

Understanding Nutrient & Sediment Loss at Pagel's Ponderosa Dairy



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Equipment, procedures and sampling

Historic agricultural water quality monitoring efforts have often focused on the growing season (spring – fall), with little or no monitoring occurring in winter months. In Wisconsin, the spring thaw is a very active period for both surface water runoff and groundwater recharge. To fully assess annual nutrient and sediment losses, the UW-Discovery Farms Program conducts year-round monitoring. In response to the need for accurate data collection during winter conditions, equipment was selected and procedures developed and implemented that provide water quality data during the full range of weather conditions. Personnel from the U.S. Geological Survey (USGS) Wisconsin Water Science Center worked cooperatively with the Discovery Farms Program to collect hydrologic and water quality data from three small watersheds on Pagel's Ponderosa Dairy (PPD) from November 2003 to November 2008.

Monitoring stations

Aluminum, clam-style enclosures were used to house most field equipment and were locked with padlocks to prevent unauthorized access. One site had electrical hookup; while the other sites utilized solar panels and gasoline-powered generators to power equipment. A digital camera at each site was programmed to take one photograph each day to track field conditions.

The areas monitored were estimated to be 20.5, 22.1 and 13.2 acres. To measure surface water runoff volume (discharge), 2.5-foot, pre-rated, fiberglass H-flumes were used based on drainage area and general terrain (Figure 1). To measure tile water runoff volume, pre-rated, fiberglass "extra-large," 60-degree, v-throat, trapezoidal flumes were used (Figure 2). The aforementioned basin area sizes were used in all data computations that involved basin area, such as runoff depth (inches) and nutrient loss (pounds per acre).

The surface flumes were attached to treated plywood, installed perpendicular to the flow in the waterway. A wing wall was designed to funnel all surface water through the flumes. The tile flumes were spliced into the existing tile line. Since the flumes were pre-rated, discharge could be directly calculated from the measurements of the water level. Heat

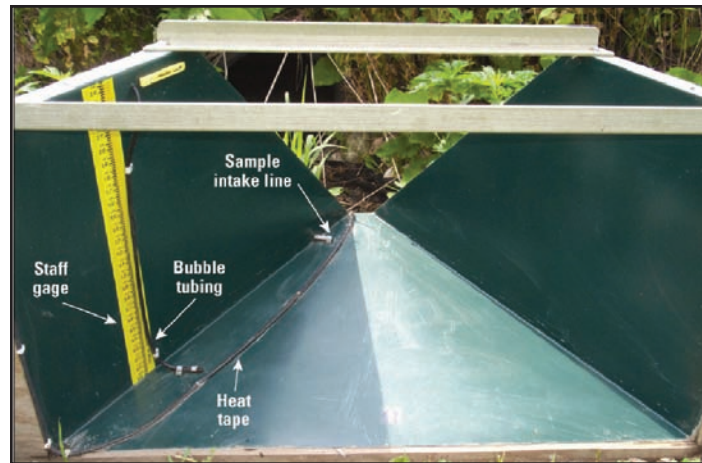


Figure 1. H-flume, bubble and sample lines

tapes were attached to sample lines and to the bottom of the H-flumes to reduce or prevent ice from forming. An automated, refrigerated, 24-bottle ISCO® 3700R sampler was used to collect surface and tile water runoff samples. A datalogger with a custom USGS program was used to remotely read and store sensor data and control station equipment.

Sample collection events

An event was defined as the time from the onset of rainfall- or snowmelt-induced surface runoff or tile line discharge to the time when flow ceased. Sampling frequency during a flow event was controlled and adjusted by the datalogger at each station. Water samples were generally retrieved within 24 hours, and equipment accuracy was checked and noted. Samples were labeled, placed in coolers with ice, and transported to the UW-Stevens Point Water and Environmental Analysis Lab (WEAL) for analysis.

WEAL took photos of each of the sampled events for visual analysis. The lab tested for several parameters. The described equipment and methods proved to collect accurate runoff data in a wide range of conditions and landscape positions. Use of the USGS NWIS (National Water Information System) database assured long-term storage. Environmental conditions were also monitored, both locally at the monitoring sites and at a central weather station.

Maintenance

Maintenance was vital to accurately measure the annual quantity and quality of water passing through the monitoring

stations. During spring, summer, and fall, the stations were periodically maintained by checking equipment mowing around the gauge and along the wing wall. Flumes were cleaned of any debris. The flumes were also surveyed at least twice per year to determine if adjustments to the water level-discharge relation were necessary. During winter, snow and ice were removed from the H-flumes and a trench dug in the snow of the waterway (Figure 3) to prevent backwater conditions. Freezing of any water present within the flume could occur during the night and flow could resume the next day, so frequent visits were necessary prior to expected events. Although some ice removal was required occasionally, winter maintenance of tile stations was less intensive than surface stations.

Discovery Farms monitoring sites utilize either hard-wired, solar, or gasoline-powered generators to power monitoring and sampling equipment. Because of long durations of flow periods combined with low solar recharge in late fall through early spring months, tile monitoring power requirements could not be met by solar power. Two of the three monitoring sites at PPD were supplied by gasoline generator power. The remote start generators were very problematic.

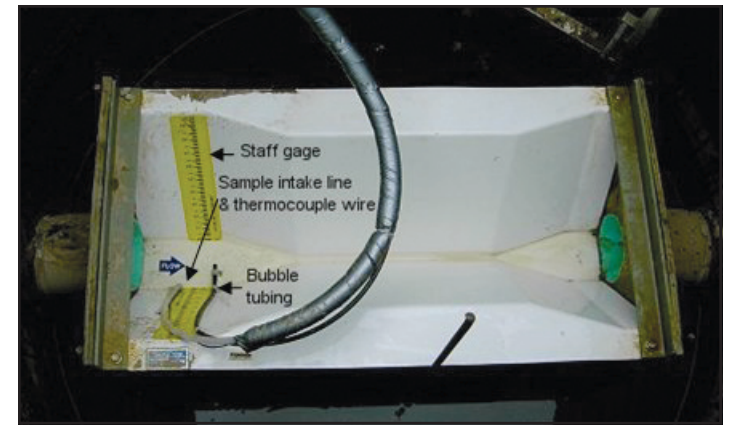


Figure 2. V-Flume, bubble line, sample line and thermocouple wire



Figure 3. Site snow removal

Mechanical problems compounded by difficulty starting during sub-zero temperatures required many site visits to either manually start the generators or fix mechanical problems.

Conclusions from this study

- Year-round (365 day) monitoring is very maintenance intensive, especially during snowmelt conditions. In addition to snow removal prior to snowmelt, freezing conditions often occurred at night during snowmelt. This caused ice build-up in the flume that had to be removed prior to thaw conditions the following day.
- Snow removal prior to snowmelt monitoring should only be done immediately (1-2 days) before snowmelt occurs otherwise blowing snow will likely negate snow removal efforts.
- Solar and battery power were not sufficient at tile monitoring sites. Tile monitoring sites should be powered by hard-wired or generator power. Additionally, many problems were

experienced maintaining the remote start generators used in this study. Future tile monitoring site selection should have hard-wire power capability whenever possible.

Additional Information

For more detailed information on sampling materials and methods, see USGS report: Methods of Data Collection, Sample Processing, and Data Analysis

for Edge-of-Field, Stream Gauging, Subsurface-Tile, and Meteorological Stations at Discovery Farms and Pioneer Farm in Wisconsin, 2001-2007. The full report can be ordered online at

<http://infotrek.er.usgs.gov/pubs/>, or for download at <http://wi.water.usgs.gov/pubs/index.html>.

Water budget at Pagel's Ponderosa Dairy

Surface water monitoring began at Pagel's Ponderosa Dairy (PPD) in November 2003 (P1, P2 & P3) and concluded at the end of October 2008; however, site P2 was concluded in September 2006 because it was not a true representative of the "typical" field in the area. Subsurface tile water monitoring began in December 2004 (P4 & P5) and concluded in October 2008. The data presented in this report is based on our definition of a field year (FY); the 12-month period from October 1 through September 30, which coincides with the crop year. The field year represents the calendar year in which it ends. Crops harvested after September were still tied to the preceding year while other activities done would be associated with the following year's crop.

Frozen precipitation was converted to its water equivalent so both forms of precipitation could be analyzed equally. The general precipitation trends for the study period were slightly lower than the 30-year average of 30.3 inches for Kewaunee County (Figure 1).

Annual water budget

The basin of P1 (surface) and P4 (tile) was 20.5 acres; P2 (surface) was 22.1 acres; and P3 (surface) and P5 (tile) was 13.2 acres. Total runoff recorded in a basin was divided by basin size to calculate inches of runoff per acre, so the data would be comparable. Conceptually, this number is the depth of water in the basin if the total runoff volume were to be evenly put on the land surface. Runoff in each of these basins was then averaged to show a farm average, also used in this fact sheet's discussions.

In field year 2004, 5.6 inches of total surface water runoff was measured (Figure 1). As annotated by asterisks on the graph, tile drainage was not monitored and the surface water site was not operational until November so October 2003 data was missed. This equates to 16% of the 36.0 inches of precipitation that ran off of the surface.

Roughly 92% of the precipitation during this year fell as rain. Of the total runoff, 47% occurred while the soil was frozen.

In FY2005, 2.9 inches total of surface water runoff and 2.4 inches of total tile flow were measured, for a combined total of 5.3 inches or 17% of the total precipitation that fell (Figure 1). Noted again by asterisks, tile monitoring began in December, thus missing any subsurface runoff that would have occurred in October, November, and part of December. Of the 5.3 inches of total flow, 55% of the measured flow was surface water runoff and 45% was tile flow. Of the total flow, 89% was during frozen ground conditions. Of the total surface water runoff, 97% occurred on frozen ground and 78% of the tile flow was during frozen ground conditions.

In FY2006, 13.0 inches of total water leaving the farm was measured, which accounted for 45% of the 29.1 inches of measured annual precipitation (Figure 1). Tile flow made up 78% of the total flow, with the remaining 22% occurring as surface water runoff. Of the total flow, 53% was during non-frozen ground conditions. Roughly 61% and 50% of surface runoff and tile line flow, respectively, occurred when the ground was not frozen.

In FY2007, 5.3 inches of total water leaving the farm was measured, which equates to 23% of total precipitation (measured at 22.8 inches). Approximately

57% of the total water leaving the farm was from tile line flow.

Of the total runoff, 68% was during frozen ground conditions. Of the total surface water runoff, 97% occurred during frozen ground conditions,

while 46% of the total tile flow occurred during frozen ground conditions.

In FY2008, 12.4 inches of total flow was measured. This was 44% of the 28.1 inches of total precipitation. Roughly 82% of the total flow was from tile lines. Of the total runoff, 55% was during frozen ground conditions, this included 34% of the total surface runoff and 59% of the total tile flow.

When five years of surface water and four years of tile line data are averaged by month, data reveals that the highest runoff month for both surface and tile flow is March, during the snowmelt

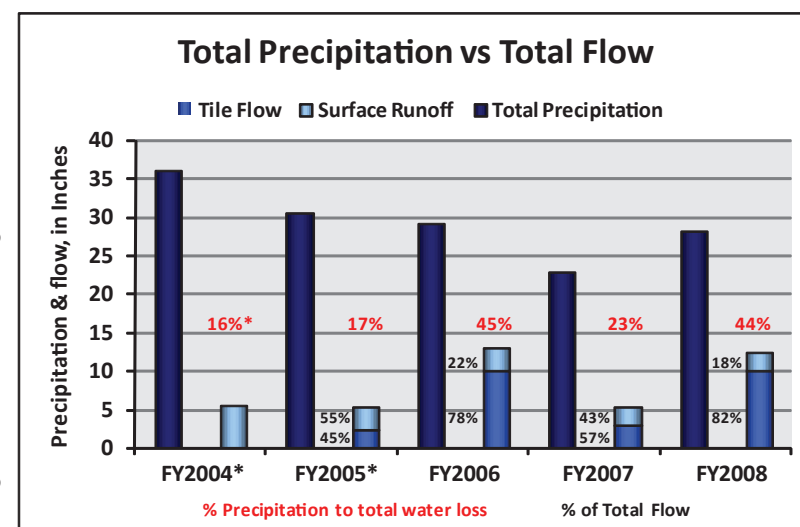


Figure 1. Precipitation versus total water leaving the farm via surface and tile

period (Figure 2). The high moisture content of the soil after this period and subsequent spring rains also result in high tile flow in April, May and June. Surprisingly, surface runoff during this monitoring period (2004-2008) was minimal in April but was more significant in May and June. Late fall and early winter precipitation and snowmelt events result in notable tile flow from November through February, with more than half (56%) of the tile flow occurring during frozen ground conditions (Figure 3). Additionally, rain-on-frozen-ground and snowmelt events also result in more than half (60%) of all surface water losses.

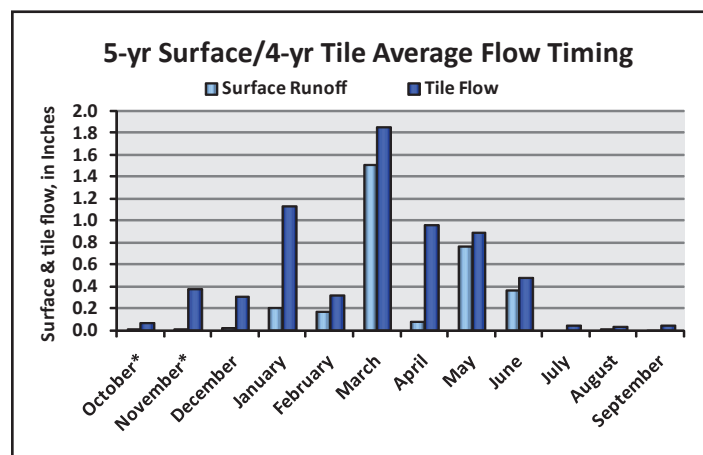


Figure 2. Farm average surface runoff and tile flow timing

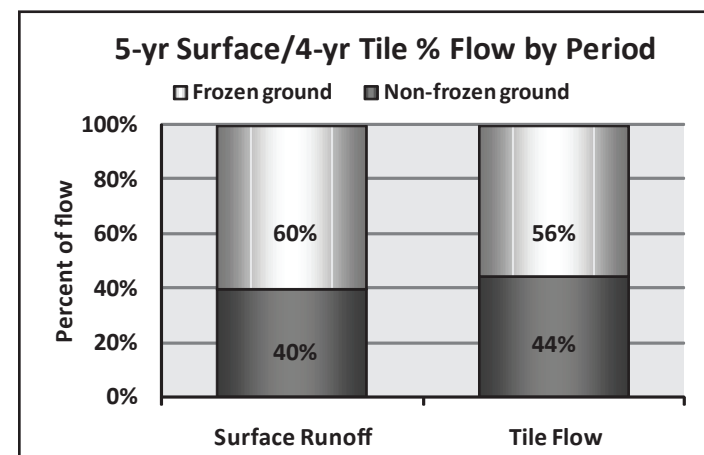


Figure 3. Percent of total water leaving the farm by period

Conclusions from this study

- The general precipitation trends for the study period were slightly lower than the 30-year average.
- Under this farming system, location and management, between 16%

and 45% of total precipitation was monitored as runoff during the five year monitoring period.

- The highest average monthly volume for both surface water and tile drainage was March. A majority of

the surface water runoff occurs in the spring. More than half of the five-year average surface water runoff occurred under frozen ground conditions.

- Highest tile drainage flow occurs mainly in the spring. More than

half of the four-year average tile flow occurred under frozen ground conditions.

Surface water



Figure 1. Surface monitored basins

Surface water monitoring

Year-round surface water monitoring at Pagel's Ponderosa Dairy (PPD) lasted for five years (started in FY2004 and ended at the end of FY2008). Roughly a month of monitoring in the first year was missed because of the time equipment was installed (annotated by an asterisk in graphs). The data presented in this report is based on our definition of a "field year", which is the 12-month period from October 1 through September 30. The field year represents the calendar year in which it ends. Surface water monitoring occurred in three sub-basins bound entirely by PPD managed land. Sites were identified as P1, P2, and P3 with monitored surface areas of 20.5, 22.1, and 13.2 acres, respectively (Figure 1). Total surface runoff recorded in these areas was divided by the basin size to calculate inches of runoff per acre, so the data would be comparable.

Basin comparison

Figure 2 shows that over the five-year study period, all three basins had very similar annual runoff patterns. Slightly higher annual runoff was observed in P3 in all years. It is suspected that the combination of longer slope lengths and a lower number of closed depression areas (bowls) in the monitored area of

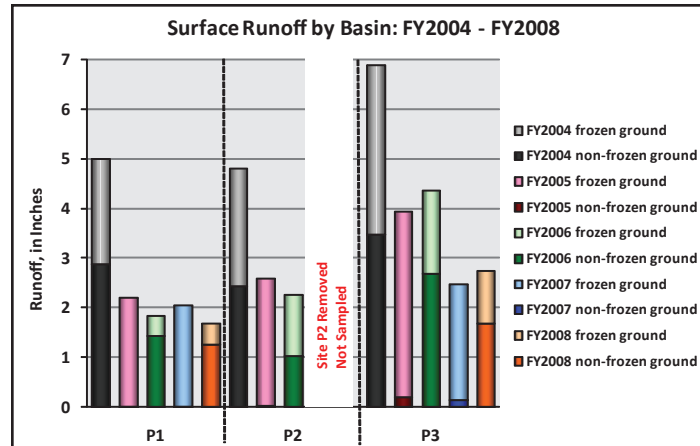


Figure 2. Annual surface water runoff timing by basin

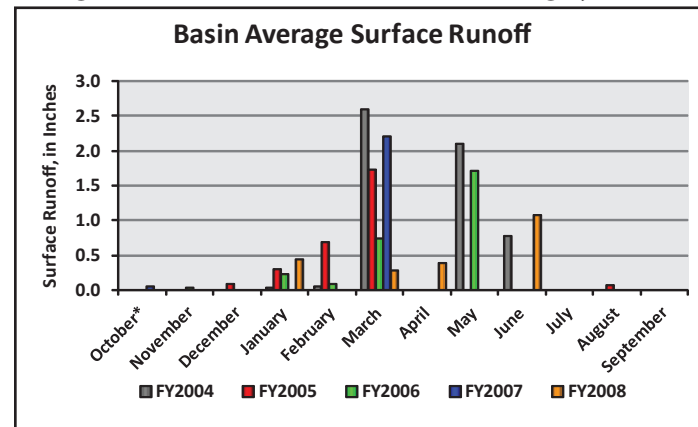


Figure 4. Monthly farm average surface runoff

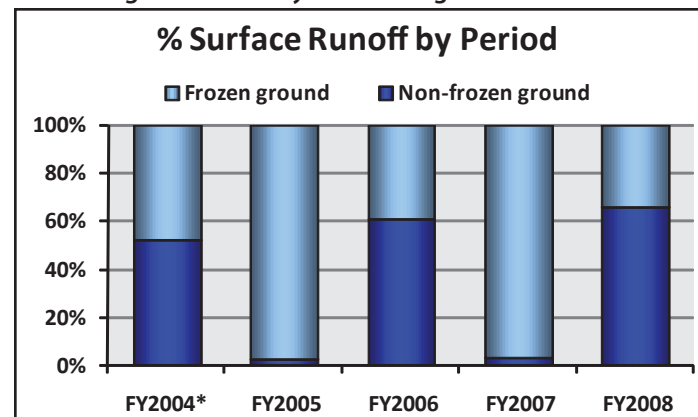


Figure 6. Yearly runoff timing for surface water

P3 resulted in higher runoff volumes compared to the other basins.

Timing of surface water runoff

The timing of precipitation events combined with the timing of snow melt

play a major role in determining the potential for surface water runoff events. Figures 3 and 4 show the importance of precipitation timing with respect to runoff.

Data from FY2004, show higher than

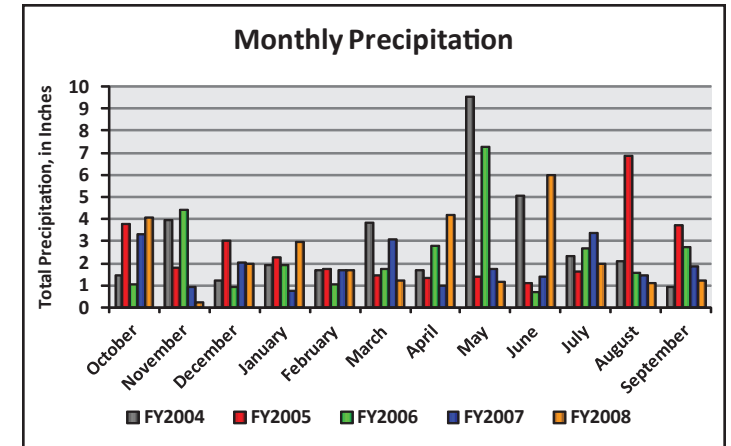


Figure 3. Monthly precipitation at PPD

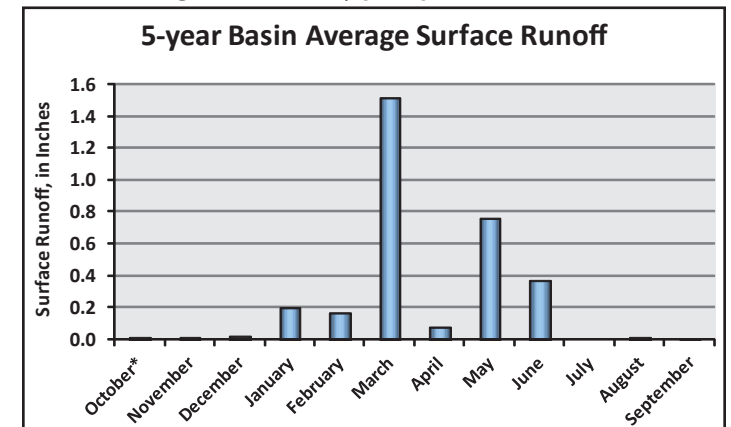


Figure 5. Monthly 5-year farm average surface runoff

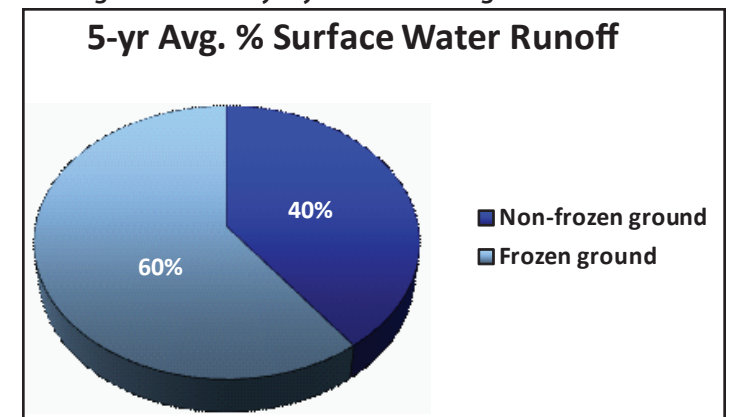


Figure 7. Percent runoff by period

average precipitation in the months of March, May and June (Figures 3 & 4). Large surface runoff amounts were observed during these months. Rain events concurrent with snow melt in

March resulted in the highest annual runoff month in most years (Figure 4) and contributed 50% of the total surface runoff of the 5-year monitoring period (Figure 5). The volume of water on the landscape from both rain and snow melt combined with decreased infiltration into frozen soils caused high runoff during March. Surface runoff during May and June is likely driven by rain on high moisture content soils.

One final point worthy of note in the precipitation data can be found at the

end of FY2005 identified by the red bars on the right-hand side of figures 3 and 4. Because of the droughty conditions during the summer of 2005, large precipitation events in both August and September resulted in almost no runoff.

Runoff data from PPD also showed the importance of frozen versus non-frozen ground in terms of the potential for surface water runoff. The vast majority of surface runoff came during frozen ground conditions in both FY2005 and FY2007 with a high of 99.9% at P1 in

FY2007 (Figure 6). The five-year average of all surface sites resulted in 60% of surface water runoff occurring during frozen ground conditions (Figure 7).

Conclusions from this study

- All three basins monitored had similar annual surface runoff patterns. Slightly higher annual surface runoff yields were observed in P3. It is hypothesized that the combination of longer slope lengths and lower occurrence of closed depression areas

(bowls) in the monitored area of P3 resulted in higher runoff volumes as compared to P1 and P2.

- Periods with high potential of surface water runoff were evident in this study. Half of all total runoff occurred in March and 97% of total runoff occurred from January through June.
- The frozen ground period accounted for 60% of total surface runoff monitored with individual basin runoff values near 100% for field years 2005 and 2007.

Tile drainage

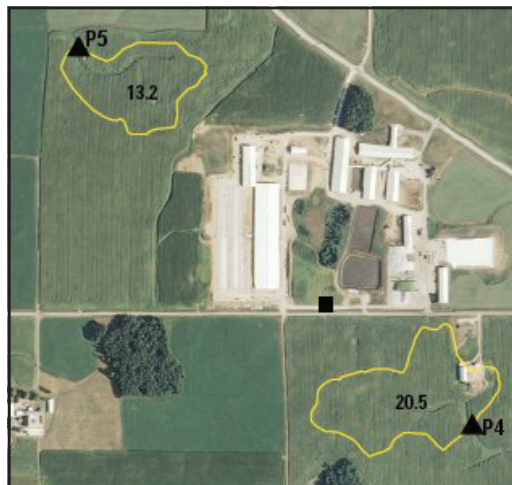


Figure 1. Tile monitoring

Tile water monitoring

Tile line monitoring at PPD lasted for four years (began in FY2005 and ended at the end of FY 2008) and occurred year-round. Roughly two months of monitoring in the first year were missed because of equipment installation (this missing data is annotated by an asterisk in the graphs). For purposes of consistent organization, the data presented in this report is based on our definition of a "field year," which is the 12-month period from October 1 through September 30. The field year always represents the calendar year in which it ends. The monitored areas, P4 and P5, were 20.5 and 13.2 acres, respectively (Figure 1). Total flow recorded in these areas was divided by the basin size to calculate inches of flow per acre.

Basin comparison

Analysis of the annual tile line flow for each basin in figure 2 shows that over the four year study period, both basins had very similar annual flow patterns. Slightly higher annual flow was observed at P4 in FY2005 and FY2007. Conversely, slightly higher annual flow was observed at P5 in FY2006 and FY2008. Additional

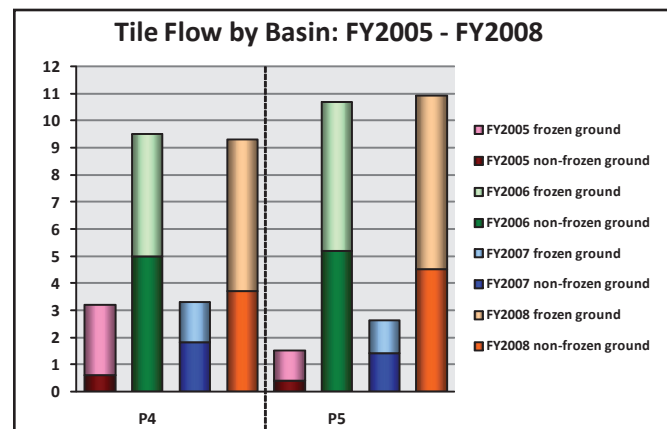


Figure 2. Annual tile line flow timing by basin

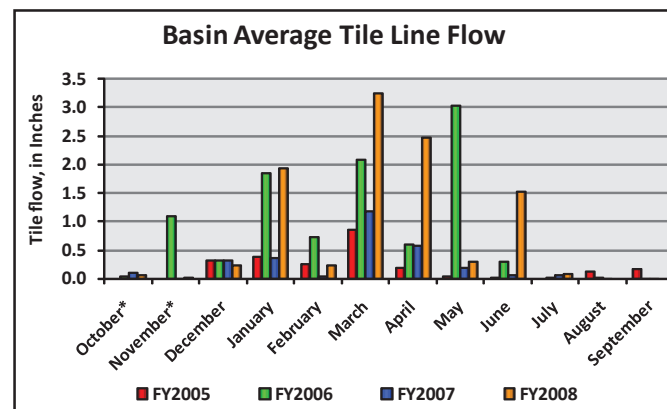


Figure 4. Monthly farm average tile flow

observation of the tile flow periods in figure 4 show very close flow timing between P4 and P5. Although flow timing was very similar, flow volumes were different based on the timing of precipitation between the two basins.

Timing of tile flow

Figures 3 and 4 show the influence of precipitation events combined with timing of snow melt in respect to tile line flow. Note in the precipitation data at the end of FY2005 (identified by the red on the right-hand side of figures 3 and 4), that because of the droughty conditions during the summer of 2005, large

precipitation events in both August and September resulted in almost no flow.

The duration of flow observed from December through June was unexpected. The highest average month (March) occurs when the ground is often partially frozen and the second highest average month (January) occurs when the ground is almost always frozen (Figure 5).

Analysis of flow potential during frozen versus non-frozen ground periods show that 46% to 78% of the tile line flow occurred under frozen ground conditions (Figure 6). Over the

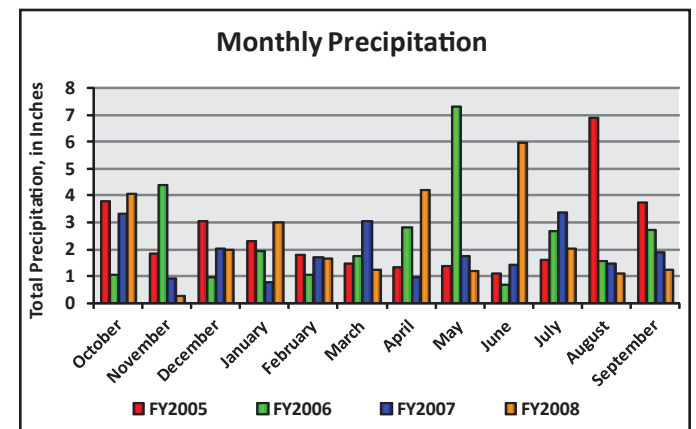


Figure 3. Monthly precipitation at PPD

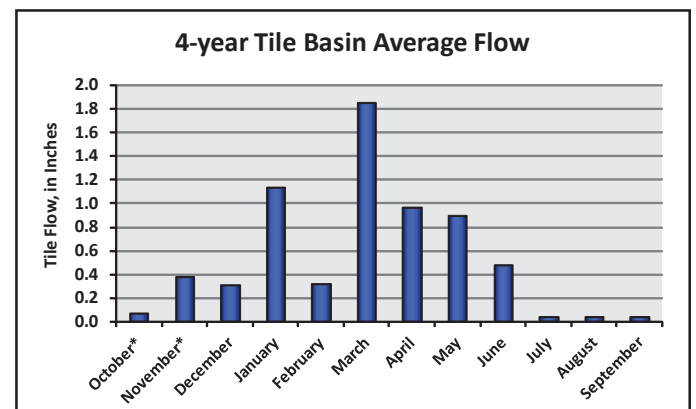


Figure 5. Monthly 4-year farm average tile flow

4-year study, approximately 56% of tile flow occurred during frozen ground conditions (Figure 7). It is believed that a combination of slow drainage of water within the soil, combined with preferential flow through macropores (worm holes, soil cracks, decayed root channels, etc.) during rain on frozen ground and snowmelt events, contribute to flow during these frozen periods.

Conclusions from this study

- Both tile drainage basins monitored had very similar tile line flow patterns. Slightly higher annual tile flow was

observed at P4 in FY2005 and FY2007. Conversely, slightly higher annual tile flow was observed at P5 in FY2006 and FY2008.

- Unexpected tile flow was observed from December through June. In all four years of monitoring, tile flow occurred to some extent from December to June. The highest average month (March) occurs when the ground is often partially frozen and the second highest average month (January) occurs when the ground is almost always frozen.
- The frozen ground period accounted for 56% of tile flow monitored with annual basin flow values between 46% and 78%.

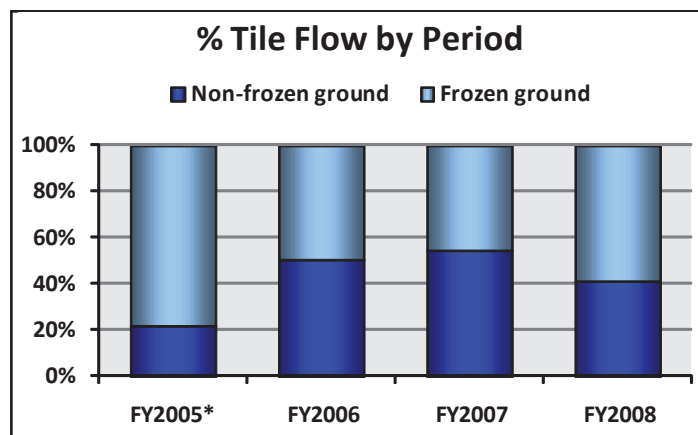


Figure 6. Yearly timing for tile flow

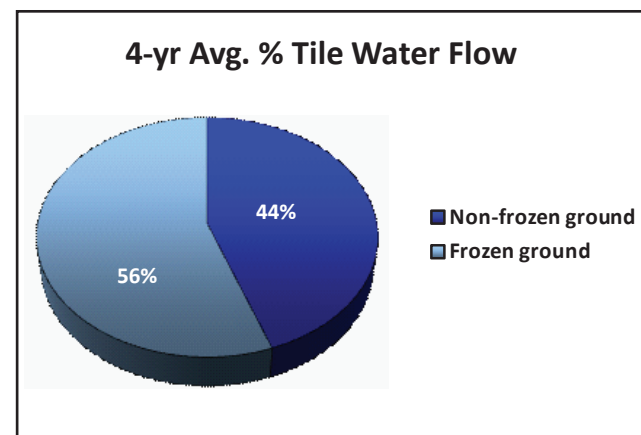


Figure 7. Percent tile flow by period

Surface and tile drainage comparison

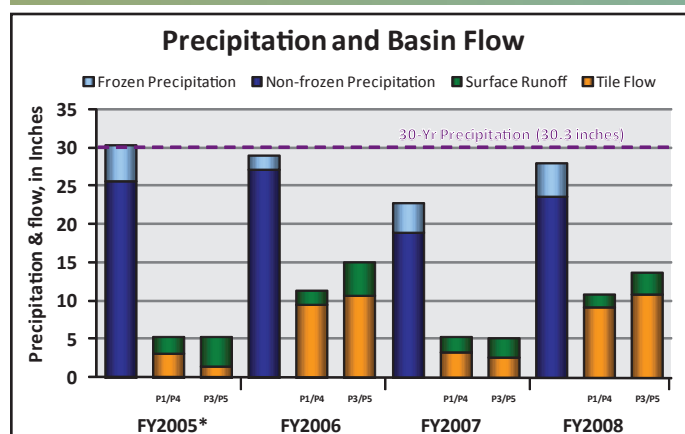


Figure 1. Yearly average surface and tile flow over a 4-year period

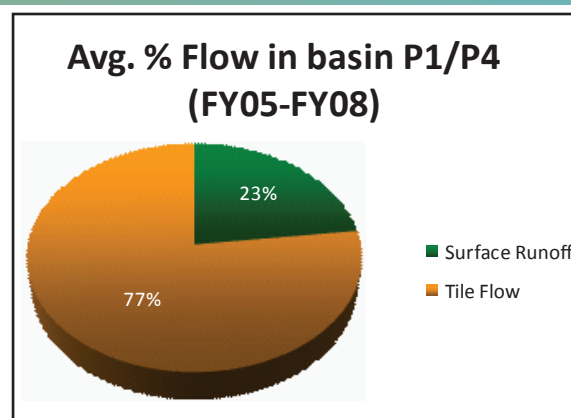


Figure 2. Average percent flow in basin P1/P4

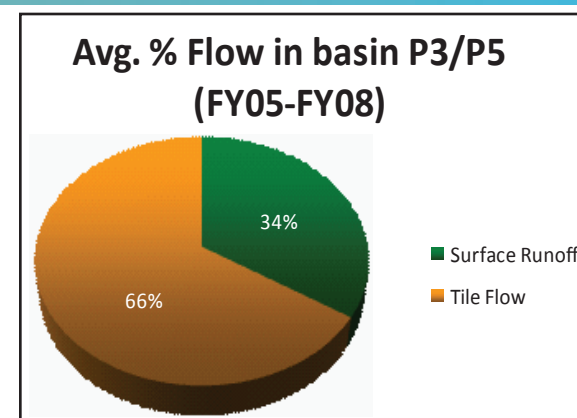


Figure 3. Average percent flow at P3/P5

Surface and tile water monitoring

Concurrent surface water and tile line monitoring began in FY2005 and ended at the end of FY2008 and occurred year-round. Roughly two months of tile drainage monitoring in the first year were missed because of the time equipment was installed (annotated by an asterisk). The data is based on our definition of a "field year", which is the 12-month period from October 1 through September 30. The field year always represents the calendar year in which it ends, which means that the field year ending September 30, 2007 is the 2007 field year (FY07). Surface and tile line monitoring occurred in two basins. Sites were identified as P1 (surface) /P4 (tile) and P3 (surface) / P5 (tile).

Basin comparison

The general precipitation trends for the study period were at or below the 30-year average of 30.3 inches for Kewaunee County for all four years of the study (Figure 1). During the four year

study period, both basins had very similar annual flow patterns. For surface runoff, P3 had higher runoff than P1 in all years. From a tile flow standpoint, slightly higher annual flow was observed at P4 in FY2005 and FY2007. Conversely, slightly higher annual flow was observed at P5 in FY2006 and FY2008.

Site P1/P4 had a higher percentage of total flow from the basin in tile line flow as compared to surface runoff than did site P3/P5 (Figures 2 & 3). This is likely because of factors such as: closed depression areas, slope lengths, preferential flow, and possible tile blowouts that caused increased tile flow at site P1/P4.

Timing of surface versus tile flow

In the winter of 2004/2005, rain on snow in January caused ice crusting on the soil over an inch deep in some areas. The combination of subsequent cold temperatures and lack of insulating snow on the surface of the land caused frost to reach deep depths in the soil with

subsequent snow accumulation on top.

As air temperatures began to rise above freezing, a small amount of tile flow began at site P1/P4 on March 25th, 2005, with more significant tile flow the following day. There was still over a foot of frost in the ground at this time. On March 27th, surface water runoff also began to flow. It was hypothesized that as air temperatures began to rise above freezing, it began to melt the ice plugs that were in the preferential flow paths; heat from below caused melting from the bottom and the warm air caused surface melting. Additionally, air flow through the tile lines accelerate the thawing of soil directly above the tile. Once the ice plugs were removed, accumulated water at the surface infiltrated into the tile lines before there was enough water to initiate surface water flow. Therefore, snowmelt water can move through frozen soil if preferential flow pathways are present. Although surface water flow was observed before tile flow at site P3/P5, tile flow still occurred while significant

frost was in the soil (Figure 4).

In addition to the frozen ground period, tile flow was observed before surface flow during the non-frozen ground period. In 2006, a large precipitation event beginning on May 11th caused tile flow to occur before surface flow at site P1/P4. A similar response was seen in both surface and tile flow timings with subsequent precipitation events in May. This exhibits the strong connection between the surface and tile line water because of preferential flow pathways or potential tile blowouts (none observed upstream during periodic inspection).

When looking at the 4-year average of flow on a monthly basis, it can be noted that tile line flow was higher than surface flow in every month of the year (Figure 5). The highest month (March) for both surface and tile flow occurs when the ground is usually frozen and air temperatures begin to rise above freezing, causing water from snowmelt to gather and begin flowing.

Conclusions from this study

- Surface and tile line flow from the two basins monitored had very similar flow timing and volume in the four years monitored. Basin P1 (surface) / P4 (tile) had a slightly higher tile flow. It is likely that closed depression areas, tile blowouts or increased preferential flow paths caused earlier flow at P4.
- Basin P1/P4 exhibited tile flow before surface water flow in both frozen and non-frozen ground periods. A rapid response to snowmelt and precipitation events in tile flow were observed in both basins. The similar timing of surface and tile flow is attributed to preferential flow through macropores and possible tile blowouts. No tile blowouts were observed in the monitored basins, but

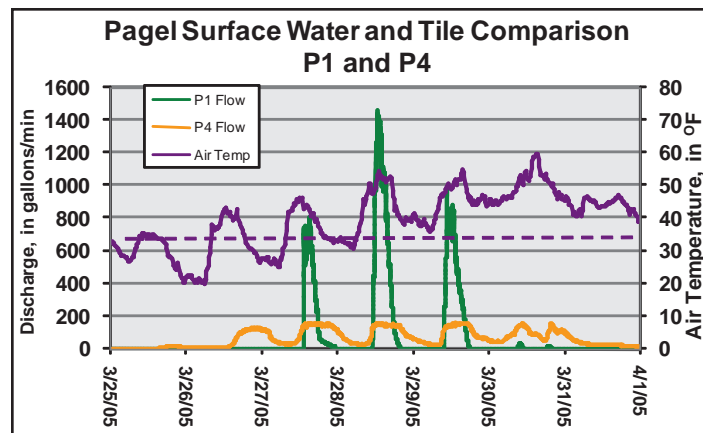


Figure 4. Surface and tile flow during snowmelt at P1/P4

- may have existed.
- Monthly averages over the four year monitoring period show that tile drainage had higher volumes when

compared to surface runoff in every month of the year. March was the highest average month for both surface and tile drainage, occurring

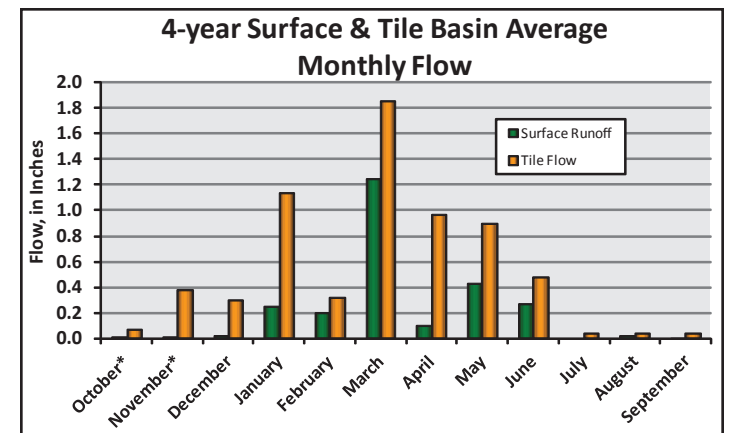


Figure 5. Monthly average surface and tile flow

at a time when the ground is often partially frozen and snow is melting.

Sediment loss potential at Pagel's Ponderosa Dairy

Surface runoff and tile line flow was monitored year-round at PPD in three basins managed entirely by PPD. Surface water monitoring began in field year 2004 at three locations (P1, P2, & P3) and tile line monitoring started in 2005 in two basins (P4 & P5). Research ended at the end of field year 2008 for all basins except for P2, which ended in 2006 because it was "non-typical" in terms of fields in this region. Roughly one month of surface and two months of tile line monitoring were missed because of the installation of equipment (missing data is annotated by an asterisk in graphs). The monitored surface area of P1/P4 was 20.5 acres, P2 was 22.1 acres, and P3/P5 was 13.2 acres. Total sediment loss recorded in these areas was divided by the basin size to calculate pounds of sediment loss per acre, so the data would be comparable. To be consistent, the data presented in this brief is based on our definition of a "field year", which is the 12-month period from October 1 through September 30. The field year always represents the calendar year in which it ends, meaning that field year 2007 ended on September 30, 2007 (FY07).

Surface sediment loss

The 5-year average surface sediment loss for all basins was 740 lbs/acre/year with a large variation in annual sediment loss. The relatively low loss in FY04, even though significant runoff took place, can be explained by the protective cover of the alfalfa crop growing in the field in all three basins (Figure 1). Protection by the

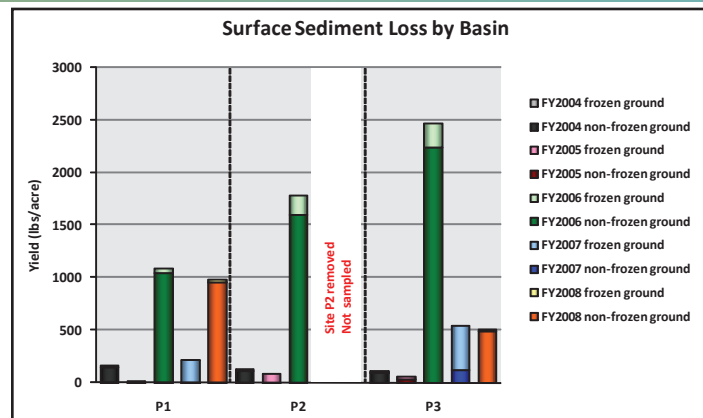


Figure 1. Surface sediment loss in each basin by field year

alfalfa in late fall and early winter of FY05, combined with extreme drought conditions in the summer resulted in very low sediment losses in FY05.

FY06 had the highest annual sediment loss caused by heavy May rains on planted corn fields resulting in high runoff (Figure 1). Heavy rains were extreme and produced prolonged saturated conditions. A majority of the corn had to be replanted in June because of the saturated conditions.

Sediment loss in FY07 was below average in both basins likely a result of low total precipitation and resulting runoff. Variances in surface sediment loss at P1 compared to P3 in FY08 (Figure 3) is likely a result of the different tillage practices in each basin.

Tile sediment loss

The combined average sediment loss

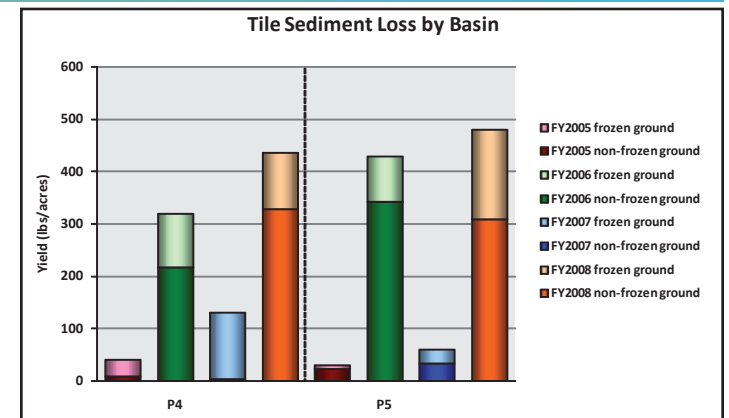


Figure 2. Tile line sediment loss in each basin by field year

through the tile lines during the 4-year monitoring period was 240 pound/acre/year. Analysis of yearly basin sediment loss data shows large variation, however, the major factor appears to be the volume of flow. Comparisons of annual flow to total sediment loss for each basin and year (Figure 4) appears to be almost a perfect match. This implies that as water moves through the soil, it carries sediment through both the preferential flow paths and soil profile. Sediment loss at PPD is typical to what has been seen on other Discovery Farm sites.

Timing of surface sediment loss

As shown in figure 3, the highest sediment loss occurred in May, although significant loss also occurred in March and June. Note the high level of surface runoff in March with resulting low sediment loss. Though the highest volumes of surface runoff occurred in

March, sediment loss was moderate because of the frozen soil. Frozen soil conditions are also a primary reason that sediment loss was low in January and February. The non-frozen conditions and lack of vegetative cover were the main factors contributing to sediment loss in May and June.

Surface runoff versus tile line flow comparison

To assess the relative sediment loss in tiled agricultural fields, total sediment loss in tile (P4 & P5) was compared to total surface sediment loss (P1 & P3). As seen in figure 4, tile sediment loss was 25% the combined total loss. While some sediment is lost via tile, surface loss is still the dominant pathway.

Conclusions

- Average sediment loss for all surface basins during the monitoring period was 740 pound/acre/year, with large

variations in sediment loss between basins and years. Vegetative cover, tillage, and surface residue are believed to be contributing factors to the variation in loss.

- Average sediment loss for all tile basins during the monitoring period was 240 pound/acre/year, with large annual variations. Total yearly sediment loss closely mirrored annual water flow indicating that the majority of sediment delivery is occurring through preferential flow paths.
- Approximately 84% of all surface sediment and 66% of all tile sediment lost during the monitoring period for all basins came from non-frozen ground; the remaining came during frozen ground. Analysis of sediment loss shows that a majority of frozen ground sediment loss happens in

the early spring of the year when the upper few inches of soil are beginning to thaw and the ground beneath is still frozen.

- May was the most dominant month for surface sediment loss. Significant losses were also noted in March and June. Even though surface runoff volumes were the highest in March, the surface sediment loss was moderate because

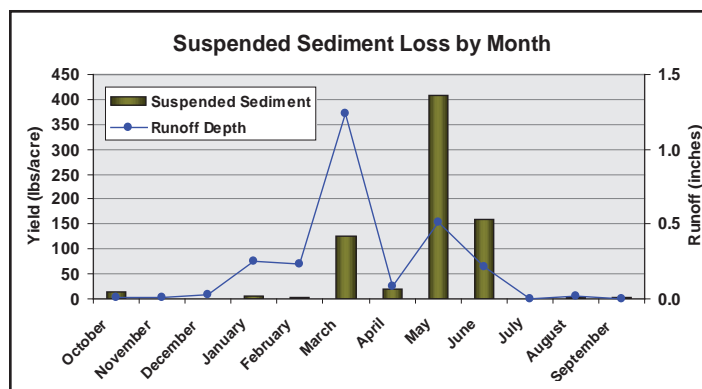


Figure 3. Monthly surface sediment loss FY05-FY08

of the frozen soil condition during portions of March. Rain events during non-frozen conditions and lack of vegetative cover were the main factors contributing to surface sediment loss in May and June.

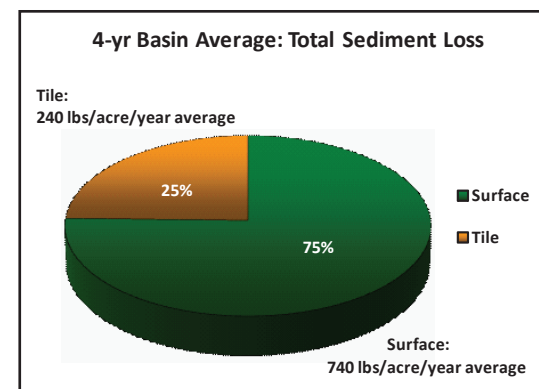


Figure 4. 4-year average sediment loss

- Surface sediment loss (75%) from fields was higher than tile line sediment loss (25%).

Phosphorus loss potential at Pagel's Ponderosa Dairy

Surface runoff and tile line flow was monitored year-round at PPD in three basins managed entirely by PPD. Surface water monitoring began in field year 2004 at three locations (P1, P2, & P3) and tile line monitoring started in 2005 in two basins (P4 & P5). Research ended at the end of field year 2008 for all basins except for P2, which ended in 2006 because it was "non-typical" in terms of fields in this region. Roughly one month of surface and two months of tile line monitoring were missed because of the installation of equipment (missing data is annotated by an asterisk in graphs). The monitored surface area of P1/P4 was 20.5 acres, P2 was 22.1 acres, and P3/P5 was 13.2 acres. Total phosphorus loss recorded in these areas was divided by the basin size to calculate pounds of sediment loss per acre, so the data would be comparable. To be consistent, the data presented in this brief is based on our definition of a "field year", which is the 12-month period from October 1 through September 30. The field year always represents the calendar year in which it ends, meaning that field year 2007 ended on September 30, 2007 (FY07).

Surface phosphorus loss

The average total phosphorus (TP) loss for all surface basins during the monitoring period was 1.8 lbs/acre/year with large annual variations in TP loss; yearly trends were similar to sediment. Low TP loss occurred in FY04 at basins P2 and P3 likely because of the growing

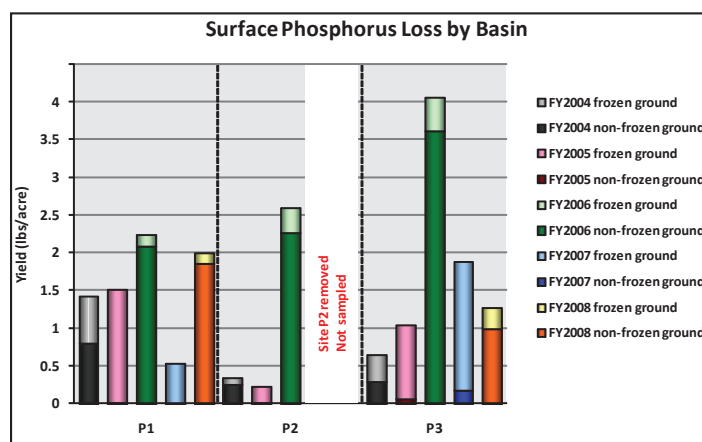


Figure 1. Surface total phosphorus loss in each basin

alfalfa crop in both basins (Figure 1). TP loss for FY05 was similar to FY04. The crop in all basins switched from alfalfa to corn, higher TP loss in basin P1 is likely the result of a few loads of sand-laden manure applied just prior and just subsequent to freezing. It is hypothesized that the snow cover enhanced the TP loss from a portion of this manure.

Field year 2006 had the highest TP loss in all basins during the monitoring period (Figure 1). Heavy May rains caused significant runoff and corresponding TP loss in mid and late May. TP loss was low in basin P1, but more substantial in basin P3 in FY07 (Figure 1) because of a late surface application of manure on frozen/snow covered ground as requested by the Discovery Farms Program to determine the effect of a surface application on

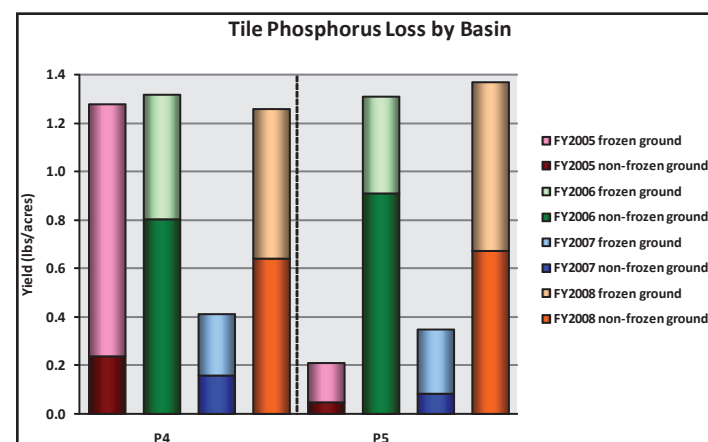


Figure 2. Tile line drainage TP loss in each basin by FY

frozen ground. The intent of the trial was to apply the manure on frozen ground without snow cover, but a storm established snow cover before the application was made. TP loss in surface runoff was unusually high in P1 as compared to P3 in FY08 (Figure 1) attributed to differences in manure applications and tillage practices performed in the two basins.

Tile phosphorus loss

The average TP loss for all tile basins during the monitoring period was 0.9 lbs/acre/year, exhibiting large annual variations in TP. The major contributing factor for TP loss in tile appears to be flow volume. The comparison of the annual tile line flow and total TP loss for each corresponding basin and year (Figure 2) appears to be a near

match with the exception of P4 in FY05 attributed to a manure application on frozen soil. This relationship indicates that as water moves through the soil, it carries phosphorus with it through both the preferential flow paths and soil profile. TP loss at PPD is typical to what is seen at other Discovery Farm sites.

Timing of surface TP loss

As shown in figure 3, May is the dominant month for TP loss. Significant TP loss also occurred in March and June. The low flow volumes in April produced low TP loss. Though runoff volumes were highest in March, TP loss was moderate because of frozen conditions. Frozen soil conditions are also the main reason that TP loss was low in January and February.

Surface versus tile comparison

To assess the relative TP loss in tiled

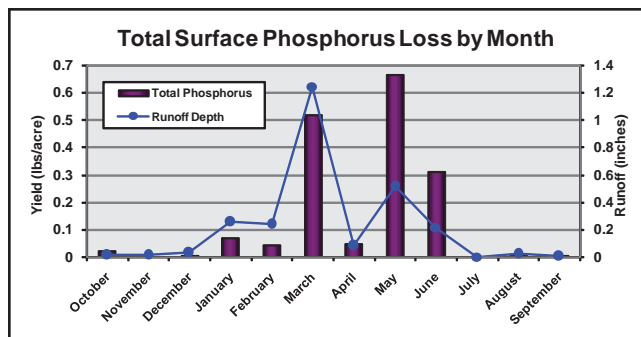


Figure 3. Average surface TP loss by month FY05-FY08

agricultural fields, the total phosphorus loss in tile (P4 & P5) was compared to surface phosphorus loss. As seen in figure 4, the tile TP loss was 34% of the combined total loss. While some phosphorus is lost via tile, surface loss is the most dominant delivery pathway.

Phosphorus speciation

The form of phosphorus leaving the field is an important aspect of understanding the potential for phosphorus loss in agricultural systems.

A species comparison of surface and tile losses can be found in figure 5. A larger percentage of TP was lost as particulate phosphorus from the surface (73%) than was lost from tile drainage (46%).

Conclusions

- Average TP loss for all surface basins during the monitoring period was 1.8 pound/acre/year and tile basins was 0.9 pound/acre/year with large

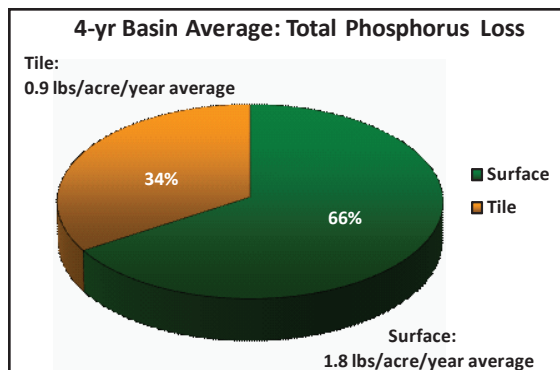


Figure 4. 4-year average total phosphorus loss in surface and tile

- variations in TP losses.
- Approximately 63% of all surface TP and 48% of all tile TP lost during the monitoring period for all basins came from non-frozen ground; the remaining from frozen.
- May was the most dominant month for surface TP loss. Significant TP loss also noted in March and June.
- Surface TP loss (66% of total) from

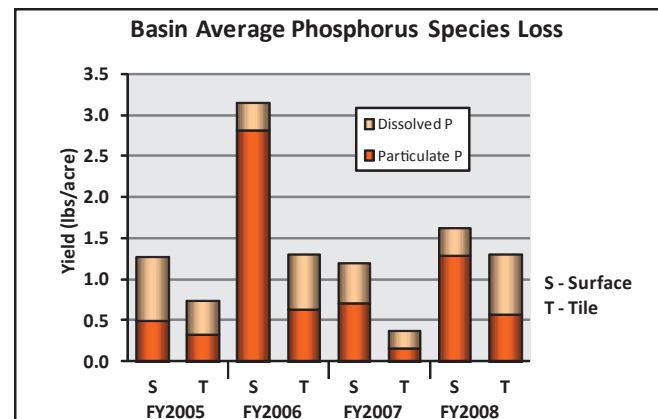


Figure 5. Basin average phosphorus loss in surface and tile

- fields was higher than tile line TP loss (34% of total).
- A higher percentage of TP was lost from the surface in the particulate form (73%); conversely, a higher percentage of TP was lost from tile drainage in the dissolved form (54%)

Nitrogen loss potential at Pagel's Ponderosa Dairy

Surface runoff and tile line flow was monitored year-round at PPD in three basins managed entirely by PPD. Surface water monitoring began in field year 2004 at three locations (P1, P2, & P3) and tile line monitoring started in 2005 in two basins (P4 & P5). Research ended at the end of field year 2008 for all basins except for P2, which ended in 2006 because it was "non-typical" in terms of fields in this region. Roughly one month of surface and two months of tile line monitoring were missed because of the installation of equipment (missing data is annotated by an asterisk in graphs). The monitored surface area of P1/P4 was 20.5 acres, P2 was 22.1 acres, and P3/P5 was 13.2 acres. Total nitrogen loss recorded in these areas was divided by the basin size to calculate pounds of sediment loss per acre, so the data would be comparable. To be consistent, the data presented in this brief is based on our definition of a "field year", which is the 12-month period from October 1 through September 30. The field year always represents the calendar year in which it ends, meaning that field year 2007 ended on September 30, 2007 (FY07).

Surface nitrogen loss

The total average nitrogen loss for all surface basins was 13 lbs/acre/year

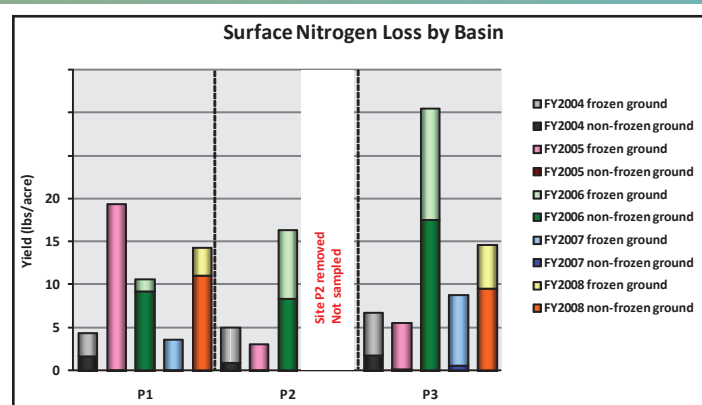


Figure 1. Surface runoff nitrogen loss in each basin

with annual variations. The relatively low surface nitrogen loss in FY04, even though considerable runoff occurred, is likely because of the protective cover of the growing alfalfa crop in all three basins protecting the soil surface and utilizing soil nitrogen (Figure 1). Nitrogen loss for FY05 was similar to FY04, though the crop in all basins switched from alfalfa to corn. Higher nitrogen loss in basin P1 is likely the result of a few loads of sand-laden manure applied just prior and subsequent to freezing (Figure 1). It is hypothesized that the snow cover enhanced the nitrogen loss from a portion of this manure.

Field year 2006 had more surface nitrogen loss than FY05 in two

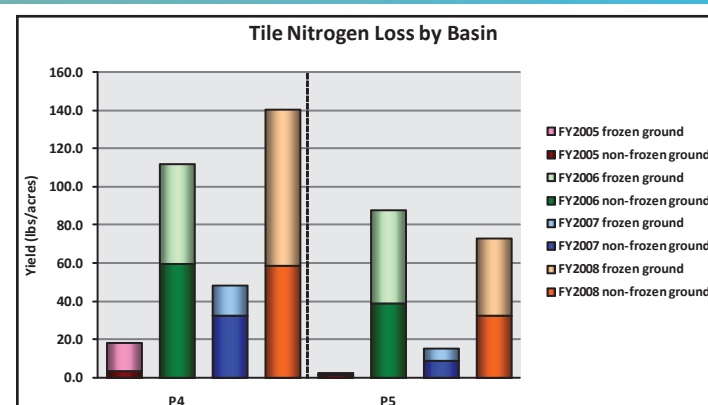


Figure 2. Tile drainage nitrogen loss in each basin

basins (Figure 1). Heavy rains caused considerable surface runoff and nitrogen loss in mid and late May. Nitrogen loss was low in basin P1, but more substantial in basin P3 in FY07 (Figure 1) because of a late surface application of manure on frozen/snow covered ground as requested by the Discovery Farms Program to determine the effect of a surface application on frozen ground. The intent of the trial was to apply the manure on frozen ground without snow cover, but a storm established snow cover before the application was made. Nitrogen loss in surface runoff was similar in P1 as compared to P3 in FY08 (Figure 1).

Tile nitrogen loss

The total average nitrogen loss for all tile basins during the monitoring period was 62 lbs/acre/year, exhibiting substantial variation in annual nitrogen loss. The major contributing factors for nitrogen loss in tile appear to be flow volume and nutrient application rate. Comparison of the annual tile flow to the total nitrogen loss for each corresponding basin shows that in years with high flow volumes (FY06 and FY08), nitrogen loss in tile was higher than years with lower flows. In the four years of monitoring, basin P4 always had higher rates of nitrogen applied compared to P5; and nitrogen losses were always higher at P4.

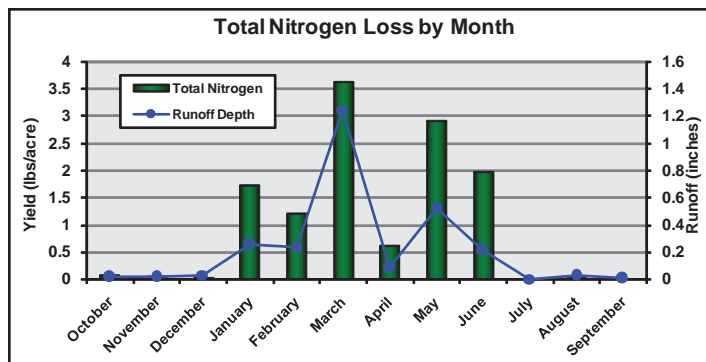


Figure 3. Average surface nitrogen loss by month FY05-08

Timing of surface nitrogen loss

Unlike surface sediment and phosphorus loss which were predominant in May, the dominant month for surface nitrogen loss is March (Figure 3). The comparison of total surface nitrogen loss to surface runoff volume. Although the speciation of nitrogen varied distinctly during the frozen versus non-frozen period, the total surface nitrogen loss seems to be dominantly controlled by volume of surface runoff.

Surface versus tile comparison

To assess the relative loss of nitrogen in tile drained landscapes, the total tile

nitrogen losses (P4 & P5) were compared against surface losses (P1 & P3). As seen in figure 4, tile nitrogen losses account for 82% of the total losses. Although some nitrogen is lost from the surface, tile loss is the dominant delivery pathway.

Nitrogen speciation

A species comparison of surface and tile nitrogen losses can be found in figure 5 (Total Kjeldahl Nitrogen [TKN] the summation of both ammonium and organic nitrogen). Most nitrogen was lost in the nitrate form in both the surface (45%) and tile drainage (93%).

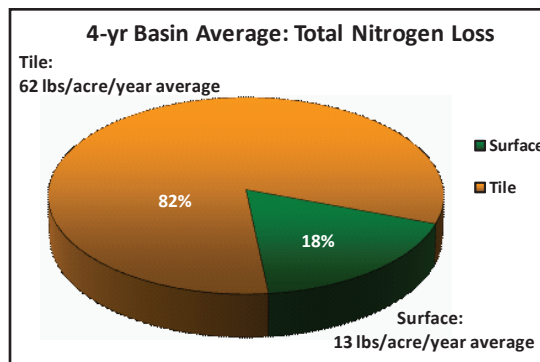


Figure 4. 4-year average nitrogen loss in surface & tile

Conclusions

- Average total nitrogen loss for all surface basins during the monitoring period was 13 pound/acre/year, and tile basins was 62 pound/acre/year with high variations in annual nitrogen loss.
- Approximately 57% of all surface nitrogen and 52% of all tile nitrogen lost during the monitoring period for all basins came from frozen ground; the remaining came from non-frozen.
- March was the most dominant month for surface nitrogen loss, with considerable losses also noted from

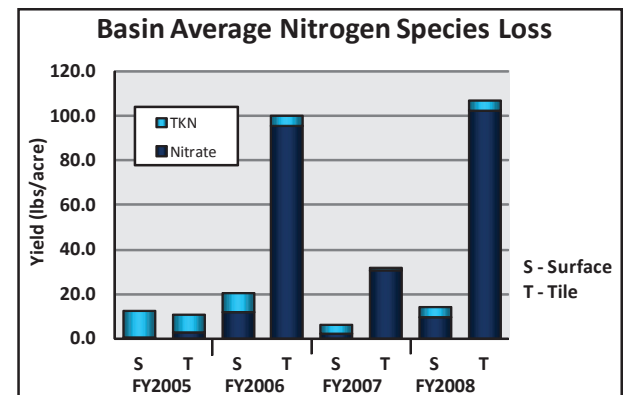


Figure 5. Basin average nitrogen loss in surface and tile

- January through June. Total surface nitrogen loss correlated strongly to the runoff volume.
- Tile drainage nitrogen loss (82% of total) from fields was higher than surface nitrogen loss (18% of total).
- Although nitrogen loss in the nitrate form was the highest in both surface and tile, nitrate was by far the most dominant in tile. Nitrogen loss in the ammonium form occurred during frozen ground conditions.

Soil moisture and potential for runoff

Surface runoff and tile line flow was monitored year-round at Pagel's Ponderosa Dairy (PPD) in three basins managed entirely by PPD. Surface water monitoring began in field year 2004 at three locations (P1, P2, & P3) and tile line monitoring started in 2005 in two basins (P4 & P5) concluding in field year 2009 at all sites. Flow was not monitored for the complete field year in 2009; however, soil moisture and precipitation data were still recorded. Additionally, when presenting data on precipitation events, only events that had greater than or equal to 0.1 inches of precipitation were used. For this brief only, events smaller than this were considered insignificant.

Non-frozen ground

Examination of precipitation events on non-frozen ground shows the importance of soil moisture on the potential for runoff. To determine the relationship between soil moisture conditions and runoff, the non-frozen ground data were divided into low (< 25%), medium (25 - 35%), and high (> 35%) soil moisture content categories. It is important to note that the soil

Soil condition	Amount of study period in category	Year with highest percentage of category
Low moisture	34%	2009 (40%)
Medium moisture	20%	2007 (24%)
High moisture	16%	2006 (28%)
Frozen	30%	2008 (35%)

Table 1. Distribution of Soil Moisture 2004 - 2009

moisture values used were the levels occurring just prior to a rain event or the antecedent values.

Each year of the study period had a different distribution of low, medium and high soil moisture content days (Table 1). During the non-frozen period, surface runoff is driven by precipitation, as compared to snowmelt driven events that occur while the soil is frozen. The majority of non-frozen surface runoff occurred during high soil moisture conditions (Table 2). The data from PPD show that 21% of rain events that occurred when the soil was not frozen resulted in surface runoff. Very few (12%) of these events occurred when

the soil had low or medium moisture. However, when rain fell on soil with high moisture, surface runoff occurred 41% of the time. The annual surface runoff volumes during the study period were highly dependent on the timing of rain events and relative soil moisture.

Frozen ground

The soil at PPD was frozen on average for 30% of the year (Table 1). The average frozen ground period was from November 30th through March 28th (Table 3). While soil moisture is not a measurement that is directly relevant to frozen soil, the data show that frozen

Soil condition	Rain events that resulted in runoff	Total runoff volume
Non-frozen soil	21%	40%
Frozen soil	51%	60%
Soil moisture content*		
Low moisture	4%	2%
Medium moisture	8%	12%
High moisture	41%	86%

Table 2. Affect of Soil Moisture on Surface Runoff

ground and soils with high soil moisture content react similarly to rain events in terms of surface runoff. Over the 5 year study period, 60% of all surface runoff occurred during frozen soil conditions (see PPD-3). Rainfall that occurred while soil was frozen had the highest risk of runoff; 51% of these events caused surface runoff (Table 2).

Precipitation volume and intensity

Soil moisture, precipitation volume, and precipitation intensity all play important roles in whether surface runoff will occur. Soils with low soil moisture

	Freeze	Thaw
Winter 2004-2005	12/13/2004	4/4/2005
Winter 2005-2006	11/24/2005	3/30/2006
Winter 2006-2007	12/3/2006	3/25/2007
Winter 2007-2008	11/29/2007	4/4/2008
Winter 2008-2009	11/20/2008	3/17/2009
Average	11/30	3/28

Table 3. Estimated frozen ground dates

Soil Condition	Mean rainfall volume that produced runoff (inches)	Minimum rainfall volume that produced runoff (inches)	Mean rainfall intensity that produced runoff (inches/hour)	Minimum rainfall intensity that produced runoff (inches/hour)
Low moisture	1.1	1.02	0.4	0.07
Medium moisture	0.9	0.42	0.5	0.20
High moisture	0.5	0.06	0.1	0.02
Frozen	0.2	0.04	0.1	0.01

Table 4. Mean and minimum amount and intensity of rainfall required to produce surface runoff

can absorb higher volumes of rainfall (additional water) to fill the remaining pore space. However, if the rain intensity exceeds the soil infiltration rate, surface runoff will occur.

To understand the effect of precipitation volume, the median rain event volume for storms that produced surface runoff was determined for each soil moisture condition (Table 4). These data show that soils with low and medium moisture can infiltrate a similar amount of precipitation without producing runoff. Soils with high moisture and frozen soils can only infiltrate a small amount of precipitation before surface runoff is generated.

Rainfall intensity also plays an important role in determining the potential of surface runoff. Table 4 shows the median intensity rain events that resulted in surface runoff. It is apparent that low and medium moisture soils can handle wider ranges of intensity before surface runoff occurs. When reviewing table 4, the events may be high intensity with little volume or vice versa. There are many other factors involved in surface runoff events.

Conclusions

- During non-frozen soil conditions, 86% of the total non-frozen runoff volume occurred during high soil

- moisture conditions, while only 12% occurred during medium and 2% during low soil moisture conditions.
- Of all the precipitation events that occurred on non-frozen ground, 21% resulted in surface runoff. During non-frozen ground conditions, precipitation on low and medium soil moisture soils only had surface runoff 4% and 8% of the time, respectively. However, high moisture soils resulted in surface runoff 41% of the time during a precipitation event.
- Surface runoff was generated 51% of the time a precipitation event occurred on frozen ground and these events resulted in 60% of the total

- runoff volume.
- Precipitation volume and intensity play important roles in the potential for surface runoff. The average volume or intensity of precipitation producing surface runoff on high moisture and frozen soils was much lower than the volume or intensity required to produce surface runoff on medium and low moisture soils.
- Soil moisture, precipitation volume, and precipitation intensity are three factors that may be used to predict runoff occurrence after a rainfall event and can be utilized to make better management decisions.

Single storm event loss comparison total annual sediment and nutrient loss

Surface runoff and tile line flow was monitored year-round at PPD in three basins managed entirely by PPD. Surface water monitoring began in field year 2004 at three locations (P1, P2, & P3) and tile line monitoring started in 2005 in two basins (P4 & P5). Research ended at the end of field year 2008 for all basins except for P2, which ended in 2006 because it was “non-typical” in terms of fields in this region. The monitored surface area of P1/P4 was 20.5 acres, P2 was 22.1 acres, and P3/P5 was 13.2 acres. Total sediment and nutrient loss recorded in these areas was divided by the basin size to calculate pounds of sediment loss per acre, so the data would be comparable. To be consistent, the data presented in this brief is based on our definition of a “field year”, which is the 12-month period from October 1 through September 30. The field year always represents the calendar year in which it ends, meaning that field year 2007 ended on September 30, 2007 (FY07).

Single storm event loss comparison to total annual sediment and nutrient loss

As discussed in prior fact sheets the timing and magnitude of sediment, phosphorus, and nitrogen loss are generally caused by a variety of environmental and management factors. To better understand the conditions where losses may be expected, the event that contributed the highest loss of

sediment, phosphorus and nitrogen for each year of the study were identified. The highest annual loss quantity was compared to the total annual load for each constituent (sediment, phosphorus or nitrogen) for all the flow events in the entire field year to determine the influence of this one event.

The analysis of this data provided surprising results. As shown in figures 1 & 2, the sediment loss from a single

storm can provide over 90% of the loss in surface and tile for the entire year. The timing of the sediment loss was typically during snowmelt in March or during large precipitation events in May and June (Table 1).

A single storm can contribute over 80% of the total annual surface phosphorus loss (Figure 3). The timing of the highest phosphorus loss was usually during the snowmelt period in March

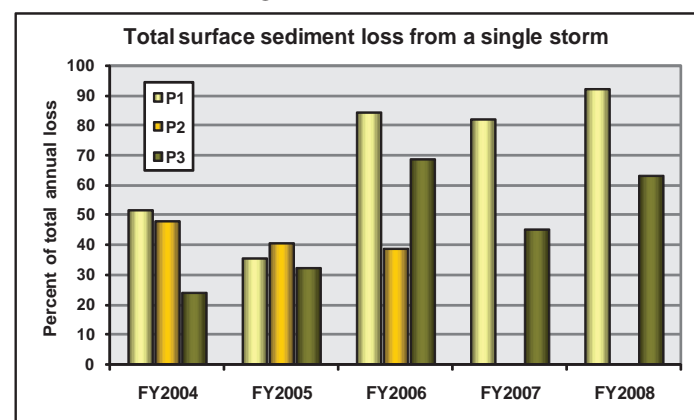


Figure 1. Total surface sediment loss

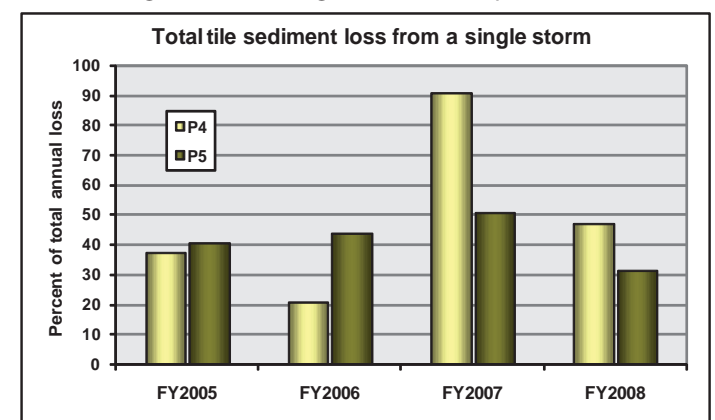


Figure 2. Total tile sediment loss

or during large surface runoff events in May and June (Table 1). These events typically coincided with the highest sediment loss. The highest phosphorus loss in tile from a single storm delivered up to 40% of the total annual loss for the year (Figure 4) typically occurring during the snowmelt period in March or during precipitation events on high moisture soils in April and May (Table 1).

A single storm can contribute up to 80% of the total surface nitrogen loss annually (Figure 5). High surface nitrogen loss events often occurred during frozen ground periods in January through early March, but also occurred in March and through non-frozen surface runoff in May and June (Table 1). The most nitrogen loss in tile from a single storm delivered less than 30% of the annual loss, which was the lowest proportion of all constituents (Figure 6). Nitrogen losses usually occurred on frozen ground in January or during runoff from high moisture soils in April (Table 1). Nitrogen losses in tile were more consistent throughout the year as compared to sediment and phosphorus losses in tile.

More in-depth analysis of this data could provide further insight on the mechanisms of sediment, phosphorus and nitrogen loss in surface and tile flow. This information could be utilized to provide agricultural producers with management options to reduce the risk of loss for these constituents while maximizing crop utilization.

Conclusions

- Surface runoff from a single storm can provide over 90% of the sediment loss and up to 80% of total phosphorus and nitrogen loss for the entire field year.
- Tile flow from a single storm can contribute over 90% of the sediment loss, 40% of total phosphorus loss, and almost 30% of total nitrogen loss for the entire field year.

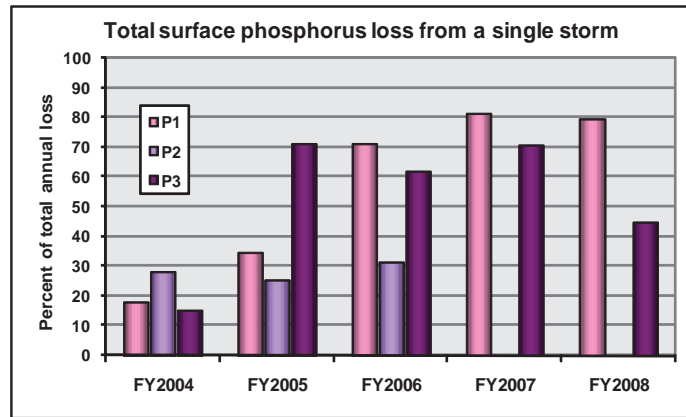


Figure 3. Total surface phosphorus loss

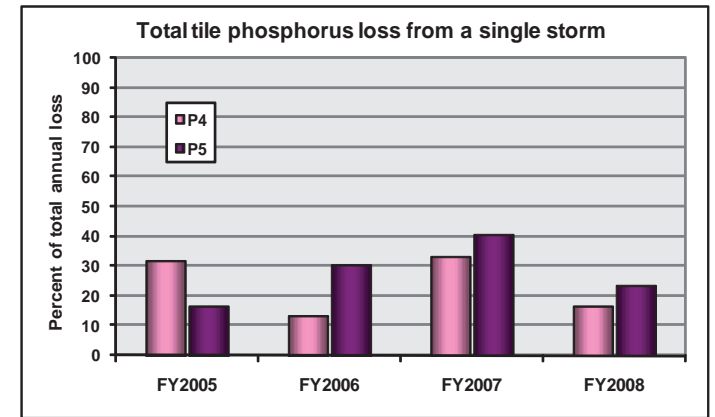


Figure 4. Total tile phosphorus loss

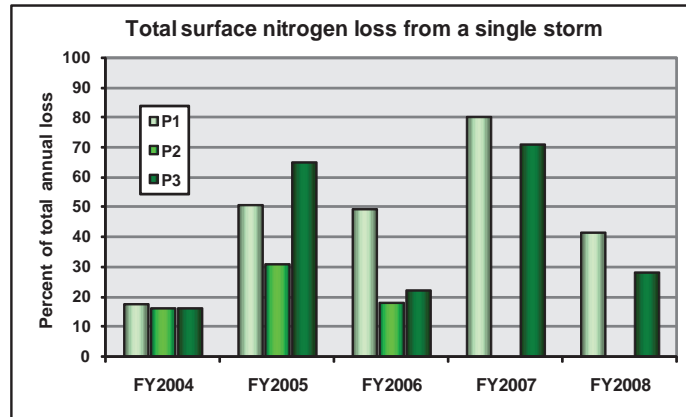


Figure 5. Total surface nitrogen loss

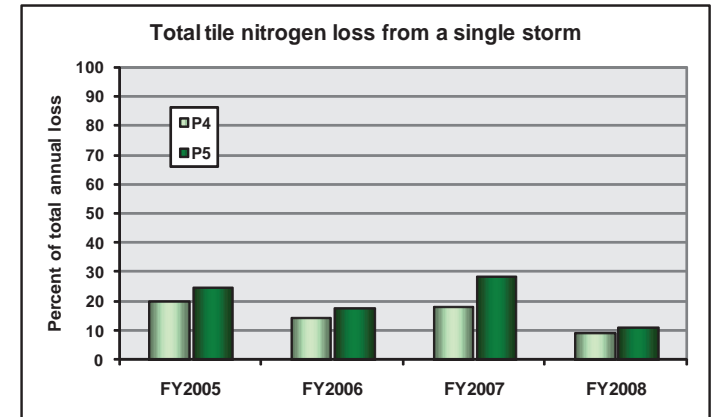


Figure 6. Total tile nitrogen loss

Site	Year	Total Sediment		Total Phosphorus		Total Nitrogen	
		Date	% flow % total	Date	% flow % total	Date	% flow % total
P1 (surface)	FY2004	05/23/04	20.2 51.4	05/23/04	20.2 17.9	03/01/04	22.2 17.7
	FY2005	03/28/05	27.8 35.5	03/28/05	27.8 34.7	02/06/05	24.6 50.5
	FY2006	05/28/06	34.5 84.5	05/28/06	34.5 71.2	05/28/06	34.5 49.3
	FY2007	03/13/07	88.6 82.2	03/13/07	88.6 81.7	03/13/07	88.6 80.1
	FY2008	06/12/08	40.4 92.0	06/12/08	40.4 79.6	06/12/08	40.4 41.3
P2 (surface)	FY2004	05/23/04	17.4 47.7	05/23/04	17.4 28.1	03/02/04	13.1 16.1
	FY2005	03/28/05	7.2 40.4	02/05/05	29.1 25.6	02/05/05	29.1 31.0
	FY2006	05/28/06	13.5 38.9	05/28/06	13.5 31.6	05/11/06	16.9 17.8
P3 (surface)	FY2004	05/23/04	10.1 24.1	03/05/04	5.9 15.5	03/05/04	5.9 16.3
	FY2005	09/13/05	1.1 32.1	03/27/05	54.8 71.2	03/27/05	54.8 64.9
	FY2006	05/28/06	18.1 68.8	05/28/06	18.1 61.9	05/28/06	18.1 22.1
	FY2007	03/13/07	79.1 45.1	03/13/07	79.1 70.9	03/13/07	79.1 70.8
	FY2008	06/12/08	23.6 63.3	06/12/08	23.6 44.9	01/08/08	15.2 28.2
P4 (tile)	FY2005	03/27/05	25.9 37.5	03/27/05	25.9 31.8	01/12/05	5.3 20.0
	FY2006	03/12/06	4.3 20.8	05/13/06	9.4 13.4	01/02/06	10.4 14.5
	FY2007	03/21/07	8.3 90.9	03/21/07	8.3 33.2	04/15/07	15.1 18.5
	FY2008	06/08/08	5.1 46.9	04/10/08	10.3 16.6	04/10/08	10.3 9.3
P5 (tile)	FY2005	08/18/05	8.0 40.8	12/13/04	11.5 16.7	09/13/05	8.1 24.9
	FY2006	05/13/06	13.2 43.6	05/13/06	13.2 30.5	01/02/06	11.0 17.7
	FY2007	10/03/06	4.5 50.7	03/21/07	12.6 40.9	04/15/07	18.7 28.5
	FY2008	04/10/08	12.4 31.1	04/10/08	12.4 23.7	04/10/08	12.4 11.1

Table 1. Highest single storm losses of sediment, phosphorus and nitrogen for each field year at each monitored basin

Concentration comparison to yield for sediment and nutrient loss

Surface runoff and tile line flow was monitored year-round at PPD in three basins managed entirely by PPD. Surface water monitoring began in field year 2004 at three locations (P1, P2, & P3) and tile line monitoring started in 2005 in two basins (P4 & P5). Research ended at the end of field year 2008 for all basins except for P2, which ended in 2006 because it was “non-typical” in terms of fields in this region. The monitored surface area of P1/P4 was 20.5 acres, P2 was 22.1 acres, and P3/P5 was 13.2 acres. Total sediment and nutrient loss recorded in these areas was divided by the basin size to calculate pounds of sediment loss per acre, so the data would be comparable. To be consistent, the data presented in this brief is based on our definition of a “field year”, which is the 12-month period from October 1 through September 30. The field year always represents the calendar year in which it ends, meaning that field year 2007 ended on September 30, 2007 (FY07).

Single storm event loss comparison to total annual sediment and nutrient loss

Data from surface runoff and tile flow were analyzed to compare concentration trends (parts per million or mg/L) to yield trends (lbs/acre) for individual events. The concentration data indicated that sediment and nutrient concentrations varied extensively between events. It also showed that the concentrations often had very little correlation to the yield of sediment or nutrients. Large variations were observed in both concentration and flow volume trends in all field years for both surface and tile drainage basins.

To demonstrate how the use of either concentration or flow volume data can be misleading, three of the highest nitrogen loss events at basin P1 during the field year 2005 were graphed. Figures 1, 2 and 3 represent the same three events during the FY2005. As indicated in figure 1, the highest concentration of total nitrogen occurred on 01/12/05; while figure 2 shows that the highest runoff volume occurred on 3/28/05. Figure 3 demonstrates that the yield

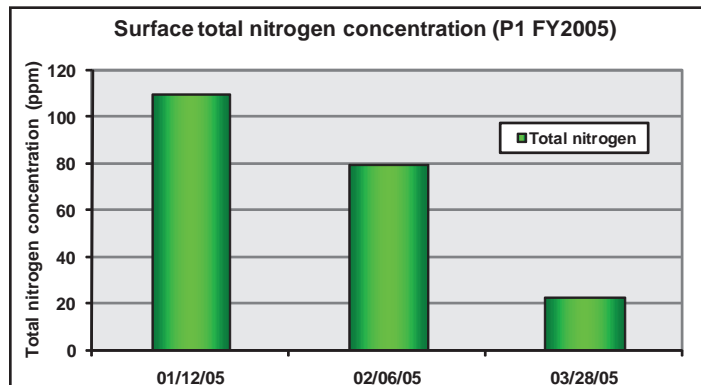


Figure 1. Surface total nitrogen concentrations

produced from these events shows a very different total nitrogen loss.

Both the concentration of nutrients in the water and the volume of water are necessary to calculate yield data. When comparing the highest total nitrogen concentration (01/12/05) to the highest surface runoff volume (3/28/05) for the field year, note that neither produced the highest yield (Figure 3). In fact, both of these storms produced yields that were substantially lower than the event on 2/6/05. This data indicates that neither event concentration nor event volume is a good indication of loss potential and that it takes both concentration **and** volume to produce high losses.

From a concentration perspective, it

is important to note that these are average concentrations over the entire event. Samples collected from an event are sub-sampled on a flow-weighted basis and combined to make a composite sample because of cost. Individual sample bottle concentrations vary to a higher extent throughout any given storm event as compared to the composite sample.

To further examine why concentration

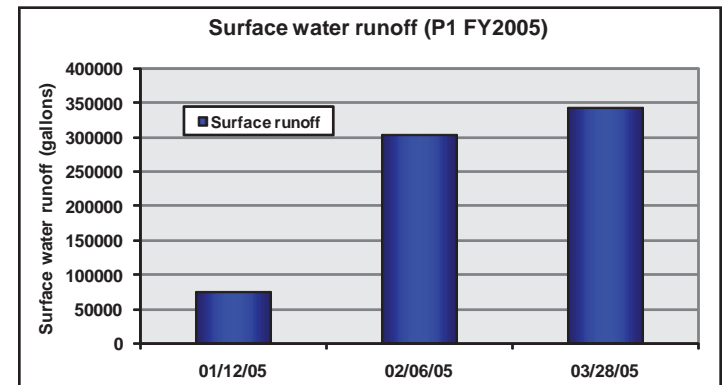


Figure 2. Surface water runoff at P1 in PY2005

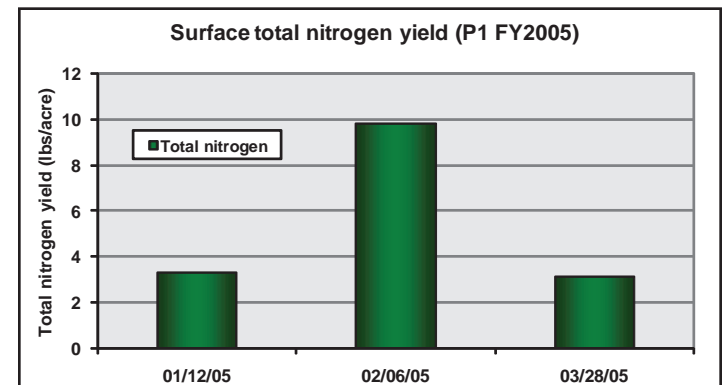


Figure 3. Surface total nitrogen yield at P1 in PY2005

data from event flow is not a good method for estimating nutrient and sediment loss, all surface and tile flow data for the entire field year were analyzed to determine if the highest

		P1 (surface)	P2 (surface)	P3 (surface)	P4 (tile)	P5 (tile)
FY2004	Sediment	N	N	N		
	Total Phosphorus	N	N	N		
	Total Nitrogen	N	N	Y		
FY2005	Sediment	N	Y	Y	N	N
	Total Phosphorus	N	N	N	N	N
	Total Nitrogen	N	N	N	Y	Y
FY2006	Sediment	Y	Y	N	N	N
	Total Phosphorus	N	Y	N	N	N
	Total Nitrogen	Y	N	N	N	Y
FY2007	Sediment	N		N	Y	Y
	Total Phosphorus	N		N	Y	Y
	Total Nitrogen	N		N	N	Y
FY2008	Sediment	Y		Y	Y	N
	Total Phosphorus	Y		Y	N	N
	Total Nitrogen	N		Y	N	N

Table 1. Highest event concentration causing highest field year event yield loss: Y - Yes; N - No

measured concentration event can be correlated to the highest annual yield. Results are in table 1 with “Y” in the field year where the highest concentration, when combined with water volume, produced the highest yield of sediment, total phosphorus, or total nitrogen. The “N” annotates field years when the correlation was not present.

As demonstrated in table 1, only 31% of surface runoff events occurred in storms that had the highest

concentration and the highest yield. In comparison, 38% of the tile flow events had the highest concentrations and the highest yield in the same storm. Further analysis of this data shows that some of the highest measured concentration events were almost the lowest yielding events for a particular field year.

Concentrations, water volume, loads, and yields each have a role in describing the quality of water leaving agricultural fields; each of these factors is

important to researchers, policy makers, and producers. In order to accurately describe any type of event, both concentration **and** volume of the water in question is necessary.

Conclusions

- Data from the highest concentration of a constituent or the highest water volume for a field year often did not result in the highest total yield.
- Concentrations of constituents and

volume of water were seen to vary substantially in a field year.

- Concentration and volume of the water being sampled is necessary to accurately characterize nutrient and sediment loss from an area, or more broadly, a farming system.
- To accurately describe the impact of any event, the total yield of a constituent should be evaluated.

Impact of Discovery Farm Research on: Agricultural management at Pagel’s Ponderosa Dairy, public perception and future Discovery Farm research site criteria

Pagel’s Ponderosa Dairy (PPD) is a confined animal feedlot operation (CAFO) located six miles northwest of Kewaunee in Kewaunee County, Wisconsin. The installation of surface water monitoring equipment began in September 2003. Three monitoring sites were installed in grassed waterways close to field boundaries and installation was completed in November 2003. Tile line monitoring sites were installed adjacent to edge-of-field surface water monitoring equipment in November 2004 to collect water from equal basin sizes at two of the three surface water site locations. Monitoring at both surface and tile sites was conducted until the end of the 2008 field year (September 30, 2008)

Major lessons learned

Both environmental factors and land management play crucial roles in the potential for sediment and nutrient loss. The dominant factors contributing to loss varied by crop, quantity and timing of nutrient applications, tillage, soil moisture and timing, volume, and intensity of precipitation events. These causal factors also varied between nitrogen, phosphorus and sediment loss for a given year. Discovery Farms gained information about when these losses have a higher potential to occur; this information will help producers make better informed management decisions in the future. The data collected at PPD exhibits the importance of monitoring

both surface runoff and tile flow in respect to sediment and nutrient loss. The comparison of surface versus tile line monitoring in the same basin quantifies the relative losses through the two pathways and how environmental conditions and management can influence losses. As we gain a better understanding of when losses are expected to occur, management practices to minimize losses during critical times can be implemented to reduce future loss.

Monitoring conducted at PPD created a unique forum for dialog between researchers, producers, policy makers and the public to discuss issues relating to agricultural management and production. A variety of educational events including public meetings, tours of the farm, research stations, exhibits, and formal speeches proved to be valuable in facilitating education and open discussion between diverse audiences.

Changes in agricultural management at PPD

The potential for management changes to occur based on information learned from Discovery Farms research is a crucial aspect to determine the success or failure of a monitoring program. It is difficult to assess management changes based solely on Discovery Farms data and outreach, as many factors often contribute to management changes. Although influences apart from

information learned through Discovery Farms may have played a role, the following changes were noted on the farm:

- Manure applications made in the fall of 2005, soon after the removal of corn silage, showed elevated loss of nitrogen to tile. Application of manure to fields in subsequent years, in all basins monitored, occurred at a later date when soils were cooler and the conversion to nitrate was minimized.
- A small volume application of sand-laden manure with a low nutrient content was applied to ice crusted soils in late 2004 and an additional winter application of manure requested by the Discovery Farms Program was performed on frozen, snow-covered ground. Elevated nutrient losses measured were attributed to the both applications. During the remainder of the monitoring period, no other observed applications were made on frozen, snow/ice-covered ground by PPD in monitored basins or surrounding fields.

PPD is very active in the community and willing to share information gained on the farm with other producers in the area. It is hard to assess changes made on neighboring farms by information learned at PPD, but two factors are believed to enhance the information passed through this method. First, information delivered by local producers or passed word-of-mouth is likely to

reach a broader audience than by educational events sponsored by the Discovery Farms Program and other outreach organizations. Second, this information is likely to have a higher level of adoption in the local area because of applicability to farms in the local region.

Changes in public perspective of agricultural losses

The coordination of educational events with PPD and local agencies and officials was beneficial to the success of the Discovery Farms Program. Numerous field day exhibits, farm and research site tours, presentations and meetings were done to deliver Discovery Farms findings and share information from PPD. These outreach events catered to a diverse group of audiences and covered a variety of topics. Some of these events included:

- General informational meetings organized and sponsored by PPD for local producers and the general public where success stories and challenges on the farm were presented by PPD and recent Discovery Farms findings were presented by Discovery Farms staff. These meetings were well attended and an open dialog was achieved between the audience, PPD and Discovery Farms staff.
- The Kewaunee County Land Conservation Department and Kewaunee County UW Extension Dairy Agent coordinated internal meetings

to discuss Discovery Farms findings with PPD and Discovery Farms staff. These meetings proved beneficial to all involved so that production, conservation and policy issues could be discussed.

- Farm tours and field days were held to showcase the Discovery Farms research being done in cooperation with PPD. These events were beneficial to members of the general public to better understand what is being done in modern agriculture to protect the environment while producing agricultural commodities.

These events were also attended by conservation agency personnel and policy makers and open dialog about new challenges facing agricultural producers occurred between tour attendees, PPD and Discovery Farms staff.

- Annual educational tours were given for four years to 6th grade students from seven surrounding schools coordinated by the Kewaunee County UW Extension Dairy Agent. These events were helpful in introducing agriculture to students without an agricultural

background. Basic farming principles, soils, environmental protection and Discovery Farms research were part of the curriculum on these tours.

Changes in research site criteria for future Discovery Farms sites

Lessons learned while monitoring at PPD has improved site selection criteria for future monitoring stations:

- Surface water and tile paired basin if possible.
- Close to power (near power lines or buildings).
- Easy access by road (able to plow in winter).

- 40 acre basin or less.
- Single field per basin if possible.
- All/majority of agricultural land in the basin under control of participant.
- No backwater (good slope away from surface site and clear discharge path for tile).
- Cooperative and good recordkeeping participant.
- Two paired surface/tile sites on same farm would be optimal.
- Perform comprehensive evaluation of basins to be monitored for potential problems with monitoring.

By Eric Cooley, Dennis Frame and Aaron Wunderlin , UW-Extension/Discovery Farms

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These briefs summarize on-farm research conducted on Pagel's Ponderosa Dairy, Kewaunee County, WI. Project results are presented in 13 fact sheets. The series includes: Farm, Site and Study Design; Equipment, Procedures and Sampling, Water Budget at Pagel's Ponderosa Dairy; Understanding Water Loss at Pagel's Ponderosa Dairy: Surface Water; Understanding Water Loss at Pagel's Ponderosa Dairy: Tile Drainage; Surface and Tile Drainage Comparison; Sediment Loss Potential at Pagel's Ponderosa Dairy; Phosphorus Loss Potential at Pagel's Ponderosa Dairy; Nitrogen Loss Potential at Pagel's Ponderosa Dairy; Soil Moisture and potential for runoff; Single storm event loss comparison to total annual sediment and nutrient loss; Concentration comparison to yield for sediment loss; Impact of Discovery Farms Research on: Agricultural Management at Pagel's Ponderosa Dairy, Public Perception, and Future Discovery Farm Research Site Criteria.

Fact sheets, briefs and presentations are available from the UW-Discovery Farms Office, PO Box 429, Pigeon Falls, WI 54760, 715-983-5668 or at our website: www.uwdiscoveryfarms.org.