United States Department of Agriculture
NATURAL RESOURCES CONSERVATION SERVICE
Environment Technical Note MT-3
February 2006

ENVIRONMENT TECHNICAL NOTE

Assessing the Risk of Ground Water Contamination from Open Lot Management on Animal Feeding Operations (AFOs)

Tom Pick, Water Quality Specialist
and
Mike Garverich, Geotechnical Engineer

INTRODUCTION

Protecting ground water supplies is critically important in Montana. Ground water is a primary source of drinking water as well as providing lesser but crucial quantities for irrigation and industrial uses in Montana. Ground water provides 94 percent of Montana's rural domestic water supply and 39 percent of the public water supply for drinking water.

In a private well water testing program conducted by the Montana State University Extension Service in 1989, 43 percent of 1,400 water samples taken from private wells exceeded the federal limit of coliform bacteria (MSU, 1989). During this same test program, nitrate-nitrogen concentrations greater than the 10 parts per million drinking water standard were detected in about six percent of the private well waters tested. A more recent survey by the Montana Department of Agriculture of wells along the lower Yellowstone River valley detected nitrate in sixty-eight percent of the wells sampled with nitrate concentrations greater than the drinking water standard in nine percent of the wells tested. While no sources were positively identified during either study, concentration of animals in open feeding and holding lots can create waste accumulations that are potential sources of pollutants to ground and surface water supplies that also serve as drinking water sources.

Montana's Water Quality Act limits discharges of pollutants to state waters (including ground water) without a Montana Pollutant Discharge Elimination System (MPDES) or a Ground Water Pollution Control System (MGWPCS) Permit. Specific information about either permit is available online at: http://www.deq.state.mt.us/wqinfo/WaterDischarge/Index.asp .

Montana's Water Quality rules (MCA-75-5-605) prohibit construction of a new waste treatment or storage facility within a 500-foot distance of existing water wells. The Department of Environmental Quality's (DEQ) Circular 9 *Montana Standards for Concentrated Animal Feeding Operations* (CAFOs) currently in draft form (01/19/06), specifies that producers utilizing land application of animal waste shall maintain a 100-foot setback or 35-foot vegetated buffer from any down gradient sinkholes, agricultural well heads or other conduits to surface waters. Additional considerations relative to MPDES design requirements can be found in the NRCS National Engineering Handbook and Agricultural Waste Management Guide located in each field office.

Often, the major or primary emphasis of the NRCS assistance with open lot treatment and animal waste management is to eliminate the potential for surface water contamination via interception or elimination of overland transport. Yet in all cases, a secondary - but no less important objective - should be to eliminate ground water contamination where this pollution potential exits. The risk for ground water contamination first must be evaluated in order to assess the need for specific ground water conservation practices.

While surface water contamination and transport vectors such as topography, proximity to open water, presence of gullies and pipes, and other physical features are usually readily visible, factors related to ground water risk are far less obvious. As opposed to waste application areas where nutrients are theoretically applied at agronomic rates and off-site runoff is controlled, the feedlot surface itself is subjected to nearly continuous application of wastes where cumulative deep leaching is possible over time. This technical note will serve as a format to provide a consistent and thorough approach to the evaluation and assessment of ground water contamination risk on open lot Animal Feeding Operations (AFOs). The approach may also aid in evaluation of risk factors for field application of animal waste.

A. Ground Water Contamination Risk Criteria

Biological, physical, and chemical activity causes the breakdown, or otherwise reduction in mass, of potential contaminants moving through the root zone. Together, these processes are termed *attenuation* and serve to reduce the potential for downward movement (*leaching*) into deeper zones where contaminants may come into direct contact with ground water aquifers.

Open feeding lots and holding pens are generally built with minimal manipulation of native soil or terrain. Investigation of inherent soil and topographic factors related to attenuation variables can lend some insight into the inherent vulnerability of the site to ground water contamination.

The following criteria are important considerations in order to thoroughly evaluate the vulnerability or risk of ground water contamination from the open surfaces associated with AFO open lot management. These criteria should be evaluated for the immediate surface area as well as for all runoff-receiving areas immediately down-gradient of the lot. These criteria apply only to un-surfaced (earthen or pervious surface) portions of the lot or runoff receiving area. They are not designed to evaluate risk associated with earthen storage basins or pits or paved or otherwise hardened, impervious lot surfaces.

Review each criterion in light of the site conditions and check the box that best fits the circumstances. Asterisks (*) denote criterion that are significant in terms of risk assessment. As such, they should not be left blank or ignored if unknown.

1. Soil Depth/Depth to Bedrock*

Greater depth of soil provides greater capacity to immobilize or otherwise neutralize nutrients and other potential pollutants. The presence of bedrock, fractured bedrock, or other highly conductive bedrock (*Karst*-type formations) provides efficient transport pathways for surface pollutants to directly contact ground water aquifers.

- □ Low Risk: Deep to moderatly deep ≥ 60 inches deep/depth to bedrock.
- □ High Risk: Shallow < 60 inches deep/depth to bedrock.

2. Soil Texture*

Soil texture provides a standard terminology related to the relative percentages of sand, silt, and clay. Modifiers are used when the percentage of particles more coarse than sand is greater than 15 percent. Classification is determined according to the Unified Soil Classification System that classifies soil based on the grain-size distribution of particles less than three inches in diameter according to properties that can affect their use as construction material.

Texture controls the capacity of the soil to attract and bind potential pollutants to individual soil particles. Finer texture soils (as influenced by the kind and percentage of clays and silts), have greater capacity to provide exchange sites and thereby bind pollutants which results in a lower transport potential. Coarser-textured soils, (sand, gravel, etc.) function oppositely in that transport potential is higher and thereby the risk for ground water contamination is relatively greater.

- □ LOW RISK: FINE TO MEDIUM TEXTURE - LOAM, SILT LOAM, CLAY LOAM, CLAY, FINE SANDY LOAM, VERY FINE SAND.
- □ HIGH RISK: COARSE TEXTURE - COARSE SAND AND GRAVEL, SAND, SANDY LOAM, LOAMY SAND.

3. Permeability or Hydraulic Conductivity *

The rate at which water moves though soil has a direct influence on the risk of ground water contamination, since dissolved or suspended contaminants are frequently transported with the water. *Permeability* is an estimated value of the relative ease with which soil transmits water. *Hydraulic conductivity* (K_{sat}) is a quantitative value (can be measured under saturated conditions and units) that relates the rate of water movement to the hydraulic gradient and is the most common reference datum used to compare water movement in different soils. Soil texture, density, and structure influence this coefficient. Where available, the measured K_{sat} rate should be used. If not available, estimated permeability rates (inches/hour) for mapped soils are found in the published soil survey under the soil properties section – physical properties tables.

PERMEABILITY RATINGS

- □ LOW RISK: IMPERMEABLE TO MODERATELY SLOW: < 0.6 INCHES/HOUR.
- □ HIGH RISK: MODERATE TO VERY RAPID: ≥ 0.6 INCHES/HOUR).

OR

- □ LOW RISK: VERY LOW TO MODERATELY LOW: $K_{sat} < 0.1417$ INCHES/HOUR (< 0.360 CM/HR).
- □ HIGH RISK: MODERATELY HIGH TO VERY HIGH: $K_{sat} \geq 0.1417$ INCHES/HOUR (≥ 0.360 CM/HR).

4. Hydrologic Group

Hydrologic group is a group of soils having similar runoff potential under similar storm and cover conditions. Associated factors are depth to a seasonally high water table, intake rate, and permeability after prolonged wetting, and depth to a very slowly permeable layer. Site specific factors related to management practices such as compaction, crusting, organic matter, and vegetative cover may affect the *hydrologic group*, but for the purposes of this risk analysis, the *hydrologic group* shown in the official soil survey is to be used.

Soils are placed into four groups: A, B, C, and D. In the definitions of the classes, *infiltration rate* is the rate at which water enters the soil at the surface and is controlled by the surface conditions.

A. The soils have a high infiltration rate even when thoroughly wetted. They primarily consist of deep, well drained to excessively-drained sands or gravels. They have a high rate of water transmission.

B. The soils have a moderate infiltration rate when thoroughly wetted. They primarily are moderately deep to deep, moderately well drained to well-drained soils that have moderately fine to moderately-coarse textures. They have a moderate rate of water transmission.

C. The soils have a slow infiltration rate when thoroughly wetted. They primarily have a layer that impedes downward movement of water or have moderately fine to fine texture. They have a slow rate of water transmission.

D. The soils have a very slow infiltration rate when thoroughly wetted. They primarily consist of clay soils that have high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission.

- □ LOW RISK – HIGH RUNOFF POTENTIAL: HYDROLOGIC GROUPS C AND D.
- □ HIGH RISK – LOW RUNOFF POTENTIAL: HYDROLOGIC GROUPS A AND B.

5. Depth to Water Table *

The presence of shallow ground water beneath or down-gradient of an AFO increases the risk associated with transport of pollutants from the AFO. This risk criterion is also related to other site factors such as soil depth, texture, and permeability so the risk level is based on a combination of factors. On-site investigations or local information should be used to assess ground water depth rather than general ground water depth information such as that found in published soil surveys. In most cases, the presence of hydrophytic vegetation is a good indicator of shallow ground water that should raise a red flag. When available, landowner records, actual measurements, or completion logs for nearby wells should be used to assess the depth to ground water. If no recorded information is available, on-site investigation techniques should be used (see Section C. Site Investigation). Various sources for well log information for wells recorded in Montana are available through the Groundwater Information Center (GWIC) at http://mbmggwic.mtech.edu/.

- ☐ LOW RISK: > 60 FEET TO GROUND WATER; OR
  > 40 FEET AND HIGH RISK FOR CRITERIA #2 AND 3; OR
  > 20 FEET AND LOW RISK FOR CRITERIA #2 AND 3.
- ☐ HIGH RISK: < 20 FEET TO GROUND WATER AND HIGH RISK FOR CRITERIA #2 AND 3; OR
  < 10 FEET TO GROUND WATER.

6. Distance to Well *

Proximity of the AFO to any water well indicates that the potential risk of contamination is inherently greater since a direct pathway to the water table is present regardless of the integrity of the well or depth of the water table.

- ☐ LOW RISK: ≥ 150 FEET TO A WATER WELL OR THE WELL IS HYDRAULICALLY AND TOPOGRAPHICALLY UP-GRADIENT OF THE OPEN LOT.
- ☐ HIGH RISK: < 150 FEET TO A WATER WELL REGARDLESS OF GRADIENT.

7. Earthen Lot Cleaning Frequency

More frequent remove of animal waste from the area and surface of the open lot reduces the likelihood of long-term buildup and continuous leaching of potential pollutants that eventually reach ground water. Discount bedding piles where used, unless their form and location create ponded-water conditions.

- ☐ LOW RISK: CLEANED ONE OR MORE TIMES PER YEAR UNDER CONTINUOUS USE CONDITIONS OR CLEANED AFTER EACH USE PERIOD WHEN NOT USED CONTINUOUSLY.
- ☐ HIGH RISK: CLEANED LESS THAN ONE TIME PER YEAR OR NEVER.

8. Manure Pack Management

Careful maintenance of the compacted surface on open lots helps to maintain the soil and manure pack seal or mulch that provides an impediment to rapid infiltration and also creates a biological mat that helps to effectively utilize nutrients. Management of the manure pack can also service as a sponge to store and later evaporate liquids that otherwise add to runoff or deep percolation.

- ☐ LOW RISK: LEAVES 1 TO 2 INCHES WHEN CLEANING OPEN LOT SURFACE.
- ☐ HIGH RISK: SCRAPED TO MINERAL SOIL EACH CLEANING.

9. Topography

A uniformly-graded lot surface promotes even runoff and surface drainage and also enhances rapid drying. Drainage of upland areas and runoff from roofs onto the lot should be also be avoided or minimized to reduce the quantity of water available to dissolve or transport potential pollutants. Bedding areas should be constructed to avoid interrupting drainage and/or ponding water.

- ☐ LOW RISK: THE LOT HAS A UNIFORM SLOPE OF 2 TO 6 PERCENT TO DRAIN PRECIPITATION AND DRY THE LOT SURFACE EVENLY. LIMITED RUN ON FROM UPLAND AREAS AND ROOFS OCCURS.
- ☐ HIGH RISK: 0 TO 1 PERCENT SLOPE OR UNEVEN TOPOGRAPHY THAT RESULTS IN POOLING OR CONCENTRATED FLOW OF RUNOFF WATER ON OR OFF THE SITE.

SUMMARY

Sites receiving 'high risk' ratings for two or more individual criterion should receive more intensive investigation. This may involve additional geologic or engineering investigations and/or the use of monitoring wells installed to sample upgradient and downgradient water quality parameters (see Section C. Site Investigation for a more detailed discussion). Sites that receive four or more high risk ratings may not be suitable for AFOs. Existing feeding operations with several high-risk factors should be investigated further (Section C) to include the use of monitoring wells (Section D) to document current and future water quality conditions.

B. Ground Water Quality Standards

With the designation of a mixing zone by the DEQ, the Montana Water Quality Act allows for the discharge of pollutants to ground water when the seepage or leachate volume, combined with the volume of ground water beneath the source, results in ground water pollutant concentrations in compliance with than the ground water quality standards. When no mixing zone has been granted by DEQ, the discharge to ground water from the source cannot exceed ground water standards prior to dilution in the ground water. Nitrate plus nitrite as nitrogen (NO^3 + NO^2 as N) and fecal coliform are the principal parameters of

concern for ground water quality as affected by animal lots. The applicable $NO^3 + NO^2$ as N standard is based on the classification of the underlying ground water and the history of the operation.

Ground water is placed in four classification categories based on its specific conductance (SC) value. SC is an index of the amount of dissolved solids in the water. The classification categories, associated SC values and applicable $NO^3 + NO^2$ as N standards are given in Table 1 (from ARM 17.30.1006).

Table 1. Ground water classification categories associated SC values and applicable $NO^3 + NO^2$ as N standards.

CATEGORY	SC (micro-SIEMENS/cm	$NO^3 + NO^2$ AS N (mg/L)	FECAL COLIFORM BACTERIA
Class I	1,000	10	< 1 organism/100 milliliters (ml)
Class II	>1,000 to 2,500	10	
Class III*	> 2,500 to 15,000	10 if SC < 7,000; 50 if SC ≥ 7,000	
Class IV*	>15,000	50	

* There is no numerical $NO^3 + NO^2$ standard if the field hydraulic conductivity of the affected ground water is less than 0.1 feet per day.

Operations that are new or increased point sources (discharging on or after April 29, 1993) must meet the non-degredation limit for $NO^3 + NO^2$ as N. This non-degredation limit is 7.5 mg/L as opposed to the 10 mg/L water quality standard concentration for Class I and II ground waters. The non-degredation limits do not apply to Class III or IV ground waters. The applicable non-degredation limit for fecal coliform bacteria in ground water is a concentration of less than one organism per 100 milliliters at the site. The Montana Water Quality Act [75-5-317(2)(6)] exempts non-point sources of pollution from non-degredation when, "all reasonable land, soil, and water conservation practices are applied and anticipated beneficial uses are fully protected."

C. Site Investigation

Ground water sampling and monitoring is used to determine the applicable ground water classification and water quality standard as well as to ensure compliance with the standard. Ground water monitoring is also useful to indicate trends that should alert an operator to a developing problem rather than waiting for the problem to occur. A ground water monitoring plan should be developed to address three variables: 1) the sampling point(s) location and depth; 2) the frequency of sampling events at each point; and 3) the specific physical or chemical measurement parameters to be sampled. A sampling and analysis plan describes how the samples are collected, transported or stored, and analyzed.

When available, existing wells in the proximity of the facility can be sampled and analyzed to give some idea of the ground water classification and background or historic concentrations. Water quality data on wells in the searchable database at GWIC (accessed at: http://mbmggwic.mtech.edu/) is sometimes available in addition to a well's depth to water and water yield.

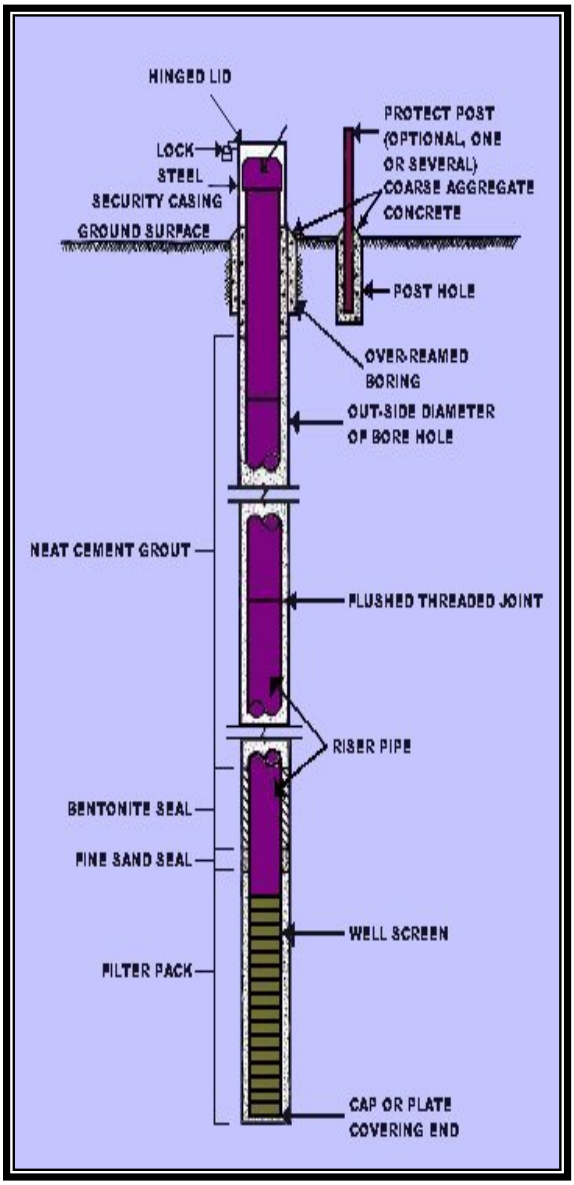
Useful tools for making preliminary assessment of the ground water near proposed animal waste sites include soil hand augers or the NRCS soil boring trucks. In addition, much useful data is available at the MBMG well data base. One should also look for nearby riparian areas, spring discharges, and other information, especially from the cooperator. The data collected during the preliminary studies can be used to construct an elevation map of the local ground water surface and help to determine if the proposed site is suitable for a waste storage or handling facility and where monitoring wells should be located if the facility is constructed. Always take care to backfill and seal any probe holes to prevent contamination as described below.

D. Monitoring Wells

Monitoring wells are used to determine the characteristics of the connection between surface waters and ground waters and the changes in water chemistry resulting from water-soil contact and the mixing of surface and ground waters. When more intensive site investigation or long-term trend information is indicated as a result of the risk evaluation and site assessment, such as the need for monitoring wells, they should be installed according to standardized methods by a Montana licensed monitoring well constructor/driller.

Ground water flow is generally in a direction perpendicular to the elevation contours on the watertable surface. For this reason, the direction of ground water flow may be unrelated to surface topography. A minimum of three monitoring wells is required to determine the direction of flow for local ground water. An additional monitoring well may be required for water quality sampling if none of the original three are suitably placed to be down gradient from the potential source of contamination. The State Geologist or Geotechnical Engineer or a qualified Groundwater Consultant should be contacted for designing a Ground Water Monitoring Plan (GWMP) for animal waste facilities.

Figure 1. A Typical Completed Monitoring Well Grade. *Source: Devinny et al, 1990.*



Components of a detailed geologic/ground water investigation for planning and design are described in more detail in the National Engineering Handbook, Part 651, Agricultural Waste Management Field Handbook, Chapter 7, June 1999. At a minimum, the GWMP should consist of a site map, proposed well locations and construction details, and the Sampling and Analysis Plan (NDEQ, 2003).

Monitoring wells provide access to the local ground water for determining its physical and chemical characteristics. As such, improperly completed monitoring wells can provide a direct pathway for contamination to travel from the surface to the water table. For this reason, monitoring well installation is controlled by the Board of Water Well Contractors and only properly licensed Monitoring Well Constructors are qualified to install monitoring wells. For the same reason, un-used or abandoned water wells should be shut in and capped (formally abandoned) using standard methods by a licensed Water Well contractor.

E. Sampling and Analysis

Where the potential for ground water contamination from the open lot operation is high, a monitoring and sampling plan should be developed and implemented. Parameters that are usually recommended for analysis are total nitrogen, ammonia nitrogen, total phosphorus, and fecal coliform bacteria. In many cases, it is wise to sample nutrient levels in the soil at 0-6 inch, 1-2 foot, and 2-4 feet intervals beneath the open lot to help determine how much, if any, nutrient movement has already occurred. Unless required otherwise by a regulating entity, ground water sample frequency should be a minimum of twice a year (at the upper extent of the water level elevation and at the lower extent) typically in spring and late fall or early winter to capture the annual extremes. Specific conductance, temperature, and pH should be measured in the field at the time of sample collection in order to assess well stabilization (see below). Sampling volumes required are dependent on the parameter and method of analysis, but should be clearly described in the sampling and analysis plan. Sample analysis must be performed by a certified laboratory using approved Quality Control/Quality Assurance (QA/QC) procedures. A list of approved analytic laboratories can be found in Technical Note, MT-ENV-1.

Contamination can occur prior to and during sampling. Adherence to proper sampling techniques and handling practices can minimize contamination errors (Gonzáles and Sankaran, 1997).

A few simple preventative practices are:

- Store, transport, and handle equipment and sample bottles to minimize contact with potential contamination sources (air and water borne). Keep sterile bottles sealed until use and then triple rinse with sample source prior to taking sample. Some lab prepared bottles may not require this step, particularly if they contain pre-added preservative material. Check with the lab as to pre-rinse requirements.
- Always handle equipment and sample bottles with new, inert, lab-grade gloves at each site.
- Place equipment and bottles on clean ground-cover or in container instead of native ground surface.
- Consistently follow the Standard Operating Procedures (SOPs) that are in the Sampling and Analysis Plan. The plan should also contain information on who does the sampling and when, water level measurement, the type of sampler device, purging or flushing the well to assure accurate representation, sample preservation, transportation and storage of samples enroute to the lab, chain of custody documentation, lab analysis methods, use of blank/duplicate (QA/QC) samples, and analysis data management.

Due to the many objective-based options that are available when developing a Sampling and Analysis Plan, the NRCS Water Quality Specialist should be contacted for assistance with completing this aspect of the project.

Unless required by the terms of a MPDES or other permit by a regulating agency, information collected during site investigation and/or monitoring on a cooperating producer's operation is covered by the Federal Freedom of Information Act (FOIA) that is described in detail in the Natural Resources Conservation Service, General Manual, Section 120, Part 408.

E. Treatment and Mitigation

An evaluation and assessment of the risk of ground water contamination is of little use to a landowner unless potential treatment and mitigation practice alternatives are developed when appropriate. In some extreme situations, or due to other unrelated factors, the only feasible alternative may be to recommend moving the facility to a lower risk site. In many cases, options that address the limiting factor(s) may provide enough risk reduction to allow continued use in conjunction with a monitoring program used to provide an adaptive management approach.

Sites with low risk scores for most criteria will still benefit in many ways from the development and implementation of good animal waste management practices.

REFERENCES

Devinny, J. S., et al. *Subsurface Migration of Hazardous Wastes*. Van Nostrand Reinhold. New York, 1990.

Gonzáles, W.G. and K. Sankaran. *Environmental Sampling and Monitoring Primer, Ground Water Monitoring Wells.* Virginia Tech, 1997. Accessed online at: http://www.ce.vt.edu/program_areas/environmental/teach/smprimer/gw/gw.html., September 22, 2004.

MSU (Montana State University). *Reports of Nitrates in Montana Drinking Water Wells Increase.* News Release from Montana State University Communication Services, Bozeman, Montana, 1998.

NDEQ (Nebraska Department of Environmental Quality). Guideline for Ground Water Monitoring Plans at Livestock Waste Control Facilities. Guidance Documents, December 2003. Accessed online at: http://www.deq.state.ne.us/, September 22, 2004.

NRCS General Manual.

U.S. Army Corps of Engineers. *Unified Soil Classification System*. U.S. Army Technical Memorandum No. 3-357 Vols. 1 and 3, March 1953.

USDA, Soil Survey Division Staff. *Soil Survey Manual*. Agricultural Handbook 18. Issued October 1962. Revised and expanded October 1993. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.