

# AGENDA

## Joint Committee Meeting

**Videoconference OR  
Highway Training Room  
1425 Wisconsin Drive  
Jefferson, WI 53549**

Monday, January 30, 2023

10:00 a.m.

### Board of Health

Dr. Jessica Coburn, Meg Turville-Heitz, Samantha LaMuro, Steve Nass, Dr. Don Williams

### Executive Committee

Joan Fitzgerald, Steve Nass, Blane Poulson, Brandon White, Michael Wineke

### Land and Water Conservation Committee

Margaret Burlingham, Walt Christensen, Matt Foelker, Dan Herbst, Kirsten Jurcek, Cassie Richardson, Meg Turville-Heitz

### Planning and Zoning Committee

Matt Foelker, George Jaeckel, Steve Nass, Blane Poulson, Cassie Richardson

### Solid Waste Committee

Joan Callan, Mark Groose, Jeff Johns, Anita Martin, Robert Preuss

Join Zoom Meeting

<https://us06web.zoom.us/j/87697754337?pwd=cnVKMzd0TkZFY3RPRHpxMW5kTGxVdz09>

Meeting ID: 876 9775 4337

Passcode: Meet2022

Dial by your location: 1 312 626 6799

1. Call to Order
2. Roll Call
3. Certification of Compliance with Open Meetings Law
4. Review of Agenda
5. Public Comment (Members of the public who wish to address the committee on specific agenda items must register at this time)
6. Discussion and staff presentation on Air, Surface Water, Groundwater, and Health Concerns Relating to Animal Operations and their Regulation followed by possible action on:
  - a. proposed reporting process for manure spills and complaints
  - b. regulation of high-capacity wells
  - c. development of composting ordinance for manure and animal mortalities
  - d. regulation related to aerial spraying (spray irrigation) of manure and other industrial waste
  - e. development of an erosion control and stormwater ordinance
7. Discussion on community outreach and education related to animal operations and their regulation.
8. Discussion and possible action on tentative future meeting schedule and agenda items
9. Adjourn

A quorum of any Jefferson County Committee, Board, Commission, or other body, including the Jefferson County Board of Supervisors, may be present at this meeting.

Individuals requiring special accommodations for attendance at the meeting should contact the County Administrator 24 hours prior to the meeting at 920-674-7101 so appropriate arrangements can be made.

Executive Committee  
Board of Health  
Land & Water Conservation Committee  
Planning and Zoning Committee  
Solid Waste Committee

January 30, 2023 Joint Meeting



# Summary to Date

- 2021 to 2022- Development of Q&A document (80 pages) of questions to state agencies from elected officials and members of the public.
- July 2022 - Joint Committee Education session related to CAFOs and agriculture regulation
- Oct 2022 - Committee Review - worked with five committees to identify and focus on potential priority of potential focus
- Oct 2022 - Jan 2023 - Staff researched five action items as directed by committees
- Jan 2023 - Presentation of five action items for discussion and potential action of next steps

# Action Items from Committees

## Motions:

- Establish a process for LWCD to report on manure complaints.
- Research the County's authority on regulating high-capacity wells.
- Research on developing composting ordinances (manure & mortalities).
- Research aerial spreading of manure and other waste products.
- Research on developing an erosion control and stormwater ordinance(s)

Requests: more community outreach and education

# Manure Complaints

Status: Task Completed

# Manure Complaints

- LWCD created a manure complaint report (handout)
- Presented to Land & Water Committee - December 2022
- Reports will be presented to Land & Water Committee twice a year
- Only include complaints/issues with LWCD involvement
- 24 complaints in 6 years
  - 10 involving CAFOs, 14 not involving CAFOs
  - 13 of the 24: compliant with standards/rules
  - 11 of the 24: non-compliant with standards/rules
    - 8 - achieved compliance
    - 2 - working on compliance (DNR & County involved)
    - 1 - compliance handled by DNR

# Manure Spills

- LWCD is sometimes involved – included on manure complaint report
- Emergency Management – receives manure spill reports from DNR
- Spill reports presented to Local Emergency Planning Committee
- 2017–2022: total of 10 manure spills
  - 4 included on LWCD manure complaint report
  - 9 are closed and 1 is still open (LWCD is working with farm)

# Manure Complaints

- Land and Water Conservation Committee
  - reviewed report & was satisfied with ongoing plan for updates



# High Capacity Wells

# High Capacity Well Regulation

Regulated by Wisconsin Statute section 281.34 and section 280.21. The Wisconsin DNR is the approval and enforcement authority. However, Counties have the ability to adopt an ordinance if such ordinance is in strict conformity with Wisconsin Statutes chapter 280 and DNR rules, section 59.70 Wis. Stats.

# High Capacity Well Regulation

## PERMIT APPLICATION:

Department of Natural Resources is required to consider the environmental impact of a proposed high capacity well when presented with sufficient concrete, scientific evidence of potential harm to waters of the state; upon what evidence, and under what circumstances, that duty is triggered is a highly fact-specific matter that depends upon the information submitted by the well owner in the well permit application and any other information submitted to the DNR decision makers while they are reviewing that permit application. *Lake Beulah Management Dist. v. State Dept. of Natural Resources* (2011) 799 N.W.2d 73, 335 Wis.2d 47.

# “Aerial Spraying” of Manure & Industrial Waste

Status: Research Ongoing - Additional Input Requested

# Spray Irrigation

- Concern: aerosolization of contaminants that could cause health impacts
- Spray Irrigation Definition (State Admin Code NR 243)
  - Spray irrigation means the application of liquid manure or process wastewater to cropland using equipment that discharges manure into the air via a single nozzle or multiple nozzles or hoses and disperses the manure over distances greater than could be achieved using typical moving vehicle or manure hauling equipment.
- Request: use the term “spray irrigation” and not “aerial spraying”

# Spray Irrigation of Industrial Waste

- Regulated by DNR
- Local authority to prohibit or require a license to conduct spray irrigation of manure using nuisance or public health as a basis



# Spray Irrigation of Manure – What It Is



Center Pivot Systems



All photos from DNR presentation: Joe Baeten and Mark Borchardt



# Spray Irrigation of Manure - What It Is

Traveling gun



All photos from DNR presentation: Joe Baeten  
and Mark Borchardt



# Spray Irrigation of Manure – What It Is Not

Liquid Manure Injection into Soil



Liquid Manure Surface Application



Solid Manure Surface Application

# Manure Spray Irrigation - Benefits

- More effective crop fertilization
  - Irrigation typically done when crop is actively growing
- Reduced surface water & groundwater contamination
  - Longer time frame for application (during growing season)
  - Reduced application volumes
  - Increased nutrient uptake of plants
  - More holding capacity of upper soils
  - Reduced nutrient losses

# Manure Spray Irrigation - Benefits

- Reduced groundwater contamination
  - Longer time frame for application
  - Reduced application volumes
  - Application during growing season
- Reduced manure vehicle trips on roads
  - Reduced vehicle emissions
  - Reduced wear and tear on roads
  - Increased road safety
- Increases flexibility for manure management

# Manure Spray Irrigation - Concerns

- Groundwater quantity
  - Dilution of liquid manure with groundwater
  - But could reduce reliance of groundwater solely for irrigation
- Odors
- Airborne fine particulate matter and pathogens
- Emerging contaminants
- Human exposure leading to gastrointestinal illness

# Microorganism Movement

- Liquid is released from irrigation
- Liquid droplets settle to the ground or are aerosolized
- Once aerosolized, droplets are inactivated or taken by wind
  
- Exposure occurs from:
  - Inhalation or touching of the pathogens that have settled on objects which is then ingested
  - Garden food
  - Vector (insects or pets that were subjected to the released manure)

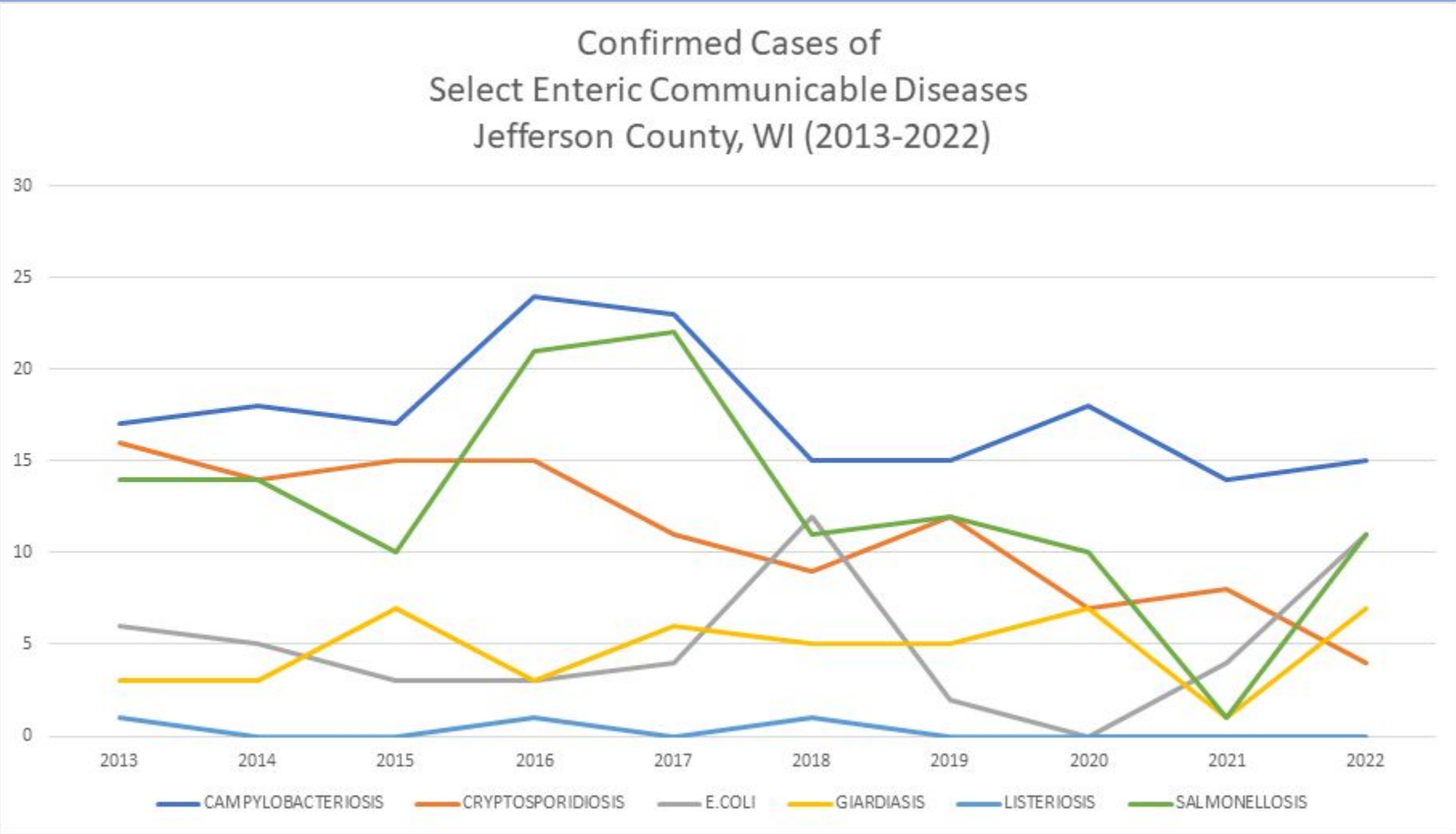


# Zoonotic Pathogens causing Enteric Illness

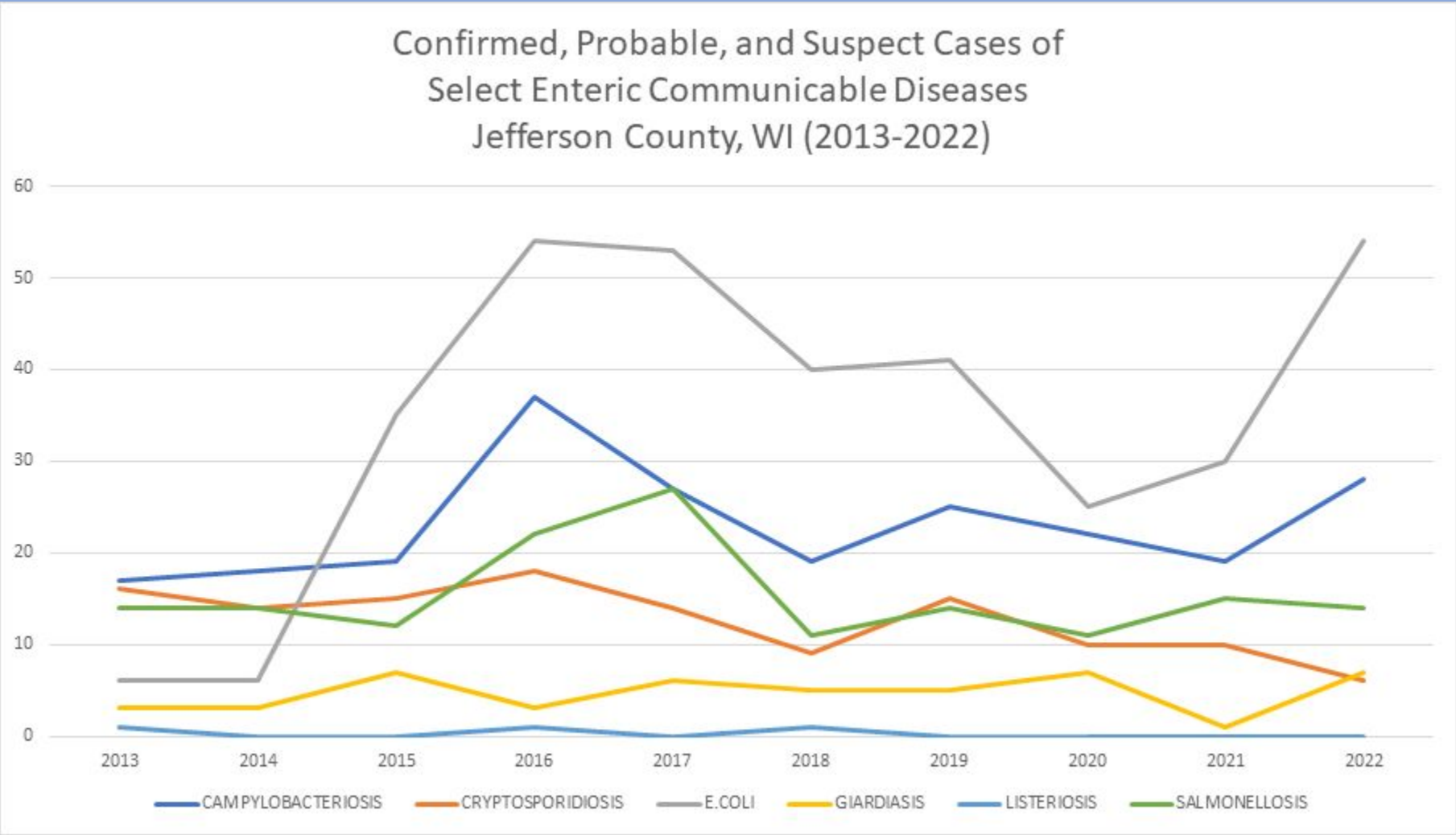
- *Campylobacter jejuni* (Campylobacteriosis)
- *Enterohemorrhagic Escherichia coli* (E. Coli)
- *Salmonella spp* (Salmonellosis)
- *Giardia lamblia* (Giardiasis)
- *Listeria monocytogenes* (Listeriosis)
- *Cryptosporidium parvum* (Cryptosporidiosis)

Enteric illness signs and symptoms include diarrhea, abdominal pain, fever, nausea, and vomiting which can progress to systemic infections

# Jefferson County Communicable Disease Statistics



# Jefferson County Communicable Disease Statistics





# Communicable Disease Follow up

- Labs reports reviewed
- Risk/exposure period determined
- Data collected based on exposure period
- High-risk work environment assessment conducted
- Disease education provided
- Exclusion
- Follow-up/notification
- Surveillance and investigation of trends and outbreaks

# Manure Spray Irrigation - Regulations

- Towns in Wisconsin
  - Most have no rules/ordinance associated with manure spray irrigation
  - Some prohibit use of center pivot
  - Some require conditional use permit
- Town of Ixonia
  - Only Town in Jefferson County with an ordinance
  - “The use of all center pivot manure distribution systems or other spray irrigation systems for the spreading of animal manure and lagoon wastewater and other liquid by-products of animal manure within the town is hereby prohibited.”

# Manure Spray Irrigation - Regulations

- Counties in Wisconsin
  - Adams County – Conditional Use Permit (signage before/after irrigation)
  - Bayfield County – prohibits spray irrigation (sprinkler system, traveling gun, center pivot)
  - Kewaunee County – Conditional Use Permit
    - Require operation plan
    - Set standards on pressure, size of nozzles, height of nozzles
    - Operational standards related to drift, wind speeds, etc.
    - Application standards related to depth to bedrock
    - Setback guidelines - 500 feet with ability to be permitted for 250 feet from homes, occupied buildings, property lines of rec areas, schools, playgrounds
    - Record keeping

# Manure Spray Irrigation - Regulations

- State Rules - All Farms
  - Nutrient Management Plan Standard 590
  - No manure applications in certain sensitive areas
  - Setbacks from wells (50-1,000 ft), depth to groundwater & bedrock (1-1.7 ft), direct conduit to groundwater (50-300 ft), navigable waters & conduits (300-1,000 ft, 0 ft as long as certain practices followed)
- State Rules - Farms  $\geq$  1,000 Animal Units (CAFOs)
  - Nutrient Management Plan = 590 + additional regulations (NR 243, NR 214)
  - Setbacks from wells (100-1,000 ft), inhabited dwelling (500 ft), depth to groundwater & bedrock (5 ft), direct conduit to groundwater (100 ft), navigable waters & conduits (25-100 feet as long as certain practices followed), wetlands (25 ft)

# Manure Spray Irrigation - Regulations

- Manure Irrigation Plan for CAFOs
  - Narrative/Questionnaire
  - Irrigation Specific Restriction Maps
  - Drift Monitoring Log
  - Equipment Specifications
  - Manure and/or process wastewater characteristics (test results)
  - Soil test information for fields planned to be used for irrigation

# Manure Irrigation Airborne Pathogen Health Risk Assessment Study

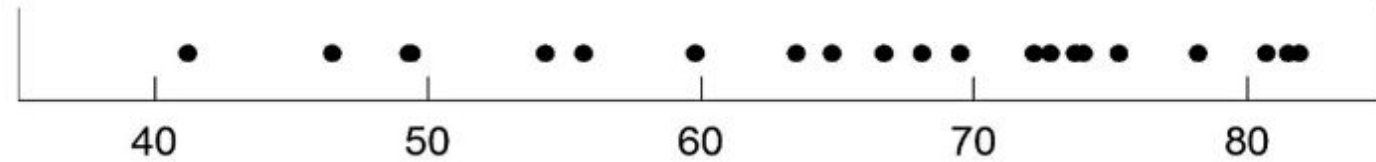
*Focus: To identify the relationship between risk of gastrointestinal illness from zoonotic pathogens and the relationship of risk according to distance from irrigation device*

- Multi-year study (2012-2014)
- 23 separate irrigation events on 3 different dairy farms in Wisconsin
- Downwind testing done at 100, 200, 350, 500, and 700 ft.
- Recorded meteorological data to evaluate relationships
- Bovine Bacteroides and Gram Negative Bacteria were tested as surrogates

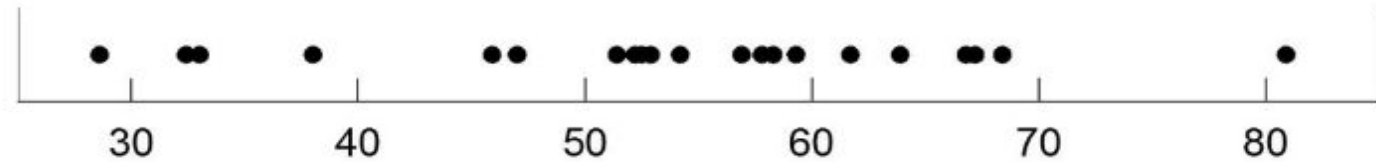
Article linked [here](#)

# Weather Conditions during Manure Irrigation Trials

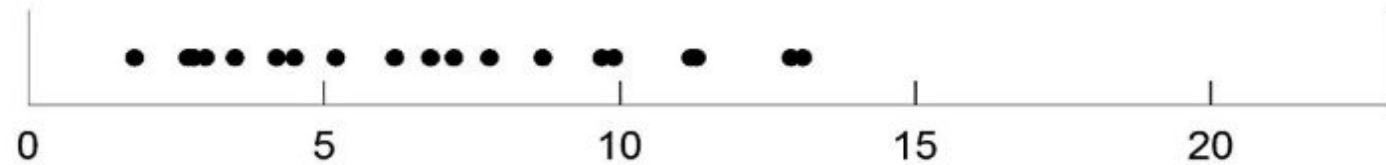
Mean temperature (°F)



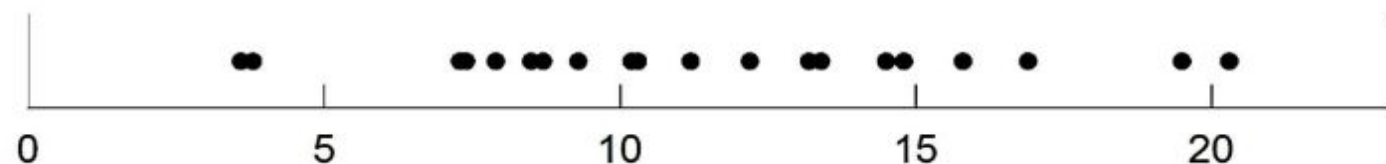
Mean relative humidity (%)



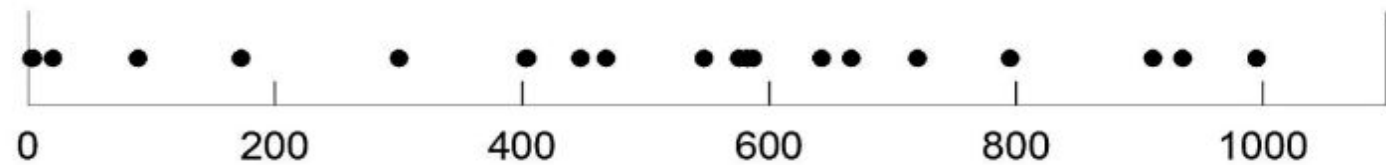
Mean wind speed (MPH)



Max wind speed (MPH)



Mean solar irradiance (W/m<sup>2</sup>)



# Study Findings

*Risk depends on pathogen type, prevalence, downwind distance, and number of irrigation events*

- Further the distance, lower the risk
- Faster the wind speed, greater concentration of organisms downwind
- Higher sunshine levels, decreased risk (higher killing rate)
- Initial concentration of microorganisms in manure plays factor
- Pathogen air concentrations downwind from manure irrigation depend on wind speed, pathogen concentrations in manure, and distance

*Risk 500 feet down wind is on the order of 1 in 100,000 to 1 in 100 per event*



# Wisconsin Manure Irrigation Workgroup

- Citizen concerns led the UW-Madison and UW-Extension to develop a workgroup with broad representation to review issues associated with manure irrigation and develop guidance and recommendations.
- Considered findings in human health risk from aerial manure irrigation report.

# Wisconsin Manure Irrigation Workgroup Report

- Consensus Recommendations on Operating Parameters
  - steps to minimize drift & ensure no overspray
  - supervise/control equipment
  - determine relevant weather info (wind speed & direction, temperature)
  - prevent backflow to water source
  - no human waste/septage is added
  - drop nozzles on center pivot
  - nozzles & operating pressures set for larger droplets

# Wisconsin Manure Irrigation Workgroup Report

- Near Consensus Recommendations on Setbacks

- Setback is distance from wetted perimeter of irrigation to item
- Public forest with no recreational access = 0 ft (consensus)
- Private forest = 0 ft
- Pastureland = 0 ft
- Cropland owned by others = 0 ft
- Road Right of Way = 0 ft
- Public rec area, school, playground property line = 100 ft if wind  $\leq$  10 mph & wind is parallel or away from property
- Dwelling or occupied building = 500-750 ft depending on wind speed/direction (current CAFO requirement = 500 ft)

# Manure Spray Irrigation – Jefferson County

- Contacted several CAFOs in Jefferson County
  - None currently use the practice
  - Some want it as an option
  - Some willing to be on a solution-based work group
- Notes
  - High initial cost of irrigation equipment
  - High cost of solid separation equipment (sand bedding)

# Considerations for Possible Ordinance

- Staffing and implementation
  - Revenues would be obtained from permit fees
  - All expenses would not be covered by permit revenues
  - More detailed analysis would need to be completed on cost of implementation - including possible additional staff

# Manure Spray Irrigation

- Joint Committee Input or Additional Action
  - Should staff continue to do research, and if so what areas?
  - Should the County regulate?
  - If the County regulates, what should they regulate?
  - If the County regulates, how should they regulate?

# Manure & Animal Mortality Composting

Regulated under NR 502 Wisconsin Administrative Code and section 243 Wis. Stats. (Wisconsin Pollution Discharge Elimination System).

Manure Composting - subject to DNR regulation and local ordinances regulating manure storage and shoreland and flood-plain zoning (NR 502.12(4))

Animal Mortality Composting - Regulated by DNR under NR 502.12(4))

# Manure & Animal Mortality Composting

- Input from a few farms
  - Farms contract with rendering company to pick up mortalities
  - Only 1 rendering company in area
  - One farm shared cost for mortality pick up: over \$40,000/yr
  - DNR is encouraging farms to consider mortality composting because rendering company may not be an option in the future



# Manure & Animal Mortality Composting

- Regulation by State (NR 243) for CAFOs
  - Animal carcasses may not be disposed of in a manner that results in:
    - discharges pollutants to surface water
    - violates of groundwater standards
    - impairs wetland function values
  - Carcasses may not be disposed of in liquid manure or process wastewater storage
  - Carcass storage or treatment facility must be adequately designed to contain and treat carcasses
  - Carcass storage or treatment facility must be approved by the DNR

# Manure & Animal Mortality Composting

## Joint Committee Input or Additional Action

- Is the concern having to do with composting or with catastrophic mortality?
- What type of composting is a concern? Does it depend on size or type (residential/backyard, business, farm manure, farm mortalities, farm catastrophic mortalities)?
- We need to do additional research including legal authority to regulate.

# Erosion Control Ordinance Stormwater Management Ordinance

Status: Research Ongoing - Additional Input Requested

# Stormwater and Erosion Control Ordinance

- Reviewed Surrounding Counties (Walworth, Rock, Dodge and Waukesha)
  - All have applicable ordinances
  - Generally, all follow DNR model ordinances. Each County has similarities and differences
- Reviewed Cities within Jefferson County
  - Have ordinances and differ due to municipal stormwater systems
  - Some implementation by city staff, but most work completed by consultant

# Stormwater and Erosion Control Ordinance

- Reviewed Towns and Local Building Inspectors
  - Towns do not implement either ordinance
  - Town Building Inspector may regulate Erosion Control with the Town Building Code Permit
    - Only reviewed if a Town Building Permit is required and it is in the Building Inspector's contract
  - Local building inspector believes County ordinances would be preferred
- Some Towns have voiced concerns about lack of erosion control and stormwater management during development

# Erosion Control

- What is Erosion Control?
  - Construction Site Erosion and Sediment Control
  - Construction Site: means an area of land disturbing construction activities
  - Erosion and Sediment Control Plan: means a comprehensive plan developed to address pollution caused by erosion and sedimentation of soil particles during construction

# Stormwater Management

- What is a Stormwater Management Plan?
  - Post-Construction Stormwater Management
  - Post Construction Site: means construction site following the completion of land disturbing activities and final site stabilization
  - Stormwater Management Plan: means a comprehensive plan designed to reduce the discharge of pollutants from stormwater, after the site has undergone final stabilization

# Purpose of Regulating Erosion Control and Stormwater

- Purpose and Goals:
  - Reduce and control runoff and soil erosion during land disturbing activities
  - Protect water resources from sedimentation
  - Prevent pollutants from discharging into the water of the State
  - Control and treat runoff and stormwater from developed sites
- It is estimated that construction site erosion is 10 times greater per acre than cropland erosion
- On average, an acre of construction with no erosion control delivers as much sedimentation at 75 acres of cropland



# Wisconsin Regulations

- Wi Stat 59.693: Construction site erosion control and stormwater management zoning
  - Allows County to adopt ordinances for all unincorporated areas of County, unless Town already regulates SW or EC
  - Ordinance would regulate Towns, not Cities or Villages
- Wi Stat Chapter 281: Water and Sewage
  - In-depth regulation of SW and EC
  - State erosion control and stormwater permitting minimum standards

# Wisconsin Regulations

- 281.33(3m): County may enact an ordinance regulating the conduct related under this section only if the ordinance strictly conforms with the uniform statewide standards established
- County may adopt more restrictive regulations to control storm water quantity and flooding or to comply with federally approved TMDL (DNR guidance)
- DNR provides model ordinances
  - [ModelOrdinances.pdf \(wi.gov\)](#)

# DNR Model Ordinances and Surrounding Counties

- Surrounding Counties utilize the DNR model Ordinances as a starting point
  - Rock County
    - Stormwater ordinance plans for a larger storm event (100 year) rather than 1, 2, 5 or 10 year event due to flooding concerns
      - Drastically increases the size of the retention areas required
    - Interprets agricultural exemptions only for agricultural practices (planting, grazing, etc.) and continues to regulate agricultural construction
  - Walworth County
    - Different permits required for different types of projects (single family, small disturbance, large disturbance, etc.)
  - Waukesha County
    - Requires financial assurance (bond, cash, etc.) be provided as part of permitting process

# Examples of when permits are required

- Erosion Control
  - Permits are required for any development or ground disturbing activities
    - Ex: Permit required for 1,000 sq. ft. of disturbance
- Stormwater Management
  - Permits are required when a larger development is proposed, or a larger amount of land is disturbed
    - Ex: Subdivision development or more than ½ of acre is disturbed
- DNR Permits are required when construction projects disturb one or more acres of land
  - Some agricultural activities are exempt from DNR permitting, but agricultural construction projects are not

# Agricultural Exemptions

- Model Ordinances:
  - Agricultural Exemptions: “agricultural facility” and “agricultural practice” are exempt from permitting requirements
    - “Agricultural facility” means a structure associated with an agricultural practice
    - “Agricultural practice” means beekeeping; commercial feedlots; dairying; egg production; floriculture; fish or fur farming; grazing; livestock raising; orchards; poultry raising; raising of grain, grass, mint and seed crops; raising of fruits, nuts and berries; sod farming; placing land in federal programs in return for payments in kind; owning land, at least 35 acres of which is enrolled in the conservation reserve program under 16 USC 3831 to 3836; and vegetable raising.
  - May be able to regulate agricultural development (building, construction, etc.), but not agricultural practices

Legal Authority General Rule – Local governments have limited authority to impose requirements on siting CAFOs per Wis. Stat. §93.90(3)(a).

The legislature expressly withdrew, with limited exceptions, the power of political subdivisions to enforce livestock facility siting standards, to disapprove livestock facility siting permits, and to condition the grant of a livestock facility siting permit on any requirement other than the state standards.

- DNR has the statutory authority to regulate and impose conditions on CAFOs

What Authority Does the County Have?

- Regulate roads such as setting weight limits for vehicles travelling on roads and enacting ordinances penalizing individuals or organizations from leaving manure on the road.
- May enact more stringent local standards which must be based on reasonable and scientifically defensible findings of fact, adopted by the local jurisdiction, which clearly show that the standard is necessary to protect public health or safety
- Zoning ordinances/regulations - CAFOs can only be located in the proper zoning district (A1) • Right to Farm limits county's authority to regulate certain violations.

# Considerations for Implementation

- Staffing and implementation
  - Revenues would be obtained from permit fees
  - All expenses would not be covered by permit revenues
    - Realistic permit fees
    - Surrounding counties note that permit revenues do not cover all expenses
  - More detailed analysis would need to be completed on cost of implementation

# Considerations for Implementation

- Total number of permits issued in 2022 by Department
  - Sanitary/Septic Permits - 151
  - Zoning and Land Use Permits - 588
- Estimated Number of Permits Requiring Erosion Control and Stormwater Permits
  - Erosion Control
    - Majority of permits issued would require erosion control = 500 - 550
  - Stormwater Permits
    - Assume single family homes and business/industrial require permits = 80



# Questions and Considerations

- Do we want to proceed with developing Erosion Control and Stormwater Ordinances?
  - If so, do we adopt the DNR model ordinances or review more restrictive provisions?

# Questions and Considerations

- What do we want to regulate?
  - What is threshold that triggers permitting requirements?
    - Erosion Control:
      - All land disturbing activities?
        - Larger than a specific square footage?
        - Located near environmentally sensitive area? (steep slopes, wetland, waterways, etc.)
    - Stormwater Management:
      - All land disturbing activities?
        - Larger than a specific square footage?
        - Located near environmentally sensitive area? (steep slopes, wetland, waterways, etc.)
  - Surrounding Counties: permitting is trigger by size of disturbance, type of development, location, etc.

# Community Outreach and Education Request

Status: Ongoing- Additional Input Requested

# Community Education and Outreach

- Education provided to all affected Highly Pathogenic Avian Influenza affected farms and employee health monitored
- Educational resources created and dispersed by state agencies
- Educational resources developed by Health Department
- Outreach plan developed

# Community Outreach and Education

Joint Committee Input or Action?

# Next Steps Slide

- Any additional questions?
- Any additional staff work needed?
  - Involvement of stakeholders
- What are potential priorities?
- Specific committee assignments/policy considerations?



Date of Complaint	Complaint/Issue	Farm	Town	DNR involved? (Y/N)	LWCD Inspection Date	Compliant?	Notes
11/30/2018	liquid manure spread on farm field, complaintant was worried it would runoff the field	Tag Lane Dairy	Ixonia	N	11/30/2018	Y	LWCD found that field was relatively flat, appeared that manure was not applied near ditch, and no manure was ponding on field. Also contacted crop consultant and found out that manure was going to be incorporated that afternoon.
10/19/2018	hose to transport manure was placed on farm field but complaintant thought it was too close to their house; also concerned about future over application of manure	Kutz Dairy	Jefferson	N	none	Y	LWCD staff explained rules to complaintant - no rule on how close a transport hose can be as long as it isn't on their property. Told complaintant to call back if there is overspreading in the future.
7/31/2018	landspreading manure on a non-cropped field	Timothy & Jean Smith	Jefferson	Y	8/1/2018	N	DNR passed on a complaint to LWCD. Manure was being placed in a wetland - DNR was handling violation. Zoning handled violation regarding no permits for horse sheds and improper handling of manure.
6/22/2018	manure in road and road ditch near wetland/pond	Straussdale Holsteins	Waterloo	N	6/22/2018	N	LWCD did site visit & contacted farmer to clean up manure on road and in ditch. No manure made it to the wetland and pond.
3/9/2018	manure pile on field	Tag Lane Dairy	Ixonia	N	3/12/2018	Y	LWCD determined from caller that there was no resource concern. Site visit found it to be headland stacking of manure that followed standards.
12/7/2017	manure spreading complaint - ponding of manure in road right of way	Tag Lane Dairy	Ixonia	N	12/7/2017	Y	Manure was being incorporated in field. Manure tank sat overnight in the right-of-way and when it was moved, there was manure in tire tracks. Farm cleaned it up.
11/28/2017	manure spreading complaint	Pond Hill Dairy	Koshkonong	N	11/28/2017	Y	LWCD site visit found no concerns with manure spreading
11/13/2017	manure spreading complaint	McFarland Dairy, Dodge County	Watertown	N	11/13/2017	Y	LWCD worked with farm and crop consultant to verify that there were no issues with application
11/1/2017	excessive spreading of manure - complaint filed with DNR on 10/31/17	Katzman Dairy	Hebron	Y	11/1/2017	Y	Requested by DNR to do site visit. No manure left the site. Some ponding of manure where farm equipment turns in the field. DNR asked farm to shut off manure when they make turns. Farm incorporated areas with ponding.
7/27/2017	manure spreading on a fallow field along CTH J	unknown	Oakland or Sumner	N	7/27/2017	Y	LWCD found no fallow field spread with manure on CTH J.
Notes	Only manure complaints/issues in which there is LWCD involvement are detailed in this list.						
	List doesn't include manure-related issues solely handled by the DNR (including spills).						
	List doesn't include communications from citizens who want information, but don't have a specific complaint.						



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# **CONSIDERATIONS** FOR THE USE OF MANURE IRRIGATION PRACTICES

Report from the Wisconsin Manure Irrigation Workgroup



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# Considerations for the Use of Manure Irrigation Practices

## Report from the Wisconsin Manure Irrigation Workgroup

This informational report was developed by members of the Manure Irrigation Workgroup. The workgroup included invited participants representing a cross-section of interests concerned with the use of irrigation equipment to land-apply livestock manure or process wastewater by agricultural operations. Future public policy regarding manure irrigation would be made by state and local governments following appropriate public participation and input; this workgroup did not have that authority. This report is informational. The report is a group product, compiled and edited by Genskow and Larson with contributions and comments from all workgroup members and writing contributions from Borchardt, Craig, Baeten, Murphy, Struss, and Thiboldeaux. The report does not represent the views of any individual workgroup member, nor the views of any of the participating organizations.

### Workgroup Members:

- Ken Genskow, University of Wisconsin-Madison & University of Wisconsin-Extension (chair/facilitator)
- Becky Larson, University of Wisconsin -Madison & University of Wisconsin-Extension
- Carrie Laboski, University of Wisconsin -Madison & University of Wisconsin-Extension
- Mark Borchardt, United States Department of Agriculture-Agricultural Research Service
- Andrew Craig, Wisconsin Department of Natural Resources
- Joe Baeten, Wisconsin Department of Natural Resources
- Pat Murphy, United States Department of Agriculture-Natural Resources Conservation Service
- Steve Struss, Wisconsin Department of Agriculture, Trade and Consumer Protection
- Rob Thiboldeaux, Wisconsin Department of Health Services
- Suzanne Gibbons-Burgener, Wisconsin Department of Health Services
- Gloria Smedema, Fond du Lac County Public Health
- Sarah Grosshuesch, Adams County Public Health
- Kenn Buelow, Dairy Farmer
- Jeff Sommers, Dairy Farmer
- Shelly Mayer, Dairy Farmer and Executive Director, Professional Dairy Producers of Wisconsin
- Jeff Polenske, Agronomist
- Dana Cook, Professional Nutrient Applicators Association of Wisconsin
- Lynn Utesch, Organic Farmer, Sustain Rural WI Network, and Kewaunee Cares
- Jim Vandenbrook, Wisconsin Land and Water Conservation Association

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Several regular attendees of workgroup meetings also contributed to this report, notably, Tucker Burch (US Geological Survey), and Sarah Koske (Wisconsin DHS).

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Please note that “Appendix C: Airborne Pathogens from Dairy Manure Aerial Irrigation and the Human Health Risk” is a stand-alone research publication authored by M. Borchardt and T. Burch. See recommended citation in Appendix C.

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## Glossary and List of Acronyms

- ATCP 50 · Chapter ATCP50 of Wisconsin Administrative Code, addressing Wisconsin's Soil and Water Resource Management Program
- CAFO · Concentration Animal Feeding Operation
- CUP · Conditional use permit
- NMP · Nutrient management plan
- NOAEL · No observable adverse effect level
- NR 151 · Chapter NR151 of Wisconsin Administrative Code, addressing Runoff Management
- NR 213 · Chapter NR213 of Wisconsin Administrative Code, addressing Lining Of Industrial Lagoons And Design Of Storage Structures
- NR 214 · Chapter NR214 of Wisconsin Administrative Code, addressing Land Treatment Of Industrial Liquid Wastes, By-Product Solids And Sludges
- NR 243 · Chapter NR243 of Wisconsin Administrative Code, addressing Animal Feeding Operations
- NRCS · Natural Resources Conservation Service Conservation Practice
- CPS 590 · Standard Code 590
- PI · Phosphorus Index
- PSI · Pounds per square inch (pressure)
- SWQMA · Surface Water Quality Management Area
- USDA-ARS · United States Department of Agriculture-Agricultural Research Service
- USEPA · United States Environmental Protection Agency
- USGS · United States Geological Survey
- UWEX · University of Wisconsin-Extension
- VMD · Volume median diameter (for droplet diameter sizing)
- WDATCP · Wisconsin Department of Agriculture, Trade, and Consumer Protection
- WDHS · Wisconsin Department of Health Services
- WDNR · Wisconsin Department of Natural Resources
- WPDES · Wisconsin Pollution Discharge Elimination System
- $\mu\text{m}$  · micrometer =  $1 \times 10^{-6}$  meter

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## Executive Summary

The Wisconsin Manure Irrigation Workgroup was convened in Spring 2013 by University of Wisconsin-Extension (UWEX) and University of Wisconsin-Madison (UW-Madison) College of Agricultural and Life Sciences at the request of Wisconsin Department of Natural Resources (WDNR) and Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP). The workgroup was asked to review a broad set of issues associated with manure irrigation and to develop guidance and recommendations for state agencies, local governments, and citizens seeking to understand this expanding technology. The workgroup has no formal authority to establish policy for any jurisdiction within Wisconsin. Any public policy action by local or state governments related to workgroup recommendations would involve appropriate public participation and input.

After hosting two public presentations and input sessions in May 2013, the workgroup met 16 times between July 2013 and September 2015. Throughout its duration, the workgroup maintained open channels for public input and comments through a website and email. Over this same time period, an independent but related study (funded by the WDNR and United States Department of Agriculture-Agricultural Research Service (USDA-ARS)) was being conducted to quantify the risk of illness associated with airborne pathogens from manure irrigation (summarized in Appendix C of this report). The timeline and results for that study influenced the timing of final conversations and recommendations from the workgroup.

The workgroup reviewed a range of issues for this report related to manure irrigation. Sections of the report identify the initial benefits and concerns around the practice that led to the workgroup formation, discussions of health and environmental risk, review of manure as a material, manure management, and existing rules and regulations associated with various aspects of manure irrigation. The report also provides descriptions for seven considerations for use of manure irrigation practices that drove workgroup discussion and provided information necessary for developing workgroup recommendations.

Decisions and recommendations made by the workgroup were based on a consensus seeking process. For many aspects of guidance and recommendations, the workgroup did achieve consensus. In particular, the workgroup reached consensus about recommendations for baseline conditions that should be in place if manure irrigation practices are used. The workgroup reached lower levels of agreement (near consensus or close-to-near consensus) for recommendations related to setback distances for different land uses under various combinations of conditions (such as wind speed, wind direction, etc.).

Consensus baseline recommendations for all uses of manure irrigation practices are that operators must:

- Follow all existing relevant state and local laws regarding animal waste and nutrient management
- Have and follow a NRCS CPS 590 Nutrient Management Plan
- Take appropriate steps to minimize drift
- Ensure no overspray of irrigated manure
- Have suitable means of supervising/controlling the equipment (e.g., active supervision, automatic sensors/controls, etc.)
- Have suitable means of determining relevant weather information (to include: wind speed, wind direction, and temperature)

- Have means of preventing contaminated backflow if equipment is connected to water sources
- Ensure that no human waste or septage is added to (or processed with) the manure.

Additional recommendations apply depending on whether and how the manure is processed. Those include issues related to time of day, wind speed, total number of applications per year, and equipment (such as nozzles that produce larger droplet sizes).

Recommendations for setback distances generally do not reflect consensus among all group members. Setback distance refers to distance from the edge of the area wetted by irrigated manure. For forests, adjacent agricultural lands, and road right-of-way wetted perimeter could be at the property line.. Minimum setback distances of 100 feet were recommended (at near consensus or close-to-near consensus) for property lines of public recreational areas, including property lines for schools or playgrounds, and distances ranging from as high as 750 feet to as low as 250 feet (with additional conditions) for dwellings and occupied buildings. In all cases, setback distances to an occupied building would take precedence over setback distance to a property line. The full set of baseline conditions and setback distances are described in Chapter 5, along with degree of consensus.

This report represents a compilation of science and knowledge vetted through the varied perspectives of workgroup members. The workgroup had limited resources and did not have the capacity to perform comprehensive reviews related to some emerging areas of science that have been identified as concerns for manure irrigation. For the issues discussed, the emphasis was placed on understanding additional risk incurred when land application of manure is conducted with irrigation practices in comparison to conventional manure application practices. As noted, this report does not establish policy for any jurisdiction in Wisconsin. It is intended to serve as a resource for citizens and elected officials engaged in discussions about appropriate next steps for their communities around the issue of manure irrigation.



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# 1. Introduction

## ■ 1.a Workgroup goals and objectives

Manure irrigation refers to the practice of applying livestock manure or process wastewater through irrigation equipment. It generally involves pumping the liquid manure from a storage area (such as a manure storage basin) through pipes or hoses to equipment conventionally used for irrigation—for example, “center pivots” or “travelling guns”—that are used to apply the liquid material to a field.

Manure irrigation as an agricultural practice is widespread in several states, but is less common in Wisconsin. Among Wisconsin’s largest livestock operations (CAFOs – or Concentrated Animal Feeding Operations), very few use the practice, and there is no estimate available for the number of smaller, non-CAFO operations that currently use manure irrigation practices (See Section 2c for more information about CAFO and non-CAFO users in Wisconsin). Yet, several factors are causing more farmers to consider manure irrigation as part of their overall manure management system.

Wisconsin’s Manure Irrigation Workgroup formed in 2013 to *review a broad set of issues associated with manure irrigation and to develop guidance and recommendations* for state agencies, local governments, and citizens seeking to understand this expanding technology. The workgroup has no formal authority and expects that any public policy action by local or state governments related to workgroup recommendations would involve appropriate public participation and input. The workgroup was convened by University of Wisconsin-Madison (UW-Madison) College of Agricultural and Life Sciences and University of Wisconsin-Extension (UWEX) at the request of Wisconsin Department of Natural Resources (WDNR) and Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP) to provide an opportunity for diverse perspectives and interests to participate in the review process. Information in this report is intended to inform those decision-making processes.

The workgroup was asked to compile and review existing information, review new research, and produce written guidance and recommendations for the use of manure irrigation practices. Workgroup members (listed on the inside of the front cover) included researchers, state and local public health officials, staff from agricultural and environmental agencies, dairy farmers, conservation interests, and concerned stakeholders. As part of its review, the workgroup served in an advisory capacity to a separate independent research project led by two workgroup members and funded by WDNR and USDA-ARS. That study focused on quantifying risk of acute gastrointestinal illness associated with airborne pathogen transport from manure irrigation sites. Although independent efforts, the workgroup and research projects shared information and were mutually beneficial. Preliminary results from the study were

presented to the workgroup over the course of several meetings in 2015 to help form the basis for workgroup recommendations. A summary of the study is included in Appendix C of this report.

The Manure Irrigation Workgroup process began in May 2013 with two public research symposia intended to help establish a common reference point for workgroup participants and other interested stakeholders. The symposia reviewed research and local knowledge related to benefits, concerns, and open questions associated with manure irrigation practices and solicited input. Presentations from the May 17, 2013 symposium are posted at the workgroup website (<http://fyi.uwex.edu/manureirrigation/>). The issues identified through those public forums provided an outline for workgroup discussions.

### ■ **1.b Workgroup process and activities**

The benefits and concerns identified by stakeholders (see Section 1c below) helped shape the agenda for the workgroup, and over its two-year duration, workgroup discussion touched on all of those issues. The workgroup met 16 times between July 2013 and September 2015. Agendas for individual meetings were set by the chair, often with suggestions and specific requests from workgroup members. There was no specific state funding allocated for workgroup support. Rather, workgroup members provided their time and in-kind support through their public agency and private organization resources. The workgroup maintained a website that included information about each meeting as well as background information and related reports. Throughout its duration, the workgroup maintained open channels for public input and comments through the website and email. All comments submitted were shared with the workgroup at the beginning of each meeting. Meetings were announced on the website and also through an email list open to anyone expressing an interest.

The workgroup operated under a set of ground rules established at the first meeting. These included agreements to focus on learning and problem solving, remain open to new information and perspectives, discuss difficult issues, and keep discussions focused. The workgroup agreed to seek consensus on workgroup decisions, and where consensus would not be possible, to note majority and minority perspectives. Most of the meetings involved discussing and vetting information from multiple perspectives. The final few meetings focused on understanding preliminary results of the Borchardt and Burch pathogen study (Appendix C) and making decisions about workgroup recommendations.

Additional details are available at the workgroup website: (<http://fyi.uwex.edu/manureirrigation/>)

### ■ **1.c Initial concerns and benefits raised regarding Manure Irrigation**

The May 2013 public symposia and subsequent comments shared with the workgroup identified potential benefits and defined concerns related to manure irrigation. Comments shared with the workgroup during and following those events represented strong and differing opinions on the relative merits and potential consequences associated with manure irrigation in Wisconsin. Comments and



opinions included outrage over perceived risks to health and quality of life, advocacy for advantages of the practices over existing alternatives, and requests for cautious assessment. The central benefits and concerns related to those comments are summarized below.

Expressed concerns initially identified for the workgroup agenda

Concerns identified for the workgroup included questions related to the physical process of manure irrigation and the potential for negative consequences from drift, deposition, and volatilization of wastewater components. The workgroup sought to understand and address these concerns, which reflected several themes:

- **Public health risk from airborne pathogens and other contaminants.** Those sharing comments against manure irrigation practices expressed very strong concerns that wet and dry airborne materials from the application process could be transported to nearby and/or distant properties and cause harmful effects. Specific concerns included potential conveyance of pathogens, particulates, antibiotics, cleaning compounds, toxic gases associated with stored and land-spread manure wastes, endocrine disruptors, and antibiotic-resistant pathogenic bacteria. There was also concern that contaminants in aerosol form might be inhaled and carry toxins to the bloodstream more directly than if ingested. In addition to the health concerns for the general population, there were additional concerns over potential increased health risks to vulnerable populations such as the elderly and those with compromised immune systems.
- **Drift.** Public comments included concerns that irrigation practices could result in drift of wet manure material that could deposit on neighboring properties, surface waters, and crops in nearby fields. Organic and specialty farm interests raised concerns about the risk of losing organic certification and/or product marketability due to drift.
- **Odor and other quality of life concerns.** Reinforced by statements of people with homes near fields using manure irrigation, concerns were expressed about odor, respiratory health, poor air quality, increased airborne particulates, general contamination and potential constraints on the use and enjoyment of public and private property.
- **Surface water quality contamination.** Concerns were expressed about the potential for contamination of surface water related to runoff from precipitation events after manure irrigation application and about direct deposition of irrigated materials into waterways.
- **Groundwater quality contamination.** Concerns raised about groundwater quality included potential threats to wells and aquifers from irrigation applications where pathways to groundwater may be more direct such as on sandy soils or fractured bedrock areas. Concern about manure backflow into aquifers through irrigation water supplies was also mentioned.

- **Groundwater quantity.** Concerns also extended to groundwater quantity, specifically that manure irrigation may draw down groundwater levels due to the installation of irrigation systems and the need for additional water to dilute manure prior to application.
- **Implementation and compliance issues.** Concerns were also raised about the ability of farm managers to implement requirements associated with the use of manure irrigation as well as challenges for public agency staff in monitoring compliance with any required manure irrigation management practices.

#### Potential benefits initially identified for the workgroup agenda

In identifying an initial set of issues for the workgroup, those supporting the use of manure irrigation practices initially identified multiple potential benefits compared to other available options for manure transportation and application. The benefits group into three main issues.

- **Timing of manure application.** In contrast to trucks and tankers that move manure onto fields primarily in spring and fall, before planting and after harvest, manure irrigation allows for application to a growing crop when plant-nutrient uptake is highest. This in-season timing has the potential to reduce the volume of manure applied in the spring and fall (when risks of surface runoff may be higher) and shift application to drier summer months. Applying nutrients during the growing season may deliver nutrients more directly to the plant during peak uptake periods and decrease potential for nutrient loss to groundwater or surface water. The ability to apply smaller volumes per acre more often during the growing season may reduce the likelihood of ponding, macro-pore transport, and weather-related runoff risks. In-season application also increases the time period for planting of fall/winter cover crops which helps reduce the risk of nutrient runoff and losses below the crop root zone to groundwater.
- **Road safety and reduced road damage.** Piping liquid manure and process wastewater to a field and distributing through irrigation equipment reduces the numbers of trucks, tankers, and other heavy equipment that would otherwise haul that material on roads. Redirecting manure transport and distribution off of the roads would reduce road traffic from farm equipment, reduce road weight and damage on roads, and reduce the risk of traffic accidents and road spills.
- **Farm management and economic benefits.** Manure irrigation practices have the potential to allow farm managers to have more precise control over application rates and timing, lower distribution costs, and reduce soil compaction due to heavy equipment on fields in spring and fall. By allowing summer application on growing crops, it reduces the timing challenges of applying manure prior to planting in a late spring (related to weather, soil moisture, availability of custom manure haulers, and planting) or following fall crop harvest before frozen ground and snow covered conditions.

## ■ 1.d Health and environmental risk - key concepts

As an introduction, several key concepts about risk and public health policy provide an important foundation for understanding potential implications of any management activities for public health and the environment. What follows are brief descriptions of risk perception, calculations of risk, individual behavior factors related to exposure, and acceptable exposure to pathogens. These concepts informed workgroup discussion and they set the stage for more detailed information used to evaluate the concerns and benefits presented throughout this report.

Closely related to these concepts is how to weigh their significance and consider public policy responses. Although not required by federal or state law, the precautionary principle as used in Europe often arises in public discussions around health and environmental risk. One version of this states, “When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. The precautionary principle says we should attempt to anticipate and avoid damages before they occur or detect them early” (Wingspread 1998). It falls to legislative and administrative bodies at local, state, and federal levels to determine the appropriate balance of factors for their jurisdictions.

### Risk perception

Daily activities present people with many situations that carry some probability or potential for harm, otherwise known as risk. Driving a car, walking down stairs, getting a medical x-ray, or eating certain foods all entail some chance of negative impact to an individual’s health or safety. The amount of actual risk involved in an activity depends upon many factors specific to the situation. For a specific activity an individual may have some fear or dread corresponding to their knowledge of a risk. Dread may increase or decrease based on ability to observe or control a perceived hazard. However, an individual’s perception of a hazard may not correspond to quantifiable estimates of risk. Risk, in an environmental sense, is defined by the USEPA as “the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor.”

### Calculation of risk

Risk can be calculated using quantifiable measurements of hazards combined with estimates of behavior or situations that bring people into contact with hazards. The calculation of human health risk in environmental situations involves two main elements: (1) the presence of a possibly harmful chemical, physical, or microbial agent in the environment at a concentration sufficient to cause harm, and (2) an exposure to that harmful substance. The calculation of risk involves the assignment of a probability to each of these main elements. It is important to understand that in terms of the probability for harm, if one of these elements is absent, the risk is interrupted. As an example, a chemical contaminant might be present in shallow groundwater in an urban area. If the people living in that area do not obtain their drinking water from that contaminated source, then there is no exposure to the contaminated source, and no corresponding risk. Environmental laws may still require reducing or elimi-

nating the contaminant due to the potential of exposure from other pathways or ecological effects.

#### Individual behaviors that affect exposure

Individual behaviors can impact a person's exposure to a contaminant. For example, people breathe different amounts of air each day, drink a range of volumes of water, eat different foods, and spend time in different environments. Public health standards and guidelines for environmental contaminants include considerations for potential harm to the most sensitive members of the population. The standards and guidelines for exposure media such as soil, food, water, and air are adjusted based upon the exposure expected for various populations. We minimize our risk of exposure to pathogens by monitoring and controlling their presence where possible, and more broadly by sanitary practices that interrupt exposure pathways. Examples include hand washing, sanitation practices for food preparation, avoiding swallowing lake water while swimming, and properly cooking meat.

The harmfulness of an environmental agent is typically developed from a dose-response study. These studies expose a population to a range of contaminant exposure levels, or doses, and measure the effect (response) in that population. Dose response studies can also be constructed following acute or chronic exposure to a contaminant. The measured response can be defined in many ways including number of illnesses, effects on reproduction, effects on a body organ or organ system, or mortality. Over the range of exposures administered to the population, there will be some high dose or concentration above which all of the population is affected. There will usually be some dose or concentration that is above zero, but below which no effects are measured, also known as a no observable adverse effect level (NOAEL). Between these extremes there is an intermediate probability that any individual within the population will be affected at a particular exposure level.

The dose-response study is a key tool used to determine acceptable exposures to an environmental agent. Many types of contaminants are widespread in the environment, and may be from both natural and human-introduced sources. The effects of some agents are difficult to measure at very low concentrations. However, it is generally accepted that contaminant concentrations levels less than the NOAEL, are below the threshold needed to produce a measured human health effect. The graphed curve of a dose-response study allows for the estimation of these NOAELs (see Figure 1d-1). There is always some uncertainty surrounding the extrapolation of a dose-response study conducted with experimental animals to humans. For this reason, an NOAEL determined experimentally on animals is generally used as a starting place to calculate an acceptable exposure for humans that is much more stringent. For most chemical contaminants, chronic exposure is considered acceptable if it results in no more than one-in-one hundred thousand to one-in-one million (10<sup>5</sup> to 10<sup>6</sup>) extra illnesses in the population over the span of one's lifetime. In many cases, the accepted approach of extrapolating from the experimental evidence may result in an environmental guideline or standard that lacks biological relevance. In other words, the established standard may be based on a calculation of infinitesimal risk. However, this approach is useful in satisfying the Precautionary Principle as it applies to public health policy.

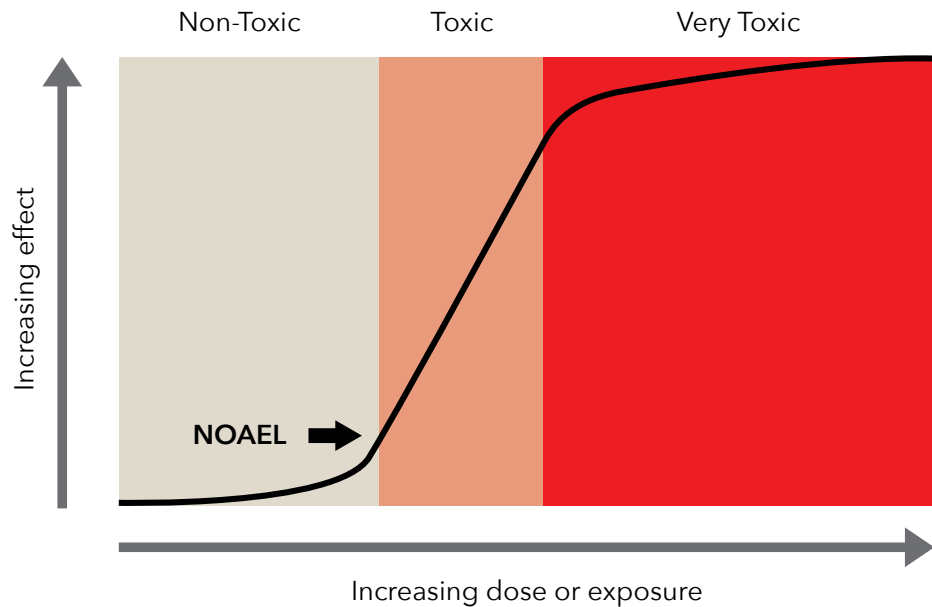


Figure 1d-1. A simple Dose-Response curve, illustrating the concept of increasing probability of effect with increasing exposure, with a threshold no observable adverse effect level (NOAEL) or non-toxic exposure range, and a saturated or very toxic exposure range. Figure modified from Osman 2011.

#### Acceptable exposure to pathogens

Exposure to a pathogen is a hazard that does not always result in disease. The risk of infection (ingesting or inhaling a certain amount of that pathogen that is necessary to cause infection in the body) is a function of factors discussed previously: 1) the presence of the potentially harmful microbial agent in the environment at a concentration sufficient to cause harm, and 2) a completed exposure pathway. The hazard from exposure to a pathogen depends not only on the probability of infection, but also the probability of developing illness from that infection, the severity of illness, duration of illness, and any potential complications.

Public health standards are based on acceptable levels of illness for different types of exposure and activity. For example, standards have been established for acceptable concentrations of fecal-related microbes in recreational surface water and drinking water in order to minimize exposure, infection, and illness. For swimming and recreational contact in surface waters, USEPA recommends concentrations of indicator bacteria (*E. coli* and Enterococci) that are estimated to result in 32 illnesses per 1,000 people who ingest water with that concentration of the microbes present. For drinking water standards, acceptable concentrations are much lower so that one in 10,000 who ingest water with that concentration are estimated to become ill. Actual individual infection rates would vary with such things as individual immune status. Recreational waters and drinking water are sampled regularly to ensure concentrations are below those threshold levels.

These key concepts around health and environmental risk are discussed throughout this report. Chapter 3 (and Section 3e in particular) provides a more detailed discussion of pathogen exposure associated with manure irrigation, drawing from the results of the research project summarized in Appendix C. The research examines issues related to the distance of pathogen drift from manure irrigation, and their viability as they are transported in the air.

## ■ 1.e Organization of the report

The remainder of this report is organized into four chapters addressing the key issues explored by the workgroup. Chapter 2 provides background information about manure, manure management, and state and local regulations relevant to manure irrigation. Chapter 3 summarizes information compiled and discussed by the workgroup related to the central concerns and benefits identified at the outset of the review process. There are sub sections in Chapter 3 for droplet drift, odor, water quality, air quality, airborne pathogens, timing related to nutrient application and road concerns, and farm management and economic issues. Chapter 4 describes scenarios where manure irrigation practices might be experienced in a realistic setting. Chapter 5 presents the workgroup response and recommendations regarding use of manure irrigation in Wisconsin.

### References for Chapter 1:

- United States Environmental Protection Agency (USEPA). Basic Information on Water Quality Criteria. Website: <https://www.epa.gov/wqc/basic-information-water-quality-criteria>
- Osman KA. 2011. Pesticides and Human Health. *Ch. 11 in Stoycheva M., ed. Pesticides in the Modern World: Effects of Pesticides Exposure.* ISBN 978-953-307-454-2.
- Wingspread Statement. 1998. cited in an essay by Schettler et al. in McCally M. (ed.) 2002. *Life Support: The Environment and Human Health.* Cambridge, MA:MIT Press. The full statement is also available at: <http://www.sehn.org/wing.html>

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## 2. Manure and Manure Application

### ■ 2.a Manure

Manure is produced from livestock as feed is degraded and then excreted. Manure contains water and solid materials comprised of organic matter, nutrients, and microorganisms among other components not removed during the animal digestion process. The concentration and form of these constituents can vary significantly based on the feed and the animal itself. Therefore, the characteristics of manure are constantly changing over time and from animal to animal. Although the content of manure is variable, numerous documents provide averages and ranges for many of the components; these include MWPS 18-1 Manure Characteristics, UWEX A2809 Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin, and ASABE Standard 384.2 Manure Production and Characteristics, listed in the references for this section.

Manure is commonly characterized by commercial laboratory analysis for total solids (TS) or dry matter (DM), nitrogen (N), phosphorus (P), and potassium (K). Additional manure analysis for specialized applications is available on a more limited basis. TS is a key characteristic because it often dictates mechanical requirements for handling, storage, and land application of manure. Generally manure TS as excreted directly from the animal are highest for poultry, followed by beef, then dairy, then swine (TS in poultry > beef > dairy > swine), although exceptions can occur. Average values for TS and nutrient content in manure is evaluated through samples submitted across the state (see Tables A-1 and A-2 in Appendix A).

Manure has long been used by Wisconsin farmers as a source of essential nutrients for crop production. Nutrient content (N, P, K, etc.) determines the amount of manure necessary to optimize crop production and minimize losses to the environment. Manure application rates are adjusted in nutrient management planning to account for the movement of nutrients in an integrated livestock and crop system. The overall goal of nutrient management planning is to apply manure nutrients to the field at a rate and time that corresponds to crop nutrient uptake optimizing yields and limiting nutrient losses. Nutrient management guidance and regulations for Wisconsin are well documented in numerous publications (including guidance in UWEX A2809 Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin and NRCS CPS 590) and are discussed in more detail in Section 2c.

Microorganisms naturally present in the animal gut (pathogenic and non-pathogenic) are also present in manure. The profile and concentration of these microorganisms can vary based on a number of factors including but not limited to animal type, herd and individual animal characteristics, and animal diet. Many microorganisms are beneficial, non-pathogenic, and do not pose a threat to the hosts. However, some microorganisms are pathogenic and may pose a health risk to other animals of the same species or may be transmitted from animals to humans (also known as zoonotic pathogens), posing a threat to human health. For example,

most strains of *Escherichia coli* (*E. coli*) are harmless to humans, but strains such as enterohaemorrhagic *E. coli* (EHEC), which includes *E. coli* 0157:H7, can cause illness in humans. As with the other manure constituents, the content of pathogens in the manure can change depending upon the health of the animals or the handling and processing of the manure. It is difficult to predict what pathogens are present in manure, and whether those pathogens are present in infectious concentrations. Table 2a-1 lists several pathogens found in livestock manure and their prevalence.

Table 2a-1: Pathogens in livestock manure and manure slurries

Pathogen	Occurrence (% of positive manure samples)*			Infective Doses
	Cattle	Poultry	Swine	
<b>Bacteria</b>				
<i>Salmonella</i> spp.	0.5 - 18	0 - 95	7.2 - 100	100 -1,000 cells
<i>E. coli</i> 0157:H7	3.3 - 28	0	0.1 - 70	5 -10 cells
<i>Campylobacter</i> spp.	5 - 38	57 - 69	14 - 98	< 500 cells
<i>Yersinia enterocolitica</i>	-	-	0 - 65	10,000,000 cells
<i>Listeria</i> spp.	0-100	8**	5.9 - 20	<10,000 cells
<b>Protozoa</b>				
<i>Cryptosporidium</i> spp.	0.6 - 23	6 - 27	0 - 45	10 -1,000 oocysts
<i>Giardia</i>	0.2 - 46	-	3.3 - 18	10-25 cysts

Source: From USEPA 2013, Page 14, Table 3-1. "Occurrence, infective doses, and diseases caused by some of the pathogens present in manure and manure slurries from cattle, poultry, and swine." (note: original table includes additional information and references.)  
 \* Percentage of manure samples testing positive for the pathogen. Range of minimum and maximum percentage as reported in the literature. \*\* Based on a single study. Pathogen not detected for species in cells with hyphen (-)

Manure may also include other materials produced by the animal (e.g. hormones) or not removed through the animal's digestion process (e.g. antibiotics). These materials are often considered to be emerging contaminants because little is known about their environmental fate and impact. Therefore they are topics of active research which has yet to establish clear relationships. Some studies have examined correlations between emerging contaminants from livestock operations and human health impacts but many mechanisms are not well understood.

#### Farmstead by-products added to manure

Although the textbook definition of manure is the material excreted by the animal, livestock and poultry facilities commonly include other by-products from the farmstead as manure is collected and stored. By-products commonly include animal urine and bedding but can also include farmstead runoff (from animal or feed storage areas), cleaning waste from milking facilities or other animal housing areas, spoiled feed and other spoiled products, runoff from animal sprinklers and other



excess water sources. This can also include animal mortalities when composting or processing is involved.

Additional products and treatments

Some facilities may also take additional products from outside the farm facility to add to processing systems (described in Section 2b below). Producers may add these products to increase efficiency or for operational feasibility (e.g., for anaerobic digesters or composting), to increase their nutrient content for land application, or for revenue from tipping fees. Many are added to manure mixes for composting to achieve the characteristics needed for degradation by aerobic microorganisms (e.g., carbon-to-nitrogen ratio, moisture, or porosity). Some products are also added to anaerobic digesters to increase the quantity or the methane content of the biogas produced during anaerobic degradation by microorganisms. As both of these systems are biological and use microorganisms to degrade organic feedstocks, products accepted for these purposes must be non-toxic to the microorganisms within the system for the system to remain viable and active. The types of waste accepted for these systems in Wisconsin are outlined in Table 2a-2 below. For additional information about content of material in manure processing, see USEPA 2013.

*Table 2a-2: Acceptable amendments for composting and digestion*

Process	Amendments or Feedstocks Added to Process
Composting	Food waste, yard clippings, sawdust, wood chips
Anaerobic Digestion	Food waste, food processing waste, fryer grease, grease trap waste from food manufacture, paunch manure, blood and sludge from animal/meat processors, leachate from paunch manure dewatering, lime slurry, whey permeate, process wastewater from dairy and vegetable processors, sweet corn silage leachate

Source: WDNR

As part of the Wisconsin Pollution Discharge Elimination System (WPDES) water quality permitting process for CAFOs in Wisconsin, WDNR adds conditions for manure content (See Section 2c below). Permitted livestock facilities are required to specify in their nutrient management plan the additional off-farm wastes that they accept. If a facility accepts waste from an outside source, the waste must then be handled according to whichever facility (source or recipient) has the stricter standards—i.e., either that of the agricultural facility or those of the facility that produced the additional waste material. Therefore if a livestock facility were to accept any material deemed to be a highly hazardous regulated waste, then that facility must follow the more strict rules attached to that waste. If a facility were to accept septage waste, they must follow the regulations outlined for pathogen control and vector attraction requirements for septage. If a facility accepts industrial waste, the content of that waste must be approved by the WDNR wastewater program regardless of the volume it accepts, even if it is below the 10% exemption pursuant to Wisconsin Administrative Code chapter NR 214.17 (as is required for proper tracking of industrial waste disposal for all permitted facilities that engage in manure pit/digester disposal).

Although each request is unique, a typical WDNR plan approval condition required for a CAFO to accept industrial wastewater into a digester would include the sample language for appropriate substrates included in the sidebar (below). Biofuel wastes, and other wastes not exclusively from food processing, are to be tested upon initial acceptance and annually thereafter for parameters in ch. NR 217 and meet the criteria for exceptional quality sludge (see Table 2a-3).

*Table 2a-3. Maximum allowable concentrations of industrial wastes not exclusively from food processing*

Parameter	Maximum Concentration
Arsenic	41 mg/kg
Mercury	17 mg/kg
Lead	300 mg/kg
Cadmium	39 mg/kg
Molybdenum	40 mg/kg
Selenium	100 mg/kg
Copper	1500 mg/kg
Nickel	420 mg/kg
Zinc	2800 mg/kg

Source: WDNR

**References for Section 2a:**

American Society of Agricultural and Biological Engineers (ASABE) Standard 384.2 “Manure Production and Characteristics.” <http://www.asabe.org/publications.aspx>

Midwest Plan Service (MWPS) 18-1 “Manure Characteristics.” Published by Iowa State University. <http://www.maeap.org/uploads/files/Livestock/MidWest-Plan-Service-Charts.pdf>

United States Environmental Protection Agency (USEPA). 2013. “Literature Review of Contaminants in Livestock and Poultry Manure and Implications for Water Quality”, Office of Water (4304T), EPA 820-R-13-002, July 2013. <http://water.epa.gov/scitech/cec/upload/Literature-Review-of-Contaminants-in-Livestock-and-Poultry-Manure-and-Implications-for-Water-Quality.pdf>

University of Wisconsin Extension (UWEX) A2809 “Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin.” <http://learningstore.uwex.edu/assets/pdfs/A2809.pdf>.

SIDE BAR: Sample language included in a WPDES permit for accepting additional material as part of manure processing.

Approved Substrates: Substrates shall be limited to the types and sources in the following table, and shall not contain septage, or chemical or physical contaminants that will adversely affect the digester effluent as a material for land application. Substrates may include mixtures co-mingled from different generators, but not waste from unspecified generators, and no waste that is subject to regulation as a hazardous waste.

Approved Substrate Type	Substrate Source
food processing & preparation by-products *	vegetable food preparation, distribution & processing; & dairy food preparation, distribution & processing
dissolved air floatation (DAF) sludge, blood, offal & other animal wastes	meat slaughtering & meat packing operations; & other meat preparation, distribution & processing, including rendering
glycerin from biodiesel manufacture, & thin stillage from ethanol manufacture	biofuels manufacturing

\* Examples of approved food processing and preparation by-products, include the following: cranberry mash; vegetable cuttings; cheese whey; fryer grease; and grease trap waste from food manufacture and food services (segregated from human waste). [Source WDNR]

## ■ 2.b Manure Management

Each livestock facility has an individualized arrangement of components that combine to create its manure management system. Manure handling systems typically have four major components: (1) collection, (2) processing/treatment, (3) storage, and (4) transfer and land application (Figure 2b-1). Although not all manure handling systems have all four components, almost all (aside from grazing systems) include manure collection and land application. Adding processing or storage into manure management systems has been a result of cost, regulation, environmental impact, or general operational efficiency changes. Manure storage components have been integrated into almost all larger livestock facilities and also for many medium and small sized facilities. Some larger livestock operations have also included (or are considering) the use of additional treatment components.

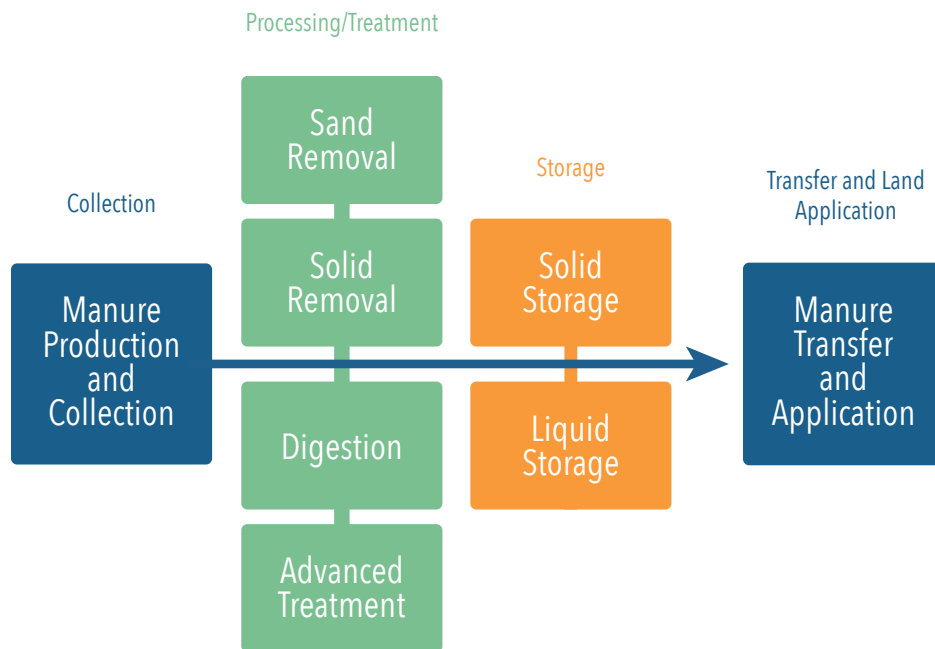


Figure 2b-1: Manure handling system components

Each of the four manure system components have multiple technology and management options that may alter manure consistency, management flexibilities, costs, and environmental impacts among others. It is critical for effective operation that all components of a manure management system are compatible. A brief overview of some of the more common manure system components (and compatibility with irrigation equipment) is provided below. More information on the tradeoffs and operational impacts of manure system component selection are discussed in Chapter 4.

#### Component 1: Collection

Manure collection includes the gathering and transfer of manure within a housing facility to other system components. The specific manure collection system has relatively little impact on manure irrigation.

#### Component 2: Processing/treatment

Manure processing systems are used to treat or alter the physical handling characteristics of manure to allow for increased management options and/or reduce negative impacts. Some manure processing systems that are in operation today include solid-liquid separation (most common), anaerobic digestion (less common), and advanced treatment (least common).

- **Solid-liquid separation.** Solid-liquid separation is the settling or mechanical separation of manure solids from manure liquids resulting in two products with different characteristics than the original product. Manure must have a low total solids content in order to be pumped and land applied as liquid. It is recommended that manure contain below 10% total solids content to enable use of

a traditional manure pump. Total solids must be even lower for material to pass through irrigation nozzles without clogging. For traveling gun systems the solids are recommended to be below 5%, and below 3% for center pivot systems (for which the irrigation nozzles are smaller). Solid-liquid separation is commonly achieved through passive settling systems such as manure basins, sometimes with numerous basins in series, or by using mechanical systems. Mechanical systems for separation include screw presses, screens in different configurations, and others which commonly use screens for separation of liquids and solids. Separation systems change the total solids content in the manures' liquid and solid forms as well as the nutrient density, pathogen content, nutrient availability to plants and other aspects. In general, the separation results in the liquid stream having an increased nitrogen-to-phosphorus ratio and the solid material having a lower ratio.

- **Anaerobic digestion.** Anaerobic digestion is a controlled biological degradation process which occurs in an environment without oxygen. This degradation occurs naturally by microorganisms which already exist in manure. Anaerobic digestion systems convert carbon within the manure to methane which is captured and combusted, commonly to generate electricity. During the digestion process, manure is heated and degraded changing manure characteristics, although the manure still remains and must be managed after the digestion process. Some of the major changes to manure following digestion include the reduction in pathogen concentrations. Significant reductions (>80%) have been shown to occur, although in cases where there are high initial concentrations of pathogens, digested manure may still retain pathogens at concentrations that could contribute to human health risk (Burch et al, 2016). In addition, anaerobic digestion systems have fluctuations in performance, and pathogen reduction efficiency may change over time. The temperature at which a digester is maintained is another important factor in reducing pathogen concentrations. Generally, mesophilic digesters operate between 90-110 °F and thermophilic digesters between 120-140 °F. Digestion systems have also been shown to mineralize nutrients (Wright et al, 2004) and reduce odors, although odor reductions are difficult to quantify. While anaerobic digestion systems have many potential benefits, they also require significant capital investment.
- **Advanced treatment.** Advanced treatment refers to the use of additional systems to further separate or reduce nutrients, pathogens, and odors from livestock manure and process wastewater. Advanced treatment systems can be used to sterilize manure (manure pasteurizers) or can be used to purify the liquid fraction of manure to meet discharge standards for water quality. Options for advanced treatment include membrane systems, biological treatment systems, reverse osmosis, and others. These systems require high initial capital costs and significant ongoing operating costs (including high energy demand), which are typically greater than the current land application costs incurred by many facilities. Advanced treatment systems are highly variable in their design and performance, and the costs associated with the systems have reduced their implementation, although they are present at some livestock facilities around the country, including in Wisconsin. Manure pasteurizers are used more commonly in many European countries and are installed specifically to reduce pathogen concentra-

tions in manure to reduce impacts during land application.

- **Composting.** Although designed for solid manure management and not compatible with manure irrigation, composting is another process option for livestock manure. Information about composting systems is readily available from multiple sources.

### Component 3: Storage

Manure storage is commonly integrated into manure systems to accommodate operational issues with manure handling and to increase flexibilities in application timing. Storage enables producers to apply manure at times which result in the least environmental impact (such as runoff and leaching) including when the ground is not frozen, soils are not saturated, and there is no precipitation forecast. Installation of manure storage systems is highly regulated and involves strict standards for design, operation, and maintenance, including a nutrient management plan (see Section 2c below for more details). A liquid manure storage system is necessary for use of manure irrigation due to the need for a large volume of manure for pumping during application periods, particularly for center pivot systems.

### Component 4: Transfer and application methods

Many manure application methods are available to apply manure to cropland. Most facilities use a combination of manure application technologies to allow them to meet environmental, operational, regulatory, and economic constraints. Commonly, manure has been hauled to fields from a storage area and applied to land with spreaders and tankers (see Figure 2b-2). The volume capacities of these range from approximately 3,000-10,000 gallons per tanker load. Permanent and non-permanent transfer lines are also used for moving manure to the field. Permanent lines are buried beneath the soil surface while non-permanent lines (typically flexible hoses) are laid out for each manure application period (generally one or two times per year). Pumping manure through transfer lines reduces the total number of truck loads and the number of miles trucks travel on roads. Permanent lines have a significant capital cost which makes them infeasible for many operations. Use of manure irrigation systems may involve a shift in manure hauling practices from road vehicles to pumping systems. However, pumping systems can also be used with other application methods, and it is common to pump manure without the use of irrigation systems. Any permanent pipelines for manure irrigation would require regular monitoring to ensure the lines do not leak. In addition, if the lines connect to water systems there must be back flow prevention to ensure no manure can contaminate those water sources.

Other common field application methods include surface broadcast of manure (where manure is spread from heights up to 10 feet above the ground using a splash plate instead of a nozzle) and injection systems (where manure is injected into the ground and covered with soil) (See Figure 2b-2). These methods can be used with tanker hauling equipment as well as the pumping techniques described above. Many facilities with liquid/slurry manure systems use a variety of techniques to apply manure. The choice is influenced by field constraints (e.g., slope, soil type), weather

and soil conditions (particularly for fields with a high moisture content), environmentally sensitive features, time of year, cropping system, and cost.

Irrigation with a traveling gun might occur when manure cannot be applied with tractors or tankers, when manure storage systems are reaching capacity and there is need to avoid overtopping, and when crops would benefit from numerous nutrient applications or need additional water during the growing season. Center pivot irrigation systems might be used to decrease compaction, apply greater volumes of more dilute manure, reduce irrigation water needs, and apply nutrients to crops throughout the growing season. Additional information about farm management issues associated with manure irrigation is presented in Sections 3f, 3g, and Chapter 4.

References for Section 2b:

- Burch, T.R., S.K. Spencer, S.S. Borchardt, R.A. Larson, A. Alkan-Ozkaynak, M.A. Borchardt. 2016. Inactivation of dairy manure-borne pathogens by anaerobic digestion. Presented at Annual Conference of the Wisconsin Chapter of American Water Resources Association. March 2016.
- Wright, P., S. Inglis, J. Ma, C. Gooch, B. Aldrich, A. Meister, & N. Scott. 2004. Comparison of Five Anaerobic Digestion Systems on Dairy Farms. 2004 ASAE/CSAE Annual International Meeting, Ottawa, Ontario, Canada. Paper No. 044032.

Figure 2b-2. Manure application equipment



1. manure injection, 2. broadcast spread with a tanker, 3. traveling gun and reel, 4. operating traveling gun, 5. center pivot with drop nozzle, 6. center pivot end gun



## ■ 2.c Existing rules, regulations, and practices related to manure irrigation

### Prevalence of Manure Irrigation in Wisconsin

The current prevalence of manure irrigation in Wisconsin is largely unknown. The existing statewide rules that directly regulate manure irrigation only apply to CAFOs that are permitted by the WDNR through the Wisconsin Pollutant Discharge Elimination System (WPDES) process. Smaller non-CAFO farms (not operating under a WPDES permit) have fewer regulations and are not required to report their use of manure irrigation practices. Information presented below addresses statewide rules for all farms, additional rules for CAFOs, and local rules in Wisconsin regarding manure irrigation.

In early 2014, the WDNR distributed a survey to all WPDES-permitted facilities asking whether the farm is currently using manure irrigation, plans on using manure irrigation within the next two years, or is not using manure irrigation and does not intend to do so within the next two years. The survey was sent to approximately 250 farms across the state and had responses from 69 farms, for a 28% response rate. Of the respondents: 12 farms indicated they had or currently use manure irrigation, 10 farms planned on using manure irrigation within the next two years, and 47 farms were not using manure irrigation and do not intend to use the technology over the next two years.

Since the survey was completed, the WDNR has required CAFO facilities to update their nutrient management plan (NMP) to include additional information related to manure irrigation. WDNR indicates that these same requirements will apply to those farms who anticipate using manure irrigation. Required updates to the CAFO NMP include information related to fields being used for manure irrigation, including required setback distances and soil types, characteristics of the manure or process wastewater that would be applied through manure irrigation, irrigation equipment design, operation practices, field monitoring, and other pertinent information. As of March 2016, seven CAFO farms in the state had successfully applied and were approved by the WDNR to use manure irrigation, and four were pending. Table 2c-1 identifies the CAFOs that are currently permitted and using manure irrigation or for which a decision is pending.

Table 2c-1. Wisconsin CAFOs Approved for Manure Irrigation

Farm	County	Equipment	Treatment
Central Sands Dairy	Juneau	Center Pivot	Manure digester
Green Valley Dairy	Shawano	Center Pivot	Manure digester
Holsum Elm & Irish Dairies	Calumet	Center Pivot (mobile)	Manure digester
Maple Leaf Dairy	Manitowoc	Center Pivot	Manure digester
Pagels Ponderosa	Kewaunee	Center Pivot (mobile)	Manure digester
Robinway Dairy LLC	Manitowoc	Center Pivot	Reverse osmosis
Rosenholm Dairy LLP	Buffalo	Traveling Gun	Solids separation with aerobic treatment for liquid manure
Dallman East River Dairy^	Calumet	Center Pivot	
Ocooch Dairy^	Vernon	Traveling Gun	
Ostrowski Farms^	Marathon	Center Pivot	
UW Arlington Research Station^	Columbia	Traveling Gun	

^Approval pending or temporarily revoked  
 [Source: WDNR, as of March 2016]

### Current Statewide Wisconsin Rules for All Farms

Current Wisconsin rules and regulations that affect the use of manure irrigation include chapters NR 151, NR214, and NR243, Wisconsin Administrative Code and Natural Resources Conservation Service Conservation Practice Standard 590 (NRCS CPS 590), sometimes called the “NRCS 590 standard” or a “590 NMP.” Non-CAFO farms do not have to meet NR 214 or NR 243 requirements. However, these farms do have to meet Wisconsin’s NR 151 performance standards that require having and implementing a NMP. As a side note, Wisconsin Department of Agriculture Trade and Consumer Protection (WDATCP) tracks NMPs filed with the state, and as of 2015, approximately 31% of total cropland acres have official plans on file (WDATCP 2015). Through chapter ATCP 50 Wisconsin Admin Code, NMPs must be consistent with the 2005 version of the NRCS CPS 590. Most Wisconsin counties also have manure storage ordinances and/or farms that participate in Wisconsin’s Farmland Preservation Program. These ordinances or tax credit programs require having and implementing a NMP consistent with the NRCS CPS 590. Table 2c-2 summarizes the setback distances a farm with a NRCS CPS 590 NMP must follow when applying manure or process wastewater regardless of the application method. NRCS adopted a new NRCS CPS 590 Nutrient Management Standard in December 2015. There are additional application restrictions included within this new standard. WDATCP is currently in the rule promulgation process to include this new standard.

Table 2c-2. Current manure application setback distances for farms with NRCS CPS 590 NMPs

Restrictive Feature	2005 Setback	Code Reference
Community Public Water Supply Well	50 feet <sup>1</sup>	NRCS CPS 590 V.A.2.(3) mechanical applications prohibited within 50', V.B. <sup>2</sup>
Non-Community Water Supply Well	50 feet <sup>1</sup>	NRCS CPS 590 V.A.2.(3) mechanical applications prohibited
Inhabited Dwelling	50 feet <sup>1</sup>	NRCS CPS 590 V.A.2.(3) mechanical applications prohibited
Depth to Groundwater & Bedrock	12 inches & 20 inches	NRCS CPS 590 V.B. <sup>2</sup>
Direct Conduit to Groundwater	200 feet	NRCS CPS 590 V.A.2.(3) incorporation <sup>3</sup>
Navigable Waters & Conduits	300 or 1,000 feet	NRCS CPS 590 V.A.2.b. Perennial streams (continuous flow) winter prohibition <sup>4</sup>
Wetland	None	
Dallman East River Dairy <sup>^</sup>	Calumet	Center Pivot
Ocooch Dairy <sup>^</sup>	Vernon	Traveling Gun
Ostrowski Farms <sup>^</sup>	Marathon	Center Pivot
UW Arlington Research Station <sup>^</sup>	Columbia	Traveling Gun

Source: WDATCP

<sup>1</sup> Maintain 50 feet setbacks from drinking water wells

<sup>2</sup> To minimize N leaching to groundwater on high permeability soils, or soils with less than 20 inches to bedrock, or soils with less than 12 inches to apparent water table, or within 1,000 feet of a municipal well NRCS CPS 590 requires:

- No fall commercial N applications except for establishment of fall-seeded crops. Commercial N application rates, where allowed, shall not exceed 30 pounds of available N per acre.
- On irrigated fields split or delayed N application to apply a majority of crop N requirement after crop establishment. Or, use a nitrification inhibitor with ammonium forms of N. Note: "Instinct N" inhibitor label prohibits using irrigation equipment to apply the product to fields
- For summer or fall manure applications limit rates to 90 or 120 lbs. of available N rate per acre depending on timing and crop.

<sup>3</sup> Maintain 200 feet setbacks from upslope areas contributing runoff to direct conduits to groundwater (wells, sinkholes, fractured bedrock at the surface, tile inlets), unless effectively incorporated within 72 hours. Note: manure irrigation may not meet effective incorporation criteria due to manure solids content/application rate

<sup>4</sup> When frozen or snow-covered soils prevent effective incorporation at the time of application, implement the following: (1) Do not apply nutrients within the *Surface Water Quality Management Area (SWQMA) being 1,000 feet from the high-water mark of the pond or lake or within 300' of streams* except for manure deposited through winter gleaning/pasturing of plant residue. (2) Do not apply nutrients to locally identified areas delineated in a conservation plan as contributing nutrients to direct conduits to groundwater or surface water as a result of runoff. (3) Do not exceed the P removal of the following growing season's crop when applying manure. Liquid manure applications are limited to 7,000 gallons per acre until spring or summer. (4) Do not apply nutrients on slopes greater than 9%, except for manure on slopes up to 12% where cropland is contoured or contour strip cropped.

To minimize entry of nutrients to surface water and groundwater, NRCS CPS 590 requires application restrictions listed below.

- Ensuring manure nutrient applications are consistent with UW publication A2809, "Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin."

- Applying manure nutrients using either the soil test P or P-Index strategy
- Documenting methods, timing, form and rates of application using calibrated application equipment to achieve the planned application rates
- Meeting specific practices when applying manure nutrients in a SWQMA (i.e., incorporation, cover crops, residue, buffers)
- No manure application on the following features: surface waters, established concentrated flow channels (grass waterways), non-harvested permanent vegetative buffers, non-farmed wetlands, wells and sinkholes
- No manure ponding, discharge to drain tiles or runoff from application fields
- No manure application on saturated soils within a SWQMA
- No manure application on fields that exceed the tolerable soil loss

Additional Statewide Rules for CAFOs

CAFO farms operating under a WPDES permit are subject to additional requirements included in chapters NR 214 and NR 243, Wis. Adm. Code. Since NR 243.14(1)(a) adopts nutrient budgeting, soil test recommendations, application practices and restrictions contained in NRCS CPS 590, the requirements from the NRCS CPS 590, at a minimum, must also be followed by a CAFO. Other Wisconsin Administrative Codes, such as NR 151 and NR 214, do not restrict the specific practice of manure irrigation but rather regulate it as a method of surface application. Table 2c-3 identifies the setback distances a CAFO must follow when applying manure or process wastewater through an irrigation system.

*Table 2c-3. Current manure irrigation setback distances for Wisconsin CAFOs*

Restrictive Feature	Setback	Code Reference
Community Public Water Supply Well	1,000 feet	NR 214.14(1)(a)
Non-Community Water Supply Well	250 feet	NR 214.14(1)(a)
Inhabited Dwelling	500 feet*	NR 214.14(1)(b)
Depth to Groundwater & Bedrock	5 feet	NR 214.14(1)(c)
Direct Conduit to Groundwater	100 feet	NR 243.14(2)(b)8
Navigable Waters & Conduits	25-100 feet	NR 243.14(4)(a)
Wetland	25 feet	NR 243.14(4)(a)

\*Distance may be reduced with the written consent of any affected owners and occupants.  
Source: WNDNR

Additional restrictions and limitations that do not include explicit numerical setback distances include:

- Ponding or runoff is prohibited on the application site – NR 214.14(2)(a) & NR 243.14(2)(b)1 & (2).
- Spray nozzles shall be arranged so that application will be evenly distributed over the acreage being loaded – NR 214.14(2)(d).
- The average hydraulic application rate may not exceed 10,000 gallons per acre per day – NR 214.14(3)(d).
- The irrigation system shall be operated in a load/rest cycle – NR 214.12(5)(a).
- The soil at each individual spray irrigation field shall be tested annually for available nitrogen, available phosphorus, available potassium and pH – NR 214.14(4)(c).
- Manure or process wastewater may not cause the fecal contamination of water in a well – NR 243.14(2)(b)3.
- Manure or process wastewater may not be applied to saturated soils – NR 243.14(2)(b)5.
- Manure or process wastewater may not be surface applied when precipitation capable of producing runoff is forecast within 24 hours of the time of planned application – NR 243.14(2)(b)13.
- Surface application of liquid manure on frozen or snow covered ground (>1 inch) is prohibited – NR 243.14(7)(a) & (b).

Other sections of NR 214 and NR 243 give the WDNR the authority to require additional monitoring and restrictions if deemed necessary. These requirements can include:

- The department may require reduced hydraulic application rates or grass buffer strips, or both, around the perimeter of the site to absorb runoff during rainfall events – NR 214(2)(g).
- The department may restrict spray irrigation during times of the year when the cover crop is dormant or not actively taking up water and nutrients – NR 214.14(3)(g).
- The department may require the discharge be monitored for BOD<sub>5</sub>, total suspended solids, forms of nitrogen, chloride, metals or any other pollutant than may be present – NR 214.14(4)(b).
- The department may require the installation of a groundwater monitoring well system – NR 214.21(a).

- The department may require the permittee to implement practices in addition to or that are more stringent than the requirements specified in section NR 243.14 when necessary – NR 243.14(10).

Current Local Wisconsin Rules

Some Town and County governments in Wisconsin have adopted local ordinances that explicitly prohibit manure irrigation or require specific conditions for its use. Those municipalities have based their local ordinances on threats to public health and/or have deemed manure irrigation to be a public nuisance. Local governments requiring a Conditional Use Permit (CUP) to operate a manure irrigation system set specific conditions to obtain a permit which can include types of equipment, timing of application, wind conditions, opportunities for public hearings, and more. The City of Algoma in Kewaunee County bans all spreading, spraying, and storing liquid manure (solids content less than 12%) within city limits as a public nuisance affecting health; this prohibition includes the use of manure irrigation. Table 2c-4 contains a list of Wisconsin Towns and Counties that have adopted a local ordinance specific to manure irrigation. Other local governments have also considered manure irrigation ordinances.

*Table 2c-4. Local Municipalities with a Manure Irrigation Ordinance*

Local Government*	County	Prohibited or Conditional Use Permit (CUP)	Ordinance Category	URL (web address at end of Chapter 2)
Adams County	Adams	Conditional Use Permit	Public Health	<a href="#">Link here</a>
Bayfield County	Bayfield	Prohibited	Public Nuisance	<a href="#">Link here</a>
Town of Brussels	Door	Prohibited		no link (on file with DATCP Ordinance No 32)
Town of Gardner	Door	Prohibited		<a href="#">Link here</a>
Town of Liberty Grove	Door	Prohibited (Center Pivot)	Public Nuisance	<a href="#">Link here</a>
Town of Sevastopol	Door	Prohibited	Public Nuisance	<a href="#">Link here</a>
Town of Sturgeon Bay	Door	Prohibited		<a href="#">Link here</a>
Town of Marshfield	Fond du Lac	Prohibited	Public Nuisance	<a href="#">Link here</a>
Town of Rosendale	Fond du Lac	Prohibited	Public Nuisance	<a href="#">Link here</a>
Town of Decatur	Green	Prohibited (Center pivot)	Public Nuisance	<a href="#">Link here</a>

*Table continues on next page.*

Table 2c-4. Continued.

Local Government*	County	Prohibited or Conditional Use Permit (CUP)	Ordinance Category	URL (web address at end of Chapter 2)
Town of Sylvester	Green	Prohibited (Center Pivot)	Public Nuisance	<a href="#">Link here</a>
Town of Lincoln	Kewaunee	Prohibited	Public Nuisance	<a href="#">Link here</a>
Town of West Kewaunee	Kewaunee	Prohibited	Public Nuisance	<a href="#">Link here</a>
City of Algoma	Kewaunee	Prohibited	Public Nuisance Affecting Health	<a href="#">Link here</a>
Town of Bradford	Rock	Conditional Use Permit		
Town of Fulton	Rock	Conditional Use Permit (Center Pivot) and Prohibited (Traveling Gun and End Gun on Center Pivot)		<a href="#">Link here</a>
Town of Harmony	Rock	Prohibited	Public Nuisance	<a href="#">Link here</a>
Town of Johnstown	Rock	Conditional Use Permit	Public Nuisance	<a href="#">Link here</a>
Town of Richmond	Walworth	Conditional Use Permit	Public Health	<a href="#">Link here</a>
Town of Utica	Winnebago	Conditional Use Permit		<a href="#">Link here</a>
Town of Saratoga	Wood	Prohibited	Public Nuisance	<a href="#">Link here</a>

\* For additional information regarding these ordinances please consult with the local government and/or their legal counsel

If a local government proposes a livestock ordinance for water quality protection (per Wisconsin Statutes section NR 92.15) that exceeds agricultural performance standards and prohibitions or related conservation practices or technical standards in ATCP 50, they need approval from either WDNR or WDATCP. That approval would indicate the regulations are necessary to achieve water quality standards under Wisconsin Statutes section 281.15. An approval from WDNR or WDATCP is not necessary if the livestock ordinance addresses cropping practices that do not directly relate to a livestock operation. Thus far, no local government in Wisconsin that has enacted a livestock ordinance that restricts or prohibits manure irrigation focused on water quality.

Local and state public health departments generally play a secondary role in these issues and have no direct regulatory authority over agriculture, except broadly in certain situations. State of Wisconsin Right-to-Farm laws (Wisconsin Statutes section 823.08) are intended to prevent inhibition of continual agricultural operations based solely on private nuisance—noise, odor, aesthetics, etc., leading to conflict over use and enjoyment of property. Exceptions to Wisconsin’s Right-to-Farm Law require the determination of a public health hazard based on established health standards and guidelines. Agricultural operations may present a nuisance, for example odor, without rising to the threshold of a health hazard. Under Wisconsin law, the local health officer has the authority to identify and order the abatement of public health hazards. Health hazards most commonly identified around agricultural operations are related to wastewater spills, runoff, and ground- and surface-water impacts. In common practice, when there is a spill or runoff incident, other regulatory agencies will have a prominent role, and the focus of the local health officer will be to ensure that local residents have a source of safe clean household water.

#### Manure Irrigation Requirements in Other States

Other states have experience using manure irrigation in agricultural operations. A brief compilation of information gathered in 2012-2013 by WDNR staff from neighboring states and others that have used the practice is included in Appendix B. Each summary includes general information about the extent of manure irrigation, the type of public complaints documented by the agency that regulates animal feeding operations, and any setback distances or special regulations for the practice. The summaries in Appendix B are not intended to be comprehensive and conditions may have changed since they were compiled.

#### References for Section 2c:

WDATCP. 2015. Wisconsin Nutrient Management Update & Quality Assurance Team Review of 2015’s Nutrient Management Plans. [<http://datcp.wi.gov/uploads/Farms/pdf/NMUpdate2015.pdf>]

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#### Direct Web Addresses for Table 2c-4 (Local Municipalities with a Manure Irrigation Ordinance)

**Adams County:** [http://www.adamscountylwcd.net/Ordinance\\_Spray\\_Irrigation.pdf](http://www.adamscountylwcd.net/Ordinance_Spray_Irrigation.pdf)

**Bayfield County:** <http://www.bayfieldcounty.org/documentcenter/view/3591>

**Town of Brussels:** not listed

**Town of Gardner:** <http://www.greenbaypressgazette.com/story/news/local/door-co/news/2014/12/12/gardner-town-board-bans-center-pivot-manure-spraying/20332065/>

**Town of Liberty Grove:** [http://libertygrove.org/uploads/documents/Ord\\_15-2.pdf](http://libertygrove.org/uploads/documents/Ord_15-2.pdf)

**Town of Sevastopol:** [http://www.townofsevastopol.com/uploads/ckfiles/files/Manure Liquid Animal & Ag Wastewater 10-23-14.pdf](http://www.townofsevastopol.com/uploads/ckfiles/files/Manure_Liquid_Animal_&_Ag_Wastewater_10-23-14.pdf)

**Town of Sturgeon Bay:** <http://www.greenbaypressgazette.com/story/news/local/door-co/news/2014/11/07/town-sturgeon-bay-passes-manure-spraying-law/18677625/>



**Town of Marshfield:** [http://townmarshfield.com/Files/Ordinances/Public\\_Nuisance\\_Manure.pdf](http://townmarshfield.com/Files/Ordinances/Public_Nuisance_Manure.pdf)

**Town of Rosendale:** <http://sustainruralwisconsin.net/wp-content/uploads/2012/09/Ordinance-Amendment-Center-Pivots-Town-of-Rosendale-07-17-2012.pdf>

**Town of Decatur:** <http://townofdecatur.com/wp-content/uploads/2016/03/manure-ordinance-rev-2-16-16-for-website.pdf>

**Town of Sylvester:** <https://greencdf.org/wp-content/uploads/2016/02/Sylvester-Center-Pivot-Irrigation-Ordinance-Final.docx>

**Town of Lincoln:** <http://s3.documentcloud.org/documents/1302564/lincoln-center-pivot-manure-irrigation-ban.pdf>

**Town of West Kewaunee:** <http://www.greenbaypressgazette.com/story/news/local/kewaunee-county/2015/02/19-first-town-ordinance-county-ban-manure-spraying-passed/23686005/>

**City of Algoma:** <https://assets.documentcloud.org/documents/1302253/algoma-manure-spreading-ban.pdf>

**Town of Bradford:** not listed

**Town of Fulton:** <http://ecode360.com/search/FU2213?query=irrigation>

**Town of Harmony:** <http://townofharmony.com/municipal-code>

**Town of Johnstown:** <https://drive.google.com/viewerng/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbmx0b3dub2Zqb2huc3Rvd24xfGd4OjEzNmE1NDI3NGQ5ODBlYzA>

**Town of Richmond:** <http://www.codepublishing.com/wi/richmond/>

**Town of Utica:** <http://townofutica.org/wp-content/uploads/2015/09/Zoning-Ordinance-2010..2013-2014.pdf>

**Town of Saratoga:** [http://www.saratogawisconsin.org/dbfiles/center\\_pivot.pdf](http://www.saratogawisconsin.org/dbfiles/center_pivot.pdf)

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## 3. Considerations for Practice

As discussed in the Introduction to this report, the workgroup focused on several key considerations associated with the practice of manure irrigation. Sections 3a-3e address expressed concerns initially identified for the workgroup agenda. Each section presents the issues, concerns, current practice, and remaining uncertainties. Each section also includes a summary table identifying practices and conditions that may limit or exacerbate aspects of each concern. Sections 3f-3g describe management issues and potential benefits associated with the practice.

As a way to visualize the considerations for practice associated with manure irrigation, Figure 3-1 provides a conceptual illustration of the elements of fate and transport of irrigated manure and agricultural wastewater and includes representations of the environmental and public health issues involved. During irrigation manure is applied on the soil surfaces and moves to the soil root zone of crop plants. The figure identifies potential sensitive areas to be avoided by misapplication or wind drift of manure irrigation. These include surface water, neighboring houses, and wellheads. The figure also illustrates that the viability of microbes in the irrigated manure is affected by environmental conditions. There are also concerns about any application of liquid manure that could enter groundwater via fractured bedrock or other direct conduits. Each of these features are discussed in the context of relative differences of manure irrigation compared to available alternative methods for manure application.

### ■ 3.a Non-Aerosolized Droplet Drift

#### Droplet Drift – Definitions

Droplet drift refers to the aerial movement of liquid material outside the intended application area. Drift is different from the direct application of liquid outside the designated application area due to overspray. Overspray occurs when the irrigation system is not correctly managed and liquid is applied directly past intended boundaries (e.g., the crop field). Overspray can be avoided with correct system design and management and should not occur with properly operating systems. Droplet drift is dependent on a number of factors including equipment, system operation, weather, and spray characteristics. However, the primary drivers of drift are wind velocity and direction, droplet size and density, and application height (Grisso et al. 2000; Zhu et al. 1994; Hewitt et al. 2002). Wind has been shown to be the most significant factor in drift, where increasing wind can increase drift (Molle et al. 2012). Droplet size determines the rate at which the droplets fall to the ground, also affecting drift. Droplets are classified by size in reference to the Volume Median Diameter (VMD), which indicates the diameter in which half of the spray droplets by volume have diameters greater than the median and half less. The difference between liquid droplets and aerosolized particles is largely dependent upon the diameter of the droplet.

For the purposes of this discussion, particles with a diameter less than 100  $\mu\text{m}$  are considered to be aerosolized particles (for comparison a dollar bill has a thickness of 110  $\mu\text{m}$ ).

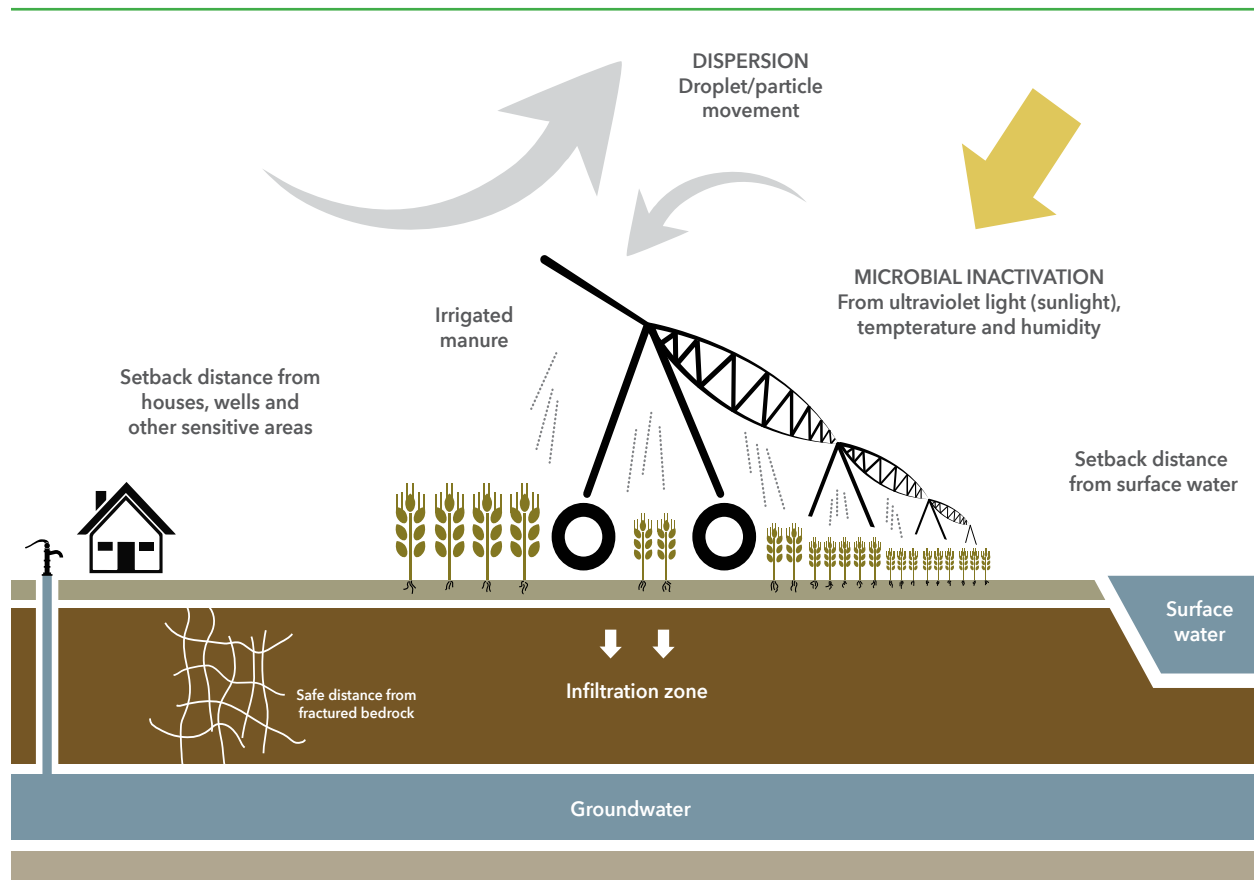


Figure 3-1. Highlighted Issues Associated with Manure Irrigation Practice

### Droplet Drift – Issues of Concern

Droplet drift can occur during application for all types of liquid manure application methods. However, methods that release manure above the crop height or at increasing heights above the soil surface are more subject to drift (as compared to injection or broadcast applications). Droplet drift is a concern when it results in manure transport beyond the intended application area. This might include drift to surface waters, well head areas, residences, public areas, or ready-to-eat crops. Droplet drift can be understood as a physical event, but the risk associated with drift is dependent upon the distance traveled, the sensitivity of the deposition area, weather conditions, and the concentration and viability of any microbes or other contaminants contained in the drifted material. In Wisconsin, concerns have been raised about drift of liquid manure onto surrounding lands if the crops are grown for human consumption, or are public or private property where any of the contents in manure are unwanted.

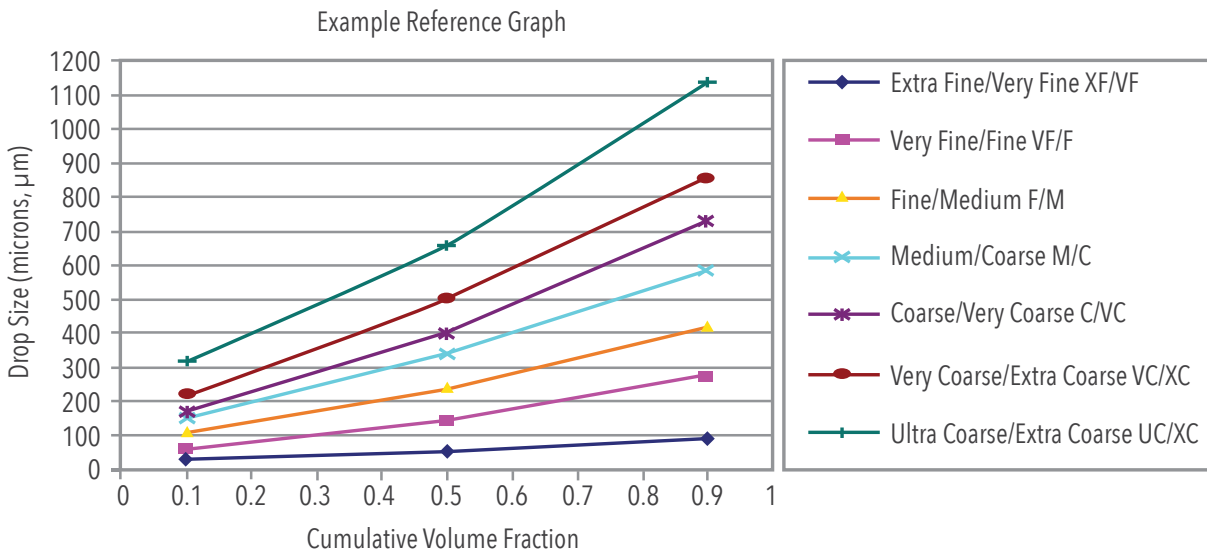
## Droplet Drift – Current Practices and Regulation

Wisconsin law prohibits pesticide overspray and significant pesticide drift (ATCP 29.50(2)), and Wisconsin's technical standards for irrigation water management specify that overspray should not reach public roads (WI NRCS Code 449). Managing manure application to reduce droplet drift (distinct from overspray) is important for multiple application methods (including surface broadcast methods), but may not be relevant for methods that do not surface apply manure (e.g., direct injection). Conventional application methods do not have regulations regarding droplet drift when applying manure, however setback distances outlined in Section 2c apply for all types of manure applications (See Section 2c and Table 2c-1 for information on setbacks).

- **Siting (location and application considerations).** Drift concerns are magnified if the end location where drift droplets land creates a risk. A recommended practice to limit the potential impacts of any droplet drift that may occur is to apply manure to fields with adjacent lands that are owned by the applicator or for which permission has been granted by the owner. Risk of negative impact can also be reduced significantly by applying manure when the wind is blowing away from populated areas or property boundaries. Installing barriers, such as vegetated wind breaks, can also reduce drift as particles can be trapped in the vegetation reducing potential impact to locations past the property boundaries.
- **Weather.** Wind speed is the dominant factor in the distance of droplet drift (Molle et al. 2012). There is a general agreement that irrigation application with wind speeds above 10 mph significantly increases drift (Grisso et al. 2000; Thistle 2004). When applying manure through irrigation systems, selecting times when temperatures are increasing will promote upward movement decreasing the impact of drift. Periods of inversion, where the weather conditions will trap particles and droplets near the ground, can result in increased distances of drift. However, application of larger droplets limits the impact of these weather factors (see below for information on increasing droplet sizes). If combined with low humidity, high air temperatures can result in increased evaporation of droplets or contribute to decreasing their size, which could increase drift (Thistle 2004). High relative humidity can also contribute to drift potential in smaller particles as it increases the distance to evaporation (Grisso et al. 2000). However, research indicates that larger particles (> 200  $\mu\text{m}$ ) do not experience a drift effect for relative humidity values from 10-80% (Grisso et al. 2000). Overall, maximizing droplet size in manure irrigation systems is important to minimize drift.
- **Equipment.** Regardless of the application method, an increase in manure application height will generally increase the distance droplets can drift. Droplets have farther to fall when released higher from the ground, and as height above the ground increases, wind also increases, further affecting potential for drift (Grisso et al. 2000). Typical/conventional land application methods can release manure below the soil depth using injection (where droplet drift is essentially zero), or directly at soil level, or above the ground height with low and high mounted spray booms and splash plates. Spray booms and splash plates located on tankers applying manure to land can range from surface height application

to greater than 10 feet in the air depending upon the application equipment. Center pivot irrigation systems have a wide variety of application heights that extend above or below the 12-14 foot tall structures. The applicator can adjust the release height from just above the ground by using drop nozzles or raise to 20+ feet in the air by using impact sprinklers mounted at the top of the structures and end guns which release manure past the end of the boom. Many drop nozzles release manure 8 feet above the soil surface in order to remain above a full-grown corn crop. Traveling gun equipment projects liquid material through a spray arc from the fixed nozzle height above most other application methods.

As noted, larger droplet sizes also reduce droplet drift. Droplets with a VMD less than 200  $\mu\text{m}$  are more prone to drift as they have insufficient weight to overcome air resistance, even when winds are below 10mph (Wilson nd.; Grisso et al. 2000; Grover et al. 1978; Byass & Lake 1977; Bouse et al. 1990). Droplet size is a factor of the nozzle selected and the operating water pressure of the system, where larger nozzle sizes and lower pressures increase droplet size (and decrease drift). Many low-drift nozzles are available which produce VMD droplet sizes between 300- 600  $\mu\text{m}$  (Grisso et al. 2000). For any commercially available nozzle, the droplet size is reported at various operating pressures according to droplet size classifications in ASAE S572.1, Spray Nozzle Classification by Droplet Spectra, Appendix A. Droplet drift is reduced by using droplet classifications of medium/coarse (VMD $\approx$ 350  $\mu\text{m}$ ), coarse/very coarse, extra coarse, and ultra-coarse. See Figure 3a-1 for an illustration of droplet size ranges in each classification.



Source: ANSI/ASAE (2013) S572.1, Figure 1. Used with permission.

Figure 3a-1 Illustration of distribution of droplet size ranges for classifications

Droplet Drift – Unknowns and Remaining uncertainties

There is wide-reaching peer reviewed literature concerning droplet drift and mitigation of that drift. However, most droplet drift studies have been conducted on irrigation systems used for water and pesticide application, and there is no available research specific to drift associated with manure irrigation. Despite this, conventional drift research does provide relevant information since the manure used in these systems is very dilute (<5% solids) resulting in similar characteristics to water (e.g., similar density and viscosity). It is reasonable to assume that the low-solids characteristics of manure-derived liquids used in irrigation systems will behave similarly to the liquids in the referenced studies. The physical characteristics of liquid manures may change with a solids content greater than 5%, but that threshold is above what is feasible for operation of a center pivot systems and unlikely in traveling gun systems. In addition, in many other applications smaller droplet sizes are required for adequate coverage upon deposition; that is not critical in manure application, and the droplet sizes are commonly much larger and less prone to drift than those used in the reference studies.

Based on available information, Table 3a-1 provides a compilation of practices expected to limit or exacerbate drift under various conditions and types of irrigation equipment.

*Table 3a-1. Droplet Drip Issues for Manure Irrigation Practice*

	Practices or conditions expected to limit Drift	Practices or conditions that exacerbate risk of Drift
Siting	Edge of field barriers (e.g., trees) as wind block  To minimize potential impact from drift, limit irrigated use to areas adjacent to own fields	Irrigated use adjacent to fields not owned by the farm may increase potential impacts if drift occurs
Weather	Winds < 4mph  High temperature  High relative humidity  Standard atmospheric conditions	Winds > 10mph  Wind in the direction of surrounding residences, other property lines, or sensitive vegetation  Low temperature  Low relative humidity (increased rate of evaporation increasing drift)  Periods of inversion

*Table continues on next page.*

Table 3a-1. Continued.

	Practices or conditions expected to limit Drift	Practices or conditions that exacerbate risk of Drift
Equipment: Center Pivot	Drop nozzles which lower the nozzle height below the boom structure. Note that nozzle heights are generally fixed for an entire season.  Nozzle selection and operating pressure which result in droplet classification of coarse, very coarse, extremely coarse, or ultra-coarse	Application from the top of a center pivot using impact sprinklers.  Nozzle selection and operating pressure which result in droplet classification of medium, fine, very fine, extra fine
Equipment: Traveling Gun	Nozzle selection and operating pressure which result in droplet classification of coarse, very coarse, extremely coarse, or ultra-coarse	Nozzle selection and operating pressure which result in droplet classification of medium, fine, very fine, extra fine

#### References for 3a. Droplet Drift

- ANSI/ASAE S572.1. 2013. "Spray nozzle classification from droplet spectra." American Society of Agricultural and Biological Engineers. (<http://www.asabe.org/standards/>)
- Bouse, L.F., Kirk, I.W., Bode, L.E., 1990. Effect of spray mixture on droplet size. Transactions of the ASAE 33, 783e788.
- Byass, J. B. and J.R. Lake. 1977. Spray drift from a tractor-powered field sprayer. Pesticide Science, 8, 117–126.
- Grisso, R.D., H. E. Ozkan, V.L. Hofman, A. Womac, R. Wolf, W. C. Hoffmann, J. Williford, T. Valco. 2000. Chapter 29: Pesticide application Equipment. In: Conservation Tillage Systems and Management Handbook, MWPS-45, Ames, IA. [http://bse.rv214.bse.vt.edu/Grisso/Ext/CH\\_29\\_MWPS\\_Pest.pdf](http://bse.rv214.bse.vt.edu/Grisso/Ext/CH_29_MWPS_Pest.pdf)
- Grover, R., L.A. Kerr, J. Maybank and K. Yoshidja. 1978. Field measurement of droplet drift from ground sprayers, I: sampling, analytical and data integration techniques. Canadian Journal of Plant Science, 58, 611–622
- Hewitt, A. J., D. R. Johnson, J.D. Fish, C. G. Hermansky, and D.L. Valcore. 2002. Development of the spray drift task force database for aerial applications. Environmental Toxicology and Chemistry. 21:3:648-658.
- Molle, B., S. Tomas, M. Hendawi and J. Granier. 2012. Evaporation and Wind Drift Losses during Sprinkler Irrigation Influenced By Droplet Size Distribution. Irrigation and Drainage, 61:240-250.

- Nuyttensa, D., K. Baetensb, M. De Schampheleirec, B. Sonck. 2007. Effect of nozzle type, size and pressure on spray droplet characteristics. *Biosystems Engineering*, 87:333-345.
- Taylor, W.A., A.R. Womac, P.C.H. Miller, and B.P. Taylor. 2004. An attempt to relate drop size to drift. International Conference on Drift, Washington State University.
- Thistle, H.W. 2004. Meteorological Concepts in the Drift of Pesticide. International Conference on Drift, Washington State University. [http://pep.wsu.edu/drift04/pdf/proceedings/pg156-162\\_Thistle.pdf](http://pep.wsu.edu/drift04/pdf/proceedings/pg156-162_Thistle.pdf)
- Wilson, J. No date. Understanding Droplet Size. South Dakota State University. <http://pesticidestewardship.org/drift/Pages/UnderstandingDropletSize.aspx>
- Zhu, H., D.L. Reichard, R.D. Fox, R.D. Brazee and H.E. Ozkan. 1994. Simulation of drift of discrete sizes of water droplets from field sprayers. *Transactions of the ASAE* 37(5):1401-1407.

### ■ 3.b Odor

#### Odor – Definition and Issues of Concern

Odor is the human perception of how something smells based upon the chemical reactions it imparts on the olfactory senses in the nose and is a significant concern for use of manure irrigation systems. Although highly variable from person to person, humans have the ability to perceive thousands of different odors, and many of those can have a profound influence on an individual's state of mind and sense of wellbeing. Exposure to odor can result in mental, physical, health, and social impacts as a result of the human responses it invokes (Stowell et al, 2007). Odor impacts range from diminished quality of life or stress for neighboring residents to economic loss from reduced land values or loss of clientele for businesses. Issues identified in Wisconsin include disruption of family gatherings, inability to enjoy the outdoors on hot humid days, potential negative impact on property value, and a negative impact to tourism. Concerns about odors can equal or surpass other concerns related to agricultural operations including water quality, traffic, noise and dust. Personal experiences shared with the workgroup and reports documenting significant negative odor and related quality of life impacts in Wisconsin and other states (e.g., NRDC 2001, Plains Justice 2010) reinforce the critical importance of odor issues and associated management practices.

Quantifying manure odors is challenging due to the fact that over 300 different compounds can contribute to their composition. In addition, no one indicator, such as ammonia or hydrogen sulfide, corresponds directly to a perceived odor. The degree to which manure odors present a nuisance depends on the type of waste, duration of storage, the chemical and biological conditions under which it is stored, processing or treatment, proximity to those affected by the odor, and local weather conditions. Manure application systems that actively aerosolize manure liquids (such as irrigation systems) can be expected to increase chemical volatilization and intensity of the corresponding odors, although potentially for a shorter duration (Krantz et al, 2007).



By changing the number and timing of applications in a given area throughout the growing season, irrigation systems have the potential to increase the frequency of odor incidents. Odor levels can be managed or mitigated with processing and storage techniques including digestion or solid separation among others. Odor mitigation practices can be used with all forms of land application.

### Odor - Current Practice and Regulations

Wisconsin Right-to-Farm legislation protects farms from nuisance complaints and litigation associated with objectionable odors resulting from the normal course of agricultural activities in the absence of associated health or safety hazards (Wisconsin Statute 823.08); see discussion in Section 2c. State agencies have little authority to require farms to change their practices or control odor levels. Many farms recognize the potential negative impacts of agricultural odors and take voluntary steps to reduce odor impacts through manure treatment and timing and method of application.

The Livestock Facility Siting Rule (ATCP 51) establishes a state standard that relies on a predictive model to estimate odor generated by manure storage, housing and animal lots. The odor standard accounts for the role of separation distance and odor control practices in reducing the impact of odors on neighboring properties. In local jurisdictions that have adopted a siting ordinance, livestock operations may need a passing odor score to obtain a siting permit. While the standard currently does not address the temporary effects of odor from the field application of manure, it does allow operators to develop an optional odor management plan identifying practices that can reduce conflicts associated with dust and odor.

- **Siting (location and application considerations).** Siting is the most critical component of odor abatement since preventing odors from reaching a receptor eliminates odor impact. Operators of irrigation systems can limit odor impacts by applying manure when winds are blowing away from receptors and avoid periods when neighbors may be outside such as weekends and holidays (Auvermann et al, 2002). Edge of field odor barriers (such as trees) may reduce the odor transport toward receptors.
- **Weather.** When odors can be dispersed, their impact is reduced. Available guidance recommends operating systems when the air is warming (such as early morning to afternoon) and when winds are above 5 mph, both of which will increase dispersion (Auvermann et al, 2002).
- **Waste Characteristics.** Reducing the odor content of the manure through processing and storage will reduce the odor impacts when the manure is applied. Anaerobic digestion and solids separation are two processing techniques which can reduce odors (composting is a manure processing technique that also reduces odors but would not apply to manure with a high liquid content). Storage in aerobic conditions or a treatment lagoon will result in degradation of organic matter and odor causing compounds reducing the odor impact upon application. A number of biological and chemical additives also have the potential to reduce odors when added to manure storage systems, however actual

performance of additives can vary significantly. Managers can also reduce the impact by excluding fresh manure from storage two weeks prior to land application, and by applying manure in mid-summer or fall after the manure storage has become active. When land applying, dilution of manure has been shown to significantly reduce odors. A 2:1 dilution is recommended for processed manures and a 15:1 dilution is recommended for raw unprocessed manure slurries (Auvermann et al, 2002). It is also recommended that additions of highly odorous materials should be avoided to reduce odor impacts.

- **Equipment.** Using drop nozzles which are below the canopy will reduce odor transport. Application from atop an irrigation boom using impact sprinklers and end guns will increase the odor transport. Smaller droplets sizes have greater surface area per unit volume of manure and will therefore increase odor (MWPS 18-3). It is recommended to select equipment and operating pressures which result in droplets sizes greater than 150 µm (MWPS 18-3), corresponding to droplet classifications of coarse, very coarse, extremely coarse, or ultra-coarse (See Figure 3a-1).

Odor – Unknowns and remaining uncertainties

As noted, quantifying odor and predicting individual reaction to odor both present challenges. Variability in individual response leads to differential effects on those exposed to odorants. Given these uncertainties, Table 3b-1 provides a compilation of practices expected to limit or exacerbate impacts from odor under various conditions and types of irrigation equipment.

*Table 3b-1. Odor Issues for Manure Irrigation Practice*

	Practices or conditions expected to limit Impact from Odor	Practices or conditions that exacerbate risk of Impact from Odor
Siting	<p>Consideration of neighbors (see Livestock Siting guidance)</p> <p>Physical separation between source and receptor, such as edge of field barriers (e.g., trees) as a wind block</p>	<p>Near populated areas/public gathering areas</p> <p>Application on weekends or holidays</p>
Weather	<p>Winds &gt; 5mph</p> <p>When temperatures are rising</p>	<p>Winds &lt; 5mph (stable conditions)</p> <p>Wind in the direction of populated areas or residences</p> <p>Periods of inversion</p>

*Table continues on next page.*

Table 3b-1. Continued.

	Practices or conditions expected to limit Impact from Odor	Practices or conditions that exacerbate risk of Impact from Odor
Waste Characteristics	<p>Waste treatment (Aerobic treatment or anaerobic digestion or treatment lagoons)</p> <p>Additives demonstrated to reduce odor</p> <p>Dilution with treated waste water or fresh water</p> <p>No new manure additions for 2 weeks prior to application</p> <p>Application in mid-summer or fall after lagoon has been active</p>	<p>Addition of highly odorous materials</p> <p>Application in spring or winter when lagoon is not active</p>
Equipment: Center Pivot	<p>Drop nozzles which lower the nozzle height below the boom structure. Greater reductions if below the canopy. Note that nozzle heights are generally fixed for an entire season.</p> <p>Nozzle selection and operating pressure which result in droplet classification of coarse, very coarse, extremely coarse, or ultra-coarse</p>	<p>Application from the top of a center pivot using impact sprinklers.</p> <p>Nozzle selection and operating pressure which result in droplet classification of medium, fine, very fine, or extra fine</p>
Equipment: Traveling Gun	<p>Nozzle selection and operating pressure which result in droplet classification of coarse, very coarse, extremely coarse, or ultra-coarse</p>	<p>Nozzle selection and operating pressure which result in droplet classification of medium, fine, very fine, or extra fine</p>

References for 3b. Odor

Auvermann, B., J. Bicudo, L.D. Jacobson, J. Lorimor, and D.R. Schmidt. 2002. Chapter 5: Managing Odors During Land Application. In: Outdoor Air Quality, Manure Management Systems Series, MWPS 18-3. Midwest Plan Service, Ames, IA.

Krantz, W.L., R.K. Koelsch, and C.A. Shapiro. 2007. Application of Liquid Animal Manures Using Center Pivot Irrigation Systems. University of Nebraska-Lincoln. Extension EC778.

Natural Resources Defense Council (NRDC). 2001. Cesspools of Shame: How factory farm lagoons and sprayfields threaten environmental and public health. 64 pages. Available at <http://www.nrdc.org/water/pollution/cesspools/cessinx.asp>

Page, Thierry. 2010. Top 20 odor impacts – social, health, mental and physical. Odor Management Blog. Published October 10, 2010. <http://blog.odotech.com/bid/53125/Top-20-odor-impacts-social-health-mental-and-physical>

Plains Justice. 2010. Public Health and Livestock Confinements: Identifying Threats to Public Health. 21 pages. Available at <http://plainsjustice.org/files/PublicHealthandCAFOs.pdf>

Schiffman, Susan S., John M. Walker, Pam Dalton, Tyler S. Lorig, James H. Raymer, Dennis Shusterman, C. Mike Williams. 2000. Potential Health Effects of Odor from Animal Operations, Wastewater Treatment, and Recycling of Byproducts, *Journal of Agromedicine*, 7:1, 7-81, DOI: 10.1300/J096v07n01\_02

Stowell, Richard R., Christopher G. Henry, Richard K Koelsch, and Dennis D Schulte. 2007. Association of Odor Measures with Annoyance: An Odor-Monitoring Field Study. Conference Presentations and White Papers: Biological Systems Engineering. Paper 16: <http://digitalcommons.unl.edu/biosysengpres/16>

### ■ 3.c Water Quality

#### Water Quality – Issues of Concern

Concerns about nutrients and microorganisms from crop fields entering surface or groundwater are present with all forms of manure application, including manure irrigation. As discussed in Section 2c, Wisconsin has numerous rules and regulations for manure management intended to protect water quality. Regardless of the type of manure application methods used, if the process is not carefully managed, there are several pathways that can lead to surface water or groundwater contamination. These include situations in which:

- Application rates and/or frequency exceed established crop nutrient needs/uptake periods
- Application rates and/or frequency exceed soil infiltration or soil available water capacity and result in:
  - ponding and surface runoff to surface waters, drain tile inlets or wells
  - losses to subsurface drain tiles that discharge to surface waters
  - losses below crop root zone depth and possibly to groundwater (can occur on highly permeable soils or cracked clay soils)
  - losses to groundwater via bedrock fractures
- Application onto established or recently harvested fields with clay soils and visible cracks or macropores in late summer or early fall that result in losses to subsurface drain tiles that discharge to surface waters or bypass of crop root zone to groundwater.
- Application on highly permeable soils in late summer or fall months to meet following spring crop nutrient requirements that result in nutrient losses below crop root zone depth and then groundwater.
- Aerial drift of applied manure occurs within or beyond the field boundary due to windy conditions that reaches surface waters or nearby drinking water wells.

Surface water and groundwater contamination are more likely to occur when manure nutrients are applied on saturated soils, prior to major rain events, soils with no growing crop, high volume rates per application, and low solids manure. For surface and groundwater protection, irrigation methods have specific management

concerns related to drift management, equipment selection and maintenance, timing, source, and rate factors.

In general, manure nutrient application via irrigation can increase the number of applications with low application rates, on growing crops with lower soil moisture and help achieve surface and groundwater quality benefits on multiple soil types and crops. Compared with other manure application methods (which typically apply manure or process wastewater weeks or months in advance of growing season and crop uptake), manure irrigation allows farms to make multiple, lower rate applications during the growing season (May-Oct) on established crops during periods of peak nutrient uptake and periods with lower rainfall intensity and runoff potential. This flexibility helps maximize liquid manure or process wastewater storage capacity, opportunities for more double cropping/use of cover crops, which can further reduce the risk for causing pollution of surface or groundwater.

It is important to note that potential runoff incidents from over-application or application when field conditions promote runoff and the associated compliance (and related enforcement) with water quality regulations were major concerns raised about the practice. A Canadian report on manure traveling gun systems from the late 1990s (LWPPP, nd), identified runoff events associated with unsupervised applications and/or applications when soil conditions led to runoff. Similarly, concerns about non-compliance with water quality permits issued to CAFOs have been documented in multiple states, including Wisconsin (e.g., SRAP 2015). These concerns underscore the importance of application management to reduce runoff from all manure application systems and effective systems to ensure compliance.

#### Water Quality – Current Practices and Regulation

See section 2c of report for current Wisconsin rules and regulations (state and local) related to using manure irrigation. As a brief recap, it is assumed in this document that all farms, at a minimum, have developed and are following a nutrient management plan consistent with the NRCS CPS 590 to minimize nutrient entry to surface and groundwaters and account for application method, rate, source, timing and placement. WPDES permitted facilities that land apply industrial wastewater and confined animal feeding operations that use irrigation equipment to apply liquid manure or process wastewater must meet more restrictive land application requirements found within Wisconsin Administrative Code chapters NR 214 and NR 243. Such restrictions help further minimize the risk for pollution (via surface runoff, leaching or drift) to surface or groundwaters beyond the NRCS CPS 590.

#### Water Quality – Unknowns and Remaining Uncertainties

Nutrients and microbial organisms (including pathogens) associated with manure or process wastewater can be transported to surface water or groundwater through runoff, discharges, infiltration and atmospheric deposition. The key factors related to the fate and transport of liquid manure or process wastewater pathogens via drift or via runoff to surface or groundwater are not well understood and need additional research. Chapters 3 and 8 of a July 2013 literature review by USEPA provide a detailed overview of manure pathogen types, pathogen survival and transport fac-

tors and management measures (USEPA 2013).

While nutrient management practices and systems do not focus specifically on controlling manure pathogens, they do address many of the potential pathways (e.g., erosion, runoff and infiltration) for microbial transport to surface or groundwater. Manure irrigation, when compared to other forms of manure application, allows for flexibility in manure management with respect to application rate, timing, frequency and placement, which, in turn, can help reduce the risk for pathogen transport and loss to surface or groundwater. As presented in Section 3e and Appendix C, the factors influencing pathogen survival (fate) include temperature, ultraviolet (UV) radiation, moisture, pH, nutrient availability, ammonia concentration in the medium and competition for nutrients (see also Rogers and Haines, 2005). Ultraviolet light exposure promotes pathogen die off. Irrigating manure or process wastewater during daylight hours within the crop growing season (May-Oct) helps promote greater die off of pathogens through exposure to UV light and desiccation, limiting potential impact on surface water or groundwater.

Based on available information, Table 3c-1 provides a compilation of practices expected to limit or exacerbate water quality issues under various conditions and types of irrigation equipment.

*Table 3c-1. Water Quality Issues for Manure Irrigation Practices\**

	Practices or conditions expected to limit Water Quality Impacts	Practices or conditions that exacerbate risk of Water Quality Impacts
Siting	<ul style="list-style-type: none"> <li>· No application within 1,000 feet from municipal wells and 250 feet from private wells</li> <li>· No application within 100 feet from surface waters (perennial or intermittent streams), conduits to surface waters, groundwater conduits and wetlands (closer may be acceptable).</li> <li>· No application within 100 feet from concentrated flow channels, conduits to navigable waters, intermittent or perennial streams, wetlands, or other surface water features (closer may be acceptable).</li> <li>· No application on soils less than 5 feet depth to groundwater or bedrock on frozen or snow covered ground.</li> <li>· No application on soils less than 5 feet depth to groundwater or bedrock during growing season when outside peak crop nutrient uptake period</li> <li>· 100 foot setbacks from tile inlets and field depressional areas leading to tiles or groundwater conduits.</li> </ul>	<ul style="list-style-type: none"> <li>· Application in intermittent or perennial streams, wetlands, or other surface water features.</li> <li>· Application onto wells or other groundwater conduits.</li> <li>· Application onto tile inlets and field depressional areas leading to tiles or groundwater conduits.</li> <li>· Application on soils with less than 5 feet to groundwater or bedrock on frozen or snow covered ground.</li> <li>· Application &gt; 15,000 gal/acre and no avoidance field areas that are tiled or contain numerous soil cracks/macropores.</li> <li>· Manure discharge through tiles to surface waters during or after application; no cease of application after tile discharges; no containment and clean up; no reporting of spills to WDNR.</li> <li>· Piping connection between manure supply lines and wells providing dilution water without a backflow preventer.</li> </ul>

*Table continues on next page.*

Table 3c-1. Continued.

	Practices or conditions expected to limit Water Quality Impacts	Practices or conditions that exacerbate risk of Water Quality Impacts
Siting	<ul style="list-style-type: none"> <li>· No tile line discharges to surface waters. If discharge, cease application and immediately contain and clean up discharges; report manure spill to WDNR.</li> <li>· Avoidance of field areas that are tiled or contain numerous soil cracks/macropores (minimal applications may be acceptable)</li> </ul>	
Weather	<ul style="list-style-type: none"> <li>· Daytime applications for UV exposure and pathogen destruction.</li> <li>· No application if rainfall amount that could cause surface runoff is forecast within 24 hours of application.</li> <li>· Consider soil moisture conditions with rainfall forecast.</li> </ul>	<ul style="list-style-type: none"> <li>· Majority of applications made during nighttime hours; no consideration for UV exposure and pathogen destruction.</li> <li>· Application during or prior to rainfall.</li> </ul>
Waste Characteristics	<ul style="list-style-type: none"> <li>· To minimize pathogen content:</li> <li>· Digested manure using thermophilic temperature ranges (&gt; 135 degrees) or Reverse Osmosis system wastewater (most effective).</li> <li>· Digested manure using mesophilic temperature range (100-135 F) (can be effective).</li> <li>· Separated or Raw Manure with periodic field and weather monitoring (can be effective).</li> </ul>	<ul style="list-style-type: none"> <li>· Operating to increase ammonia can contribute to increased regional atmospheric deposition on surface waters.</li> </ul>
Equipment: Center Pivot (with or without end gun)	<ul style="list-style-type: none"> <li>· Effective monitoring of environmental conditions, irrigation equipment, downwind/down-gradient areas for drift, ponding and runoff from field and setback distances.</li> </ul>	<ul style="list-style-type: none"> <li>· No monitoring of environmental conditions, irrigation equipment, downwind/down-gradient areas for drift, ponding and runoff from field, setbacks.</li> </ul>
Equipment: Traveling Gun	<ul style="list-style-type: none"> <li>· Application does not cause ponding, drift or runoff from field into surface waters, wells, tile lines or other groundwater conduits.</li> </ul>	<ul style="list-style-type: none"> <li>· Drift or runoff from field into surface water, wells; discharges to tile lines or onto other groundwater conduits.</li> </ul>

References for Section 3c. Water Quality

Livestock Manure Pollution Prevention Project (LMPPP). N.d. High Level Spray Irrigation of Manure in Ontario. (Working Group of Environment Canada's Water Quality Working Group, active in late 1990s). 5 pages. Available at <http://thamesriver.on.ca/landowner-grants-stewardship/waterquality-and-agriculture-researchreports/livestock-manure-p3/>

Rogers, S., and J. Haines. 2005. Detecting and mitigating the environmental impact of fecal pathogens originating from confined animal feeding operations: review. EPA-600-R-06-021. USEPA, Office of Research and Development, National Risk Management Research Laboratory. Cincinnati, OH.

Socially Responsible Agricultural Project (SRAP). 2015. The Rap Sheets: Industrial Dairies in Kewaunee, Wisconsin. 137 pages. Available at [http://sraproject.org/pdfs/SRAP\\_rapsheet\\_2015.pdf](http://sraproject.org/pdfs/SRAP_rapsheet_2015.pdf)

United States Environmental Protection Agency (USEPA). 2013. "Literature Review of Contaminants in Livestock and Poultry Manure and Implications for Water Quality", Office of Water (4304T), EPA 820-R-13-002, July 2013. <http://water.epa.gov/scitech/cec/upload/Literature-Review-of-Contaminants-in-Livestock-and-Poultry-Manure-and-Implications-for-Water-Quality.pdf>

### ■ 3.d Air Quality

#### Air Quality – Issues of Concern

Application of all manure regardless of method has the potential to negatively impact air quality in terms of (1) nuisance odors, (2) hazardous air pollutants, primarily ammonia and hydrogen sulfide, (3) greenhouse gas emissions (methane, carbon dioxide, and nitrous oxide), and (4) particulate matter. The hazardous air pollutants potentially present at concentrations to be of concern to humans from direct inhalation from manure systems are ammonia (see Table 3d-1) and hydrogen sulfide (see Table 3d-2). Other hazardous compounds such as amines, aldehydes, and organic acids are typically present at lower concentrations where the main effects are contributions to odor.

**Formaldehydes** have been a source of concern as they are used in foot baths at livestock facilities, but a study conducted by the Vermont Department of Health found no difference in the level of formaldehydes in manure at facilities that used formaldehyde footbaths and those that did not. It also found that farms using formaldehyde footbaths did not impact indoor or outdoor concentrations, even during land application (Vermont Department of Health 2012). Although at sufficient concentrations, **ammonia** can cause respiratory issues or death, at lower concentrations measured around livestock operations the primary concern is regional air quality and not effects from direct inhalation. **Hydrogen sulfide** may be present around livestock operations at nuisance levels, and it can be an acute hazard in confined spaces; more rarely is hydrogen sulfide identified as a public health hazard around agricultural operations (Minnesota Department of Health 2009; Plains Justice 2010). Hazards associated with hydrogen sulfide are typically near the manure storage or other confined spaces on the farmstead, not by fields. **Methane** and **carbon dioxide** emissions are released from manure during its degradation in storage, during application, and from the soils following application. These greenhouse gases are a concern for global climate change, however the concentrations do not pose direct concerns to human when field applied. Manure-related respirable particulate matter can form directly from bio-aerosols generated from agricultural activities, or can form indirectly on a regional scale from atmospheric reactions involving **ammonia** released from a vari-



ety of sources, including agricultural practices (Harper et al. 2009; Hristov 2009). **Particulate matter** at dangerous levels can cause respiratory illness, lung inflammation, and issues related to respiratory disease (Laden et al. 2006; Venners et al. 2003; Danielsen et al. 2010).

It is expected that any type of irrigated manure application will increase air emissions as compared to direct injection. Techniques and equipment are available that would be expected to reduce air emissions relative to other aerial spray application methods (e.g., using drop nozzles to lower application height as compared to using impact guns that project above a center pivot boom), although many of these practices have not been evaluated in scientific studies. Earlier work done by regulatory and advisory workgroups in Wisconsin have addressed air emissions in greater detail. That work recommended best practices to reduce air quality impacts at the various stages of livestock waste production, storage, transport, and land application (see WDNR 2010 and NRCS document in references). Irrigation application of liquid manure was not listed among the best practices to reduce air emissions.

*Table 3d-1: Ammonia toxicity progression (Michigan Department of Environmental Quality 2006)*

Property	Concentration in air (ppm)
Detectable odor	0.04-53
Eye, nose irritation	50-100
Strong cough	50-100
Airway dysfunction	150
Lethal in 30 minutes	2,500-4,500
Immediately lethal	5,000-10,000

*Table 3d-2: Hydrogen sulfide toxicity progression (ATSDR 2006)*

Property	Concentration in air (ppm)
Typical background level	0.0002
Odor threshold (AIHA 1989)	0.001-0.008
Offensive odor, headache	0.3
Very offensive odor	3-5
Asthmatics affected	2
Human flatus	3-18
Olfactory paralysis	150

*Table continues on next page.*

Table 3d-2: continued

Property	Concentration in air (ppm)
Central nervous system depression, loss of consciousness, neurological problems may persist	>500
Lung paralysis, collapse, death	>600-1,000 (concentrations in actual events are uncertain)

### Air Quality – Current Practices and Regulation

The primary goals of reducing air quality impacts focuses on reduced emissions from the four negative impact categories: (1) nuisance odors, (2) hazardous air pollutants, primarily ammonia and hydrogen sulfide, (3) greenhouse gas emissions (methane, carbon dioxide, and nitrous oxide), and (4) particulate matter. Tradeoffs associated with selecting a manure application system based on emissions mitigation can complicate efforts to reduce emissions across all four categories.

Reducing ammonia emissions is important both in preserving the economic value of nitrogen and for avoiding the release of nitrogen into the atmosphere where it can contribute to the atmospheric formation of oxides of nitrogen, ammonium nitrate, and fine particulate matter [PM<sub>2.5</sub>] (Harper et al. 2009; Hristov 2009). Injection of manure is a best practice for reducing ammonia emissions (Rotz 2004), followed by incorporation. According to some literature which ranks manure application methods in order of typical nitrogen losses, manure irrigation is listed as the method with the highest average N loss (Rotz 2004). However, more recent field studies have suggested that losses of ammonia are similar to other application methods (which is likely due to the dilute nature of manure applied through irrigation systems) (Misselbrook et al. 2004). As irrigation requires lower manure dry matter content than other application methods, it may increase the infiltration of manure which results in less ammonia losses to volatilization (Meisinger and Jokela 2000).

Federal and Wisconsin regulations directly impacting agricultural air quality and emissions from production areas or from land application do not currently exist. Reductions in greenhouse gases are not currently regulated at agricultural facilities and practices to reduce them remain voluntary. OSHA regulates air quality occupational health standards for farm workers at livestock facilities which have at least ten employees for ammonia, carbon dioxide, hydrogen sulfide, methane, PM 2.5, and formaldehyde (see Table 3d-3). Greenhouse gas emissions and the global warming potential resulting from manure irrigation have not been measured. As compared to injection methods, there may be a reduction in N<sub>2</sub>O emissions, but it can be assumed that carbon dioxide (CO<sub>2</sub>) would likely increase using irrigation systems.

Table 3d-3: OSHA Occupational Standard and Wisconsin Ambient Air Standard

Air Contaminant	OSHA Occupational Standards			Ambient Air Standard [expressed as 24 hour average] (µg/m <sup>3</sup> )
	8-hr Time Weighted Average	Ceiling (ppm)	Additional Notes	
Ammonia	50 ppm	--	--	418*
Carbon Dioxide	5,000 ppm	--	--	na
Hydrogen Sulfide	--	20	50 ppm acceptable maximum peak above ceiling conc. for 10 minutes once if no other measured exposure occurs	335*
Methane	--	--	No exposure limits, simple asphyxiate, oxygen levels must be maintained above 19.5%	na
PM <sub>2.5</sub>	5 mg/m <sup>3</sup> (particulate not otherwise regulated)			35 (primary and secondary)**
Formaldehyde	0.75 ppm			na

\* Wisconsin Administrative Code Chapter NR 445.07 Table A;

\*\* USEPA National Ambient Air Quality Standard

- **Siting (location and application considerations).** Although air quality impacts are likely to be regional in nature, edge of field barriers can be used to reduce particle transport and potentially reduce impacts.
- **Weather.** Low wind speed may actually reduce emissions during and following manure application. It has been found that increasing wind speeds up to 5.6 mph increases ammonia emissions from manure (Rotz 2004). As temperature is directly related to manure emission rates, applying manure in lower temperatures will reduce emission losses. Similar to odor, periods of inversion should be avoided since dispersion is limited during these times. Higher temperatures and low humidity may promote evaporation and increase emissions and should therefore be avoided.
- **Waste Characteristics.** To minimize potential for air quality impacts, operators should avoid additions of materials that will result in higher concentrations of chemicals or compounds that are of concern to air quality since increased

concentrations typically lead to increased emissions. For example, an increase in ammonium or ammonia content will increase ammonia losses when applied. If using irrigation practices, diluting manure with fresh water can reduce ammonia emissions during land application (MWPS 18-3). Integrating recovery systems to remove components of concern is recommended to reduce the impact to air quality (e.g., ammonia recovery systems prior to land application).

- **Equipment.** Drop nozzles below the vegetative canopy are expected to reduce air quality impacts as the vegetated canopy may capture some of the compounds of concern. Applying manure from the top of the pivot increases the path length of the droplet, which may increase emissions and increase potential for a negative impact on air quality.

#### Air Quality – Unknowns and Remaining Uncertainties

Researchers have not actually measured many of the air quality parameters in Table 3d-3 for manure irrigation, and much of the information represents data collected on other manure application methods including surface broadcast, surface broadcast with incorporation, or injection. The mechanisms and trends behind emissions from other systems can be used to understand and predict the impacts from manure irrigation. However, it should be noted that this information has not been measured directly in manure irrigation systems, and (aside from noted studies) models have not been calibrated for manure irrigation. It is also important to understand that there are many tradeoffs between the emissions from these practices, and it is difficult to put importance over one impact versus the other.

Based on available information, Table 3d-4 provides a compilation of practices expected to limit or exacerbate regional air quality impacts under various conditions and types of irrigation equipment.

Table 3d-4 Air Quality –Regional Air Quality Issues for Manure Irrigation Practices

	Practices or conditions expected to limit Regional Air Quality Impacts	Practices or conditions that exacerbate risk of Regional Air Quality Impacts
Siting	Edge of field barriers or other plant surfaces (for adsorption)	
Weather [3]	Low wind < 5 mph Low temperature	High > 5 mph High temperature Inversion periods Winds toward populated areas and residences
Waste Characteristics [2]	Low initial ammonia concentration or ammonia recovery technologies	Additions of material with high nitrogen or sulfur content.
Equipment: Center Pivot [1]	Drop nozzles which lower the nozzle height below the boom structure. Note that nozzle heights are generally fixed for an entire season.  Nozzle selection and operating pressure which result in droplet classification of coarse, very coarse, extremely coarse, or ultra-coarse.	Application from the top of a center pivot.  Nozzle selection and operating pressure which result in droplet classification of medium, fine, very fine, or extra fine.
Equipment: Traveling Gun	Nozzle selection and operating pressure which result in droplet classification of coarse, very coarse, extremely coarse, or ultra-coarse.	Nozzle selection and operating pressure which result in droplet classification of medium, fine, very fine, or extra fine.

References for 3d. Air Quality

Aguirre-Villegas, H., R.A. Larson, and D. Reinemann. 2014. From Waste-To-Worth: Energy, Emissions, and Nutrient Implications of Manure Processing Pathways. *Biofuels, Bioproducts & Biorefining*, 8:770-793.

American Industrial Hygiene Association (AIHA). 1989. Odor thresholds for chemicals with established occupational health standards. American Industrial Hygiene Association. Fairfax VA. Stock no. 108-EA-89.

Agency for Toxic Substances and Disease Registry (ATSDR). 2006. Toxicological profile for Hydrogen Sulfide. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Danielsen PH, Peter Møller,† Keld Alstrup Jensen, Anoop Kumar Sharma, Hakan Wallin, Rossana Bossi, Herman Autrup, Lars Mølhave, Jean-Luc Ravanat, Jacob Jan Briede, Theo Martinus de Kok, and Steffen Loft. 2011. Oxidative Stress, DNA Damage, and Inflammation Induced by Ambient Air and Wood Smoke

- Particulate Matter in Human A549 and THP-1 Cell Lines. *Chem. Res. Toxicol.* 18:24(2):168-84.
- Harper LA, Flesch TK, Powell JM, Coblenz WK, Jokela WE, Martin NP. 2009. Ammonia emissions from dairy production in Wisconsin. *J. Dairy Sci.* 92:2326–2337.
- Hristov AN. 2009. Livestock Contribution to Fine Particulate Matter (PM2.5) in the US. Penn State University College of Agricultural Sciences Extension Bulletin. Internet: <http://extension.psu.edu/animals/dairy/news/2009/livestock-contribution-to-fine-particulate-matter-pm2.5-in-the-us>.
- Laden, Francine, Joel Schwartz, Frank E. Speizer, and Douglas W. Dockery. 2006. Reduction in Fine Particulate Air Pollution and Mortality: Extended Follow-up of the Harvard Six Cities Study. *Am J Respir Crit Care Med* 173:667–672.
- Meisinger, J. J., and W. E. Jokela. 2000. Ammonia volatilization from dairy and poultry manure. Pages 334–354 in *Managing, Nutrients and Pathogens from Animal Agriculture*. NRAES-130, Natural Resource, Agriculture, and Engineering Service, Ithaca, NY.
- Michigan Department of Environmental Quality. 2006. Concentrated Animal Feedlot Operations (CAFOs): Chemicals Associated with Air Emissions. CAFO subcommittee of the Michigan Department of Environmental Quality (MDEQ), Toxics Steering Group (TSG) Concentrated Animal Feedlot Operations (CAFOs). Internet: [http://www.michigan.gov/documents/CAFOs-Chemicals\\_Associated\\_with\\_Air\\_Emissions\\_5-10-06\\_158862\\_7.pdf](http://www.michigan.gov/documents/CAFOs-Chemicals_Associated_with_Air_Emissions_5-10-06_158862_7.pdf)
- Midwest Plan Service (MWPS) 18-3 “Outdoor Air Quality (Livestock Manure)” Published by Iowa State University. <https://www-mwps.sws.iastate.edu>
- Minnesota Department of Health. 2009. Excel Dairy- Background and Exposure Investigation Report. Minnesota Department of Health; <http://www.health.state.mn.us/divs/eh/hazardous/sites/marshall/exceldairy/excelinfo.html>
- Misselbrook, T.H., K.A. Smith, D.R. Jackson, and S.L. Gilhespy. 2004. Ammonia Emissions from Irrigation of Dilute Pig Slurries. *Biosystems Engineering*, 89(4):473-484.
- NRCS 68-3A75-5-157, <http://datcp.wi.gov/uploads/Farms/pdf/CIGFinalReport.pdf>
- Plains Justice. 2010. Public Health and Livestock Confinements: Identifying Threats to Public Health. 21 pages. Available at <http://plainsjustice.org/files/PublicHealthandCAFOs.pdf>
- Rotz, C.A. 2004. Management to reduce nitrogen losses in animal production. *Journal of Animal Science*, 82:E119-E137. <http://agron-www.agron.iastate.edu/Courses/agron515/Rotz2004.pdf>

Rotz, C.A., M.S. Corson, D.S. Chianese, F. Montes, S.D. Hafner, and C.U. Coiner. 2012. The integrated Farm System Model. Reference Manual Version 3.6. USDA ARS Pasture Systems and Watershed Management Research Unit. <http://ars.usda.gov/SP2UserFiles/Place/19020000/ifsmreference.pdf>

Sommer, S.G., J.E. Olesen, and B.T. Christensen. 1991. Effects of temperature, wind speed and air humidity on ammonia volatilization from surface applied cattle slurry. *Journal of Agricultural Science*, 117:91-100. [http://journals.cambridge.org/download.php?file=%2FAGS%2FAGS117\\_01%2FS0021859600079016a.pdf&code=6e8d53159bbe717e3592b187924f0996](http://journals.cambridge.org/download.php?file=%2FAGS%2FAGS117_01%2FS0021859600079016a.pdf&code=6e8d53159bbe717e3592b187924f0996)

Venners, Scott A., Binyan Wang, Zhonggui Peng, Yu Xu, Lihua Wang, and Xiping Xu. 2003. Particulate Matter, Sulfur Dioxide, and Daily Mortality in Chongqing, China. *Environmental Health Perspectives*, 111(4 ): 562-567.

Vermont Department of Health. 2012. Study of Formaldehyde Footbaths On-Farm. [http://healthvermont.gov/enviro/formaldehyde/documents/formaldehyde\\_farm\\_study.pdf](http://healthvermont.gov/enviro/formaldehyde/documents/formaldehyde_farm_study.pdf)

WDNR 2010, <http://dnr.wi.gov/topic/AirQuality/documents/bmp/FinalReport101213.pdf>

### ■ 3.e Airborne Pathogens

#### Airborne Pathogens – Definition and Issue of concern

Application of liquid dairy manure by traveling gun or center pivot irrigation systems is becoming more common in Wisconsin. A primary concern raised about these practices by stakeholders is that manure irrigation could increase the risk of airborne pathogen transmission to humans and livestock. The concern stemmed from the potential increase in airborne droplets and more frequent application compared to other application methods. To address the issue of airborne pathogen transmission, this section summarizes a Wisconsin study on dairy manure irrigation and human health risks (Borchardt and Burch 2016, included as Appendix C). Much of the text in this section of the report is extracted from Appendix C (with permission); other parts are paraphrased for brevity.

The study summarized here is a Quantitative Microbial Risk Assessment (QMRA) developed using data collected from several Wisconsin farms employing manure irrigation practices. The Wisconsin study had two primary objectives:

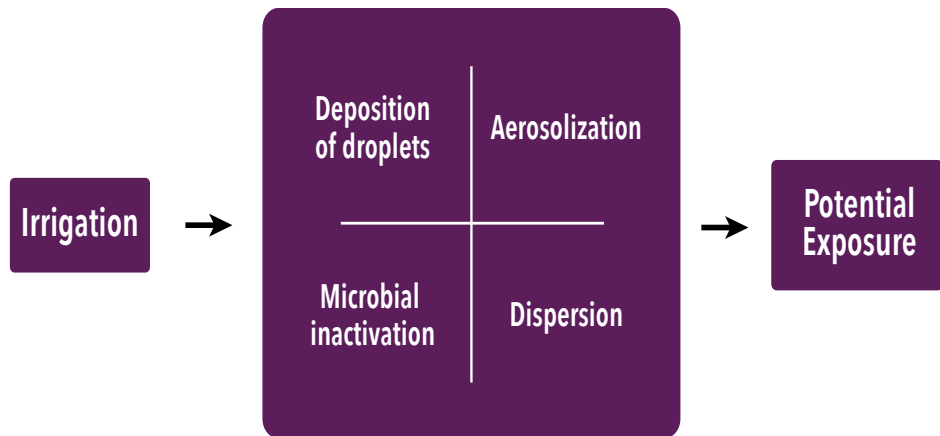
1. Identify weather variables (e.g., wind speed, solar radiation, and relative humidity) most important for airborne pathogen transport during manure irrigation.
2. Use microbial risk assessment to estimate the risk of illness for people exposed to airborne pathogens downwind from manure irrigation sites.

Appendix C includes the research study details and a summary of previous research on health risks associated with airborne fecal pathogens. Based on assumptions outlined below and in Appendix C, the study quantifies risk of acute gastrointestinal illness from pathogens at different downwind distances.

### Airborne Pathogens – An Overview of QMRA Study

#### **Conceptual Model of Pathogen Transport, Inactivation, and Exposure in Air.**

Airborne transport of pathogens from irrigated manure to humans depends on four processes (Figure 3e-1). Following release from the irrigation nozzle, manure droplets are deposited on the ground due to gravity, while aerosols are transported downwind. During transport, the aerosolized pathogens disperse in the atmosphere (reducing their concentration) and are inactivated (i.e., killed). The rate of inactivation can occur quickly and depends on temperature, relative humidity, and ultra-violet light from sunshine. For example, a representative inactivation rate during daytime conditions is 0.07 per second (Teltsch et al. 1980), which corresponds to a half-life of 10 seconds. This means that the initial pathogen concentration in the aerosol is reduced by half for every 10 seconds of exposure to environmental conditions. However, while inactivation occurs quickly during the day, it can be much slower during nighttime conditions (Teltsch et al. 1980; Paez-Rubio and Peccia 2005). Human exposure to pathogens that survive airborne transport can occur through four routes: 1) inhalation, with some fraction of the inhaled aerosols being swallowed and reaching the gastrointestinal system; 2) deposition of the pathogens onto food or crops that are then eaten; 3) deposition of pathogens onto inanimate surfaces, followed by hand-to-mouth transmission; and 4) contact with vectors (e.g., pets or insects) that cause secondary, indirect transmission. Following exposure, the pathogens may result in infection and/or illness depending on the host's immune system.



*Figure 3e-1 Conceptual model of pathogen airborne transport and human exposure during manure irrigation.*

*[note: Also Figure C-1 in Appendix C]*



Finally, it is important to recognize that the pathogen content of dairy manure can be highly variable from herd to herd and in the same herd over time. Thus, exposure to dairy manure does not always result in exposure to pathogens. On the other hand, the absence of pathogens in a specific dairy herd at a specific point in time does not equate to the universal absence of health risk from that herd over time.

#### **Risk assessment study methods.**

For the study, risk was defined as the probability of acute gastrointestinal illness (AGI) due to airborne transmission of pathogenic bacteria from irrigated manure to humans. It considered the most immediate exposure route described above – inhalation followed by ingestion – at distances up to 1,000 feet from the irrigation wetted perimeter. Unlike similar studies previously conducted, risk estimates were based on empirical field data for 21 full-scale dairy manure irrigation events from three dairy farms. Note, using AGI as the risk outcome errors towards higher risk estimates because the more severe illnesses that can result from these pathogens (e.g., septicemia, hemolytic uremic syndrome) are less likely to happen than AGI.

Because the pathogens of interest were rarely found in the manure at the study farms, two non-pathogenic bacteria that were always present in manure were used as surrogates to represent airborne transmission of pathogens. The surrogates measured in the study were selected to show a range of risk associated with losses through transport. Bovine *Bacteroides* had the highest detection frequencies in the downwind air and is used in the analysis to represent pathogens with high potential for survival during transport. Gram negative bacteria had the lowest detection frequencies in the downwind air and is used in the analysis to represent pathogens with lower potential for survival during transport. Air concentrations of both surrogates decreased with distance from the manure irrigated wetted perimeter.

Risk from exposure was considered for three pathogens, *C. jejuni*, EHEC, and *Salmonella* spp., because these pathogens are common on U.S. dairy operations (USDA 2003; USDA 2011). The risk assessment accounted for variation in people's susceptibility to infection by relying on millions of combinations of age, time spent outdoors, inhalation rate, and inhalation volume drawn randomly from statistical distributions for these parameters (see Figure C-4).

The risk assessment also accounted for variability in pathogen content of dairy manure by modeling two different values for pathogen prevalence in the manure influent. For the three pathogens considered, the first value was a typical prevalence for dairy operations of 39%, 40%, and 90% for EHEC, *Salmonella* spp., and *C. jejuni*, respectively (USDA 2003; USDA 2011). The second value was conservative as it assumed 100% prevalence for each pathogens considered. The combination of two surrogates and two pathogen prevalence values yielded four risk scenarios that circumscribe the range of risk estimates obtained in this study.

In addition to the QMRA, researchers also developed empirical models to investigate the relationship between measured concentrations of airborne microorganisms and environmental factors measured during each field trial. These factors included distance, wind speed, relative humidity, sunlight, temperature, and concentrations of microorganisms in source manure.

**Study Findings.**

Median risk estimates varied between roughly 1 in 100,000 and 1 in 100 depending on different combinations of pathogen prevalence and the surrogate used to represent airborne transmission of pathogens. Though wide, this range is considerably narrower and somewhat higher than most risk estimates from previous similar studies. It also largely falls between acceptable risk thresholds for drinking water (1 infection per 10,000 people per year) and recreational water (32 illnesses per 1,000 swimmers per event). Finally, it must be recognized that these risk estimates represent single exposure events. If individual fields are irrigated multiple times in a season, then the cumulative risk over that season will be higher. That cumulative risk can be estimated as the product of the single exposure risk and the number of exposure events per season.

Overall, the most important factor for interpreting risk estimates was pathogen prevalence in the source manure. However, if a pathogen is present, then results suggest that distance and wind speed were the most important environmental factors related to measured airborne microorganism concentrations.

**Implications for Siting (location and application considerations).**

Anticipated risks related to airborne pathogens vary based on distance from a manure irrigation source. Understanding this variation is essential for informing recommendations of setback distances between manure irrigation and neighboring receptors such as residences, schools, gardens, surface water, and well heads. It is also important for those making decisions to determine their acceptable risk threshold and the combination of pathogen prevalence and surrogate used for risk determination.

The most important weather variable in determining downwind microbe concentrations is wind speed. Other factors, such as solar irradiance and dispersion interact with wind speed and distance to affect downwind concentrations of active microbes. Prevalence, initial concentration of pathogens in the source manure, and distance downwind from the source are also critical non-weather factors.

In general, this analysis shows that four actions provide the biggest payoff in reducing the risk of airborne disease transmission from dairy manure irrigation: 1) improvements in herd health to reduce pathogen prevalence in manure; 2) treatment to reduce or eliminate manure pathogens; 3) irrigate in low wind speed conditions to reduce downwind transport; and 4) maximize the distance between irrigated manure and people.

**Airborne Pathogens – Unknowns and remaining uncertainties.**

Additional information about unknowns and remaining uncertainties is presented in the more complete study summary in Appendix C. The discussion of study limitations and data interpretation is especially important for understanding this study.

Table 3e-2. Airborne Pathogen Issues for Manure Irrigation Practices

	Practices or conditions to limit airborne pathogen risk	Practices or conditions that exacerbate airborne pathogen risk
Siting	<p>Edge of field barriers</p> <p>Maximize separation distance to inhabited dwellings/public spaces</p> <p>Avoid irrigating when wind direction is towards inhabited dwellings</p>	<p>Irrigating near households with young children, elderly people, or people that have compromised immune systems</p> <p>Irrigating near an inhabited dwelling</p>
Weather	<p>Applications during:</p> <ul style="list-style-type: none"> <li>· Low wind velocities</li> <li>· Warm temperatures</li> <li>· Bright sunshine</li> <li>· Low humidity</li> </ul>	<p>Applications during:</p> <ul style="list-style-type: none"> <li>· High wind velocities</li> <li>· Cool temperatures</li> <li>· Overcast periods</li> <li>· Nighttime</li> <li>· High humidity</li> <li>· Inversion periods</li> </ul>
Waste Characteristics	<p>Good herd health</p> <p>Maintaining low pathogen level in applied material through:</p> <ul style="list-style-type: none"> <li>· Anaerobic digestion</li> <li>· Storage for 30 to 90 days in manure lagoon</li> <li>· Aeration of lagoon effluent</li> <li>· Pasteurization</li> <li>· Advanced treatment</li> </ul> <p>Pathogen analysis before application</p>	<p>High initial levels of pathogens in applied material. Higher potential from:</p> <ul style="list-style-type: none"> <li>· Fresh manure or manure stored for &lt; 30 days</li> <li>· Calf manure</li> </ul>
Equipment: Center Pivot	<p>Drop nozzles which lower the nozzle height below the boom structure. Note that nozzle heights are generally fixed for an entire season.</p> <p>Low pressure</p> <p>Large droplet sizes</p>	<p>Application from the top of a center pivot using impact sprinklers.</p> <p>High pressure</p> <p>Small droplet sizes</p>
Equipment: Traveling Gun	<p>Large droplet sizes</p>	<p>Small droplet sizes</p>

References for 3e. Airborne Pathogens

All references for this section are found in Appendix C.

### ■ 3.f Timing of application for nutrient benefits, road safety, and road damage

Over time, the equipment used by farmers and custom manure applicators for nutrient land application and hauling have increased in size and weight. Increased vehicle size and traffic volume from livestock operations during manure land application has raised questions about public safety and the negative impacts on quality of life when trucks and/or large farm equipment is operating frequently. A related issue of concern to local governments is the negative impacts that large farm equipment can have on local road systems, as revealed by the Wisconsin DOT *Implements of Husbandry* report.

#### Manure handling is changing

As discussed in Chapter 2, livestock manure characteristics and handling techniques have changed in recent decades. At the same time the livestock housing systems consolidate low solids agricultural by-products other than manure which contributes to a more liquid manure mix. A general increase in farm size has further accelerated the trend toward use of high-volume liquid manure storage systems. As noted, the reduction in winter spreading of manure has further condensed the calendar windows for applying livestock manure to the land.

As discussed in Chapter 3, solids separation is commonly practiced on larger dairy farms. Separated manure allows the liquid fraction to be handled using a variety of application techniques (often at a higher application rate per acre due to the reduced nutrient content). The separated solid fraction of the manure can be partially recycled as animal bedding or land applied. In addition, the reduction of water from separated solids increases nutrient density and allows hauling to greater distances and nutrient application onto fields that may not have previously received manure.

The majority of livestock manure hauled in the state of Wisconsin is less than 11% dry matter. Transportation of liquid or slurry manure is primarily by tanker wagons pulled by farm tractors or semi-truck tankers. A common strategy when developing a manure application plan is to minimize hauling distances from the livestock production site to reduce hauling costs.

A significant portion of Wisconsin's manure is transported by professional nutrient applicators. These contractors move from farm to farm with specialized manure agitation/loading equipment and utilize a fleet of transport vehicle and non-permanent drag hose lines to efficiently haul and land-apply manure. With the shift to professional land application of manure by nutrient applicators, there has been improved capacity for conformance with nutrient management plans and environmental restrictions. An unintended negative consequence is that a limited number of haulers are available to provide service to numerous farms during the short spring and fall land application windows typically available in Wisconsin.

## Timing Issues

Much of Wisconsin's livestock manure is applied during relatively short time periods in the spring before planting (which can be complicated by late thaws or extended wet periods) and in the fall, after harvest when applications can be complicated by late harvest, extended wet periods, or early snow or freezing. Livestock manure can also be applied in late spring/summer months on alfalfa or after harvest of winter wheat crops. Yet, those narrow spring and fall time periods of intensive action concentrate risks related to rural road safety problems (congestion and accidents involving farm vehicles), the potential for application mistakes and spills, and nuisance concerns related to odor and operation of agricultural equipment (noise, lights, dust, etc.). As noted in other parts of the report, the timing of application also affects nutrient uptake, nitrogen leaching, and other runoff or water quality factors.

Fields need to be dry prior to planting and once planted cannot have manure applied by vehicles, limiting the time period for application. Applying manure after alfalfa cutting is an exception, but may be limited to a short period after cutting because of regrowth, rain occurring after harvest, and soil moisture. Similarly, fall application is limited by when crops are harvested from the field and when the ground freezes and snow accumulates on the surface. Figure 3f-1 illustrates annual time periods when the majority of manure is applied to crop fields. Within the manure application periods are additional crop planting and harvesting operations that limit manure application.

With manure irrigation, the time period for applications increases to include the summer months during the growing season. This allows:

- The timing of application to be more selective based on weather and soil conditions.
- Applications to be divided over several dispersed time intervals during the crop growing season reducing the risk of nutrient and bacteria surface runoff or loss/entry into groundwater (e.g., potentially four applications of 0.2 inches each rather than a single application of 0.8 inches).
- Application to occur in drier soil conditions which allows nutrients, microorganisms, and water to be absorbed in the upper soil layer reducing losses. De-nitrification does not occur when soil moisture is below 50-55%, thereby reducing nitrous oxide (a greenhouse gas) production.
- Application to occur on growing crops which allows
  - Roots to absorb applied nutrients and water, potentially increasing plant yields and reducing the risk of nutrient leaching to groundwater.
  - Plant structure to reduce the risk of surface runoff.
  - Reductions in groundwater use during dry conditions.
- Applications to the surface of plants and soil allowing for pathogen inactivation from desiccation and solar radiation
- Improvement in nitrogen use efficiency (reduction in nitrogen loss) as nitrogen is applied when roots are actively growing and drawing nitrogen from the soil unlike traditional application where substantial nitrogen leaching can occur in the late winter and spring (Masarik et al 2014).

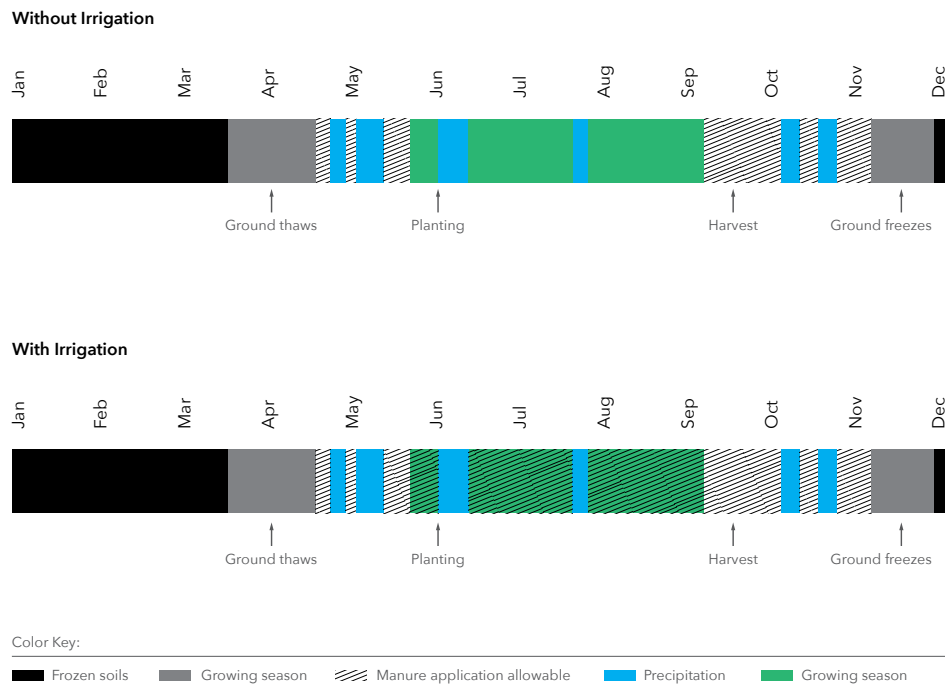


Figure 3f-1. Annual Timeline showing potential land-application periods for manure with and without irrigation

### Manure hauling affects road safety, and increases road wear and maintenance

The network of township roads that typically surround livestock operations were built using state/federal grant funds. Historically, Town leaders took advantage of these incentives to surface most of the town roads in Wisconsin to reduce dust and annual maintenance costs inherent to un-surfaced roads (routine grading to maintain a level road surface). At the time these roads were constructed, they were not designed to accommodate the changes in traffic volume and vehicle loads associated with contemporary manure application. Township roads tend to be narrower than county roads, with narrower shoulders and portions of many were constructed on less than ideal subgrade materials. Results and recommendations included in the *Implements of Husbandry* study will likely affect how town roads are used for manure hauling.

As outlined in that report, to address safety concerns and to minimize road damage, many livestock operations have worked with local governments to implement manure hauling best management practices. Examples include temporarily converting local roads to one-ways. The one-way traffic pattern prevents smaller vehicles from having to move far right to when encountering large equipment on a two-way road. The one-way traffic pattern also allows heavy tanker equipment to travel down the center of the road, which allows for better weight distribution to the road surface and reduces the chance for break up along the edge of the road.

Interest in using permanent and mobile piping for distributing manure is also increasing (see Chapter 2). Part of the interest can be attributed to new road vehicle weight and size limitations included in recent Implements of Husbandry legislation (2013 Wisconsin Act 377). As an alternative to hauling manure to fields, some livestock operations have installed permanent underground pipe systems to convey manure liquids to centralized field locations. Those piping systems allow for application using irrigation equipment or pump/drag hose systems. The underground pipe systems have a significant initial capital cost but can significantly reduce vehicle traffic associated with hauling and applying manure.

### References

Masarik, K.C., Norman, J.M. and Brye, K.R. (2014) Long-Term Drainage and Nitrate Leaching below Well-Drained Continuous Corn Agroecosystems and a Prairie. *Journal of Environmental Protection*, 5, 240-254. <http://dx.doi.org/10.4236/jep.2014.54028>

Wisconsin Department of Transportation (WDOT). 2013. Implements of Husbandry Study: Phase I Report to the Secretary of the Wisconsin Department of Transportation (January 2013); Phase II Report to the Secretary of the Wisconsin Department of Transportation (July 2013); Phase II Addendum Report to the Secretary of the Wisconsin Department of Transportation (September 2013). Reports available at <http://wisconsindot.gov/Pages/dmv/agri-eq-veh/study.aspx>

## ■ 3.g Additional farm management and economic issues

Manure irrigation offers options for livestock operations that can improve overall farm management and influence farm economics. Decisions by farm managers to use available technology and practices involve considerations for cost, convenience, impacts to existing farm operations and management, and conservation and stewardship objectives. Livestock operations have multiple reasons for considering manure irrigation as part of their overall farm system. These include the potential for the following:

- Better control over the timing of manure applications to allow for application during the summer growing season.
- Improved accuracy of nutrient application and potential nutrient efficiency and crop benefits from delivering nutrients when plants are growing.
- Flexibility to modify application rates based on crop development and nutrient status (within the overall constraints of a nutrient management plan).
- Reduced soil compaction (or risk of soil compaction) due to field traffic of manure application equipment.
- Improved crop yields with nutrient and water delivery.
- Shifting manure distribution toward piped systems and away from tankers/trailers on roads.
- Reduced traffic and road concerns (for the farmer/operator as well as other drivers and neighbors).
- Reduced cost of application of nutrients (reduced fuel usage and costs).
- Reduced demand on custom manure applicators when weather, crop, and soil

conditions result in shortened acceptable periods of time to apply nutrients in Spring and Fall.

- Increased likelihood manure storage structures will remain at lower levels throughout the growing season and will not enter the winter season with manure remaining, reducing the risk of overtopping.
- Capturing manure management benefits as part of investments in irrigation systems installed as protection against drought.

Understanding costs associated with manure irrigation compared to other available practices is helpful for understanding farm management decisions. As discussed in section 2b, livestock operations use a variety of methods for collecting, processing, transporting, and field-applying manure. Decisions about any one part of a manure management system are interdependent with decisions about the other parts of that system. Any options for field application are limited by spreading restrictions, agronomic application rates, weather, and soil conditions.

#### General cost considerations

Section 2b identified four main components associated with manure management and hauling. General costs associated with different component options are outlined below.

- **Manure processing/treatment:** As noted in section 2b, costs associated with installing manure processing systems can be highly variable as can the maintenance and operational costs of different systems. Digester systems and cost of manure processing equipment to remove fiber and segregate nutrients can cost millions of dollars. Nutrient segregation systems can allow for greater control of nutrient content in the liquid manure applied through manure irrigation systems, which may be especially useful for applying small doses of nutrients at specific times in the plant growing cycle through center pivot systems. Nutrient segregation systems begin with removal of fiber, and can then progress with additional investment to remove phosphorus, and with more investment removal of nitrogen (ammonia) and pathogens. Nutrient segregation will result in concentrated nutrient sources which can be transported to fields further from the animal operations and applied in a manner similar to how commercial fertilizers are used.
- **Manure transport through piping systems:** Installing pipes for transporting liquid manure from storage structures to fields eliminates the need to transport the material in trucks. Estimated cost of installing and permitting pipelines to irrigation systems can range from approximately >\$110,000/mile - \$150,000/mile.
- **Traveling gun systems:** As described in section 2b, travelling guns are highly mobile pieces of equipment that can be moved easily from field to field. Hoses attached to traveling guns can connect to either piping systems, tanker trucks, or directly to storage facilities. Traveling guns also require low solids content (from 4 to 7% solids). Costs to purchase and use traveling guns are relatively low.



- **Center pivot systems:** Cost of center pivot irrigation systems are approximately \$1,000/acre or more (add reference/source). Inclusion of special nozzles (including drop-nozzles that lower the discharge point closer to the ground), remote web-based management technologies for controlling pivot rotation speed and flow rates for individual nozzles increase costs. As noted in section 2c, use of center pivot systems requires low solids content in order for the nozzles to function. Older center pivot equipment may not be fitted for the drop nozzles and rotators recommended for use.

#### Operational cost estimates for transport and application

Several estimates regarding operational cost associated with differing management aspects of manure irrigation practices are provided below. Manure irrigation is one component of manure management and application for an operation. Costs associated with other practices and technologies for transporting and applying manure to fields are included for context and comparison.

#### **Fuel costs**

- \$3.50/gal
- pumps/tractors/trucks use 5 gallons/hour or 5 miles/gallon

#### **Application rates**

- vary between 10,000-20,000 gallons/acre of unprocessed manure (note: 27,000 gal/acre is approximately 1 inch of liquid/acre)

#### **Hosing application**

- Pumping capacity 650-1,000 gal/minute.
- Each additional mile from source requires additional pump.
- Ability to place hose/pipe under roads.
- Requires 3-person crew to run system plus an additional person per pump. Field setup requires additional tractor, hose trailers and 1hr down time for each hose set for a 20-40 acres.
- Application is observed continuously to prevent runoff.

#### **Trucking application**

- Often in combination with hosing application where nutrients are trucked to field, emptied into a tank, and from tank to hosing application. This complicates the application with trucks lining roads waiting for hose application delays.
- When applied directly to fields the following apply: soil compaction concerns; tractor and equipment needed to incorporate manure into the soil; mud tracked on to roads when leaving fields; and application rates more variable depending on soil type/conditions, topography, truck speed and load.
- 5-20 trucks running at a time depending on distances hauled which can range up to 30 miles one way.
- Average truck tank holds 5600 gallons and takes three minutes to fill or empty.
- Primarily applied in spring prior to planting or fall post crop harvesting. Can also be applied in season on alfalfa crop within a 5 day period after cutting (with limitations by soil moisture and soil compaction concerns).

### **Center Pivot Irrigation**

- 45 acre pivot, 30 hp electric nutrient pumps, 10 hp pivot motor 0.5 gal/hr. pump capacity 450 gal/minute.
- Ability to apply spring, summer, and/or fall, on growing crops with multiple applications (application rates consistent with nutrient management plan and crop utilization).
- Depending on the level of dilution from solid separation and nutrient segregation technology, volumes may vary from 40,000-150,000 gals/acre (1.5 – 5.5 inches of liquid per acre) applied through numerous applications throughout the seasons. Tables A-1 and A-2 in Appendix A presents estimates of nutrient content of manure.



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## 4. Scenarios

The individual situations in which manure irrigation might be used as a land application practice would determine the extent of potential risks and benefits. The scenarios below are intended to illustrate how the addition of manure irrigation might change producers' management practices and how those changes may affect their neighbors. Three simplified scenarios below represent three different farm sizes: 150-cow, 600-cow, and 2,500-cow operations. All three operations use a mix of manure irrigation and conventional application methods. For each scenario, tables reflect increasing percentages of manure that could be applied with irrigation technology relative to conventional methods. Scenario assumptions are identified, and each scenario highlights differences in manure hauling, potential reduction in tanker trips for neighbors, reduced tanker road mileage, and the producer's cost impacts for hauling.

### ■ 4.a Three Dairies

#### Assumptions for all three scenarios

The following assumption apply to all three scenarios and throughout this section of the report:

- Animals: Milking cows are 1,400 pound milking cows (and the farm includes no support animals)
- Manure production: 18.7 gallons of manure per 1,000 pounds of cow per day
- Manure solids content: all manure is considered to be 5% solids content to allow for irrigation (center pivot systems require additional solids removal as outlined)
- Total manure volumes: Manure production values are multiplied by 1.8 to account for additional wastes produced on the farm (e.g. urine, milking parlor wash water)
- Manure hauling frequency: 150-cow farm hauls throughout the year; the 600-cow and 2,500-cow operations haul primarily in spring and fall
- Average hauling distance: 150 cow farm is 0.9 miles, 600 cow farm is 1.5 miles, and a 2,500 cow farm is 3.8 miles (note: consistent with a recent manure survey conducted in Wisconsin)
- Tanker volume: A tanker holds 8,000 gallons of manure
- Cost of land application: Tanker land application is \$0.015/gallon and irrigation application is \$0.0075

Note: capital costs are significant for center pivot systems

- center pivot systems commonly cost upwards of \$1,000 per acre
- permanent buried manure lines range \$110,000-\$150,000 per mile
- non-permanent drag hose lines \$6,000-\$13,000 per mile depending upon hose-line diameter
- manure pumping systems also require pumps at approximately \$50,000 each (roughly one pump per linear mile)

### Dairy with 150 cows

This 150 milking cow dairy produces 3,927 gallons of manure per day (1,433,355 gallons annually), and 7,069 gallons of total manure and other agricultural by-products combined (2,580,039 gallons annually). If applied every 4 days (roughly 89 times per year) that is 28,990 gallons per application. That would translate to three tanker loads driving 0.9 miles to the field and back every 4 days for the entire year (or approximately 6 tanker trucks per week). If this dairy decided to integrate a traveling gun system to haul some of the manure, it would affect the truck traffic and application costs depending on the amount applied with a traveling gun system (see Table 4a-1).

*Table 4a-1: Differences associated with shifting 0-50% of manure application to irrigation for the 150-cow dairy*

	Annual Percent of Manure Applied by Traveling Gun				
	0%	10%	20%	30%	50%
Annual Manure Volume Applied by a Tanker (gallons)	2,580,039	2,322,035	2,064,031	1,806,027	1,290,020
Annual Manure Volume Applied by a Traveling Gun (gallons)	0	258,004	516,008	774,012	1,290,020
Annual Manure Tanker Trips	323	290	258	226	161
Annual Total Tanker Distance Traveled (miles)	583	524	466	408	291
Application Cost (\$)	\$38,701	\$36,766	\$34,831	\$32,895	\$29,025

It is highly unlikely that a producer would use a center pivot manure irrigation system at a small dairy. Use of a center pivot system for manure irrigation requires manure storage (only 25% of smaller farms use storage) and solids removal processing, which is beyond the investment capabilities of this size farm.

### Dairy with 600 cows

This 600 milking cow dairy produces 15,708 gallons of manure per day (~5.7 million gallons annually), and 28,274 gallons of total manure and other agricultural by-products combined (~10 million gallons annually). If applied on average 15 times per year that is ~700,000 gallons per application period. That would translate to 645 tanker loads driving 1.5 miles to the field and back both during the spring and fall each year.

If this dairy decided to integrate a traveling gun or center pivot irrigation system to haul manure it would affect the truck traffic and economics according to the amount applied with the irrigation system, Table 4a-2.

Table 4a-2: Differences associated with shifting 0-50% of manure application to irrigation for the 600-cow dairy

	Annual Percent of Manure Applied by Traveling Gun				
	0%	10%	20%	30%	50%
Annual Manure Volume Applied by a Tanker (gallons)	10,320,156	9,288,140	8,256,125	7,224,109	5,160,078
Annual Manure Volume Applied by a Traveling Gun or Center Pivot (gallons)	0	1,032,016	2,064,031	3,096,047	5,160,078
Annual Manure Tanker Trips	1,290	1,161	1,032	903	645
Annual Total Tanker Distance Traveled (miles)	9,821	8,839	7,857	6,875	4,910
Application Cost (\$)	\$154,802	\$147,062	\$139,322	\$131,582	\$116,102

Dairy with 2,500 cows

The 2,500 milking cow dairy produces 65,450 gallons of manure per day (~24 million gallons annually), and 117,810 gallons of total manure and other agricultural by-products combined (~43 million gallons annually). If applied on average 2 times per year that is ~2 million gallons per application period. That would translate to almost 450 tanker loads driving 3.8 miles to the field and back for two different application periods in the year if all manure was applied through tankers. The annual cost to haul the manure is ~\$645,000

If this dairy decided to integrate a traveling gun or center pivot irrigation system to haul manure it would affect the truck traffic and economics according to the amount applied with the irrigation system, Table 4a-3.

Table 4a-3: Differences associated with shifting 0-50% of manure application to irrigation for the 2,500-cow dairy

	Annual Percent of Manure Applied by Traveling Gun				
	0%	10%	20%	30%	50%
Annual Manure Volume Applied by a Tanker (gallons)	43,000,650	38,700,585	34,400,520	30,100,455	21,500,325
Annual Manure Volume Applied by a Traveling Gun or Center Pivot (gallons)	0	4,300,065	8,600,130	12,900,195	21,500,325
Annual Manure Tanker Trips	5,375	4,838	4,300	3,763	2,688
Annual Total Tanker Distance Traveled (miles)	40,920	36,828	32,736	28,644	20,460
Application Cost (\$)	\$645,010	\$612,759	\$580,509	\$548,258	\$483,757

## ■ 4.b Implications for Manure Distribution, Application and Transport

### Potential Impacts to Manure Distribution – with 600 Cow Example

Manure application rates are generally limited by phosphorus allowances in nutrient management plans (depending on phosphorus soil test levels and cropping systems) or by volume limits (limited by infiltration to prevent runoff). Using a manure irrigation system requires low solids content and some degree of processing that can separate the nutrients for management. Regardless of the processing method used, the total amount of nutrients involved does not change. Operators must apply, recycle, or export (including off site sales) nutrients.

Using the previous scenario for 600 cows, these cows produce 10,320,156 gallons of total manure each year. Assuming a 1,200 acre land base and even distribution, that results in a manure application rate of 8,600 gallons per acre per year. Separating that manure through processing for use in a manure center pivot irrigation system allows a producer to fractionate that manure into two forms. For example 8,000,000 gallons of manure could contain half of the nutrients (now more dilute), and the remaining 2,320,156 gallons would contain the other half of the nutrients (now very concentrated and closer to a solid); this will change options for land application rate. A producer could apply 13,333 gallons per acre each year in two separate applications to half of the fields of the more dilute liquid, and 3,287 gallons per acre one time per year to the other half of the acres available. Different manure technologies and management systems would control the separation of nutrients and thereby control the land application. Some manure application to certain fields each year may be eliminated or reduced (e.g., fields with high runoff risk or proximity to other sensitive areas) and other lower risk fields could receive more of a diluted manure.

### Potential Impacts to Application and Transport– with 600 Cow Example

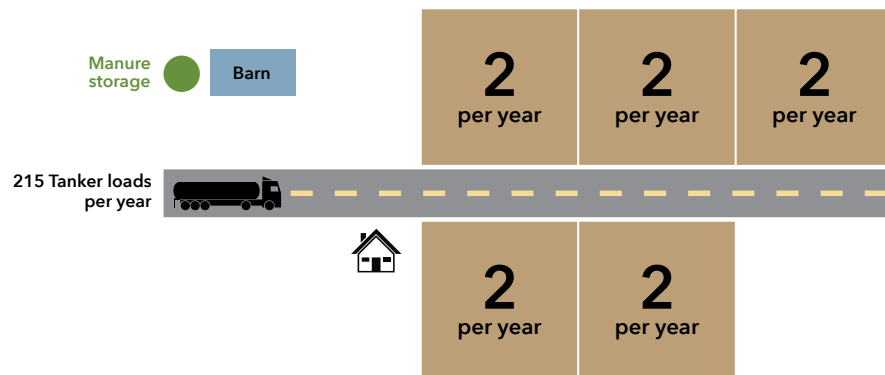
Assume the same 600 cow dairy in the example above hauls a portion of their manure to five fields that are each 40 acres (square parcels 1,320 feet by 1,320 feet). If using a conventional manure application system, assuming a tanker hauling 8,000 gallons of manure per trip and an application rate of 8,600 gallons per acre, then 215 truck-tanker loads per year would be required to transport the manure to these five fields. These tankers would concentrate manure application during two periods each year, one manure application during spring and an application during the fall.

As illustrated in Figure 4b-1, manure irrigation would change the transport situation. If one center pivot system was added on one of these fields, each field would still receive the same amount of manure nutrients (as dictated by a nutrient management plan). As solids separation is required to reach the low solids content necessary for irrigation systems, the volume of manure applied to each field would change. Looking at the same five fields, the field with the center pivot system would receive four applications per year of more dilute liquid manure (fewer nutrients per gallon). Two of the five fields would now receive one application of solid manure each year (spring or fall) with higher nutrient density. Two fields would have no change in manure application and would receive one application in the spring and one in the fall. In

this scenario, a manure pipeline would be used to transport the liquid manure to the center pivot, reducing 86 tanker loads for a total of 129 tankers per year (assuming the total manure volume remains constant before and after separation and a solid spreader holds the same volume as the liquid tanker).

This example simply illustrates one way of many that manure could be redistributed with the addition of manure irrigation. Although manure transport and application are altered, the total nutrients applied will not change. Additionally, as highlighted by the circle around the house in Figure 4b-1, different setbacks apply (as with a dwelling) when using manure irrigation systems, which influence system placement. Recommendations for setbacks and other operational guidelines are described in the next section.

### Manure Applications with Conventional Methods



### Manure Applications with Conventional Methods & Irrigation

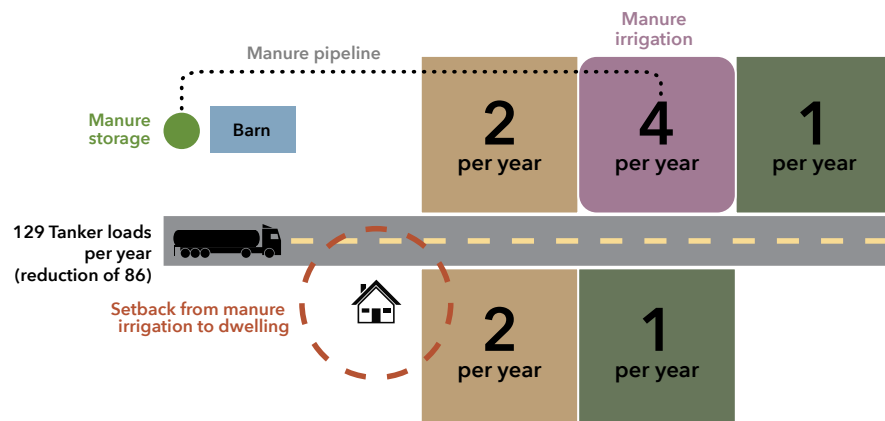


Figure 4b-1 Differences in field application of manure with irrigation and without





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## 5. Workgroup Response and Recommendations

The Manure Irrigation Workgroup formed to review a broad set of issues associated with manure irrigation and to develop guidance and recommendations for state agencies, local governments, and citizens seeking to understand this expanding technology. As outlined in Chapter 1 of this report, the workgroup met over approximately two-and-a-half years to fulfill its charge. The group primarily reviewed and vetted information and held lengthy discussions around issues of public health, risk, dairy and livestock management, rural land use conflict, and the set of issues in Chapter 3. The opportunity for the workgroup to engage with and include researchers conducting the QMRA study (Appendix C) offered unique insights into the issues involved as well as the strengths and limitations of that study. Although much of the information compiled for this report is based in well-established science, research on a number of issues specifically associated with manure irrigation is incomplete or inconclusive. This includes research regarding environmental fate and transport of hormones and the potential for antibiotic resistance associated with livestock management. While the group did not have access to resources to conduct new studies, all of those issues were discussed to some extent. Section 5a below revisits the main issues identified for the workgroup agenda at the outset of this process, and Section 5b presents recommendations based on areas of agreement among workgroup members.

### ■ 5.a Responses to expressed concerns and potential benefits

#### 1. Public health risk from airborne pathogens and other contaminants

There are public health risks related to the use of manure irrigation. Although not all of these risks were quantified, research revealed that manure irrigation practices can be managed to reduce these risks associated with the most pathogenic microbes found in manure below common thresholds used for public health. The study found that reducing the pathogen prevalence in manure and limiting exposure pathways were also effective in reducing health risks associated with acute gastrointestinal illness. Risk of exposure can be minimized by applying setback distances as reported in the study, but also by applying manure at low wind speeds, using physical barriers, or applying manure closer to the ground, among other actions. Reducing prevalence can be accomplished through herd health management or destruction of pathogens using processing systems (e.g., anaerobic digestion or pasteurization) or by applying manure when environmental conditions result in microbial inactivation.

The research summary in Appendix C provides risk estimates at specific setback distances for a given pathogen prevalence and concentration. Throughout, the study team emphasized that whenever they faced a choice regarding input for the analytical model (see Figure C-4 in Appendix C), they chose the option that would be more conservative toward public health. For example, for each of the millions of

simulations behind the QMRA results, the study assumed a person would remain at a constant distance from the wetted perimeter (e.g., 100 feet, 500 feet, etc.) for the entire time they were outdoors; for cumulative risk exposure (Figure C-9, Appendix C), the analysis assumed constant exposure and constant distance, which are both additional conservative assumptions. Therefore the study results modeling 100 percent pathogen prevalence can be viewed as a conservative worst-case scenario; use of practices to reduce prevalence and concentrations of pathogens can reduce public health risk below this threshold.

Uncertainties about transport and exposure for other contaminants remain and are likely associated with operation management. The QMRA study did not (and could not) include every pathogen and contaminant potentially present in livestock manure, however it did analyze pathogens commonly found in dairy manure (see Table C-1 in Appendix C and Table 2a-1 in the report). The study broke new ground in quantifying risk from manure irrigation (both in measurement and analysis), and it helped narrow the band of calculated risk estimates compared to any previous research. Those results and the multiple conservative assumptions were important elements of workgroup discussion and influenced the recommendations below. Additional factors expected to limit or exacerbate airborne pathogen risk are listed in Table 3e-2.

## 2. Drift

Drift of irrigated manure could occur with sufficient wind and droplet sizes prone to drift. Several management actions can be taken to minimize and prevent drift. A more detailed discussion of drift is included in Section 3a, including a list of conditions expected to limit drift or exacerbate risk of drift in Table 3a-1.

## 3. Odor and other quality of life concerns

Concerns about odor and negative impacts to quality of life from manure irrigation practices were among the strongest expressed to the workgroup and will undoubtedly be central to future public policy discussions around this issue. Odor and factors expected to limit or exacerbate its impact are discussed in some detail in Section 3b. Broader quality of life issues were raised in multiple workgroup discussions and presentations, but given the many individual experiences and perspectives that are encompassed by quality of life along with landscape and community variations across Wisconsin, the workgroup found it difficult to discuss the issue objectively or reach consensus.

Certainly concerns about severe personal hardship resonated with workgroup members, including testimonials shared with the workgroup about effects of nearby manure irrigation on adjacent homeowners. The reports mentioned in Section 3b illustrate those concerns. One of the very challenging points in discussing potential setback distances from dwellings or occupied buildings centered around whether the distances could be reduced (under various conditions) with permission of the owner or the building occupants. The question raised concerns about inequities and power imbalances, including if the occupant was a residential owner or renter and their status relative to neighboring landowners and the community. Although many quality

of life issues are not addressed explicitly, the issues surrounding quality of life were discussed throughout the process and the recommendations below are intended to minimize or eliminate negative quality of life impacts if manure irrigation practices are used.

#### 4. Surface water quality contamination

Interactions between manure irrigation and surface water quality are discussed in Section 3c. As with all forms of manure application, if not managed correctly, manure irrigation could lead to surface water contamination from runoff. Yet, manure irrigation, when compared to conventional manure application methods, also has the potential to reduce risk of surface water contamination by opening a longer time frame for applying manure to avoid application periods when increased runoff is expected, increasing infiltration due to the dilute nature of the manure, and reducing application volumes applied during each application period. As noted in Section 3c, it also has potential for over-application if used without supervision.

#### 5. Groundwater quality contamination

Similar to surface water, if not managed correctly in sensitive areas, manure irrigation applications could lead to groundwater contamination. However, a series of smaller/lower-rate applications using manure irrigation systems during the growing season and at times of peak crop need can increase nutrient uptake by plants and provide more effective holding capacity in the upper soil surface layers, both of which would reduce the potential for leaching of nutrients and other contaminants to groundwater. Interactions between manure irrigation and groundwater quality are discussed in Section 3c.

#### 6. Groundwater quantity concerns

At the outset of workgroup activities, concerns were raised that manure irrigation would lead to increased pumping of groundwater to dilute manure for irrigation or simply to take advantage of irrigation equipment. The workgroup did not determine if manure irrigation would have a negative impact on groundwater quantity due to additional pumping for dilution of manure during application. However, the practice may reduce groundwater use if liquid manure could be applied to crops in a system which would otherwise use groundwater.

#### 7. Implementation and compliance issues

Concerns about the ability of farmers to implement required actions and the capacity for regulators to monitor compliance are common and well-justified. Those concerns are reinforced and magnified by broadly circulated real examples of non-compliance that have led to harm. Implementation issues were discussed throughout manure irrigation workgroup meetings, including interactions with a nationally recognized speaker on the issue at an April 2014 workgroup meeting. Ongoing conversations in Wisconsin around challenges of monitoring, compliance, and enforcement associated with livestock agriculture have been a consistent part of the context for workgroup meetings and were an important factor in developing recommendations.

These concerns are expected to continue, and they highlight the importance of effective working relationships among those using manure irrigation, their neighbors and communities, and those working with producers on both voluntary and regulatory programs.

#### 8. Timing of manure application

The ability to apply manure nutrients to a growing crop at a time when the crop is most likely to use the nutrients is a clear benefit from manure irrigation practices. This flexibility allows for application during summer months instead of typical application in spring or fall. Application throughout the season may reduce nutrient losses as more nutrients may be used by the crop leaving less available for potential loss to the environment. In addition, using manure irrigation may interrupt common routes affecting nutrient losses to the environment during spring and fall application periods. More information about timing issues is included in Section 3f.

#### 9. Road safety and reduced road damage

Shifting manure transport from practices requiring road use into piped distribution systems reduces the number of manure vehicle trips on the roads. In addition, the reduction of manure related traffic during common manure hauling periods may further reduce road damage as those periods correspond to times when the weather can increase risk for damage. More information about this issue is available from the Implements of Husbandry Report mentioned in Section 3f. Given the geographic distribution of fields used for manure application by a single livestock operation, implementing manure irrigation will not eliminate the use of manure tankers and trucks. However, as illustrated in Section 4, it can reduce the amount of manure transported on the roads. It should be noted that piped distribution systems can be used with other manure application methods (separate from manure irrigation), and the benefits could be achieved with other application systems.

#### 10. Farm management and economic benefits

Manure irrigation increases flexibility for manure management. In combination with other system components for manure processing and storage, producers using manure irrigation practices can manage nutrients more precisely to meet crop needs over time. Although those system components involve high initial capital costs, multiple dilute applications of manure through manure irrigation methods may reduce individual application costs, compared to conventional methods. Additional information about these components is included in Sections 2a and 2b, and more about the farm management and economic benefits associated with manure irrigation is found in Section 3g and Chapter 4.

### ■ **5b. Recommendations**

Consistent with the original ground-rules established by the workgroup, all decisions were consensus seeking. Consensus was defined as unanimous agreement among workgroup members that they could “live with” whatever item was being presented for a decision. When consensus was not possible, the group also used “near consensus” to establish a very high level of agreement (one or two not agreeing), “close

to near consensus” (a few not agreeing), and “no agreement” when there was broad disagreement. Leading up to the final meeting, the workgroup had reached multiple consensus agreements around baseline conditions for the use of manure irrigation. As the most challenging issues around setback distances were presented for decisions at the final workgroup meeting, the group relied on the near consensus, close to near consensus, and no agreement measures.

When items were discussed and presented for a decision, those who could not agree with the set of conditions being discussed were asked what, if anything, could change their position. If something could be adjusted, the adjusted conditions would be presented until those adjustments led other people to change from agreement to disagreement, all the while seeking the highest level of agreement possible. Because of the workgroup charge to better understand issues related to manure irrigation and to provide information and recommendations to other stakeholders for their own decision-making, this summary is reporting on general levels of agreement among diverse workgroup perspectives rather than vote counts.

### Consensus Baseline Recommendations

As stated throughout this report, the recommendations proposed by the workgroup are intended to inform decisions by state bodies and local governments. They carry no authority. Rather, they represent the deliberations and perspectives of a diverse set of interests and experts who invested their time to review these issues in an effort to understand the balance of potential benefits and concerns about manure irrigation.

**All manure irrigation applications.** In all cases, if manure irrigation practices are to be used, operators must:

- Follow all existing relevant state and local laws regarding animal waste and nutrient management
- Have and follow a NRCS CPS 590 NMP
- Take appropriate steps to minimize drift
- Ensure no overspray of irrigated manure
- Have suitable means of supervising/controlling the equipment (e.g., active supervision, automatic sensors/controls, etc.)
- Have suitable means of determining relevant weather information (to include: wind speed, wind direction, and temperature)
- Have means of preventing contaminated backflow if equipment is connected to water sources.
- Ensure that no human waste or septage is added to (or processed with) the manure.
- Wind-speed will be determined as a 15-minute mean measurement on the field.
- Drop nozzles on the center pivot.
- Nozzles and operating pressures selected to provide “coarse” or larger drop-let sizes (based on ANSI/ASAE classifications, see Figure 3a-1)).
- Apply all materials and abide by all setbacks in accordance with an approved NRCS CPS 590 NMP

- No more than 8 irrigation applications to any given field per growing season (potential to increase if manure is treated using accepted pathogen reduction technologies\*).

\*Treated refers to additional manure processing, including but not limited to:

- Digestion meeting NRCS Standard 366 – Anaerobic Digester, combined with solids separation to 2% solids or less.
- Digestion with a Hydraulic Retention Time (HRT)  $\geq$  25 days at 100°F or a HRT  $\geq$  5 days at 140°F.
- Pasteurization to reduce bacterial levels by a minimum of 75%.
- Aeration to 2 mg/l oxygen concentration.
- Flocculation using polymers to 1% solids or less.
- The workgroup recognized that if acceptable testing and sampling protocols were to be developed in the future, then testing that demonstrated acceptable results at time of application could substitute for treatment.

Note: There were several discussions about the similarities between traveling gun and end gun mounted to a center pivot boom, but no decisions made regarding recommendations for end gun use.

#### Recommendations for Setback Distances

Given the many factors involved, the workgroup did not reach full consensus on recommendations for setback distances from various land uses and property types. In one case, the group did reach consensus, and for several situations, the group reached near consensus or close to near consensus. These areas of agreement around setback distances assume that all baseline recommendations listed above would be in place in addition to the setback distances. If a dwelling or occupied building is present, then setback distance to a dwelling/occupied building would take priority over distance to a property line. As noted above, during the discussion various conditions were added or removed in attempts to reach higher levels of agreement. When consensus was not reached, it was either because the conditions had become too restrictive or not restrictive enough from the perspective of workgroup members.

Before presenting further recommendations, it is important to clarify two terms used as part of the recommendations: wetted perimeter and setback distance. **The wetted perimeter** is the outer edge of the area receiving liquid manure through irrigation equipment. Figure 5-1 shows an illustration of the wetted perimeter for traveling gun and center pivot equipment. For a center pivot using an end-gun for field corners, the wetted perimeter would be a square rather than a circle. **The setback distance** is the minimum distance between the wetted perimeter of irrigation and the item or land use in question. Figure 5-2 illustrates the setback distance between the outside of a house and the wetted perimeter for a traveling gun application.

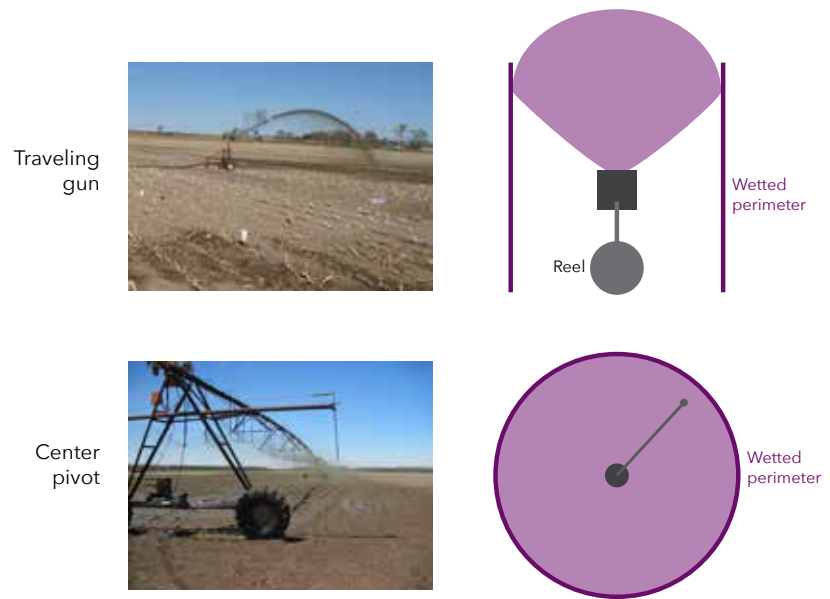


Figure 5-1. Wetted perimeter

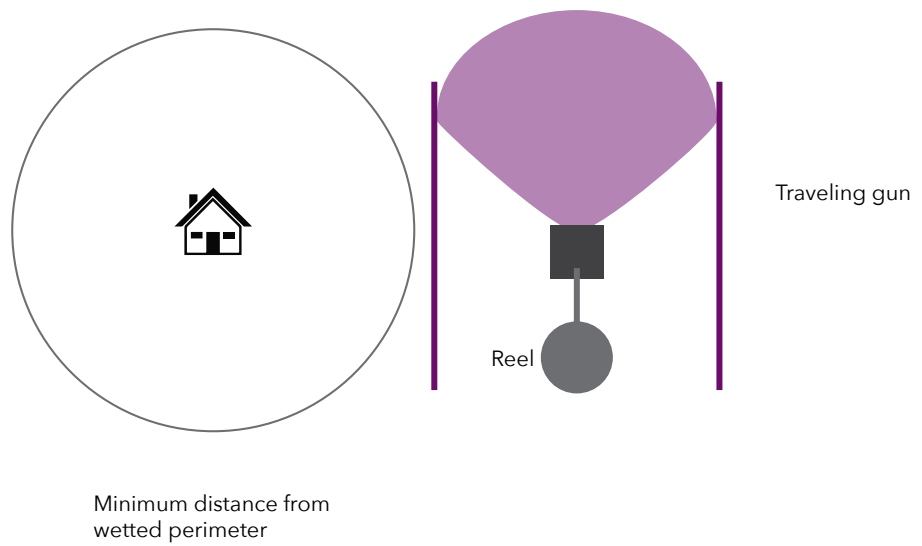


Figure 5-2. Setback distance



### Setback: Forests

For application near **the property line for public forest land with no recreational access**, (e.g., county or state lands without forest recreation or trails), there was **consensus** for a setback distance of **0 feet**, with no additional conditions.

For application near **the property line for private forest land**, there was **near consensus** for a setback distance of **0 feet**, with no additional conditions. The differences between the two had to do with potential inadvertent recreational contact for private lands.

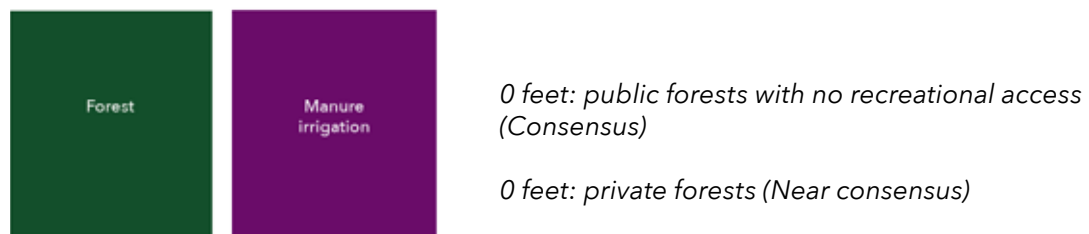


Figure 5-3a: Forests

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### Setback: Adjacent agricultural lands

For application near **the property line for pasture land (that is used as pasture)**, there was **near consensus** for a setback distance of **0 feet**, with no additional conditions. There was **no agreement** for any additional restrictions near pastureland.

For application near **the property line for cropland owned by others**, there was **near consensus** for a setback distance of **0 feet**, under the condition that the adjacent cropland was not used to produce organic or raw consumed crops. There was **close to near agreement** for setback distances of 0 feet and 50 feet regardless of the crop grown on adjacent cropland.

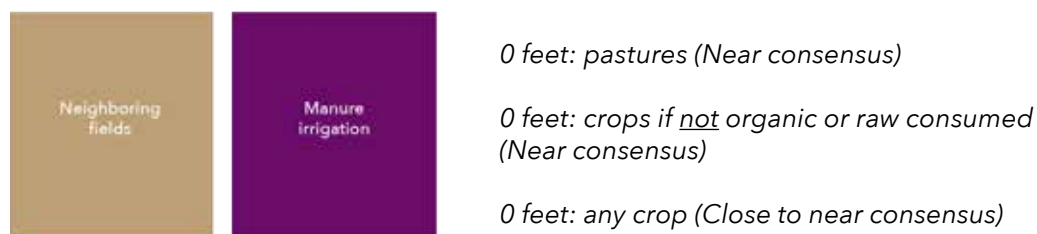


Figure 5-3b: Adjacent agricultural lands

Setback: Road right of way

For application near **the property line for a road Right-of-Way**, for all types of roads, ranging from rural roads to interstate highways, there was **near consensus** for a setback distance of **0 feet**, with no additional conditions.

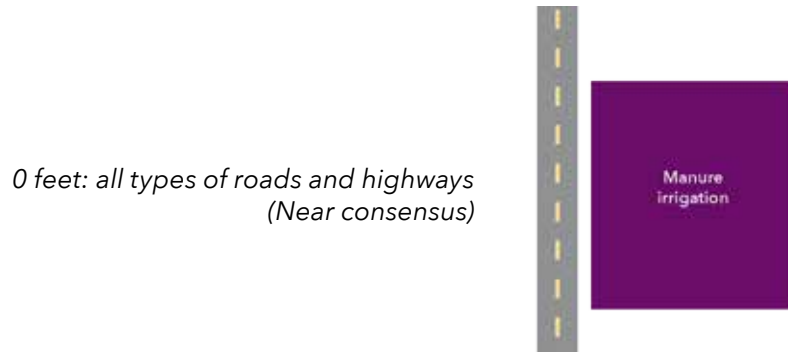


Figure 5-3c: Road right of way line

Setback: Property line for public recreational area, school, or playground

For application near **the property line for a school, playground, or public recreation area**, there was **near consensus** for a setback distance of **100 feet, under the following conditions**: wind-speed  $\leq 10$  mph, wind direction parallel or away from the property line. There was **no agreement** for other conditions at 100 feet or for distances  $< 100$  feet or  $> 100$  feet under various conditions

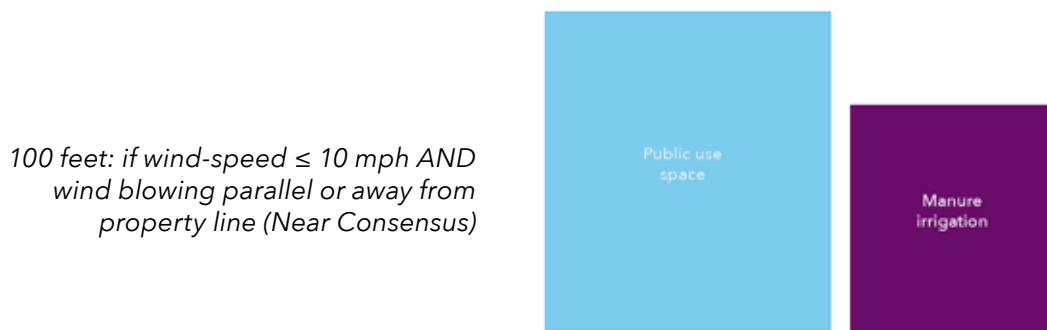


Figure 5-3d: Property line for public recreational area, school, or playground

### Setback: Dwelling or occupied building

The workgroup reached some level of agreement for setback distances of 750, 500, and 250 feet from dwellings and occupied buildings, when applications occur during daylight hours and assuming that all baseline recommendations are in place.

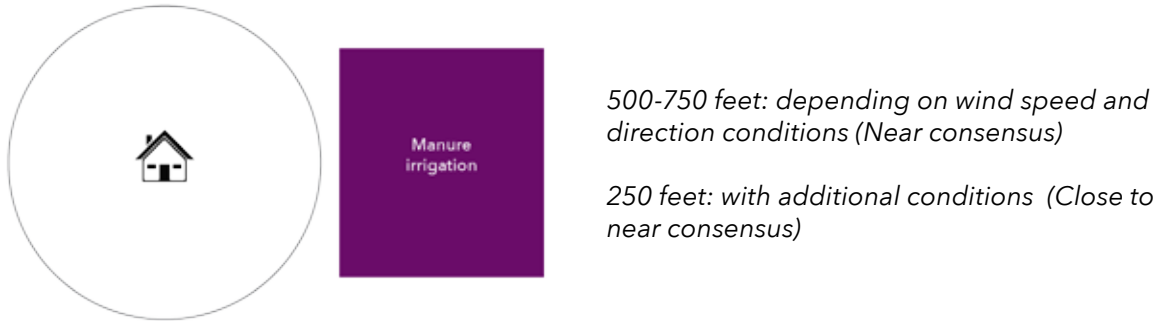


Figure 5-3b: Adjacent agricultural lands

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**At 750 feet** from wetted perimeter to building, the group reached **near consensus** for each of the following sets of conditions (independent of one another):

- 750 feet with no wind-speed restrictions regardless of wind direction (near consensus)
- 750 feet with wind-speed  $\leq 10$  mph regardless of wind direction (near consensus)
- 750 feet with wind-speed  $\leq 15$  mph regardless of wind direction (near consensus)

**At 500 feet** from wetted perimeter to building, the group reached **near consensus** for each of the following sets of conditions (independent of one another):

- no wind-speed restrictions if wind direction is parallel to or away from the building (near consensus)
- wind-speed  $\leq 10$  mph regardless of wind direction (near consensus)

**At 250 feet** from wetted perimeter to building, the workgroup **did not reach consensus or near consensus** for any combination of practices. **At 250 feet** from wetted perimeter to building, there was **close to near consensus** on each of the following sets of conditions (independent of one another):

- Manure is treated to reduce pathogens (or tested to document pathogen levels similar to those resulting from other practices described previously), wind speed  $\leq 10$  mph, wind direction is parallel to or away from building (close to near consensus).
- Permission is granted by the building occupant (close to near consensus).
- Permission granted by the building occupant and wind speed  $\leq 10$  mph regardless of wind direction (close to near consensus).

The workgroup did not reach any level of agreement on recommendations for conditions at distances less than 250 feet to dwellings/occupied buildings. In other words, there was broad disagreement about any distance of less than 250 feet to a dwelling or occupied building.

#### Recommendations for Manure Irrigation during night-time hours:

Workgroup discussions around night-time use of manure irrigation practices raised both potential benefits and potential concerns. Benefits centered around potential for lower wind-speeds and therefore less drift. It was also thought that potential benefits included less impact to neighbors for odor and pathogen inhalation as they are less likely to be outdoors during these times. Concerns included loss of potential for microbial inactivation from ultraviolet light, and the possibility that a wind speed of zero could prevent microbial inactivation from dispersion. There were also concerns about the logistics of monitoring night-time application to ensure proper system function, proper system monitoring, and proper application to intended areas as suggested in the baseline recommendations.

For application during night-time hours (if all consensus baseline recommendations are in place), the workgroup reached **near consensus** for allowing night-time application using the same setbacks as daytime application, under the following conditions: manure is treated or tested following accepted protocol, the wind speed is  $\geq 2$  mph and  $\leq 10$  mph, and wind direction is parallel or away from the building or property line.

The group reached **close to near consensus** for allowing night-time application using the same setbacks as daytime application, under the following conditions (independent of one another):

- manure is treated or tested following accepted protocol and the wind speed is  $\geq 2$  mph and  $\leq 10$  mph; or
- manure is treated or tested following accepted protocol, the wind speed is  $\geq 4$  mph and  $\leq 10$  mph, and wind direction is parallel or away from the building or property line.

There was **no agreement** that night-time application should be allowed with only treatment, and there was re-affirmation of a previous baseline recommendation consensus decision that untreated manure should not be applied at night using irrigation practices, where untreated refers to manure considered raw or processes only through physical separation (see \* above).

#### Other Issues and levels of agreement

There was **near consensus *against*** a proposal to recommend a 3-mile setback from any public recreation areas or commercial businesses for odor control, with provisions for reducing setback with permission of business owners.

For dwellings, several combinations of conditions were rejected by the workgroup. At 250 feet and 500 feet there was **no agreement** on the following sets of conditions:

- At both 500 feet and 250 feet, there was **no agreement** on allowing use with no

restrictions for application at this distance.

- At both 500 feet and 250 feet, there was **no agreement** on requiring manure treatment or testing required for application via irrigation with no other conditions.
- At 500 feet, there was **no agreement** on requiring manure treatment or testing and wind-speed  $\leq 10$  mph with no other conditions
- At 500 feet, there was **no agreement** on requiring manure treatment or testing and wind-speed  $\leq 15$  mph with no other conditions
- At 250 feet, there was **no agreement** on a requirement for wind-speed  $\leq 10$  mph regardless of wind direction, with no other conditions.
- At 250 feet, there was **no agreement** on a requirement wind-speed  $\leq 10$  mph regardless of wind direction if manure treated or tested.
- At 250 feet, there was **no agreement** on a requirement for wind direction to be parallel to or away from building, with no other restrictions.

Beyond those areas of disagreement, the workgroup reached consensus or near consensus on multiple situations for which manure irrigation could be an appropriate tool for manure management. All of the recommendations were discussed and developed with the intention of informing local and state policy decisions by providing a measure of agreement among broad and diverse perspectives on the issue of manure irrigation. The workgroup consistently emphasized its lack of authority to act on the recommendations. Any additional public deliberation to occur in the context of decisions by elected and administrative officials at local and state levels. Workgroup discussions also emphasized the benefits and importance of good neighbor considerations, such as those for odor in Section 3b, along with all other recommendations when using manure irrigation practices.

## Appendix A: Nutrient Content in Manure

Table A-1. Nitrogen and dry matter composition of dairy and swine manure samples analyzed in Wisconsin from 1998 to 2012.

		Maximum	75th percentile	50th percentile <sup>†</sup>	25th percentile	Minimum	Mean	Standard deviation of Mean	Standard Error of Mean	N <sup>+</sup>
Dairy, liquid	Total N, lb/1,000 gal	108.8	18.2	14.5	10.3	0.2	14.1	6.6	0.2	1505
	NH <sub>4</sub> -N, lb/1,000 gal	55.7	10.0	8.5	6.5	1.1	8.7	4.2	0.2	289
	NH <sub>4</sub> -N/Total N, % *	130.4	64.5	58.3	45.8	7.8	56.9	13.6	0.8	289
	Dry Matter, %	4.0	3.4	2.5	1.6	0.1	2.4	1.1	0.0	1505
Dairy, slurry	Total N, lb/1,000 gal	283.1	27.5	23.1	20.4	1.7	24.2	8.9	0.2	1695
	NH <sub>4</sub> -N, lb/1,000 gal	36.8	13.7	11.1	9.5	0.1	11.3	4.5	0.3	217
	NH <sub>4</sub> /Total N, %	117.6	53.2	46.6	39.0	1.9	46.1	14.0	0.9	217
	Dry Matter, %	11.0	8.1	6.3	5.0	4.1	6.7	1.9	0.0	1695
Dairy, semi-solid	Total N, lb/1,000 gal	71.6	9.6	8.0	6.7	0.0	8.3	3.3	0.1	1196
	NH <sub>4</sub> -N, lb/1,000 gal	5.4	3.5	2.6	2.1	0.0	2.7	1.1	0.1	154
	NH <sub>4</sub> /Total N, %	83.3	48.0	38.7	28.6	0.0	37.6	15.8	1.3	154
	Dry Matter, %	20.0	17.5	15.3	13.4	11.1	15.4	2.5	0.1	1196
Dairy, solid	Total N, lb/1,000 gal	78.5	13.0	9.2	7.0	0.2	11.0	7.0	0.2	1709
	NH <sub>4</sub> -N, lb/1,000 gal	51.0	2.5	1.8	1.1	0.0	2.1	3.2	0.2	411
	NH <sub>4</sub> /Total N, %	820.9	32.1	23.1	16.5	0.0	26.0	43.2	2.1	411
	Dry Matter, %	99.4	41.3	29.4	23.9	20.1	36.7	18.8	0.5	1709
Swine-farrow, liquid	Total N, lb/1,000 gal	42.7	22.5	16.7	9.7	0.6	16.3	8.7	0.8	117
	NH <sub>4</sub> -N, lb/1,000 gal	32.6	19.1	16.4	10.3	2.5	15.3	6.2	1.0	42
	NH <sub>4</sub> /Total N, %	99.7	86.6	76.7	70.6	43.0	77.5	10.8	1.7	42
	Dry Matter, %	4.0	1.9	1.0	0.5	0.1	1.3	1.0	0.1	117

Table continued on following page.

Table A-1. continued

		Maximum	75th percentile	50th percentile <sup>†</sup>	25th percentile	Minimum	Mean	Standard deviation of Mean	Standard Error of Mean	N <sup>‡</sup>
Swine-farrow, slurry		No data fewer than 25 samples								
Swine-finish-indoor, liquid	Total N, lb/1,000 gal	78.1	38.3	29.2	18.6	1.8	28.3	12.3	0.7	346
	NH <sub>4</sub> -N, lb/1,000 gal	42.8	28.4	22.5	13.9	2.5	21.6	9.8	1.1	74
	NH <sub>4</sub> /Total N, %	95.2	85.0	79.6	74.1	26.9	78.5	10.6	1.2	74
	Dry Matter, %	4.0	3.3	2.5	1.4	0.1	2.4	1.1	0.1	346
Swine-finish-indoor, slurry	Total N, lb/1,000 gal	89.1	57.8	52.5	45.7	22.9	52.1	9.9	0.5	405
	NH <sub>4</sub> -N, lb/1,000 gal	59.7	43.2	39.6	33.1	6.4	37.9	8.9	0.8	111
	NH <sub>4</sub> /Total N, %	89.3	76.8	72.4	68.5	13.9	70.4	11.6	1.1	111
	Dry Matter, %	11.0	8.1	6.3	5.1	4.1	6.7	1.9	0.1	405
Swine-finish-outdoor, liquid	Total N, lb/1,000 gal	51.5	27.4	16.4	6.9	0.9	18.1	12.7	0.9	180
	NH <sub>4</sub> -N, lb/1,000 gal	44.8	28.1	12.8	4.6	1.5	16.3	13.4	2.0	47
	NH <sub>4</sub> /Total N, %	96.1	85.8	76.0	65.5	25.5	73.7	15.8	2.3	47
	Dry Matter, %	4.0	2.4	1.3	0.4	0.1	1.5	1.2	0.1	180
Swine-finish-outdoor, slurry	Total N, lb/1,000 gal	74.6	62.1	54.1	46.1	19.7	53.1	12.6	1.4	78
	NH <sub>4</sub> -N, lb/1,000 gal	61.6	56.9	42.9	40.4	25.8	46.1	9.4	1.5	37
	NH <sub>4</sub> /Total N, %	91.7	85.6	78.6	73.6	63.2	79.0	7.2	1.2	37
	Dry Matter, %	11.0	8.0	6.9	5.5	4.1	6.8	1.7	0.2	78

(Source: C. Laboski. UW-Madison, Department of Soil Science.)

<sup>†</sup> The 50th percentile is the median. For data like this, the median is a better measure of central tendency than the mean because it is not influenced by unusually high or low values.

<sup>‡</sup> N is the number of samples analyzed.

\* NH<sub>4</sub>-N/Total N is the percentage of total N that is NH<sub>4</sub>-N. Not every sample had NH<sub>4</sub>-N analyzed. This was calculated using only the samples where NH<sub>4</sub>-N and Total N were analyzed.

Table A-2. Daily manure production and characteristics, as-excreted

Animal	Size (lbs)	(lb/day)	Total manure (ft <sup>3</sup> /day) (gal/day)	Water (%)	Density (lb/ft <sup>3</sup> )	Nutrient content (lb/day) (N) (P <sub>2</sub> O <sub>5</sub> ) (K <sub>2</sub> O)
<b>Dairy cattle</b>	150	13	0.20 1.5	88	65	0.05 0.01 0.04
Dairy cattle	250	21	0.32 2.4	88	65	0.08 0.02 0.07
Heifer	750	65	1.0 7.8	88	65	0.23 0.07 0.22
Lactating cow	1,000	106	1.7 12.7	88	62	0.58 0.30 0.31
Lactating cow	1,400	148	2.4 17.7	88	62	0.82 0.42 0.48
Dry cow	1,000	82	1.30 9.7	88	62	0.36 0.11 0.28
Dry cow	1,400	115	1.82 13.6	88	62	0.50 0.20 0.40
Veal	250	9	0.14 1.1	96	62	0.04 0.03 0.06
<b>Beef cattle Calf</b>	450	26	0.42 3.1	92	63	0.14 0.10 0.11
High forage	750	62	1.0 7.5	92	62	0.41 0.14 0.25
High forage	1,100	92	1.4 11.0	92	62	0.61 0.21 0.36
High energy	750	54	0.87 6.5	92	62	0.38 0.14 0.22
High energy	1,100	80	1.26 9.5	92	62	0.54 0.21 0.32
Cow	1,000	63	1.00 7.5	88	63	0.31 0.19 0.26
<b>Swine</b>						
Nursery	25	2.7	0.04 0.3	89	62	0.02 0.01 0.01
Grow-Finish	150	9.5	0.15 1.2	89	62	0.08 0.05 0.04
Gestating	275	7.5	0.12 0.9	91	62	0.05 0.04 0.04
Lactating	375	22.5	0.36 2.7	90	63	0.18 0.13 0.14
Boar	350	7.2	0.12 0.9	91	62	0.05 0.04 0.04

Table continued on following page.



Table A-2. continued

Animal	Size (lbs)	(lb/day)	Total manure (ft <sup>3</sup> /day) (gal/day)	Water (%)	Density (lb/ft <sup>3</sup> )	Nutrient content (lb/day) (N) (P <sub>2</sub> O <sub>5</sub> ) (K <sub>2</sub> O)
<b>Sheep</b>	100	4.0	0.06 0.4	75	63	0.04 0.02 0.04
Poultry Layer	4	0.26	0.004 0.031	75	65	0.0035 0.0027 0.0016
Broiler	2	0.18	0.003 0.021	74	63	0.0023 0.0014 0.0011
Turkey	20	0.90	0.014 0.108	75	63	0.0126 0.0108 0.0054
Duck	6	0.33	0.005 0.040	73	62	0.0046 0.0038 0.0028
<b>Horse</b>	1,000	50	0.80 5.98	78	63	0.28 0.11 0.23

(Source: Manure Characteristics MWPS-18 Manure Management Systems Series, December 2000)

Values are as-produced estimations and do not reflect any treatment. Values do not include bedding. The actual characteristics of manure can vary ± 30% from table values. Increase solids and nutrients by 4% for each 1% feed wasted above 5%

\*Weights represent the average size of the animal during the stage of production.

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## Appendix B: Manure Irrigation Information from Other States

Wisconsin DNR staff contacted state agency staff that regulate animal feeding operations (AFOs) in other states. Contacts were made by email or telephone during 2012-2013. Each state contacted was asked about the extent of manure irrigation use in that state, extent of complaints received by the agency about the practice, and any regulations regarding setbacks or other requirements. The USEPA Region 5 office works with Wisconsin state agencies and local governments to implement regulatory and non-regulatory programs related to water quality and public and environmental health. Results are included below grouped by states within Wisconsin's same USEPA region and outside of that USEPA region.

### States in the same USEPA region as Wisconsin (Region 5):

#### **Illinois**

- **Extent of Manure Irrigation Use:** Manure irrigation is limited to a few farms. Permanent pivots and mobile guns are used.
- **Complaints:** Complaints received by agency primarily focus on odor. Fecal drift does not appear to be a large issue.
- **Setbacks/Other Requirements:**
  - Dept. of Ag rule requires a 1/4 mile (1320 feet) setback from any residence for spray irrigation, except if the operation was doing it before 1997, they are exempt from the setback, or if they are spreading on frozen or snow-covered ground, they are exempt.
  - *Illinois Waste Management Plan Regulations*
    - Livestock waste applied within 1/4 mile of any residence not part of the facility shall be injected or incorporated on the day of application. However, livestock management facilities and livestock waste handling facilities that have irrigation systems in operation prior to May 21, 1996, or existing facilities applying waste on frozen ground, are not subject to the provisions of this subsection (o) [510 ILCS 77/20 (f)(5)];
    - Livestock waste may not be applied within 200 feet of surface water unless the water is upgrade or there is adequate diking and waste will not be applied within 150 feet of potable water supply wells [510 ILCS 77/20(f)(6)];
    - Livestock waste may not be applied in a 10-year flood plain unless the injection or incorporation method of application is used [510 ILCS 77/20(f)(7)];
    - Livestock waste may not be applied in waterways. [510 ILCS 77/20(f) - for the purposes of this Part, a grassed area serving as a waterway may receive livestock waste through an irrigation system if there is no runoff, the distance from applied livestock waste to surface water is greater than 200 feet, the distance from applied livestock waste to potable water supply wells is greater than 150 feet; the distance from applied livestock waste to a non-potable well, an abandoned or plugged well, a drainage

well, or an injection well is greater than 100 feet; and precipitation is not expected within 24 hours

- **For more information:**
  - [http://web.extension.illinois.edu/clmt/pdf/rules\\_il-manure-plan-rules.pdf](http://web.extension.illinois.edu/clmt/pdf/rules_il-manure-plan-rules.pdf)
  - <http://web.extension.illinois.edu/sfmm/dairy.cfm>
  - <http://www.epa.state.il.us/water/cafo/>

## Indiana

- **Extent of Manure Irrigation Use:** No response on number of farms using manure irrigation or equipment types.
- **Complaints:** As of the review, the staff responding reported that no complaints had been received by the agency related to manure irrigation (e.g., odors, drift, health impacts).
- **Setbacks/Other Requirements:** No specific manure irrigation setbacks. 100 ft setbacks for surface waters, conduits to surface waters, tile inlets, wells, sink-holes (same as Federal CAFO requirements or department approved alternative). 10 foot setbacks when vegetative buffer established. No application allowed within grassed waterways or swales that are conduits to surface waters
- **For more information:** Indiana CAFO permit: <http://www.in.gov/legislative/iac/T03270/A00160.PDF> - page 27 setbacks

## Michigan

- **Extent of Manure Irrigation Use:** Only a few CAFO's use manure irrigation (permanent center pivots).
- **Complaints:** Complaints received by the agency for manure irrigation as well as other methods of manure application include: odors, flies, hydrogen sulfide poisoning, drift. No confirmation of chronic or acute public health impacts from complaint investigations.
- **Setbacks/Other Requirements:** No specific manure irrigation setbacks. 100 ft Setbacks for surface waters, conduits to surface waters, tile inlets, wells, and sinkholes -(same as Federal CAFO requirements or department approved alternative). 35 foot setbacks when vegetative buffer established. No application within grassed waterways or swales that are conduits to surface waters
- **For more information:** [http://www.michigan.gov/documents/deq/wb-np-des-cafo-generalpermit-MIG019000-2010\\_316373\\_7.pdf](http://www.michigan.gov/documents/deq/wb-np-des-cafo-generalpermit-MIG019000-2010_316373_7.pdf)

## Minnesota

- **Extent of Manure Irrigation Use:** Only a few CAFO's use manure irrigation method; permanent pivots and mobile guns are used.
- **Complaints:** No complaints received by the agency related to manure irrigation (e.g., odors, drift, health impacts).
- **Setbacks/Other Requirements:**
  - 10 counties in MN have passed ordinances prohibiting spray irrigation (permanent or mobile) and at least 9 other counties have ordinances that do not directly ban spray irrigation, but instead require mechanical incorporation of manure within 24 hrs.
  - CAFO's have specific spray irrigation manure setbacks: For CAFOs, no surface application within 300ft of lakes, streams, intermittent streams, wetlands, waterways w/o berms, wells.

- Smaller farms also have spray irrigation setbacks (cant spray wider than 50ft within special protection areas (e.g. Lakes streams, intermittent streams, wetlands, waterways w/o berms, wells). If spray is less than 50ft spray irrigation allowed in special protection areas.
- **For more information:** <http://www.pca.state.mn.us/index.php/view-document.html?gid=3530>

## Ohio

- **Extent of Manure Irrigation Use:** Manure irrigation is limited to a few farms. Permanent pivots and mobile guns are used.
- **Complaints:** Limited number of manure irrigation complaints received by the agency. Fecal drift does not appear to be a large issue (odor is the issue).
- **Setbacks/Other Requirements:**
  - Required setbacks specify distances from various water and land features (e.g. wells) to be followed when land-applying manure application methods. The setbacks range from 100 feet to 300 feet.
  - Land application restrictions also specify considerations for determining the appropriate timing, location, and methods for land application of manure, including considerations for soil types and field conditions, weather conditions and seasonal considerations, location of subsurface tile drains, and the like. Part VII of individual permits [PDF 113K] contain the standard language CAFOs must comply with.
- **For more information:**
  - [http://epa.ohio.gov/dsw/cafo/land\\_app.aspx](http://epa.ohio.gov/dsw/cafo/land_app.aspx)
  - [http://epa.ohio.gov/Portals/35/cafo/CAFO\\_NPDES\\_PARTVII.pdf](http://epa.ohio.gov/Portals/35/cafo/CAFO_NPDES_PARTVII.pdf)
  - <http://www.lakeimprovement.com/sites/default/files/manure-management-guide.pdf>. See pages 54-57, 82-84, 96-97, and 110 for manure irrigation and pathogen information

## Other States

### Idaho

- **Extent of Manure Irrigation Use:** No information provided.
- **Complaints:** No information provided.
- **Setbacks/Other Requirements:** No information provided.
- **For more information:**
  - Wastewater Irrigation Guidelines: [https://www.deq.idaho.gov/media/529643-microbial\\_risk\\_assessment.pdf](https://www.deq.idaho.gov/media/529643-microbial_risk_assessment.pdf)

### Iowa

- **Extent of Manure Irrigation Use:** Some confinement feeding operations use manure irrigation method; permanent pivots and mobile guns are used.
- **Complaints:** Complaints related to odors, drift, concerns about health have been received. Public health impacts have not been confirmed.
- **Setbacks/Other Requirements:** Manure irrigation requirements include:
  - General
    - Equipment shall be operated in a manner and with an application rate and timing that does not cause runoff of the manure onto the property adjoining the property where the spray irrigation equipment is being

- operated.
- For manure from an earthen waste slurry storage basin, earthen manure storage basin, or formed manure storage structure, restricted spray irrigation equipment shall not be used unless the manure has been diluted with surface water or groundwater to a ratio of at least 15 parts water to 1 part manure. Emergency use of spray irrigation equipment without dilution shall be allowed to minimize the impact of a release as approved by the department.
- Setbacks
  - *Required separation distance from a residence* not owned by the titleholder of the land, a business, a church, a school, or a public use area is 750 feet, as specified in Iowa Code section 459.204. The separation distance for application of manure by spray irrigation equipment shall be measured from the actual wetted perimeter and the closest point of the residence, business, church, school, or public use area.
  - *Separation distance for spray irrigation from property boundary line.* Spray irrigation equipment shall be set up to provide for a minimum distance of 100 feet between the wetted perimeter as specified in the spray irrigation equipment manufacturer's specifications and the boundary line of the property where the equipment is being operated. The actual wetted perimeter, as determined by wind speed and direction and other operating conditions, shall not exceed the boundary line of the property where the equipment is being operated. For property which includes a road right-of-way, railroad right-of-way or an access easement, the property boundary line shall be the boundary line of the right-of-way or easement.
  - The separation distance specified above shall not apply if any of the following apply:
    - The liquid manure is injected into the soil or incorporated within the soil not later than 24 hours after the original application.
    - The titleholder of the land benefitting from the separation distance requirement executes a written waiver with the titleholder of the land where the manure is applied.
    - The liquid manure originates from a small animal feeding operation.
    - The liquid manure is applied by low-pressure spray irrigation equipment
  - *Distance from structures for low-pressure irrigation systems.* Low-pressure irrigation systems shall have a minimum separation distance of 250 feet between the actual wetted perimeter and the closest point of a residence, a business, church, school or public use area
  - *Manure application on land adjacent to water bodies* - Unless adequate erosion controls exist on the land and manure is injected or incorporated into the soil, manure application should not be done on land areas located within 200 feet of and draining into a stream or surface intake for a tile line or other buried conduit. No manure should be spread on waterways except for the purpose of establishing seeding.
- **For more information:**
  - <http://www.iowadnr.gov/afo/files/sepdstb4.pdf>

- [http://search.legis.state.ia.us/NXT/gateway.dll/ar/iac/5670\\_\\_\\_environmental%20protection%20commission%20\\_\\_5b567\\_\\_5d/0650\\_\\_\\_chapter%2065%20animal%20feeding%20operations/\\_c\\_5670\\_0650.xml?f=templates\\$fn=default.htm](http://search.legis.state.ia.us/NXT/gateway.dll/ar/iac/5670___environmental%20protection%20commission%20__5b567__5d/0650___chapter%2065%20animal%20feeding%20operations/_c_5670_0650.xml?f=templates$fn=default.htm)

## Nebraska

- **Extent of Manure Irrigation Use:** No information provided.
- **Complaints:** No information provided.
- **Setbacks/Other Requirements:** Manure irrigation requirements include:
  - Summary: 100 ft standard setbacks; no drift or pathogen reduction requirements; backflow prevention requirements for irrigation equipment
  - University of Nebraska Extension document on Manure Irrigation equipment, management practices and regulatory requirements: <http://ianrpubs.unl.edu/live/ec778/build/ec778.pdf>
- **For more information:**
  - Nebraska CAFO Manure or Process waste water Regulations:
    - Title 119 - Rules and Regulations Pertaining to the Issuance of Permits under the National Pollutant Discharge Elimination System
    - Title 130 - Livestock Waste Control Regulations
    - Nebraska Land Application of Wastewaters Regulations: Title 119 Chapter 12 provides Authorization by Rule for domestic wastewater treatment plant effluent land application. For these facilities that meet the requirements of the chapter and maintain records in accordance with this chapter, no NPDES permit is necessary.

## North Carolina

- **Extent of Manure Irrigation Use:** Big gun hose reel irrigation is used by estimated > 95% of swine facilities in the state.
- **Complaints:** No information provided about type or extent of complaints. Staff commented that NC has not had any documented public health impacts from manure irrigation applications.
- **Setbacks/Other Requirements:**
  - See: <http://www.ncagr.gov/SWC/tech/documents/AppenxWasteAppSetbacks.pdf>
  - Prohibition on new facilities or existing facilities that expand above current live weight [http://www.ncleg.net/EnactedLegislation/Statutes/pdf/BySection/Chapter\\_143/GS\\_143-215.10I.pdf](http://www.ncleg.net/EnactedLegislation/Statutes/pdf/BySection/Chapter_143/GS_143-215.10I.pdf)
- **For more information:**
  - <http://portal.ncdenr.org/web/wq/aps/afo/rules> - See SB 1217 info
  - <http://portal.ncdenr.org/web/wq/aps/afo/news> - see performance standards for New or Expanding Swine Farms
  - General Permits for Swine Dairy and Poultry - some irrigation requirements noted in I-1 and II-19 <http://portal.ncdenr.org/web/wq/aps/afo/perm>

## Other General Information about Manure spreading setbacks and other restrictions within multiple states

- <http://www.extension.org/pages/14881/state-specific-manure-nutrient-management-information>
- <http://nmplanner.missouri.edu/software/setbacks.asp>

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## Appendix C: Airborne Pathogens from Dairy Manure Aerial Irrigation and the Human Health Risk

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### Pathogens in Dairy Manure

Dairy manure, like the fecal excrement from any domesticated or wild animal, can contain pathogens capable of infecting humans and causing illness or even death. Pathogens in dairy manure can be broadly divided into categories of taxonomy or infectiousness. Dividing by taxonomy there are three pathogen groups in dairy manure: viruses (e.g., bovine rotavirus), bacteria (e.g., *Salmonella* species), and protozoa (e.g., *Cryptosporidium parvum*). There are two categories of infectiousness for pathogens found in animals: those that are zoonotic and those that are not. A zoonotic pathogen is one that can infect both human and animal hosts. Some zoonotic pathogens found in dairy manure cause illness in both hosts (e.g., *Salmonella*) while other zoonotic pathogens, like *Escherichia coli* O157:H7, (enterohemorrhagic *E. coli* (EHEC)) cause illness only in humans. As a general rule, the gastrointestinal viruses found in dairy manure are not zoonotic. While there are exceptions (e.g., rare reports of bovine rotavirus infecting children), for the most part the viruses in dairy manure are not a human health concern. The primary concerns are the zoonotic bacteria and protozoa in dairy manure.

Six zoonotic pathogens found in dairy manure are frequently associated with human health effects: *Salmonella* spp., enterotoxigenic *E. coli*, *Campylobacter jejuni*, *Listeria monocytogenes*, *Cryptosporidium parvum*, and *Giardia lamblia* (US EPA 2013). These all cause acute gastrointestinal illness with diarrhea, abdominal pain, fever, nausea, and vomiting. In some cases illness can progress to a systemic infection involving other organ systems, for example, kidney failure caused by toxigenic *E. coli* or acute paralysis (i.e., Guillain-Barré syndrome) caused by *Campylobacter jejuni*. There are another eight zoonotic pathogens that are sometimes present in dairy manure but are rarely associated with illnesses in humans. These are microsporidia, *Brucella* spp., *Bacillus anthracis*, *Clostridium perfringens*, *Coxiella burnetii*, *Leptospira* spp., *Mycobacterium bovis*, and Aphthovirus (foot and mouth disease) (Atwill et al. 2012; Dungan 2010).

A recent study conducted by the Centers for Disease Control and Prevention estimated the annual burden of gastrointestinal illness in the United States caused by direct or indirect contact with animals to be more than 440,000 gastrointestinal illnesses per year (Hale et al. 2012). Animals in the study by CDC included livestock and pets such as dogs, cats, reptiles and amphibians. Four pathogens were respon-

#### Recommended citation:

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sible for the majority of these illnesses: *Campylobacter* spp. (17%), *Cryptosporidium* spp. (16%), toxigenic *E. coli* (14%), and *Salmonella* spp. (11%). These four pathogens are some of the most common found in dairy manure and thus were the focus of the Wisconsin study investigating the human health risk from airborne pathogens from dairy manure irrigation.

### Conceptual Model of Pathogen Transport in Air

When considering how pathogens in irrigated dairy manure could travel through the air, come into contact with a person, and cause illness, it is helpful to break down the process into a sequence of steps (Figure C-1). First, manure is released from the irrigation nozzle in the form of droplets. This release results in a rapid pressure change to the pathogen where the effect, called the impact factor, sometimes has been found to decrease pathogen numbers by death (US EPA 1982), increase pathogen numbers by disaggregating particle clumps (US EPA 1982), or have no effect at all (Dungan et al. 2011).

Following release, the larger droplets fall by gravity to the ground whereas smaller droplets can become aerosolized, suspended in the air, and transported by wind. During airborne transport, aerosolized pathogens are subjected to environmental factors that can kill them. This process is called inactivation, and the three main factors relevant to airborne pathogens are warm temperatures, low humidity, and ultraviolet light as part of sunshine. Inactivation can be fast. A representative inactivation rate during daytime conditions is  $-0.07 \text{ s}^{-1}$  (Teltsch et al. 1980). This means, for example, that 1% of the original number of pathogens traveling at a wind speed of 5 miles per hour would still be alive when they reach 500 feet from the irrigation nozzle. Of course, the absolute quantity of pathogens – the number most important for determining infection risk – could still be high if the original number of pathogens is high. One percent of a large number is still a large number. Inactivation is much slower during nighttime darkness, cool temperatures, and high humidity (Teltsch et al. 1980; Paez-Rubio and Peccia 2005)

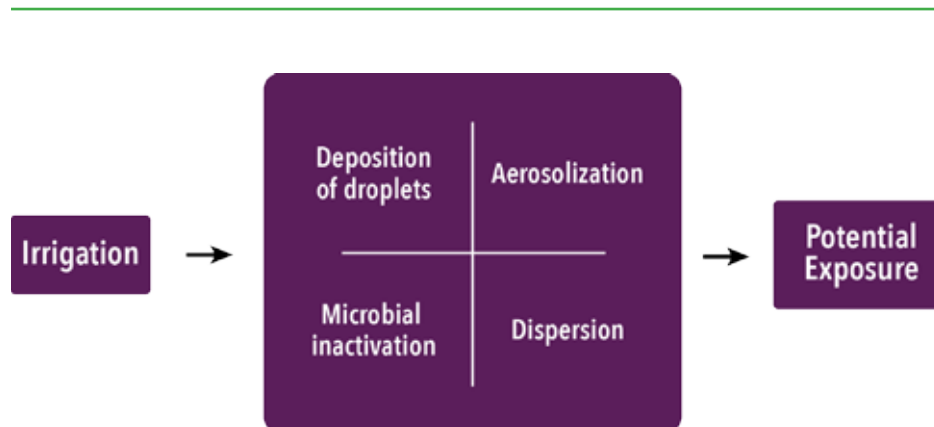


Figure C-1. Conceptual model of pathogen airborne transport and human exposure during manure irrigation.



## **Human Exposures to Airborne Pathogens**

Human exposure to those pathogens that survive transport through the air can result from four general routes: 1) inhalation, with some fraction of the inhaled aerosols being swallowed and reaching the gastrointestinal system; 2) deposition of the pathogens onto a food product or crop that is then ingested; 3) deposition of pathogens onto an inanimate surface (i.e., a fomite), such as a toy, that through hand to mouth behavior results in ingestion; and 4) contact with a vector, such as a pet or insects, that through multiple possible indirect routes could result in human exposure. After ingestion, it is possible that the previously airborne pathogen could initiate infection and, consequently, illness.

Two additional concepts are necessary for understanding the potential health risks from airborne pathogens in irrigated dairy manure. First, people exposed to pathogens, regardless of the source, vary in their susceptibility to infection. Most susceptible are young children, the elderly, and people with compromised immune systems resulting from chemotherapy, organ transplants, HIV infection, or certain medications. Second, it is important to recognize that the number and types of pathogens in dairy manure can be highly variable from herd to herd and even in the same herd through time. Thus, exposure to dairy manure does not always equate to exposure to human pathogens. On the other hand, the absence of pathogens in a specific dairy herd at a specific point in time does not equate to the universal absence of health risk from exposure to dairy manure. The risk assessment described in this report accounted as best as possible for varying infection susceptibilities in the population and varying pathogen presence in dairy manure.

## **Previous Studies on Fecal-Borne Pathogens in Air and Health Risk**

There are seven previous studies that have investigated the human health risk from airborne pathogen transport from aerosolized manure, human wastewater, or municipal biosolids. Five of these studies (Brooks et al. 2005a; Brooks et al. 2005b; Brooks et al. 2012; Dowd et al. 2000; Dungan 2014) have been published in the peer-reviewed, scientific literature. A sixth study (Hardy et al. 2006) is outlined in a report assembled by the Idaho Department of Environmental Quality (IDEQ) while the seventh study (Michael Cook, personal communication) is unpublished data produced by IDEQ. Only three of the seven studies deal with bovine manure (Brooks et al. 2012; Dungan 2014; Michael Cook, personal communication), and only two of those three consider irrigation (center pivot) of livestock manure (Dungan 2014; Michael Cook, personal communication). None of these studies considered traveling gun application of livestock manure. Only two studies consider more than one wind speed (Dowd et al. 2000; Michael Cook, personal communication). This is a significant shortcoming of the existing body of knowledge, because wind speeds can vary significantly over both short and long time-scales. Airborne pathogen transport in four studies was predicted by some formulation of the traditional air dispersion model (Dowd et al. 2000; Hardy et al. 2006; Michael Cook, personal communication; Dungan 2014). Versions of this model (varying in their levels of sophistication) are used widely by atmospheric scientists and contain input parameters that make them adaptable to a wide variety of meteorological conditions, source geometries, and landscape features. The three studies by Brooks et al. relied on the same empirical

fate and transport model reported in Brooks et al. 2005a. Empirical models can be extremely practical and effective, but many times are constructed in a fashion that limits their application to conditions similar to those under which the models were developed.

Thus, existing studies on airborne pathogen transport and health risk vary significantly in their methods, assumptions, fecal source types, pathogens, exposure times, and application methods. This variation in approach produces significant variation in the risk estimates. Nonetheless, such variation in study design yields insights on those factors which require further investigation and, *in toto*, allows the weight of evidence for airborne disease transmission from manure irrigation to be evaluated.

Figure C-2 summarizes the risk estimates from the seven studies relative to distance from the fecal source. The horizontal dashed line at  $10^{-4}$  indicates the acceptable level of risk for drinking water in the United States, one infection per 10,000 people per year. The vertical dashed line indicates the 500 foot distance, Wisconsin's current regulatory setback from a manure irrigation source to an inhabited dwelling. Five of the seven studies predict that by the time pathogens are transported 200 feet downwind from the fecal source the risk of infection is less than 1 in 10,000. The other two studies predict much higher risk levels. Dungan 2014 is not shown in Figure C-2 because the downwind distances in his study are from 3,300 to more than 30,000 feet, making it difficult to scale the figure to include all studies. At the 3,300 foot distance, Dungan reports risk estimates that range from  $1 \times 10^{-15}$  infections per person per exposure event to almost 1 infection per person per exposure event. This variation in risk estimates is a function of the variation in input parameters Dungan considered in his risk assessment model. Dowd et al. (2000) also predict much higher risk levels than the majority of studies. Dowd et al. worked with two different air dispersion models: a point-source model and an area-source model. The output from the latter is reported in the figure. However, they made unconventional modifications to the point-source model that appear to produce invalid air concentrations, and it is not clear if they made the same modifications to their area-source model.

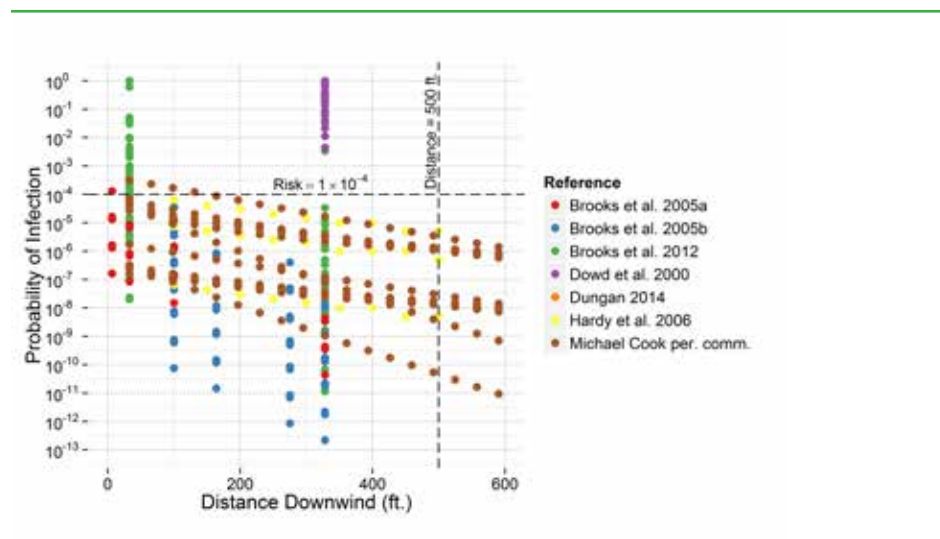


Figure C-2. Risk estimates of airborne pathogen transmission from previous studies.

One recent study investigated the risk of illness from eating leafy green vegetables grown downwind from a dairy manure application site (Jahne et al. 2016). The study focused on three pathogens (*Salmonella* spp., *Campylobacter* spp., and *E. coli* O157:H7) and movement of bioaerosols from the soil surface to leafy vegetable surfaces, after manure had been applied. The median level of risk was less than 1 infection per 10,000 people per year at 525 feet downwind, although at that distance the parameter termed peak risk by the researchers (the 95th percentile) was 1 in 100.

A key difference between the Wisconsin manure irrigation and human health risk study and the previous studies is the number of air samples collected to estimate downwind transport of pathogens and other microorganisms. Only three previous studies collected air samples (of indicator microorganisms), and the number of samples were limited. Brooks et al. 2005a used a series of indicator concentrations at multiple distances from a tanker truck spraying groundwater seeded with an indicator virus to develop their empirical model. Brooks et al. 2005b used coliphage and total coliform concentrations at only one distance very close to the source to establish initial concentrations for the application of the empirical model from Brooks et al. 2005a. Dowd et al. 2000 also used indicator concentrations close to the source to determine a source term for their air dispersion model. None of the three studies that considered livestock manure as a source collected actual air samples; pathogen concentrations in air were estimated from their concentrations in the source manure. The Wisconsin study is the first to collect air samples downwind from dairy manure irrigation.

### **Wisconsin Study on Dairy Manure Irrigation and Human Health Risks**

The growing use of aerial irrigation equipment to apply dairy manure in Wisconsin and concerns about airborne pathogens generated from this practice prompted the Department of Natural Resources to fund field research on this topic. The interdisciplinary research team included microbiologists, engineers, and risk modelers from USDA-Agricultural Research Service, USGS Wisconsin Water Science Center and University of Wisconsin – Madison Department of Biological Engineering. Funding for the study was also provided by USDA-ARS.

#### Study Objectives and Approach

The Wisconsin study had two primary objectives.

1. Identify weather variables (e.g., wind speed, solar radiation, and relative humidity) most important for airborne pathogen transport during manure irrigation.
2. Use microbial risk assessment to estimate the risk of illness for people exposed to airborne pathogens downwind from manure irrigation sites.

At the foundation of this effort was extensive field sampling for airborne pathogens during multiple irrigation events from 2012 through 2014. The researchers' goal was to obtain the most comprehensive data set to date on airborne pathogens downwind from a fecal source. Two approaches were taken to model and predict downwind pathogen transport based on these air measurements: 1) empirical statistical modeling and 2) Gaussian air dispersion modeling. The output from each approach is air concentration of pathogens as a function of downwind distance from the irrigation

source. These concentrations provided the input values for risk assessment modeling. At the present time, the research team is relying on the statistical model output for the risk assessment.

#### Sampling for airborne microbes

Air samples were collected by two methods: 1) button samplers for collecting microorganism genetic material quantified by real-time quantitative polymerase chain reaction (qPCR) and 2) impactor samplers for quantifying culturable bacteria on solid growth media. The latter included media for gram negative bacteria, *E. coli*, enterococci, and *Campylobacter* spp. Bacterial colonies observed growing on the media were tested by qPCR to confirm their taxonomic identity. Liquid manure sampled at the time of irrigation from a center pivot nozzle or a traveling gun pump valve was always analyzed first in the laboratory before the air samples. If a particular microorganism, for example, *E. coli* O157:H7 was not present in the irrigation source manure, the air samples were not tested for this microorganism. We took this approach to save time and reduce costs.

The configuration of air samplers in irrigated fields was nearly the same for every irrigation trial. Sometimes conditions at the site or problems with equipment meant there were small changes in the ideal sampling configuration. Samplers were placed downwind of the irrigation equipment in a line parallel to the predominant wind direction at approximately 100, 200, 350, 500, and 700 feet from the edge of the irrigated wetted perimeter. At each distance two identical sets of samplers (a set is defined as one button and two impactor samplers) were placed 50 feet apart, perpendicular to the wind direction. Two sets of air samplers were placed far upwind of the irrigation equipment to serve as controls, one for background air concentrations of manure-related microorganisms before irrigation commenced and the other for upwind concentrations during irrigation. Meteorological conditions during irrigation were measured using a portable weather station set up at the same location as the upwind controls.

The start time for air sampling was coordinated to maximize the likelihood of detecting airborne microorganisms. For center pivot systems, air sampling began as soon as the system was fully pressurized and the nozzle boom started pivoting away from the samplers. For the traveling gun, the travel rate was measured, and the air samplers, placed approximately 2/3s of the pull distance from the reel, were turned on for the one hour period when the gun was located most directly upwind of the samplers. The time length of air sampling was either 60 minutes (traveling guns) or 90 minutes (center pivots) for the button samplers and 20 minutes for the impactors. After 20 minutes, the growth media was exchanged for a duplicate plate and another 20 minute sample was collected.

We conducted air sampling during 23 irrigation trials on three dairy farms in Wisconsin. Irrigation was by center pivot for 8 trials and by traveling gun for 15. Two trials are omitted from this analysis because the wind direction shifted 85° or more during irrigation and the samplers were no longer downwind (i.e., 21 trials were analyzed). Three trials were conducted under low light conditions at sunset or nighttime. Air samples were analyzed for culturable bacteria in 13 trials and for microorganism genetic markers in 23 trials. In two additional trials we measured airborne transport

of microorganisms during conventional manure application by a tanker with a high splash-plate.

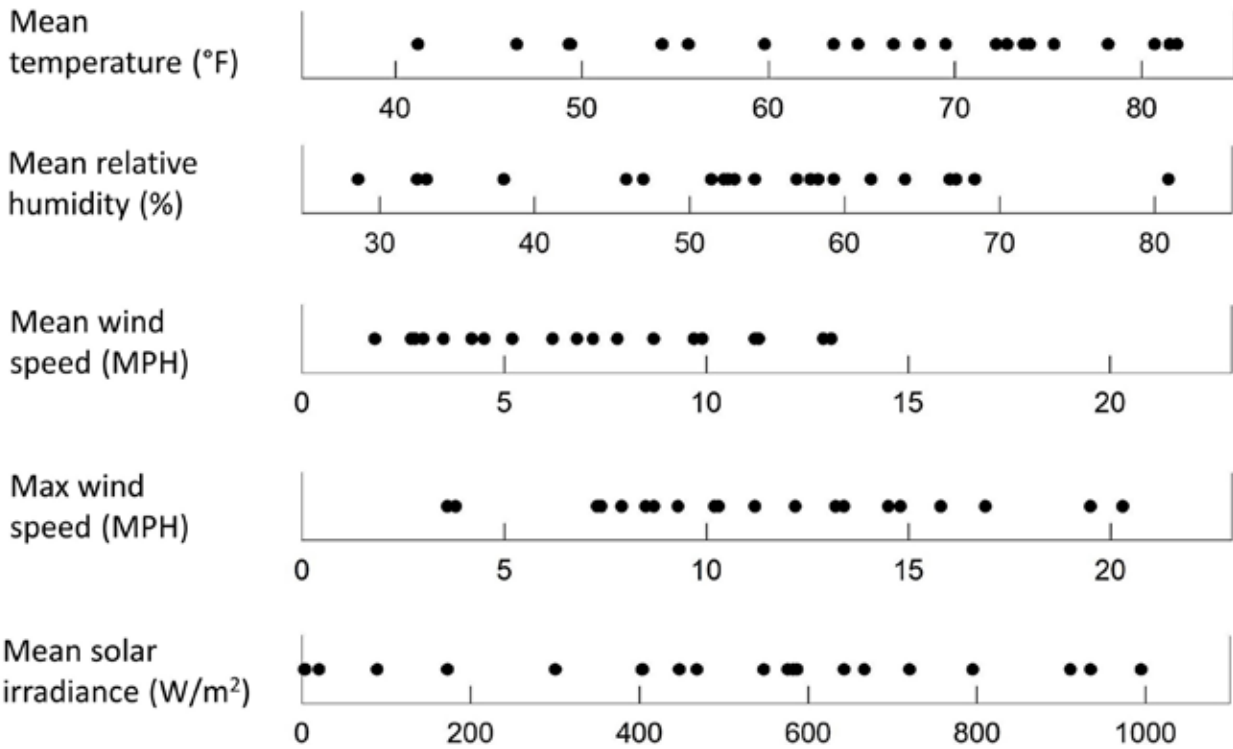


Figure C-3. Weather conditions during the irrigation trials. Each point represents a trial.

#### Weather conditions

Sampling for airborne pathogens during manure irrigation was conducted under a wide range of meteorological conditions (Figure C-3). No samples were collected during snowfall or rainfall conditions.

#### Risk assessment

Figure C-4 depicts the first steps of the quantitative microbial risk assessment (QMRA) – calculating the dose of pathogens ingested from the air. As depicted by the blue boxes in the figure, we used the air sample data of non-pathogenic bacteria that were always present in cattle manure, for example, bovine *Bacteroides* to construct a statistical model to predict downwind concentrations. These surrogate bacteria were necessary because pathogenic bacteria were rarely detected in the manure from the three participating farms.

**Statistical modeling.** The statistical modeling approach we used to relate bacterial air concentrations to distance from the irrigation equipment is called hierarchical or multilevel modeling. This approach accounts for the many levels of variability that can affect a measurement. In this study there were two levels: 1) the level of irrigation trials (which includes variability due to weather conditions, irrigation equipment, and the farm where measurements were taken); and 2) the level of individual samples (which includes the effect of distance). Taking into account these multiple sources

of variability makes model interpretation practical and useful. There is no need to preface the predictions of downwind microbe concentrations with a series of “it depends” statements. For instance, when obtaining a prediction it is not necessary to specify that it depends on a particular farm, or type of irrigation equipment, or set of weather conditions. Instead we can make general predictions of microbe concentrations in air based solely on distance. All the variability in predicted air concentrations that result from differences in farms, irrigation equipment, weather, has already been accounted for.

**Pathogen-to-surrogate ratios.** Surrogate bacteria concentrations we measured in dairy manure samples collected just before the manure was irrigated were used to calculate pathogen-to-surrogate ratios. As *Salmonella* and *E. coli* O157:H7 were never detected in our study, we relied on the scientific literature for concentrations of these two pathogens in stored dairy manure. *Campylobacter jejuni* was present in the manure samples we tested, making it possible to derive a *C. jejuni*-to-surrogate ratio specific to our study. These ratios were used to translate surrogate air concentrations to pathogen air concentrations as related to distance from the irrigation equipment.

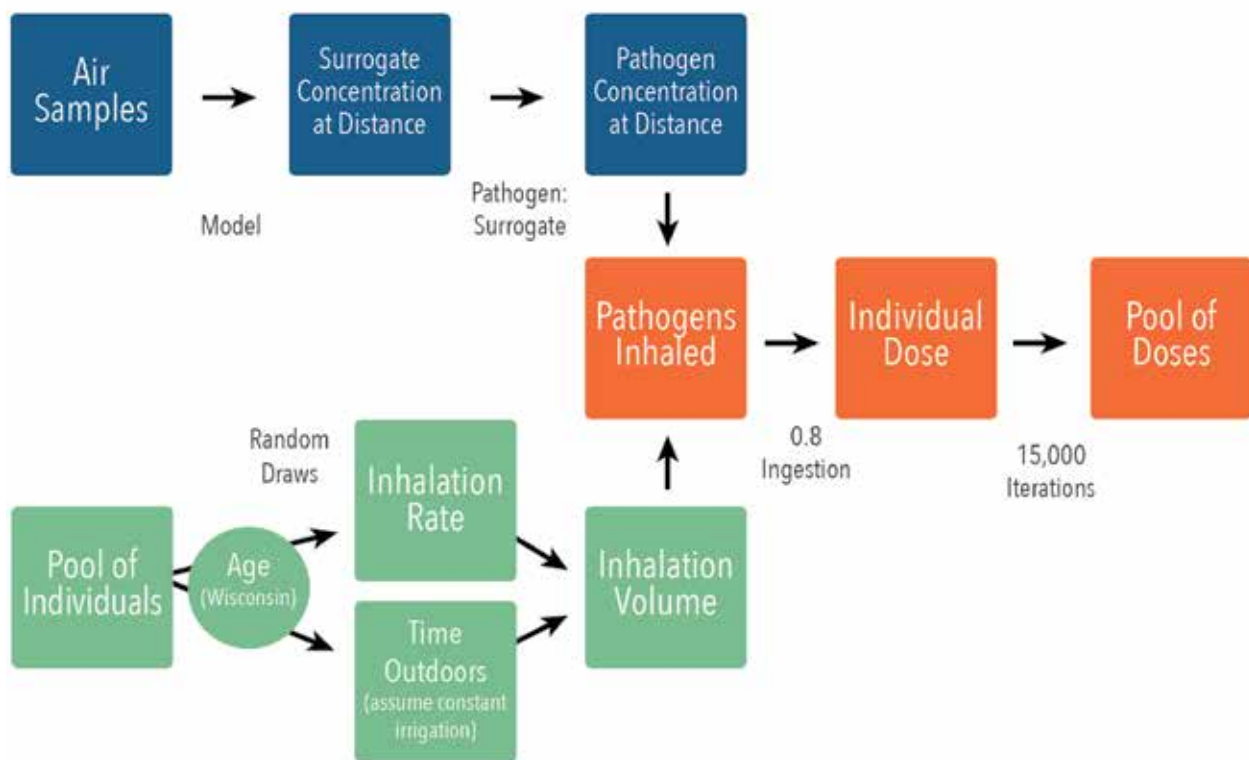


Figure C-4. Schema for calculating pathogen dose and accounting for variability in exposure.

**Inhalation volumes.** The green boxes in Figure C-4 show the steps for developing the statistical distribution of inhalation volumes. From a hypothetical pool of 15,000 individuals a “person” is randomly drawn from the age distribution for Wisconsin residents as reported in the 2010 USA census. Age determines the distributions for

inhalation rate and time spent outdoors from which values are randomly drawn for the “person”. These distributions are from the US EPA Exposure Factors Handbook (2011). Inhalation rates relate to light intensity activities, like walking or watering plants, and time spent outdoors refers to activities outside one’s home. We used distributions, instead of point estimates, for age, inhalation rate, and time outdoors to account for the variability in these parameters. Multiplying inhalation rate and time for 15,000 individuals results in the statistical distribution of inhalation volumes.

We assume manure irrigation is underway the entire time period our “person” is spending outdoors. In other words, if the random draw yields a five minute outdoor time we assume the pathogens from manure irrigation are in the air at the concentration predicted by the statistical model at a specified distance for the five minute period. If a one hour time was randomly selected, the pathogens are assumed to be in the air for one hour, etc. Our risk assessment does not address pathogens in the indoor air environment that have entered from open windows, doors, or other openings to the air outside. We do not have information on the fraction of outdoor airborne pathogens that can enter indoors and selecting such a value would just be a guess. In our opinion, the assumption that manure irrigation occurs for at least as long a time period as the individual is outdoors is already conservative towards protecting public health.

**Pathogens ingested.** The last set of steps (orange boxes in Figure C-4) combines the inhalation volumes and pathogen air concentrations to yield the number of pathogens inhaled and ultimately ingested (i.e., the dose). Pathogens in manure are transmitted by the fecal-oral route. In other words, the pathogens must be ingested to initiate infection. As we are dealing with gastrointestinal pathogens in air, we must estimate the number of ingested pathogens from the number that are inhaled. In our opinion, the manure irrigation risk assessment conducted by the Idaho Department of Environmental Quality provides the soundest estimate of the ingested fraction of inhaled pathogens, 80%. This number is derived from estimates of the aerosol particle size distribution of irrigated human wastewater (assumed to be similar to irrigated manure) and an understanding of human physiology and the size of aerosol particles that are swallowed following inhalation. Multiplying the number of pathogens inhaled by 0.8 for the 15,000 individuals yields a distribution of pathogen doses.

**Dose-response curves.** The last step of the risk assessment is to calculate the probability of illness based on dose-response curves selected from the literature. We used dose-response curves for three pathogens: *Salmonella* spp., *C. jejuni*, and EHEC (enterohemorrhagic *E. coli*) (Figure C-5). Each pathogen has its own dose-response curve because pathogens differ in how many must be ingested to cause illness. Our major criteria for selecting among alternative dose-response curves for each pathogen was to use disease outbreak-based curves whenever they were available. Outbreak-based curves reflect real-world strains of pathogens circulating in the population rather than strains that have lived in a laboratory for years losing their potential for infection. They are also usually representative of the population in terms of age and immune status. In contrast, dose-response curves derived from controlled feeding studies rely on healthy young adults, which likely results in curves that underestimate risk. Outbreak-based curves were available for *Salmonella* and EHEC. Thus, insofar as these dose-response curves reflect the general population, the

risk estimates for *Salmonella* and EHEC in this report account for people living near manure irrigation that vary in age, health, and immune status. We used a feeding study-based curve for *C. jejuni* because reliable outbreak-based curves for this pathogen are currently not available. The *C. jejuni* dose-response curve that we selected is based on a biologically plausible range of dose-response parameters, as opposed to other *C. jejuni* dose-response models that allow for extremely wide variation in the host-pathogen interaction.

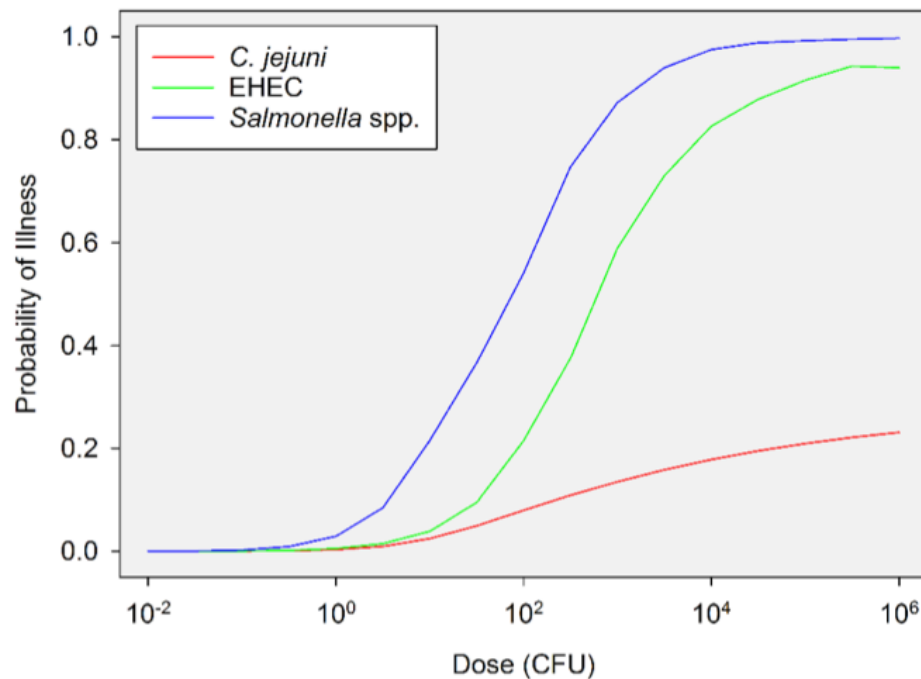


Figure C-5. Example of pathogen dose-response curves.

Because the doses input into a dose-response curve are a statistical distribution, it is important to keep in mind that the output of illness risk probabilities is also a statistical distribution. The benefit of using a risk distribution instead of a single number is that a distribution conveys the variability and uncertainty of the risk estimates. Still, for ease of presentation, for this study we will often report the risk estimates as a single number, the median of the risk distribution.

### Study Findings

*Airborne bacteria detection frequencies and concentrations.* Table 1 reports how often various types of bacteria were detected in irrigated manure and in air samples collected downwind during manure irrigation. Not surprisingly, bacteria that normally live in the gut tract of cattle (*Bacteroides*, gram negative bacteria, *E. coli*, and *Enterococci*) were present in manure 100% of the time. Among the three bacterial pathogens analyzed, only one (*C. jejuni*) was present in the study manure. While *Bacteroides*, gram negative bacteria, commensal *E. coli*, *Enterococcus* spp., and *C.*



*jejuni* were detected frequently in manure samples, they were detected less frequently in downwind air samples. The greatest difference was for non-pathogenic *E. coli*; it was detected in 100% of manure samples but only 11% of air samples.

Table 1. Detection frequencies of bacteria in manure and in air downwind of manure irrigation.

Microbe (method)	Manure Detection % (n of total trials)	Downwind Air Detection % (n of total air samples)
Bovine <i>Bacteroides</i> (qPCR)	100% (18 of 18)	86% (159 of 185)
Gram negative bacteria (culture)	100% (10 of 10)	54% (68 of 127)
Commensal <i>E. coli</i> (culture)	100% (8 of 8)	11% (10 of 92)
<i>Enterococcus</i> spp. (culture)	100% (10 of 10)	56% (55 of 98)
<i>C. jejuni</i> (qPCR)	89% (16 of 18)	17% (30 of 176)
<i>C. jejuni</i> (culture)	70% (7 of 10)	6% (7 of 112)
<i>E. coli</i> O157:H7 (qPCR)	0% (0 of 17)	Not measured
<i>Salmonella</i> spp. (qPCR)	0% (0 of 17)	Not measured
<i>Salmonella</i> spp. (culture)	0% (0 of 10)	0.8% (1 of 126)

Like detection frequencies, concentrations of the bacteria in air decreased with increasing distance downwind from manure irrigation. Figure C-6 illustrates this relationship for one bacteria group that had the highest overall detection frequency in air, bovine *Bacteroides*. The blue lines represent the change in concentrations for each irrigation trial. The red line is the overall trend determined by the statistical analysis, and it represents a typical irrigation event encompassing all the variability introduced by weather conditions, irrigation equipment, farm, etc. In general, the *Bacteroides* concentration decreased approximately 30% for every 100-foot increase in downwind distance. At a distance of 500 feet the expected *Bacteroides* concentration is one genetic copy (equivalent to one bacterium) per liter of air (1,000 genetic copies per cubic meter). When *C. jejuni* and non-pathogenic *E. coli* are detected in air the expected concentrations are much lower, on the order of 0.001 colonies per liter of air.

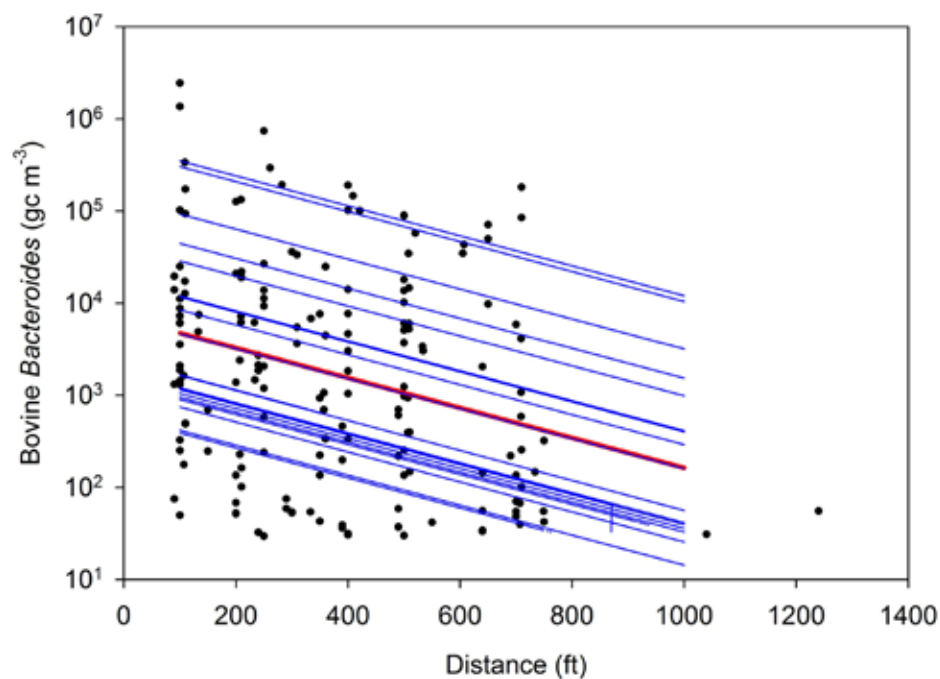


Figure C-6. Air concentrations of bovine *Bacteroides* as related to distance from the wetted perimeter of irrigated manure. Each blue line represents an irrigation trial ( $n = 20$ ). The red line shows the overall trend determined from the statistical model.

**Losses in airborne bacteria.** The decrease in detection frequency and concentration when bacteria move from liquid manure to air during irrigation is demonstrated visually in Figure C-7. The figure shows colonies of gram negative bacteria from samples collected during one manure irrigation trial. The colonies are the pink dots on the growth media plates. There are many colonies in the manure sample, but at 100 feet downwind from the edge of the area wetted by irrigated manure, there were only two colonies in 540 liters of air. There were also two colonies at 350 feet, but at 500 and 670 feet no colonies were detected.

Why are bacteria detections and concentrations in air so much less than in manure? Four well-known processes are responsible, although from our study design it is difficult to ascertain which process is the most important during manure irrigation. 1) When liquid manure is released through an irrigation nozzle, very few bacteria become aerosolized and suspended in the air. In a study conducted by the US EPA of irrigated municipal wastewater, the aerosolization efficiency was only about 1% (US EPA 1980). 2) Gravitational settling of manure aerosols onto surfaces, like plants and soil, as they move through the air removes aerosol-associated bacteria from the air stream, reducing their concentration further downwind. 3) Dilution by the wind scattering and dispersing manure aerosols and bacteria into the larger atmosphere also reduces bacteria concentrations. 4) Lastly, inactivation by warm temperatures, low humidity, and sunshine kills the bacteria, reducing their numbers in air. Despite

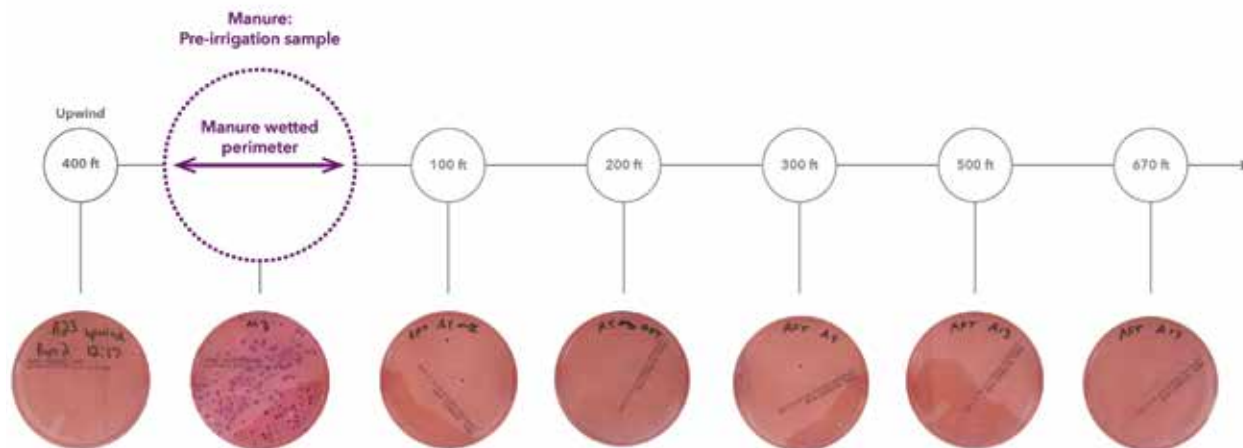


Figure C-7. Gram negative bacteria (pink dots) in air upwind and at five distances downwind from dairy manure irrigated by traveling gun, May 22, 2014. Air sampling was by Andersen impactors containing the MacConkey agar plates shown here. Air volume sampled = 540 liters; wind speed = 11 mph; solar irradiance = 530 Watts/m<sup>2</sup>; relative humidity = 50%, temperature = 68°F. Manure collected before it exited the traveling gun was diluted 1:100 with sterile water before plating 100 microliters on MacConkey agar (upper, second from left, plate).

these environmental processes, manure-borne bacteria can still be measured downwind from manure irrigation and the question then becomes: “Do these concentrations pose a risk to public health?”

**Illness risk as related to distance.** Figure C-8 reports illness risk levels as related to the distance downwind from the edge of the area being wetted during manure irrigation. The relationship was obtained by repeating the QMRA process illustrated in Figure C-4 at 50-foot distance increments. Bacteria concentration at each distance input into the QMRA was determined from the statistical models (e.g., the red line in Figure C-6). It is important to recognize that the red line is illustrating only the general trend, and the actual bacteria air concentrations input at each distance were from a distribution encompassing the variability introduced by weather conditions, irrigation method, farm, and initial manure concentration. This generates a distribution of risk estimates at each distance and is the reason the median risk is reported in Figure C-8.

Figure C-8 is organized as a 2x2 table where the columns and rows are pathogen prevalence in manure and surrogate type, respectively. These are two of the main determinants of risk in this study. The surrogates bovine *Bacteroides* and gram negative bacteria are presented because they span differences in air measurement methods (gram negatives were measured by culture and *Bacteroides* by qPCR), differences in inactivation (*Bacteroides* are the most environmentally resistant surrogate group) and differences in air concentrations. The risk assessment was conducted at two levels of prevalence in dairy manure for each pathogen: 1) 100% prevalence, which assumes the pathogen is present during every exposure to aerosolized dairy manure, and 2) a pathogen-specific “typical” prevalence value. These pathogen-specific values

were 39%, 40%, and 90% for EHEC, *Salmonella* spp., and *C. jejuni*, respectively (USDA 2003, USDA 2011). The typical prevalence values for EHEC and *Salmonella* spp. represent national averages. The *C. jejuni* value was derived from our own field data and is close to its corresponding national average (93%) (USDA 2011). The four panels in Figure C-8 circumscribe the range of risk estimates obtained in this study.

Setting pathogen prevalence levels in dairy manure to typical values and using gram negative bacteria as the surrogate yields the least conservative risk estimates (Panel A). Under this scenario, the median risk levels for one-time exposures to spray irrigated dairy manure are near zero for EHEC and *Salmonella*, and the corresponding risk level for *C. jejuni* is approximately 1 in 100,000. They are all well below 1 infection/10,000 people/year, which is the acceptable level of illness risk for drinking water in the United States (US EPA 1989). At the same prevalence levels but using *Bacteroides* as the surrogate (Panel B), the risk for illness from *C. jejuni* exceeds the drinking water threshold at distances less than about 500 feet. When pathogen prevalence is changed to 100% and using the gram negative bacteria surrogate (Panel C), the illness risk from *Salmonella* exceeds the drinking water threshold at all distances up to 1,000 feet. Panel D represents the most conservative scenario, with pathogen prevalence equal to 100% and bovine *Bacteroides* as the pathogen surrogate. This scenario results in illness risk levels that exceed the drinking water risk threshold for all three pathogens. Furthermore, *Salmonella* risk levels are near the acceptable level of risk for recreational water in the United States (32 illnesses per 1,000 swimmers per exposure event) at distances less than approximately 500 feet (US EPA 2012). Using the other two surrogate groups, *Enterococci* and an alternative measure of bovine *Bacteroides* (M3 *Bacteroides*), or using a direct risk assessment of the air concentration data for the pathogen *C. jejuni*, all result in risk estimates consistent with or lower than those reported in Figure C-8.

**Cumulative risk estimates.** The risk estimates reported in Figure C-8 are for a one-time exposure event to manure irrigation. According to DNR staff some dairy farms irrigate with manure up to 12 times on a field. The cumulative risk from exposures at a 500 foot distance to multiple irrigation events is reported in Figure C-9. The figure is organized as previously, with four scenarios varying pathogen prevalence and surrogate. When the number of irrigation events is greater than one, three of the four scenarios result in risk estimates that exceed the drinking water threshold. Under the scenario most conservative towards public health (100% prevalence, *Bacteroides* as the surrogate), irrigating more than seven times results in *Salmonella* illness risk levels greater than the acceptable level of risk for recreational water. Cumulative risk, as calculated here, refers to multiple exposures from discrete irrigation events over time (e.g., three events in a month); this risk assessment does not explicitly address exposure from multiple irrigation events happening simultaneously on different agricultural fields.

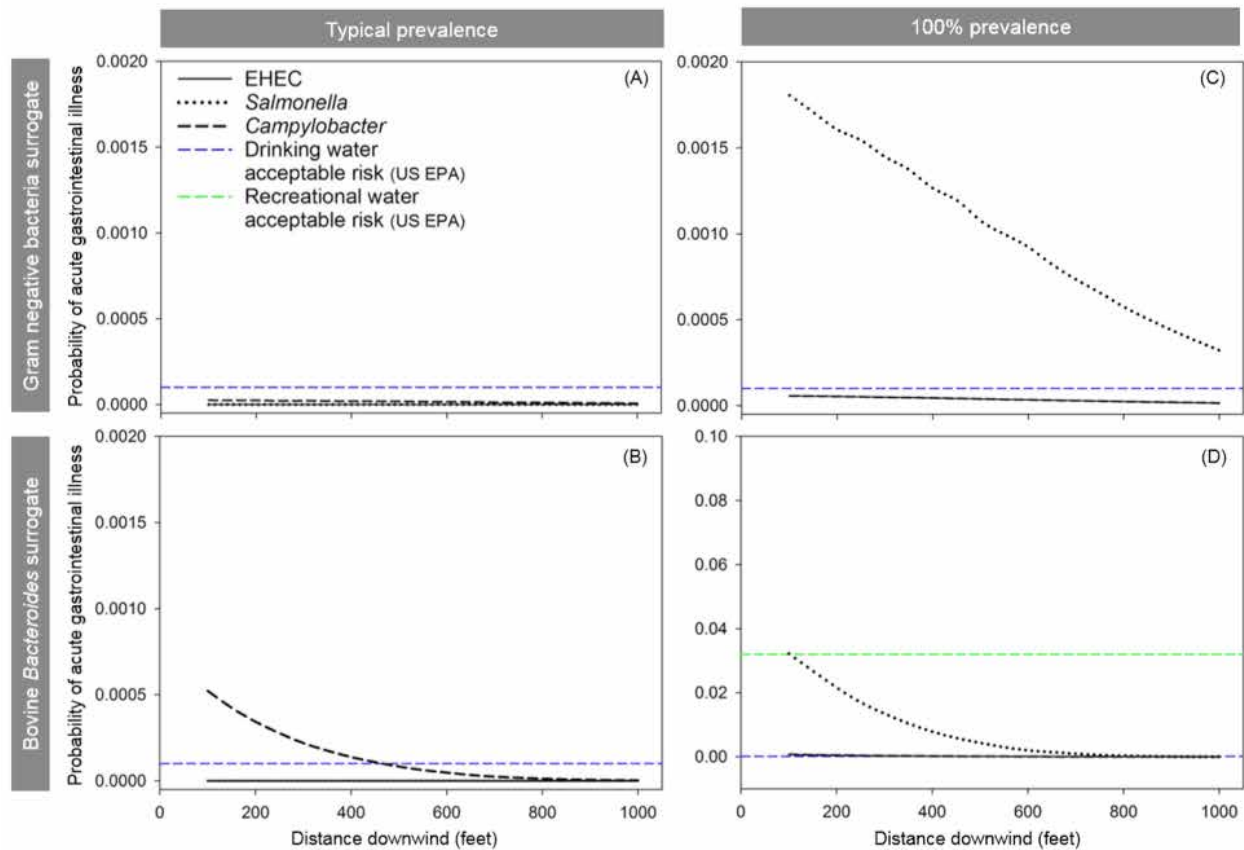


Figure C-8. Risk estimates for acute gastrointestinal illness caused by three pathogens as related to distance from the wetted perimeter of dairy manure irrigated by traveling gun or center pivot. Panels represent pathogens modeled using typical prevalence values and gram negative bacteria as a surrogate (A), typical prevalence values and bovine *Bacteroides* as a surrogate (B), 100% prevalence and gram negative bacteria as a surrogate (C), and 100% prevalence and bovine *Bacteroides* as a surrogate (D). The lines report the median of the risk distribution (i.e., half the risk estimates are higher and half are lower than the line). Horizontal blue and green dashed lines indicate benchmarks in the United States for acceptable levels of risk from exposures to drinking water and recreational water, respectively. Plots are organized by surrogate type and pathogen prevalence in dairy manure as a means of circumscribing the range of risk estimates obtained in this study (see text for details). Note the change in the y-axis scale for Panel D.

**Sensitivity analysis.** We performed a sensitivity analysis to determine the factors most important to the outcomes of the risk analysis. Pathogen prevalence in dairy manure has the greatest influence, and this intuitively makes sense. When manure does not contain a particular pathogen, it is not possible for that pathogen to appear *de novo* in the air during irrigation and cause illness. The length of time a person is exposed to manure irrigation and the effect of distance on decreasing pathogen concentration were two factors with an intermediate level of influence on the risk outcomes. A person's breathing rate and age had only negligible influence on the risk outcomes.

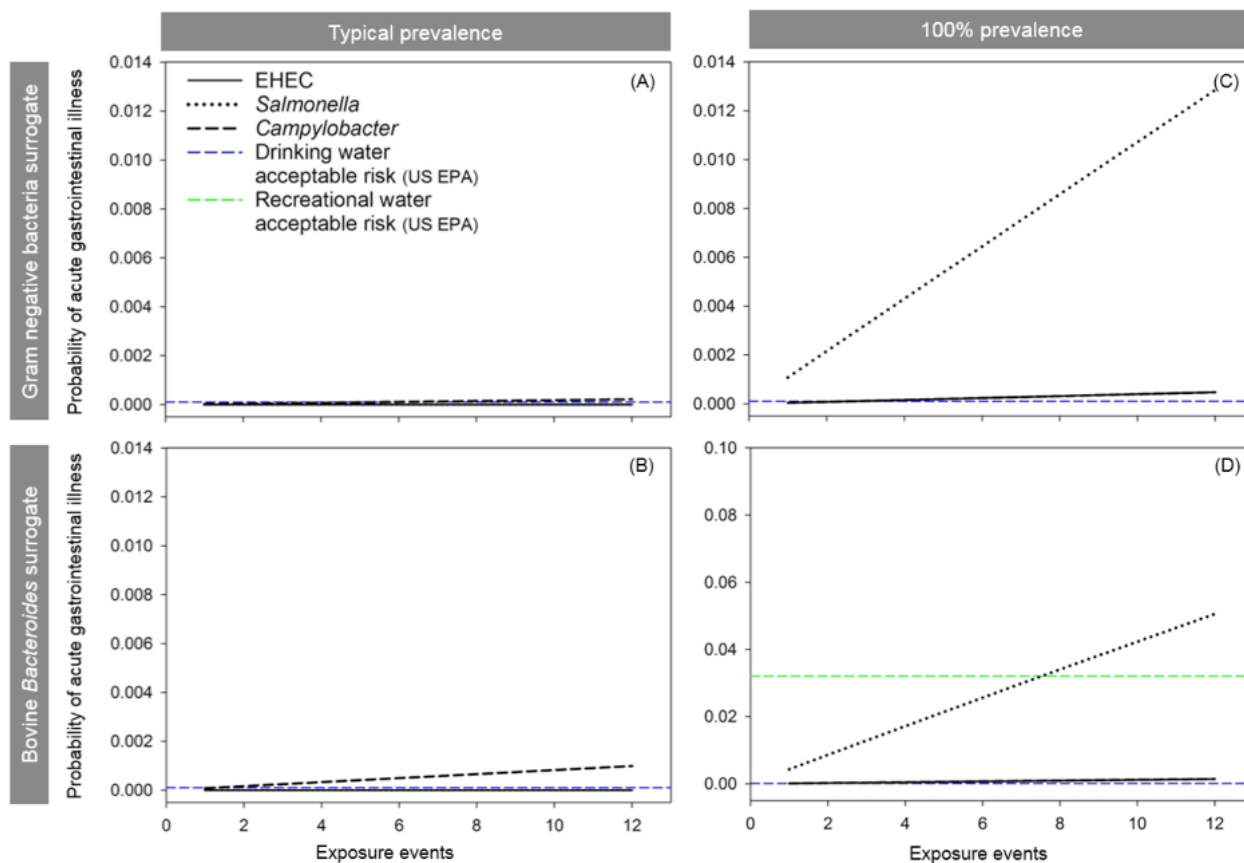


Figure C-9. Cumulative risk (median) for acute gastrointestinal illness at 500 feet from irrigated manure wetted perimeter as related to the number of exposure events (i.e., number of irrigation events). Line and panel designations are the same as the previous figure. Note the change in the y-axis scale for Panel D.

**Factors that affect downwind microbe concentrations.** As described earlier, for predicting downwind microbe concentrations that were input into the QMRA, we used a hierarchical statistical model that mathematically accounted for the variability in air concentrations introduced by the combined effects of weather conditions and microorganism concentrations in manure. Lumping the effects of these variables together was advantageous for interpreting the risk outcomes because it avoided having to make a number of conditional statements, for example, “the risk was W when wind speed was X and temperature was Y but not when temperature was Z.” However, to understand the individual effects of weather conditions and microorganism concentrations in manure on microbe concentrations in air downwind from manure irrigation, we constructed a second set of statistical models using these variables as explicit predictors.

The most important weather variable in determining downwind microbe concentrations is wind speed. Other studies have shown that high solar irradiance and low relative humidity favor rapid inactivation of airborne pathogens, but with our data we did not see clear-cut effects of these two weather variables. Solar irradiance and rel-

ative humidity were only rarely significant predictors of microbe air concentrations, and the observed relationship between relative humidity and microbe air concentrations was opposite that of what we would expect based on biological mechanisms. This does not mean necessarily that solar irradiance and relative humidity do not affect microbe air concentrations during manure irrigation, only that of the weather variables measured, wind speed is the best at predicting downwind concentrations.

Two non-weather variables that were as important as wind speed in predicting microbe concentrations downwind from manure irrigation were distance downwind and the microbe concentration in the manure source. One way to compare these variables is to examine their equivalent effects, that is, how much one variable must change to equal the effect of another variable. For wind speed, a decrease of 2 miles per hour would have the same reducing effect on *Bacteroides* air concentration as increasing the distance approximately 190 feet. Such comparisons, while illustrative, are cumbersome for setting specific quantitative weather conditions for manure irrigation because there are so many permutations. In general, what this analysis shows is that four actions provide the biggest payoff in reducing the risk of airborne disease transmission from dairy manure irrigation: 1) Improve herd health and prevent pathogens from being present in manure in the first place; 2) If pathogens are present, use practices and treatments to reduce their concentrations; 3) Irrigate under low wind speed conditions; 4) Maximize the distance between irrigated manure and people living downwind.

#### Comparison of manure irrigation with conventional spreading by tanker

On two dates we measured airborne transport of pathogens and microbial surrogates during dairy manure application by conventional tanker. Two tankers applied manure to the field site, alternately traveling between the field and manure lagoon. Manure exited the tankers approximately 8 feet from the ground, hitting a splash plate to create a fan pattern. Air sampling equipment was located downwind from the manure application site, and the weather conditions were similar to the manure irrigation trials, (daylight hours, wind speeds of 5 and 7 mph, and relative humidity of 69% and 73%). There was no clear pattern in the differences in downwind microbe concentrations during manure application by tanker or irrigation (Tables 2 and 3). Depending on the microbe type measured and the method of measurement (qPCR or culture) for some comparisons there was no statistical difference between application methods, and for other comparisons sometimes the tanker produced significantly lower air concentrations and sometimes irrigation produced significantly lower air concentrations. With only two tanker trials, it is not possible to determine definitively which application method creates the fewest airborne microbes.

Table 2. Comparison of tanker and irrigation manure application methods on the probability of detecting microbes downwind.

Microbe (Measurement)	P-Value of Statistical Significance	Method with Lower Probability of Detection	Number of Measurements	Number of Trials
Bovine Bacteroides (qPCR)	0.05	tanker	205	22
M3 Bacteroides (qPCR)	0.004	tanker	215	23
Enterococcus spp. (culture)	0.2	Indeterminate <sup>1</sup>	114	25

<sup>1</sup>Two trials were by tanker manure application.

<sup>1</sup>P-value is greater than the statistical threshold of 0.05.

Table 3. Comparison of tanker and irrigation manure application methods on the concentration of microbes downwind.

Microbe (Measurement)	P-Value of Statistical Significance	Method with Lower Concentration	Number of Measurements	Number of Trials
Bovine Bacteroides (qPCR)	0.07	Indeterminate <sup>1</sup>	170	22
M3 Bacteroides (qPCR)	0.8	Indeterminate	132	22
Enterococcus spp. (culture)	0.9	Indeterminate	61	19
Gram Negative Bacteria (culture)	0.001	irrigation	88	24

<sup>1</sup>Two trials were by tanker manure application.

<sup>1</sup>P-value is greater than the statistical threshold of 0.05.

#### Traveling gun versus center pivot manure irrigation

Comparing traveling gun versus center pivot manure irrigation methods, there are no statistical differences in the probabilities of detection or levels of concentration of airborne bovine *Bacteroides* or gram negative bacteria (Tables 4 and 5). The traveling gun method did result in a significantly lower probability of detection and concentration of enterococci bacteria in air. Overall, however, there was no clear pattern of differences between traveling gun and center pivot manure irrigation methods in the downwind transport of microbes.

Table 4. Comparison of traveling gun and center pivot manure irrigation on the probability of detecting microbes downwind.

Microbe (Measurement)	P-Value of Statistical Significance	Method with Lower Probability of Detection	Number of Measurements	Number of Trials
Bovine Bacteroides (qPCR)	0.06	Indeterminate <sup>1</sup>	185	20
M3 Bacteroides (qPCR)	0.4	Indeterminate	195	21
Enterococcus spp. (culture)	0.002	Traveling gun	98	21
Gram Negative Bacteria (culture)	0.3	Indeterminate	127	21

<sup>1</sup>P-value is greater than the statistical threshold of 0.05.



Table 5. Comparison of traveling gun and center pivot manure irrigation on the concentration of microbes downwind.

Microbe (Measurement)	P-Value of Statistical Significance	Method with Lower Concentration	Number of Measurements	Number of Trials
Bovine Bacteroides (qPCR)	0.5	Indeterminate <sup>1</sup>	159	20
M3 Bacteroides (qPCR)	0.1	Indeterminate	130	21
Enterococcus spp. (culture)	0.007	Traveling gun	55	17
Gram Negative Bacteria (culture)	0.6	Indeterminate	68	20

<sup>1</sup>P-value is greater than the statistical threshold of 0.05.

#### Study Limitations and Data Interpretation

Several limitations of the study design need to be kept in mind when interpreting the data. Likely the most important was using non-pathogenic microbes in manure as surrogates for pathogens. This was necessitated because during the study period pathogen prevalence on the three study farms was low; only *C. jejuni* was detected. While the surrogate-to-pathogen ratios we used were based on a combination of published data and our own study data, it was not possible to explore the variability of the ratios and what effects these would have on the risk outcomes. To mitigate this limitation our analysis relied on multiple surrogates and variable levels of pathogen prevalence as a means of circumscribing the range of predicted risks.

This study focused on the primary zoonotic pathogens in dairy manure; we did not conduct analyses for less common but still important pathogens, for example, *Listeria monocytogenes* or *Leptospira*. For many of these less common pathogens, the requisite data for conducting the QMRA are limited or unavailable. We chose to focus on common pathogens for which the abundant information available would yield the most robust QMRA with the least number of assumptions. The importance of pathogen prevalence and concentration in dairy manure in determining risk for *C. jejuni*, EHEC, and *Salmonella* suggests that risk levels are probably the same or lower for less common pathogens like *Listeria*.

It is tempting to think the risk levels determined in this QMRA are the risk levels for every dairy farm that practices manure irrigation. However, this type of thinking, where an attribute of the group is applied to a specific individual, is a common error called the “ecological fallacy”. For example, suppose a school has the highest average reading score in the state. This does not necessarily mean that every student in the school is an excellent reader. Each student is just one member of the distribution of reading scores that is summarized by the school’s average. Similarly, the manure irrigation risk values reported here are medians that summarize the risk distribution; a specific dairy farm or specific manure irrigation event could have risk levels that are higher or lower than the median.

In using scientific data in setting public policy it only makes sense to use a group-level measure because the policy will apply to the group. Intuitively, we know airborne pathogen measurements on one farm do not represent all farms, just like

all students of a school do not have the same reading scores. It is the summary measure of the group that is informative. For this QMRA, we have chosen to report the median risks where half of the irrigation events have higher risks and the other half are lower. For a more conservative approach, policymakers could use the 75<sup>th</sup> percentile risk level, meaning 25% of irrigation events exceed the summary measure (Figure C-10), or the 95<sup>th</sup> percentile where only 5% of the risk estimates are higher (Figure C-11). The difficult decision is which summary measure to use.

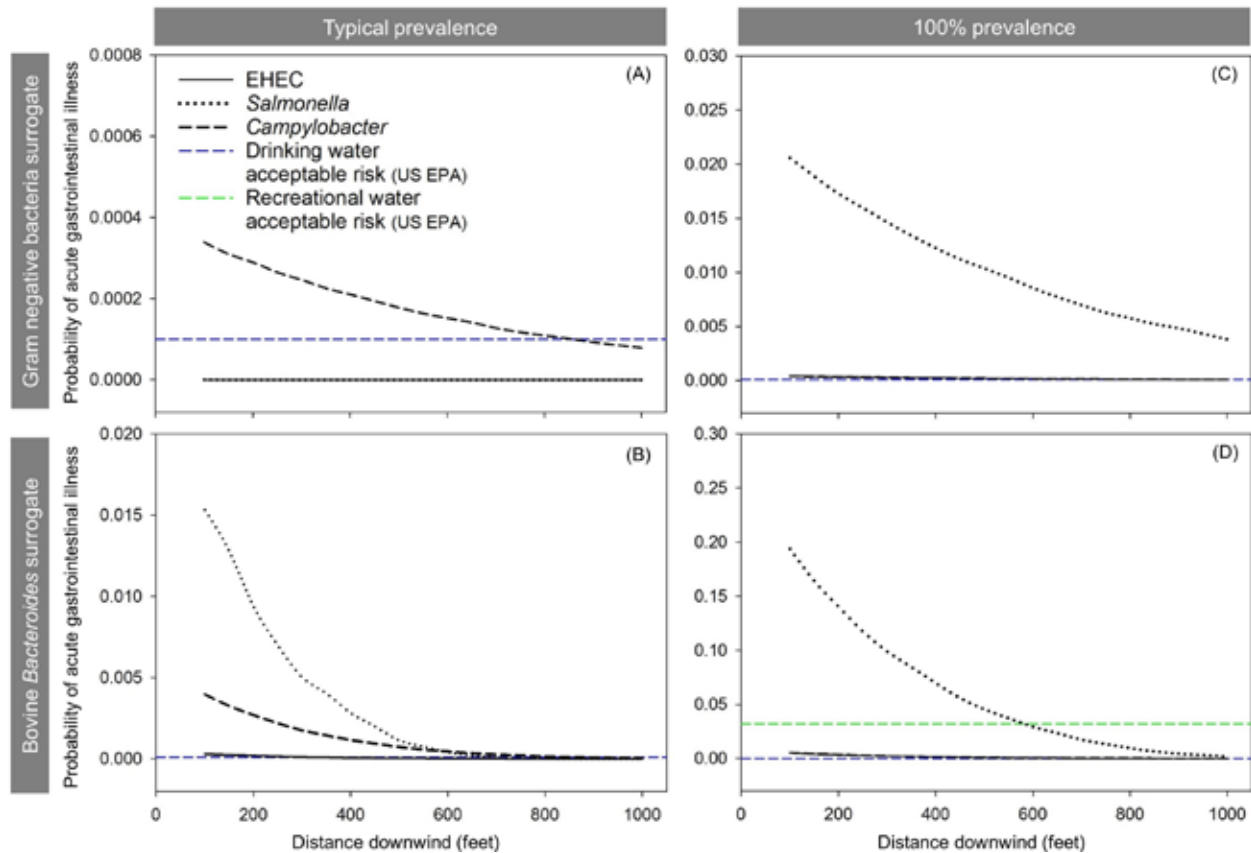


Figure C-10

Figure C-10. Risk estimates using the 75<sup>th</sup> percentiles of the risk distributions for acute gastrointestinal illness caused by three pathogens as related to distance from the wetted perimeter of irrigated dairy manure. Irrigation was by traveling gun or center pivot. The lines for each pathogen indicate the risk estimate at which 25% of the risk estimates are higher and 75% are lower. Notation and organization of the plots are identical to Figure C-8.

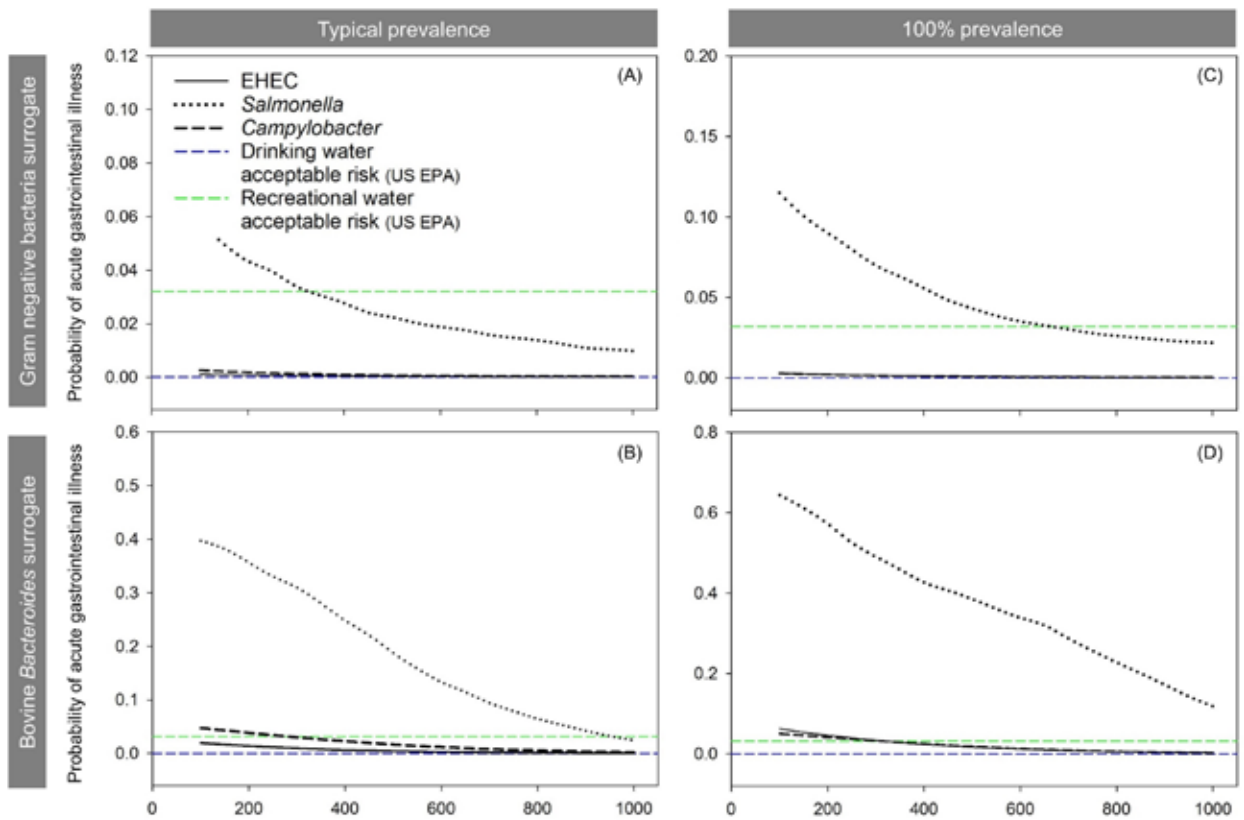


Figure C-11

Figure C-11. Risk estimates using the 95th percentiles of the risk distributions for acute gastrointestinal illness caused by three pathogens as related to distance from the wetted perimeter of irrigated dairy manure. Irrigation was by traveling gun or center pivot. The lines for each pathogen indicate the risk estimate at which 5% of the risk estimates are higher and 95% are lower. Notation and organization of the plots are identical to Figure C-8.

### Study Summary

This is a non-technical summary of a study that has extensive supporting data and technical analysis. Data, statistical models, and results are available from the authors upon request. Another publication, with additional details of the study, is anticipated.

Application of liquid dairy manure by traveling gun or center pivot irrigation systems is becoming more common in Wisconsin because it offers several potential benefits: reduced road impacts from hauling, optimal timing for crop nutrient uptake, and reduced risks of manure runoff and groundwater contamination. However, irrigation could also increase the risk of airborne pathogen transmission from manure to humans and livestock compared to other application methods. We measured air concentrations of manure-related microbes during 23 manure irrigation events on three Wisconsin dairy farms at multiple distances, typically up to 700 feet, downwind from the irrigated wetted perimeter. We also measured background air concentrations before irrigation and upwind concentrations during irrigation. Air was sampled by two methods at each distance: button samplers for qPCR analysis

of microbial targets and Andersen impactors for culturable bacteria. Meteorological conditions during irrigation were measured with a portable weather station.

Results show that microbial concentrations decline with distance, but can still be measurable at 700 feet downwind from irrigation depending on wind velocity and the microbe initial concentration in manure. Using quantitative microbial risk assessment, we estimate the risk for acute gastrointestinal illness for exposure to airborne pathogens 500 feet downwind from dairy manure irrigation is on the order of 0.00001 to 0.01 (1 in 100,000 to 1 in 100) per irrigation event. The risk estimate depends primarily on pathogen type, pathogen prevalence on dairy farms, downwind distance from the irrigation equipment, and the number of irrigation events during a growing season. Also, it is important to recognize the risk values reported herein are medians of the risk distribution; users of this report might decide to use lower or higher percentiles of the risk distributions.

This comprehensive risk assessment is the first to use measured concentrations of airborne pathogens during manure irrigation. Overall, the decisions made in conducting this risk assessment were conservative towards protecting public health. Using bovine *Bacteroides* as a surrogate, which possesses high resistance to environmental inactivation, likely leads to higher detection frequencies and concentrations downwind than what might be expected for most pathogens. Assuming that 100% of dairy farms have a specific pathogen, like *Salmonella*, in their manure also results in conservative risk estimates. Other elements of the risk assessment were favorable for producing the most accurate risk estimates. The bacteria air concentrations during manure irrigation were from actual field measurements. The dose-response models derived from outbreak data likely represent the pathogen strains circulating in the population and likely include the health outcomes of the most vulnerable populations. The distributions for age, inhalation rate, and time spent outdoors were from widely accepted sources. And, the ingestion to inhalation ratio was derived from empirical data and first principles.

The findings from this study will be useful to policymakers and public health officials for establishing safe setback distances from irrigated dairy manure.

## **Acknowledgements**

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## References

- Atwill ER, Partyka ML, Bond RF, Li X, Xiao C, Karle B (2012). Introduction to waterborne pathogens in agricultural watersheds. Natural Resources Conservation Service Nutrient Management Technical Note No. 9.
- Brooks JP, Tanner BD, Gerba CP, Haas CN, Pepper IL (2005a). Estimation of bio-aerosol risk of infection to residents adjacent to a land applied biosolids site using an empirically derived transport model. *Journal of Applied Microbiology*, 98(2), 397-405.
- Brooks JP, Tanner BD, Josephson KL, Gerba CP, Haas CN, Pepper IL (2005b). A national study on the residential impact of biological aerosols from the land application of biosolids. *Journal of Applied Microbiology*, 99(2), 310-322.
- Brooks JP, McLaughlin MR, Gerba CP, Pepper IL (2012). Land application of manure and class B biosolids: An occupational and public quantitative microbial risk assessment. *Journal of Environmental Quality*, 41(6), 2009-2023.
- Dowd SE, Gerba CP, Pepper IL, Pillai SD (2000). Bioaerosol transport modeling and risk assessment in relation to biosolid placement. *Journal of Environmental Quality*, 29(1), 343-348.
- Dungan RS (2010). Board-invited review: Fate and transport of bioaerosols associated with livestock operations and manures. *Journal of Animal Science*, 88(11), 3693-3706.
- Dungan RS, Bjorneberg DL, Leytem AB (2011). Effect of sprinkler pressure and spray plate on culturable microorganism concentrations during simulated irrigation of dairy wastewater. *Transactions of the ASABE*, 54(5), 1669-1673.
- Dungan RS (2014). Estimation of infectious risks in residential populations exposed to airborne pathogens during center pivot irrigation of dairy wastewaters. *Environmental Science & Technology*, 48(9), 5033-5042.
- Hale CR, Scallan E, Cronquist AB, Dunn J, Smith K, Robinson T, Lathrop S, Tobin-D'Angelo M, Clogher P (2012). Estimates of enteric illness attributable to contact with animals and their environments in the United States. *Clinical Infectious Diseases*, 54(suppl 5), S472-S479.
- Hardy R, Schilling K, Fromm J, Dai X, Cook M (2006). Technical background document: microbial risk assessment and fate and transport modeling of aerosolized microorganisms at wastewater land application facilities in Idaho. Idaho Department of Environmental Quality.
- Jahne MA, Rogers SW, Holsen TM, Grimberg SJ, Ramler IP, Kim S (2016). Bioaerosol deposition to food crops near manure application: quantitative microbial risk assessment. *Journal of Environmental Quality*, 45:666-674.

- Paez-Rubio T, Peccia J (2005). Estimating solar and nonsolar inactivation rates of airborne bacteria. *Journal of Environmental Engineering*, 131(4), 512-517.
- Teltsch B, Shuval HI, Tadmor J (1980). Die-away kinetics of aerosolized bacteria from sprinkler application of wastewater. *Applied and Environmental Microbiology*, 39(6), 1191-1197.
- USDA (2003). *Escherichia coli O157 on U.S. dairy operations*. USDA-APHIS-VS, CEAH. Fort Collins, CO. #N404.1203.
- USDA (2011). *Salmonella, Listeria, and Campylobacter on U.S. dairy operations, 1996 – 2007*. USDA-APHIS-VS, CEAH. Fort Collins, CO. #578.0311.
- US EPA (1980). The evaluation of microbiological aerosols associated with the application of wastewater to land. EPA-600/1-80-015.
- US EPA (1982). Estimating microorganism densities in aerosols from spray irrigation of wastewater. EPA-600/9-82-003.
- US EPA (1989). Drinking water; national primary drinking water regulations; filtration, disinfection; turbidity, *Giardia lamblia*, viruses, legionella, and heterotrophic bacteria. Final Rule, 40 CFR parts 141 and 142. Federal register 54:27486-27541.
- US EPA (2011). Exposure factors handbook: 2011 edition. National Center for Environmental Assessment, Washington, DC. EPA/600/R-09/052F.
- US EPA (2012). Recreational water quality criteria. EPA 820-F-12-058.
- US EPA (2013). Literature review of contaminants in livestock and poultry manure and implications for water quality. EPA 820-R-13-002.



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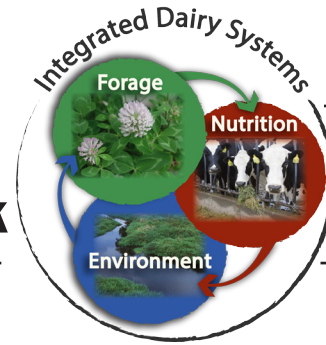
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# Airborne pathogens from dairy manure aerial irrigation and the human health risk

by Mark A. Borchardt and Tucker R. Burch



U.S. Dairy Forage Research Center

Application of liquid dairy manure by traveling gun or center pivot irrigation systems is becoming more common because it offers several potential benefits: reduced road impacts from hauling, optimal timing for crop nutrient uptake, and reduced risks of manure runoff and groundwater contamination.

However, irrigation could also increase the risk of airborne pathogen transmission from manure to humans and livestock compared to other application methods. This concern about airborne pathogens prompted the Wisconsin Department of Natural Resources to fund field research on this topic. This fact sheet is a summary of that study, the first study to use measured concentrations of airborne microorganisms during irrigation of dairy manure on working farms to estimate human health risk.



Setting up the equipment in the field to measure microorganism transport during irrigation.

## Pathogens in dairy manure

Dairy manure, like the fecal excrement from any domesticated or wild animal, can contain pathogens capable of infecting humans. Six pathogens that can be

found in dairy manure and are frequently associated with human health effects include: *Salmonella*, *E. coli*, *Campylobacter jejuni*, *Listeria monocytogenes*, *Cryptosporidium parvum*, and *Giardia lamblia*. These all cause acute gastrointestinal illness with diarrhea, abdominal pain, fever, nausea, and vomiting. In some

cases illness can progress to a systemic infection involving other organ systems.

It is important to recognize that the number and types of pathogens in dairy manure can be highly variable from herd to herd and even in the same herd through time. Thus, exposure to dairy manure does not always equate to exposure to human pathogens. On the other hand, the absence of pathogens in a specific dairy herd at a specific point in time does not equate to the universal absence of health risk from exposure to

dairy manure. The risk assessment described in this fact sheet accounted as best as possible for varying infection susceptibilities in the exposed population and varying pathogen presence in dairy manure.

## Study summary

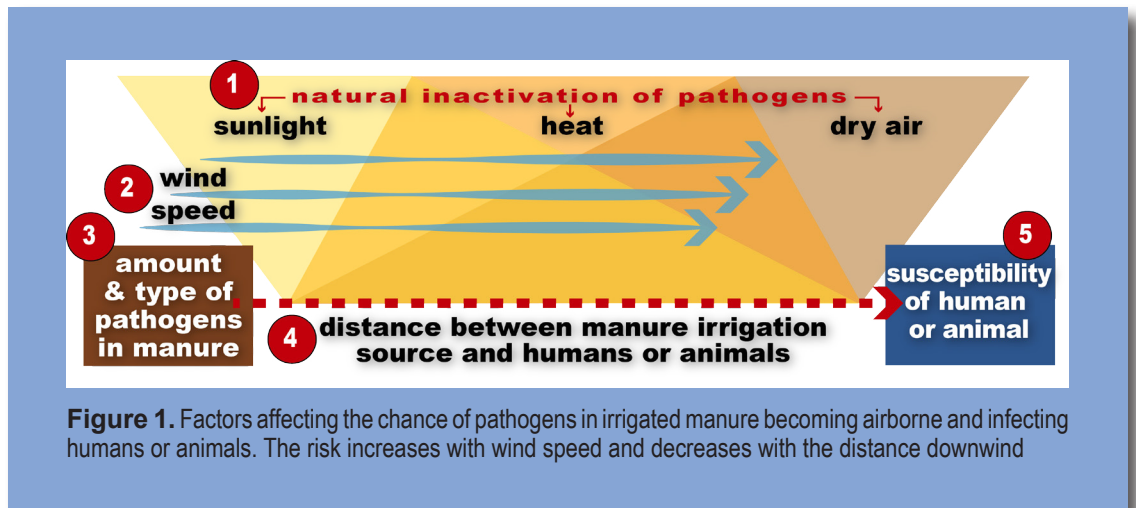
Airborne microbial concentrations, some of which may be pathogenic, decline with distance but can still be measurable at 700 feet downwind from irrigation depending on wind velocity and the initial concentration of the microorganism in manure.

Using quantitative microbial risk assessment, we estimate the risk for acute gastrointestinal illness for exposure to airborne pathogens 500 feet downwind from dairy manure irrigation is on the order of 1 in 100,000 to 1 in 100 per irrigation event.

The risk estimate depends primarily on pathogen type, pathogen prevalence on dairy farms, downwind distance from the irrigation equipment, and the number of irrigation events during a growing season.

Also, it is important to recognize the risk values reported herein are medians of the risk distribution; users of this report might decide to use lower or higher percentiles of the risk distributions.





## Wisconsin study

The Wisconsin study described in this fact sheet had two primary objectives. The first objective was to identify weather variables (e.g., wind speed, solar radiation, and relative humidity) most important for airborne pathogen transport during manure irrigation. The second objective was to estimate the risk of illness for people by using microbial risk assessment computer models.

At the foundation of this effort was an extensive, largest of its kind, field sampling for airborne microorganisms during 23 irrigation events (8 trials by center pivot and 15 trials by traveling gun) in 2012 through 2014. Air samples were analyzed for culturable bacteria in 13 trials and for microorganism genetic markers in 23 trials.



Weather data were collected every 30 seconds during each trial -- wind direction and speed, air temperature, solar radiation, relative humidity, and precipitation, which was always zero.

In two additional trials we measured airborne transport of microorganisms during conventional manure application by a tanker with a high splash-plate.

## Study findings

**Airborne bacteria detection frequencies.** Not surprisingly, bacteria that normally live in the gut tract of cattle (*Bacteroides*, gram negative bacteria, *E. coli*, and *Enterococci*) were present in manure 100% of the time. In addition, *Campylobacter jejuni* also was present in the study manure. While the bacteria listed above were detected frequently in manure samples, they were detected less frequently in downwind air samples. The greatest difference was for non-pathogenic *E. coli*, which was detected in 100% of manure samples versus 11% of air samples, while the smallest difference was for *Bacteroides*, which were detected in 100% of manure samples versus 86% of air samples.

**Airborne bacteria concentrations.** Like detection frequencies, concentrations of the bacteria in air decreased with increasing distance downwind from manure irrigation. In general, the concentration of the bacteria with the highest survival rate (most likely to cause illness) decreased approximately 30% for every 100-foot increase in downwind distance.

## Weather variables

Why are bacteria detections and concentrations in air so much less than in manure? Four well-known processes are responsible. 1) When liquid manure is released through an irrigation nozzle, very few bacteria become aerosolized and suspended in the air. 2) Gravitational settling of manure aerosols onto surfaces, like plants and soil, as they move through the air removes aerosol-associated bacteria from the air stream, reduc-

ing their concentration further downwind. 3) Dilution by the wind scattering and dispersing manure aerosols and bacteria into the larger atmosphere also reduces bacteria concentrations. 4) Lastly, inactivation by warm temperatures, low humidity, and sunshine kills the bacteria, reducing their numbers in air (Figure 1).

In this study, the most important weather variable in determining downwind microbe concentrations was wind speed. Two non-weather variables that were as important as wind speed in predicting microbe concentrations downwind from manure irrigation were distance downwind and the microbial concentration in the manure source.

### Human health risk

Despite environmental processes that inactivate airborne pathogens, airborne pathogens can still be measured downwind from manure irrigation. The question then becomes: “Do these concentrations pose a risk to public health?”

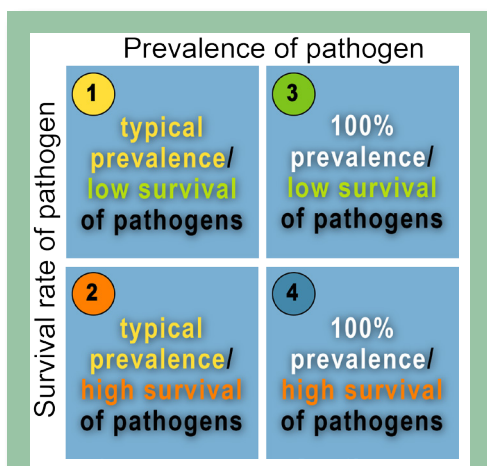
The prevalence and concentration of pathogens in manure is always changing. In order to make conclusions about the potential health risk, we analyzed the data under four different scenarios that differ in their assumptions and therefore lead to different levels of precaution toward protecting public health.

The four scenarios are shown in Figure 2. We compared two rates of prevalence: 1) the typical prevalence of a pathogen in manure as reported in existing

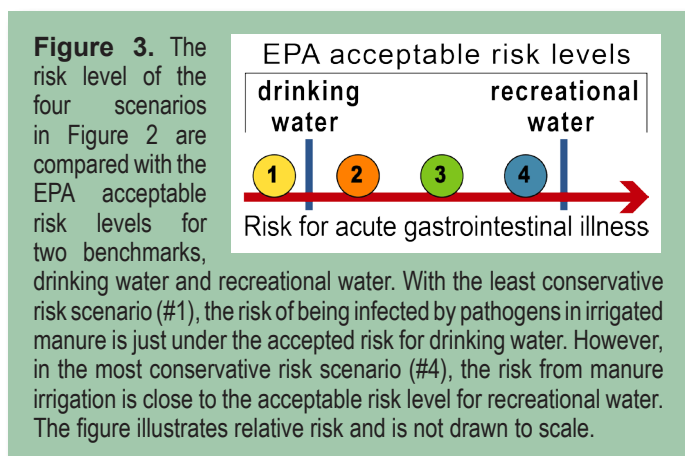
national data; and 2) a worst case scenario in which a pathogen is present in 100% of manure. And we used two different microorganisms in the analysis, one that has a high rate of survival in the environment and is more likely to transmit a disease, and one that has a low rate of survival and is unlikely to result in disease transmission. If you assume the pathogen is present in all manure and has a high rate of survival, the estimated health risk is much higher than if you assume the pathogen is present at typical levels and has a low rate of survival.

Then we compared the risk level determined for each scenario against water quality standards already in use by the EPA: 1) acceptable level of illness risk for drinking water, 1 infection/10,000 people/year; and 2) acceptable level of risk for recreational water, 32 illnesses/1,000 swimmers/exposure event. As seen in Figure 3, risk from manure irrigation is generally between the acceptable risk levels for drinking water and recreational water.

There are two caveats to consider. The reported risk levels are for a single manure irrigation event. However, manure can be irrigated multiple times on a field during a growing season and each time people are exposed to irrigated manure the risk of illness increases. Second, the reported risk levels are medians of the outputted risk distributions (i.e., 50% of the risk estimates are lower and 50% are higher). Risk managers may wish to use a summary statistic more conservative toward protecting public health (e.g., 75th percentile).



**Figure 2.** Four scenarios used in the risk assessment. Number 1 has the least conservative assumptions and Number 4 the most conservative assumptions. Policy makers must decide the level of precaution needed.





## Comparison of spreading and the two different irrigation methods

**Conventional tanker versus irrigation.** On two dates we measured airborne transport of pathogens and microbial surrogates during dairy manure application by conventional tanker. There was no clear pattern in the differences in downwind microbe concentrations during manure application by tanker or irrigation. For some comparisons there was no statistical difference between application methods, and for other comparisons sometimes the tanker produced significantly lower air concentrations and sometimes irrigation produced significantly lower air concentrations. With only two tanker trials, it is not possible to determine definitively which application method creates the fewest airborne microbes.

**Traveling gun versus center pivot irrigation.** Comparing traveling gun versus center pivot manure irrigation methods, there are no statistical differences in the probabilities of detection or levels of concentra-

tion of airborne bovine *Bacteroides* or gram negative bacteria. The traveling gun method did result in a significantly lower probability of detection and concentration of enterococci bacteria in air. Overall, however, there was no clear pattern of differences between traveling gun and center pivot manure irrigation methods in the downwind transport of microbes.

### What producers can do to reduce the health risk from irrigated manure

Four actions provide the biggest payoff in reducing the risk of airborne disease transmission from dairy manure irrigation.

- 1) Improve herd health and prevent pathogens from being present in manure in the first place.
- 2) If pathogens are present, use practices, such as anaerobic digestion or manure storage greater than three months, to reduce their concentrations.
- 3) Irrigate under low wind speed conditions.
- 4) Maximize the distance between irrigated manure and people living downwind.

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## **BUREAU OF WATERSHED MANAGEMENT PROGRAM GUIDANCE**

### **Storm Water Management Program**


### **Model Ordinances for Construction Site Erosion and Sediment Control and Post-Construction Storm Water Management**

**Effective Date: April 2015  
Guidance #: 3800-2015-05**

*Notice: This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.*

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**APPROVED:**

  
Pam Biersach, Director  
Bureau of Watershed Management

4-6-2015  
Date



## **A. Purpose**

The purpose of this guidance is to provide local governments with two model ordinances for:

- construction site erosion and sediment control and
- post-construction storm water management.

The model ordinances in this guidance contain the performance standards in ss. NR 151.11 (6m) and 151.122 through 151.126, Wis. Adm. Code, as applicable for construction site erosion and sediment control and post-construction storm water management.

## **B. Background**

Section 281.33 (4), Wis. Stats., directs the Department of Natural Resources (Department) to prepare model ordinances for construction site erosion control and storm water management in the form of an administrative rule. Furthermore, 2013 Wisconsin Act 20 (“Act 20”) became effective on July 2, 2013, and amended s. 281.33, Wis. Stats. The amendments relate to the Department establishing uniform statewide standards for construction site erosion control and storm water management and requiring ordinances regulating these activities enacted by a local government to strictly conform with the uniform statewide standards. However, a local government may enact more restrictive ordinances to control storm water quantity and flooding or to comply with a federally approved TMDL. In October 2014, the Department issued final guidance on how it will implement the changes to s. 281.33, Wis. Stats., as a result of Act 20. That final guidance is available from the Department website at <http://dnr.wi.gov/water/egadsearch.aspx> and searching for Publication Number 3800-2014-03.

## **C. Discussion**

Notwithstanding the directive to prepare the model ordinances in the form of an administrative rule, several local governments need the guidance that the model ordinances provide sooner than can be accomplished through the administrative rule process. Municipalities covered under a municipal separate storm sewer system (MS4) permit pursuant to ch. NR 216, Wis. Adm. Code, need to update their ordinances as appropriate to comply with the performance standards promulgated in ch. NR 151, Wis. Adm. Code, effective January 2011. Consequently, the Department is offering assistance by presenting the model ordinances as guidance.

This guidance includes two model ordinances prepared by the Department. One is a model ordinance for construction site erosion and sediment control associated with land disturbing construction activities. The other is a model ordinance for post-construction storm water management. The purpose of making these model ordinances available to local units of government is to secure so far as practicable the voluntary uniformity of local regulations regarding construction site erosion and sediment control and storm water management, to further the purpose of s. 281.33 (1), Wis. Stats., and to promote consistency with state non-agricultural performance standards authorized under s. 281.16 (2)(a), Wis. Stats.

Use of either model ordinance by a local government is voluntary. However, other administrative rules, such as chs. NR 120, 153 and 216, Wis. Adm. Code, require conformance of local regulations with the performance standards of ch. NR 151, Wis. Adm. Code. The performance standards for construction site

erosion and sediment control and post-construction storm water management are incorporated into the model ordinances. The Department believes that a local government that enacts an ordinance that incorporates the performance standards in the model ordinances meets the strict conformance requirements of s. 281.33 (3m), Wis. Stats. Use of the model ordinances is optional. The model ordinances are intended to provide a framework for local governments to draft ordinances that meet the MS4 permit requirements for implementation and enforcement of the legal authorities in s. NR 216.07(4) and (5), Wis. Adm. Code. However, municipalities not covered under an MS4 permit may also use the models. Please be aware that the Department cannot provide legal review of local ordinances. Therefore, the Department requests that a municipality regulated under an MS4 permit pursuant to subch. I of NR 216, Wis. Adm. Code, submit a legal opinion from its corporation counsel stating that its ordinances are compliant with the MS4 permit requirements.

## **D. Guidance**

***Note to Users:** The “Users” in this document are the municipalities that use this guidance in developing their ordinances. “Note to Users” appears in italics throughout these model ordinances and should not be included in the final ordinance. This model ordinance includes the use of brackets [ ] around phrases that are to be filled in by the municipality. For example, the phrase [administering authority] is frequently used. Where the municipality chooses to have the ordinance administered by the City Engineer, the phrase [administering authority] should be replaced by "City Engineer". In a few places, the model ordinance includes phrases in brackets that are underlined [\_\_\_\_\_]. In these cases, one of the underlined phrases should be selected verbatim. For example, if the phrase includes statutory citations, several underlined choices may be given such as [59.693, 60.627, 61.354, or 62.234]. A county would replace the phrase in brackets with "59.693", since that is the appropriate citation for a county to use. Some sections and subsections are optional for users to include in the ordinance and will be identified as such in a “Note to Users”. An asterisk ( \* ) denotes subsequent numbering and references to numbered sections or subsections that would be affected by exclusion of the optional text.*

## **MODEL CONSTRUCTION SITE EROSION AND SEDIMENT CONTROL ORDINANCE**

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***Note to Users:** An asterisk ( \* ) denotes subsequent numbering and references to numbered sections or subsections that would be affected by exclusion of the optional text.*



## MODEL CONSTRUCTION SITE EROSION AND SEDIMENT CONTROL ORDINANCE

### AN ORDINANCE TO CREATE CHAPTER [NUMBER] OF THE [CODE OR ORDINANCE] OF THE [NAME OF MUNICIPALITY] RELATING TO THE CONTROL OF CONSTRUCTION SITE EROSION AND SEDIMENTATION RESULTING FROM LAND DISTURBING CONSTRUCTION ACTIVITIES

#### FOREWORD.

Use of this ordinance will foster consistent, statewide application of the construction site performance standards for new development and redevelopment contained in subchapters III and IV of ch. NR 151, Wis. Adm. Code.

The [governing body] of the [name of municipality] does hereby ordain that Chapter [number] of the [code or ordinance] of the [name of municipality] is created to read as follows:

#### [CHAPTER]

#### CONSTRUCTION SITE EROSION AND SEDIMENT CONTROL

##### S. 01 AUTHORITY.

- (1) This ordinance is adopted under the authority granted by s. [59.693, for counties; 60.627, for towns; 61.354, for villages; 62.234, for cities], Wis. Stats. This ordinance supersedes all provisions of an ordinance previously enacted under s. [59.69, 60.62, 61.35, or 62.23], Wis. Stats., that relate to construction site erosion control. Except as otherwise specified in s. [59.693, 60.627, 61.354, or 62.234], Wis. Stats., s. [59.69, 60.62, 61.35, or 62.23], Wis. Stats., applies to this ordinance and to any amendments to this ordinance.

***Note to Users:** There may be instances where this ordinance does not supersede other ordinances relating to construction erosion control previously adopted by the governing body.*

- (2) The provisions of this ordinance are deemed not to limit any other lawful regulatory powers of the same governing body.
- (3) The [governing body] hereby designates the [administering authority] to administer and enforce the provisions of this ordinance.

- (4) The requirements of this ordinance do not pre-empt more stringent erosion and sediment control requirements that may be imposed by any of the following:
- (a) Wisconsin Department of Natural Resources administrative rules, permits or approvals, including those authorized under ss. 281.16 and 283.33, Wis. Stats.
  - (b) Targeted non-agricultural performance standards promulgated in rules by the Wisconsin Department of Natural Resources under s. NR 151.004, Wis. Adm. Code.

## **S. 02 FINDINGS OF FACT.**

The [governing body] acknowledges that runoff from land disturbing construction activity carries a significant amount of sediment and other pollutants to the waters of the state in [name of municipality].

## **S. 03 PURPOSE.**

It is the purpose of this ordinance to maintain safe and healthful conditions; prevent and control water pollution; prevent and control soil erosion and sediment discharge; protect spawning grounds, fish and aquatic life; control building sites, placement of structures and land uses; preserve ground cover and scenic beauty; and promote sound economic growth by minimizing the amount of sediment and other pollutants carried by runoff or discharged from land disturbing construction activity to waters of the state in the [name of municipality].

## **S. 04 APPLICABILITY AND JURISDICTION.**

### **(1) APPLICABILITY.**

- (a) Except as provided under par. (b), this ordinance applies to any construction site as defined under S. 05 (6).
- (b) This ordinance does not apply to the following:
  - 1. Transportation facilities, except transportation facility construction projects that are part of a larger common plan of development such as local roads within a residential or industrial development.

**Note to Users:** *Transportation facility projects directed and supervised by Wisconsin Department of Transportation are not subject to this ordinance. Notwithstanding this ordinance, a municipality is required to comply with the construction site transportation facility performance standards in subch. IV of NR 151, Wis. Adm. Code, for its own transportation-related projects. If a municipality has regulatory authority over the activities of another local unit of government, it*

*may be appropriate to include the construction site transportation facility performance standards in ss. NR 151.225(3) and 151.23(4m), Wis. Adm. Code, in its ordinance if those types of projects occur.*

2. A construction project that is exempted by federal statutes or regulations from the requirement to have a national pollutant discharge elimination system permit issued under chapter 40, Code of Federal Regulations, part 122, for land disturbing construction activity.
  3. Nonpoint discharges from agricultural facilities and practices.
  4. Nonpoint discharges from silviculture activities.
  5. Routine maintenance for project sites that have less than 5 acres of land disturbance if performed to maintain the original line and grade, hydraulic capacity or original purpose of the facility.
- (c) Notwithstanding the applicability requirements in par. (a), this ordinance applies to construction sites of any size that, as determined by the [administering authority], are likely to result in runoff that exceeds the safe capacity of the existing drainage facilities or receiving body of water, that causes undue channel erosion, or that increases water pollution by scouring or transporting of particulate.

**Note to Users:** *The municipality may want to consider separate legal authority to address situations where persons other than the responsible party destroy or render ineffective Best Management Practices (BMPs) constructed to meet the performance standards of this ordinance.*

(2) JURISDICTION.

This ordinance applies to [land disturbing construction activity on lands within the boundaries and jurisdiction of the [name of municipality];

or

land disturbing construction activities on lands within the boundaries and jurisdiction of the [name of municipality], as well as the extraterritorial division of land subject to an ordinance enacted pursuant to s. 236.45 (2) and (3), Wis. Stats.;

or

land disturbing construction activities on lands within the boundaries and jurisdiction of the [name of municipality], as well as all lands located within the extraterritorial plat approval jurisdiction of [name of municipality], even if plat approval is not involved].

**Note to Users:** *These options differ in the amount of land area covered by this ordinance and may have ramifications for enforcement authority. For counties, the first option is the only option since counties do not have extraterritorial authority. Under s. 59.693 (10), Wis. Stats., if a county ordinance exists at the time of annexation, then the municipal ordinance must be at least as restrictive as the county ordinance.*

(3) EXCLUSIONS.

This ordinance is not applicable to activities conducted by a state agency, as defined under s. 227.01 (1), Wis. Stats.

**S. 05 DEFINITIONS.**

- (1) “Administering authority” means a governmental employee, or a regional planning commission empowered under s. [59.693, 60.627, 61.354, or 62.234], Wis. Stats., that is designated by the [governing body] to administer this ordinance.
- (2) “Agricultural facilities and practices” has the meaning in s. 281.16 (1), Wis. Stats.
- (3) “Best management practice” or “BMP” means structural or non-structural measures, practices, techniques or devices employed to avoid or minimize soil, sediment or pollutants carried in runoff to waters of the state.
- (4) “Business day” means a day the office of the [administering authority] is routinely and customarily open for business.
- (5) “Cease and desist order” means a court-issued order to halt land disturbing construction activity that is being conducted without the required permit or in violation of a permit issued by the [administering authority].
- (6) “Construction site” means an area upon which one or more land disturbing construction activities occur, including areas that are part of a larger common plan of development or sale where multiple separate and distinct land disturbing construction activities may be taking place at different times on different schedules but under one plan. A long-range planning document that describes separate construction projects, such as a 20-year transportation improvement plan, is not a common plan of development.
- (7) “Design Storm” means a hypothetical discrete rainstorm characterized by a specific duration, temporal distribution, rainfall intensity, return frequency and total depth of rainfall.
- (8)\* “Division of land” means the creation from one parcel of [number] or more parcels or building sites of [number] or fewer acres each in area where such creation occurs at one time or through the successive partition within a 5-year period.

**Note to Users:** *This definition is only needed depending on the type of jurisdiction selected under S. 04 (2) above.*

- (9) "Erosion" means the process by which the land's surface is worn away by the action of wind, water, ice or gravity.
- (10) "Erosion and sediment control plan" means a comprehensive plan developed to address pollution caused by erosion and sedimentation of soil particles or rock fragments during construction.
- (11)\* "Extraterritorial" means the unincorporated area within 3 miles of the corporate limits of a first, second, or third class city, or within 1.5 miles of a fourth class city or village.
- Note to Users:** *This definition is only needed depending on the type of jurisdiction selected under S. 04 (2) above.*
- (12) "Final stabilization" means that all land disturbing construction activities at the construction site have been completed and that a uniform perennial vegetative cover has been established with a density of at least 70 percent of the cover for the unpaved areas and areas not covered by permanent structures or that employ equivalent permanent stabilization measures.
- (13) "Governing body" means town board of supervisors, county board of supervisors, city council, village board of trustees or village council.
- (14) "Land disturbing construction activity" means any man-made alteration of the land surface resulting in a change in the topography or existing vegetative or non-vegetative soil cover, that may result in runoff and lead to an increase in soil erosion and movement of sediment into waters of the state. Land disturbing construction activity includes clearing and grubbing, demolition, excavating, pit trench dewatering, filling and grading activities.
- (15) "Landowner" means any person holding fee title, an easement or other interest in property, which allows the person to undertake cropping, livestock management, land disturbing construction activity or maintenance of storm water BMPs on the property.
- (16) "Maximum extent practicable" means the highest level of performance that is achievable but is not equivalent to a performance standard identified in this ordinance as determined in accordance with S. 055 of this ordinance.
- (17) "Performance standard" means a narrative or measurable number specifying the minimum acceptable outcome for a facility or practice.
- (18) "Permit" means a written authorization made by the [administering authority] to the applicant to conduct land disturbing construction activity or to discharge post-construction runoff to waters of the state.
- (19) "Pollutant" has the meaning given in s. 283.01 (13), Wis. Stats.
- (20) "Pollution" has the meaning given in s. 281.01 (10), Wis. Stats.
- (21) "Responsible party" means the landowner or any other entity performing services to meet the requirements of this ordinance through a contract or other agreement.
- (22) "Runoff" means storm water or precipitation including rain, snow or ice melt or similar water that moves on the land surface via sheet or channelized flow.

- (23) "Sediment" means settleable solid material that is transported by runoff, suspended within runoff or deposited by runoff away from its original location.
- (24) "Silviculture activity" means activities including tree nursery operations, tree harvesting operations, reforestation, tree thinning, prescribed burning, and pest and fire control. Clearing and grubbing of an area of a construction site is not a silviculture activity.
- (25) "Site" means the entire area included in the legal description of the land on which the land disturbing construction activity is proposed in the permit application.
- (26) "Stop work order" means an order issued by the [administering authority] which requires that all construction activity on the site be stopped.
- (27) "Technical standard" means a document that specifies design, predicted performance and operation and maintenance specifications for a material, device or method.
- (28) "Transportation facility" means a highway, a railroad, a public mass transit facility, a public-use airport, a public trail or any other public work for transportation purposes such as harbor improvements under s. 85.095 (1)(b), Wis. Stats. "Transportation facility" does not include building sites for the construction of public buildings and buildings that are places of employment that are regulated by the Department pursuant to s. 281.33, Wis. Stats.
- (29) "Waters of the state" includes those portions of Lake Michigan and Lake Superior within the boundaries of this state, and all lakes, bays, rivers, streams, springs, ponds, wells, impounding reservoirs, marshes, watercourses, drainage systems and other surface water or groundwater, natural or artificial, public or private, within this state or its jurisdiction.

#### **S. 055 APPLICABILITY OF MAXIMUM EXTENT PRACTICABLE.**

Maximum extent practicable applies when a person who is subject to a performance standard of this ordinance demonstrates to the [administering authority]'s satisfaction that a performance standard is not achievable and that a lower level of performance is appropriate. In making the assertion that a performance standard is not achievable and that a level of performance different from the performance standard is the maximum extent practicable, the responsible party shall take into account the best available technology, cost effectiveness, geographic features, and other competing interests such as protection of public safety and welfare, protection of endangered and threatened resources, and preservation of historic properties.

## **S. 06 TECHNICAL STANDARDS.**

All BMPs required for compliance with this ordinance shall meet design criteria, standards and specifications based on any of the following:

- (1) Design guidance and technical standards identified or developed by the Wisconsin Department of Natural Resources under subchapter V of chapter NR 151, Wis. Adm. Code.
- (2) Soil loss prediction tools (such as the Universal Soil Loss Equation (USLE)) when using an appropriate rainfall or runoff factor (also referred to as the R factor) or an appropriate design storm and precipitation distribution, and when considering the geographic location of the site and the period of disturbance.

***Note to Users:** The USLE and its successors RUSLE and RUSLE2, utilize an R factor which has been developed to estimate annual soil erosion, averaged over extended time periods. The R factor can be modified to estimate monthly and single-storm erosion.*

- (3) Technical standards and methods approved by the [administering authority].

***Note to Users:** The following section, S. 07, "Performance Standards for Construction Sites Under One Acre," is optional.*

## **S. 07 PERFORMANCE STANDARDS FOR CONSTRUCTION SITES UNDER ONE ACRE.**

- (1) RESPONSIBLE PARTY. The responsible party shall comply with this section.
- (2) EROSION AND SEDIMENT CONTROL PRACTICES. Erosion and sediment control practices at each site where land disturbing construction activity is to occur shall be used to prevent or reduce all of the following:
  - (a) The deposition of soil from being tracked onto streets by vehicles.
  - (b) The discharge of sediment from disturbed areas into on-site storm water inlets.
  - (c) The discharge of sediment from disturbed areas into adjacent waters of the state.
  - (d) The discharge of sediment from drainage ways that flow off the site.
  - (e) The discharge of sediment by dewatering activities.
  - (f) The discharge of sediment eroding from soil stockpiles existing for more than 7 days.
  - (g) The transport by runoff into waters of the state of chemicals, cement, and other building compounds and materials on the construction site during the construction period.

However, projects that require the placement of these materials in waters of the state, such as constructing bridge footings or BMP installations, are not prohibited by this subdivision.

- (3) LOCATION. The BMPs shall be located so that treatment occurs before runoff enters waters of the state.
- (4) IMPLEMENTATION. The BMPs used to comply with this section shall be implemented as follows:
  - (a) Erosion and sediment control practices shall be constructed or installed before land disturbing construction activities begin.
  - (b) Erosion and sediment control practices shall be maintained until final stabilization.
  - (c) Final stabilization activity shall commence when land disturbing activities cease and final grade has been reached on any portion of the site.
  - (d) Temporary stabilization activity shall commence when land disturbing activities have temporarily ceased and will not resume for a period exceeding 14 calendar days.
  - (e) BMPs that are no longer necessary for erosion and sediment control shall be removed by the responsible party.

**S. 08\* PERFORMANCE STANDARDS FOR CONSTRUCTION SITES OF ONE ACRE OR MORE.**

- (1) RESPONSIBLE PARTY. The responsible party shall comply with this section and implement the erosion and sediment control plan developed in accordance with S. 10\*.
- (2) EROSION AND SEDIMENT CONTROL PLAN. A written site-specific erosion and sediment control plan shall be developed in accordance with S. 10\* of this ordinance and implemented for each construction site.

**Note to Users:** *The written plan may be that specified within s. NR 216.46, Wis. Adm. Code, the erosion and sediment control portion of a construction plan or other plan.*

- (3) EROSION AND OTHER POLLUTANT CONTROL REQUIREMENTS. The erosion and sediment control plan required under sub. (2) shall include the following:
  - (a) EROSION AND SEDIMENT CONTROL PRACTICES. Erosion and sediment control practices at each site where land disturbing construction activity is to occur shall be used to prevent or reduce all of the following:
    - 1. The deposition of soil from being tracked onto streets by vehicles.
    - 2. The discharge of sediment from disturbed areas into on-site storm water inlets.



3. The discharge of sediment from disturbed areas into adjacent waters of the state.
4. The discharge of sediment from drainage ways that flow off the site.
5. The discharge of sediment by dewatering activities.
6. The discharge of sediment eroding from soil stockpiles existing for more than 7 days.
7. The discharge of sediment from erosive flows at outlets and in downstream channels.
8. The transport by runoff into waters of the state of chemicals, cement, and other building compounds and materials on the construction site during the construction period. However, projects that require the placement of these materials in waters of the state, such as constructing bridge footings or BMP installations, are not prohibited by this subdivision.
9. The transport by runoff into waters of the state of untreated wash water from vehicle and wheel washing.

(b) **SEDIMENT PERFORMANCE STANDARDS.** In addition to the erosion and sediment control practices under par. (a), the following erosion and sediment control practices shall be employed:

1. BMPs that, by design, discharge no more than 5 tons per acre per year, or to the maximum extent practicable, of the sediment load carried in runoff from initial grading to final stabilization.
2. No person shall be required to employ more BMPs than are needed to meet a performance standard in order to comply with maximum extent practicable. Erosion and sediment control BMPs may be combined to meet the requirements of this paragraph. Credit may be given toward meeting the sediment performance standard of this paragraph for limiting the duration or area, or both, of land disturbing construction activity, or for other appropriate mechanisms.
3. Notwithstanding subd. 1., if BMPs cannot be designed and implemented to meet the sediment performance standard, the erosion and sediment control plan shall include a written, site-specific explanation of why the sediment performance standard cannot be met and how the sediment load will be reduced to the maximum extent practicable.

(c) **PREVENTIVE MEASURES.** The erosion and sediment control plan shall incorporate all of the following:

1. Maintenance of existing vegetation, especially adjacent to surface waters whenever possible.
2. Minimization of soil compaction and preservation of topsoil.

3. Minimization of land disturbing construction activity on slopes of 20 percent or more.
  4. Development of spill prevention and response procedures.
- (d) LOCATION. The BMPs used to comply with this section shall be located so that treatment occurs before runoff enters waters of the state.

**Note to Users:** *While regional treatment facilities are appropriate for control of post-construction pollutants, they should not be used for construction site sediment removal.*

- (4) IMPLEMENTATION. The BMPs used to comply with this section shall be implemented as follows:
- (a) Erosion and sediment control practices shall be constructed or installed before land disturbing construction activities begin in accordance with the erosion and sediment control plan developed in S. 08\* (2).
  - (b) Erosion and sediment control practices shall be maintained until final stabilization.
  - (c) Final stabilization activity shall commence when land disturbing activities cease and final grade has been reached on any portion of the site.
  - (d) Temporary stabilization activity shall commence when land disturbing activities have temporarily ceased and will not resume for a period exceeding 14 calendar days.
  - (e) BMPs that are no longer necessary for erosion and sediment control shall be removed by the responsible party.

**S. 09\* PERMITTING REQUIREMENTS, PROCEDURES AND FEES.**

- (1) PERMIT REQUIRED. No responsible party may commence a land disturbing construction activity subject to this ordinance without receiving prior approval of an erosion and sediment control plan for the site and a permit from the [administering authority].
- (2) PERMIT APPLICATION AND FEES. The responsible party that will undertake a land disturbing construction activity subject to this ordinance shall submit an application for a permit and an erosion and sediment control plan that meets the requirements of S. 10\*, and shall pay an application fee to the [administering authority] in the amount specified in S. 11\*. By submitting an application, the applicant is authorizing the [administering authority] to enter the site to obtain information required for the review of the erosion and sediment control plan.

- (3) PERMIT APPLICATION REVIEW AND APPROVAL. The [administering authority] shall review any permit application that is submitted with an erosion and sediment control plan, and the required fee. The following approval procedure shall be used:
- (a) Within [number] business days of the receipt of a complete permit application, as required by sub. (2), the [administering authority] shall inform the applicant whether the application and erosion and sediment control plan are approved or disapproved based on the requirements of this ordinance.
  - (b) If the permit application and erosion and sediment control plan are approved, the [administering authority] shall issue the permit.
  - (c) If the permit application or erosion and sediment control plan is disapproved, the [administering authority] shall state in writing the reasons for disapproval.
  - (d) The [administering authority] may request additional information from the applicant. If additional information is submitted, the [administering authority] shall have [number] business days from the date the additional information is received to inform the applicant that the erosion and sediment control plan is either approved or disapproved.
  - (e) Failure by the [administering authority] to inform the permit applicant of a decision within [number] business days of a required submittal shall be deemed to mean approval of the submittal and the applicant may proceed as if a permit had been issued.
- (4) SURETY BOND. As a condition of approval and issuance of the permit, the [administering authority] may require the applicant to deposit a surety bond or irrevocable letter of credit to guarantee a good faith execution of the approved erosion and sediment control plan and any permit conditions.
- (5) PERMIT REQUIREMENTS. All permits shall require the responsible party to:
- (a) Notify the [administering authority] within 48 hours of commencing any land disturbing construction activity.
  - (b) Notify the [administering authority] of completion of any BMPs within 14 days after their installation.
  - (c) Obtain permission in writing from the [administering authority] prior to any modification pursuant to S. 10\* (3) of the erosion and sediment control plan.
  - (d) Install all BMPs as identified in the approved erosion and sediment control plan.
  - (e) Maintain all road drainage systems, storm water drainage systems, BMPs and other facilities identified in the erosion and sediment control plan.
  - (f) Repair any siltation or erosion damage to adjoining surfaces and drainage ways resulting from land disturbing construction activities and document repairs in a site inspection log.

- (g) Inspect the BMPs within 24 hours after each rain of 0.5 inches or more which results in runoff during active construction periods, and at least once each week. Make needed repairs and install additional BMPs as necessary, and document these activities in an inspection log that also includes the date of inspection, the name of the person conducting the inspection, and a description of the present phase of the construction at the site.
  - (h) Allow the [administering authority] to enter the site for the purpose of inspecting compliance with the erosion and sediment control plan or for performing any work necessary to bring the site into compliance with the erosion and sediment control plan. Keep a copy of the erosion and sediment control plan at the construction site.
- (6) PERMIT CONDITIONS. Permits issued under this section may include conditions established by [administering authority] in addition to the requirements set forth in sub. (5), where needed to assure compliance with the performance standards in S. 07\* or S. 08\*.
- (7) PERMIT DURATION. Permits issued under this section shall be valid for a period of 180 days, or the length of the building permit or other construction authorizations, whichever is longer, from the date of issuance. The [administering authority] may grant one or more extensions not to exceed 180 days cumulatively. The [administering authority] may require additional BMPs as a condition of an extension if they are necessary to meet the requirements of this ordinance.
- (8) MAINTENANCE. The responsible party throughout the duration of the construction activities shall maintain all BMPs necessary to meet the requirements of this ordinance until the site has undergone final stabilization.

**S. 10\* EROSION AND SEDIMENT CONTROL PLAN, STATEMENT AND AMENDMENTS.**

- (1) EROSION AND SEDIMENT CONTROL PLAN STATEMENT. For each construction site identified under S. 04 (1)(c), an erosion and sediment control plan statement shall be prepared. This statement shall be submitted to the [administering authority]. The erosion and sediment control plan statement shall briefly describe the site, the development schedule, and the BMPs that will be used to meet the requirements of the ordinance. A site map shall also accompany the erosion and sediment control plan statement.
- (2) EROSION AND SEDIMENT CONTROL PLAN REQUIREMENTS.
- (a) An erosion and sediment control plan shall be prepared and submitted to the [administering authority].

- (b) The erosion and sediment control plan shall be designed to meet the performance standards in S. 07\*, S. 08\* and other requirements of this ordinance.
- (c) The erosion and sediment control plan shall address pollution caused by soil erosion and sedimentation during construction and up to final stabilization of the site. The erosion and sediment control plan shall include, at a minimum, the following items:
1. Name(s) and address(es) of the owner or developer of the site, and of any consulting firm retained by the applicant, together with the name of the applicant's principal contact at such firm. The application shall also include start and end dates for construction.
  2. Description of the construction site and the nature of the land disturbing construction activity, including representation of the limits of land disturbance on a United States Geological Service 7.5 minute series topographic map.
  3. Description of the intended sequence of major land disturbing construction activities for major portions of the construction site, including stripping and clearing; rough grading; construction of utilities, infrastructure, and buildings; and final grading and landscaping. Sequencing shall identify the expected date on which clearing will begin, the estimated duration of exposure of cleared areas, areas of clearing, installation of temporary erosion and sediment control measures, and establishment of permanent vegetation.
  4. Estimates of the total area of the construction site and the total area of the construction site that is expected to be disturbed by land disturbing construction activities.
  5. Calculations to show the compliance with the performance standard in S. 08 (3)(b)1.
  6. Existing data describing the surface soil as well as subsoils.
  7. Depth to groundwater, as indicated by Natural Resources Conservation Service soil information where available.
  8. Name of the immediate named receiving water from the United States Geological Service 7.5 minute series topographic maps.
- (d) The erosion and sediment control plan shall include a site map. The site map shall include the following items and shall be at a scale not greater than 100 feet per inch and at a contour interval not to exceed five feet.
1. Existing topography, vegetative cover, natural and engineered drainage systems, roads and surface waters. Lakes, streams, wetlands, channels, ditches and other watercourses on and immediately adjacent to the site shall be shown. Any identified 100-year flood plains, flood fringes and floodways shall also be shown.
  2. Boundaries of the construction site.

3. Drainage patterns and approximate slopes anticipated after major grading activities.
  4. Areas of soil disturbance.
  5. Location of major structural and non-structural controls identified in the erosion and sediment control plan.
  6. Location of areas where stabilization BMPs will be employed.
  7. Areas which will be vegetated following land disturbing construction activities.
  8. Area(s) and location(s) of wetland on the construction site, and locations where storm water is discharged to a surface water or wetland within one-quarter mile downstream of the construction site.
  9. Areas(s) used for infiltration of post-construction storm water runoff.
  10. An alphanumeric or equivalent grid overlying the entire construction site map.
- (e) Each erosion and sediment control plan shall include a description of appropriate control BMPs that will be installed and maintained at the construction site to prevent pollutants from reaching waters of the state. The erosion and sediment control plan shall clearly describe the appropriate erosion and sediment control BMPs for each major land disturbing construction activity and the timing during the period of land disturbing construction activity that the erosion and sediment control BMPs will be implemented. The description of erosion and sediment control BMPs shall include, when appropriate, the following minimum requirements:
1. Description of interim and permanent stabilization practices, including a BMP implementation schedule. The erosion and sediment control plan shall ensure that existing vegetation is preserved where attainable and that disturbed portions of the site are stabilized.
  2. Description of structural practices to divert flow away from exposed soils, store flows or otherwise limit runoff and the discharge of pollutants from the site. Unless otherwise specifically approved in writing by the [administering authority], structural measures shall be installed on upland soils.
  3. Management of overland flow at all areas of the construction site, unless otherwise controlled by outfall controls.
  4. Trapping of sediment in channelized flow.
  5. Staging land disturbing construction activities to limit exposed soil areas subject to erosion.
  6. Protection of downslope drainage inlets where they occur.
  7. Minimization of tracking at all vehicle and equipment entry and exit locations of the construction site.
  8. Clean up of off-site sediment deposits.

9. Proper disposal of building and waste material.
  10. Stabilization of drainage ways.
  11. Installation of permanent stabilization practices as soon as possible after final grading.
  12. Minimization of dust to the maximum extent practicable.
- (f) The erosion and sediment control plan shall require that velocity dissipation devices be placed at discharge locations and along the length of any outfall channel as necessary to provide a non-erosive flow from the structure to a water course so that the natural physical and biological characteristics and functions are maintained and protected.

**Note to Users:** *The erosion and sediment plan requirements of this subsection will meet the erosion control plan requirements of s. NR 216.46, Wis. Adm. Code, when prepared in accordance with good engineering practices and the design criteria, standards and specifications published by the Wisconsin Department of Natural Resources under subchapter V of chapter NR 151, Wis. Adm. Code.*

- (3) **EROSION AND SEDIMENT CONTROL PLAN AMENDMENTS.** The applicant shall amend the erosion and sediment control plan if any of the following occur:
- (a) There is a change in design, construction, operation or maintenance at the site which has the reasonable potential for the discharge of pollutants to waters of the state and which has not otherwise been addressed in the erosion and sediment control plan.
  - (b) The actions required by the erosion and sediment control plan fail to reduce the impacts of pollutants carried by construction site runoff.
  - (c) The [administering authority] notifies the applicant of changes needed in the erosion and sediment control plan.

#### **S. 11\* FEE SCHEDULE.**

The fees referred to in other sections of this ordinance shall be established by the [administering authority] and may from time to time be modified by resolution. A schedule of the fees established by the [administering authority] shall be available for review in [location].

#### **S. 12\* INSPECTION.**

If land disturbing construction activities are occurring without a permit required by this ordinance, the [administering authority] may enter the land pursuant to the provisions of ss. 66.0119 (1), (2), and (3), Wis. Stats.

**S. 13\* ENFORCEMENT.**

- (1) The [administering authority] may post a stop work order if any of the following occurs:
  - (a) Land disturbing construction activity regulated under this ordinance is occurring without a permit.
  - (b) The erosion and sediment control plan is not being implemented in good faith.
  - (c) The conditions of the permit are not being met.

***Note to Users:*** *The [administering authority] should inspect any construction site that holds a permit under this chapter at least once a month between March 1 and October 31, and at least 2 times between November 1 and February 28 to ensure compliance with the approved erosion and sediment control plan.*

- (2) If the responsible party does not cease activity as required in a stop work order posted under this section or fails to comply with the erosion and sediment control plan or permit conditions, the [administering authority] may revoke the permit.
- (3) If the responsible party, where no permit has been issued or the permit has been revoked, does not cease the activity after being notified by the [administering authority], or if a responsible party violates a stop work order posted under sub. (1), the [administering authority] may request the [district attorney, city attorney, town attorney, village attorney or county corporation counsel] to obtain a cease and desist order in any court with jurisdiction.
- (4) The [administering authority, board of appeals, or board of adjustment] may retract the stop work order issued under sub. (1) or the permit revocation under sub. (2).
- (5) After posting a stop work order under sub. (1), the [administering authority] may issue a notice of intent to the responsible party of its intent to perform work necessary to comply with this ordinance. The [administering authority] may go on the land and commence the work after issuing the notice of intent. The costs of the work performed under this subsection by the [administering authority], plus interest at the rate authorized by [administrative authority] shall be billed to the responsible party. In the event a responsible party fails to pay the amount due, the clerk shall enter the amount due on the tax rolls and collect as a special assessment against the property pursuant to subch. VII of ch. 66, Wis. Stats.



- (6) Any person violating any of the provisions of this ordinance shall be subject to a forfeiture of not less than [amount] nor more than [amount] and the costs of prosecution for each violation. Each day a violation exists shall constitute a separate offense.
- (7) Compliance with the provisions of this ordinance may also be enforced by injunction in any court with jurisdiction. It shall not be necessary to prosecute for forfeiture or a cease and desist order before resorting to injunctive proceedings.

**Note to Users:** *Injunctive orders are authorized pursuant to s. 59.69 (11), 61.35, or 62.23 (8), Wis. Stats., for counties, villages and towns with village powers, and cities respectively.*

#### **S. 14\* APPEALS.**

- (1) BOARD OF [APPEALS or ADJUSTMENT]. The board of [appeals or adjustment] created pursuant to section [number] of the [county's, town's, city's or village's] ordinance pursuant to s. [59.694, 60.65, 61.354 (4)(b) or 62.23 (7)(e)], Wis. Stats.:
  - (a) Shall hear and decide appeals where it is alleged that there is error in any order, decision or determination made by the [administering authority] in administering this ordinance except for cease and desist orders obtained under S. 13\* (3).
  - (b) May authorize, upon appeal, variances from the provisions of this ordinance which are not contrary to the public interest and where owing to special conditions a literal enforcement of the provisions of the ordinance will result in unnecessary hardship; and
  - (c) Shall use the rules, procedures, duties and powers authorized by statute in hearing and deciding appeals and authorizing variances.
- (2) WHO MAY APPEAL. Appeals to the board of [appeals or adjustment] may be taken by any aggrieved person or by any office, department, board, or bureau of the [name of municipality] affected by any decision of the [administering authority].

#### **S. 15\* SEVERABILITY.**

If a court of competent jurisdiction judges any section, clause, provision or portion of this ordinance unconstitutional or invalid, the remainder of the ordinance shall remain in force and not be affected by such judgment.

**S. 16\* EFFECTIVE DATE.**

This ordinance shall be in force and effect from and after its adoption and publication. The above and foregoing ordinance was duly adopted by the [governing body] of the [name of municipality] on the [number] day of [month], [year].

Approved: \_\_\_\_\_

Attested: \_\_\_\_\_

Published on [day, month, and year].

# MODEL POST-CONSTRUCTION STORM WATER MANAGEMENT ORDINANCE

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*Note to Users: An asterisk ( \* ) denotes subsequent numbering and references to numbered sections or subsections that would be affected by exclusion of the optional text.*

## MODEL POST-CONSTRUCTION STORM WATER MANAGEMENT ORDINANCE

### AN ORDINANCE TO CREATE CHAPTER [NUMBER] OF THE [CODE OR ORDINANCE] OF THE [NAME OF MUNICIPALITY] RELATING TO THE CONTROL OF POST-CONSTRUCTION RUNOFF

#### FOREWORD.

The intent of this ordinance is to reduce the discharge of pollutants carried in storm water runoff to waters of the state. Use of this ordinance by municipalities will foster the consistent, statewide application of post-construction performance standards for new development and redevelopment contained in subchapters III and IV of chapter NR 151, Wis. Adm. Code.

The [governing body] of the [name of municipality] does hereby ordain that Chapter [number] of the [code or ordinance] of the [name of municipality] is created to read as follows:

#### [CHAPTER]

#### POST-CONSTRUCTION STORM WATER MANAGEMENT

##### S. 01 AUTHORITY.

- (1) This ordinance is adopted by the [governing body] under the authority granted by s. [59.693, for counties; 60.627, for towns; 61.354, for villages; or 62.234, for cities], Wis. Stats. This ordinance supersedes all provisions of an ordinance previously enacted under s. [59.69, 60.62, 61.35, or 62.23], Wis. Stats., that relate to storm water management regulations. Except as otherwise specified in s. [59.693, 60.627, 61.354, or 62.234], Wis. Stats., s. [59.69, 60.62, 61.35, or 62.23], Wis. Stats., applies to this ordinance and to any amendments to this ordinance.

***Note to Users:** There may be instances where this ordinance does not supersede other ordinances relating to construction erosion control previously adopted by the governing body.*

- (2) The provisions of this ordinance are deemed not to limit any other lawful regulatory powers of the same governing body.
- (3) The [governing body] hereby designates the [administering authority] to administer and enforce the provisions of this ordinance.

- (4) The requirements of this ordinance do not pre-empt more stringent storm water management requirements that may be imposed by any of the following:
  - (a) Wisconsin Department of Natural Resources administrative rules, permits or approvals including those authorized under ss. 281.16 and 283.33, Wis. Stats.
  - (b) Targeted non-agricultural performance standards promulgated in rules by the Wisconsin Department of Natural Resources under s. NR 151.004, Wis. Adm. Code.

## **S. 02 FINDINGS OF FACT.**

The [governing body] acknowledges that uncontrolled, post-construction runoff has a significant impact upon water resources and the health, safety and general welfare of the community and diminishes the public enjoyment and use of natural resources. Specifically, uncontrolled post-construction runoff can:

- (1) Degrade physical stream habitat by increasing stream bank erosion, increasing streambed scour, diminishing groundwater recharge, diminishing stream base flows and increasing stream temperature.
- (2) Diminish the capacity of lakes and streams to support fish, aquatic life, recreational and water supply uses by increasing pollutant loading of sediment, suspended solids, nutrients, heavy metals, bacteria, pathogens and other urban pollutants.
- (3) Alter wetland communities by changing wetland hydrology and by increasing pollutant loads.
- (4) Reduce the quality of groundwater by increasing pollutant loading.
- (5) Threaten public health, safety, property and general welfare by overtaxing storm sewers, drainage ways, and other minor drainage facilities.

## **S. 03 PURPOSE AND INTENT.**

- (1) **PURPOSE.** The general purpose of this ordinance is to establish long-term, post-construction runoff management requirements that will diminish the threats to public health, safety, welfare and the aquatic environment. Specific purposes are to:
  - (a) Further the maintenance of safe and healthful conditions.
  - (b) Prevent and control the adverse effects of storm water; prevent and control soil erosion; prevent and control water pollution; protect spawning grounds, fish and aquatic life; control building sites, placement of structures and land uses; preserve ground cover and scenic beauty; and promote sound economic growth.
  - (c) Control exceedance of the safe capacity of existing drainage facilities and receiving water bodies; prevent undue channel erosion; and control increases in the scouring and transportation of particulate matter.

(d) Minimize the amount of pollutants discharged from the separate storm sewer to protect the waters of the state.

(2) INTENT. It is the intent of the [governing body] that this ordinance regulates post-construction storm water discharges to waters of the state. This ordinance may be applied on a site-by-site basis. The [governing body] recognizes, however, that the preferred method of achieving the storm water performance standards set forth in this ordinance is through the preparation and implementation of comprehensive, systems-level storm water management plans that cover hydrologic units, such as watersheds, on a municipal and regional scale. Such plans may prescribe regional storm water devices, practices or systems, any of which may be designed to treat runoff from more than one site prior to discharge to waters of the state. Where such plans are in conformance with the performance standards developed under s. 281.16, Wis. Stats., for regional storm water management measures and have been approved by the [governing body], it is the intent of this ordinance that the approved storm water management plan be used to identify post-construction management measures acceptable for the community.

#### **S. 04 APPLICABILITY AND JURISDICTION.**

(1) APPLICABILITY.

(a) Except as provided under par. (b), this ordinance applies to a post-construction site whereupon one acre or more of land disturbing construction activity occurs during construction.

***Note to Users:** The one acre land disturbance threshold is consistent with state and federal laws regarding applicability of construction site erosion control permits. The municipality may apply its ordinance to sites of less than one acre.*

(b) A site that meets any of the criteria in this paragraph is exempt from the requirements of this ordinance:

1. A post-construction site with less than ten percent connected imperviousness, based on the area of land disturbance, provided the cumulative area of all impervious surfaces is less than one acre. However, the exemption of this paragraph does not include exemption from the protective area standard of this ordinance.
2. Agricultural facilities and practices.
3. Underground utility construction, but not including the construction of any above ground structures associated with utility construction.

(c) Notwithstanding the applicability requirements in par. (a), this ordinance applies to post-construction sites of any size that, as determined by the [administering authority], are likely to result in runoff that exceeds the safe capacity of the existing drainage facilities or receiving body of water, causes undue channel erosion, or increases water pollution by scouring or the transportation of particulate matter.

(2) JURISDICTION.

This ordinance applies to [post construction sites within the boundaries and jurisdiction of the [name of the municipality]];

or

[post construction sites within the boundaries and jurisdiction of the [name of municipality], as well as the extraterritorial division of land subject to an ordinance enacted pursuant to s. 236.45 (2) and (3), Wis. Stats.;

or

[post construction sites within the boundaries and jurisdiction of the [name of the municipality], as well as all lands located within the extraterritorial plat approval jurisdiction of the [name of municipality], even if plat approval is not involved].

**Note to Users:** *These options differ in the amount of land area covered by this ordinance and may have ramifications for enforcement authority. For counties, the first option will be the only option since counties do not have extraterritorial authority. Under s. 59.693 (10), Wis. Stats., if a county storm water management ordinance exists at the time of annexation, then the municipal ordinance must be at least as restrictive as the county ordinance.*

(3) EXCLUSIONS.

This ordinance is not applicable to activities conducted by a state agency, as defined under s. 227.01 (1), Wis. Stats.

**S. 05 DEFINITIONS.**

(1) "Adequate sod, or self-sustaining vegetative cover" means maintenance of sufficient vegetation types and densities such that the physical integrity of the streambank or lakeshore is preserved. Self-sustaining vegetative cover includes grasses, forbs, sedges and duff layers of fallen leaves and woody debris.

(2) "Administering authority" means a governmental employee, or a regional planning commission empowered under s. [59.693; 60.627; 61.354; or 62.234], Wis. Stats., that is designated by the [governing body] to administer this ordinance.



- (3) "Agricultural facilities and practices" has the meaning given in s. 281.16 (1), Wis. Stats.
- (4) "Atlas 14" means the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Precipitation-Frequency Atlas of the United States, Volume 8 (Midwestern States), published in 2013.
- (5) "Average annual rainfall" means a typical calendar year of precipitation as determined by the Wisconsin Department of Natural Resources for users of models such as WinSLAMM, P8 or equivalent methodology. The average annual rainfall is chosen from a department publication for the location closest to the municipality.
- (6) "Best management practice" or "BMP" means structural or non-structural measures, practices, techniques or devices employed to avoid or minimize sediment or pollutants carried in runoff to waters of the state.
- (7) "Business day" means a day the office of the [administering authority] is routinely and customarily open for business.
- (8) "Cease and desist order" means a court-issued order to halt land disturbing construction activity that is being conducted without the required permit or in violation of a permit issued by the [administering authority].
- (9) "Combined sewer system" means a system for conveying both sanitary sewage and storm water runoff.
- (10) "Connected imperviousness" means an impervious surface connected to the waters of the state via a separate storm sewer, an impervious flow path, or a minimally pervious flow path.
- (11) "Design storm" means a hypothetical discrete rainstorm characterized by a specific duration, temporal distribution, rainfall intensity, return frequency and total depth of rainfall.
- (12) "Development" means residential, commercial, industrial or institutional land uses and associated roads.
- (13) "Direct conduits to groundwater" means wells, sinkholes, swallets, fractured bedrock at the surface, mine shafts, non-metallic mines, tile inlets discharging to groundwater, quarries, or depressional groundwater recharge areas over shallow fractured bedrock.
- (14)\* "Division of land" means the creation from one parcel of [number] or more parcels or building sites of [number] or fewer acres each in area where such creation occurs at one time or through the successive partition within a 5-year period.  
**Note to Users:** *This definition is only needed depending on the type of jurisdiction selected under S. 04 (2) above.*
- (15) "Effective infiltration area" means the area of the infiltration system that is used to infiltrate runoff and does not include the area used for site access, berms or pretreatment.
- (16) "Erosion" means the process by which the land's surface is worn away by the action of wind, water, ice or gravity.
- (17) "Exceptional resource waters" means waters listed in s. NR 102.11, Wis. Adm. Code.

- (18)\* "Extraterritorial" means the unincorporated area within three miles of the corporate limits of a first, second, or third class city, or within one and a half miles of a fourth class city or village.
- Note to Users:** *This definition is only needed depending on the type of jurisdiction selected under S. 04 (2) above.*
- (19) "Filtering layer" means soil that has at least a 3-foot deep layer with at least 20 percent fines; or at least a 5-foot deep layer with at least 10 percent fines; or an engineered soil with an equivalent level of protection as determined by the regulatory authority for the site.
- (20) "Final stabilization" means that all land disturbing construction activities at the construction site have been completed and that a uniform perennial vegetative cover has been established with a density of at least 70 percent of the cover for the unpaved areas and areas not covered by permanent structures or that employ equivalent permanent stabilization measures.
- (21) "Financial guarantee" means a performance bond, maintenance bond, surety bond, irrevocable letter of credit, or similar guarantees submitted to the [administering authority] by the responsible party to assure that requirements of the ordinance are carried out in compliance with the storm water management plan.
- (22) "Governing body" means town board of supervisors, county board of supervisors, city council, village board of trustees or village council.
- (23) "Impervious surface" means an area that releases as runoff all or a large portion of the precipitation that falls on it, except for frozen soil. Rooftops, sidewalks, driveways, gravel or paved parking lots and streets are examples of areas that typically are impervious.
- (24) "In-fill" means an undeveloped area of land located within an existing urban sewer service area, surrounded by development or development and natural or man-made features where development cannot occur.
- (25) "Infiltration" means the entry of precipitation or runoff into or through the soil.
- (26) "Infiltration system" means a device or practice such as a basin, trench, rain garden or swale designed specifically to encourage infiltration, but does not include natural infiltration in pervious surfaces such as lawns, redirecting of rooftop downspouts onto lawns or minimal infiltration from practices, such as swales or road side channels designed for conveyance and pollutant removal only.
- (27) "Land disturbing construction activity" means any man-made alteration of the land surface resulting in a change in the topography or existing vegetative or non-vegetative soil cover, that may result in runoff and lead to an increase in soil erosion and movement of sediment into waters of the state. Land disturbing construction activity includes clearing and grubbing, demolition, excavating, pit trench dewatering, filling and grading activities.
- (28) "Landowner" means any person holding fee title, an easement or other interest in property, which allows the person to undertake cropping, livestock management, land disturbing construction activity or maintenance of storm water BMPs on the property.

- (29) "Maintenance agreement" means a legal document that provides for long-term maintenance of storm water management practices.
- (30) "Maximum extent practicable" means the highest level of performance that is achievable but is not equivalent to a performance standard identified in this ordinance as determined in accordance with S. 055 of this ordinance.
- (31) "New development" means development resulting from the conversion of previously undeveloped land or agricultural land uses.
- (32) "NRCS MSE3 or MSE4 distribution" means a specific precipitation distribution developed by the United States Department of Agriculture, Natural Resources Conservation Service, using precipitation data from Atlas 14.
- (33) "Off-site" means located outside the property boundary described in the permit application.
- (34) "On-site" means located within the property boundary described in the permit application.
- (35) "Ordinary high-water mark" has the meaning given in s. NR 115.03 (6), Wis. Adm. Code.
- (36) "Outstanding resource waters" means waters listed in s. NR 102.10, Wis. Adm. Code.
- (37) "Percent fines" means the percentage of a given sample of soil, which passes through a # 200 sieve.
- (38) "Performance standard" means a narrative or measurable number specifying the minimum acceptable outcome for a facility or practice.
- (39) "Permit" means a written authorization made by the [administering authority] to the applicant to conduct land disturbing construction activity or to discharge post-construction runoff to waters of the state.
- (40) "Permit administration fee" means a sum of money paid to the [administering authority] by the permit applicant for the purpose of recouping the expenses incurred by the authority in administering the permit.
- (41) "Pervious surface" means an area that releases as runoff a small portion of the precipitation that falls on it. Lawns, gardens, parks, forests or other similar vegetated areas are examples of surfaces that typically are pervious.
- (42) "Pollutant" has the meaning given in s. 283.01 (13), Wis. Stats.
- (43) "Pollution" has the meaning given in s. 281.01 (10), Wis. Stats.
- (44) "Post-construction site" means a construction site following the completion of land disturbing construction activity and final site stabilization.
- (45) "Pre-development condition" means the extent and distribution of land cover types present before the initiation of land disturbing construction activity, assuming that all land uses prior to development activity are managed in an environmentally sound manner.
- (46) "Preventive action limit" has the meaning given in s. NR 140.05 (17), Wis. Adm. Code.
- (47) "Protective area" means an area of land that commences at the top of the channel of lakes, streams and rivers, or at the delineated boundary of wetlands, and that is the greatest of the

following widths, as measured horizontally from the top of the channel or delineated wetland boundary to the closest impervious surface.

- (48) "Redevelopment" means areas where development is replacing older development.
- (49) "Responsible party" means the landowner or any other entity performing services to meet the requirements of this ordinance through a contract or other agreement. "Runoff" means storm water or precipitation including rain, snow or ice melt or similar water that moves on the land surface via sheet or channelized flow.
- (50) "Separate storm sewer" means a conveyance or system of conveyances including roads with drainage systems, streets, catch basins, curbs, gutters, ditches, constructed channels or storm drains, which meets all of the following criteria:
  - (a) Is designed or used for collecting water or conveying runoff.
  - (b) Is not part of a combined sewer system.
  - (c) Is not part of a publicly owned wastewater treatment works that provides secondary or more stringent treatment.
  - (d) Discharges directly or indirectly to waters of the state.
- (51) "Silviculture activity" means activities including tree nursery operations, tree harvesting operations, reforestation, tree thinning, prescribed burning, and pest and fire control. Clearing and grubbing of an area of a construction site is not a silviculture activity.
- (52) "Site" means the entire area included in the legal description of the land on which the land disturbing construction activity occurred.
- (53) "Stop work order" means an order issued by the [administering authority] which requires that all construction activity on the site be stopped.
- (54) "Storm water management plan" means a comprehensive plan designed to reduce the discharge of pollutants from storm water, after the site has undergone final stabilization, following completion of the construction activity.
- (55) "Storm water management system plan" is a comprehensive plan designed to reduce the discharge of runoff and pollutants from hydrologic units on a regional or municipal scale.
- (56) "Technical standard" means a document that specifies design, predicted performance and operation and maintenance specifications for a material, device or method.
- (57) "Top of the channel" means an edge, or point on the landscape landward from the ordinary high-water mark of a surface water of the state, where the slope of the land begins to be less than 12 percent continually for at least 50 feet. If the slope of the land is 12 percent or less continually for the initial 50 feet landward from the ordinary high-water mark, the top of the channel is the ordinary high-water mark.
- (58) "Total maximum daily load" or "TMDL" means the amount of pollutants specified as a function of one or more water quality parameters, that can be discharged per day into a water quality limited segment and still ensure attainment of the applicable water quality standard.

- (59) "TP-40" means Technical Paper No. 40, Rainfall Frequency Atlas of the United States, published in 1961.
- (60) "TR-55" means the United States department of agriculture, natural resources conservation service (previously soil conservation service), Urban Hydrology for Small Watersheds, Second Edition, Technical Release 55, June 1986, which is incorporated by reference for this chapter.
- (61) "Transportation facility" means a highway, a railroad, a public mass transit facility, a public-use airport, a public trail or any other public work for transportation purposes such as harbor improvements under s. 85.095 (1)(b), Wis. Stats. "Transportation facility" does not include building sites for the construction of public buildings and buildings that are places of employment that are regulated by the Department pursuant to s. 281.33, Wis. Stats.
- (62) "TSS" means total suspended solids.
- (63) "Type II distribution" means a rainfall type curve as established in the "United States Department of Agriculture, Soil Conservation Service, Technical Paper 149, published in 1973".
- (64) "Waters of the state" includes those portions of Lake Michigan and Lake Superior within the boundaries of this state, and all lakes, bays, rivers, streams, springs, ponds, wells, impounding reservoirs, marshes, watercourses, drainage systems and other surface water or groundwater, natural or artificial, public or private, within this state or its jurisdiction.

#### **S. 055 APPLICABILITY OF MAXIMUM EXTENT PRACTICABLE.**

Maximum extent practicable applies when a person who is subject to a performance standard of this ordinance demonstrates to the [administering authority]'s satisfaction that a performance standard is not achievable and that a lower level of performance is appropriate. In making the assertion that a performance standard is not achievable and that a level of performance different from the performance standard is the maximum extent practicable, the responsible party shall take into account the best available technology, cost effectiveness, geographic features, and other competing interests such as protection of public safety and welfare, protection of endangered and threatened resources, and preservation of historic properties.

#### **S. 06 TECHNICAL STANDARDS.**

The following methods shall be used in designing the water quality, peak discharge, and infiltration components of storm water practices needed to meet the water quality standards of this ordinance:

- (1) Consistent with the technical standards identified, developed or disseminated by the Wisconsin Department of Natural Resources under subchapter V of chapter NR 151, Wis. Adm. Code.

- (2) Where technical standards have not been identified or developed by the Wisconsin Department of Natural Resources, other technical standards may be used provided that the methods have been approved by the [administering authority].

**Note to Users:** *Pollutant loading models such as DETPOND, WinSLAMM, P8, or equivalent methodology may be used to evaluate the efficiency of the design in reducing total suspended solids. Use the most recent version of the model and the rainfall files and other parameter files identified for Wisconsin users unless directed otherwise by the regulatory authority.*

## **S. 07 PERFORMANCE STANDARDS.**

- (1) RESPONSIBLE PARTY. *RESPONSIBLE PARTY. The responsible party shall comply with this section.*
- (2) STORM WATER MANAGEMENT PLAN. A written storm water management plan in accordance with S. 09 shall be developed and implemented for each post-construction site.
- (3) MAINTENANCE OF EFFORT. For redevelopment sites where the redevelopment will be replacing older development that was subject to post-construction performance standards of NR 151 in effect on or after October 1, 2004, the responsible party shall meet the total suspended solids reduction, peak flow control, infiltration, and protective areas standards applicable to the older development or meet the redevelopment standards of this ordinance, whichever is more stringent.
- (4) REQUIREMENTS. The storm water management plan required under sub. (2) shall include the following:
  - (a) TOTAL SUSPENDED SOLIDS. BMPs shall be designed, installed and maintained to control total suspended solids carried in runoff from the post-construction site as follows:

**Note to Users:** *Under s. 281.33 (6)(a)2., Wis. Stats., the municipality may enact and enforce provisions of an ordinance that are stricter than the TSS performance standards in ch. NR 151, Wis. Adm. Code, if the stricter provisions are necessary to comply with federally-approved total maximum daily load requirements.*

1. BMPs shall be designed in accordance with Table 1. or to the maximum extent practicable as provided in subd. 2. The design shall be based on an average annual rainfall, as compared to no runoff management controls.

Table 1. TSS Reduction Standards	
Development Type	TSS Reduction
New Development	80 percent
In-fill development	80 percent
Redevelopment	40 percent of load from parking areas and roads

2. Maximum Extent Practicable. If the design cannot meet a total suspended solids reduction performance standard of Table 1., the storm water management plan shall include a written, site-specific explanation of why the total suspended solids reduction performance standard cannot be met and why the total suspended solids load will be reduced only to the maximum extent practicable.

**Note to Users:** Pollutant loading models such as DETPOND, WinSLAMM, P8 or equivalent methodology may be used to evaluate the efficiency of the design in reducing total suspended solids. Use the most recent version of the model and the rainfall files and other parameter files identified for Wisconsin users unless directed otherwise by the regulatory authority.

3. Off-Site Drainage. When designing BMPs, runoff draining to the BMP from off-site shall be taken into account in determining the treatment efficiency of the practice. Any impact on the efficiency shall be compensated for by increasing the size of the BMP accordingly.

(b) PEAK DISCHARGE.

**Note to Users:** Under s. 281.33 (6)(a)1., Wis. Stats., the municipality may enact and enforce provisions of an ordinance that are stricter than the peak discharge performance standards in ch. NR 151, Wis. Adm. Code, if the stricter provisions are necessary to control storm water quantity or control flooding.

1. By design, BMPs shall be employed to maintain or reduce the 1-year, 24-hour; and the 2-year, 24-hour post-construction peak runoff discharge rates to the 1-year, 24-hour; and the 2-year, 24-hour pre-development peak runoff discharge rates respectively, or to the maximum extent practicable. The runoff curve numbers in Table 2. shall be used to represent the actual pre-development conditions. Peak discharges shall be calculated using TR-55 runoff curve number methodology, Atlas 14 precipitation depths, and the appropriate NRCS

Wisconsin MSE3 or MSE4 precipitation distribution. On a case-by-case basis, the [administering authority] may allow the use of TP-40 precipitation depths and the Type II distribution.

**Note to Users:** For determining compliance with the peak flow requirement, the Department recommends use of the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Precipitation Frequency Estimates for precipitation depth. The Natural Resources Conservation Service (NRCS) – Wisconsin has calculated county-specific Atlas 14 precipitation depths and they are to be used in combination with the appropriate NRCS MSE3 or MSE4 precipitation distribution. The NRCS calculated county-specific Atlas 14 precipitation depths and MSE3 and MSE4 precipitation distributions are available at:

[http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/technical/engineering/?cid=nrcs142p2\\_025417](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/technical/engineering/?cid=nrcs142p2_025417).

<b>Table 2. Maximum Pre-Development Runoff Curve Numbers</b>				
Runoff Curve Number	Hydrologic Soil Group			
	A	B	C	D
Woodland	30	55	70	77
Grassland	39	61	71	78
Cropland	55	69	78	83

**Note to Users:** Where the pre-development condition is a combination of woodland, grassland, or cropland, the runoff curve number should be pro-rated by area.

2. This subsection of the ordinance does not apply to any of the following:
  - a. A post-construction site where the discharge is directly into a lake over 5,000 acres or a stream or river segment draining more than 500 square miles.
  - b. Except as provided under S. 07 (3), a redevelopment post-construction site.
  - c. An in-fill development area less than 5 acres.

**Note to Users:** The intent of the peak discharge standard is to minimize stream bank erosion, under bank-full conditions. For water quantity concerns, the post-development peak flow rate for the 10-, 25-, 50- and



*100-year – 24-hour storm events should also be controlled either at or below pre-development discharge rates. This has not been addressed in this model ordinance but may need to be included in the local ordinance to address local flood control issues.*

(c) INFILTRATION.

1. Best Management Practices. BMPs shall be designed, installed, and maintained to infiltrate runoff in accordance with the following or to the maximum extent practicable:
  - a. *Low imperviousness.* For development up to 40 percent connected imperviousness, such as parks, cemeteries, and low density residential development, infiltrate sufficient runoff volume so that the post-development infiltration volume shall be at least 90 percent of the pre-development infiltration volume, based on an average annual rainfall. However, when designing appropriate infiltration systems to meet this requirement, no more than one percent of the post-construction site is required as an effective infiltration area.
  - b. *Moderate imperviousness.* For development with more than 40 percent and up to 80 percent connected imperviousness, such as medium and high density residential, multi-family development, industrial and institutional development, and office parks, infiltrate sufficient runoff volume so that the post-development infiltration volume shall be at least 75 percent of the pre-development infiltration volume, based on an average annual rainfall. However, when designing appropriate infiltration systems to meet this requirement, no more than 2 percent of the post-construction site is required as an effective infiltration area.
  - c. *High imperviousness.* For development with more than 80 percent connected imperviousness, such as commercial strip malls, shopping centers, and commercial downtowns, infiltrate sufficient runoff volume so that the post-development infiltration volume shall be at least 60 percent of the pre-development infiltration volume, based on an average annual rainfall. However, when designing appropriate infiltration systems to meet this requirement, no more than 2 percent of the post-construction site is required as an effective infiltration area.
2. Pre-development. The pre-development condition shall be the same as specified in Table 2 of the Peak Discharge section of this ordinance.
3. Source Areas.

- a. *Prohibitions.* Runoff from the following areas may not be infiltrated and may not qualify as contributing to meeting the requirements of this section unless demonstrated to meet the conditions identified in S. 07 (4)(c)6.:
  - i. Areas associated with a tier 1 industrial facility identified in s. NR 216.21 (2)(a), including storage, loading and parking. Rooftops may be infiltrated with the concurrence of the regulatory authority.
  - ii. Storage and loading areas of a tier 2 industrial facility identified in s. NR 216.21 (2)(b).

**Note to Users:** *Runoff from the employee and guest parking and rooftop areas of a tier 2 facility may be infiltrated but runoff from the parking area may require pretreatment.*

- iii. Fueling and vehicle maintenance areas. Runoff from rooftops of fueling and vehicle maintenance areas may be infiltrated with the concurrence of the regulatory authority.
- b. *Exemptions.* Runoff from the following areas may be credited toward meeting the requirement when infiltrated, but the decision to infiltrate runoff from these source areas is optional:
  - i. Parking areas and access roads less than 5,000 square feet for commercial development.
  - ii. Parking areas and access roads less than 5,000 square feet for industrial development not subject to the Prohibitions under par a.
  - iii. Except as provided under S. 07 (3), redevelopment post-construction sites.
  - iv. In-fill development areas less than 5 acres.
  - v. Roads on commercial, industrial and institutional land uses, and arterial residential roads.

4. Location of Practices.

- a. *Prohibitions.* Infiltration practices may not be located in the following areas:
  - i. Areas within 1000 feet upgradient or within 100 feet downgradient of direct conduits to groundwater.
  - ii. Areas within 400 feet of a community water system well as specified in s. NR 811.16 (4) or within the separation distances listed in s. NR 812.08 for any private well or non-community well for runoff infiltrated

from commercial, including multi-family residential, industrial and institutional land uses or regional devices for one- and two-family residential development.

iii. Areas where contaminants of concern, as defined in s. NR 720.03 (2), are present in the soil through which infiltration will occur.

b. *Separation distances.*

i. Infiltration practices shall be located so that the characteristics of the soil and the separation distance between the bottom of the infiltration system and the elevation of seasonal high groundwater or the top of bedrock are in accordance with Table 3:

<b>Table 3. Separation Distances and Soil Characteristics</b>		
<b>Source Area</b>	<b>Separation Distance</b>	<b>Soil Characteristics</b>
Industrial, Commercial, Institutional Parking Lots and Roads	5 feet or more	Filtering Layer
Residential Arterial Roads	5 feet or more	Filtering Layer
Roofs Draining to Subsurface Infiltration Practices	1 foot or more	Native or Engineered Soil with Particles Finer than Coarse Sand
Roofs Draining to Surface Infiltration Practices	Not Applicable	Not Applicable
All Other Impervious Source Areas	3 feet or more	Filtering Layer

ii. Notwithstanding par. b., applicable requirements for injection wells classified under ch. NR 815 shall be followed.

c. *Infiltration rate exemptions.* Infiltration practices located in the following areas may be credited toward meeting the requirements under the following conditions, but the decision to infiltrate under these conditions is optional:

i. Where the infiltration rate of the soil measured at the proposed bottom of the infiltration system is less than 0.6 inches per hour using a scientifically credible field test method.

ii. Where the least permeable soil horizon to 5 feet below the proposed bottom of the infiltration system using the U.S. Department of Agriculture method of soils analysis is one of the following: sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, or clay.

5. Alternate Use. Where alternate uses of runoff are employed, such as for toilet flushing, laundry, or irrigation or storage on green roofs where an equivalent

portion of the runoff is captured permanently by rooftop vegetation, such alternate use shall be given equal credit toward the infiltration volume required by this section.

6. Groundwater Standards.

- a. Infiltration systems designed in accordance with this section shall, to the extent technically and economically feasible, minimize the level of pollutants infiltrating to groundwater and shall maintain compliance with the preventive action limit at a point of standards application in accordance with ch. NR 140. However, if site specific information indicates that compliance with a preventive action limit is not achievable, the infiltration BMP may not be installed or shall be modified to prevent infiltration to the maximum extent practicable.
- b. Notwithstanding par. a., the discharge from BMPs shall remain below the enforcement standard at the point of standards application.

7. Pretreatment. Before infiltrating runoff, pretreatment shall be required for parking lot runoff and for runoff from new road construction in commercial, industrial and institutional areas that will enter an infiltration system. The pretreatment shall be designed to protect the infiltration system from clogging prior to scheduled maintenance and to protect groundwater quality in accordance with subd. 6. Pretreatment options may include, but are not limited to, oil and grease separation, sedimentation, biofiltration, filtration, swales or filter strips.

8. Maximum Extent Practicable. Where the conditions of subd. 3. and 4. limit or restrict the use of infiltration practices, the performance standard of S. 07 (4)(c) shall be met to the maximum extent practicable.

(d) PROTECTIVE AREAS.

1. Definition. In this section, “protective area” means an area of land that commences at the top of the channel of lakes, streams and rivers, or at the delineated boundary of wetlands, and that is the greatest of the following widths, as measured horizontally from the top of the channel or delineated wetland boundary to the closest impervious surface. However, in this section, “protective area” does not include any area of land adjacent to any stream enclosed within a pipe or culvert, so that runoff cannot enter the enclosure at this location.
  - a. For outstanding resource waters and exceptional resource waters, 75 feet.

- b. For perennial and intermittent streams identified on a U.S. Geological Survey 7.5-minute series topographic map, or a county soil survey map, whichever is more current, 50 feet.
- c. For lakes, 50 feet.
- d. For wetlands not subject to par. e. or f., 50 feet.
- e. For highly susceptible wetlands, 75 feet. Highly susceptible wetlands include the following types: calcareous fens, sedge meadows, open and coniferous bogs, low prairies, coniferous swamps, lowland hardwood swamps, and ephemeral ponds.
- f. For less susceptible wetlands, 10 percent of the average wetland width, but no less than 10 feet nor more than 30 feet. Less susceptible wetlands include: degraded wetland dominated by invasive species such as reed canary grass; cultivated hydric soils; and any gravel pits, or dredged material or fill material disposal sites that take on the attributes of a wetland.
- g. In pars. d. to f., determinations of the extent of the protective area adjacent to wetlands shall be made on the basis of the sensitivity and runoff susceptibility of the wetland in accordance with the standards and criteria in s. NR 103.03.
- h. Wetland boundary delineation shall be made in accordance with s. NR 103.08 (1m). This paragraph does not apply to wetlands that have been completely filled in compliance with all applicable state and federal regulations. The protective area for wetlands that have been partially filled in compliance with all applicable state and federal regulations shall be measured from the wetland boundary delineation after a fill has been placed. Where there is a legally authorized wetland fill, the protective area standard need not be met in that location.
- i. For concentrated flow channels with drainage areas greater than 130 acres, 10 feet.
- j. Notwithstanding pars. a. to i., the greatest protective area width shall apply where rivers, streams, lakes and wetlands are contiguous.

**Note to User:** *A stream or lake is not eligible for a lower protective area width even if contiguous to a less susceptible wetland.*

- 2. Applicability. This section applies to post-construction sites located within a protective area, except those areas exempted pursuant to subd. 4.

3. Requirements. The following requirements shall be met:
  - a. Impervious surfaces shall be kept out of the protective area entirely or to the maximum extent practicable. If there is no practical alternative to locating an impervious surface in the protective area, the storm water management plan shall contain a written, site-specific explanation.
  - b. Where land disturbing construction activity occurs within a protective area, adequate sod or self-sustaining vegetative cover of 70 percent or greater shall be established and maintained where no impervious surface is present. The adequate sod or self-sustaining vegetative cover shall be sufficient to provide for bank stability, maintenance of fish habitat, and filtering of pollutants from upslope overland flow areas under sheet flow conditions. Non-vegetative materials, such as rock riprap, may be employed on the bank as necessary to prevent erosion such as on steep slopes or where high velocity flows occur.

**Note to Users:** *It is recommended that seeding of non-invasive vegetative cover be used in the protective areas. Some invasive plants that should not be used are listed in ch. NR 40, Wis. Adm. Code. Flood and drought-tolerant vegetation that can provide long-term bank stability because of an extensive root system is preferable. Vegetative cover may be measured using the line transect method described in the University of Wisconsin extension publication number A3533, titled "Estimating Residue Using the Line Transect Method".*

- c. BMPs such as filter strips, swales, or wet detention ponds, that are designed to control pollutants from non-point sources, may be located in the protective area.

**Note to Users:** *Other laws, such as ch. 30, Wis. Stats., and chs. NR 103, 115, 116 and 117, Wis. Adm. Code, and their associated review and approval processes may apply in the protective area.*

4. Exemptions. This section does not apply to any of the following:
  - a. Except as provided under S. 07 (3), redevelopment post-construction sites.
  - b. In-fill development areas less than 5 acres.

- c. Structures that cross or access surface water such as boat landings, bridges, and culverts.
- d. Structures constructed in accordance with s. 59.692 (1v), Stats.
- e. Areas of post-construction sites from which the runoff does not enter the surface water, including wetlands, without first being treated by a BMP to meet the local ordinance requirements for total suspended solids and peak flow reduction, except to the extent that vegetative ground cover is necessary to maintain bank stability.

**Note to Users:** *A vegetated protective area to filter runoff pollutants from post-construction sites described in par. (e) is not necessary since the runoff at that location is treated prior to entering the surface water. Other practices necessary to meet the requirements of this section, such as a swale or pond, will need to be designed and implemented to reduce runoff pollutants prior to runoff entering a surface water of the state.*

- (e) FUELING AND MAINTENANCE AREAS. Fueling and vehicle maintenance areas shall have BMPs designed, installed, and maintained to reduce petroleum within runoff, so that the runoff that enters waters of the state contains no visible petroleum sheen, or to the maximum extent practicable.

**Note to Users:** *A combination of the following BMPs may be used: oil and grease separators, canopies, petroleum spill cleanup materials, or any other structural or non-structural method of preventing or treating petroleum in runoff.*

**Note to Users:** *The following subsection, "Swale Treatment for Transportation Facilities," is optional.*

- (f) SWALE TREATMENT FOR TRANSPORTATION FACILITIES.

- 1. Requirement. Except as provided in subd. 2., transportation facilities that use swales for runoff conveyance and pollutant removal are exempt from the requirements of local ordinance requirements for peak flow control, total suspended solids control, and infiltration, if the swales are designed to do all of the following or to the maximum extent practicable:

- a. Swales shall be vegetated. However, where appropriate, non-vegetative measures may be employed to prevent erosion or provide for runoff treatment, such as rock riprap stabilization or check dams.

**Note to Users:** *It is preferred that tall and dense vegetation be maintained within the swale due to its greater effectiveness at enhancing runoff pollutant removal.*

- b. Swales shall comply with sections V.F. (Velocity and Depth) and V.G. (Swale Geometry Criteria) with a swale treatment length as long as that specified in section V.C. (Pre-Treatment) of the Wisconsin Department of Natural Resources technical standard 1005 “Vegetated Infiltration Swales”, dated May 2007, or a superseding document. Transportation facility swale treatment does not have to comply with other sections of technical standard 1005.

2. Other requirements.

- a. Notwithstanding subd. 1., the [administering authority] may, consistent with water quality standards, require that other requirements, in addition to swale treatment, be met on a transportation facility with an average daily traffic rate greater than 2,500 and where the initial surface water of the state that the runoff directly enters is one of the following:
  - i. An outstanding resource water.
  - ii. An exceptional resource water.
  - iii. Waters listed in section 303 (d) of the Federal Clean Water Act that are identified as impaired in whole or in part, due to non-point source impacts.
  - iv. Water where targeted performance standards are developed pursuant to s. NR 151.004, Wis. Adm. Code.
- b. The transportation facility authority shall contact the [administering authority] to determine if additional BMPs beyond a water quality swale are needed under this subsection.

(5) GENERAL CONSIDERATIONS FOR STORM WATER MANAGEMENT MEASURES. The following considerations shall be observed in on-site and off-site runoff management:

- (a) Natural topography and land cover features such as natural swales, natural depressions, native soil infiltrating capacity, and natural groundwater recharge areas shall be preserved and used, to the extent possible, to meet the requirements of this section.



- (b) Emergency overland flow for all storm water facilities shall be provided to prevent exceeding the safe capacity of downstream drainage facilities and prevent endangerment of downstream property or public safety.

(6) BMP LOCATION.

- (a) To comply with the performance standards required under S. 07 of this ordinance, BMPs may be located on-site or off-site as part of a regional storm water device, practice or system, but shall be installed in accordance with s. NR 151.003, Wis. Adm. Code.

**Note to Users:** *This section does not supersede any other applicable federal, state or local regulation such as ch. NR 103, Wis. Adm. Code, and ch. 30, Wis. Stats.*

- (b) The [administering authority] may approve off-site management measures provided that all of the following conditions are met:

1. The [administering authority] determines that the post-construction runoff is covered by a storm water management system plan that is approved by the [name of municipality] and that contains management requirements consistent with the purpose and intent of this ordinance.
2. The off-site facility meets all of the following conditions:
  - a. The facility is in place.
  - b. The facility is designed and adequately sized to provide a level of storm water control equal to or greater than that which would be afforded by on-site practices meeting the performance standards of this ordinance.
  - c. The facility has a legally obligated entity responsible for its long-term operation and maintenance.

- (c) Where a regional treatment option exists such that the [administering authority] exempts the applicant from all or part of the minimum on-site storm water management requirements, the applicant shall be required to pay a fee in an amount determined in negotiation with the [administering authority]. In determining the fee for post-construction runoff, the [administering authority] shall consider an equitable distribution of the cost for land, engineering design, construction, and maintenance of the regional treatment option.

- (7) ADDITIONAL REQUIREMENTS. The [administering authority] may establish storm water management requirements more stringent than those set forth in this ordinance if the [administering authority] determines that the requirements are needed to control storm water quantity or control flooding, comply with federally approved total maximum daily load requirements, or control pollutants associated with existing development or redevelopment.

**S. 08 PERMITTING REQUIREMENTS, PROCEDURES AND FEES.**

- (1) PERMIT REQUIRED. No responsible party may undertake a land disturbing construction activity without receiving a post-construction runoff permit from the [administering authority] prior to commencing the proposed activity.
  
- (2) PERMIT APPLICATION AND FEES. Unless specifically excluded by this ordinance, any responsible party desiring a permit shall submit to the [administering authority] a permit application on a form provided by the [administering authority] for that purpose.
  - (a) Unless otherwise excluded by this ordinance, a permit application must be accompanied by a storm water management plan, a maintenance agreement and a non-refundable permit administration fee.
  - (b) The storm water management plan shall be prepared to meet the requirements of S. 07 and S. 09, the maintenance agreement shall be prepared to meet the requirements of S. 10, the financial guarantee shall meet the requirements of S. 11, and fees shall be those established by the [governing body] as set forth in S. 12.
  
- (3) PERMIT APPLICATION REVIEW AND APPROVAL. The [administering authority] shall review any permit application that is submitted with a storm water management plan, maintenance agreement, and the required fee. The following approval procedure shall be used:
  - (a) Within [number] business days of the receipt of a complete permit application, including all items as required by sub. (2), the [administering authority] shall inform the applicant whether the application, storm water management plan and maintenance agreement are approved or disapproved based on the requirements of this ordinance.
  - (b) If the storm water permit application, storm water management plan and maintenance agreement are approved, or if an agreed upon payment of fees in lieu of storm water management practices is made, the [administering authority] shall issue the permit.
  - (c) If the storm water permit application, storm water management plan or maintenance agreement is disapproved, the [administering authority] shall detail in writing the reasons for disapproval.
  - (d) The [administering authority] may request additional information from the applicant. If additional information is submitted, the [administering authority] shall have [number] business days from the date the additional information is received to inform the applicant that the storm water management plan and maintenance agreement are either approved or disapproved.

- (e) Failure by the [administering authority] to inform the permit applicant of a decision within [number] business days of a required submittal shall be deemed to mean approval of the submittal and the applicant may proceed as if a permit had been issued.
- (4) PERMIT REQUIREMENTS. All permits issued under this ordinance shall be subject to the following conditions, and holders of permits issued under this ordinance shall be deemed to have accepted these conditions. The [administering authority] may suspend or revoke a permit for violation of a permit condition, following written notification of the responsible party. An action by the [administering authority] to suspend or revoke this permit may be appealed in accordance with S. 14.
- (a) Compliance with this permit does not relieve the responsible party of the responsibility to comply with other applicable federal, state, and local laws and regulations.
  - (b) The responsible party shall design and install all structural and non-structural storm water management measures in accordance with the approved storm water management plan and this permit.
  - (c) The responsible party shall notify the [administering authority] at least [number] business days before commencing any work in conjunction with the storm water management plan, and within [number] business days upon completion of the storm water management practices. If required as a special condition under sub. (5), the responsible party shall make additional notification according to a schedule set forth by the [administering authority] so that practice installations can be inspected during construction.
  - (d) Practice installations required as part of this ordinance shall be certified "as built" or "record" drawings by a licensed professional engineer. Completed storm water management practices must pass a final inspection by the [administering authority] or its designee to determine if they are in accordance with the approved storm water management plan and ordinance. The [administering authority] or its designee shall notify the responsible party in writing of any changes required in such practices to bring them into compliance with the conditions of this permit.
  - (e) The responsible party shall notify the [administering authority] of any significant modifications it intends to make to an approved storm water management plan. The [administering authority] may require that the proposed modifications be submitted to it for approval prior to incorporation into the storm water management plan and execution by the responsible party.
  - (f) The responsible party shall maintain all storm water management practices in accordance with the storm water management plan until the practices either become the

responsibility of the [governing body], or are transferred to subsequent private owners as specified in the approved maintenance agreement.

- (g) The responsible party authorizes the [administering authority] to perform any work or operations necessary to bring storm water management measures into conformance with the approved storm water management plan, and consents to a special assessment or charge against the property as authorized under subch. VII of ch. 66, Wis. Stats., or to charging such costs against the financial guarantee posted under S. 11.
  - (h) If so directed by the [administering authority], the responsible party shall repair at the responsible party's own expense all damage to adjoining municipal facilities and drainage ways caused by runoff, where such damage is caused by activities that are not in compliance with the approved storm water management plan.
  - (i) The responsible party shall permit property access to the [administering authority] or its designee for the purpose of inspecting the property for compliance with the approved storm water management plan and this permit.
  - (j) Where site development or redevelopment involves changes in direction, increases in peak rate and/or total volume of runoff from a site, the [administering authority] may require the responsible party to make appropriate legal arrangements with affected property owners concerning the prevention of endangerment to property or public safety.
  - (k) The responsible party is subject to the enforcement actions and penalties detailed in S. 13, if the responsible party fails to comply with the terms of this permit.
- (5) **PERMIT CONDITIONS.** Permits issued under this subsection may include conditions established by [administering authority] in addition to the requirements needed to meet the performance standards in S. 07 or a financial guarantee as provided for in S. 11.
- (6) **PERMIT DURATION.** Permits issued under this section shall be valid from the date of issuance through the date the [administering authority] notifies the responsible party that all storm water management practices have passed the final inspection required under sub. (4)(d).

## **S. 09 STORM WATER MANAGEMENT PLAN.**

- (1) **STORM WATER MANAGEMENT PLAN REQUIREMENTS.** The storm water management plan required under S. 07 (2) shall contain at a minimum the following information:
- (a) Name, address, and telephone number for the following or their designees: landowner; developer; project engineer for practice design and certification; person(s) responsible for installation of storm water management practices; and person(s) responsible for

maintenance of storm water management practices prior to the transfer, if any, of maintenance responsibility to another party.

- (b) A proper legal description of the property proposed to be developed, referenced to the U.S. Public Land Survey system or to block and lot numbers within a recorded land subdivision plat.
- (c) Pre-development site conditions, including:
  - 1. One or more site maps at a scale of not less than 1 inch equals [number] feet. The site maps shall show the following: site location and legal property description; predominant soil types and hydrologic soil groups; existing cover type and condition; topographic contours of the site at a scale not to exceed [number] feet; topography and drainage network including enough of the contiguous properties to show runoff patterns onto, through, and from the site; watercourses that may affect or be affected by runoff from the site; flow path and direction for all storm water conveyance sections; watershed boundaries used in hydrology determinations to show compliance with performance standards; lakes, streams, wetlands, channels, ditches, and other watercourses on and immediately adjacent to the site; limits of the 100 year floodplain; location of wells and wellhead protection areas covering the project area and delineated pursuant to s. NR 811.16, Wis. Adm. Code.
  - 2. Hydrology and pollutant loading computations as needed to show compliance with performance standards. All major assumptions used in developing input parameters shall be clearly stated. The geographic areas used in making the calculations shall be clearly cross-referenced to the required map(s).
- (d) Post-development site conditions, including:
  - 1. Explanation of the provisions to preserve and use natural topography and land cover features to minimize changes in peak flow runoff rates and volumes to surface waters and wetlands.
  - 2. Explanation of any restrictions on storm water management measures in the development area imposed by wellhead protection plans and ordinances.
  - 3. One or more site maps at a scale of not less than 1 inch equals [number] feet showing the following: post-construction pervious areas including vegetative cover type and condition; impervious surfaces including all buildings, structures, and pavement; post-construction topographic contours of the site at a scale not to exceed [number] feet; post-construction drainage network including enough of the contiguous properties to show runoff patterns onto, through, and from the site; locations and dimensions of drainage easements; locations of maintenance

easements specified in the maintenance agreement; flow path and direction for all storm water conveyance sections; location and type of all storm water management conveyance and treatment practices, including the on-site and off-site tributary drainage area; location and type of conveyance system that will carry runoff from the drainage and treatment practices to the nearest adequate outlet such as a curbed street, storm drain, or natural drainage way; watershed boundaries used in hydrology and pollutant loading calculations and any changes to lakes, streams, wetlands, channels, ditches, and other watercourses on and immediately adjacent to the site.

4. Hydrology and pollutant loading computations as needed to show compliance with performance standards. The computations shall be made for each discharge point in the development, and the geographic areas used in making the calculations shall be clearly cross-referenced to the required map(s).
  5. Results of investigations of soils and groundwater required for the placement and design of storm water management measures. Detailed drawings including cross-sections and profiles of all permanent storm water conveyance and treatment practices.
- (e) A description and installation schedule for the storm water management practices needed to meet the performance standards in S. 07.
  - (f) A maintenance plan developed for the life of each storm water management practice including the required maintenance activities and maintenance activity schedule.
  - (g) Cost estimates for the construction, operation, and maintenance of each storm water management practice.
  - (h) Other information requested in writing by the [administering authority] to determine compliance of the proposed storm water management measures with the provisions of this ordinance.
  - (i) All site investigations, plans, designs, computations, and drawings shall be certified by a [licensed professional engineer] to be prepared in accordance with accepted engineering practice and requirements of this ordinance.
- (2) **ALTERNATE REQUIREMENTS.** The [administering authority] may prescribe alternative submittal requirements for applicants seeking an exemption to on-site storm water management performance standards under S. 07 (5).

**S. 10 MAINTENANCE AGREEMENT.**

- (1) MAINTENANCE AGREEMENT REQUIRED. The maintenance agreement required under S. 08 (2) for storm water management practices shall be an agreement between the [administering authority] and the responsible party to provide for maintenance of storm water practices beyond the duration period of this permit. The maintenance agreement shall be filed with the County Register of Deeds as a property deed restriction so that it is binding upon all subsequent owners of the land served by the storm water management practices.
  
- (2) AGREEMENT PROVISIONS. The maintenance agreement shall contain the following information and provisions and be consistent with the maintenance plan required by S. 09 (1)(f):
  - (a) Identification of the storm water facilities and designation of the drainage area served by the facilities.
  - (b) A schedule for regular maintenance of each aspect of the storm water management system consistent with the storm water management plan required under S. 08 (2).
  - (c) Identification of the responsible party(s), organization or city, county, town or village responsible for long term maintenance of the storm water management practices identified in the storm water management plan required under S. 08 (2).
  - (d) Requirement that the responsible party(s), organization, or city, county, town or village shall maintain storm water management practices in accordance with the schedule included in par. (b).
  - (e) Authorization for the [administering authority] to access the property to conduct inspections of storm water management practices as necessary to ascertain that the practices are being maintained and operated in accordance with the agreement.
  - (f) A requirement on the [administering authority] to maintain public records of the results of the site inspections, to inform the responsible party responsible for maintenance of the inspection results, and to specifically indicate any corrective actions required to bring the storm water management practice into proper working condition.
  - (g) Agreement that the party designated under par. (c), as responsible for long term maintenance of the storm water management practices, shall be notified by the [administering authority] of maintenance problems which require correction. The specified corrective actions shall be undertaken within a reasonable time frame as set by the [administering authority].
  - (h) Authorization of the [administering authority] to perform the corrected actions identified in the inspection report if the responsible party designated under par. (c) does not make the required corrections in the specified time period. The [administering authority] shall enter

the amount due on the tax rolls and collect the money as a special charge against the property pursuant to subch. VII of ch. 66, Wis. Stats.

#### **S. 11 FINANCIAL GUARANTEE.**

- (1) ESTABLISHMENT OF THE GUARANTEE. The [administering authority] may require the submittal of a financial guarantee, the form and type of which shall be acceptable to the [administering authority]. The financial guarantee shall be in an amount determined by the [administering authority] to be the estimated cost of construction and the estimated cost of maintenance of the storm water management practices during the period which the designated party in the maintenance agreement has maintenance responsibility. The financial guarantee shall give the [administering authority] the authorization to use the funds to complete the storm water management practices if the responsible party defaults or does not properly implement the approved storm water management plan, upon written notice to the responsible party by the [administering authority] that the requirements of this ordinance have not been met.
  
- (2) CONDITIONS FOR RELEASE. Conditions for the release of the financial guarantee are as follows:
  - (a) The [administering authority] shall release the portion of the financial guarantee established under this section, less any costs incurred by the [administering authority] to complete installation of practices, upon submission of "as built plans" or "record" drawings by a licensed professional engineer. The [administering authority] may make provisions for a partial pro-rata release of the financial guarantee based on the completion of various development stages.
  - (b) The [administering authority] shall release the portion of the financial guarantee established under this section to assure maintenance of storm water practices, less any costs incurred by the [administering authority], at such time that the responsibility for practice maintenance is passed on to another entity via an approved maintenance agreement.

#### **S. 12 FEE SCHEDULE.**

The fees referred to in other sections of this ordinance shall be established by the [administering authority] and may from time to time be modified by resolution. A schedule of the fees established by the [administering authority] shall be available for review in [location].



### **S. 13 ENFORCEMENT.**

- (1) Any land disturbing construction activity or post-construction runoff initiated after the effective date of this ordinance by any person, firm, association, or corporation subject to the ordinance provisions shall be deemed a violation unless conducted in accordance with the requirements of this ordinance.
- (2) The [administering authority] shall notify the responsible party by certified mail of any non-complying land disturbing construction activity or post-construction runoff. The notice shall describe the nature of the violation, remedial actions needed, a schedule for remedial action, and additional enforcement action which may be taken.
- (3) Upon receipt of written notification from the [administering authority] under sub. (2), the responsible party shall correct work that does not comply with the storm water management plan or other provisions of this permit. The responsible party shall make corrections as necessary to meet the specifications and schedule set forth by the [administering authority] in the notice.
- (4) If the violations to a permit issued pursuant to this ordinance are likely to result in damage to properties, public facilities, or waters of the state, the [administering authority] may enter the land and take emergency actions necessary to prevent such damage. The costs incurred by the [administering authority] plus interest and legal costs shall be billed to the responsible party.
- (5) The [administering authority] is authorized to post a stop work order on all land disturbing construction activity that is in violation of this ordinance, or to request the [municipal attorney, corporation counsel] to obtain a cease and desist order in any court with jurisdiction.
- (6) The [administering authority] may revoke a permit issued under this ordinance for non-compliance with ordinance provisions.
- (7) Any permit revocation, stop work order, or cease and desist order shall remain in effect unless retracted by the [administering authority] or by a court with jurisdiction.
- (8) The [administering authority] is authorized to refer any violation of this ordinance, or a stop work order or cease and desist order issued pursuant to this ordinance, to the [municipal attorney, corporation counsel] for the commencement of further legal proceedings in any court with jurisdiction.

- (9) Any person, firm, association, or corporation who does not comply with the provisions of this ordinance shall be subject to a forfeiture of not less than [number] dollars or more than [number] dollars per offense, together with the costs of prosecution. Each day that the violation exists shall constitute a separate offense.
- (10) Compliance with the provisions of this ordinance may also be enforced by injunction in any court with jurisdiction. It shall not be necessary to prosecute for forfeiture or a cease and desist order before resorting to injunctive proceedings.

**Note to Users:** *Injunctive orders are authorized pursuant to s. 59.69 (11), 61.35, or 62.23 (8), Wis. Stats., for counties, villages and towns with village powers, and cities respectively.*

- (11) When the [administering authority] determines that the holder of a permit issued pursuant to this ordinance has failed to follow practices set forth in the storm water management plan, or has failed to comply with schedules set forth in said storm water management plan, the [administering authority] or a party designated by the [administering authority] may enter upon the land and perform the work or other operations necessary to bring the condition of said lands into conformance with requirements of the approved storm water management plan. The [administering authority] shall keep a detailed accounting of the costs and expenses of performing this work. These costs and expenses shall be deducted from any financial security posted pursuant to S. 11 of this ordinance. Where such a security has not been established, or where such a security is insufficient to cover these costs, the costs and expenses shall be entered on the tax roll as a special charge against the property and collected with any other taxes levied thereon for the year in which the work is completed.

#### **S. 14 APPEALS.**

- (1) BOARD OF [APPEALS or ADJUSTMENT]. The board of [appeals or adjustment], created pursuant to section [number] of the [name of municipality] ordinances pursuant to s. [59.694, 60.65, 61.354 (4)(b), or 62.23 (7)(e)], Wis. Stats., shall hear and decide appeals where it is alleged that there is error in any order, decision or determination made by the [administering authority] in administering this ordinance. The board shall also use the rules, procedures, duties, and powers authorized by statute in hearing and deciding appeals. Upon appeal, the board may authorize variances from the provisions of this ordinance that are not contrary to the public interest, and where owing to special conditions a literal enforcement of the ordinance will result in unnecessary hardship.

- (2) WHO MAY APPEAL. Appeals to the board of [appeals or adjustments] may be taken by any aggrieved person or by an officer, department, board, or bureau of the [name of municipality] affected by any decision of the [administering authority].

**S. 15 SEVERABILITY.**

If any section, clause, provision or portion of this ordinance is judged unconstitutional or invalid by a court of competent jurisdiction, the remainder of the ordinance shall remain in force and not be affected by such judgment.

**S. 16 EFFECTIVE DATE.**

This ordinance shall be in force and effect from and after its adoption and publication. The above and foregoing ordinance was duly adopted by the [governing body] of the [name of municipality] on the [number] day of [month], [year].

Approved: \_\_\_\_\_

Attested: \_\_\_\_\_

Published on [day, month, year].

CREATED:

Suzan Limberg  
Suzan Limberg, Storm Water Specialist

4/02/2015  
Date

APPROVED:

Mary Anne Lowndes  
Mary Anne Lowndes, Chief  
Runoff Management Section

4/2/15  
Date

Runoff Management Policy Management Team approved on 4/02/2015 (date).

W:\Storm\_Water\Guidance\Model Ordinances\Model Ordinances Final

**1. Labs reports are reviewed** to determine if the lab is a PCR or culture – this helps determine how the case is confirmed based on state criteria

**2. Determine Risk/exposure period**

Exposure period is determined by the below guidelines:

**7 Day Incubation: Exposure Period = 7 days prior to onset date to onset date**

Campylobacter, E. coli, Shiga-toxin producing (STEC), E. coli, Enterotoxigenic (EPEC), Hemolytic uremic syndrome (HUS), Salmonella, Yersinia

**14 Day Incubation: Exposure Period = 14 days prior to onset date to onset date**

Cryptosporidium, Giardia

**4 Day Incubation: Exposure Period = 4 days prior to onset date to onset date**

Shigella E. coli, Enteroinvasive (EIEC)/Shigella, E. coli, Enteropathogenic (EPEC)

**3. Information is then collected from the client based on the exposure period determined above. (When DHS is able, they will assist with the interview)**

- Travel or unusual activities
- Animal exposures
  - o Pets and pet food (including brand), animals in the environment including home, fair petting zoo or school
- soil/manure/compost exposure
- fecal exposure: adults or children using diapers & did the person have diarrhea
- water exposure
  - o municipal water system, rural well, river/lake/pond, chlorinated pool, splashpad, private well, bottled water, ocean, wading pool, standing water
- food source
  - o list all grocery stores and supermarkets where food was purchased and ate
  - o hunting, trapping, private kill, own garden, home delivery, farmers market
  - o pasteurized/unpasteurized food
- Commercial food establishments
  - o What establishment, what was consumed (food/drink), was there a buffet/salad bar
- Large Gatherings
  - o What food and drink was provided and where was it prepared

Additional information is collected for Salmonellosis or shiga-toxin producing E.coli infections. This includes **all** foods potentially consumed during the exposure period.

**4. Determine if client works in a high-risk setting** including food handling, providing patient care or childcare, or attending a childcare facility, and if so, exclude symptomatic patients generally until asymptomatic for 24 hours. Follow-up/notify the high-risk facility to determine potential exposures and provide education.

**\*\*Return to high-risk activities for a person diagnosed with a STEC infection routinely requires evidence of two stool specimens negative for Shiga toxin-producing E. coli by culture be provided to the LHD. Test of cure should be collected 1) after the individual is asymptomatic and 2) at least 48 hours after discontinuing of antimicrobial therapy. Specimens should be collected at least 24 hours apart.\*\***

**5. Provide the client with education on proper handwashing, food handling and preparation, and any additional disease specific education.**