# Recommendations
# of the
# Technical Workgroup

## Liquid Manure Storage in the Karst Region

To the

Minnesota Senate and House
Agriculture and Rural Development Committees

December 20, 2000

Convened by the Minnesota Pollution Control Agency

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## Acknowledgements

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# Executive Summary

Much of the karst region of southeastern Minnesota represents a sensitive environment for contamination of ground water and surface waters, due largely to:

- shallow soils above highly fractured bedrock;
- rapid transport of water into and through the subsurface;
- sinkholes and other openings to the fractured bedrock;
- hydrogeology that is highly variable and difficult to predict; and
- an interconnected system of surface water and ground water.

One of the environmental concerns in karst regions is the potential for sinkholes to form below wastewater or manure storage structures, causing contaminants to be directly channeled into the ground water. Excessive seepage from liquid impoundments can cause underlying soil to wash into bedrock fractures, leading to an eventually soil collapse or sinkhole formation. Low permeability liners reduce the likelihood of sinkhole formation below liquid storage areas.

Sinkholes have developed under three poorly lined municipal wastewater treatment ponds in the karst region, draining several million gallons of wastewater into the ground water below. In addition, several cropland runoff retention ponds established for erosion control have also failed when sinkholes developed under the ponds. No liners of any sort were used for construction of these runoff retention ponds. Sinkhole development below liquid manure storage systems has not been known to occur at the hundreds of structures in southeastern Minnesota, but has occurred in at least five instances in other states with karst geology. Other karst states have also had failures of wastewater treatment ponds into sinkholes. All failures in Minnesota and other states have been associated with earthen storage ponds having either no liner, or a soil liner designed to seep more than current Minnesota requirements for cohesive soil liners.

Ground water contamination problems can also result from chronic seepage of liquid manure moving into fractured bedrock (without sinkhole formation). Well water was severely contaminated at one southeastern Minnesota farm when liquid manure continuously leaked through a soil liner into the fractured bedrock immediately below the earthen basin. Long-term chronic seepage into fractured bedrock can add bacteria, viruses and other potential contaminants to the uppermost bedrock aquifers.

Recognizing the potential for both chronic and catastrophic failure of liquid manure storage systems in the karst region, the Minnesota Pollution Control Agency (MPCA or Agency) established guidelines for construction of liquid manure storage systems in areas susceptible to soil collapse or sinkhole formation. The agency encourages producers and design engineers to follow these guidelines. Some of the standards in the guidelines were incorporated into MPCA proposed revisions to Minn. R. ch. 7020, governing animal feedlots and the STORAGE, TRANSPORTATION, AND UTILIZATION of manure. Prior to going into effect on October 23, 2000, the revised rule underwent an extensive public review process involving oversight by an Administrative Law Judge. The MPCA made several changes to the rules in response to comments from the public and the Judge. In addition, the Minnesota Legislature reviewed the proposed rules and passed legislation

requiring changes to several parts of the proposed rules (2000 Session Laws, Chapter 435). No changes were made by the MPCA or the Legislature to proposed rules pertaining to manure storage in areas susceptible to sinkhole formation. However, the Legislature requested that a workgroup be convened to review and propose standards related to this topic. The legislation in section 13 of 2000 Session Laws, Chapter 435, states:

> "The commissioner of the Pollution Control Agency shall convene a workgroup consisting of representatives from Natural Resources Conservation Services and private sector licensed professional engineers, including individuals with expertise in hydraulics, structural systems, and geology, to review and propose design standards for liquid manure storage facilities in areas susceptible to soil collapse and sinkhole formation. This review shall include an evaluation of whether such standards should be volume based or animal unit based."

The MPCA responded to the legislation by convening a workgroup consisting of ten engineers with collective backgrounds in structural engineering; hydraulics; geology; design and construction of liquid manure storage systems in the karst region; assessing seepage through manure storage system liners; geotechnical evaluation; alternative liners for liquid containment; and liner reinforcement. All workgroup recommendations were made by the ten engineers forming the workgroup, none of whom are employed by state regulatory agencies. At the request of the workgroup, two or more hydrogeologists experienced in the karst region were present at each meeting to advise on issues pertaining to karst geology, soils and hydrogeology.

The workgroup was specifically asked by the legislature to target standards for liquid manure storage in areas "susceptible to soil collapse or sinkhole formation." The workgroup considered areas "susceptible to soil collapse or sinkhole formation," to include all land where the depth to carbonate bedrock is less than 50 feet, and the uppermost bedrock is fractured carbonate materials or other geologic strata where soil collapse or sinkhole formation occurs. In areas not susceptible to soil collapse or sinkhole formation, the workgroup recommends that the same rules should apply for liquid manure storage design, construction and operation as throughout the rest of the state.

A shortcoming noted by the workgroup with existing information is the lack of geostatistical analyses indicating the likelihood of soil collapse to occur in a given area. The Minnesota Geological Survey, University of Minnesota and Department of Natural Resources are currently examining the relationship between the presence of karst features and associated geologic conditions. The recommended measures in this report are intended to serve as interim standards until the study is completed and the standards can be revised to more specifically reflect a geostatistical evaluation of sinkhole formation.

The workgroup did not build from existing MPCA policy, but rather took a fresh look at needed standards for the karst region. Existing MPCA policy was only briefly considered during the workgroup process. Workgroup recommendations made in this report reflect the best professional judgement of the workgroup members made after considerable study and discussion of available information on this topic.

The workgroup recommends the following protective measures for areas susceptible to soil collapse or sinkhole formation. These measures are meant to be used in addition to the existing protective measures required by the MPCA throughout the state. These standards pertain to 1) location restrictions, 2) design, and 3) identifying and responding to failures. The standards can be summarized as follows:

*Location restrictions*

- Maintain a 300-foot setback from sinkholes;
- Relocate site if subsoil inspections during excavation indicate soil subsidence or sinkhole development;
- Avoid construction over mapped caves that become registered with the State;

*Design specifications*

- Use dual-liners, concrete liners or above ground glass-fused metal
- Limit maximum capacity of a single cell to three million gallons (no total capacity limit per farm and no restrictions based on animal unit numbers);
- Maintain a five-foot minimum separation between manure and bedrock, with some exceptions;
- Convey roof and site runoff waters away from the storage area;

*Identifying and responding to failures*

- Monitor manure levels regularly and conduct an annual inspection of the liner; and
- Develop an emergency response plan.

The workgroup recommends that the proposed standards in this report replace existing MPCA rules pertaining to design standards in areas susceptible to sinkhole formation. They also suggest that these recommendations be reviewed and refined after completing further study of the likelihood of sinkhole formation under various geologic conditions.

Many similarities can be found when comparing Minn. R. ch. 7020 and workgroup recommendations for areas susceptible to soil collapse or sinkhole formation. For example, both the rules and the workgroup recommendations:

- establish setbacks from sinkholes of 300 feet;
- include major restrictions on use of cohesive soil liners alone;
- allow for use of concrete lined, dual-lined and above ground storage; and
- establish a similar minimum soil thickness needed above bedrock for use of concrete, composite and above ground liners at small to moderate-sized feedlots;

Yet, the specific criteria for some of the recommendations are different. Current MPCA rules for separation to bedrock restrictions vary from five to fifteen feet for concrete pits, dual-lined basins and above ground tanks, depending on the type of liner and the number of animal units on the farm. Whereas, the workgroup recommends that separation to bedrock be a minimum of five-feet, except for two types of designs where separation to bedrock can be less than five feet. MPCA rules allow cohesive soil liners alone where there is a substantial soil thickness between

manure and bedrock (e.g., 20 to 40 feet). The workgroup recommends no cohesive soil liners to be used alone without another liner in areas with less than 50 feet from ground surface to carbonate bedrock until further geologic study identifies the areas with less than 50 feet to bedrock that have a low potential for soil collapse or sinkhole formation.

Other workgroup recommendations, such as inspections of subsoil during construction and diverting freshwater away from the manure storage area, are not stated in MPCA rules but are consistent with MPCA guidelines. The MPCA requires manure storage system designs to include plans for periodic inspection of the liner. This is consistent with, but not as specific as workgroup recommendations to require regular monitoring of manure levels and annual liner inspections. The workgroup recommended emergency response plan requirements for all new liquid manure storage systems constructed in areas susceptible to sinkhole formation. Emergency response plans are currently required by MPCA rules at feedlots with 1000 or more animal units.

Another difference between current MPCA policy and workgroup recommendations relates to storage capacity limits. MPCA rules set a 250,000 gallon limit per storage cell in areas with four or more sinkholes within 1000 feet. No other storage capacity limits are set in rules; however, recommended guidelines suggest limits that vary with the liner type and geologic conditions. The workgroup recommends a three million gallon limit in all areas susceptible to sinkhole formation, regardless of proximity of karst features (with the exception of the 300 foot setback requirement from sinkholes).

The workgroup emphasized that further work is needed to:

- Determine the geostatistical probabilities of soil collapse in different types of geologic settings;
- Study pathogen transport through soils below liquid manure storage systems in the karst region;
- Develop generic emergency response plans that can then be tailored for specific feedlot operations;
- Conduct research and demonstration projects on alternative manure management approaches that do not rely on liquid storage;
- Conduct regular monitoring and inspections of existing liquid manure storage systems; and
- Collect, manage, analyze, interpret and map geologic and hydrogeologic information needed for engineers designing liquid storage basins in karst areas.

# Chapter 1 - Introduction

## 1.1 Workgroup Charge and Scope

In December 1999, the Minnesota Pollution Control Agency (MPCA) proposed revisions to rules (Minn. R. ch. 7020) governing animal feedlots and the storage, transportation, and utilization of manure. The rule revision updated the 20-year old rules and modified the approach to permitting feedlots. The rule revision also added technical standards for such activities as land application of manure, manure transportation, open lot discharges, manure storage closure, stockpiling, and construction of liquid storage systems. Several new requirements specifically addressed construction of liquid manure storage systems in areas susceptible to sinkhole formation.

Prior to going into effect on October 23, 2000, the revised rule underwent an extensive public review process involving oversight by an Administrative Law Judge. The MPCA made several changes to the rules in response to comments from the public and the Judge. In addition, the Minnesota State Legislature reviewed the rules and passed legislation requiring further changes to the proposed feedlot rules (2000 Session Laws, Chapter 435). No changes were made to the rules pertaining to manure storage in areas susceptible to sinkhole formation. However, the legislature requested that a workgroup be convened to review and propose standards related to this topic. The legislation in section 13 of 2000 Session Laws, Chapter 435, states:

> "The commissioner of the Pollution Control Agency shall convene a workgroup consisting of representatives from Natural Resources Conservation Services and private sector licensed professional engineers, including individuals with expertise in hydraulics, structural systems, and geology, to review and propose design standards for liquid manure storage facilities in areas susceptible to soil collapse and sinkhole formation. This review shall include an evaluation of whether such standards should be volume based or animal unit based. The commissioner shall submit the findings and recommendations of the workgroup to the Senate and House Agriculture and Rural Development Committees by October 31, 2000."

In response, the MPCA convened a technical workgroup to address the specific issues required in the legislation. The workgroup focused on standards for water quality protection that are directly related to the design and construction of liquid manure storage systems in areas susceptible to soil collapse or sinkhole formation. Several issues were considered to be beyond the scope of the workgroup, including in-depth analysis about economics and affordability, extensive investigation of current water quality throughout southeastern Minnesota, and the socio-political ramifications of implementing these recommendations as state law. Risks associated with manure application to fields, liquid manure spills and air emissions were also considered to be beyond the scope and charge of the workgroup (yet these issues are linked to manure storage techniques).

This document discusses workgroup recommendations made for new liquid manure storage areas and major modifications made to existing structures. The workgroup did not address standards for existing liquid manure storage systems currently operating in the karst region.

The MPCA requested and was granted an extension of the report deadline from October 31, 2000, to January 4, 2001.

## 1.2 Workgroup Members

The MPCA convened a workgroup consisting of individuals who collectively met the requirements of the legislation. The group includes engineers with expertise in the areas of structural engineering, hydraulics, and geology. In addition, engineers were selected who have experience in the following areas: a) designing and constructing liquid manure storage systems in the karst region, b) studying seepage through manure storage system liners, c) evaluating geotechnical information, and d) using alternative liners and liner reinforcement for liquid containment systems.

The ten engineers in the workgroup are listed below. Their education, experience, expertise, addresses and phone/e-mail is included in Attachment A.

- Dr. Randal Barnes, P.E. - University of Minnesota, Department of Civil Engineering
- Dr. Chuck Clanton, P.E., P.S.S. (alternate Dr. Kevin Janni, P.E.) - University of Minnesota, Department of Biosystems and Agricultural Engineering
- Mr. Pete Fryer, P.E. - Joint Powers Board, working in association with NRCS and SWCDs
- Mr. Stephan Gale, P.E. - Gale-Tech Engineering
- Mr. Art Kalmes, P.E. - Polaris Group
- Mr. Robert Mensch, P.E. - Mensch Engineering
- Mr. Larry Roehl, P.E. - WHKS & Co.
- Mr. Rob Romocki, P.E. - Natural Resources Conservation Service
- Mr. Scott Swanberg, P.E. - Natural Resources Conservation Service
- Mr. Colby Verdegan, P.E. - Chosen Valley Testing

The MPCA understood the intent of the legislation was for the recommendations to be made by the people from organizations specified in the legislation. All workgroup recommendations included in this report were made by the ten workgroup engineers. The recommendations in this report were not made by the state agency regulatory staff participating in this process. This is very different from a rule-making process where state agencies, local government, private organizations and the public at large provide input into the environmental regulation development process.

The workgroup engineers requested that hydrogeologists experienced in the karst region be present at all meetings. A minimum of two hydrogeologists experienced in the karst region were present at each meeting to advise on issues pertaining to karst geology, soils and hydrogeology. The hydrogeologists included:

- Mr. Jeff Green, P.G. - Minnesota Department of Natural Resources
- Mr. Bruce Olsen, P.G. - Minnesota Department of Health
- Mr. Dave Wall, P.S.S., P.G. - Minnesota Pollution Control Agency

In addition, five other geologists and hydrogeologists with karst expertise were invited to attend one of two meetings held on September 7 and October 2, 2000. These individuals included:

Dr. Calvin Alexander - University of Minnesota, Dept. of Geology and Geophysics
Mr. Robert Libra - Iowa Geological Survey
Dr. Tony Runkel - Minnesota Geological Survey
Mr. Robert Tipping - Minnesota Geological Survey
Dr. Mike Trojan - Minnesota Pollution Control Agency

Mr. Roger Steinberg, Minnesota Extension Service, assisted with meeting facilitation.
Mr. Dave Wall, Minnesota Pollution Control Agency, coordinated workgroup activities and developed the report as directed by the workgroup.

## 1.3 Workgroup process and principles

The workgroup did not build from existing MPCA policy, but rather took a fresh look at needed standards for the karst region. Existing MPCA policy was only briefly considered during the workgroup process.

The workgroup held all-day meetings on eight days between August 10 and November 27, 2000. Notes from each meeting were incorporated into written summaries that were reviewed and refined by workgroup members following each meeting. Written resource materials were handed out to workgroup members as supplemental information for review and consideration during development of the recommended standards (see Bibliography in Attachment B).

The following background topics were studied by the workgroup during the first four meetings:

- Mechanisms potentially leading to chronic and catastrophic failure when operating liquid manure storage systems in the karst region;
- Environmental consequences of manure storage failures in karst areas;
- Environmental consequences of unachievable standards;
- Standards for liquid manure storage in karst areas outside of Minnesota;
- Historical record of failed and successful waste storage systems in karst regions;
- Minnesota's karst-related standards for other types of contaminant containment;
- Ground water impacts from liquid manure storage systems;
- Site characterization techniques; and
- Perspectives from MPCA, Minnesota Department of Health, Minnesota Department of Natural Resources;

Prior to the development of recommended standards, the workgroup spent considerable time discussing the criteria and principles to use as a basis for developing the standards. The workgroup agreed that the standards should protect the environment from both chronic problems resulting from seepage out of the liquid manure storage system, and from catastrophic problems resulting from a soil collapse below the storage system. The workgroup decided that the design

standards needed to be developed in conjunction with standards for construction, operation and monitoring.

Workgroup discussions about risk management led to the conclusion that no matter how a system is engineered, there will still be a potential for environmental failure. The workgroup suggested that the goal should not be to develop standards that prevent all risk of pollution, but that the standards should be developed to greatly reduce the potential for environmental problems. The workgroup sought to develop standards that will minimize risks to water quality to the maximum extent practical, while considering the following criteria:

1. Maintain the level of environmental risk at or near the level of risk as for other non-karst areas of Minnesota (particularly as it pertains to chronic seepage effects on water quality).

2. Prevent acceleration of soil collapse below a manure storage system (compared to conditions prior to construction) that could result from seepage out of the storage system or poor surface water drainage conditions on the land surface near the manure storage system.

3. Allow for construction activities that would provide a greater level of environmental protection than existing operating conditions, or the "next best alternative" that would exist if there was to be no construction (e.g. to allow for new liquid manure storage systems that will replace old unlined basins or to correct a serious manure runoff problem to surface waters).

4. Do not construct storage systems in areas or in ways likely to lead to failure, based on an understanding of the processes that can lead to failure.

5. Use best available technology when the best available technology is needed to meet the above objectives and is considered feasible.

6. Develop standards that will not preclude the continued operation of animal agriculture throughout much of the karst region (e.g. maintain standards that are within economic reason).

The recommendations in this report reflect the best professional judgement of workgroup members made after considerable study and discussion of existing resources related to this topic.

As required by Minnesota Statutes Section 3.197, the cost to convene the workgroup, develop the recommendations and write, print and distribute the report, including all public and private sector contribution of time, is $48,956 ($21,356 MPCA and 27,600 non-MPCA).

# Chapter 2 - Background

## 2.1 Environmental concerns of liquid manure storage in karst areas

Much of Southeastern Minnesota is considered a "karst" landscape (Figure 1). Karst is a geologic term for a landscape area created over soluble rock with efficient drainage. The underlying carbonate[1] bedrock in karst regions dissolves over long periods of geologic time to produce solution enlarged joints and cracks. These features can result in rapid transmission of contaminants from the land's surface to the ground water below. Karst areas often have features such as sinkholes,[2] caves, springs, and blind valleys.[3] However, the lack of these features does not mean that an area does not have "karst" geology. The extent of karst feature development varies tremendously across southeastern Minnesota, and often changes abruptly within a scale of hundreds of feet.

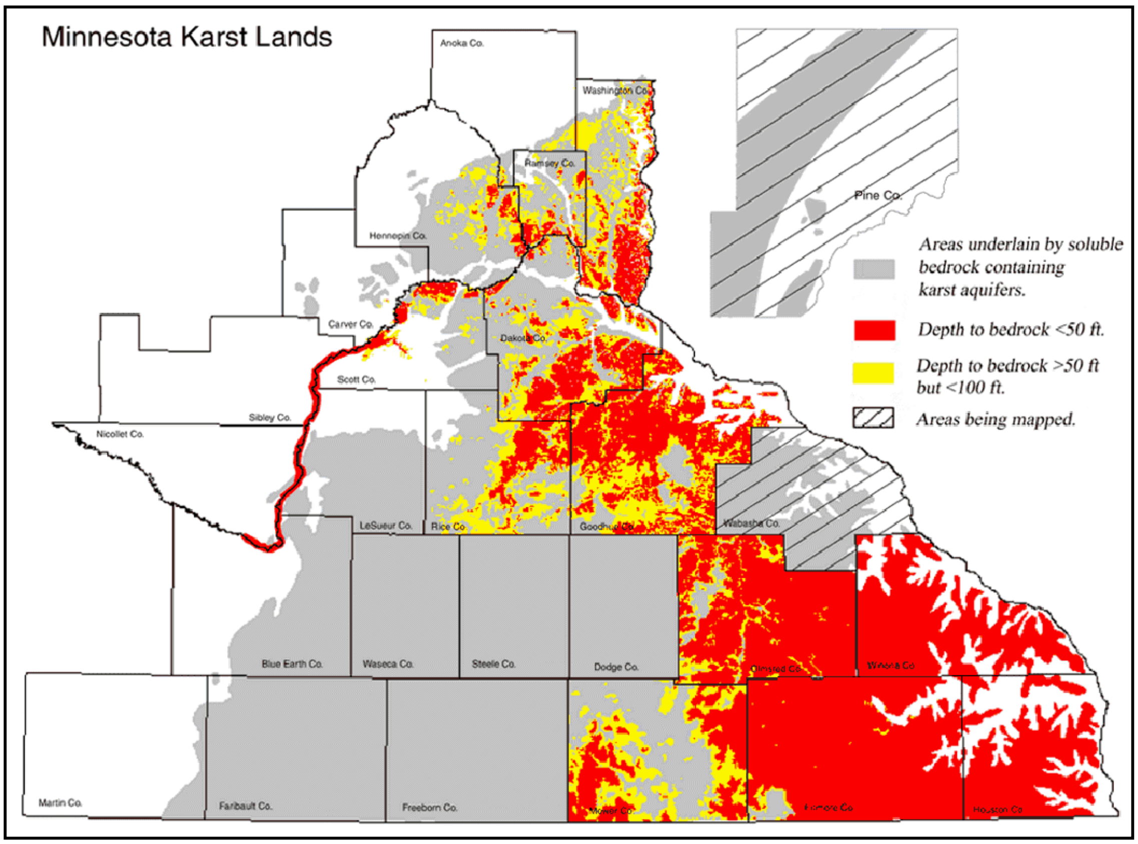


Figure 1 Minnesota Karst Lands - Most karst features are found in areas with less than 50 feet of sedimentary cover over bedrock (from Gao et al., 2000 in draft)

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1 Carbonate bedrock – typically dolostone or limestone.
2 Sinkhole – surface depression caused by collapse of soil or overlying formation above fractured or cavernous bedrock, or such depressions that have been filled.
3 Blind valley – valleys that have no surface outlet and water from the stream or intermittent stream enters the ground.

Karst conditions represent a sensitive environment for contamination of the upper aquifers and surface waters. Some of the heightened environmental concerns characteristic of karst areas include:

1. *Shallow soils above bedrock* – reducing the chance for treatment and attenuation of contaminants introduced at the land surface;
2. *Highly fractured bedrock* - potentially leading to rapid contaminant transport to other underground locations or streams, and making it very difficult to collect, remove and treat contaminants after moving into bedrock;
3. *Soil collapse/sinkhole development* - that can lead to failure of liquid impoundment structures;
4. *Existing Sinkholes and other openings into the ground* – that can funnel contaminants in surface runoff directly into the ground water;
5. *Interconnected system of surface and ground water* – so that contaminants entering ground water can be rapidly transported to surface waters, and visa-versa;
6. *Steeply sloping landscapes* – accelerating surface runoff and erosion;
7. *Large number of wells in the uppermost bedrock aquifer* – so that many private domestic water sources and some public water sources are vulnerable to contamination;
8. *Highly variable and unpredictable geology* – leading to a lower level of certainty regarding contaminant transport.

Several concerns have been raised in recent years regarding the construction and operation of liquid manure storage systems in Minnesota's karst region. Four potential water quality risks associated with liquid manure storage systems in the karst region are described below. The first and second risks could lead to long-term chronic problems, whereas the third risk is a catastrophic failure.

1. Seepage of contaminants through the storage facility and underlying soil to fractured bedrock and subsequently to ground water;
2. Soil subsidence below the structure which breaches the integrity of the liner, causing slow continuous leaking of manure from the storage system to ground water; and
3. A sinkhole forming below a manure storage system causing either a rapid flow of manure directly into ground water, or a collapse in a basin sidewall resulting in a release of manure onto the ground surface where it could then flow to streams.
4. Surface runoff of liquid manure from the storage area to sinkholes, blind valleys, losing streams or areas with very thin soils above bedrock (e.g. resulting from a spill, overflow, or sidewall failure).

Manure entering ground water will threaten drinking water supplies as it travels toward streams. Most of the people in southeastern Minnesota rely on ground water for drinking water supplies. Manure entering ground water will ultimately discharge into streams within a period of time ranging from hours to decades depending on the site-specific hydrogeology. The karst region of Minnesota maintains a large number of high quality trout streams. A rapid discharge of a large quantity of manure into a stream will destroy the aquatic life for a stretch of the stream until the stream is rejuvenated. Ultimately the discharge will also increase contaminant loading into the

receiving waters of the Mississippi River system. Manure that travels in the ground water for a longer period before discharging into streams will be more diluted and may not destroy aquatic life, but can still contribute to stream pollution upon discharge into the stream.

Basin overflows and discharges from manure storage structures have been problems at some facilities in Minnesota. Another potential water quality risk from liquid manure storage systems is a failure of earthen basin sidewalls to hold liquid manure. This type of risk appears to be minimal with systems permitted in Minnesota, given that sidewall failures are not known to have occurred in Minnesota at any of the over 2500 earthen basin facilities permitted by the MPCA.

## 2.2 Historical record of failed and successful waste storage systems in karst regions

Hundreds of manure storage systems have been constructed in the karst region in Minnesota and have been in operation for several years to several decades. The Natural Resources Conservation Service (NRCS) and Soil and Water Conservation Districts (SWCDs), which provided assistance with the design and construction of many of these systems, is not aware of any catastrophic failures of liquid manure storage systems into sinkholes in Minnesota. However, the NRCS and SWCDs are aware of several cropland runoff retention ponds for erosion control that have failed into sinkholes. Runoff retention ponds are typically constructed without any sort of a liner and are not designed to minimize seepage.

The MPCA is aware of one instance in Fillmore County, Minnesota, where manure seepage through a soil liner into fractured bedrock occurred at such a rapid rate that the storage system did not ever need to be pumped and the farmer's well was severely contaminated. During the original construction of the earthen basin, the soil was reportedly excavated to depths exceeding those in the approved design plan. A new well and installation of a synthetic liner corrected the problem for that producer. There have been few farms with ongoing monitoring or documentation of manure levels throughout southeastern Minnesota to gain an understanding of how frequently excessive seepage problems occur in areas with shallow soils above bedrock.

The workgroup contacted people in ten other states with karst geology to find out if there have been any sinkholes forming below liquid manure storage systems in these other states. Sinkholes have developed below four earthen hog manure storage systems in Kentucky, as reported in Crawford, 1998. In Florida, a sinkhole developed in a new storage system after the basin was filled with water to check for problems. No other known sinkhole-related manure storage failures were reported by the other states for manure storage.

Sinkholes have formed below municipal wastewater treatment ponds in Minnesota. Between 1974 and 1992, sinkholes opened below three of the twenty-two municipal wastewater treatment ponds in Minnesota's karst region. Sinkholes developed in Altura's ponds in 1974 during construction and in 1976 when it first filled to capacity (Alexander and Book, 1984). A sinkhole developed in a Lewiston pond in 1991 after eighteen years of use (Jannik et al., 1992). Several sinkholes developed in a Bellchester pond in 1992 after twenty-two years of use (Alexander et al., 1993). The amounts of partially treated wastewater draining into sinkholes at the three

respective sites was 3.7, 2.3, and 7.7 million gallons. The ponds were constructed of earthen materials with a designed seepage rate not to exceed 3,500 gallons per acre per day (note that the current minimum design standard for manure storage with soil liners is 500 gal/ac/d and is 50 gal/ac/d for composite liners). Several sinkholes are located within about a mile from all three sites, yet no sinkholes were mapped within about a quarter of a mile from the sites. The environmental consequences of these failures were not thoroughly studied. Sinkholes have also formed below municipal wastewater treatment ponds in Missouri (Aley et al., 1972) and Pennsylvania (Bachir et al., 1999).

These failures clearly demonstrate the potential for sinkholes to develop in southeastern Minnesota when large quantities of liquids are stored in sinkhole prone areas with minimal barriers between the liquid and underlying materials. Similar problems can develop when storing liquid manure above permeable liner materials. It should be noted that allowable design seepage rates for cohesive-soil lined manure storage systems in Minn. R. ch. 7020 is more protective than the standards used for the failed municipal wastewater pond construction. It is also important to consider that the contaminant concentrations in manure are often over 100 times greater than municipal wastewater pond liquids. Thus, the environmental consequences of a catastrophic manure release will be much worse than a similar release from a municipal pond failure.

## 2.3 Benefits of livestock agriculture in the karst region

Livestock agriculture and liquid manure storage can benefit water quality in the karst region, helping to offset some of the risks to water quality. For example, manure application to land in row crop production can enhance soil properties and reduce soil erosion. Hayland and pastureland associated with dairy and beef cattle operations result in little losses of sediment, pesticides, phosphorus, and oxygen demanding substances. If dairy and beef operations leave southeastern Minnesota, then much of the pasture and hay ground would be converted to row crop agriculture. Erosion rates would be expected to dramatically increase as land is converted to row crop agriculture.

The trends to construct new and expanded feedlot facilities and the associated liquid manure storage system may potentially result in enhanced protection of surface water quality. Liquid manure storage structures increase management flexibility, making it easier to apply at proper rates and to avoid winter-time manure application. Many of the older feedlot facilities in southeastern Minnesota are located next to streams and do not have containment of manure or manure-contaminated runoff. Most facilities with new liquid manure storage structures have total containment of manure so that there is no manure in rainfall and snowmelt runoff waters leaving the feedlot area.

## 2.4 Minnesota policy on liquid manure storage in karst areas

Minnesota Rules pertaining to construction of liquid manure storage systems are found in Minn. Rules Chapter 7020.2005 and 7020.2100 (attachment C). These rules went into effect on

October 23, 2000. The minimum requirements specific to the karst region are found in the following sections of Chapter 7020.

7020.2005 subpart 1 – setback from sinkholes
7020.2100 subpart 2, Item A – storage capacity limit in high risk areas
7020.2100 subpart 2, Item B – Separation to bedrock and liner design requirements
7020.2100 subpart 2, Item C – Exceptions for feedlots with less than 300 animal units
7020.2100 subpart 4, Item A(3) and (4) – soil investigation depth requirements
7020.2100 subpart 4, Item A(7) – karst feature identification requirements

The MPCA has also developed interim guidelines that incorporate the minimum standards in the revised feedlot rules and additional recommended site specific evaluations and measures to safeguard water quality (attachment D). A comparison of the current MPCA policy with workgroup recommendations is included in Chapter 4 of this report.

The Minnesota Environmental Quality Board recently modified their rules to include a provision for the karst region. Minn. Rules Chapter 4410.4300 subpart 29, requires that an Environmental Assessment Worksheet (EAW) be completed when there is an expansion of more than 500 animal units or a new feedlot is constructed with more than 500 animal units, and a karst feature exists within 1000 feet of the proposed site. Karst features specified in the rule include sinkholes, caves, resurgent springs, disappearing springs, karst windows, blind valleys, or dry valleys.

## **2.5 Other states' standards for liquid manure storage in karst areas**

The workgroup reviewed the liquid manure storage system policies of ten other states with karst geology. The requirements for other states can be summarized as follows:

- The requirements vary greatly among the various states;

- Very few multi-million gallon manure storage systems are being constructed in areas that have a high degree of karstification. (For example, Florida's climate and cropping systems are such that they can typically apply manure year-round and therefore they do not need large manure storage systems. In northern U.S. karst states, most of the farms in the karst regions are reportedly small.)

- Most states rely largely on the design engineers to determine the needed measures for protection, and many of the engineers are recommending concrete, above ground storage or impermeable liners. In Florida, Pennsylvania and Indiana, concrete liners are used at most of the manure storage systems constructed in karst areas. Above-ground manure storage is typical in Ohio's karst region.

- Many states allow cohesive soil liners to be constructed in karst regions if the liner has a permeability less than either 1X10-6 cm/sec or 1X10-7 cm/sec. Missouri does not allow

cohesive-soil liners alone in areas where a geologic assessment identifies severe karst risks and in some areas of moderate risk. Iowa's laws state that for operations exceeding 200,000 pounds of swine or poultry or 400,000 pounds of bovine (approximately 1333 finishing hogs or 400 cows), earthen basins (using only a cohesive soil liner) shall not be located on a site that exhibits karst features such as sinkholes or solution channeling.

- Kentucky, Missouri, Wisconsin, and Iowa have setbacks from sinkholes of 150, 300, 400 and 500 feet, respectively.

- Missouri, Florida, and Wisconsin require a site assessment to determine the relative risk of the site before determining the needed type of liner system.

- Depth to bedrock requirements vary. Some states did not report to have minimum depth to bedrock standards. Other states set minimum separation to bedrock from 2 to 4 feet, with additional separation needed if using a cohesive soil liner alone (i.e. 10 or 20 feet). For example, Iowa's separation to bedrock laws (which apply only to larger feedlots) require four feet of soil above bedrock for use of a composite liner, and ten feet where only a soil liner is used. Iowa does not specify a bedrock separation for concrete.

# Chapter 3: Workgroup Recommendations

## 3.1 Defining areas susceptible to soil collapse or sinkhole formation

The workgroup was asked by the Minnesota State Legislature to propose standards for "areas susceptible to soil collapse or sinkhole formation." Until further geologic refinements can be completed, the areas determined by the workgroup as potentially susceptible to soil collapse and sinkhole formation include all land where the depth to carbonate bedrock is less than 50 feet and the uppermost bedrock is fractured carbonate materials or other geologic strata where soil collapse or sinkhole formation occurs (e.g. New Richmond Sandstone or base of the St. Peter Sandstone). In addition, land with more than 50 feet to bedrock may also be considered susceptible to sinkhole formation if karst features exist within 1000 feet of the proposed site, and geologic conditions near the karst features are similar to geologic conditions at the proposed site. Karst features include sinkholes, blind valleys, mapped caves registered in accordance with recommendation B, resurgent springs, karst windows, blind valleys and dry valleys. The workgroup recognized that there is a wide range of soil collapse risks within all lands considered by the workgroup to be "susceptible to soil collapse or sinkhole formation."

In areas not susceptible to soil collapse or sinkhole formation, the workgroup recommends that the same rules should apply for liquid manure storage design, construction and operation as throughout the rest of the state. These low risk areas include land where there is over 50 feet of soil, unconsolidated sandstone, and shale above carbonate bedrock and no karst features exist within 1000 feet.

The workgroup made the following recommendations in regards to defining areas susceptible to soil collapse or sinkhole formation:

**Recommendation A -** The workgroup recommends that the Minnesota Geological Survey complete investigations to determine areas where there is less than 50 feet of soil above bedrock, and to assess the geologic conditions in these areas that indicate susceptibility to soil collapse and sinkhole formation (please also see related recommendations for further study in Chapter 6).

**Recommendation B -** The workgroup recommends that where published maps showing areas with less than 50 feet to consolidated bedrock are not available, that such maps be developed by the Minnesota Geological Survey.

## 3.2 Recommended standards for areas potentially susceptible to soil collapse or sinkhole formation

The workgroup made several recommendations for additional protective measures in areas considered to be potentially susceptible to soil collapse or sinkhole formation. The workgroup suggests that the recommended standards replace existing Minnesota rules pertaining to design

standards in areas susceptible to soil collapse or sinkhole formation. The recommendations are intended to be in addition to minimum statewide standards set in Minn. Rules Chapter 7020. A comparison of workgroup recommendations with existing MPCA policy for karst regions is included in Chapter 4. A discussion of workgroup considerations and justification related to these recommendations is included in Chapter 5.

The workgroup recommendations for areas susceptible to soil collapse or sinkhole formation include several standards that should be added to existing statewide minimum requirements. These added standards pertain to 1) location restrictions, 2) design specifications, and 3) identifying and responding to failures, as follows:

### 3.2.1 Location restrictions

The workgroup agreed on the following three recommendations concerning sites where construction of liquid manure storage systems should be prohibited. The workgroup discussion pertaining to these recommendations is found in section 5.1.

**Recommendation C** - The workgroup recommends that liquid manure storage systems not be constructed directly over sinkholes or within 300 feet from the outside edge of sinkholes. For the purposes of this recommendation, sinkholes refer to surface depressions caused by collapse of soil or overlying formation above fractured or cavernous bedrock, or such depressions that have been filled.

**Recommendation D -** The workgroup recommends requiring a construction inspection of the soil subgrade by a licensed geologist, soil scientist or engineer with education and experience in karst geology. An inspection form should be completed by an inspector and submitted to the design engineer so that it can be part of the construction report. Construction should not be allowed in areas where subsoils have moved into fractured bedrock so as to cause voids in the soil or a downward movement of topsoil. If the inspector identifies possible indications of potential soil subsidence or sinkhole development, including soil voids, piping, channels, or topsoils found at deeper depths, then the inspector must notify the MPCA and design engineer so than an evaluation can be made of whether the site must be moved to an alternative location.

**Recommendation E** - The workgroup recommends that the state establish an official registration process for caves and determine the location of land areas which could affect the registered caves. The workgroup recommends that liquid manure storage systems be prohibited from being constructed over mapped and registered caves.

**Recommendation F -** The workgroup recommends that the state complete research of statistical probabilities of soil collapse in different types of geologic settings. The topic of location restrictions should be revisited after obtaining a better understanding of the statistical relationship between geologic conditions and soil collapse.

### 3.2.2 Design Specifications

The following protective measures are recommended for areas susceptible to soil collapse or sinkhole formation. These measures are meant to be used in addition to the existing protective measures required by the MPCA throughout the entire state.

**Recommendation G –** The workgroup recommends that the liquid manure storage system design be one of the following:

(i) A dual-lined or composite-lined manure storage system consisting of one of the following combinations of materials: a) compacted cohesive soil liner meeting MPCA standards over a geomembrane or geosynthetic liner, or b) two geomembrane liners separated by enough material so that a puncture of one layer is unlikely to penetrate the other liner. These designs should include five feet or more of soil between the manure and bedrock, including any soil used for part of the liner system.

(ii) Concrete-lined manure storage area, and five feet or more of soil between the manure and bedrock;

(iii) Above ground tanks with concrete floors, and five feet or more of soil between the top of the concrete and bedrock.

(iv) Concrete lined with a secondary geomembrane liner for leachate collection. Leachate, tank leakage and rain water percolating down through backfill, shall be collected in a tile above the plastic liner and conveyed by non-perforated pipe or tile to a grassed daylight outlet at least 50 feet from the manure storage area. A separate perimeter drainage tile may be required to control the elevation of the water table or saturated soils. No minimum separation distance from the bedrock is established, except that the plastic liner shall be placed on a cushion of soil or sand with a thickness determined by the design engineer.

(v) Above-ground tanks with concrete floors and a secondary geomembrane liner for leachate collection. Any seepage liquids and rain water percolating through backfill, shall be collected in a tile above the plastic liner and conveyed by non-perforated pipe or tile to a grassed area at least 50 feet from the manure storage area. No minimum separation distance from the bedrock is established, except that the plastic liner shall be placed on a cushion of soil or sand with a thickness determined by the design engineer.

**Recommendation H –**Design plans shall indicate the method for regular measurement of liquid manure levels in association with Recommendation K(1)**.**

**Recommendation I –** The workgroup recommended that at sites susceptible to soil collapse, a new or modified liquid manure storage area should be limited to a maximum of three million gallons. A storage area is considered a single cell that is spaced far enough from adjacent cells so that a sinkhole forming below one cell will not affect the integrity of the adjacent cell(s). If cells are connected by pipes and designed such that if one cell drains the other one will also drain, then the total capacity of the individual cells should be no greater than 3 million gallons.

**Recommendation J -** The workgroup recommends that design plans show how barn roof runoff, rain water percolating through uncompacted backfill, tile line waters, and surface runoff near the liquid manure storage area will be intercepted, collected and conveyed away from the liquid manure storage area. All pipes conveying water must not outlet within 50 feet of the manure storage area and must discharge onto sloping land such that no ponding of water occurs within 300 feet of the liquid manure storage area.

### 3.2.3 Identifying and responding to failures

To help ensure that the manure storage areas are operating as intended by the design engineer, and to minimize the risk of environmental damage from any failed systems, the workgroup strongly recommended the following requirements.

**Recommendation K -** The workgroup recommends that at sites susceptible to soil collapse, inspections and monitoring be conducted as follows:

(1) An annual visual inspection of the storage system should be conducted after pump-down, except that inspections should not be required in confined spaces such as the interior of earthen basins that have a membrane cover for odor control, concrete pits under slat floor barns and other covered storage areas; and

(2) Manure levels should be checked and documented at least weekly within drinking water supply management areas where the aquifer is vulnerable, and at least monthly for other areas (preferably weekly at all sites, where possible).

**Recommendation L -** The workgroup recommends that an emergency response plan be required at all feedlots in areas susceptible to soil collapse. The plan should include notification procedures and action steps for any spill or loss of liquid manure from the structure.

# Chapter 4: Comparison of workgroup recommendations with current Minnesota policy

## 4.1 Comparison overview

Minnesota rules pertaining to construction of liquid manure storage systems are found in Minn. R. ch. 7020.2005 (attachment C). The MPCA has also developed interim guidelines that incorporate the minimum standards in the revised feedlot rules and additional recommended site specific evaluations and measures to safeguard water quality (attachment D). The workgroup understood that the intent of the legislation was for the workgroup to take a fresh look at needed standards for the karst region, and thus not focus on existing MPCA policy. Therefore, existing MPCA policy was only briefly considered during the workgroup process. Following the finalization of the workgroup proposals, the MPCA drafted this Chapter 4 comparison of current MPCA policy to workgroup proposals.

The Table below shows a comparison summary of MPCA requirements in rules, recommendations in MPCA guidelines, and how existing policy compares to recommendations developed by the workgroup.

| Issue | MPCA minimum requirements for karst areas as stated in rules Chapter 7020 | MPCA recommended guidelines | Workgroup Recommendation for rules |
|---|---|---|---|
| **Prohibited Sites for liquid manure storage** | 300 feet from sinkholes (7020.2005 subp. 1) | 300 feet from sinkholes | 300 feet from sinkholes (existing and filled) and over registered caves |
| **Areas where rules are the same as the rest of the state.** | Areas not susceptible to soil collapse or sinkhole formation (no further definition of these areas is included in the rules) | Same as rules. Guidelines indicate the types of conditions where there is a low risk of soil collapse. | Areas where there is at least 50 feet of unconsolidated materials above carbonate bedrock and also no karst features within 1000 feet. |
| **Maximum storage capacity in areas susceptible to sinkhole formation** | 250,000 gallon limit per cell where four or more sinkholes exist within 1,000 feet. No other capacity limits. Some exceptions for feedlots with less than 300 animal units correcting pollution problems. | Same as rules. In addition, one million gallon limit per farm is recommended for areas with a high risk of soil collapse, as defined in the guidelines. | Three million gallons per storage cell. No maximum limit per farm. |
| **Use of cohesive soil liners (with no secondary liner) in areas susceptible to soil collapse** | Permitted only in areas with a separation distance between manure and bedrock of 20, 30 and 40 feet for operations with <300, 300-1000, and >1000 animal units, respectively. Some exceptions if <300 AU. | Same as rules. In addition, only recommended for use where the risk of soil collapse is considered low in accordance with the guidelines. | Do not allow earthen liners alone in areas susceptible to soil collapse until further geologic study is completed |

| Issue | MPCA minimum requirements for karst areas as stated in rules Chapter 7020 | MPCA recommended guidelines | Workgroup Recommendation for rules |
|---|---|---|---|
| **Use of concrete liners and composite liners (2 foot cohesive soil liner overlain by a geomembrane liner) in areas susceptible to soil collapse** | Permitted in areas with at least 5 to 15 feet of separation to bedrock, varying with the size of the farm (in animal units). Some exceptions for feedlots with less than 300 animal units correcting pollution problems. | Same as rules. In addition, these liners are not recommended for storage of more than about 2 million gallons where the risk of soil collapse is considered high in accordance with the guidelines. | Permit in areas with at least a five foot separation to bedrock. |
| **Use of concrete liners over secondary liners in areas susceptible to soil collapse** | Permitted where separation to bedrock is at least 5 and 10 feet for operations with less than and more than 1,000 animal units, respectively. Some exceptions for feedlots with less than 300 animal units correcting pollution problems. | Same as rules | Permitted as long as secondary liner is geomembrane material and a ground surface outlet is installed for any drainage waters. No minimum separation to bedrock. |
| **Site Investigation** | Soil investigations to a depth that verifies minimum separation to bedrock requirements and karst feature identification within a half mile of the proposed site. | Same as rules. Site investigation methods and analysis are included in the guidelines. | Soil investigations to a depth that verifies separation to bedrock requirements will be met. Identify all existing and filled sinkholes to ensure that all setbacks and other laws are being met. |
| **Monitoring** | Design plans must include a plan for operation, periodic inspection and maintenance of the storage area. Specific plans to be decided by the design engineer. | Regular inspections for liner damage, seepage problems, or soil collapse. | Weekly to monthly monitoring of manure levels. Annual inspections following manure removal. |
| **Construction Requirements** | Numerous requirements for all areas of the state. No specific requirements for karst areas. | In addition to statewide requirements, inspect subsoil during construction for possible karst features | In addition to statewide requirements, inspect subsoil during construction for possible karst features |
| **Water infiltration near the storage area** | No requirements in rules. | Grading and routing water so that freshwater from roof runoff and other collected precipitation does not infiltrate near the storage area. | Grading and routing water so that freshwater from roof runoff and other precipitation does not infiltrate near the storage area. |
| **Emergency Response Plan** | Not specific to karst region. All feedlots with over 1,000 animal units must develop an emergency response plan. | Not included in current guidelines. | Plans needed for all new or modified liquid storage in areas susceptible to soil collapse. |

Many of the workgroup recommendations are generally consistent with MPCA policy. For example, both MPCA rules and workgroup recommendations:

- establish 300 foot setbacks from sinkholes;
- include major restrictions on use of cohesive soil liner used alone without other liners;
- allow for use of concrete lined, composite lined and above ground storage in karst areas;
- establish a similar degree of separation to bedrock conditions for use of concrete, composite and above ground liners for small to moderate-sized feedlots; and
- include site investigation requirements for soil investigations.

Yet, several of the workgroup proposals are found in MPCA recommended guidelines, but not in MPCA rules (mandatory).

The workgroup proposals generally fall into three categories:

1) *Workgroup proposed additions to MPCA rules* - recommendations that are not currently included in Minn. Rules Chapter 7020, but that are generally consistent with MPCA guidelines and past permit requirements;

2) *Recommended alternative standards to MPCA rules* - recommendations to replace existing provisions of MPCA rules with new standards; and

3) *Proposals for further study* - recommendations for additional research, study or work that will provide clearer justification for modifying/refining design standards, and that will better enable engineers to locate and design liquid manure storage systems in karst regions.

Each of these three categories are discussed below.

## 4.2 Workgroup proposed additions to MPCA rules

Several workgroup recommendations are not currently included in Minn. Rules Chapter 7020. The workgroup recommended that the following be added to MCPA requirements for liquid manure storage systems in areas susceptible to soil collapse or sinkhole formation:

**Recommendation D –** Construction inspections of subsoils for karst features (currently in guidelines, not in rules)
**Recommendation J –** Design and construct to convey surface runoff away from manure storage areas (currently in guidelines, not in rules)
**Recommendations H and K –** Manure level monitoring and inspections and design plans showing method of manure level monitoring (currently in rules, but not as specific as workgroup recommendations)
**Recommendation L** - Emergency response plans for all new liquid manure storage constructed in areas susceptible to soil collapse or sinkhole formation (currently emergency response plans are required statewide for 1000 or more animal units).

## 4.3 Recommended alternative standards to MPCA rules

Two of the workgroup recommendations are different from existing MPCA policy: 1) storage cell capacity limits, and 2) separation to bedrock requirements. The workgroup recommended that their proposed standards replace related existing MPCA rule provisions.

### 4.3.1 Storage cell capacity limits

*Current MPCA rules* - MPCA rules set a 250,000-gallon limit per storage cell in areas with four or more sinkholes within 1000 feet (7020.2100, subpart 2, Item A). No other storage capacity limits are set in MPCA rules. The MPCA allows exceptions to the 250,000-gallon limit, if the farm has less than 300 animal units and the storage system is needed to correct a pollution hazard (see 7020.2100 Subpart 2, Item C). Roughly two to ten percent of land in the counties with karst geology have sinkhole densities that would trigger the 250,000-gallon limit. Few liquid manure storage systems have been proposed in high sinkhole density areas (e.g., more than 4 sinkholes within 1000 feet) in recent years. MPCA guidelines recommend storage capacity limits that vary with the liner type and an assessment of the karst geology conditions.

It should also be noted that a mandatory environmental assessment worksheet (EAW) is required before an expansion of 500 or more animal units when one or more sinkholes is within 1,000 feet of a proposed site (Minn. R. 4410.4300, subp. 29). A discretionary EAW may be requested by the MPCA for other sites below the 500 animal unit threshold if the agency determines that the project may have the potential for significant environmental effects (Minn. R. 4410.5400).

*Workgroup recommendation* - The workgroup recommends a three million gallon limit in all areas susceptible to sinkhole formation (recommendation I). The workgroup proposes that the three million-gallon limit be the only storage capacity requirement at this time. The three million-gallon limit for all areas susceptible to sinkhole formation would replace the MPCA rule in 7020.2100, subpart 2, item A. Workgroup recommendation I could be considered to be more restrictive than MPCA rules for areas outside of high sinkhole density zones (e.g., 3 million-gallon cell capacity limit, instead of no limits in the current rules). However, recommendation I is less restrictive than MPCA rules for high sinkhole density areas (e.g., allowing a three million-gallon cell capacity limit instead of a 250,000 gallon limit). Both MPCA rules and workgroup recommendations prohibit construction within 300 feet of a sinkhole. A comparison of MPCA rules and workgroup proposals for different situations is included below (Table 4.1).

Table 4.1 Single-cell manure storage capacity limits

| Site Conditions | MPCA Policy | Workgroup Proposal |
|---|---|---|
| **Four or more sinkholes w/in 1000 ft. No pollution hazard or more than 300 animal units (AU)** | 250,000 gallon limit in rule | 3 million gallons |
| **Four or more sinkholes w/in 1000 ft. Feedlot has less than 300 AU and is correcting a pollution hazard** | No limit in rules. Guidelines suggest total farm manure storage capacity limits based on liner type and geologic conditions. | 3 million gallons |
| **One or more sinkholes w/in 1000 ft. and more than 500 AU** | EAW required. Guidelines suggest total farm manure storage capacity limits based on liner type and geologic conditions | 3 million gallons |
| **Less than four sinkholes within 1000 ft. and No EAW required** | No limit in rules Guidelines suggest total farm manure storage capacity limits based on liner type and geologic conditions | 3 million gallons |

### 4.3.2 separation to bedrock requirements

Current MPCA rules for separation to bedrock restrictions vary from 5 to 15 feet for concrete pits, dual-lined basins and above ground tanks, depending on the type of liner and the number of animal units on the farm. Whereas, the workgroup recommends that separation to bedrock be a minimum of five feet for these same types of manure storage systems, except for two types of designs where no minimum separation to bedrock is necessary. MPCA rules allow cohesive soil liners alone where there is a substantial soil thickness between manure and bedrock (e.g., 20 to 40 feet). The workgroup recommends no cohesive soil liners to be used alone without another liner in areas with less than 50 feet from ground surface to carbonate bedrock. However, the workgroup recommended review and potential revising of this requirement after further geologic study identifies the areas with less than 50 feet to bedrock that have a low potential for soil collapse or sinkhole formation.

A more specific comparison of MPCA rules and workgroup recommendations related to separation distances between manure and the underlying bedrock is shown below (Table 4.2).

Table 4.2 Comparison of separation to bedrock restrictions (all units in feet)

| | **Composite, Concrete, above ground tanks** | | **Concrete w/geomembrane or above ground tank with geomembrane** | | **Soil liners only (assuming basin is 10 feet below ground surface)** | |
|---|---|---|---|---|---|---|
| | MPCA Rules | Work-group | MPCA Rules | Work-Group | MPCA Rules | Work-Group |
| **Less than 300 AU** | 5 | 5 | 5 | Engineer determines Soil cushion | 20 | 40 |
| **300 to 999 AU** | 5-10 | 5 | 5 | Engineer determines Soil cushion | 30 | 40 |
| **1000 or more AU** | 10-15 | 5 | 10 | Engineer determines Soil cushion | 40 | 40 |

## 4.4 Proposals for further study

The remaining workgroup proposals pertain to areas needing further research, study or work, including:

**Recommendation A** - Assessing geologic conditions that indicate susceptibility to soil collapse and sinkhole formation (use this information for future revisions to rules).

**Recommendation B** - Developing/completing maps showing areas with less than 50 feet to bedrock (tool for engineers, producers, state/local agencies).

**Recommendation E** - Developing registration and mapping process for caves (joint MDNR and MGS effort).

**Recommendation F** - Researching statistical probabilities of soil collapse in different geologic settings (use this information for various policy decisions).

Several other recommendations for further study are also included in Chapter 6, including:

- Studying pathogen transport below liquid manure storage areas
- Developing template emergency response plans
- Exploring and demonstrating alternatives to liquid manure
- Conducting inspections of existing liquid manure in karst areas
- Collecting, analyzing, interpreting and mapping karst feature information

# Chapter 5: Workgroup Considerations and Justification

## 5.1 Location Restrictions

The workgroup considered whether there are sites where liquid manure storage systems should not be constructed, no matter how small the storage system is, or how it is designed?" Several potential site restrictions were discussed, including a) over a known sinkhole, b) in high risk geographic areas such as sinkhole plains, c) over known caves, d) in close proximity to conduits to ground water, e) in vulnerable wellhead protection areas for municipal wells, and f) near private wells.

The workgroup agreed that the only criteria that should be used in state rules to prohibit construction are a) directly over or within 300 feet of a sinkhole or b) over a registered cave. There was discussion about the possibility of building on top of sinkholes by using void spanning concrete designs or geogrids to span a distance of twice the depth to bedrock (assuming a slope no greater than 45 degrees on the sinkhole sidewalls). However, the workgroup decided that manure storage systems can usually be moved to be more than 300 feet from sinkholes and there are uncertainties about sinkhole diameter and practical limits (e.g. 10-20 feet) of void spanning reinforcement.

Prior to setting the 300 foot setback, the workgroup considered using a 50-foot setback from sinkholes since sinkholes in Minnesota rarely expand to have a diameter of over 50 feet. In addition, the workgroup did not have geostatistical evidence indicating that new sinkholes are more apt to form 50 feet from an existing sinkhole than 300 feet from an existing sinkhole. However, the workgroup agreed that a 50-foot setback does not provide a sufficient margin of safety. Several examples were cited regarding subsurface conduits that extended well beyond 50 feet from existing sinkholes. The workgroup decided that 300 feet provided a greater margin of safety. A 300 foot setback from sinkholes exists in current MPCA rules for all new feedlots, not just liquid manure storage construction. A 300-foot setback is also more consistent with other states where setbacks range between 150 and 500 feet.

The workgroup discussed whether construction should be prohibited over known caves, due to the potential for bedrock collapses over the cave and the potential for long-term damage to the cave ecosystem. The workgroup agreed that preservation of certain caves is important, and they agreed on the concept of prohibiting construction of liquid manure storage directly over large cavernous openings directly below the ground. However, several concerns were raised about automatically prohibiting construction over known caves. Some of the concerns include:

a) The likelihood of bedrock collapse is small, particularly if the cave is deep within the bedrock;
b) Caves are networks of conduits and it is too difficult to define the areas where caves are located. A manure spill into one conduit that is not mapped as a cave can lead to a cave;
c) Defining what should be considered a cave and where the caves are located is difficult and subjective, and would likely result in conflict and disagreement among those who want the feedlot and those who do not want a new manure storage system in a given area; and

d) Individuals may know of caves, but they do not tell anybody because they do not want others exploring these caves.

The workgroup reviewed the restriction in Kentucky prohibiting construction of liquid manure storage directly over mapped cave systems associated with national or state parks. This concept was generally supported among the workgroup if the caves were clearly mapped and commercial caves were also included. The workgroup recommended that before sites are prohibited due to the proximity of caves, the legislature should initiate a process to register and map existing caves. Additionally, the workgroup suggested that the state develop recommendations regarding how these caves should be protected (see also related discussion in Chapter 6).

The workgroup discussed the possible need to define high risk-zones within the general areas considered to be susceptible to soil collapse (e.g. in sinkhole plains). For such high risk areas, there was discussion of possibly using geophysics to identify voids and then require void spanning designs where geophysics indicate anomalies or potential voids in the soils/geology. The workgroup agreed that there is currently not enough understanding about the geostatistics and probability of new sinkhole development to be able to specify zones around karst features where these additional measures should be required. The workgroup considered using geophysics to better define site risks, but concluded that the decision to use geophysics should be left to the design engineer given that this work does not provide assurances of a safe site and can be quite costly.

The workgroup agreed that there should be no special provisions for wellhead protection areas, watersheds with trout streams, or land near state parks, other than adopting the protective measures for all land susceptible to soil collapse.

## 5.2 Areas with similar water quality risks as the rest of the state

The workgroup consulted karst geologists who have studied SE Minnesota to determine the geologic conditions where sinkholes rarely form. Such areas include land where there is more than 50 feet of unconsolidated materials above bedrock. Sinkholes can still form even when there is over 50 feet of cover materials, but the likelihood of soil collapse or sinkhole formation is very low in these areas. The workgroup decided that areas with over 50 feet to bedrock and no karst features within 1,000 feet should be excluded from restrictions for areas "susceptible to soil collapse or sinkhole formation."

The workgroup also suggested that there can be areas with less than 50 feet of unconsolidated material above bedrock, and yet still not be susceptible to soil collapse. For example, in areas where there is a substantial thickness of Decorah shale, sinkholes are not likely to form. However, the workgroup was unsure at this time about the minimum thickness of Decorah shale to prevent sinkhole formation. The workgroup recommends that the Minnesota Geological Survey identify other geologic conditions where sinkholes are not likely to form (in the zones with less than 50 feet to consolidated bedrock).

The workgroup highly recommended that maps be developed to clearly identify areas where the depth to consolidated bedrock is less than 50 feet. A preliminary map (with some missing counties) was developed showing areas where there is less than 50 feet of soil cover above fractured bedrock (see Figure 1). Larger scale maps should be developed for individual counties or townships where such maps have not been completed. The workgroup also agreed that at sites where it is not certain from the maps that there is over 50 feet of cover (i.e., fringe areas), then borings and/or further geologic analysis should be conducted to demonstrate the presence of over 50 feet of unconsolidated materials.

## 5.3 Liner Types

The workgroup recognized that excessive seepage through liners can cause underlying soil to be washed into fractures in the bedrock, and thus induce sinkhole development. One of the primary ways the workgroup sought to minimize risk of catastrophic failure is to use liners that are durable and have very low seepage rates. These liners also have the benefit of reducing chronic risks associated with bacteria/virus movement into fractured bedrock.

The workgroup first listed the main types of liquid storage systems and ranked these systems from highest to lowest risk, based mostly on the seepage rate, durability and ease with which leaks are visible. The workgroup suggested the following, beginning with highest risk:

1. Structures without any type of a liner

2. Earthen basins (2 foot cohesive soil liner)

3. a) Earthen basins (3-4 foot cohesive soil liner), or
   b) Geosynthetic liner with NO underlying clay liner

4. a) In-ground concrete (cast in place w/inspections was considered to be better than precast), or
   b) HDPE (high density Polyethylene) or other plastic-type geomembranes with NO underlying clay liner

5. Dual lined systems
   a) composite liner – geomembrane underlain by cohesive soil liner
   b) concrete underlain by a geomembrane

6. Double-composite lined systems – geomembrane underlain by cohesive soil liner which is then underlain by another geomembrane

7. Systems with very low seepage rates and where major seepage problems are visible:
   a) Above-ground glass-fused metal tank
   b) Above-ground concrete tank

The workgroup also discussed the use of void spanning materials to reinforce geomembrane and composite types of liner systems. Reliable materials have been used and tested extensively for landfills that span voids that are between 10 and 20 feet in diameter. There are some products that have not been found to work well and other products that are more reliable. Mr. Gale noted that the most reliable material is polyester geotextiles or geogrids made by one of three companies 1) Tensar, 2) Mirafi, and 3) Heusaer, all of which can reportedly be installed for $5 to $15 per square yard. However, additional excavation costs will also be incurred since the geotextile/geogrid must be installed beneath the earthen berms. Reinforced concrete can also be used to span voids; however the cost of reinforced void spanning concrete makes it essentially not feasible for manure storage systems.

Initially, the workgroup discussed the possibility of requiring different liner standards depending on the geologic risk of soil collapse found at the site. For example, the workgroup could recommend clay liners at the moderately low risk sites, composite and concrete liners at moderately high-risk sites and the use of void spanning reinforcement for extremely high risk situations. However, the workgroup decided to recommend the same liner requirements in all areas considered susceptible to sinkhole formation, due largely to the lack of clear-cut scientifically justifiable criteria available at this time for assigning different levels of soil collapse risk. In addition, substantial leakage from liquid storage systems has induced sinkhole formation in areas that do not have much evidence of previous soil collapse. Another point was made that many sinkholes have been filled and we can not rely entirely on existing sinkholes as indicators of future collapse at a specific site.

In areas susceptible to sinkhole formation, the workgroup agreed that standard compacted cohesive soil liners alone should generally not be allowed. While cohesive soil liners can be more effective in limiting seepage if they are installed under optimum conditions, the workgroup still had concerns about liner durability and seepage rates that could lead to soil collapse in the karst region. One alternative type of earthen liner design was suggested as a possible option for the karst region. This alternative design would include seven feet of earthen materials, including three feet of compacted cohesive soils (< 1*10-7 cm/sec) overlain by four feet of soil. The four feet of overlying soil would protect the clay liner from problems of desiccation, freeze/thaw, roots, and erosion. Some workgroup members stated that a spillway would be needed so that the basin did not get filled above the elevation of the clay- liner. Concerns about this spillway were also expressed. The workgroup was doubtful whether this type of design would be preferred by anyone instead of a composite-lined system.

The workgroup also discussed the possibility that a cohesive soil liner could be used without a geomembrane if sufficiently thick soils existed below the basin to greatly reduce the seepage from entering the fractured bedrock directly below the basin. Some workgroup members suggested that sites with less than 50 feet of soil cover should not necessarily be prohibited for use of cohesive soil liners alone. The workgroup seemed to believe that there was some merit to considering use of cohesive soil liners alone in areas with less than 50 feet to bedrock. The workgroup decided to wait for more geostatistical information to be completed in order to identify under what soil/geologic conditions soil collapse is unlikely in zones with less than 50

feet to bedrock (and then to reconsider allowing construction of cohesive soil liners alone in such zones).

The workgroup agreed that a dual-lined or composite-lined manure storage area should be allowed in areas susceptible to soil collapse if one of the following combinations of materials is used: a) compacted cohesive soil liner meeting MPCA standards overlain by a geomembrane or geosynthetic liner, or b) two geomembrane liners separated by enough material so that a puncture of the upper layer is unlikely to penetrate the second liner. These types of liners have very low seepage rates, and if one liner is damaged, a secondary liner is in place to retard seepage through the damaged areas. The workgroup also agreed that concrete liners and glass-fused metal or concrete tanks should be allowed in areas susceptible to soil collapse or sinkhole formation. These types of liners are durable and have leakage rates that are very low. The workgroup estimated that the costs of constructing a dual-liner with clay and geomembranes are approximately $1 more per square foot.

The workgroup strongly recommended that further investigations be conducted to gain a better understanding of the likelihood of soil collapse under different geologic conditions, and that the recommendations in this report be reviewed and adjusted in the future to correspond with the more specific geologic criteria.

## 5.4 Separation to bedrock

The workgroup emphasized that the types of liners allowed in areas susceptible to soil collapse would result in very little seepage, but that there would still be a small amount of seepage. The primary purpose of separation to bedrock requirements are to 1) allow for adsorption of viruses and bacteria onto soil particles until they die-off, or 2) slow the time of travel of liquids so that bacteria and viruses will likely die prior to the liquids entering fractured bedrock. In addition, the soil separation to bedrock will also allow for some attenuation of nutrients and other contaminants associated with manure. Once contaminants enter fractures in the bedrock, there will be very little contaminant treatment. The workgroup generally believed that five feet of soil should likely be sufficient to attenuate bacteria from low seepage rates if there is at least a couple feet of the underlying materials are unsaturated. However, the workgroup also recognized that more research is needed on pathogen transport below manure storage areas and that the five-foot separation should only be used until further research better supports different requirements.

The workgroup discussed the difference between saturated and unsaturated soils below the storage area. Saturated soils or seasonally saturated soils below the basin are characteristic of low permeability soils. Bacteria and viruses are less likely to be adsorbed onto soil particles under saturated conditions; however, the rate of water flow will be reduced in situations where there is a perched water table, providing additional time for bacteria and virus die-off.

The recommendations for separation distance to bedrock for the different liner types were based on the best professional judgement of the workgroup members after considering studies of pathogen transport, seepage through liners, and the practical issues associated with limited soil thickness conditions in the karst region.

The workgroup recommended that construction of certain dual-lined manure storage systems that collect and drain seepage liquids be allowed directly on top of bedrock. With this type of a liner, the hydraulic pressures on the secondary liner will be alleviated, and the risks of seepage through this secondary liner will therefore be very low. A blanket of soil is needed to separate the liner from bedrock to prevent punctures and to allow for differential settlement over uneven bedrock. The thickness of this soil blanket is to be determined by the design engineer or manufacturer of the liner.

## **5.5 Feedlot size and storage capacity**

The workgroup discussed possible options to factor feedlot size/capacity into making decisions about design standards. The workgroup addressed whether design standards should vary with a) number of animal units on the farm, b) number of animal units contributing to an individual storage system, c) total capacity of liquid manure storage at the farm, d) capacity of the individual storage cell, e) none of the above." The workgroup agreed that design standards should vary with capacity of the individual storage cell. Risk is related to the consequence of failure and the probability of failure. As the capacity of the storage system cell increases, the consequences of a failure are generally expected to be worse, reasoned the workgroup.

The workgroup considered several issues before deciding on the best alternative. One consideration was that by setting standards based on cell capacity, we may be encouraging design and use of under-sized manure storage basins, possibly leading to storage system overflow and/or winter application of manure. However, the group reasoned that winter application is not prohibited in state rules and more storage cells can be added if necessary. The workgroup also considered that multiple cells with sloping sidewalls will create more surface area than one individual cell, thereby, increasing the probability of failure compared to one larger cell. More surface area of storage also can create more odor and gaseous emissions into the air. However, the group still agreed after considering these issues that the capacity of the individual cell was the best variable to use in setting standards.

The group also agreed that to be considered an individual cell, a certain separation distance between cells should be maintained. The needed separation distance should be inversely related to depth to bedrock, and directly related to storage system seepage rates- and risks related to the local geology.

The workgroup also pointed out that if two cells are connected by pipes and designed such that if one cell drains the other one will also drain, then the capacity of the two cells should be added and considered as one cell. An overflow pipe can be used to prevent this situation.

After the workgroup decided that standards should vary with cell capacity, the next question was should there be a sliding scale of storage cell capacity limits, or would it be best to set one limit that could be used throughout all areas susceptible to soil collapse? They decided that a single threshold would be best. They reasoned that the consequences of a large manure release (e.g. 20-million gallons) would be much greater than the consequences of a small release (e.g. 20,000

gallons). However, the workgroup had a difficult time selecting one threshold number since there was a poor understanding of the consequences related to releasing various amounts of manure into the ground water or surface waters. Because the workgroup did not believe they could justify specific thresholds based solely on consequences of release alone, the workgroup decided to base cell capacity limits on storage needs of small to moderate sized farms.

The NRCS compiled liquid manure storage capacity information for manure storage systems designed by the NRCS from 1994 to 1998. The average capacity of Dairy and Beef liquid manure storage systems was roughly 1.3 million gallons and the maximum was 2.6 million gallons. These systems were designed to correct problems associated with manure runoff from feedlots. The workgroup also reviewed the annual manure storage needs for a 300 animal unit dairy operation. The 300 animal unit farm is a commonly used threshold in federal and state rules. The workgroup concluded that about 3 million gallons was needed for a dairy operation with 300 animal units. Swine manure storage needs are much less per animal unit than dairy. Based on the NRCS designs and the storage needs for a 300 animal unit dairy, the workgroup suggested two numbers as possible thresholds for maximum storage capacity of a single cell – 3 million gallons and 1.5 million gallons. If they had to pick one number, the group agreed that the better number was 3 million gallons per storage cell. The workgroup agreed that by using either number economic hardship for producers would be minimized, except possibly for large dairies where multiple cells would be needed.

Overall, the workgroup did not have good scientific information to believe that a 3-million gallon release was much worse than a 1.5-million gallon release. Several workgroup members expressed a desire to keep the maximum cell capacity as low as possible without significant hardship to producers. One concern raised about setting small cell capacity limits is that many smaller existing dairy and beef farms do not have enough space near the barns to split the storage systems into multiple cells (e.g., they are adjacent to hills, have shallow depths to bedrock, or the barns are adjacent to other features that limit room for the storage basins). The workgroup agreed that multiple cells, when added together, should be allowed to exceed three million gallons (e.g. no capacity limits per farm).

The workgroup also debated the merits of requiring the manure storage system to hold at least seven months of manure production. The reason for this recommendation was to ensure that the producer will have enough storage capacity to be able to apply manure at a time of year when the manure could be immediately incorporated, thereby avoiding winter application. The workgroup felt this was justified for the karst region given the number of conduits to ground water, rapid contaminant transport, and potentially rapid ground water/surface water interaction.

Two concerns were raised in regards to the seven-month minimum storage recommendation. First, many small farmers often request a smaller storage area to reduce feedlot runoff to streams in a way that is affordable. When small storage systems are used, the farmers will still be applying manure throughout the year, but manure runoff to streams can be greatly reduced. Second, a seven-month capacity minimum was proposed for the purpose of better manure spreading practices, and consideration of manure application practices was not part of the directive given to the workgroup by the legislature. The workgroup decided to highly

recommend a **seven-month minimum storage design capacity**, but not to make this a requirement for all feedlots where a manure storage system is constructed.

## 5.6 Diverting surface runoff

The primary goal of requiring liners with very low seepage rates is to limit the possibility of soils below the manure storage system from being washed into underlying fractures, thereby inducing soil collapse. Infiltration of precipitation waters near the manure storage system can also accelerate sinkhole development. If excessive infiltration of water occurs near the manure storage system, then a sinkhole could develop below the manure storage system. Therefore, the workgroup considered it important to convey precipitation falling on the barn roofs and land near the manure storage system to a location that is not likely to affect sinkhole development near the manure storage system.

The workgroup discussed whether the recommended requirements should specify how far from the manure storage system that freshwater runoff needs to be routed or diverted away from the site. At many sites, the land is sloped sufficiently to carry freshwater away from the site without the need for below ground pipes. The workgroup considered it important that pipes carrying water discharge at least 50 feet from the manure storage area, and that the site is planned so that no ponding of waters occurs within 300 feet of the manure storage area.

## 5.7 Construction requirements

The workgroup reviewed the new (Chapter 7020) rules related to statewide standards for construction of liquid manure storage systems. The workgroup thought that statewide requirements for construction, inspections, testing and reporting are fairly comprehensive, but recommended that two requirements should be added for all manure storage systems constructed statewide, as follows: **1) for all liner construction, the installer of the liner should certify that the subgrade preparation is acceptable and that all necessary testing of the liner was completed in accordance with the design engineer plans and specifications, and 2) the manufacturer of liners should provide certification of material specifications**.

The workgroup also considered what additional construction standards may need to be added specifically for construction in the karst region. The workgroup concluded the only construction-related requirement that should be recommended specifically for the karst region is for construction inspection of the soil subgrade by a licensed geologist, soil scientist or engineer with education and experience in karst soils/geology. An inspection form should be completed by the inspector and submitted to the design engineer so that it can be part of the construction report. The purpose for this inspection is to identify karst features such as soil piping or other conditions indicative of potential soil subsidence. If such features are identified, then the site would need to be moved, or potentially void-spanning reinforcement could be added to the design.

## 5.8 Monitoring

The workgroup considered three types of possible monitoring: 1) visual inspections of the manure storage area, 2) regular monitoring of manure levels, and 3) monitoring of ground water quality below the manure storage systems. The workgroup agreed that inspections and monitoring of manure levels were important and should be required. However, the workgroup agreed that water quality in the subsurface below liquid manure storage systems should not be monitored more extensively in the karst region than elsewhere in Minnesota (e.g., through the use of monitoring wells, lysimeters, spring sampling and/or perimeter tile lines). The workgroup concluded that the water quality monitoring would often not provide useful information, the money for monitoring would be better spent on installing highly protective liners, and monitoring contamination in karst geology can be fairly complicated and costly.

The workgroup believed that routine inspections are important to make sure that the liner has not been damaged. Inspections are most useful after the manure has been pumped out of the storage system. Several suggestions were made about who should conduct an annual inspection (county feedlot officer (CFO), MPCA, dairy inspectors, feedlot owner, private party). One suggestion was to have the feedlot owner conduct the inspection and then mail the inspection form to the MPCA or county feedlot officer. The CFO or MPCA could follow-up with an inspection as time and priorities allow. The workgroup agreed that inspection of the interior of concrete pits covered by barns should not be required due to the durability of concrete and the human dangers involved in the inspection process.

The workgroup thought that manure level monitoring and documentation should be conducted to ensure that the manure storage system is operating as expected and to detect potential releases of manure into the environment (and thus take measures as specified in an emergency response plan). Some possible methods of checking levels suggested by the workgroup include a) measure on the concrete ramp, b) installing a liquid level monitoring pipe, or c) use of pressure transducers. Total costs for a pressure transducer and data recorder were reported to be about $6,000 to $8,000. An article was provided by a workgroup engineer showing how a manure-level monitoring pipe could be installed. The workgroup agreed that the method of measuring manure levels should be left up to the design engineer and feedlot owner. The workgroup also agreed that the frequency of manure level monitoring should be greater in drinking water supply management areas for public wells where the aquifer is vulnerable to contamination. The workgroup had varying opinions about the recommended frequency of manure level measurement. Some thought that weekly measurements was best, and others believed weekly measurements were excessive and unnecessary, except in vulnerable drinking water supply management areas.

## 5.9 Emergency Response Plan

The workgroup believed that each farmer with liquid manure storage systems in sinkhole prone areas should be required to develop an emergency response plan for the farm. The workgroup suggested that southeastern Minnesota counties and the state should work together to develop generic emergency response plans that can then be individually tailored for specific sites. The

feedlot owner should develop and submit to the MPCA or delegated county a plan for how the owner will respond if it appears that manure levels have been decreasing or there is other evidence of a manure release. The emergency response plan should include notification procedures for informing the MPCA, Minnesota Department of Health, local authorities, and others in the event of a manure release.

# Chapter 6 - Recommendations for further study

The workgroup recommends to the legislature that the following additional work be conducted:

1. Determine the geostatistical probabilities of soil collapse in different types of geologic settings;

2. Study pathogen transport through soils below liquid manure storage systems;

3. Develop generic emergency response plans that can then be tailored for specific feedlot operations;

4. Conduct research and demonstration projects on alternative manure management approaches that do not rely on liquid storage.

5. Conduct regular monitoring and inspections of existing liquid manure storage systems constructed in areas susceptible to sinkhole formation or soil collapse to determine whether any major seepage problems are occurring at these sites; and

6. Collect, manage, analyze, interpret and map geologic information needed by engineers designing liquid storage basins in karst areas. A more specific description of this recommendation is included below:

   The Minnesota Geological Survey (MGS) was established in 1872 to serve as the state's repository for geological information. The MGS is part of the N.H. Winchell School of Earth Sciences at the University of Minnesota and has no regulatory authorities. As such, it is in a unique position to critically evaluate geological information and make unbiased interpretations regarding the physical geology of an area. It is appropriate that MGS serve as the focal point to store and provide geological information needed by engineers who design liquid manure storage basins in sensitive karst areas. The potential roles for the MGS include:

   1. *Prepare maps showing depth to bedrock –*

      Depths to bedrock greater than 50 feet are generally considered to greatly reduce the likelihood that collapse of a liquid storage basin will occur as a result of the piping of unconsolidated deposits into karst bedrock.

      Depth to bedrock maps showing areas where there is less than 50 feet of cover over karst bedrock have been prepared for Dakota, Fillmore, Goodhue, Olmsted, Rice, Scott, Wabasha, and Washington Counties (1/100,000 scale or 1 inch equals about 1.6 miles)

      MGS has the capability to prepare maps showing where there is less than 50 feet of cover over karsted bedrock for Blue Earth, Carver, Dodge, Faribault, Freeborn, Houston, Le Sueur, Nicollet, Pine, Steele, and Waseca, Winona counties.

MGS needs the resources to evaluate additional data describing depth to bedrock so that county depth to bedrock maps can be updated and the data base of subsurface data can be maintained and made accessible to the public. Maps should be made available to the public through a web site.

2. *Karst database* -

Develop and maintain a data base of karst features that can be used to determine the design requirements for liquid manure storage basins in sensitive karst areas. MGS is developing this data base and intends to make it available to the public through a web site. The following items need to be integrated with this effort to address the data needs of state feedlot regulations:

- prepare formal definitions of karst features that will be used by state and local agencies including sinkhole, karsted bedrock, blind valley, resurgent spring, cave, and karst feature;
- coordinating the collection, evaluation, and dissemination of information describing a karst feature;
- implement a formal procedure for 1) determining and documenting the existence of a karst feature and 2) updating the karst features data base;
- educate permitting staff to use karst features data to support decision making; and
- maintain the karst features data base on a web site.

**Other Considerations -**

The agency responsible for protecting caves needs to be identified. MGS responsibilities do not address issues relating to 1) protection of a cave as a natural resource or 2) protection of plant and animal communities that populate the cave. The mission of the Minnesota Department of Natural Resources might be a better match to address these issues. However, there are inter-agency issues relating to designating a cave as being “protected” that should be considered in any future actions:

- identify a lead agency responsible for 1) designating a “protected” cave and 2) integrating cave protection with the land and water resource protection efforts of other state and local agencies;
- designate formal criteria that will be used to designate a “protected” cave;
- determine the protocol for mapping a cave so that the cave can be referenced when making regulatory decisions; and
- make the area overlying a “registered and protected” cave publicly available (possibly using the MGS karst features data base).

# Attachment A
# Information about Workgroup Members

## Art Kalmes, P.E.

Polaris Group
8200 Humboldt Avenue South Suite 302
Bloomington, MN 55431
952-881-0878
akalmes@polarisgroupinc.com

**Education:**
B.S. Agricultural Engineering, Iowa State University
M.S. Civil Engineering, University of Missouri - Columbia

**Experience:**
- Designed animal waste storage lagoons in southeastern Minnesota
- Evaluated and designed alternatives for sinkhole treatments
- Involved in design and construction of landfill liner leachate collection and cover system.
- Grew up on a farm in southeast Minnesota

**Areas of Expertise:**
- Water resources (storm water management, flood control, hydrology, hydraulics)
- General civil (system design, plans, specifications, grading, utilities, drainage)

## Rob Romocki, P.E.

Natural Resources Conservation Service
330 Elton Hills Dr.
Rochester, MN 55901
507-289-7454
robert.romocki@mn.usda.gov

**Education:**
B.S. Engineering, Cornell University – 1977
Master of Engineering, Cornell University - 1978

**Experience:**
- Twenty-two years working as an engineer with the NRCS at several locations in the state.
  - ❖ Thief River Falls, 1978-82 – Civil Engineer working in Area 1, northwest Minnesota. Worked with LO on waste system, WWAVS, grade stab. str.
  - ❖ Mora, 1982-84 – Project Engineer for Knife Lake Dam
  - ❖ Lewiston, 1984-87 – Civil Engineer for Garvin Brook Watershed
  - ❖ Rochester, 1987-92 – Project Engineer for South Zumbro Watershed
- Licensed P.E. in Minnesota.

**Areas of Expertise:**

- Soil and water conservation practices (design and construction)
- Flood control structures (design and construction)
- Animal waste storage systems (design and construction)

## Dr. Chuck Clanton, P.E., P.S.S.

Univ. of Minn. - Department of Biosystems and Agricultural Engineering
1390 Eckles Avenue
St. Paul MN 55108-6005
612-625-9218
clant001@umn.edu

**Education:**
B.S. Agricultural Engineering – Nebraska
B.S. Animal Science – Nebraska
M.S. Agricultural Engineering – Nebraska
Ph.D. Agricultural Engineering – Minnesota

**Experience:**

- Twenty-one years teaching/research in manure management

**Areas of Expertise:**

- Manure characterization and nutrient management
- Odor and gases emission and control
- Soil and concrete sealing by manure

## Dr. Randal J. Barnes, P.E.

University of Minnesota
122 Civil Engineering
500 Pillsbury Drive SE
Minneapolis, MN  55455
barne003@tc.umn.edu

**Education:**
B.S. Civil Engineering, University of Washington
M.S. Mining Engineering, Colorado School of Mines
Ph.D. Mining Engineering, Colorado School of Mines

**Experience:**

- Two years – U.S. Navy ROICC
- Two years – Instructor at Colorado School of Mines
- Thirteen years – Professor (Assistant and Associate) at the University of Minnesota, Department of Civil Engineering

**Areas of Expertise:**

- Geotechnical engineering
- Ground water modeling
- Geologic site characterization

## Stephan Gale, P.E.

Gale-Tech Engineering
15500 Wayzata Blvd., Suite 832
Minneapolis, MN 55391
612-473-7193
galetec@aol.com

**Education:**
B.S.C.E. Geotechnical/Structural Engineering, Ohio State University
M.S. Geotechnical Engineering, Ohio State University

**Experience:**

- Twenty-five years consulting experience

**Areas of Expertise:**

- Liner design – clay and geosynthetic for individual and public facilities
- Reinforcement design – void spanning
- Soil borings/geophysical site evaluations

## Scott Swanberg

Natural Resources Conservation Service
600 Farm Credit Bldg
375 Jackson St.
St. Paul, MN 55101
651-602-7877
sls@mn.nrcs.usda.gov

**Education:**
B.S. Civil Engineering, University of Minnesota

**Experience:**

- Eighteen years with NRCS – Project Engineer, Planning Engineer, Design Engineer

**Areas of Expertise:**

- System planning
- Structural design
- Soil mechanics

## Pete Fryer, P.E.

Agricultural Services Center
P.O. Box 39
Lewiston MN 55952
507-523-2171
prf@mnlewiston.fsc.usda.gov

**Education:**
B.S. Agricultural Engineering – University of Minnesota – specializing in soil and water

**Experience:**
- Working with SWCDs by determining farmer needs, designing and constructing BMP's best suited to sites
- Engineering consultant business in metro area for watershed districts. Surface water hydrology/hydraulics and water quality protection projects and review.
- Surface water runoff from project work and erosion control/water quality protection
- Engineer working in karst area designing manure storage systems and erosion control projects.

**Areas of Expertise:**
- Engineering of structures involving conservation and protection of soil and water resources.
- Design and construction of various types of manure facilities on existing farmsteads.

## Robert Mensch, P.E.

Mensch Engineering
927 East 10th St.
Fairmont, MN 56031
507-235-9151
FAX: 507-235-2605

**Education:**
B.S. Agricultural Engineering – 1959
M.S. Agricultural Engineering – 1962

**Experience:**
- Six years teaching and researching farm buildings – Kansas State University
- Started consulting office in 1968 working with livestock producers
- Six years with UNDP-FAO pig farm development in Singapore
- Dairy farm project in Indonesia
- Extensive work with Minnesota livestock producers manure storage and feedlot permits

**Areas of Expertise:**
- Feedlot planning
- Structural engineering

## Larry Rohl, P.E.

WHKS & Co.
1412 - 6th St. SW
PO Box 1467
Mason City, Iowa 50401
515-423-8271
masoncity@whks.com

**Education:**
M.S. Agricultural Engineering, North Dakota State University
B.S. Agricultural Engineering, North Dakota State University

**Experience:**
- Design – Livestock waste handling systems
  concrete, earthen, geomembrane, Karst areas
- Ag. Research, NDSU and USMARC, Clay Center, NE
- Consulting Engineer P.E. in MN and IA

## Dr. Kevin Janni, P.E.

University of Minnesota - Department of Biosystems and Agricultural Engineering
1390 Eckles Avenue
St. Paul MN 55108
612-625-9218
kjanni@umn.edu

**Education:**
B.S. Agricultural Engineering, University of Minnesota, 1976
M.S. Agricultural Engineering, Purdue University, 1977
Ph.D. Agricultural Engineering, Purdue University, 1979

**Experience:**
- University of Minnesota Biosystems and Agricultural Engineering faculty – 1980 to present.

**Areas of Expertise:**
- Livestock housing systems
- Ventilation
- Air quality
- Biofiltration

**Colby Verdegan, P.E.**

Chosen Valley Testing
2130 S. Broadway, Suite 470
Rochester, MN 55904
507-281-0968
verdegan@aol.com

**Attachment B**

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# CONSTRUCTING NEW MANURE STORAGE SYSTEMS IN THE KARST REGION

Interim Guidance Document
last revised 3-20-00

Minnesota Pollution Control Agency

## PURPOSE OF THESE GUIDELINES

These guidelines are established by the Minnesota Pollution Control Agency (MPCA) to define the measures and considerations generally needed to ensure that, to the maximum extent practicable, ground water is protected when new liquid manure storage systems are constructed in the karst region. Minnesota rules 7060.0500 state that it is the "policy of the Minnesota Pollution Control Agency to control wastes as may be necessary to ensure that to the maximum practicable extent the underground waters of the state are maintained at their natural quality." Maintaining high quality ground water supplies is challenging in the karst region of southeastern Minnesota due to the rapid transport of contaminants from the land surface to ground water in this unique geologic setting. These guidelines are also intended to provide greater consistency during MPCA staff and County Feedlot Officers permitting decisions in the karst region.

This document incorporates minimum standards proposed in the revised feedlot rules (chapter 7020) and additional site-specific evaluations and measures needed to safeguard ground water in the karst region. The proposed feedlot rules for chapter 7020 will establish the minimum standards for depth to bedrock and define areas adjacent to sinkholes that are not suitable for construction of liquid manure storage systems. However, the proposed feedlot rules are not intended to define all considerations and measures needed to protect ground water from construction of new liquid manure storage systems in this region. A site-specific review process in this document defines what information must be considered in the case-by-case analyses to evaluate the water quality protection measures needed for specific site locations in the karst region.

It is important for livestock producers and their technical advisors to understand karst risk considerations early in the planning and site selection process. Some questions addressed in these guidelines include: 1) why are additional precautionary measures needed in the karst region? 2) what are the minimum depth to bedrock and sinkhole setback restrictions? 3) what site conditions pose the highest risk of failure? 4) what type of manure storage system designs are needed to protect ground water quality? and 5) what investigations and evaluations must be conducted prior to obtaining a feedlot permit application for construction of a liquid manure storage system in the karst region?

This document will be used as "interim" guidance until the proposed feedlot rules are finalized, pending legislation is resolved, and any resulting modifications are incorporated. The State Senate is currently proposing legislation directing the MPCA to convene a workgroup consisting of representatives from the Natural Resources Conservation Service and private sector engineers to review and propose design standards for liquid manure storage facilities in areas susceptible to soil collapse and sinkhole formation.

## BACKGROUND

## KARST REGION OF MINNESOTA

Much of Southeastern Minnesota is considered a "karst" landscape (Figure 1). Karst is a geologic term for a landscape area created over soluble rock with efficient drainage. The underlying carbonate bedrock in a karst region dissolves over time to produce solution enlarged joints and cracks. These features can result in rapid transmission of contaminants from the land surface to the ground water below. Karst areas are characterized by sinkholes, caves, springs, losing streams, and blind valleys. Sinkholes are surface depressions on the earth formed by a collapse of soil or bedrock; losing streams lose some of their flow into the ground; and blind valleys are valleys that have no surface outlet and the runoff waters enter the ground. The extent of karst feature development varies tremendously across southeastern Minnesota, and often changes abruptly within a few hundred feet.

Figure 1. Minnesota Karst Lands. These guidelines pertain to much of the land in the dark shaded areas (from Alexander, E.C. Jr., University of Minnesota).

## BENEFITS OF LIVESTOCK AND MANURE STORAGE STRUCTURES

Livestock agriculture can benefit water quality in the karst region, helping to offset some of the risks to water quality. For example, manure applied to land in row crop production can reduce soil erosion. Hay land and pastures associated with cattle operations result in very little soil erosion and pesticide transport on the steeply sloping soils common in the karst region.

The trends to construct new and expanded feedlot facilities with liquid manure storage systems can potentially further enhance protection of surface water quality. Manure storage structures increase management flexibility, making it easier to apply at proper rates and to avoid winter-time manure application. Many of the older feedlot facilities are located adjacent to streams and do not have containment of manure or manure-contaminated runoff. Most facilities with new liquid manure storage structures have total containment of manure so that there is no manure in rainfall and snowmelt runoff waters leaving the feedlot area. Also, the liquid manure in containment structures is usually injected below the soil surface and is less subject to surface runoff compared to the soil surface spreading practices of many feedlot facilities without liquid manure storage.

## RISKS OF MANURE STORAGE SYSTEMS IN KARST REGIONS

While liquid manure storage systems can benefit water quality, they can also pose several heightened risks. Three potential water quality risks associated with liquid manure storage systems in the karst region are described below. Two of the risk factors could lead to long-term (chronic) problems, whereas the third risk factor is associated with catastrophic failure. The water quality risks include:

1) seepage of contaminants through the liner and underlying soil to fractured bedrock and subsequently to ground water;
2) gradual soil subsidence or formation of a shallow sinkhole below the storage structure that breaches the integrity of the liner, causing slow and perhaps undetectable leaking of manure from the storage system to ground water; and
3) a larger sinkhole forming below a manure storage system leading to a rapid flow of manure into ground water or causing a collapse in a basin sidewall and a release of manure onto the ground surface.

Conditions stated in 2 and 3 above are referred to in this document as “soil collapses.” In general, the potential for soil collapse increases as the seepage rate through the storage system liner increases. With high seepage rates, the seepage liquids can wash or erode underlying soils into fractures in the bedrock. As more soil moves down the fractures, the soil may either gradually subside or suddenly collapse. In some cases, the underlying bedrock can dissolve to the degree that it suddenly collapses, causing the soil above to also collapse. Soil collapses can also form in some areas with very low seepage rates due to natural processes occurring over the past centuries or from changes in water infiltration rates near the manure storage system.

Manure entering ground water will discharge into streams within a period of time ranging from hours to decades depending on the site-specific hydrogeology. The karst region of Minnesota maintains a large number of high quality trout streams. A rapid discharge of a large quantity of manure into a stream will destroy the aquatic life for a stretch of the stream and also result in increased nutrient loading into the receiving waters of the Mississippi River system. Manure that travels in the ground water for a longer period before discharging into streams will be more diluted

and may not destroy aquatic life, but will threaten drinking water supplies as it travels toward the stream, and then still contribute to stream pollution upon discharge.

Using liners with very low seepage rates can reduce the probability of a soil collapse below a manure storage system. Risks of failure can also be reduced by such measures as proper siting of the storage facility on the landscape; minimizing the manure storage capacity; preventing excess infiltration of runoff waters around the storage facility; and maintaining a certain separation distance between the manure and fractured bedrock.

Basin overflows and intentional discharges from manure storage structures have been problems at some facilities in Minnesota. Enforcement of intentional manure overflows and direct discharges to waters has increased during recent years in an effort to curb blatant violations. Another potential water quality risk from liquid manure storage systems is failure of manure storage system sidewalls to hold liquid manure. Sidewall failures are not known to have occurred in Minnesota, possibly due to engineering review and regulation of construction activities.

## SOIL SUBSIDENCE AND SINKHOLE DEVELOPMENT

### *Learning experiences from sinkholes forming under municipal wastewater treatment ponds*

Between 1974 and 1992, sinkholes opened below three of the twenty-two municipal wastewater treatment ponds in Minnesota's karst region. Sinkholes developed in Altura's ponds in 1974 during construction and in 1976 when it first filled to capacity (Alexander and Book, 1984). A sinkhole developed in a Lewiston pond in 1991 after eighteen years of use (Jannik et al., 1992). Several sinkholes developed in a Bellchester pond in 1992 after twenty-two years of use (Alexander et al., 1993). The amount of partially treated wastewater draining into sinkholes at the three respective sites was 3.7, 2.3, and 7.7 million gallons. The ponds were constructed of earthen materials with a designed seepage rate not to exceed 3500 gallons per acre per day. Several sinkholes are located within about a mile from all three sites, yet no sinkholes have been identified within a quarter of a mile from the sites.

These failures clearly demonstrate the potential for sinkholes to develop in southeastern Minnesota when large quantities of liquids are stored in sinkhole prone areas with minimal barriers between the liquid and underlying materials. Similar problems can develop when storing liquid manure above permeable liner materials. It should be noted that the current maximum allowable design seepage rate for manure storage systems is more protective than the standards used for the failed municipal wastewater pond construction. It is also important to consider that the contaminant concentrations in manure are often over 100 times greater than municipal wastewater pond liquids, and thus the environmental consequences of a catastrophic manure release could be much worse than municipal pond failures.

In Minnesota, there have been no documented failures of manure storage systems due to sinkhole formation, but there have been several farm-field runoff retention ponds that have failed into sinkholes. Manure seepage into fractured bedrock occurred at one southeastern Minnesota farm at such a rapid rate that the storage system did not ever need to be pumped and the farmer's well was

severely contaminated. In other states with karst geology, sinkholes have been documented to form below soil-lined manure storage systems.

*Sinkhole Probability Mapping and Research*

Sinkhole mapping and research completed during the past two decades has made it easier to determine the relative soil subsidence risks when siting new liquid manure storage systems in Southeastern Minnesota. Sinkhole probability maps have been completed for Winona County, Fillmore County, and Olmsted County (Dalgleish and Alexander, 1984; Alexander and Maki, 1988; Witthuhn and Alexander, 1995). A Karst Hydrology map has also been published for Leroy Township of Mower County (Green, Mossler, Alexander and Alexander, 1997). A Goodhue County sinkhole probability will be published soon. Additional hydrogeologic investigation has been conducted over much of the karst region and more karst hydrogeology maps are expected in the future for other counties.

The probability of sinkhole formation has been found to vary tremendously across the karst region. Some areas have in excess of 50 sinkholes per square mile and other areas have no sinkholes. Often high-density clusters of sinkholes are adjacent to areas with widely scattered individual sinkholes. Bedrock composition, position in the landscape, and thickness of glacial materials over bedrock have all been found to affect the likelihood of sinkhole formation.

Most sinkholes in southeastern Minnesota appear where there is less than about 50 feet of soil cover over carbonate and sandstone bedrock. The proximity of nearby sinkholes remain the single best predictor of new sinkhole development (Witthuhn and Alexander, 1995). Magdalene and Alexander (1995) concluded that on the scale of several kilometers, new sinkholes in Winona County tend to develop in the areas of existing sinkholes, especially near newly developed sinkholes. The risk of soil collapse has generally been found to increase in areas of ponded or intermittently flowing water, and in areas with indications of more extensive karstification, including areas with disappearing streams, caves, springs and solution cavities.

## REQUIRED MEASURES PRIOR TO CONSTRUCTING A STORAGE SYSTEM

To meet the agency’s water quality protection goals, the MPCA requires livestock producers to take several precautionary measures prior to obtaining a permit to construct a liquid manure storage system in the karst region. The measures are intended to prevent siting of a new system in areas that pose a high probability of failure, and to ensure that the system design and construction are best suited for the conditions at the proposed site. The investigations, evaluations and planning needed to manage risks related to manure seepage and soil collapse include the following:

- Investigate area for sinkholes and other karst features;
- Select potential construction sites in lower risk locations;
- Investigate site for soil characteristics;
- Evaluate soil collapse risk;
- Design storage system for the site-specific conditions; and
- Develop an inspection plan for construction activities.

A description of each of these measures is described below.

## INVESTIGATING AREA FOR SINKHOLES AND OTHER KARST FEATURES

Site investigations for karst features are required when considering construction of liquid or semi-solid manure storage systems in areas with a sinkhole probability of "low to moderate" or greater in geologic atlases published by the Minnesota Geological Survey, University of Minnesota and/or Minnesota Department of Natural Resources. Where no sinkhole probability maps are available, site investigations for karst features are required on all land expected to have less than about 75 feet of soil above fractured bedrock.

Investigations of nearby sinkholes and other karst features are needed for three primary reasons: a) to determine whether an Environmental Assessment Worksheet (EAW) is needed for the site; b) to ensure that minimum setbacks from sinkholes will be met; and c) to enable selection of the best possible site location and evaluation of the soil collapse risk at potential site locations.

*EAWs* – The Minnesota Environmental Quality Board rules 4410.4300 specify that an EAW must be completed for construction of an animal feedlot facility of more than 500 animal units, or expansion of an existing animal feedlot facility by more than 500 animal units, if the facility is located within 1000 feet of a known sinkhole, cave resurgent spring, disappearing spring, karst window, blind valley or dry valley.

*Sinkhole Setbacks* – The second reason for the karst feature investigation is to ensure that minimum setbacks from sinkholes are met. These setbacks are designed to prevent construction where there is a very high risk of soil collapse. Two specific provisions in the proposed MPCA feedlot rules chapter 7020 identify minimum setback distances between sinkholes and new manure storage systems. Proposed rules 7020.2005, subpart 1, prohibit a new feedlot or manure storage area within 300 feet of a sinkhole. Proposed Minn. R. 7020.2100, subpart 2, prohibits construction of liquid manure storage systems with a capacity exceeding 250,000 gallons where four or more sinkholes are located within 1000 feet of the proposed site, except where geologic conditions are not suitable for sinkhole development, or where the manure storage system is constructed to address an existing pollution hazard at a feedlot with less than 300 animal units.

*Use in selecting site and evaluating risks* - The third reason for obtaining information about the locations of nearby sinkholes and karst features is for use in selecting the lowest risk site location and evaluating the risk of soil collapse. The proximity and characteristics of sinkholes, blind valleys, springs, caves, and other karst features from the proposed storage system can be used to help evaluate the risk of soil collapse.

The following investigations and information are needed prior to selecting a potential construction site. This information must accompany a permit application for constructing a liquid manure storage system in the karst region.

- *Sinkhole Maps* - Include a copy of published sinkhole location and/or probability maps showing the area within two miles of the proposed facility. If a sinkhole map shows the proposed

manure storage site location to be in an area designated as "low" or "no" probability, then the other steps for the site investigation need not be completed. Sinkhole Probability maps are currently available from the Minnesota Geological Survey (612-627-4782) for Olmsted Co., Winona Co., Fillmore Co., and LeRoy Township of Mower Co..

- *Field Inspection* - Include a map of the proposed site showing the location of all small and large depressions in the landscape. At a minimum, all land within a 1000 feet radius of the potential manure storage structure location must be closely inspected. The best period of time to conduct this investigation is when crop-cover, leaf cover, and snow-cover are minimal.

- *Sinkhole/depression Characteristics* - Include a description of the following for all sinkholes, filled sinkholes and potential sinkholes: a) whether the sinkhole is currently open or has been filled; b) decade when formed, if known; c) position on landscape (show on topographic map); d) diameter and depth, and e) explanations about how the hole or depression formed if not believed to be a sinkhole.

- *Other karst features* - Include a description of other known karst features located within 1 mile of the proposed facility, including disappearing streams, caves, dry valleys, blind valleys, springs, solution cavities or dry valleys.

The following additional information is needed for liquid manure storage structures proposed in counties where a sinkhole location/probability map has not been prepared:

- *Soils Maps and Aerial Photos* - topographic maps, soil survey maps and aerial photos of all land within a one-mile radius of the site. All known open and filled sinkholes must be highlighted on these maps. Closed depressions identified on topographic maps are to be identified and inspected.

- *Land owner interviews* - a list of all long-term residents (living in area at least 15 years) and land owners in the area who were interviewed and asked about the location of existing and filled sinkholes located within a 1 mile radius of the proposed facility. All sinkholes or potential sinkholes (open or filled) are to be identified on a map or photo of the site.

- *Well Logs* - Geologic information from well logs within a 2 mile radius of the proposed site location

## SELECTING POTENTIAL CONSTRUCTION SITES IN LOWER RISK LOCATIONS

After obtaining the information about nearby sinkholes and karst features, select potential construction site locations according to the following criteria:

- Locate the storage system as far as practically possible from topographic lows, depressions or ravines on the farm site, especially where such locations have historically received flowing water or water accumulation.

- Locate the storage system as far as practically possible from existing or historically filled sinkholes and other karst features in the area. Proposed MPCA rules 7020.2005, subpart 1, prohibit a new feedlot or manure storage area within 300 feet of a sinkhole.

- Avoid siting in sinkhole plains or other areas with high densities of sinkholes. Proposed rules 7020.2100 subpart 2 prohibit construction where there are four or more sinkholes within 1000 feet of the proposed site and the design capacity exceeds 250,000 gallons. Exceptions can be made where geologic conditions change drastically between the sinkholes and the proposed site such that the proposed site location is not suitable for sinkhole development. Exceptions are also allowed in the proposed rules where the manure storage system is constructed to address an existing pollution hazard at a feedlot with less than 300 animal units.

- To the extent possible, select potential construction site locations, which are situated in different parts of the landscape than where nearby sinkholes and other karst features are found.

- Select potential site locations expected to have the greatest thickness of fine-textured soils. The minimum allowable separation distances between manure and fractured bedrock are described in the following section.

## INVESTIGATING SITE FOR SOIL CHARACTERISTICS

A soils investigation is needed at potential construction sites to: a) select areas which have soil conditions most protective of ground water, b) ensure that minimum separation distances from manure to fractured bedrock can be met, c) ensure that the appropriate soil materials are available for construction, and d) aid in evaluation of soil collapse risks and selecting appropriate designs.

A certain minimum soil thickness between liquid manure and bedrock is needed to allow treatment of manure seepage prior to the seepage reaching bedrock. The separation distance is also needed to minimize the risk of conduits forming in the soil between the liquid manure and fractures in the bedrock. In some cases, the soil separation may provide increased protection from soil collapse below the storage system.

The minimum vertical separation distance between liquid manure and fractured bedrock is identified in Table 1 for different types of liners and livestock numbers contributing to liquid manure storage on the farm. The separation distances in Table 1 are consistent with the proposed feedlot rule revision (Chapter 7020.2100, Subpart 2). Exceptions can be made for constructing manure storage systems to correct existing pollution hazards at feedlots with less than 300 animal units.

To determine whether the minimum separation distance will be met, the owner must conduct soil thickness investigations at a minimum of four locations for the first one-half acre of manure storage area surface area and a minimum of two additional locations for each additional acre. Soil thickness investigations can be conducted using soil borings, trenches, or geophysical surveys supported by information from borings. If the soil thickness investigations indicate an uneven bedrock surface or

highly variable soil conditions, additional investigation can be required. The bedrock elevation is considered to be the highest elevation of encountered bedrock.

Table 1. Minimum separation distance requirements between liquid manure and fractured bedrock for different size feedlots (based on animal units) and type of liner construction.

| **Number of Animal Units contributing to liquid storage on the entire farm** | Minimum separation distance when using earthen liners or unsealed concrete liners | Minimum separation distance when using composite* liners or sealed concrete*** liners | Minimum separation distance when using composite* liners with 3 feet compacted clay, above ground** or sealed concrete*** with a secondary liner under the concrete. |
|---|---|---|---|
| **< 300 AU** | 20 feet | 5 feet | 5 feet |
| **300 to 999 AU** | 30 feet | 10 feet | 5 feet |
| **>1000 AU** | 40 feet | 15 feet | 10 feet |

The following are descriptions of liner types listed in Table 1.

* A composite-lined storage system consists of at least two feet of compacted cohesive soil below a geomembrane ($\geq$40 mil) liner.

** An above ground storage system such as a slurrystore.

*** Concrete-lined systems must include water stops or joint sealant materials at all construction joints, sealing of all cracks which may extend through the concrete, and a floor having a concrete thickness of not less than 5 inches, where the required area of steel reinforcing in the floor is based on subgrade drag theory in American Concrete Institute, Slabs on Grade, ACI-360.

EVALUATING SOIL COLLAPSE RISK

In many areas, the minimum sinkhole setback and soil thickness restrictions can be met, yet the proposed site can still have a high risk of soil collapse. Therefore, a site-specific evaluation is needed at proposed sites for storage systems to exceed a capacity of 250,000 gallons. Locations and characteristics of all nearby sinkholes and karst features are assessed in conjunction with information about soils and manure storage capacity. The evaluation of soil collapse risk is conducted to determine whether a more protective design is needed or whether the site poses such high risk that the location should not be used without a much more extensive geologic investigation.

The soil collapse risk factor is determined from available sinkhole probability map information, along with site specific soils, landscape function, geology, and sinkhole information. The following site-specific information is considered when determining the risk of soil collapse:

- density of sinkhole distribution;
- the topographic and geologic setting which sinkholes are found;
- patterns and characteristics of nearby sinkhole formation;
- type and condition of first encountered bedrock;
- depth to bedrock;
- soil and subsoil types;
- presence of other nearby karst features (e.g. disappearing streams, blind valleys, dry valleys, caves, springs, and karst features observed in exposed bedrock along roadways); and
- proximity of storage system to the nearest sinkhole or karst feature.

Characteristics indicative of various collapse risk categories are listed below, ranging in scale from 0 (lowest risk) to 7 (highest risk sites). While these general descriptions largely refer to proximity to sinkholes and sinkhole densities, the other site specific variables noted above are also evaluated for proposed sites in order to determine the most fitting risk category. The following descriptions are only intended to serve as general guidelines. The numbers 0 to 7 below correspond with the numbers in Figure 2 on page 12.

**0** - Areas where the first encountered bedrock is not subject to sinkhole formation.

**1 -** Areas underlain by carbonate bedrock, but in which very few sinkholes are found. No known sinkholes exist within a one-mile radius of the proposed site, and the soils and geologic information indicate that there is minimal risk of sinkhole formation at the site under consideration.

**2** - No sinkholes or buried sinkholes are known within a 1/2-mile radius of the proposed site. However, widely scattered sinkholes have been identified in the area and the depth to bedrock is less than about 50 feet.

**3 -** No sinkholes or buried sinkholes are known within a 1/4-mile radius of the site. However, there are scattered sinkholes (e.g. 2 - 5 sinkholes in a 1 mile radius of proposed site) and/or other geologic factors that make the area susceptible to sinkhole formation.

**4** - Similar sinkhole densities as #5 risk zones, but the soils and other information about karst features indicate that the specific construction site has a lower sinkhole risk than the #5 risk category.

**5** - There is typically either 1 sinkhole or buried sinkhole within a 1/4 mile radius or 2-4 sinkholes or buried sinkholes within a 1/2 mile radius and the soils and karst feature information indicates minimal protection.

**6** - Sinkholes are common in the area (e.g. 2 to 4 sinkholes in a 1/4-mile radius or 5 or more sinkholes within a 1/2-mile radius).

**7** - Sinkholes are the dominant landform, with typical sinkhole densities exceeding about 4 sinkholes in a 1/4-mile radius from any point.

## DESIGNING STORAGE SYSTEMS FOR SITE SPECIFIC CONDITIONS

The type of storage system liner will be largely determined by the depth to bedrock requirements in Table 1. However, in areas with an elevated risk of soil collapse, the storage system design may need to be enhanced beyond the requirements in Table 1, and in some cases the site poses such high risk that the location should not be used without a much more extensive geologic investigation.

The MPCA recommends the use of design options that correspond with Figure 2. The storage capacity of all storage systems on the farm and the site specific soil collapse risk factor are both considered in the Figure 2 design options. The measures in table 2 are intended to be flexible enough to encourage application of sound judgment, innovation and experience. Other liner types and alternative designs can be considered by the agency during the permit application review process. Flexibility can also be given when a new manure storage structure is designed to correct existing surface or ground water pollution problems without a significant expansion in operation size. For example, at some existing operations, it can be better for the environment to have a new liquid containment structure built in a sinkhole prone area than to have direct feedlot runoff into streams or the continued use of an old structure that was constructed using less stringent standards. Other considerations for determining acceptable options include: maximum manure volume to be stored in any single manure storage structure, site history and management, planned contingency efforts, and specific properties of the soils.

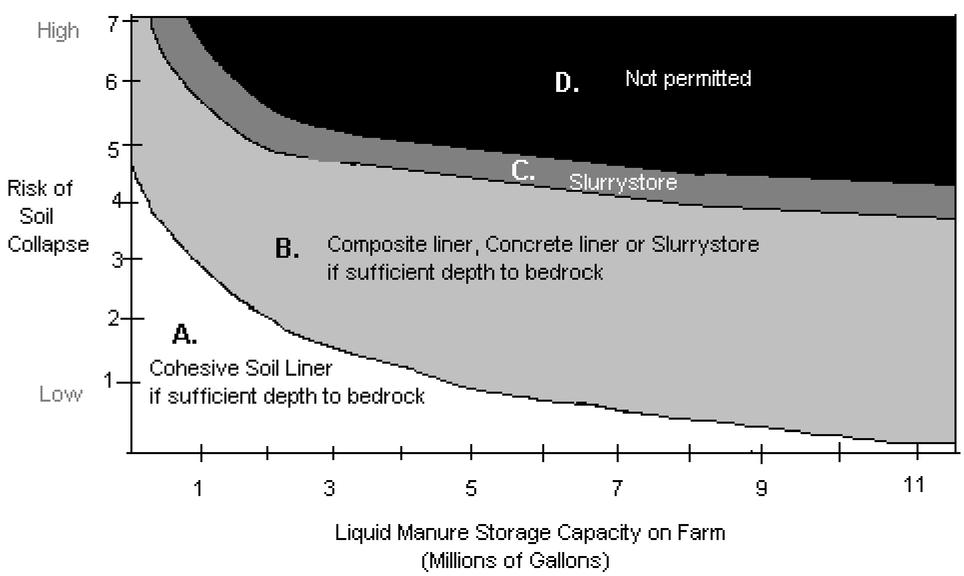
Figure 2. General guidelines for manure storage system options in different soil collapse risk zones. The soil collapse risk factor 0 to 7 in the figure is associated with the soil collapse risk factor described on pages 10 and 11. The Design capacity considers the combined storage capacity of all manure storage structures at the feedlot and manure storage facility.

A. Cohesive soil liner designed/constructed in accordance with MPCA standards can be used if the separation to bedrock restrictions are met.

B. Composite liner system or sealed concrete liner can be used if the minimum separation to bedrock is met. A composite liner system consists of a combination of compacted clay covered by an approvable geomembrane or geosynthetic liner. Sealed concrete-lined systems must include water stops or joint sealant materials at all construction joints, sealing of all cracks which may extend through the concrete, and a floor having a concrete thickness of not less than 5 inches, where the required area of steel reinforcing in the floor is based on subgrade drag theory in American Concrete Institute, Slabs on Grade, ACI-360.

C. Above ground storage (e.g. slurrystore)

D. Solid manure handling recommended. Liquid storage not permitted unless a more extensive geologic investigation indicates that the site is safe for construction of a liquid manure storage system.

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Another design goal to reduce soil collapse risks is to minimize the amount of rainfall and roof runoff water infiltrating soils in the area of the storage system. This can be accomplished by sloping soils away from the manure storage system, and routing all barn-roof runoff and perimeter tile waters to a discharge point as far as possible from the manure storage system. The discharge point should be onto a sloped runoff channel or to some other area where ponding of water will not occur.

DEVELOPING AN INSPECTION PLAN FOR CONSTRUCTION ACTIVITIES.

A subsoil inspection is required when constructing manure storage systems (over 250,000 gallons) in areas suitable for sinkhole formation. This inspection is in addition to other construction inspections required for all regions of the state. A subsoil inspection is needed to provide greater assurance that the construction site is not in an area where soil collapse problems are imminent. The inspection must be conducted following removal of the soil B horizon to determine whether there is any indication of potential sinkhole development observed in the soil (piping, voids, channels, topsoil found at deeper depths or other indications of soil subsidence).

The subsoil inspection plan must include the following minimum elements:

- Who will conduct the inspection – a professional registered soil scientist or professional registered geologist experienced with karst is recommended;

- During what periods of construction the inspection will be conducted – recommended at least following removal of the soil B horizon;

If any indications of potential sinkhole development are observed, the permittee must notify the MPCA and the design engineer so that an evaluation can be made of whether the site must be abandoned or if alternative measures can be implemented to prevent future soil collapse.

## POST CONSTRUCTION MANAGEMENT

Following the construction of the manure storage system, the permittee is responsible for on-going maintenance and operation in accordance with all specifications in the permit application. The storage system must be regularly inspected for liner damage, seepage problems or soil collapse. All damage must be immediately repaired. All seepage or soil collapse problems must be immediately reported to the Minnesota Pollution Control Agency. Report any spills or discharge incidents immediately to the duty officer at 1-800-422-0798.

Where manure is to be pumped from the manure storage system to be applied onto cropland, the requirements in proposed 7020.2225 must be met. These requirements include limits on maximum rate of application, precautionary measures when applying near waters or waterways, development of a comprehensive manure management plan, record keeping and plans for soil and manure testing. Proposed manure application rules specific to the karst region include:

- Manure must not be applied within 50 feet of a sinkhole. Manure must be immediately incorporated to land sloping toward a sinkhole and that is within 300 feet of the sinkhole. Exceptions are made where diversions prevent manure-contaminated runoff from entering the sinkhole.

- All manure management plans for feedlots or manure storage areas with a capacity of 300 or more animal units must include a description of measures to protect ground water when applying manure to soils with less than three feet above limestone bedrock.

## FOR FURTHER INFORMATION

For further information about the use of these guidelines or other questions about feedlot and manure storage system construction in the karst region, please call the feedlot helpline at 1-877-333-3508.

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