RESEARCH REPORT

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ENVIRONMENT

TITLE: Evaluating Nutrient (nitrogen and ortho-phosphate) Export with Subsurface Drainage Water from Spring Applied Swine Manure to Soybean Planted Micro-watersheds - **NPB #12-117**

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INSTITUTION: Iowa State University

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1. INDUSTRY SUMMARY

The objective of this project is to evaluate the impact of spring applied swine manure for soybean crop on sub-surface drainage water quality from non-replicated micro-watersheds. To evaluate this impact, sub-surface flow from tile outlets in two micro-watersheds planted to soybeans was monitored for nutrients (nitrogen and ortho-phosphate). Two additional micro-watersheds, planted to corn and with no manure application, were also monitored during this time period. Tile outlets from the micro-watersheds were instrumented with ISCO flow samplers and flow meters. This has been done to record flow volumes being discharged from the micro-watersheds. Water samples were collected to determine nitrate-nitrogen and ortho-phosphate concentrations in tile flow. Manure was applied to one of the paired micro-watersheds in spring of 2012 before it was planted to soybeans. Both micro-watersheds were monitored and data was recorded from April 26 to November 30, 2012. Analysis of data shows that the flow weighted nitrate-N (NO_3-N) concentrations were higher for the micro-watershed A for the post-manure application time period in comparison with the pre-manure application time period. Flow weighted nitrate-N (NO_3-N) concentrations were comparable for the micro-watershed A where manure was applied with micro-watershed B where no manure was applied, with both watersheds planted to soybeans. When micro-watershed C and D (both planted to corn with no manure application) were compared, micro-watershed D had higher flow weighted nitrate-N concentration in comparison to micro-watershed C. The flow weighted ortho phosphate-P (PO_4-P) concentrations were slightly higher for the micro-watershed A where manure was applied in comparison to all other micro-watersheds. Very few water samples for micro-watersheds B, C, and D showed ortho-phosphate concentrations above the non-detect limit. As 2012 was a drought year, the limited data available from this study should be carefully evaluated and used. The project was carried out in collaboration with Iowa Select Farms. Funding, wholly or in part, was provided by The National Pork Board on behalf of the Iowa Pork Producers Association.

2. KEYWORDS: nitrates, soybeans, loss, tile, drainage, subsurface, water quality

3. SCIENTIFIC ABSTRACT

Manure application to soybeans has been put under focus in the recent years. Currently, in Iowa, there is a limit of 100 pounds per acre of available nitrogen that can be applied for soybean crop use. A One-year study was conducted to compare nutrient movement with sub-surface tile water between a manure applied micro-watershed and a no manure applied micro-watershed, with both planted to soybeans. Two additional micro-watersheds, planted to corn with no manure and fall – applied nitrogen, were monitored in 2012. These two micro-watersheds were planted to soybeans and monitored in 2011. Nutrients observed in this study were nitrate-N (NO_3-N) and ortho-phosphate (PO_4-P). Micro-watershed with manure applied yielded more flow volume than the micro-watershed with no manure application, with both planted to soybeans. Consequently, nitrate-N mass was higher for the micro-watershed with manure applied in comparison with the micro-watershed with no manure application. The sub-surface drainage area contributing flow to drainage tile line can be different than the surface area of the watershed due to changes in the hydraulic conductivity of the soils below the ground surface. As such, flow weighted nutrient concentrations present a better comparison statistic. Flow weighted nitrate-N concentration was higher for the micro-watershed post manure application in comparison to the pre-manure application time period. Flow weighted ortho- phosphate concentration was higher for the micro-watershed with manure applied than the micro-watersheds with no manure applied. A very limited number of water samples showed ortho-phosphate concentrations above the non-detect limit. The use of data presented in this report should be evaluated carefully as it is a non-replicated study with data observed and reported during a drought year.

4. INTRODUCTION

Ninety percent of total freshwater input into the Gulf of Mexico originates in the Mississippi-Atchafalaya River Basin, which drains 41 percent of the continental United States. According to Goolsby, 1999 and Rabalais et al., 1999; this freshwater discharges an estimated 1.6 million metric tons of nitrogen annually. Sixty-one percent of this nitrogen discharge is in the form of nitrate (the mobile form of nitrogen). Similar data are available for phosphorus losses. Agricultural nitrogen losses are the major contributor to nitrogen loads in the Mississippi River. Of particular importance is the explicit focus on agricultural subsurface (tile) drainage, which has been identified as the major pathway for agricultural nitrate-nitrogen and soluble phosphorus (ortho-phosphate) losses in the upper Midwest. Agricultural subsurface tile drainage removes excess surface and sub-surface water from fields. This allows for development of a well-aerated soil profile allowing for optimal plant growth. A well-drained soil profile promotes good plant growth and allows for timely field operations. Agricultural subsurface tile drainage has also been shown to reduce the loss of phosphorus, organic nitrogen, and other pollutants, such as certain pesticides, with surface runoff to waterways (Skaggs et al., 1994). Transport of soluble nutrients (nitrate-nitrogen and soluble phosphorus) occurs at the subsurface level. Agricultural subsurface tile drainage can significantly hasten their movement to the edge of the field, and, thus, into an adjacent stream.

To limit the movement of nutrients to water bodies in Iowa, a simple strategy to utilize optimal amounts of nutrients has gained popularity and is being followed in production agriculture. Recently, manure nutrient application to soybean crop has come under focus. Soybean plant is a leguminous plant and is expected to fix atmospheric nitrogen for its own needs. As such, any nutrient application is being viewed as excess nutrient application on the agricultural landscape. In November 2008, Iowa Department of Natural Resources (IDNR) implemented a limit on liquid manure or open lot effluent that can be land applied to fields that will be planted to soybeans. This limit is specified as 100 pounds of available nitrogen, or N, per acre and applies to liquid manure or runoff containing manure from both open feedlots and animal confinements.

Iowa State University initiated a detailed research project at the Research and Demonstration Farm near Nashua, Iowa to study nutrient losses in agricultural subsurface tile drainage from manure applied fields planted to soybeans. This project is at research plot scale and is into its fifth year. At the micro-watershed level, Iowa State University worked as a sub-contractor to Iowa Soybean Association in 2010 and initiated a non-replicated study to look at the nutrient losses (nitrate-nitrogen and ortho-phosphate) with agricultural subsurface tile drainage from two micro-watersheds planted to soybeans in Hamilton County. This study was suspended at the end of 2010 as Iowa State University's sub-contract with Iowa Soybean Association was not renewed. In 2011, Iowa State University partnered with Iowa Select Farms and initiated the same study in Hardin County using two different micro-watersheds planted to soybeans. In 2012, Iowa State University partnered with Iowa Select Farms again and initiated the same study in both Hamilton and Hardin Counties using all four micro-watershed where the two micro-watersheds in Hamilton County were planted to soybeans and the two in Hardin County were planted to corn. One of the two micro-watersheds in Hamilton County received spring manure application in 2012.

5. OBJECTIVES

Iowa State University worked with Iowa Select Farms as co-collaborators on a one-year project for 2012. The objective of this project was to evaluate the impact of spring manure application for soybean crop on sub-surface drainage water quality. In 2012, sub-surface groundwater flow from tile outlets in four micro-watersheds was monitored for nutrients (nitrate-nitrogen and ortho-phosphate). The Hamilton County site consisting of micro-watershed A and B was planted to soybeans in 2012. The Hardin County site consisting of micro-watershed C and D was planted to corn in 2012. Micro-watershed C and D were monitored to see if any differences exist when the two micro-watersheds are subject to same treatments. Micro-watershed A and B were planted to soybeans in 2012 and served to provide data for comparing sub-surface drainage water quality for manure applied micro-watershed A with no-manure applied micro-watershed B in this non-replicated study.

6. MATERIALS AND METHODS

Site Preparation: Two of the micro-watersheds were located in Section 16, T87N, R26W in Hamilton County, IA. Micro-watershed A (MJE) was approximately 8 acres and Micro-watershed B (MJW) was approximately 3 acres (Figure 1). The other two micro-watersheds were located in Section 22, T87N, R20W in Hardin County, IA. Micro-watershed C (J-North) was approximately 4.3 acres and Micro-watershed D (J-South) was approximately 5.8 acres (Figure 2).

Swine finishing manure at the rate of 2,000 gallons per acre was applied to micro-watershed A using a 7300 gallon Houle with disc covering toolbar. The tool bar on the Houle wagon provided similar tillage to both micro-watersheds. Manure application was turned off in the passes over Micro-watershed B to avoid any additional equipment passes over the field. The manure application took place on May 14, 2012. Soybeans were planted to both micro-watersheds A and B with a planting density of 140,000 plants per acre. No manure was applied to micro-watershed B which served as control for this non-replicated micro-watershed study. Micro-watersheds C and D in Hardin County, IA were planted to corn. No manure was applied to these two micro-watersheds but had 180 pounds of fall-applied nitrogen (knifed-in as anhydrous ammonia).

Instrumentation: Tile outlets for all four micro-watersheds were secured for instrumentation by placing rodent guards at outlet. An ISCO low profile area velocity sensor was placed at the base of the tile outlet such that it would be submerged as the flow exited the tile (Figure 3). An ISCO portable sampler intake was also placed along with the velocity sensor for collecting tile water samples. The ISCO portable sampler was linked with the low profile area velocity sensor using an ISCO link module. ISCO portable sampler was programmed to record the depth and velocity of flow every minute and collect 3.3 ounce (100 mL) water samples every twelve hours. Two, twelve-hour samples were composited into one ISCO sampler bottle to obtain a daily representative sample of the sub-surface drainage water exiting the tile outlet. ISCO samplers were placed in job-boxes (Figure 4) to protect them from environmental conditions and to ensure interruption free automatic sampling. ISCO samplers and area velocity sensor were powered with 12-volt deep-cycle batteries which were kept charged using solar panels. Tile flow sampling and rate measurement equipment, for the two micro-watersheds in Hardin County, was purchased in 2011 and used in 2011. In 2012, this equipment was activated on April 4th, 2012. Tile flow sampling and rate measurement equipment, for two watersheds in Hamilton County, was purchased in 2012. Flow rate measurement equipment was activated on April 12th, 2012 whereas the water sample collection was activated on April 26th, 2012.

Sample Collection: Two manure samples were taken prior to application from the manure storage site from the same location where the manure was to be drawn for application. A 2-inch PVC pipe, fitted with a ball plug on a rope, was used to collect three sub-samples. The sub-samples were placed in a five gallon bucket, mixed thoroughly, and then re-sampled. The procedure was repeated to collect the second sample. These two manure samples were collected to plan an application rate that will provide approximately 100 pounds of available nitrogen per acre. Two additional manure samples were collected during application, one from each load of the Houle wagon. About a third of a gallon of manure was collected from the four discharge points of the applicator toolbar in a five gallon bucket, at the beginning, mid-way, and at the end of application of the Houle-wagon load, to get an as-applied manure sample. The procedure was repeated to get the second sample. Manure application occurred using a tool-bar fitted with a previously calibrated manure application rate controller.

Four feet deep soil samples were taken from all four micro-watersheds prior to manure application in April 2012 to get background nutrient data. Soil sampling was repeated in November 2012 to get status of nutrients in the four foot soil profile after harvest. Soil cores were taken using Giddings Soil Probe mounted on the bed of Ford Pick-up truck. The core tubes were cut into depths of 0-6 inch, 6-12 inch, 12-24 inch, 24-36 inch, and 36-48 inch. The soil from the cores was mixed thoroughly to obtain a representative sample for each depth section. The samples were submitted for analysis to the soils laboratory. An extensive soil sample strategy was not deemed necessary as the sub-surface watershed which contributes to the tile flow is different than the surface watershed. Determination of the extents of the sub-surface watershed contributing to the tile flow in each micro-watershed was not a part of this project.

7. RESULTS

Pre-application manure analysis showed total nitrogen of 51 pounds per thousand gallons (Table 1). Using this analysis, a manure application rate was planned as 2,000 gallons per acre. The manure application resembled surface application with immediate incorporation. As such, a five (5) percent nitrogen application loss due to volatilization was considered for calculating available nitrogen. Secondly, a ninety (90) percent first year nitrogen availability factor was used in calculating available nitrogen. Using these two factors, the planned application of available nitrogen calculated as 87.2 pounds per acre. These conversion factors were obtained from Iowa State University Extension and Outreach publication number PMR 1003 titled "Using Manure Nutrients for Crop Production". Manure analysis from samples taken during application, provided in Table 1, show an average total nitrogen of 58.5 pounds per thousand gallons. The rate of 2,000 gallons per acre, thus, provided for 100 pounds per acre of available nitrogen application, as-applied to micro-watershed A (MJ-East). As-applied results show that average phosphorus (P_2O_5) concentration was 15 pounds per 1,000 gallons. Using an application rate of 2,000 gallons per acre, the application rate for phosphorus (P_2O_5) was 30.0 pounds per acre.

Flow data, obtained from the ISCO Samplers logging the data from flow velocity sensors, was compiled for all four micro-watersheds. Head of water above the sensor mounted in the known diameter pipe outlet was used to calculate the cross-sectional area for each data point. This cross-sectional area was multiplied with the corresponding flow velocity reading to obtain the flow rate in gallons per second. The flow rate was converted to gallons per minute as the head and velocity readings were recorded every minute, and then added for the entire day to obtain a daily flow total for each micro-watershed. Data in Figure 5 shows that no tile flow occurred from the start of July 2012 for all four micro-watersheds due to lack of adequate rainfall. As shown in Table 2, a total of 435,032 gallons of tile flow volume after manure application was recorded for micro-watershed A (soybeans, manure applied). In the 17 days of recording prior to manure application, the total flow recorded from micro-watershed A was 516,894 gallons. The flow volume number for micro-watershed B (soybeans, no manure) was 497,643 gallons. The corresponding numbers for micro-watershed C (corn, no manure) and micro-watershed D (corn, no manure) were 775,704 and 566,979 gallons respectively (Table 3).

Nitrate-N mass calculations were performed on daily flow data and nitrate concentrations in the water samples collected daily. Nitrate-N mass in drainage water added to 48.5 and 46.8 pounds for the micro-watershed A, prior to and after manure application, respectively (Table 2). Nitrate-N mass in drainage water for micro-watershed B, C and D was 53.5, 84.1, and 77.5 pounds respectively (Table 2 & 3). Data for Micro-watersheds A and B was recorded from April 26th through November 30, 2012. In the month of July, sub-surface drainage water was flowing for only first few days of the month before it stopped flowing due to lack of rain in all four micro-watersheds.

An attempt was made to conduct similar calculations for obtaining the ortho-phosphate mass using the instantaneous flow data and daily water samples collected. Data analysis from the water samples shows only a handful of samples showed ortho-phosphate concentrations above the non-detect limit. The samples in which ortho-phosphate concentrations were above the non-detect limits were used to calculate the ortho-phosphate mass in drainage water for all micro-watersheds. These masses and the corresponding flow weighted ortho-phosphate concentrations are presented in Table 2 and Table 3 for reference.

8. DISCUSSION:

Both Hamilton and Hardin counties experienced drought conditions like the rest of Iowa in 2012. Very little rainfall was received in the early part of the year till end of June and extremely dry weather from start of July was observed in 2012 till the end of the monitoring in November 2012. Daily flow volume of sub-surface drainage water is presented in Figure 5 and 6 for the paired micro-watersheds. Micro-watershed A had almost similar nitrate mass detected in the drainage water for both prior to and after manure application during the recording period. The total nitrate mass, for the entire recording period, was greater for the micro-watershed A than for micro-watershed B. Micro-watershed D has relatively larger surface area than micro-watershed C; however, greater flow volumes were recorded for micro-watershed C than for micro-watershed D. The total nitrate-N mass for micro-watershed C was greater than the total nitrate-N mass for micro-watershed D. Taking the surface area of the micro-watershed A into account, the nitrate-N mass (pounds per acre) in sub-surface drainage was 6 (prior to manure application) and 5.8 (post manure application). The total nitrate-N mass (pounds per acre) of the four micro-watersheds A, B, C, and D was 11.8, 17.8, 19.6, and 9.7, respectively. As the sub-surface area contributing to tile flow can be different from the surface area of a watershed, comparing nitrate-N mass in subsurface drainage on pounds per acre of surface area does not appropriately represent the nutrient movement in such micro-watersheds. A flow-weighted average nitrate-N concentration is a better comparison as it takes into account the flow volume yield in subsurface drainage water irrespective of the watershed size on the surface. Flow weighted average nitrate-N concentration for micro-watershed A was 11.2 and 12.9 mg/L, both prior to and post manure application, respectively. This represents a 1.7 mg/L increase in the nitrate-N flow weighted concentration post manure application. Flow weighted nitrate-N concentrations were same (12.9 mg/L) when compared between post manure applied flow from micro-watershed A and the entire flow from micro-watershed B. When micro-watershed C and D were compared, micro-watershed D had higher flow weighted concentration for nitrate-N (higher by about 3 mg/L) in comparison to micro-watershed C (Table 3). Micro-watershed D had received manure application in May 2011 and 180 pounds of fall application of nitrogen for 2012 corn crop. In 2011 when micro-watershed C and D were planted to soybeans, the micro-watershed D, where manure was applied, did show slightly higher flow weighted nitrate-N concentrations (higher by about 1 mg/L) when compared with the micro-watershed C where no manure was applied.

Daily nitrate-N concentrations for sub-surface drainage water in micro-watershed A and B, both prior to and post manure application are presented in Figure 7. Daily nitrate-N concentrations in tile water for micro-watershed A were relatively lower than the nitrate-N concentrations for micro-watershed B prior to manure application. This trend was reversed post manure application. Immediately after manure application, the daily nitrate-N concentration for micro-watershed A, initially stayed lower, but slowly increased and became greater than the concentrations for micro-watershed B. Linear regression performed on this data shows that the concentrations for both watersheds increased as the season progressed although the R^2 values for regression fits for both micro-watersheds were low. The daily nitrate-N concentrations for micro-watershed D were consistently higher than the concentration for micro-watershed C. These concentrations for both micro-watershed C and D showed a downward trend towards the end of June into early July 2012. Slope of linear regression lines showed an upward trend for these concentrations for both micro-watersheds (Figure 8), however, the R^2 values were low. Nitrate-N concentrations in sub-surface drainage water represent what leaches out of the soil profile. These concentrations are a function of how different pools of nitrogen interact with the amount of water moving through the soil profile under different conditions of temperatures and soil types. As such, concentrations need to be evaluated together with the flow volume to estimate the flow weighted nitrate-N concentrations in drainage water.

A similar comparison for the flow-weighted average ortho-phosphate concentrations in tile water, taking into account the flow volume yield in subsurface drainage water, was performed. The data for these calculations are presented in Table 2 and Table 3. No meaningful comparisons could be drawn from this data as too few daily water samples showed ortho-phosphate concentration above the non-detect level for micro-watersheds B, C, and D.

Average nitrate-N concentrations in soil for different depths for all four micro-watersheds are presented in Table 4A for April 2012 sampling and in Table 4B for November 2012 sampling. For Spring 2012 measurements, nitrate-N concentrations in micro-watershed A where manure was applied in May 2012 were comparable for all depths with micro-watershed B nitrate-N concentrations. Similar concentrations, when compared between micro-watersheds C and D, were higher for micro-watershed D for the 0-6 inch and 6-12 inch depths. For Fall 2012 measurements, nitrate-N concentrations in micro-watershed A where manure was applied in May 2012 were higher than micro-watershed B nitrate-N concentrations for all depths as shown in Table 4B. Micro-watershed C showed higher nitrate-N concentrations for the 0-6 inch and 6-12 inch depths when compared with micro-watershed D.

9. CONCLUSIONS:

1. Year 2012 represents a drought year for Iowa and for most of Iowa counties. Four micro-watersheds in this study received some rainfall from April through June, but it became extremely dry after the first week in July with almost negligible rainfall. Rainfall that did occur after the first week in July failed to produce any drainage water flow in the tile lines as the soil profiles were empty for all four micro-watersheds. The use of data in this report should be evaluated carefully due to drought conditions for 2012.

2. Majority of manure application in Iowa takes place in fall. As manure in this study was applied in May 2012 before planting, comparison of data presented in this report to fall- applied manure conditions is not recommended.

3. Data collection did not occur on Micro-watersheds A and B for most of April due to equipment purchase and activation. Thus, the data contained in this report does not represent the entire growing season (April 15 through November 15) or the entire calendar year for micro-watersheds A and B. On the other hand, data collection was complete for micro-watersheds C and D from April through the end of November, 2012.

4. This one year study shows that the flow-weighted nitrate-N concentrations in tile water were comparable between micro-watersheds A following manure application and micro-watershed B where no manure was applied. Micro-watershed A, where manure was applied, did show slightly higher flow weighted nitrate-N concentrations (higher by about 1.7 mg/L) when pre- and post-manure application concentrations were compared. One year data cannot provide conclusive and repeatable results as a minimum of three to five years water quality data would be needed for such large size plots.

5. In case of ortho-phosphate (PO_4) for 2012, very few water samples tested at or above the non-detect limit (0.002 mg/L) for micro-watershed B, C, and D. Micro-watershed A, where manure was applied, showed higher ortho-phosphate flow weighted concentrations when compared to watersheds B, C, and D using the limited available data.

10. CREDIT:

The project was carried out in collaboration with Iowa Select Farms. Funding, wholly or in part, was provided by The National Pork Board on behalf of the Iowa Pork Producers Association.

Figure 1: Project Site Map for Hamilton County, IA

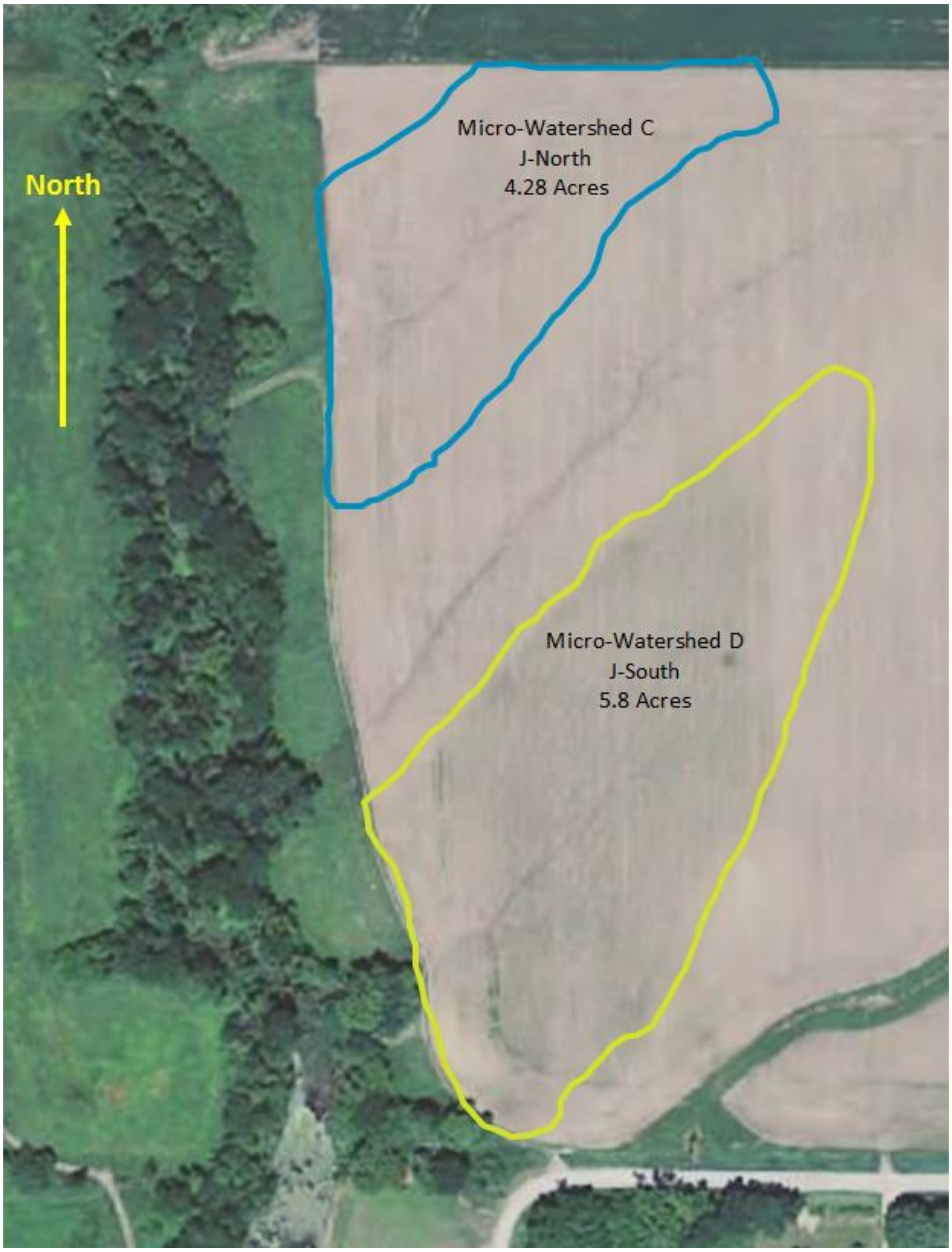

Figure 2: Project Site Map for Hardin County, IA

Figure 3: Area velocity flow sensor placed in the tile outlet along with ISCO sampler intake.

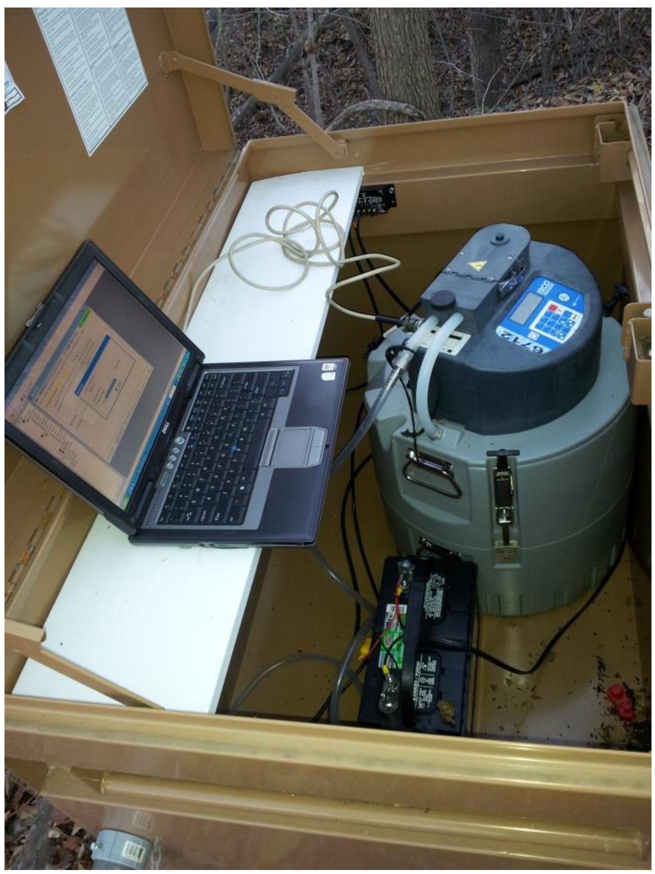

Figure 4: ISCO Portable Sampler placed in the job-box.

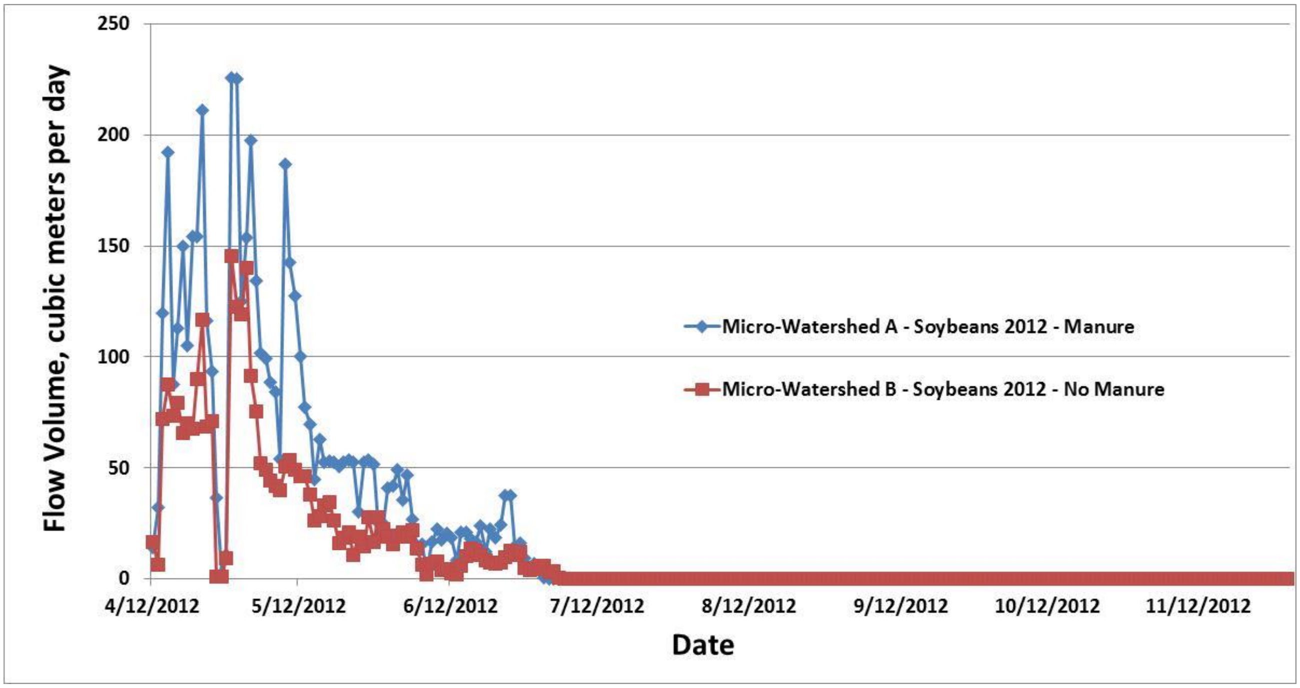

Figure 5: Drainage flow rate (m3/day) for micro-watersheds A & B in Hamilton County, IA

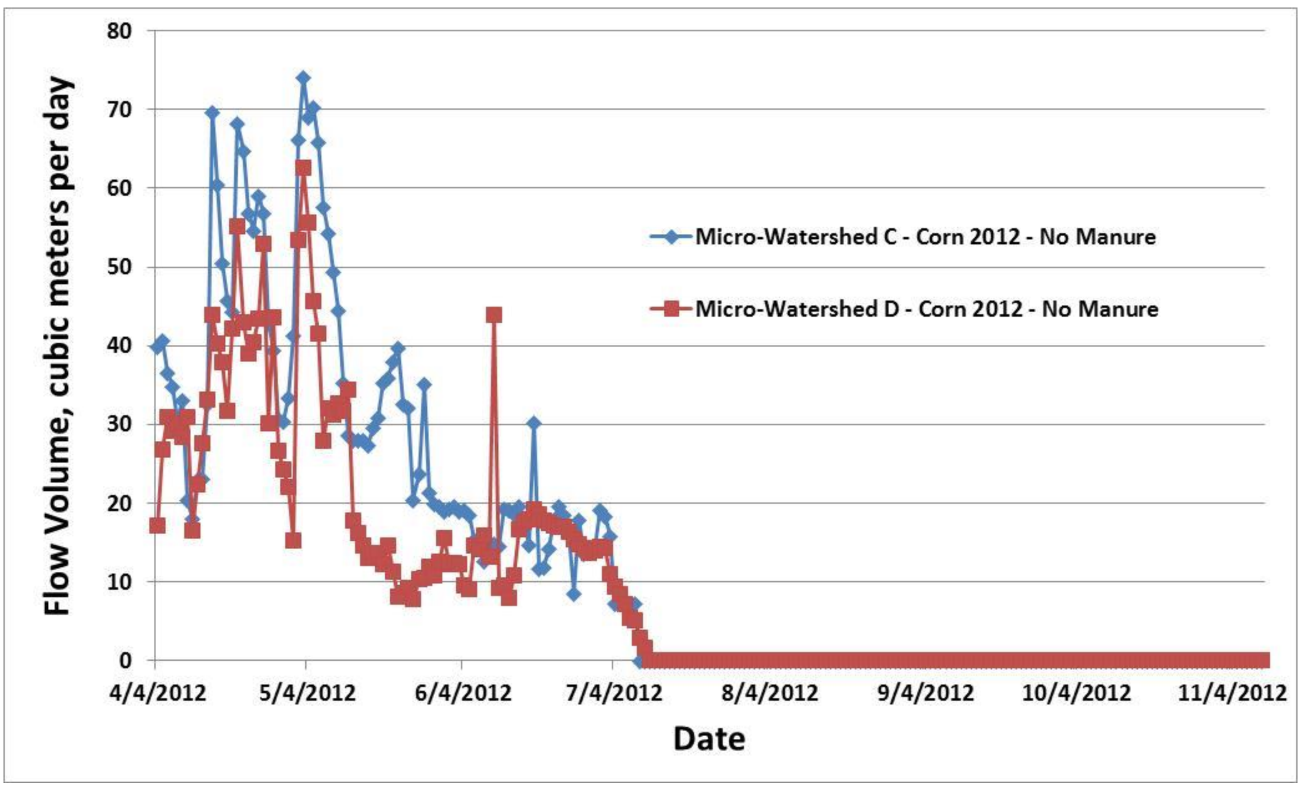

Figure 6: Drainage flow rate (m3/day) for micro-watersheds C & D in Hardin County, IA.

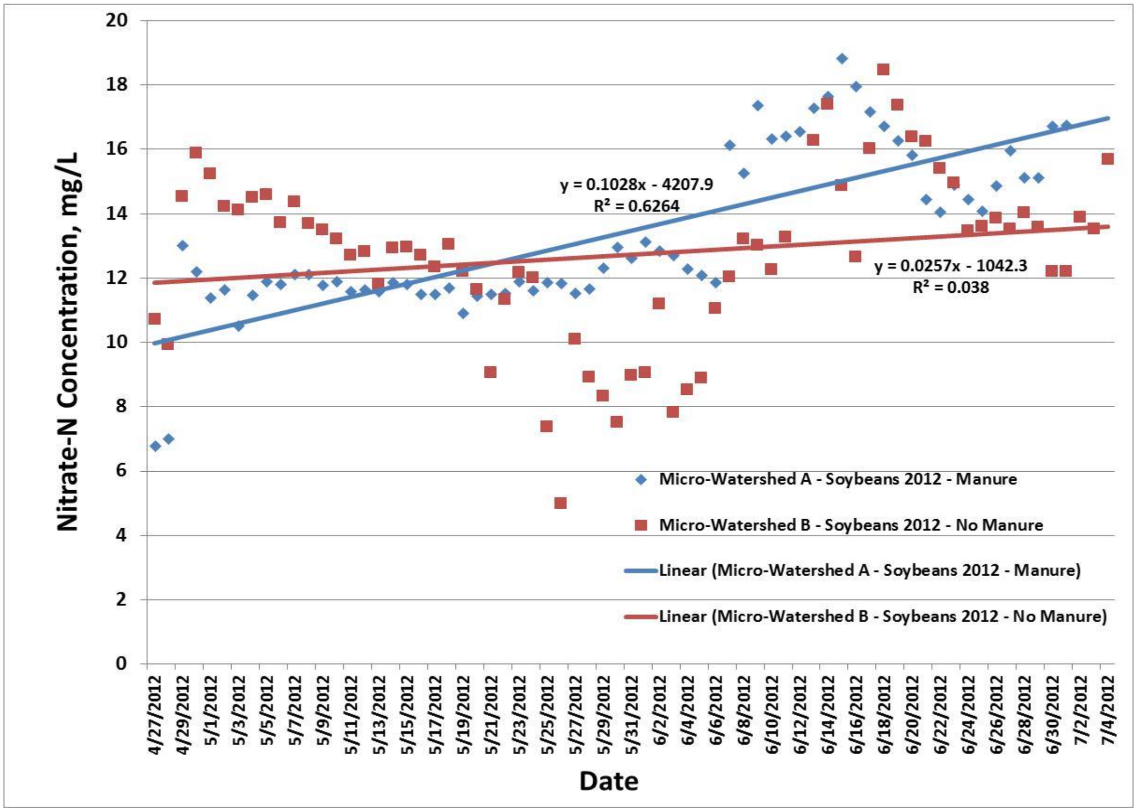

Figure 7: Nitrate-N concentrations in drainage water for micro-watersheds A and B both prior to and post manure application on micro-watershed A.

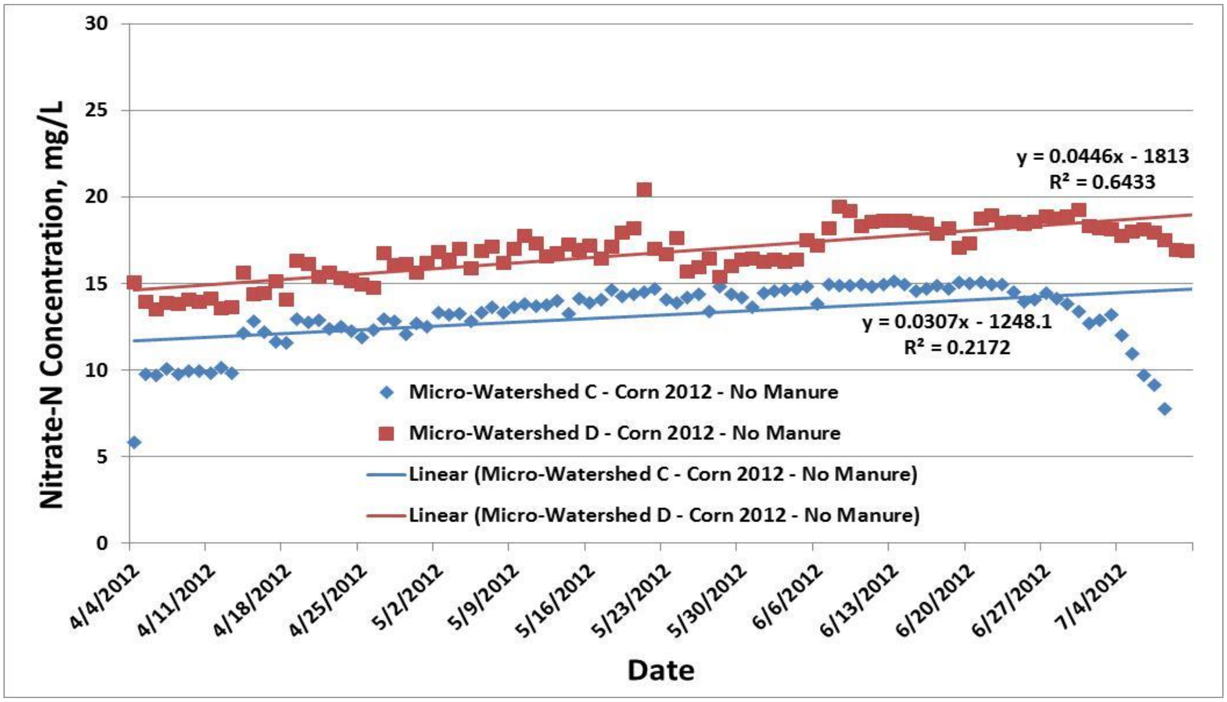

Figure 8: Nitrate-N concentrations in drainage water for micro-watersheds C and D planted to corn in 2012.

Table 1: Analysis of finishing swine manure applied in May 2012 to micro-watershed A before planting. Samples were collected both prior to and at the time of application.

		Sampled Prior to Application		Sampled During Application	
Analyte	Units	Sample 1	Sample 2	Sample 3	Sample 4
Moisture	%	95.7	95.7	95.6	95.8
Total Nitrogen	%	0.60	0.60	0.65	0.73
Phosphorus (as P2O5)	%	0.17	0.20	0.18	0.18
Potassium (as K2O)	%	0.26	0.27	0.30	0.33
Ammonia Nitrogen	%	0.44	0.45	0.52	0.51
Sulfur	%	0.10	0.07	0.08	0.08
Copper	mg/kg	45.5	44.3	35.4	34.6
Calcium	mg/kg	1150	1160	1200	1170
Iron	mg/kg	77.8	79.7	77.6	70.4
Magnesium	mg/kg	671	676	654	624
Manganese	mg/kg	17.5	17.8	15.7	15.0
Sodium	mg/kg	854	858	930	935
Zinc	mg/kg	42.9	42.4	39.8	39.4

Table 2: Monthly flow volumes, mass and flow weighted concentrations for nitrate-N and ortho-phosphate for micro-watersheds A and B located in Hamilton County, IA.

Micro-Watershed A - Soybeans 2012 - Manure						
Prior to Manure Application		Flow Volume	Nitrate Mass	Flow Weighted Nitrate Concentration	Ortho-P Mass	Flow Weighted Ortho-P Concentration
Month	Monitoring Days	gallons	pounds	mg/L	pounds	mg/L
April	4	154,940	13.5	10.4	0.233	0.180
May	13	361,955	35.0	11.6	0.090	0.030
Total	17	516,894	48.5	11.2	0.322	0.075

Micro-Watershed A - Soybeans 2012 - Manure						
After Manure Application		Flow Volume	Nitrate Mass	Flow Weighted Nitrate Concentration	Ortho-P Mass	Flow Weighted Ortho-P Concentration
Month	Monitoring Days	gallons	pounds	mg/L	pounds	mg/L
May	18	275,537	26.93	11.7	0.119	0.052
June	30	159,326	19.86	14.9	0.082	0.062
July	31	168	0.02	16.7	0.000	0.103
August	31	0				
September	30	0				
October	31	0				
November	30	0				
Total	201	435,032	46.8	12.9	0.201	0.055

Micro-Watershed B - Soybeans 2012 - No Manure						
		Flow Volume	Nitrate Mass	Flow Weighted Nitrate Concentration	Ortho-P Mass	Flow Weighted Ortho-P Concentration
Month	Monitoring Days	gallons	pounds	mg/L	pounds	mg/L
April	4	104,841	11.5	13.2	0.063	0.072
May	31	315,849	33.9	12.8	0.035	0.013
June	30	73,601	7.8	12.7	0.010	0.016
July	31	3,351	0.4	13.1	0.001	0.032
August	31	0				
September	30	0				
October	31	0				
November	30	0				
Total	218	497,643	53.5	12.9	0.109	0.026

Table 3: Monthly flow volumes, mass and flow weighted concentrations for nitrate-N and ortho-phosphate for micro-watersheds C & D located in Hardin County, IA.

Micro-Watershed C - Corn 2012 - No Manure						
		Flow Volume	Nitrate Mass	Flow Weighted Nitrate Concentration	Ortho-P Mass	Flow Weighted Ortho-P Concentration
Month	Monitoring Days	gallons	pounds	mg/L	pounds	mg/L
April	26	301,651	29.2	11.6	0.107	0.042
May	31	317,877	36.3	13.7	n.d.	n.d.
June	30	132,316	16.2	14.6	0.009	0.008
July	31	23,860	2.3	11.7	0.009	0.043
August	31	0				
September	30	0				
October	31	0				
November	30	0				
Total	240	775,704	84.1	13.0	0.124	0.019

Micro-Watershed D - Corn 2012 - No Manure						
		Flow Volume	Nitrate Mass	Flow Weighted Nitrate Concentration	Ortho-P Mass	Flow Weighted Ortho-P Concentration
Month	Monitoring Days	gallons	pounds	mg/L	pounds	mg/L
April	26	240,439	30.1	15.0	0.101	0.051
May	31	183,956	25.8	16.8	0.006	0.004
June	30	121,499	18.5	18.2	0.005	0.005
July	31	21,085	3.2	18.0	0.000	0.002
August	31	0				
September	30	0				
October	31	0				
November	30	0				
Total	240	566,979	77.5	16.4	0.113	0.024

Table 4A: Soil analysis data for micro-watersheds A, B, C, and D for Spring 2012.

Micro - Watershed	Depth (inches)	Date Taken	Organic Matter (%)	pH	buffer pH	Mehlich-3 P ppm	K ppm	Nitrate ppm
A	0 – 6	Apr-12	3.0	6.7	6.9	41.0	155.3	4.0
A	6 – 12	Apr-12	2.2	6.4	6.8	27.8	54.3	3.7
A	12 – 24	Apr-12	1.5	6.5	6.9	10.3	48.0	2.4
A	24 – 36	Apr-12	1.4	7.0	7.1	8.8	60.3	1.1
A	36 – 48	Apr-12	1.0	7.7	7.4	10.5	51.3	1.3
B	0 – 6	Apr-12	2.9	6.4	6.8	20.3	74.3	4.4
B	6 – 12	Apr-12	1.7	6.0	6.3	6.0	40.0	2.6
B	12 – 24	Apr-12	1.6	6.1	6.6	6.3	53.3	1.6
B	24 – 36	Apr-12	1.2	7.0	7.0	8.3	51.0	0.8
B	36 – 48	Apr-12	0.7	8.1	7.4	4.0	36.0	1.3
C	0 – 6	Apr-12	2.6	6.1	6.6	6.7	77.3	4.4
C	6 – 12	Apr-12	2.4	6.3	6.9	5.3	60.0	4.0
C	12 – 24	Apr-12	2.1	7.1	7.2	2.3	39.7	3.1
C	24 – 36	Apr-12	0.8	7.9	7.5	2.3	36.3	3.0
C	36 – 48	Apr-12	0.5	8.1	7.6	4.7	34.7	1.8
D	0 – 6	Apr-12	2.7	6.1	6.7	32.3	221.0	50.5
D	6 – 12	Apr-12	2.2	6.4	6.9	10.7	103.3	17.1
D	12 – 24	Apr-12	1.5	7.0	7.1	5.0	54.0	4.9
D	24 – 36	Apr-12	0.8	7.5	7.3	5.0	71.7	3.0
D	36 – 48	Apr-12	0.7	7.8	7.5	4.7	68.7	2.4

Table 4B: Soil analysis data for micro-watersheds A, B, C, and D for Fall 2012.

Micro - Watershed	Depth	Date Taken	Organic Matter (%)	pH	buffer pH	Mehlich-3 P	K	Nitrate
	(inches)					ppm	ppm	ppm
A	0 – 6	Nov-12	3.2	6.3	7.2	28.8	148.3	12.3
A	6 – 12	Nov-12	2.2	6.3	7.2	6.8	70.3	8.8
A	12 – 24	Nov-12	2.1	6.3	7.1	4.8	78.3	5.2
A	24 – 36	Nov-12	1.7	7.1	7.4	6.0	80.0	1.7
A	36 – 48	Nov-12	1.1	7.9	7.7	6.3	60.8	1.6
B	0 – 6	Nov-12	2.5	6.6	7.2	17.3	75.0	9.3
B	6 – 12	Nov-12	1.8	6.3	7.1	5.0	71.0	5.3
B	12 – 24	Nov-12	1.7	6.0	7.0	5.3	105.0	2.9
B	24 – 36	Nov-12	1.4	7.1	7.3	6.0	88.7	0.4
B	36 – 48	Nov-12	1.1	8.2	7.6	4.0	69.3	0.9
C	0 – 6	Nov-12	3.4	5.1	6.4	6.7	90.3	11.5
C	6 – 12	Nov-12	3.7	6.1	6.9	5.7	64.7	20.2
C	12 – 24	Nov-12	2.7	6.3	7.1	3.3	63.0	9.6
C	24 – 36	Nov-12	1.5	6.9	7.3	3.7	66.0	0.8
C	36 – 48	Nov-12	0.8	7.4	7.5	5.3	48.0	0.6
D	0 – 6	Nov-12	3.3	5.2	6.2	21.7	120.3	6.2
D	6 – 12	Nov-12	3.8	5.7	6.6	7.3	84.3	5.8
D	12 – 24	Nov-12	3.0	6.3	6.9	4.3	80.7	2.2
D	24 – 36	Nov-12	1.6	6.9	7.3	6.0	83.0	0.8
D	36 – 48	Nov-12	1.1	7.4	7.4	8.7	61.0	0.6