Cornell University

Animal Science Publication Series
No. 245

Revised winter and wet weather manure spreading guidelines to reduce water contamination risk

December 2015

Karl Czymmek[1], Larry Geohring[2],
Quirine Ketterings[1], Peter Wright[3],
Todd Walter[2], Greg Albrecht[4],
Jacqueline Lendrum[5] and Angus Eaton[5]

[1]Department of Animal Science; [2]Department of Biological and Environmental Engineering, Cornell University; [3]Department of Animal Science and formerly New York Natural Resources Conservation Service (NY-NRCS); [4]New York State Department of Agriculture and Markets (NYS-DAM), and [5]New York State Department of Environmental Conservation (NYS-DEC)

Executive Summary

For many farms, manure is a primary source of nutrients for crop production. Recycling local manure nutrients to grow crops helps reduce fertilizer imports into watersheds and builds organic matter for healthy soils. However, runoff from manure spreading can cause water quality problems. Runoff and related water quality violations have resulted in fines by the New York State Department of Environmental Conservation (NYS-DEC) for several New York Concentrated Animal Feeding Operations (CAFO) as well as for smaller, unregulated farms. Regardless of the farm size or type, following a Comprehensive Nutrient Management Plan (CNMP) is the first step to reduce the risk of manure runoff. However, the NYS-DEC will take action when staff observe water quality violations caused by farm practices that can be traced to the source, even if the practice was in compliance with the farms' Comprehensive Nutrient Management Plan (CNMP). The NYS-DEC considers the implementation of these guidelines necessary to comply with the water quality requirements of the CAFO general permits.

Producers and planners should use the following to reduce risk of impacting water quality:

- It is most important that managers ensure the farm has adequate storage for all types of manure to minimize the risk that manure needs to be applied when runoff risk is high.
- There should be a winter spreading plan (a requirement for permitted CAFOs) that includes, at a minimum, fields that have been identified and reserved (in advance) for spreading as a last resort (e.g. in cases where storage is full, etc.). Operations that use last resort fields in emergency conditions every year need more storage. For solid manure, if the manure can be piled, identify temporary pile areas as an alternative to land application in high risk conditions.
- Till-incorporate or inject manure into the soil when soil conditions allow.
- Before spreading, especially during wet or snowy periods, evaluate runoff potential, taking into account soil wetness, ice layers or deep frost, weather forecast for rainfall or snowmelt, and presence of waterways, diversions, field ditches, drainage tile, wells, or karst features. Do not spread during high risk conditions unless it is an emergency and adjust spreading rate per acre and total amount of manure that must be applied at once, commensurate with the level of risk.

Introduction

Manure serves as the primary nutrient source for crop production on many farms. It contains all nutrients essential for crop growth. Recycling manure nutrients for crop production reduces the need for nutrient imports from purchased fertilizers. Land application of manure is the most cost-effective and generally accepted method for handling manure removed from animal housing facilities.

To reduce the risk of manure needing to be applied to land under conditions where runoff is likely, some amount of storage is needed. However, even with adequate storage in an average year, delayed corn harvest and excessive wetness or high amounts of snow in fall and spring can still result in manure needing to be applied in less than ideal conditions. These conditions do not always occur. Research in New York (Klausner et al., 1976) and elsewhere shows that contaminants in runoff from winter/early spring manure applications can be variable. In some conditions, contaminant levels in runoff from manured areas was significantly higher than background levels, while in other conditions, levels were similar to runoff from non-manured areas. Komiskey et al. (2011) concluded "that both the timing and amount of applied LDM [liquid dairy manure] were important factors for concentrations and losses of TN [total nitrogen] in runoff during FGPs [frozen ground periods]". See https://www.extension.org/sites/default/files/14novPPcooley.pdf for examples of variability in winter period runoff with lower losses during winters with limited runoff or where soil is not frozen. The annual variability in high risk winter conditions also means that some years will require longer/more manure storage than other years and there is a need to ensure that adequate storage capacity is available so that applications can be avoided during high risk conditions.

It should be recognized that there are specific field situations where late fall or winter application is agronomically appropriate. Some examples include frost injection of manure, incorporation of manure on fields with clay soils that are prone to compaction in the spring, and application of manure to hayfields and fields planted to winter cereal crops that benefit from the nutrients and organic matter applied with the manure.

To reduce the risk of manure nutrients being transported to surface or groundwater, various nutrient management planning tools have been developed. For example, the New York Phosphorus Index (NY PI) is intended to reduce soil P accumulation near transport sensitive areas, and to estimate relative runoff risk of dissolved and particulate phosphorus from manure or fertilizer spreading activities. This assessment is based on field attributes and the general likelihood of runoff occurring during different times of the year. The NY PI evaluates spreading suitability in a given season or month based on historical averages (location risk), but it does not consider the actual conditions on the ground for any given day (present conditions risk). **Therefore, the NY PI should not be used to answer the question: Is today the right day to spread?**

The New York Nitrate Leaching Index (NY NLI) was developed to evaluate nitrate leaching risk based on long term precipitation averages and general soil drainage characterization (expressed as hydrologic group). **The NY NLI is also a planning tool and does not quantify actual manure or nutrient movement** during runoff events. Work is ongoing to develop tools that can predict when runoff and leaching are most likely to occur. An example of such a runoff tool can be found at: http://hsadss.bee.cornell.edu/OwascoLake/. However, such tools need to be further developed and tested at other locations in the state.

Why Revise the Guidelines?

The runoff events that have occurred in New York in recent years indicate that producers could use additional information to improve manure spreading decisions. These events also reinforce the idea that following the CNMP is not enough to avoid a water quality problem or related fine, and that farm managers need to take additional steps to evaluate the field and weather conditions that exist before manure application. A few significant rainfall or snowmelt events, often in February or March, contribute a substantial portion of the nutrient and sediment load to water bodies and where these conditions are likely (as described more fully below), producers should strive to avoid manure application during late winter and early spring altogether. The guidelines below are provided to help evaluate high risk manure spreading conditions. These guidelines are suggested to reduce the risk of ground and surface water contamination by manure. They are designed to help producers better assess actual field conditions and answer the following basic question: ***Given the current soil and ground conditions and the weather forecast, should manure be applied to all or part of this field today*?**

Spreading Guidelines

For all farms, there are twelve factors to evaluate to help assess storage adequacy, better manage available storage capacity, and determine if spreading is appropriate on any given day. These factors can be divided into three groups: (1) field conditions; (2) weather conditions; and (3) manure application management.

Field Conditions:

1. *Soil moisture/saturation, frozen or not:*
   Except in very cold, open winter conditions, the soil drainage classification is currently the best available general soil index to evaluate soil moisture status for planning purposes during the winter months. The poorly-drained soils will be the wettest throughout the soil profile. These soils are somewhat slower to freeze and tend to generate the first runoff. Large 4-wheel-drive equipment and drainage improvements (e.g., tile drainage) may make these soils accessible for spreading manure, but even with tile drainage the runoff risk will be greater than for other soils. In addition, flows from tile could result in a water quality violation. Runoff occurs when moisture conditions exceed field capacity. Excess water starts to saturate the soil and this can lead to direct surface runoff or redistribution within the soil profile as interflow that emerges elsewhere downslope in the landscape. Gauging the moisture condition of the soil under the snow or frost layer in the soil, the moisture soon to be delivered by melt or rain, and the additional moisture that will be added from the manure can help inform the producer on the risk of manure runoff from an application. For example, if 6 inches of medium density snow (1 inch of water per foot of snow) all melted, it would contribute 0.50 inches of water. In comparison, a manure application of 10,000 gallons/acre adds almost 0.40 inches of liquid. An application at this rate is relatively low risk on a soil that is dry under the frost layer (1 inch/foot of water holding capacity). However, when the soil is close to saturation and/or the 6 inch snow layer is dense (3 inches of water per foot), a 10,000 gallon application is risky. Add projected rainfall amounts to these scenarios and runoff is likely even without the addition of manure and its associated moisture.

2. *Snow, ice, and frozen soil:*
   Runoff from manure is significantly reduced when manure can infiltrate into the soil or dry onto plant residues. Recent winter runoff research from Wisconsin (Komiskey et al. 2011) has identified the following conditions as high risk for runoff loss:

   Frozen soil. Frost can create a wide range of conditions. Soil that is dry when it freezes stays in a granular form and manure applied on the top can infiltrate into drier layers below. Soil that is saturated when it freezes creates a solid, impermeable layer called "concrete frost". Concrete frost forms more readily in soils that are conventionally tilled, especially if the soils are not well drained. Concrete frost can form in any circumstance when the soil is saturated followed by very cold temperatures. Concrete frost, especially when a few inches or more in thickness, prevents all infiltration so if manure is applied it is at substantial risk for runoff. It is important to be able to identify this condition to evaluate runoff risk. During the winter of 2014, a significant portion of New York experienced concrete frost conditions. Brief warm periods produced rainfall, generated snowmelt, and created saturated soil. The deep cold period that followed produced concrete frost. Just as it sounds, the soil tends to be rock hard and well-sealed because the water that resided in soil pore spaces froze in place. As cold temperatures continue, frost is driven to greater depths. If temporary warm periods return, the surface melts, but the concrete frost layer remains below the shallow, muddy layer until the air temperature is warm for many days. While most soils are vulnerable at times to this type of frost condition, soils that are less well drained, have little crop cover, and/are in an annual tillage/row crop portion of a rotation are more prone. Concrete frost conditions can also contribute to significant soil erosion loss, with or without manure applications. Manure applications on concrete frost should be avoided, especially in the February-April time period when rainfall or snowmelt could occur at any time.

Ice layers on soil surface or in snowpack. Although a frozen soil surface can support manure spreading equipment, a surface ice layer can also prevent manure from infiltrating into the soil. Ice may form on the soil surface, or be embedded within the snow pack. Either way, when an ice layer is approximately 0.5 inch or more in thickness, and largely unbroken, it will prevent manure from contacting the soil, and present high risk for runoff. This condition was experienced in large areas of northern New York in 2014. Manure applications when this condition exists should be avoided. When soil is not frozen, or is in a frozen/granular condition that allows manure to infiltrate, application may be made directly under or to the soil surface. This can be accomplished by breaking up the ice layer with tillage equipment, or, when the ice layer is in the snowpack, by clearing with a blade.

Snowpack. Manure that is surface applied and has a chance to infiltrate or interact with soil and crop residues presents minimal additional runoff risk as compared to background conditions, even if followed by significant snowfall. Also, manure applications that are on snow, early in the season, and become integrated into snow pack are of low to moderate risk, especially when the eventual thaw is from the bottom up and much of the water infiltrates the soil. However, applications can be very risky when made late in the season just before snowmelt, especially on snowpack (risk increases with depth and water content). Experience and research (Klausner et al. 1976) in New York indicates that manure applied in this situation can produce significant runoff losses. Large applications should be avoided in this condition. Clearing away the snowpack so that application can be made directly to the soil surface (frozen/granular or not frozen) reduces risk of runoff as long as the soil is not in a concrete frost condition.

3. *Ground cover (vegetation, residue cover, and roughness):*
   A good ground cover intercepts rainfall, improves infiltration into the soil profile, and reduces the tendency for runoff water to move quickly across the surface. Ground cover and

vegetated buffers help to trap and filter water, suspended manure particles, and soil. These conditions reduce risk but cannot override the three risk factors of frozen soil raised in item 2 above.

4. *Slope and slope length:*
   The risk for runoff is more dependent on a soil's infiltration rate than slope steepness. Runoff risk on sloping fields will be greatest for soils with a low infiltration rate or when they are frozen. Slope length is usually not a good indicator of runoff risk in New York, but manure applications made at the top of a long slope should be less risky than those made at the top of a short slope, especially when good ground cover is present. The risky locations to apply manure on sloping soils are usually at the base of concave slopes where water often emerges or on slopes where less permeable layers are close to the surface and excess water causes side hill seepage zones on the slope. Avoid application to these areas under high risk weather conditions.

5. *Drain tile, surface inlets, ditches, concentrated flows/draws:*
   By their very nature these features create hydrologically active areas. If winter manure application is necessary, the NRCS code 590 nutrient management standard (2013) calls for flowpath application setbacks of 100 feet from surface waters, surface inlets, springs, sinkholes and swallets, an absolute setback distance of 100 feet from wells, and avoidance of application in concentrated flow areas with well-defined channels. These setbacks are especially important when spreading under wet conditions. Spreading manure near to and upslope of surface ditches that go across the slopes (i.e., those that intercept water) will be more risky than applying where ditches tend to run parallel with the major slope. Though tile drainage is a very important agronomic practice, and overall surface runoff may be reduced, special care should be taken when spreading manure on fields with tile-drainage. Fields that exhibit preferential flow paths to drainage tile (tending to have more clay) can be very vulnerable, and any application when the tile outlets are flowing directly to a watercourse require caution. When applying manure to fields with flowing tiles, tile outlets should be monitored for evidence of contamination. If contamination is visible, immediately discontinue application and, if possible, incorporate manure that was applied but remained on the surface. Even if an entire field does not seem wet, the redistribution of excess interflow or runoff tends to collect and concentrate in draws, swales and lower parts of the field causing these areas to saturate quickly and produce tile flow and runoff. Carefully evaluate fields for the occurrence of these flow paths and concentrated flows and avoid spreading manure directly in these areas, especially before anticipated rainfall events. Follow the guidelines for setbacks, and if such flow paths are persistently occurring consider taking steps to slow or divert the flow of runoff in these areas and protect the flow paths with permanent vegetation. A number of NRCS conservation practice standards provide options to further protect those areas of the field and reduce risk for the rest of the field. Agricultural Environmental Management (AEM) Certified Planners and other conservation professionals at the local Soil and Water Conservation District and NRCS can help plan and implement such soil conservation systems. Very flat fields that are suitable for drainage water management, where the drains can be blocked or raised during the winter or prior to spreading, will have less risk of loss through the drain outlet. Although there is some temporary risk of saturated conditions

and surface loss, overall losses can be reduced.

6. *Nearby surface water:*
   Higher risk exists where surface runoff from a field is expected to flow directly to a stream or waterbody. This is most likely to occur in fields that are both close to surface water and where the field surface slope is oriented toward the waterbody.

7. *Nearby wells or karst features:*
   Wells that are near or in the path of field runoff, as well as karst features (sinkholes, depressions, and/or shallow soils over carbonate rock) receiving runoff, are at risk for contamination. Manure applied without incorporation should be avoided in portions of fields that drain to wells or karst features during frozen, snow covered, or saturated conditions (see http://nmsp.cals.cornell.edu/publications/files/Karst_2_15_2011.pdf).

Weather Conditions:

8. *Forecast shows probability of precipitation? When? How much?*
   Weather forecasts for 24 to 48 hours are quite accurate with respect to the probability of precipitation and temperature. If the probability of precipitation is 30 to 50% or more, it is very likely some precipitation will occur. This is particularly true when the precipitation is expected from a wide-area low front type storm, compared to 'isolated' thundershowers. Unfortunately, forecasting how much rain will fall is more difficult and predictions tend to be less accurate, although significant improvements have been made in recent years. If the expected precipitation amount is 0.25 inches or less, there is usually little risk of runoff, even from wet and frozen soils. Precipitation amounts of 0.25 to 0.5 inches will likely produce some runoff from wet soils, but not much from soils that have high infiltration capacities, providing they are not already saturated or frozen. It is difficult to simplify the runoff risk for different soil and site conditions when precipitation exceeds 0.5 inches, but avoid manure applications when projected amounts are expected to exceed 1 inch.

9. *Warm front expected to generate significant snowmelt?*
   Warm fronts can occur at any time throughout the winter. The likelihood of generating runoff from snowmelt increases quickly when the temperature approaches about 40^{o}F for 6 hours or more. An older snowpack will require a high(er) temperature or longer duration to produce runoff. If nighttime temperatures also remain above freezing, the runoff risk is increased further. Snowmelt periods are good times to observe how different fields respond in terms of runoff. The most risky runoff locations within a field are soon exposed because the snow cover tends to disappear more quickly where runoff is occurring. Avoid manure applications on snowpack when the weather forecast indicates a warm front of above freezing temperatures within the next few days, and especially if the overnight forecast lows are also to remain above freezing.

Manure Application Management:

10. *Manure consistency:*
    Liquid manure is more likely to move across the surface as runoff or through soil to tile drains, than semi-solid or bedded pack manure. However, semi-solid and bedded pack manure will generate runoff losses too in the high risk conditions discussed in this document.

This was experienced in the winter of 2014. Producers should have storage options available, not only for liquid manure, but also for other forms of manure. Liquid manure with less than 5% solids is especially vulnerable to movement with soil drainage water, so extra care needs to be taken when using manure with low solids content on tile drained fields.

11. *Method of application:*
    Manure that is surface-applied presents a higher risk because the material is less able to mix and react with soil. Manure injection or incorporation with shallow mixing can reduce runoff risk. This can be done in-season but also when there is a 1-2 inch frost layer at the soil surface through a process called frost tillage or injection. Depending on the equipment used, incorporation may conflict with no-till principles.

12. *Application rate and total spreading volume:*
    An operation spreading 3 or 4 tons of manure following a nutrient management plan each day on selected fields over time does not present the same level of risk as one that may spread (even following a plan at the same rate per acre) large amounts of liquid manure on many acres in one or two days. In risky conditions, when manure needs to be applied, and plans are to cover whole fields or significant acreage, split applications and reduced rates should be considered.

Recognizing High Risk Situations

High risk spreading conditions are more likely when:

1. Significant rainfall or snowmelt is predicted within the next 48 hours.
2. Concrete frost, ice layer on soil or in snow pack, deep or dense snow, or water saturated soil is present.
3. Tile drains are flowing at least moderately from field drainage (as opposed to ground water interception).

Manure application under the conditions outlined above have a high probability of causing water pollution. Avoid spreading on fields with:

1. Past runoff problems or groundwater/well problems.
2. Significant surface runoff or subsurface flow that can reach a stream or ditch.
3. An orientation toward a stream or watercourse with a slope greater than 3-5%.
4. Concentrated flows.

Summary

Producers should work with their AEM Certified Planner to find ways to avoid having to spread during high risk and emergency situations. Even if the NY P Index or Nitrate Leaching Index allow for spreading on particular fields during a certain time of year, the decision to apply or not on any given day needs to be based on actual field and weather conditions. Sufficient manure storage and a well-designed and executed winter spreading plan can go a long way toward reducing losses. Actual manure application decisions should consider:

1. **Near-term weather**: Rain or snowmelt in the forecast?
2. **Actual field conditions**: Extent of snowpack, ice layer, frozen soil, or soil saturation.
3. **Use of lower risk fields, identified in advance**: On farms where some application is planned during winter months, work with your AEM Certified Planner to identify a significant acreage of lower risk fields for those applications (e.g., no history of runoff or groundwater issues, limited surface connection to streams/ditches, mild slopes, no concentrated flows, no karst or shallow soil features, high crop residue or surface roughness, etc.). Also with your Certified Planner, identify a smaller set of fields to save for emergency application fields or pile areas where manure can be taken in case of unexpected extreme conditions. Fields should have no history of runoff problems, be less than 5% slopes; as far as practical from any stream, ditch, well, or karst feature – preferably at least 300 feet; be accessible for equipment; have minimal runoff from upslope areas; and not be prone to frequent or occasional flooding (see NRCS 590 Standard for temporary manure pile siting).
4. **Beneficial application management to further reduce runoff risk**: Injection or incorporation, reducing application rates, introducing or increasing setback distance, applying to lower risk fields, applying to fields with ground cover such as hayfields, applying manure over a period of several days as opposed to all in one day, etc.
5. **Access to manure storage**: Including working with your Planner to develop more storage capacity if finding that applications during higher risk conditions are becoming commonplace. Also, consider asking a neighbor if they have storage room to spare.

Accurately predicting weather is difficult. The guidelines in this document cannot prevent all runoff, but increasing awareness of the conditions that contribute to runoff and development and implementation of winter spreading plans based on these guidelines should reduce the risk of significant runoff and water quality violations. It is most important that farm managers take steps to observe fields after applications to learn from what happens and to adjust practices accordingly. Further, producers and planners should carefully evaluate existing storage capacity to ensure adequate storage to avoid application during high risk conditions year in and year out, and consider that wet field conditions may need to be evaluated differently from concrete frost, ice or snow pack.

References

- Klausner, S.D., P.J. Zwerman, and D.F. Ellis. 1976. Nitrogen and phosphorus losses from winter disposal of dairy manure. Journal of Environmental Quality 5(1): 47-49.
- Komiskey, M.J., T.D. Stuntebeck, D.R. Frame, and F.W. Madison. 2011. Nutrients and sediment in frozen-ground runoff from no-till fields receiving liquid-dairy and solid-beef manures. Journal of Soil Water Conservation 66(5): 303-312.