total number of animals ______________ X ______________ gallons/head/day = ______________ gallons/day (q)
(a+b+c)
gallons/day (q)/7.5 = ______________ cu. ft./day (r)
gallons/day (q) x 365 = ______________ gallons/year (s)
cu. ft./day (r) x 365 = ______________ cu. ft./year (t)

Total manure and wastewater volume: (i + q) ______________________ gallons/day (u)
[Storage needs = days of planned (k + s) ______________________ gallons/year (v)
storage X cu. ft./day (y)] (h + r) ______________________ cu. ft./day (y)
(j + t) ______________________ cu. ft./year (z)

Major nutrients produced from manure:

NITROGEN: Total animal weight factor (w) ______________ X 0.15 = ________________ lb total nitrogen/year (n)
Total lb of nitrogen/year (n) ____________ X ____________ % of N avail. calc. from tables and from crop production records = ____________ lb of N avail/yr. (o)
Lb of available nitrogen/year (o) ______________ + ______________ lb nitrogen/acre for crop (from crop production records and type of crop to be grown) = ______________ crop acres needed

PHOSPHORUS: Total animal weight factor (w) ____________ X 0.13 = ______________ lb total phosphate/year (p)
Lb of phosphate/year (p) ______________ + ______________ lb phosphate/acre for crop (from crop production records and type of crop to be grown) = ______________ crop acres needed

POTASSIUM: Total animal weight factor (w) ______________ X 0.10 = ________________ lb total potash/year (k)
Lb of potash/year (k) ______________ + ______________ lb potash/acre for crop (from crop production records and type of crop to be grown) = ______________ crop acres needed

*Adapted from USDA National Engineering Agricultural Waste Management Handbook

SWINE MANURE GENERATION EXAMPLE WORKSHEET

(For estimating and preliminary planning purposes only -- consult more specific tables or a professional nutrient management advisor for detailed figures.)

Group	Number		Avg. Size (lbs/each)		Manure Production Factor		
Nursery pigs	4,000 (a)	X	25 lb	X	1.6	= 160,000	(d)
Grower/Finisher	3,000 (b)	X	150 lb	X	1.0	= 450,000	(e)
Sows/Boars	200 (c)	X	300 lb	X	.6	= 36,000	(f)
Total Animals	7,200		Total	=	646,000 (w) animal wgt. factor (d+e+f)		

Manure Volume:

Total animal weight factor (w) 646,000 X .001 = 646 cu. ft./day (h)
cu. ft/day (h) X 7.5 = 4,845 gallons/day (i)
cu. ft/day (h) X 365 = 235,790 cu. ft./year (j)
gallons/day (i) X 365 = 1,768,425 gallons/year (k)

Add in waste water volume - if unknown, use .1 to .25 gallons/head/day as an estimate:

Total number of animals 7200 (a+b+c) X .25 gallons/head/day = 1,800 gallons/day (q)
gallons/day (q)/7.5 = 240 cu. ft./day (r)
gallons/day (q) x 365 = 657,000 gallons/year (s)
cu. ft./day (r) x 365 = 87,600 cu. ft./year (t)

Total manure and wastewater volume: (i + q) 6,645 gallons/day (u)
[Storage needs = days of planned (k + s) 2,425,425 gallons/year (v)
storage X cu. ft./day (y)] (h + r) 886 cu. ft./day (y)
(j + t) 323,390 cu. ft./year (z)

Major nutrients produced from manure:

NITROGEN: Total animal weight factor (w) 646,000 X 0.15 = 96,900 lb total nitrogen/year (n)
Total lb of nitrogen/year (n) 96,900 X 0.50 % of N avail. calc. from tables and from crop production records = 48,450 lb of N avail/yr. (o)
Lb of available nitrogen/year (o) 48,450 ÷ 120 lb nitrogen/acre for crop (from crop production records and type of crop to be grown) = 403 crop acres needed

PHOSPHORUS: Total animal weight factor (w) 646,000 X 0.13 = 83,980 lb total phosphate/year (p)
Lb of phosphate/year (p) 83,980 ÷ 80 lb phosphate/acre for crop (from crop production records and type of crop to be grown) = 1,050 crop acres needed

POTASSIUM: Total animal weight factor (w) 646,000 X 0.10 = 64,600 lb total potash/year (k)
Lb of potash/year (k) 64,600 ÷ 120 lb potash/acre for crop (from crop production records and type of crop to be grown) = 538 crop acres needed

*Adapted from USDA National Engineering Agricultural Waste Management Handbook

Table 1: Manure Production and Characteristics as Produced

Values are approximate. The actual characteristics of a manure can easily have values 30% or more above or below the table values. The volumes of waste a system handles can be much larger than the table values due to the addition of water, bedding, etc. For example, liquid waste systems for swine farrowing and gestation units may have to handle twice as much waste volume as indicated; swine nurseries 3-4 times as much, because of large amounts of wash and wasted water.

	Total Manure Production					Density	TS	VS	BOD_5	Nutrient content, lb/day		
Animal	**Size, lb**	**lb/day**	**ft^3/day**	**gal/day**	**water, %**	**lb/ft^3**	**lb/day**	**lb/day**	**lb/day**	**N**	**P_2O_5**	**K_2O**
SWINE												
Nursery pig	35	2.3	0.04	0.3	90.8	62	0.39	0.30	0.11	0.02	0.012	0.012
Growing pig	65	4.2	0.07	0.5	90.8	62	0.72	0.55	0.20	0.03	0.022	0.023
Finishing pig	150	9.8	0.16	1.2	90.8	62	1.65	1.28	0.47	0.07	0.050	0.054
	200	13.1	0.21	1.6	90.8	62	2.20	1.71	0.63	0.09	0.067	0.072
Gestating sow	275	9.0	0.15	1.1	90.8	62	0.82	0.66	0.27	0.07	0.050	0.050
Sow and litter	375	22.5	0.36	2.7	90.8	62	2.05	1.64	0.68	0.10	0.055	0.055
Boar	350	11.5	0.19	1.4	90.8	62	1.04	0.84	0.34	0.09	0.064	0.064

Source: American Society of Agricultural Engineers, data adapted from 1992 ASAE standard D384.1

TS = Total solids (taken from 1992 ASAE data)

VS = Volatile solids (taken from 1992 ASAE data)

BOD_5 = The oxygen used in the biochemical oxidation of organic matter in 5 days at 68°F. A standard test to assess wastewater strength *(taken from 1992 ASAE data)*

N = Total nitrogen

Elemental P (phosphorus) = 0.44 x P_2O_5

Elemental K (potassium) = 0.83 x K_2O

Densities are from 1992 ASAE Standards

Nutrient contents taken from Purdue University data

4-18

Table 2: Secondary and Micronutrient Content of Swine Manures

Manure Type	Ca	Mg	S	Na	Fe	Mn	B	Mo	Zn	Cu
					lb/ton					
Fresh	7.9	1.7	1.8	1.6	0.39	0.04	0.074	0.00066	0.12	0.029
Paved lot scraped	12.0	2.3	2.2	1.6	1.03	0.19	0.015	0.00007	0.35	0.15
					lb/1,000 gallons					
Liquid slurry	8.6	2.9	4.7	3.7	0.69	0.15	0.069	0.0011	0.39	0.11
Lagoon sludge	15.8	4.5	8.3	2.9	1.8	0.28	0.023	0.0095	0.67	0.23
					lb/acre-inch					
Lagoon effluent	25.5	8.3	10.0	57.7	2.4	.34	0.18	0.0045	1.5	0.3

Source: Biological and Agricultural Engineering Department, NCSU

Table 3: Method of Calculating N Availability of Manures[a] - Midwest Conditions

Available Nitrogen %		Time of Application	Days Until Incorporated[b]
NH4	Organic	Date	Days
50	33	Nov-Feb	≤ 5
25	33	Nov-Feb	> 5
50	33	Mar-Apr	≤ 3
25	33	Mar-Apr	> 3
75	33	Apr-Jun	≤ 1
25	33	Apr-Jun	> 1
75	15	Jul-Aug	≤ 1
25	15	Jul-Aug	> 1
25	33	Sep-Oct	≤ 1
15	33	Sep-Oct	> 1

[a] The calculations are for all animal manures.

[b] Incorporation is the mixing of manure and soil in the tillage layer. Disking is usually enough tillage for conserving N availability.

[c] Only about one-third of the organic nitrogen in animal manure is available to crops during the year it is applied. The remaining two-thirds, residual organic nitrogen, becomes part of the soil organic matter. It is mineralized or becomes available at the rate of about 5 percent a year. To determine how much nitrogen will be available to crops from manure applications, growers must take into account the mineralized nitrogen that will become available from previous manure applications.

Table 4: Nitrogen Losses During Storage and Handling[a]

System	Nitrogen Lost %
Solid	
Daily scrape and haul	15-35
Manure pack	20-40
Open lot	40-60
Deep pit	15-35
Liquid	
Below-ground storage tank	15-30
Above-ground storage tank	10-30
Earth storage	20-40
Anaerobic lagoon	70-80

[a] Typical losses due to storage and handling between excretion and land application. Values adjusted for dilution. These values are in addition to any losses that occur during land application.

Table 5 provides a comparison of nitrogen losses due to storage and handling. Land application methods also affect the amount of nutrients available for crop uptake. Most losses occur within 24 hours of application. Manure should be incorporated into the soil as soon as possible after application. Injecting, chiseling, or knifing liquid manure into the soil minimizes odors and nutrient losses to the air or as surface runoff.

Table 5: Estimated N Availability % as a Function of Soil Properties, Environment, and Application Time and Method for the First Year After Application

Soil Organic Matter Level	Time of Application	Soil Texture	Rainfall	Broadcast w/o incorp. %	Broadcast w/incorp. %	Knife Injection %
Low	Fall	Coarse	Low, Norm	30	55	45
			High	20	45	40
		Fine	Low, Norm	35	60	50
			High	30	55	45
	Spring	Coarse	Low, Norm	40	55	50
			High	35	50	45
		Fine	Low, Norm	45	55	45
			High	45	55	40
High	Fall	Coarse	Low, Norm	30	40	50
			High	25	35	40
		Fine	Low, Norm	35	55	45
			High	35	50	40
	Spring	Coarse	Low, Norm	40	50	50
			High	35	45	45
		Fine	Low, Norm	40	50	45
			High	40	50	40

Source: AG-FO-3553-C. Manure Management in Minnesota. Cooperative Extension Service -- University of Minnesota.

Table 6: Nutrient Composition of Swine Manure

Manure Type	Total N	Ammonium NH_4-N	Phosphorus P_2O_5	Potassium K_2O
		lb/ton		
Fresh	12	7	9	9
Scraped[1]	13	7	12	9
		lb/1,000 gallons		
Liquid slurry[2]	31	19	22	17
Anaerobic lagoon sludge	22	6	49	7
		lb/acre-inch		
Anaerobic lagoon liquid	136	111	53	133

Source: Abridged from *North Carolina Agricultural Chemicals Manual.*

[1]Collected within 1 week.

[2]Six-12 months accumulation of manure, urine, and excess water usage; does not include fresh water for flushing or lot runoff.

ANNUAL FARM SUMMARY

Farm Name:______________________________ Calendar Year______________

Routine/ Field	Crops	Soil Test Results						PA** Nutrient Required			NCNS* Applied	PA NCNS			Crop Removal			PA Net Balance		
		pH	CEC	P-I	K-I	Zn	Cu	N	P_2O_5	K_2O		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
								pounds per acre for crop			tons, acre in. 1000 gal	pounds per acre			pounds per acre			pounds per acre		

On-Farm and Imported Solid NCNS	Total Applied, tons		If you have an excess manure balance, you need to consider transporting it off farm.
	Total Produced or Imported, tons		
	Solid NCNS Balance, tons		
On-Farm and Imported Liquid NCNS	Total Applied, 1000 gal or acre in.		
	Total Produced or Imported, 1000 gal or acre in.		
	Balance, 1000 gal or acre in.		

* NCNS is noncommercial nutrient source = manure

** PA = Plant Available

4-22

Lagoon Effluent Irrigation Field Records

Farm Owner:____________________________ Irrigation Operator:____________________________

Field No.	Date	Crop Type	Field Size, acres	Irrigation Time			Number of Sprinklers Operating	Sprinkler Nozzle				
				Start	End	Total mins.		Diameter inch	Pressure psi	Flow gpm	Spacing, ft. width	length

4.23

Lagoon Effluent Irrigation Records

	Farm Owner	Custom Applicator (if used)
Name:	______________________	______________________
Address:	______________________	______________________
	______________________	______________________
Phone:	______________________	______________________

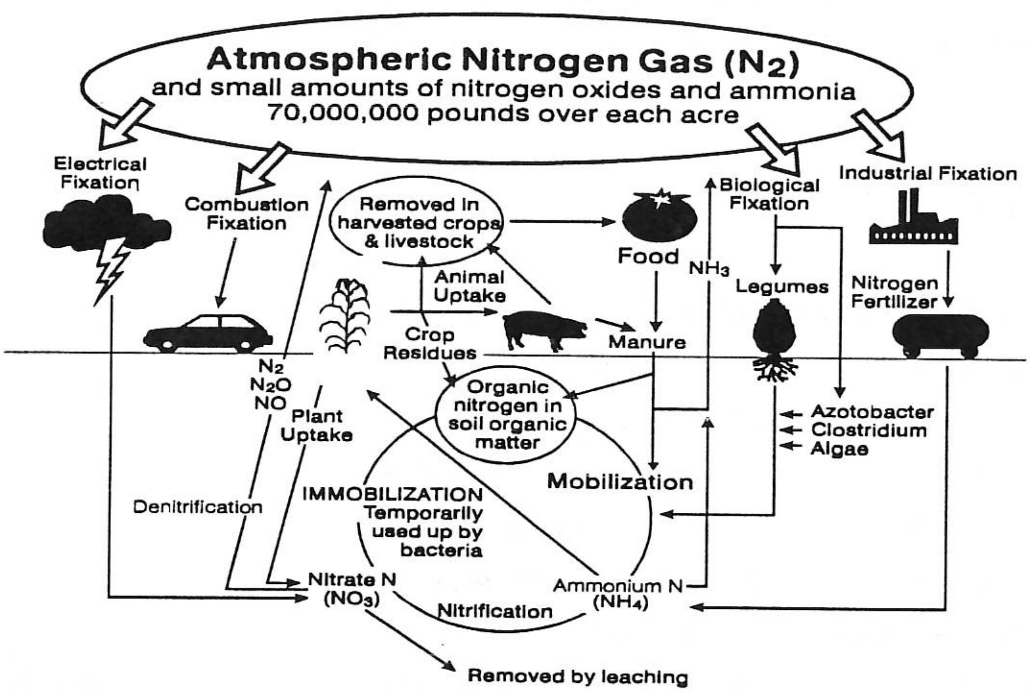
Field No.	Date	Irrigation		Soil Type	Crop Type	Realistic Yield; lb bu, ton/acre	Nutrient Recommendations, lbs/acre			Liquid Analysis Plant Available Nutrients, lbs/1000 gallons					Liquid Nutrients Applied Plant Available, lbs/acre					Nutrient Balance, +/-, lbs/acre				
		volume, gals	area, acres				N	P_2O_5	K_2O	N	P_2O_5	K_2O	Zn	Cu	N	P_2O_5	K_2O	Zn	Cu	N	P_2O_5	K_2O	Zn	Cu
Totals:																								

4-34

Hog manure does benefit soil quality. Along with nitrogen, phosphorus and potassium, several trace minerals are also found in manure. If properly used, the nutrients can reduce commercial fertilizer needs for many crops. Along with the nutrient value, hog manure can increase microorganisms and improve soil organic matter, soil tilth, and soil structure. These improvements in soil quality can reduce erosion, improve drainage, and increase soil productivity. Let's take a closer look at the valuable components of hog manure.

Nitrogen

Nitrogen is important for all plants and animals; the nitrogen in manure is no different than the nitrogen found in synthetic fertilizers. Nitrogen comes from many sources and in many different forms. The nutrient and pollution potential of manure nitrogen depends on the form and amount in the environment. Understanding the different forms allows you to better manage this important nutrient.



The two main forms of nitrogen (N) in hog manure are organic N (proteins, amino acids and urea, which are unavailable to plants) and inorganic N (ammonium, nitrates, ammonia). Ammonium N is the predominant component of available nitrogen in manure.

When manure is applied to soil, the organic N begins to break down to inorganic N, which is available to plants. This process is called ammonification or mineralization, and is affected by temperature, moisture, and time. These same processes occur in an anaerobic storage lagoon, which is why nitrogen values are reduced in these systems. Warm conditions have a higher rate of organic N conversion than cooler temperatures. Approximately 33-50% of organic N is converted to ammonium or available N each year after the manure is land applied.

When organic N is converted to available N, it starts as ammonium N. Ammonium N is available for plant uptake and is not mobile in the soil. The process of nitrification eventually converts ammonium N to nitrate N. While nitrate N is available to plants, it is also susceptible to denitrification (loss to the air) and to leaching. Ammonia N can be quickly lost by being converted to ammonium and volatilized. Incorporating manure into soil can prevent this process.

Phosphorus and Potassium

Phosphorus and potassium are also important nutrient components of manure. Both nutrients are needed for proper plant and root growth. While they generally bind tightly with soil, they can move into surface waters by moving on eroded soil particles. Phosphorus may move directly into surface waters in areas with extremely high phosphorus levels. Excessive concentrations of phosphorus in water can contribute to excessive aquatic plant growth and depletion of oxygen. However, phosphorus and potassium have little potential for leaching and have no direct toxic effects on humans or wildlife. By using proper conservation techniques (such as conservation tillage, terraces, filter strips, etc.) movement of phosphorus or potassium into surface water can be reduced.

The Bottom Line on Manure and Nutrients In Your Area

Factors Affecting the Application of Manure

What are some "environmental" considerations for land application of manure?

The answer to this question depends on several factors:

- soil texture -- the amount of sand, silt, clay and organic matter influences the binding potential of manure;
- soil erosion potential -- nutrients that are bound to soil can move into water;
- depth to groundwater -- the closer groundwater is to the soil surface, the greater the potential for contamination;
- distance to surface water -- the closer to surface water, the greater the potential for contamination;
- amount of precipitation -- greater amounts of precipitation or moisture increase the potential for leaching and runoff;
- temperatures -- higher temperatures increase volatilization of manure and influence the form of nutrient available (especially N);
- wind directions -- direction of the wind influences when and where manure applications should be made;
- manure storage system -- capacity and type of system influences the amount of nutrients available. In general, systems such as anaerobic storage lagoons considerably reduce the amount of nitrogen in manure;
- manure application method -- application influences the amount of odor, degree of volatilization and area to which it is applied;
- crops grown -- different crops have varying nutrient needs and rates of nutrient uptake.

Application Considerations

Of all the factors that need to be considered for environmentally friendly applications of manure, some of the most important are timing, method and rate of application. Let's take a closer look at each of these.

Time of application

Time of application influences nutrient availability and potential movement. The environmental management plan for your operation, including the storage capacity of your handling system, should determine when manure is applied.

Fall applications, either injected or broadcast, allow more time for organic portions of the manure to break down and be available for plant uptake. However, the increased time for breakdown also allows for more potential nitrogen loss to the environment. Coarse textured soils have the greatest chances for leaching with fall applied manure. Manure applied in the spring has the least amount of time for nitrogen loss to occur. Spring applications also create the greatest likelihood for soil compaction. The exact impact of time of application depends on temperature and soil type. As a general rule, when applying manure, follow the same local guidelines as for anhydrous ammonia application.

Frozen or saturated soils can increase the potential for environmental contamination. In some areas, regulations prevent these applications. Incorporation is not feasible under these conditions, so nitrogen loss can be high. Nitrogen and phosphorus movement into surface water is also potentially high. When manure is applied to frozen ground, it should be applied on relatively flat land. Land with grass, hay or small grain stubble should be used for these applications. In southern climates, grass is an excellent cover crop for nutrient uptake and should be utilized to its fullest extent.

Method of application

Method of application can also impact the environmental fate of manure. Injecting or incorporating manure soon after application reduces nitrogen loss and minimizes odor. Producers should use care when injecting manure on highly erodible land. Injection and incorporation may not always be possible because injectors may not leave adequate crop residue on the soil surface. If your USDA Conservation Compliance Plan includes a minimum crop residue requirement, check to be sure you're maintaining adequate levels. In some cases, broadcast application may be needed.

When applying or transporting liquid manure through irrigation systems, care needs to be taken to avoid surface and groundwater contamination. Irrigators also need to be concerned about applying effluent at a rate that matches the infiltration rate of the soil to avoid runoff and ponding.

Rate of application

With all application methods, the proper amount of manure needs to be applied based on soil tests, manure tests, soil type, crop needs, and proper calibration techniques. Consult your local Natural Resource Conservation Service, Extension Service or crop consultant for specifics.

IV. Handling Manure to Protect the Environment

Manure Treatment and Utilization Considerations

What were your key considerations when you designed your manure management system?

If you could change your manure management system today, what would you change?

Environmental Considerations of Manure Storage and Treatment Systems

The primary environmental threats from manure storage systems are overflow and leaks. To prevent these problems, keep the following in mind:

- **provide adequate storage.** Storage should be consistent with your manure management plan and meet regulatory requirements. By having adequate storage, manure can be applied when workload is the lightest, crop benefit is the greatest and environmental conditions are best. Outdoor lots should use retainment structures or should drain to an approved manure storage facility.

- **keep rainwater and excess water out of storage area**. This helps prevent overflow of storage capacity and reduces manure handling costs. If rainwater does come in contact with manure, it is important to retain and eventually use the nutrient value of this water.

- **evaluate the location of current and future manure storage systems**. What can be done to minimize the runoff and odor from your current system? Planting trees, building concrete barriers, and grading land can all minimize odor and manure movement. Use the environmental audit form of this program annually to evaluate your manure system.

- **use proper construction techniques**. Actual construction techniques vary depending on the system. However, environmental considerations need to be paramount. Storage units should be designed and constructed to ensure that manure liquid does not move into groundwater or vice versa, either during storage or in transit to the storage structure. For earthen lagoons, either a properly constructed compacted soil liner or an industrial membrane liner may be needed if the native soil is highly permeable. Check with state and local personnel to get specifics on your construction requirements. Natural Resource Conservation Service (NRCS), State Department of Agriculture or Natural Resources, or private consultants and engineers may assist on design, construction and maintenance recommendations.

- **have a plan in case of an accident**. Being prepared in the case of an overflow or leak reduces environmental problems. An emergency plan should include techniques to clean up the spill, whom to contact, needed documentation, and additional contingencies that may fit your operation. Identify the person within your state regulatory agency to contact in the event of a spill. Keep a list of contacts who can help you in an emergency next to your phone.

Manure Treatment

Manure treatment systems are popular where the land base for manure applications is limited and the nutrient load from manure needs to be reduced. Treatment systems include:

- **anaerobic treatment lagoons**: reduce organic matter and nitrogen, concentrate phosphorus in the sludge, and can reduce odor;
- **digesters**: stabilize organic matter and produce methane and carbon dioxide for energy and help reduce odor (Note: These systems do not reduce nutrient content);
- **aerobic treatment lagoons**: stabilize and reduce organic matter and nitrogen and are effective for odor control;
- **liquid-solid separators**: separate some nutrients from effluent, can improve the effectiveness of treatment lagoons, and can reduce odor;
- **constructed wetlands, grass waterways, filter strips:** reduce nutrient concentration in diluted effluent;
- **composting:** stabilize manure nutrients, kill bacteria and may reduce nitrogen content.

Use environmental considerations similar to those for storage when using treatment systems. Keep in mind that every manure storage system has a potential for environmental contamination; therefore, proper design, construction and maintenance techniques are critical.

Manure Reduction Strategies

Some producers may benefit from reducing the amount or nutrient value of the manure a pig produces. By improving feed efficiency, the amount of nutrients in manure can be reduced. Producers who have used this strategy match the genetics of their pigs with proper nutrition, use phase feeding techniques, and feed barrows and gilts with different diets.

Feed additives

Feed additives can also be used to improve digestion and utilization of feed. Reducing the crude protein content of feed through the addition of supplemental amino acids (lysine, methione, tryptophan, and theronine) can also reduce manure nitrogen concentration. Researchers have reported that use of synthetic lysine reduces nitrogen excretion in finishing pigs by up to 22%. The same researchers (Cromwell and Coffee) predict that reducing the crude protein content by 4% with the use of synthetic amino acids would reduce nitrogen excretion by 41%. Replacing a portion of the soybean meal with 0.15% synthetic lysine in the starter, grower, and finisher diets would reduce the annual nitrogen output of a 500-sow farrow to finish operation by 55 lbs per day (10 tons per year).

Table 7: Effect of Reducing Dietary Protein and Supplementing with Amino Acids on N Excretion by 200-lb Finishing Pigs*

N balance	14% protein + lysine	12% protein + theronine	10% protein + tryptophan
N intake (g/day)	67	58	50
N retained (g/day)	26	26	26
N excreted in feces (g/day)	7	7	7
N excreted in urine (g/day)	34	25	17
Reduction in N excreted (%)	–	22	41

*Assumes an intake of 6.7 lbs/day, a growth rate of 2 lbs/day, a carcass lean tissue gain of 0.9 lbs/day, a carcass protein gain of 0.2 lbs/day, and that carcass N retention represents 66% of the total N retention.
(Cromwell, 1993. NPPC Environmental Symposium, Minneapolis, MN).

Manure reduction strategies make sense if the producer cannot efficiently use manure nutrients in crop production. Contact your feed company or feed consultant for more information on feeding strategies that can reduce manure volume and nutrients.

Phase Feeding

The term *phase feeding* refers to feeding several diets for short periods of time, compared with feeding only one diet for a long period of time. Phase feeding several diets from birth to market allows producers to meet the nutrient requirements for the pig more accurately. This minimizes the periods when the pig is fed below its nutrient requirements — which impair pig performance and feed conversion, and the periods of overfeeding — which increase the amount of excess nitrogen excreted (up to 30%). However, because the pig's nutrient requirements change rapidly, the potential savings in nitrogen reduction are smaller than those observed with feeding low-protein, amino-acid fortified diets. It would not be unreasonable to expect 5 to 8% reductions in nitrogen excretion by feeding only two diets, as is common in much of the U.S. today. This would result in reduced nitrogen excretion of 15 to 24 lb per day (2.7 to 4.5 tons per year) for a 500-sow operation.

Other management practices that allow for more accurately meeting the pigs' nutrient requirements include split-sex feeding, where barrows and gilts are fed different diets separately. Other management practices can reduce nitrogen excretion similar to phase feeding.

Nutrient Application Plans

Good recordkeeping is critical to the success of a farm operation and of manure management. A nutrient management plan should include at least the following:

1. Farm and field maps (if possible, use aerial photos) showing acreage, crops, soil types, water bodies, and environmentally sensitive areas such as sinkholes, Karst areas or wetlands.

2. Realistic yield expectations for the crops to be grown.

3. Information on manure and soil fertility levels

    - soil tests results for pH, phosphorus, nitrogen (if applicable) and potassium for each field

    - nutrient analysis of manure

4. Amount, dates, and climatic conditions when manure was applied

5. Other sources of nutrients:

    - nitrogen contribution from legumes;
    - commercial fertilizers or sludge applied;
    - irrigation water nutrients.

6. Records of the proper calibration and operation of nutrient application equipment.

Nutrient Utilization Exercise

A swine producer has an anaerobic treatment lagoon with 2,000,000 gallon storage capacity and 200,000 gallon storage pit under a separate nursery facility. Both must be land-applied on cropland after fall harvest of corn or soybeans. Laboratory tests showed that the lagoon had an analysis of 1 lb of organic nitrogen, 3.5 lbs of ammonia nitrogen, 1 lb of phosphate and 4.5 lbs of potash per 1,000 gallons with 99.5% moisture content. The pit manure analyzed 31 lbs of organic nitrogen, 44 lbs of ammonia nitrogen, 48 lbs of phosphate and 45 lbs of potash per 1,000 gallons with 93% moisture content. Use the assumption that 1/3 of the organic nitrogen and 1/2 of the ammonia nitrogen will be available to next year's crop.

1. How many gallons/acre can be applied to provide 150 lb/A of nitrogen to next year's corn crop from

    - the lagoon wastewater:

    - the pit manure:

2. If there are 27,000 gallons per acre per inch of wastewater, how many inches of the lagoon wastewater can be applied (on a per acre basis) to meet the requirements of question 1?

3. How many acres would be required to empty the storage structures based on the above rates from

    - the lagoon wastewater:

    - the pit manure:

4. Using the above application rates, how much phosphate and potash would be applied per acre from

   - the lagoon wastewater

     phosphate:

     potash:

   - the pit manure

     phosphate:

     potash:

5. If soil tests called for the application of 85 lb of phosphate/acre, how many gallons of the pit manure per acre would provide the phosphate required?

6. How many acres would be required to spread at that rate from the pit?

7. Based on the volume and analysis of the lagoon wastewater, what might be other viable economical and environmentally safe alternatives for its use?

Air Quality

There are two major air quality concerns when evaluating environmental assurance. We all know that odor can be a problem, but air quality for workers also needs to be considered. In this section, we will examine factors surrounding both the odor and human health air quality considerations.

Odor

On many operations, odor is likely to be the number one environmental issue for both producers and the general public. Because people can detect a smell they find offensive, they assume there is an environmental problem. What are some perceptions of swine odor that your neighbors and members of your community may have?

Sources of odor

The good news is that odor can be managed by reducing sources of odor. Decomposing manure is the most obvious source. Generally, decomposing manure that has undergone some type of anaerobic (without oxygen) breakdown has a more offensive odor than fresh manure. The actual odor is the result of the type of ration, animal metabolism and environmental conditions in which manure is stored and spread. Decomposing feed and carcasses can also contribute to odor.

What makes manure smell?

The primary smell components in manure are ammonia, hydrogen sulfide, skatole, indole, amines, and mercaptans. When these compounds are present in confined spaces at high enough concentrations, there can be human health problems. However, manure odor does not have human health consequences in normal manure handling or application situations.

Odor Reduction Strategies

- **Use good planning**. Since odor is essentially a manure management issue, make sure your manure storage is adequate. Consider odor in planning and design a system that has little potential for leaks or overflows. Odor complaints can be minimized by proper site selection.

- **Minimize the escape of odor-causing compounds**. Covering manure storage tanks or using additives can help minimize smell.

- **Limit the amount of moisture**. Limiting moisture in manure reduces the biological breakdown process. Generally, manure needs to be less than 40% moisture to reduce these processes. Designing well-drained outdoor lots, using watering systems that do not leak or drain into the lot, and using runoff control systems reduce moisture in manure.

- **Keep animals clean and dry.**

- **Manage and maintain manure handling systems**. If lagoons are used, they should not be overloaded. They should be located as far as possible from neighbors. Landscaping, particularly wind breaks, can also be used to reduce the perception of smell and possibly block wind movement of odor.

- **Use proper disposal and application practices**. Be aware of wind conditions and locations of sensitive neighbors. Morning applications are more desirable than evening applications because they dry more quickly. Incorporation or injection into the soil can also reduce odor.

- **Others**: Additional odor reduction techniques are available. These include anaerobic digesters, aerated lagoons, and air scrubbers.

Air Quality and Human Health Considerations

Good management and safety considerations need to be used to ensure that liquid manure storage facilities do not become hazardous. The major concerns are toxic gases that can be produced as the result of anaerobic decomposition of manure. These gases include ammonia, carbon dioxide, methane and hydrogen sulfide. Health risks from these gases can be reduced by:

- using proper ventilation when agitating and pumping manure from a deep pit system;
- leaving at least one foot of air space between the manure level and the bottom of a slotted floor in a deep pit system;
- constructing manure storage facilities outside of buildings;
- using a pit recharge system;
  - pit recharge uses a valve that is opened to drain the manure out of the pit approximately once a week. Immediately after the pit is emptied, the valve is closed and about 12 inches of treatment lagoon water or fresh water is added back into the pit. The extra water adequately liquifies the manure to reduce solids buildup. The environment in some older buildings may be greatly improved by adapting them for pit recharge.
- monitoring ventilation systems;
  - the purpose of ventilation is to provide satisfactory air for breathing, to control room temperature in mild weather, to provide for animal comfort in hot weather, and to remove gases, odor, and moisture produced by the respiration of pigs during cold weather.

Ventilation safeguards the health and welfare of both animals and caretakers.

– the ventilation rate should be sufficient to maintain air quality in swine production buildings at or below acceptable concentrations, except for brief periods in weather extremes or during manure handling. Ventilation recommendations, according to the Midwest Plan Service or other recognized sources, when combined with good sanitation, cleaning, feed handling, and manure management, normally ensure acceptable air quality in swine facilities.

Confined Space Safety

Producers and their employees have died of asphyxiation from entering manure pits. Would-be rescuers have also been overcome resulting in multiple deaths in some of these incidents. To avoid potential fatalities:

- post all confined spaces with keep out signs and other placards that alert employees and family to potential dangers;

- do not enter confined spaces without a self-contained breathing apparatus or other proper safety equipment;

- educate local emergency officials about your facilities and conditions that cause potential problems.

Facilities Management

The old saying that "hindsight is 20/20" applies to facility management: most producers would change something about their operation if it were economically feasible. The change may be as major as the location of a building or as minor as the direction a door opens. In any case, the best way to avoid these frustrations is to conduct sound planning when considering new construction. Environmental regulations now require this planning in many states. However, there are several factors you may want to consider when planning new facilities:

- **Establish a baseline of water, soil and environmental conditions.** Take water and soil samples to determine baseline information before you build. Well monitoring or regular well testing may also be needed if ground or surface water quality is a concern. A thorough soil evaluation by a professional soil scientist should be performed before storage or lagoon structures are designed.

- **Location, location, location**. Thoroughly evaluate the impacts of the facility on the environment (including ground and surface water and wildlife) as well as surrounding neighbors and communities.

- **Evaluate drainage, topography, hydrology, geology and possibility of future development (both your own and the surrounding areas).** Also consider if natural buffers such as wetlands or woodlots exist.

- **Evaluate manure utilization options and soil types**. What are the historical yields of surrounding soils? Do they have any special agronomic challenges? Within your present cropping system, is there sufficient acreage available for the capacity of your facilities? Do you need to make changes in your cropping pattern or manure treatment options to fully utilize your manure nutrients?

- **Manure storage setbacks**. This distance depends on size and type of manure storage structure and local regulations.

Techniques for Improving Management of Current Facilities

Let's review some environmentally sound facility management considerations for current facilities:

- **Appearance of the operation.** How a facility looks has a large impact on what people think and their perceptions of odor.
- **Cleanliness of the operation.** Having a clean facility improves herd health, reduces odor, and makes management easier. Dead carcass disposal is critical for good sanitation and the impression it makes on neighbors.
- **Maintenance.** Having a routine building maintenance program helps reduce environmental mishaps.
- **Recordkeeping.** Having a manure management recordkeeping system lets you monitor manure analysis, fertility levels, historical yields, dates of application, location of application and overall profitability.
- **Water use and drainage**. Understanding the locations of aquifers, surface waters, drainage patterns and tile lines reduces the chance of environmental contamination.

Aesthetics and Neighbor Relations

Aesthetics and neighbor relations should be a consideration when locating and managing a swine facility. Well-maintained buildings and landscaping indicate that the producer and his/her employees are concerned about the environment. Trees and shrubs can help screen facilities and reduce odor and noise. Manure storage and other necessary parts of the operation commonly associated with odor should be located as far from public view as possible. The direction of prevailing wind should be considered in locating pork production facilities.

Swine facility managers should consider neighbor's activities when planning operations that may increase odor. For example, ask nearby neighbors about any planned outdoor events when preparing to land-apply manure. If possible, apply when prevailing winds are not in the direction of nearby residences.

Community Relations Case Study

Chuck Wagon has a 200-sow herd and farms 750 acres of crop land about 1.5 miles from town. He and his family are actively involved in the community. He is especially proud of being the chairperson of the baseball park remodeling committee. With the help of Chuck's active community involvement, a new computer business has recently moved to his rapidly growing town. Several of Chuck's neighbors have sold off 5-acre lots along the blacktop road leading to his farm operation to the employees of the new computer company who want "the country experience." When the wind blows out of the east, he usually can count on getting complaints about odor from these new computer people. He is really getting concerned because a lawyer (who works for the law firm of Dewey Cheatum and Howe) recently built a house close to his operation and organized the neighbors in a petition drive to save an endangered species located in the county.

What are five things Chuck can do to prevent further problems?

In the case of a law suit, what should he do?

V. Key Regulations

Pork producers can be regulated in many different ways, from federal regulations to state and local laws. Along with these governmental regulations, private citizens can sue a producer for nuisance.

Federal Regulations

The primary federal regulations that affect pork producers deal with water quality issues.

- **Federal Water Pollution Control Act (commonly called the Clean Water Act).** The Clean Water Act is a broad piece of legislation that is designed to protect the waters of the United States, primarily from point source pollutants. This law prohibits the discharge of pollutants into a waterway from a point source unless authorized by a permit from the appropriate agency. A concentrated livestock feeding operation that discharges into the nation's waters is considered a point source and must obtain a permit. However, in the legislation, point sources are not defined; the conditions in which a livestock operation is a "point source" are not mentioned. The nation's waters generally are considered to be rivers, streams, lakes, and other bodies of surface water and subsurface water not entirely confined upon land owned or leased by an individual or group. Most state regulatory agencies enforce the Clean Water Act. Under the Clean Water Act, a regulated discharge that occurs without first obtaining an National Pollutant Discharge Elimination System permit subjects the violator to fines of $25,000 per day. The legislation also allows provisions for citizen suits against point source discharges including Concentrated Animal Feeding Operations.

- **Coastal Zone Act Reauthorization Amendments.** This act is designed to reduce pollutants in coastal waters through non-point control practices. This is the first type of federal legislation designed to reduce non-point pollution. States are required to implement the non-point source management regulations. These management measures include nutrient management plans, pest irrigation and animal manure management.

State and Local Regulations

Many federal regulations require adoption by states in order to be implemented. State regulations that implement federal regulations often differ from the federal intent. However, states are free to develop their own regulations (they must meet minimum federal standards) that may affect a hog operation.

Most local regulations are in the form of zoning ordinances that dictate land use. Your facilitator will provide you with an update of recent State and Local regulations.

Nuisance Laws

Private nuisance lawsuits may be filed against pork producers. Nuisance law is based on the right of landowners to be free from unreasonable interference with the enjoyment of their property. Nuisance claims against pork producers often involve situations such as odor problems, dust, noise, flies, rodents, water contamination or manure spills. If a nuisance law suit is brought against a pork producer, changes in production practices may have to be made, damages may have to be paid, or the operation may be closed. The primary steps a producer can use to avoid these types of actions are to have good records, use a manure management plan and follow the suggestions in this program. Many states have enacted right to farm laws that may offer some protection from nuisance lawsuits. In some areas, producers have traded development rights for nuisance protection. Following the steps in the Environmental Assurance Program will give you a start at reducing the chances of a nuisance lawsuit against your operation.

Twenty Tips for Responding to a Nuisance Suit

1. **Recognize the potential threat of a nuisance suit.** It is very important to recognize a serious legal threat posed by a nuisance suit. To treat the matter lightly is to risk losing. You should respond to the petition initiating the suit within the deadline provided by the law.

2. **Contact your attorney if you are sued or threatened with a suit.** If you are sued, contact your attorney immediately. Give your attorney a copy of the petition that contains the allegations against you. If you do not have an attorney, find one. Consider asking other farmers or agricultural officials for advice on attorneys familiar with agricultural law. The American Agricultural Law Association has 900 members nationwide, and many county and state bar associations have

nationwide, and many county and state bar associations have committees devoted to agricultural law. You may also contact the Pork Producers Environmental Law Education Network at 1-800-705-6270.

3. **Work closely with your attorney to prepare a defense.** You will need to educate your attorney about your operation (and maybe about agriculture). Be sure the attorney is aware of the state right to farm law.

4. **Develop a detailed history of your farm.** Information about your farm will be valuable to your attorney. Prepare a detailed history of your farm, including information about when the different facilities were constructed, when the livestock operation was added, and when any expansions or additions began.

5. **Compile facts and documents about the operation.** In connection with preparing the history, collect documents and other evidence supporting information such as dates of construction. If you obtained state and local permits, provide copies and the history of when they were obtained. The lawsuit may turn on the question of when you established your operation and if it is reasonably operated.

6. **Keep detailed records for your operation.** Good recordkeeping can be valuable for many purposes, including financing and taxes. Good records are important in a nuisance suit. The main issue, which is whether or not you are a nuisance, will depend on how you operate the farm. If you have records on topics such as when you spread waste, how much, and where, they could help refute claims you are a nuisance.

7. **Compile a list of your contacts with the person suing you.** An important issue may be whether you knew of the plaintiff's concerns and whether you made an effort to resolve the problems. You should prepare a record of contacts with them. Issues that could be important include whether they complained before, if they told you of their concerns, if you made changes in response to the complaints, if they complained to the state officials, and, if so, what resulted.

8. **Determine who was there first, you or the neighbor.** As part of the history of your operation, determine the chronology of who was there first. Did the neighbors know of your livestock operation when they moved in? If so, it will be important to document this.

9. **Determine when expansions or new facilities were established.** Another important issue in a nuisance suit is when the activity in question began. The issue often relates to when an existing farm expanded or added a new activity, such as feeding hogs. If you made changes in the operation since the plaintiff moved nearby, your attorney needs to know.

10. **Listen to your attorney's advice.** Remember, your attorney works for you. It is the attorney's ethical duty to represent your interests zealously and competently. You are paying for advice, so follow it.

11. **Don't be impatient with the pace of the case.** Legal disputes can take a long time to go to trial. The parties must prepare, and much time will be spent on developing the facts. You will be asked to answer questions from the other side, and you can do the same during what is called "discovery." There may be delays when the attorneys file legal motions concerning how the case will be handled. Delays may also be

experienced getting a time for the court to hear the case. In some states, it may take several years for a case to come to trial.

12. **Don't forget the possibility of negotiating a settlement.** In some cases, you may not want to compromise with the people who sued you. But in other situations, negotiating a settlement may be the best for both sides. Perhaps there is some change you can make in your operation, such as where you dispose of manure, that will satisfy them. Fighting over the "principle" of the matter may be important, but not if doing so will cost a fortune, risk losing the "war," and close your farm as a nuisance.

13. **Determine how you will pay for your defense.** Legal representation will cost money, but it is a cost you must consider taking. Legal fees to defend a nuisance suit are an investment in the future of your operation. Ask your attorney for an estimate of the cost and how long it might take. The estimate may not be exact, but it will give you an idea of what you can expect. You might consider contacting local farm organizations or livestock groups for assistance in sharing the defense costs.

14. **Get farm groups and the media involved in your case.** It may be helpful to have the support of other agricultural producers in defending a nuisance case. These groups can provide both moral support and testimony concerning the reasonableness of your farming practices. They may also help influence the community attitude to such cases. The farm media may help warn producers about what can happen and why they need to guard against nuisance suits.

15. **Explain to the court why you farm and that it is your way of life and business.** If your case goes to trial, you will be asked to testify.

Your testimony will be important to the judge and jury. Explain clearly how you operate your facility and what steps you take to be sensitive to the concerns of neighbors. Maintain a positive and cooperative attitude when participating in the trial. Don't let the jury or judge believe you think you have the right to conduct a nuisance just because you are a farmer. Remember, the jury will be local people; some will understand farming and some won't. The jurors and judge may be as sympathetic to the plaintiff as to you.

16. **Use available legal defenses.** Be sure you know the law and use it. The law in your state may provide other defenses such as "coming to the nuisance." Even if the right to farm law in your state is untested, as many are, don't ignore it. Perhaps your case will be the test case that shows the law's value in protecting farmers. Right to farm laws will never be an important legal protection unless parties use them.

17. **If you comply with state and federal environmental laws, prove it.** Livestock producers are required to comply with state and federal laws concerning water quality protection. The state law may contain guidelines for disposing of animal wastes. If you are in compliance with these laws, obtain proof and use it at your trial. Evidence you are satisfying the legal requirements for your operation will not prevent a nuisance finding, but it is good evidence that your facility is reasonably operated.

18. **Explain why farming is reasonable where you are located.** One issue will be whether your activity is reasonable where it's located. One way to show your farm is reasonable is to document the nature of the area. Show the court the number of animals raised within 5 miles of you, and the number of farmers similarly situated. Make the court understand that if your operation can be enjoined, there may be

nowhere else for farming to go in your area. Explain how animal agriculture aids the local economy and how many jobs it creates. Use the information to show that livestock production is important to your area and that it is a reasonable use of your land.

19. **Use expert witnesses to support your claims.** Courts will hear from expert witnesses concerning the case. Use university professors to testify your operation uses state-of-the-art technology or is well run. Experts can measure the odors and show they are not in violation of state law. By using experts to build your case, the decision won't rest just on emotion and the plaintiff's allegations.

20. **Consider filing a counterclaim against the plaintiffs.** A nuisance suit can cause you serious harm, both financially and emotionally. If you feel the suit was filed to harass you or is frivolous, ask your attorney if you have grounds to file a counterclaim. You can seek damages from the neighbors and make them feel the threat of a legal suit if the facts support your claim.

Reprinted with permission from A Livestock Producer's Legal Guide to Nuisance, Land Use Control, and Environmental Law by Professor Neil Hamilton, Drake University Agricultural Law Center, 1992.

VI. Environmental Assurance Action Plan

When it comes to environmental challenges, knowledge is power. Now that you have completed the Environmental Assurance workshop, you need to take what you've learned home to thoroughly evaluate your own operation. The following self-assessment is designed as a tool to improve your operation's efficiency, make sure you are conforming to current regulations and provide you with a road map to ensure environmentally sound management techniques today and well into the future. Some of the evaluations in the assessment may not apply to your operation; however, they may give you ideas on other activities that you may want to do.

How to Use This Tool

This is your assessment. Honestly evaluate your operation using the following questions. Mark the proper boxes and action steps that need to be taken. You don't have to share this assessment with anyone, but don't be afraid to ask for help. There are numerous public and private sources who can help you, not only in answering the questions but in designing the action steps that will make up your environmental management plan. Additional information on the topics found in the assessment can also be found in the appendix of this program. When you have completed the assessment, complete the survey needed to receive your Environmental Assurance Certificate and return to: Environmental Assurance Program, National Pork Producers Council, P.O. Box 10383, Des Moines, IA, 50306.

Water Quality

1. Do you know your depth to groundwater?

YES	NO	ACTION TO BE TAKEN

2. Have you had your well water tested for nitrates and bacteria?

YES	NO	ACTION TO BE TAKEN

3. Are manure applications made to prevent runoff into ditches, streams, lakes or neighbor's land?

YES	NO	ACTION TO BE TAKEN

4. Do you apply manure to sloping ground. If yes, can you use techniques to reduce the amount of runoff?

YES	NO	ACTION TO BE TAKEN

5. Do you utilize filter strips, vegetative borders, or setbacks when applying manure or lagoon water in proximity to environmentally sensitive lands (ditches, rivers, streams)?

YES	NO	ACTION TO BE TAKEN

6. Do you consider the distance to a well when you load or apply manure?

YES	NO	ACTION TO BE TAKEN

Nutrient Management

7. Do you have a plan for the utilization of the nutrients that are produced by your facility?

YES	NO	ACTION TO BE TAKEN
☐	☐	

8. Do you determine the nutrient content (minimum N, P and K) of manure or lagoon water at a minimum of once per year?

YES	NO	ACTION TO BE TAKEN
☐	☐	

9. Do you annually soil sample the fields that will receive manure or lagoon water applications?

YES	NO	ACTION TO BE TAKEN
☐	☐	

10. Do you credit other sources of nutrients such as legumes (soybean, alfalfa, etc.)?

YES	NO	ACTION TO BE TAKEN

11. Is runoff potential considered before applying manure or lagoon water to frozen or saturated ground?

YES	NO	ACTION TO BE TAKEN

12. If using irrigation water, do you conduct a nutrient analysis of the water and credit it?

YES	NO	ACTION TO BE TAKEN

13. Do you base your manure and fertilizer application rates on realistic yield goals for specific fields?

YES **NO** **ACTION TO BE TAKEN**

14. When taking a manure sample for analysis, do you take a representative sample from a well-agitated pit or tank?

YES **NO** **ACTION TO BE TAKEN**

15. Do you use plant tissue analysis to determine the efficiency of nutrient uptake?

YES **NO** **ACTION TO BE TAKEN**

16. Do you know what your manure or irrigation water application rates are and calibrate equipment to ensure that the proper rate is delivered?

YES **NO** **ACTION TO BE TAKEN**

17. When possible, is manure/slurry injected or incorporated into the soil after application to avoid volatilization loss and odor problems?

YES **NO** **ACTION TO BE TAKEN**

18. Is manure uniformly applied to soil?

YES **NO** **ACTION TO BE TAKEN**

19. Do you keep records of manure or lagoon water application that include date and time of application, wind direction, amount applied, nutrient analysis, and soil test reports?

YES	NO	ACTION TO BE TAKEN

20. Are manure applications made at a time to maximize nutrient uptake in the plant (spring or side dressed)?

YES	NO	ACTION TO BE TAKEN

21. Are cover crops used to maximize nutrient uptake of manure if applications are made in the fall of the year?

YES	NO	ACTION TO BE TAKEN

22. Do you avoid making applications of manure to coarse textured soil (sands) in the fall and winter time unless winter cover crops (winter rye, rye grass) are used?

YES **NO** **ACTION TO BE TAKEN**

23. Is irrigation of lagoon water conducted at multiple times and reduced rates to maximize infiltration and minimize runoff potential?

YES **NO** **ACTION TO BE TAKEN**

Facility Management

24. Do you have a map of your facility showing drainage patterns and bodies of water?

YES **NO** **ACTION TO BE TAKEN**

25. Do you have a plan and materials available for spill/overflow control of manure?

YES	NO	ACTION TO BE TAKEN
☐	☐	

26. Do your manure storage and treatment facilities meet specifications and guidelines found in the USDA NRCS Field Office Technical Guides or that of state or local regulatory agencies?

YES	NO	ACTION TO BE TAKEN
☐	☐	

27. If runoff storage ponds or treatment lagoons are used, are they designed to handle all runoff and rainfall from a 25-year, 24-hour storm?

YES	NO	ACTION TO BE TAKEN
☐	☐	

28. Do you conduct inspections on manure storage areas, pumps, tanks, and other pertinent manure storage and handling equipment?

YES	NO	ACTION TO BE TAKEN

29. Do you maintain records of inspection activities (for at least 3 years), of any spills or overflows that occur, and of water quality?

YES	NO	ACTION TO BE TAKEN

30. Do you use a preventative maintenance program that includes periodic testing of equipment, repair, and records of maintenance?

YES	NO	ACTION TO BE TAKEN

31. Do you have an employee training program that includes pollution prevention techniques and what to do in case of a manure spill or overflow?

YES	NO	ACTION TO BE TAKEN

32. Do new hires receive manure management/pollution prevention training within 30 days of employment?

YES	NO	ACTION TO BE TAKEN

33. If using lagoons, are rainfall records kept to determine the contribution of precipitation to field saturation and storage capacity?

YES	NO	ACTION TO BE TAKEN

34. Are you current on all necessary permits needed for manure storage and handling?

YES **NO** **ACTION TO BE TAKEN**

Odor Management

35. Is manure applied in the morning rather than in the late afternoon?

YES **NO** **ACTION TO BE TAKEN**

36. Is wind direction considered before applying manure?

YES **NO** **ACTION TO BE TAKEN**

37. Is manure spread on holidays or weekends?

YES	NO	ACTION TO BE TAKEN
☐	☐	

38. Are vegetation barriers such as bushes and shrubs used to filter and dissipate odors?

YES	NO	ACTION TO BE TAKEN
☐	☐	

39. If you are using outdoor lots, are you using methods to reduce the amount of moisture in the manure?

YES	NO	ACTION TO BE TAKEN
☐	☐	

40. Are appropriate neighbor relations techniques used to prevent or handle complaints about odor?

YES	NO	ACTION TO BE TAKEN

41. Do you dispose of dead animals according to state and/or local regulations?

YES	NO	ACTION TO BE TAKEN

Worker Health & Safety

42. Does your ventilation plan consider both animal and human health?

YES	NO	ACTION TO BE TAKEN

43. Do you have necessary safety equipment and placards around manure storage areas?

YES	NO	ACTION TO BE TAKEN

44. Are you or someone at your facility trained in first aid techniques?

YES	NO	ACTION TO BE TAKEN

45. Do you notify other personnel when someone is working or entering a confined-space manure handling facility?

YES	NO	ACTION TO BE TAKEN

Environmental Assurance

Congratulations on completing your environmental assurance program. The next step is to send your completed survey to NPPC to receive your Environmental Assurance Certificate. We suggest you conduct the assurance audit on an annual basis to ensure you are meeting the minimum requirements.

Your actions reflect the image of the entire industry. As we continue to accept our environmental responsibility, there are a number of action steps you need to choose from, which may include the following:

- Manure management plan
- Emergency action plan
- Seek professional assistance when reviewing management plans and/or facility evaluations
- Do an on-farm assessment
- Community relations activities

Appendix

Groundwater Protection

Protecting groundwater is critical for your farm operation and the community. For proper protection, it is important to understand several fundamental concepts.

How to determine the depth to groundwater

Groundwater depths varies from field to field and by the season. Several factors influence the location of groundwater. These include:

Soil texture: Soils higher in silt and clay generally hold water better than sandy soils, and often have water tables closer to the soil surface.

Time of the year: Spring and early summer are often the times when groundwater levels are at their highest.

Amount of precipitation: Excessive precipitation causes groundwater levels to rise. Lack of precipitation has the opposite effect.

Use demands: Irrigation or other uses that reduce the water levels in aquifers (without adequate recharge) can lower the level of groundwater.

Environmental Assurance

Name____
Address____
City____________________ State______________ Zip_________
Telephone____
Fax____
Date and location of training session you attended______________
____

Send to:
EAP Manager
National Pork
Producers Council
P.O. Box 10383
Des Moines, IA 50306

Please circle or check answers that apply to you:

What is your total number of hogs/pigs sold annually from this operation?

______Less than 1,000	______3,000-4,999	______20,000-49,000
______1,000-1,999	______5,000-9,999	______50,000+
______2,000-2,999	______10,000-19,999	

What is the total number of sows on this operation?

______Less than 50	______100-199	______500 or more
______50-99	______200-499	______Other

Which best describes your hog/pig operation?

______Farrow to Finish	______Farrowing	______Other
______Breeding	______Finishing	

What is your title?

______Owner	______Veterinarian	______Herdsman
______Owner/Operator	______Consultant	______Other
______Manager	______Animal Nutritionist	

Total acres (owned and rented):

______None	______200-299	______500-999
______Under 200	______300-499	______1,000 or more

My approximate age is:

______Under 35	______45-54	______65 and over
______35-44	______55-64	

I own a personal computer _____Yes _____No

Environmental Questions:

Do you have a nutrient management plan? _________Yes ______No

How often do you currently test soil to determine nutrient levels before applying manure?
______Annually ______Every 2-4 years ______>4 years ______Never

How much manure storage do you have?
______0-3 months ______3-6 months ______6-9 months ______9-12 months

How frequently do you test your well water?
______Annually ______Every 2-4 years ______>4 years ______Never

Which of the following practices are used on your farm to reduce soil erosion and control the movement of water?
_____Crop Residue Mgmt. _____Grass Waterways _____Pasture Mgmt. ______Terraces
_____Conservation Tillage _____Tile _____Hayland Mgmt. ______Cover Crops
_____Crop Rotation _____Structures _____Pond ______Strip Cropping
_____Contour Farming

Have you had neighbor complaints about odor or other manure management practices?
_____Yes ______No

If Yes:_____1-3 ______3-5 ______5-10 ______10 or more

How frequently do you test manure nutrients that are land applied?
_____Each application ______Annually ______Every 2-4 years ______Never

Which type of manure application do you rely on most?
_____Irrigation ______Incorporation _____Broadcast ______Injection _____Other

How much do you reduce the use of purchased fertilizers by using hog manure in your cropping practices?
_____0-10% ______10-25% _____25-50% ______50-75% _____75-100%

What is the greatest environmental management challenge that your operation faces?
_____Soil erosion ______Manure ______Dead carcass
_____Water quality ______Odor

As a result of this program, do you plan on changing any management practices? _____Yes ______No

If yes, what do you plan to change?
____
____
____

Methods of groundwater depth determination

There currently are no standardized maps that can be used to determine the depth of groundwater. However, the following methods may be helpful in determining the depth to groundwater on your farm operation.

Dig a hole: Digging a hole may be the easiest way to determine your groundwater level. However, remember that just because you have found water does not mean this is a visible aquifer. The factors that were described previously influence the actual level.

Check with a local well driller: Well drillers often keep logs on the depth of groundwater and locations of aquifers.

Check with the state geological survey or water quality specialists: These individuals often have data on groundwater and aquifer locations. Contact your land grant university or extension service for who these individuals are in your state.

Sampling well water

Sampling for nitrates and bacteria in well water is the most common type of testing. Many private and public laboratories can conduct water analysis. It may be beneficial to get specific sampling guidelines and materials from the lab before you begin the process. Some general guidelines include the following:

1. Use a clean glass bottle. Today's technology is very sensitive and can pick up small amounts of contaminants that may have been in the sampling bottles.

2. Take a uniform sample. Take samples from wells that you or your animals are using for drinking water. Allow the water to run for several minutes before taking a sample.

3. Provide proper information and shipping. It is best to refrigerate the sample if it cannot be shipped immediately. Also, use a rapid form of shipping. Provide at least the date of sampling and what you want the lab to sample for (i.e. nitrates, bacteria, etc).

When you receive the results, the lab often gives you concentrations in part per million (ppm) or parts per billion (ppb). A part per million (ppm) means that for every one part of detected material there are a million parts of water. A part per billion (ppb) means that for every one part of detected material there are a billion parts of water. The lab also lists their detection limit for finding contaminants. This level is listed as a ppm or ppb and is the lowest level at which the lab techniques can detect contaminants.

Surface Water Protection

Many best management practices can be used to protect surface water. It is important to understand how manure and nutrients can move into surface water.

> *Direct discharges:* Applying manure too close to a ditch, stream or pond may result in direct discharge. Direct discharges can deplete the oxygen level in the water and raise the level of bacteria.

Movement of nutrients that are attached to soil particles: The nutrients that are found in manure can attach to clays and organic matter in soil and move on eroded soil particles and into surface water.

Movement in water: Manure and nutrients that are dissolved in rain or irrigation water can move into surface water. This situation would be most likely when high levels of rainfall or irrigation water are used.

Sloping soils likely have the greatest rate of soil erosion. This corresponds to high potential movement of nutrients attached to soil particles and nutrients in surface water runoff.

Erosion can be more severe on frozen soils because the lack of sufficient water infiltration. Therefore, it is important to consider the runoff potential of land before making manure applications to frozen ground. When making applications to frozen ground, consider:

- distance to surface water
- rate of manure application
- slope of land
- time of year (early winter vs late winter)
- previous experiences with runoff in similar situations

Soil erosion prevention techniques such as conservation tillage, terraces, buffer strips and waterways can all be beneficial in reducing the amount of soil erosion.

Systems for minimizing runoff of manure

Runoff from open feedlots that contains manure may contaminate surface waters. There are several systems available for controlling runoff. The basic principle for all of these systems is to collect, store and apply contaminated runoff on land. Whatever type of system is used, the following factors need to be considered:

- rainfall amounts
- size of lot
- topography
- soil type

All type of systems should strive to limit the amount of clean water that enters the runoff control systems. Therefore, gutters, terraces, channels, and surface water diversion should be used whenever possible.

Available systems

Settling basins

Settling basins are used to remove solids from lot runoff before it enters holding ponds or vegetative infiltration areas. A typical settling basin removes 50 to 85% of the manure from runoff.

Holding ponds

Holding ponds are designed to store runoff temporarily before application to land. These systems are not meant to be used as a treatment lagoon. Once the liquids are removed, it may be necessary to periodically remove any settled solids. Ponds should be pumped whenever land applications can be made without excessive runoff. Pumping and irrigating directly to land is usually the most economical method of emptying ponds. Exact pond design is determined by local weather conditions, but most ponds have a minimum capacity to handle a 25-year, 24-hour storm.

Infiltration areas

Use of infiltration areas is an alternative system of runoff management. In these systems, runoff flows from settling basins to vegetated areas, where it will be used by plants and settle into the soil. These systems are most useful for small swine operations that need a low-cost system.

Check with your NRC's office or private engineer for details on proper design and construction for any of the above systems.

Soil and Manure Sampling

Proper soil and manure sampling techniques ensure that the greatest level of profitability can be achieved.

Chemical analysis of soils or soil testing is a means to determine the nutrient supplying power of the soil. The sample should be a true representation of the area sampled, as the laboratory results reflect only the nutrient status of the sample that is received. To obtain such sample, the following items should be taken into consideration.

Sampling tools

Several different tools, such as an auger, soil sampling tube, or spade, may be used. Sample tubes or augers should be made either of stainless steel or be chrome plated. If using a pail to collect the soil, it should be plastic to avoid contamination from trace elements (like zinc).

Sample preparation

A subsample should be 1 to 1 1/2 cup of soil, taken from a well-mixed composite from 10 to 20 random locations in the field. Mix the various cores or slices together in a clean plastic container and take a subsample to be put into the sample bag. It is advisable to air-dry extremely wet samples before they are bagged. Identify the sample bags with name, sample number, and field number, which should correspond with identification on sample information sheet.

Sample area

Area to be sampled generally should not be more than forty acres. Smaller acreages may be sampled when the soil is not uniform throughout the field. Soils that differ in soil type, appearance, crop growth or past treatment should be sampled separately. Avoid small areas that are dead furrows, end rows, and poorly drained. Stay away from barns, roads, lanes, and fence rows.

Sampling depth

The required depth of sampling is influenced by many factors, as discussed below.

Tillage Method

- Conventional .... plow depth
- Reduced Tillage .... 3/4 of tillage depth
  - if nutritional problems....................... 0-4" and 4-8"
- Continuous Ridging................................ 0-6" in ridge
  0-4" in valley
- No till... 0-8"
  - to check pH...................................... 0-2"

Plant tissue analysis

Use of plant tissue analysis in conjunction with soil testing allows for a more thorough monitoring of nutrient use by crops. Soil analysis indicates the relative availability of nutrients in the soil for crop use, and plant analysis provides an indication of the nutrients that are actually used by the plants. In addition to this information, it is important to consider other factors that may be preventing proper nutrient uptake (compaction, pH, etc.). By using both of these processes, the producer can have a better idea of how efficiently manure is used by the crop. Your crop consultant, county extension agent, or retail fertilizer dealer can assist you with your specific plant tissue analysis needs.

Manure sampling

Using a thorough laboratory analysis is the most accurate method to determine the nutrient value of manure. Most of these analysis include information on dry matter, ammonium nitrogen, total nitrogen, phosphorus and potassium.

To get the best possible results from the analysis, it is necessary to have proper agitation and sampling. A considerable amount of variation in the analysis can be expected if the sample is not properly obtained.

For liquid samples, the manure pit should be agitated to obtain a well-mixed sample. In most cases, closely follow lab collection procedures to ensure proper sampling. Place the sample in a quart-size plastic container with a screw-on lid and tighten.

For solid manure, sample several areas of the manure source. Place the samples in a plastic bag and seal it. Preserve the sample by freezing, and ship the sample in an insulated container using a fast shipping method.

Considerations for setting realistic crop yield goals

With any crop management system, realistic yield goals need to be the baseline of making management decisions. Since manure is a critical fertility component of a swine producer's crop production system, its value must be completely evaluated. When setting yield goals, consider the following:

- what the nutrient value of the manure that is going to be applied is
- how much manure is available for crop production
- what the total land area available is
- what type of crop rotation is available and what is the fertility contribution from the crops in the rotation (soybean, alfalfa, etc.)
- what the historical yields are
- what factors have prevented maximum economical yield in the past
- what the baseline soil fertility level is
- how the desired yield goal impacts the immediate demands on soil fertility and the long-term amount of fertility in the soil

Working with your fertilizer dealer or consultant allows you to determine the optimum yield goal for your particular operation.

Farm*A*Syst

Pork producers who would like to do a more complete assessment of their farm should consider the Farm*A*Syst Program. Farm*A*Syst is a confidential, voluntary assessment process that guides users in assessing water pollution risk from potential contaminant sources around the farmstead. An expanded version addresses the application of agricultural waste, other nutrients, and pesticides to the land.

Using a series of worksheets, producers evaluate sources of toxicants, microorganisms, and nitrates. Worksheets include well evaluation, fertilizer and pesticide storage and application, management of hazardous waste, household waste water treatment, and storage and application of animal waste. The worksheet information is further evaluated in terms of the soil, geologic and hydrologic features unique to the site. A series of fact sheets are used to provide support information needed to identify voluntary actions to reduce high risks that are identified.

The assessment materials incorporate current state and federal regulations. The voluntary action plan that is developed ranks relative pollution risks from all the sources assessed. It includes practices, current technologies, and changing facilities and structures to reduce risks and prevent pollution.

Information on the Farm*A*Syst Program can be obtained from the National Farm*A*Syst Office at B-142 Steenbock Library, 550 Babcock Drive, Madison, WI 53706-1293. The phone number is 608-262-0024 or FAX 608-265-2775. You may also talk with your individual state contact from the following list of Farm*A*Syst contacts.

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4-89

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Evaluation
NPPC Environmental Assurance Program

1. In general I thought this session was:

Poor 1 2 3 4 5 6 7 Very Good

2. Evaluate the following: Subject matter covered – General

Very Inappropriate 1 2 3 4 5 6 7 Very Appropriate

3. Evaluate the following: Visual – Transparencies

Not Helpful At All 1 2 3 4 5 6 7 Very Helpful

4. The most useful idea or skill I learned in this seminar is:

____

____

5. The thing I like most about this seminar is:

____

____

6. One thing that would improve this seminar is:

____

____

7. My reaction to the instructor is:

____

____

8. One suggestion I have for the instructor is:

____

____

9. Would you suggest others in situations similar to yours attend this seminar?

Not At All 1 2 3 4 5 6 7 Very Strongly

4-93