

Reducing the Risk of Nutrient Loss in Surface Water Runoff

–Frozen and Snow Cover Soils–

Paul T. Kivlin
UW - Extension

UW – NPM / Discovery Farms Program

- 
- A red tractor is pulling a yellow manure spreader across a field with patches of snow. In the background, there are farm buildings, including a large barn and two silos. The sky is clear and blue.
- ▶ Potential issues
 - ▶ About Dis. Farms and winter monitoring
 - ▶ Study location and design
 - ▶ Surface water runoff
 - ▶ Nutrient losses
 - ▶ Challenges with winter manure
 - ▶ Conclusions

Negative impacts of improper manure applications and runoff

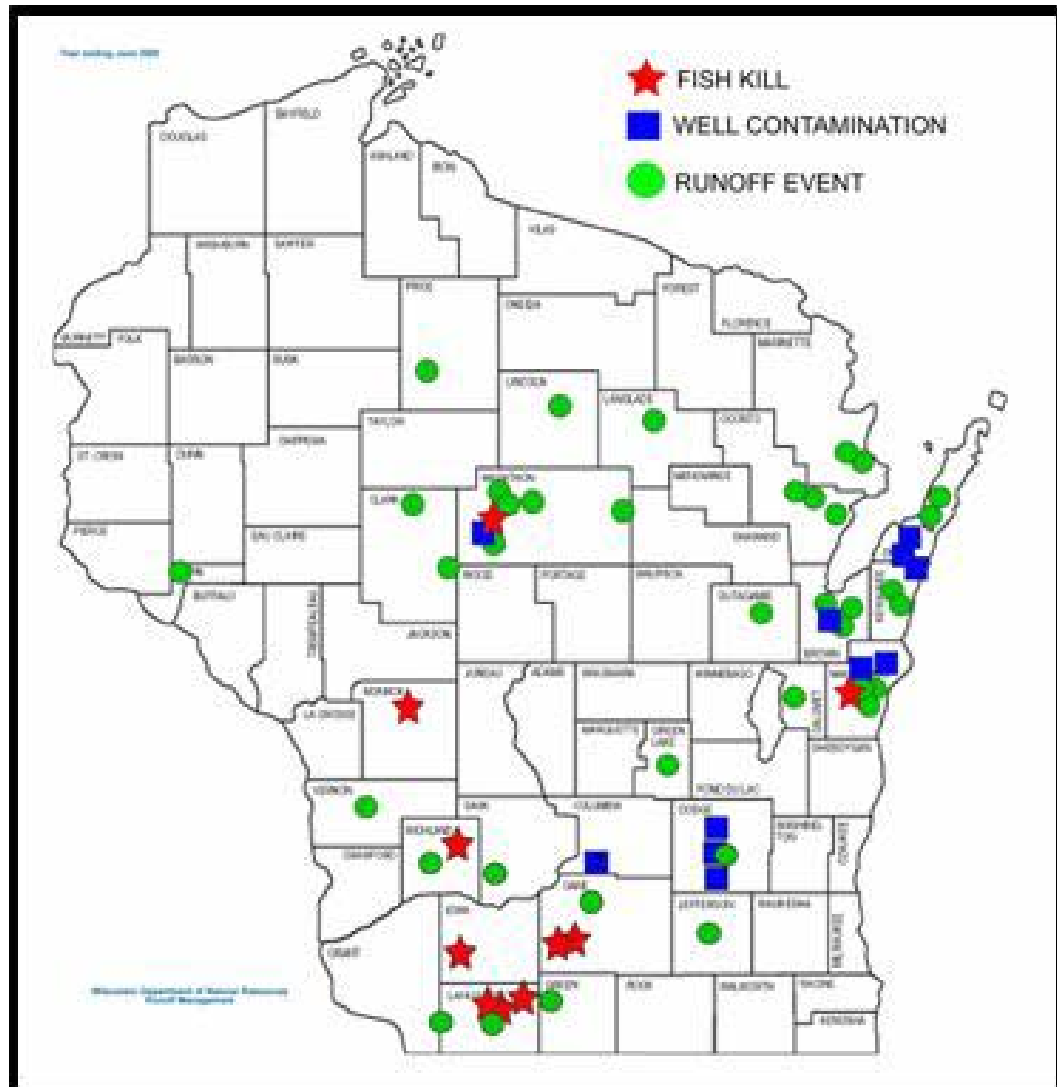
▶ Environmental Impacts

- Eutrophication of water bodies
- Hypoxia
- Worse!!

▶ Human Health Concerns

- Contaminated Drinking Water (surface and ground water)
- Beach Closures

➤ Ag's Public Relations!



Wisconsin DNR, 2005

Manure spills and fish kills!



UW – Discovery Farms Program

- ▶ Privately owned farms
 - ▶ Variety of management styles
 - ▶ Multiple agricultural landscape setting
 - ▶ “Real-world” situations
 - ▶ USGS Monitoring from 2003 – 2008
- 

Monitoring Locations

Discovery Farms

- 21 Water-Quality Monitoring Stations (6-640 acres) (7 farms)

- 12 edge-of-field
- 5 subsurface tile
- 4 stream

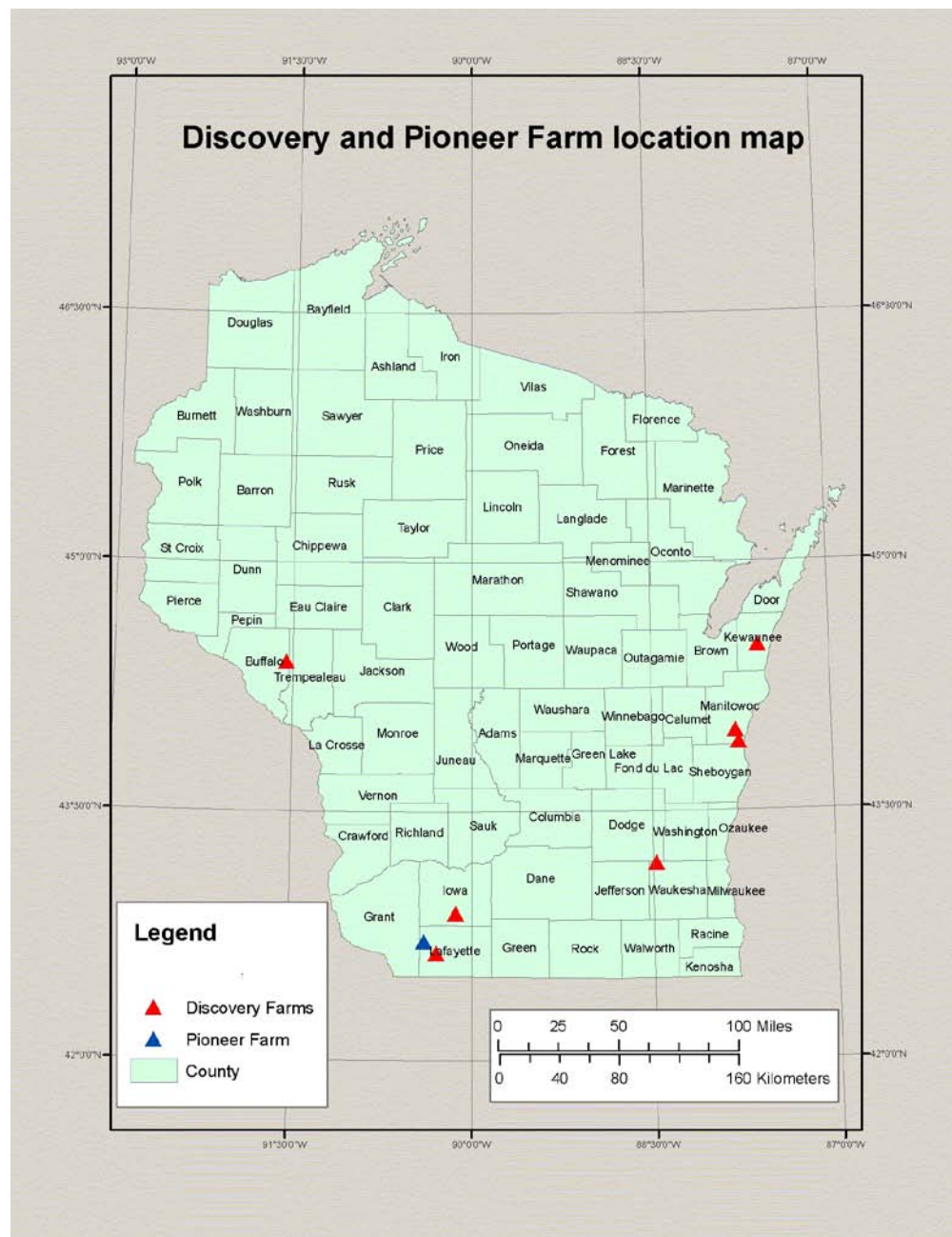
- 5 Meteorological Stations

Pioneer Farm

- 15 Water-Quality Monitoring Stations (0.25--1900 acres)

- 13 edge-of-field
- 2 stream


- 1 Meteorological Station



Data Collection



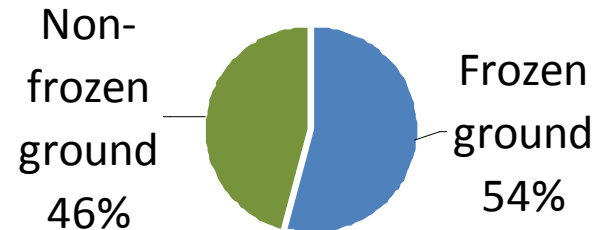
Data Collection

- ▶ Data was collected at individual stations during each year – termed “farm years” (10/1–9/30)
 - ▶ Summarizes the precipitation–runoff relations and water–quality characteristics for each farm year
 - ▶ Data split into frozen–ground and non–frozen ground runoff periods to describe typical field–scale losses in temperate climate regions like Wisconsin
- 

Is Wintertime Monitoring Important?

- ▶ Across all farms
- ▶ Comprised over $\frac{1}{2}$ of annual runoff
- ▶ Up to 100% of runoff in any given year

**Distribution of Annual Runoff
Edge-of-Field Stations**



Why hasn't this been done much before?



Winter in Wisconsin!

- ✓ Biggest challenges are from ice and snow
 - Backwater from snow/ice
 - Daytime runoff / nighttime freezing
 - Frozen equipment lines, flumes
 - Site Access



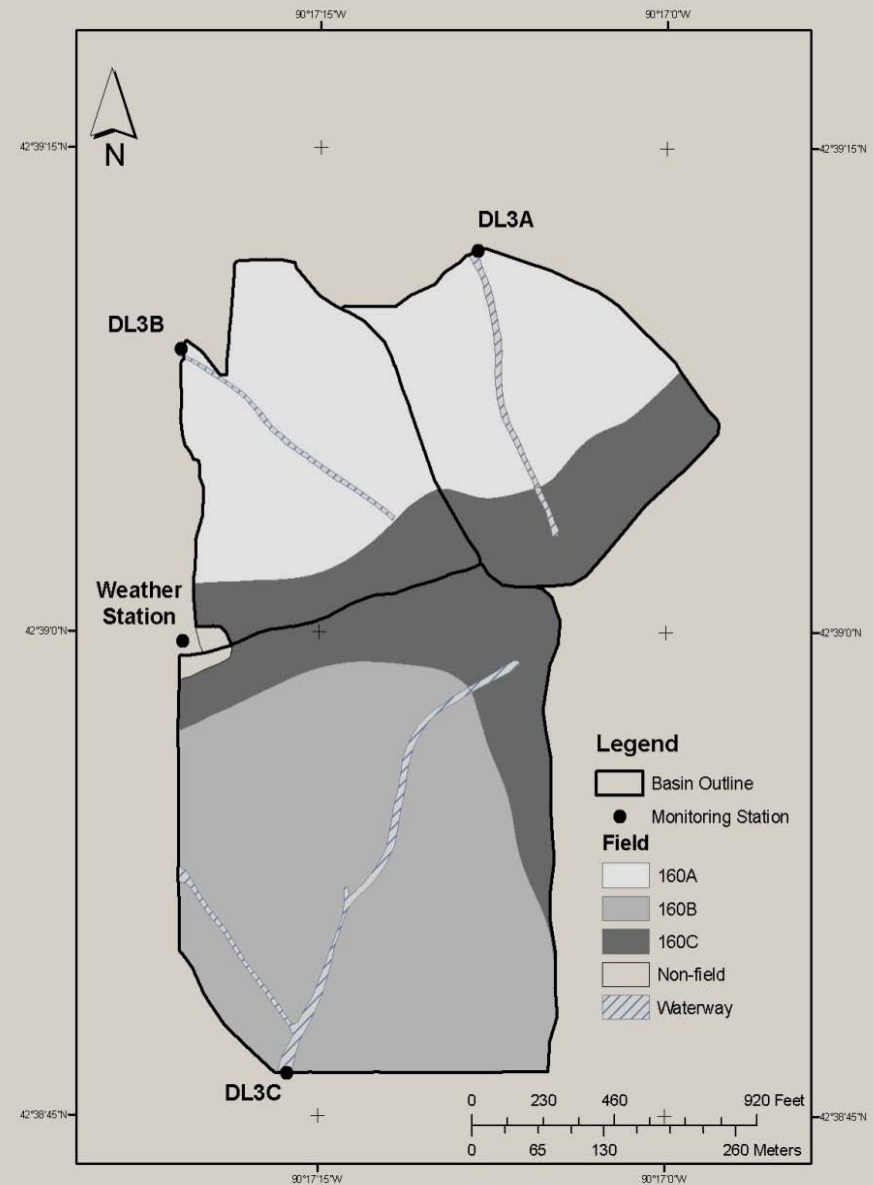
Typical Winter Scenario

1. Warm temperatures or rain are predicted
2. Site visits to clear ice and snow
3. Snowmelt starts
4. Temperatures drop below freezing at night
5. Start the whole process again!



Site Location

- ▶ Located on privately owned “no-till” farm in Southwest, WI
- ▶ Monitoring three small (16.9–39.5 acre) adjacent basins
- ▶ Slopes are 8–10 %
- ▶ Equipment located in grassed waterways at field edges
- ▶ Monitored annual losses but will only talk about the frozen ground period (**FGP**), typically November – March
- ▶ Variations in manure types, rates, and timing of application



Manure Applications

▶ FGP04

- Liquid dairy manure (LDM) application shortly preceding runoff (~4300gal/acre) in DL3A and DL3B. LDM (5400 gal) on DL3C in November

▶ FGP05

- Solid beef manure (SBM) applications shortly preceding runoff and on top of melting snow (average 5.3T/acre) in DL3C

▶ FGP06

- no manure application

▶ FGP07

- small SBM application shortly preceding runoff (13T/acre) in parts of DL3A and DL3B

Surface Water Runoff Results

Total runoff depth and mean flow-weighted concentrations of sediment, total nitrogen, and total phosphorus during frozen-ground periods at a no-till Discovery Farm in Southwest, WI , 2004 - 2007.

Basin Name	Residue Type	Runoff (in)	Sediment	Total N mg L ⁻¹	Total P
Frozen Ground 2004 (n=5 (runoff), n=4 (constituents))					
DL3A	Corn/Corn	0.74a	26.6a	46.6b	14.6b
DL3B	Corn/Corn	0.97a	61.0b	22.8b	9.0b
DL3C	Corn/Soybean-Corn*	0.68a	6.7a	3.9a	2.3a
Frozen Ground 2005 (n=22 (runoff), n=9 (constituents))					
DL3A	Corn/Soybean	4.38a	14.1a	3.1a	1.8a
DL3B	Corn/Soybean	3.79a	17.9a	3.1a	1.9a
DL3C	Soybean-Corn*/Corn-Soybean*	2.75a	45.1a	11.5b	5.8b
Frozen Ground 2006**					
DL3A	Soybean/Corn	0.54	61.0	8.0	7.7
DL3B	Soyben/Corn	—	—	—	—
DL3C	Corn-Soybean*/Corn	0.14	205.0	11.0	5.6
Frozen Ground 2007 (n=6 (runoff), n=3 (constituents))					
DL3A	Corn/Corn	0.28a	24.7a	4.0a	3.1a
DL3B	Corn/Corn	0.67a	32.4a	7.8a	6.7a
DL3C	Corn/Soybean-Corn*	1.06a	248.1b	5.7a	3.6a

* First residue type listed comprises 80% of the basin area, second listed comprises 20%

** Statistics not computed

Values within a column and year followed by the same letter are not significantly different at p = 0.050; letters correspond to nonparametric analysis based on data ranks rather than mean as shown.

Surface Water Runoff



- ▶ Runoff depths were not different between the basins in any given year
- ▶ Neither the type of manure nor the timing or rates of application affected runoff volumes
- ▶ **The frozen ground period of runoff is a substantial component of the annual runoff observed from this setting**

Critical Runoff Periods

- ▶ 4 years of data (2004 –2007) averaged for three sites on one farm
- ▶ No-till operation
- ▶ Periods which are “best” for producers to apply manure coincide with the periods which are higher risk for runoff!

January 8%	February 52%	March 26%
April	May 9%	June 3%
July 2%	August <1%	September
October	November	December

Average percent of annual runoff

Nutrient Losses



Total Nitrogen Results

Total runoff depth and mean flow-weighted concentrations of sediment, total nitrogen, and total phosphorus during frozen-ground periods at a no-till Discovery Farm in Southwest, WI , 2004 - 2007.

Basin Name	Residue Type	Runoff (in)	Sediment	Total N mg L ⁻¹	Total P
Frozen Ground 2004 (n=5 (runoff), n=4 (constituents))					
DL3A	Corn/Corn	0.74a	26.6a	46.6b	14.6b
DL3B	Corn/Corn	0.97a	61.0b	22.8b	9.0b
DL3C	Corn/Soybean-Corn*	0.68a	6.7a	3.9a	2.3a
Frozen Ground 2005 (n=22 (runoff), n=9 (constituents))					
DL3A	Corn/Soybean	4.38a	14.1a	3.1a	1.8a
DL3B	Corn/Soybean	3.79a	17.9a	3.1a	1.9a
DL3C	Soybean-Corn*/Corn-Soybean*	2.75a	45.1a	11.5b	5.8b
Frozen Ground 2006**					
DL3A	Soybean/Corn	0.54	61.0	8.0	7.7
DL3B	Soyben/Corn	—	—	—	—
DL3C	Corn-Soybean*/Corn	0.14	205.0	11.0	5.6
Frozen Ground 2007 (n=6 (runoff), n=3 (constituents))					
DL3A	Corn/Corn	0.28a	24.7a	4.0a	3.1a
DL3B	Corn/Corn	0.67a	32.4a	7.8a	6.7a
DL3C	Corn/Soybean-Corn*	1.06a	248.1b	5.7a	3.6a

* First residue type listed comprises 80% of the basin area, second listed comprises 20%

** Statistics not computed

Values within a column and year followed by the same letter are not significantly different at p = 0.050;

letters correspond to nonparametric analysis based on data ranks rather than mean as shown.

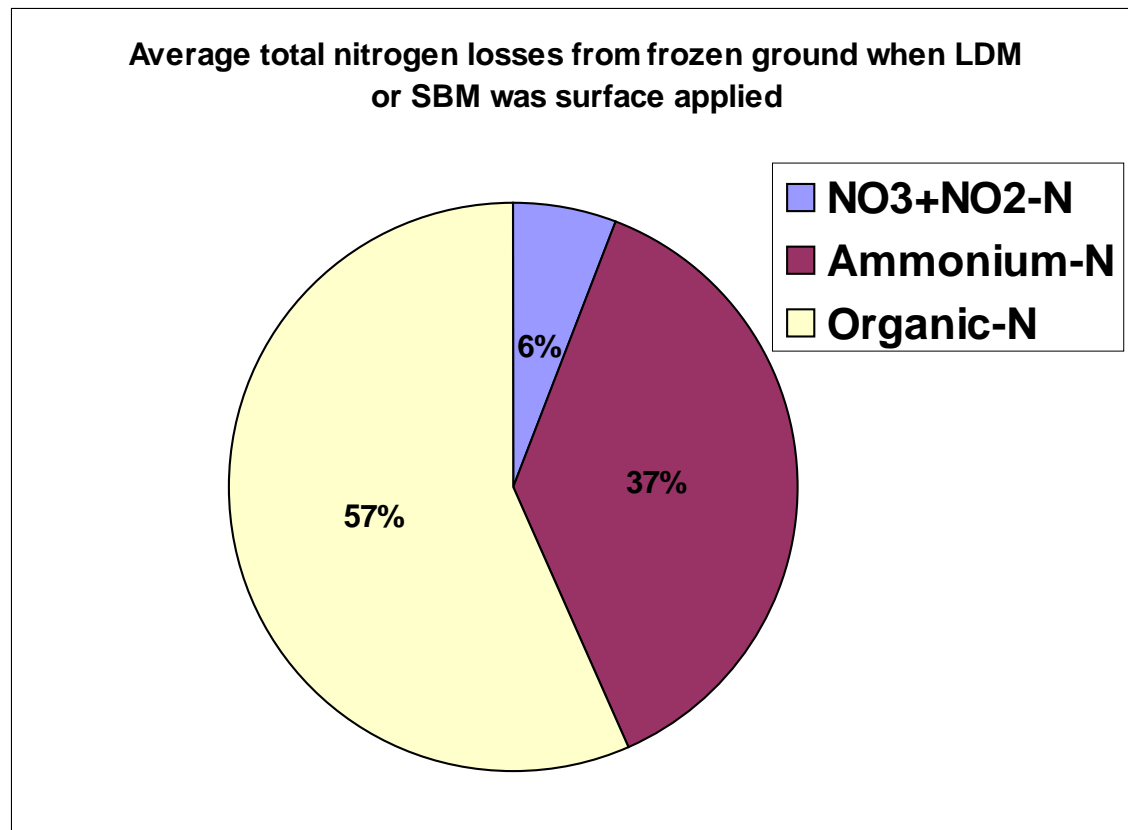
Nitrogen



- ▶ Both LDM and SBM increased TN event-mean concentrations and losses
- ▶ TN concentrations were the highest when LDM was applied shortly preceding snowmelt (highest event-mean concentration was 46.6 mg/L)
- ▶ Concentrations of ammonium-N were seen up to 43.6 mg/L from basins receiving LDM shortly preceding runoff
- ▶ Lower concentrations and losses were observed when manures were applied in the fall and early winter

Total Nitrogen Forms

- ▶ Organic-N made up the majority of the TN measured in surface water runoff when LDM or SBM was surface applied
- ▶ Ammonium-N is typically used as an indicator of manure affected runoff water



Total Phosphorus Results

Total runoff depth and mean flow-weighted concentrations of sediment, total nitrogen, and total phosphorus during frozen-ground periods at a no-till Discovery Farm in Southwest, WI, 2004 - 2007.

Basin Name	Residue Type	Runoff (in)	Sediment ————	Total N mg L ⁻¹	Total P
Frozen Ground 2004 (n=5 (runoff), n=4 (constituents))					
DL3A	Corn/Corn	0.74a	26.6a	46.6b	14.6b
DL3B	Corn/Corn	0.97a	61.0b	22.8b	9.0b
DL3C	Corn/Soybean-Corn*	0.68a	6.7a	3.9a	2.3a
Frozen Ground 2005 (n=22 (runoff), n=9 (constituents))					
DL3A	Corn/Soybean	4.38a	14.1a	3.1a	1.8a
DL3B	Corn/Soybean	3.79a	17.9a	3.1a	1.9a
DL3C	Soybean-Corn*/Corn-Soybean*	2.75a	45.1a	11.5b	5.8b
Frozen Ground 2006**					
DL3A	Soybean/Corn	0.54	61.0	8.0	7.7
DL3B	Soyben/Corn	—	—	—	—
DL3C	Corn-Soybean*/Corn	0.14	205.0	11.0	5.6
Frozen Ground 2007 (n=6 (runoff), n=3 (constituents))					
DL3A	Corn/Corn	0.28a	24.7a	4.0a	3.1a
DL3B	Corn/Corn	0.67a	32.4a	7.8a	6.7a
DL3C	Corn/Soybean-Corn*	1.06a	248.1b	5.7a	3.6a

* First residue type listed comprises 80% of the basin area, second listed comprises 20%

** Statistics not computed

Values within a column and year followed by the same letter are not significantly different at p = 0.050; letters correspond to nonparametric analysis based on data ranks rather than mean as shown.

Phosphorus

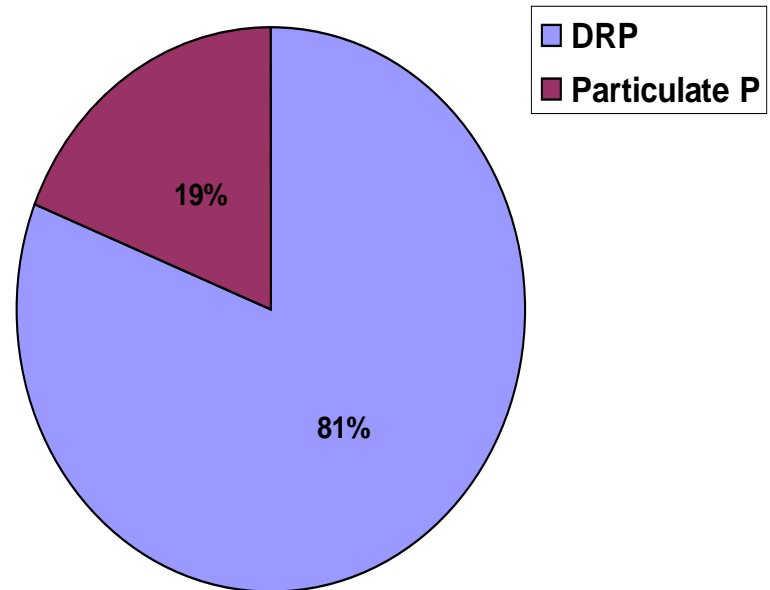
- ▶ TP was increased with either LDM or SBM was applied within one week preceding runoff
- ▶ TP concentrations and losses were highest when LDM was applied (highest event-mean concentration was 14.6 mg/L)
- ▶ Lower concentrations and losses were observed when manures were applied in the fall and early winter



Total Phosphorus Forms

- ▶ Of the Total P measured when LDM or SBM was surface applied the majority is in the dissolved form
- ▶ Particulate phosphorus is typically associated with sediment particles but has also shown up with application of manure

Average total phosphorus losses from frozen ground when LDM or SBM was surface applied



Why Spread?



2/20/2004 10:14

Why Spread Manure in the Winter?

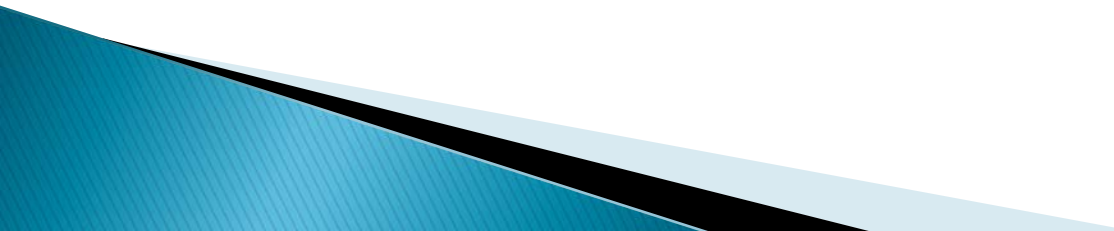
January	February	March Haul manure, tillage, fertilize,
April Haul, till, fertilize, plant, spray	May Haul, till, fertilize, plant, spray	June No open fields, hay harvest, spraying
July No open fields, hay harvest, spraying	August No open fields, hay harvest, small grains	September Hay harvest, corn silage,
October Corn/Beans Manure, till	November Corn/Beans Manure, till	December Corn/Beans Manure, till

Why apply manure during the frozen ground period?

- ▶ Animal Health
- ▶ Large window for application
 - Open fields
 - Time
 - Frozen soils
- ▶ LIMITED CHOICE!
 - Storage
 - Equipment
 - Investment



Manure applications on frozen/snow-covered ground: What the data show

- ▶ Runoff is more likely in February and March than in early winter.
 - ▶ Wintertime runoff can comprise a significant amount of annual surface-water runoff and nutrient losses.
 - ▶ The shorter the time between a manure application and a runoff event, the greater potential for nutrient losses.
- 

Why not ban winter spreading?

- ▶ Having all livestock farms apply manure in a narrow window greatly increases the risk
- ▶ Spreading entire field verses portions of a field can increase risk
- ▶ Storage does not reduce the risk of a runoff event – **management reduces risk**
- ▶ **Work with producers to limit spreading in high risk periods, offer options to storage**
 - **Stacking; spreading fields with limited risk; etc**

Conclusions

- ▶ Surface water runoff was not significantly affected by the surface application of manure, suspected that the low rates of the application may influence this
- ▶ Both LDM and SBM significantly increased the losses of TN and TP when applied within one week of runoff
- ▶ Nutrient losses were less when manures were applied in the fall or early winter

Needed research:

- ▶ Impacts of manure applications to frozen/snow-covered ground in early winter compared to late winter.
- ▶ Distance/rate/manure type impacts.
- ▶ Are “low” recommended rates really ok?
- ▶ Wintertime runoff “forecasting”
- ▶ Impact via subsurface Tiles

Any Questions?

