Section 319 Nonpoint Source Pollution Control Program:
319 Demonstration, Education, Research
Final Report

Cottonwood River Native Vegetation Water Quality

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Consultant's Report

Table of Contents

List of Figures

List of Tables

Grant Project Summary

Project title: Cottonwood River Native Vegetation Water Quality

Organization (Grantee): Minnesota Department of Agriculture

Project start date: 1/31/2011 Project end date: 8/30/14 Report submittal date: 10/20/14

Grantee contact name: Bill VanRyswyk Title: Supervisor

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Basin (Red, Minnesota, St. Croix, etc.): Cottonwood River County: Redwood

Project type (check one):

- ☐ Clean Water Partnership (CWP) Diagnostic
- ☐ CWP Implementation
- ☐ Total Maximum Daily Load (TMDL) Development
- ☐ 319 Implementation
- ☒ 319 Demonstration, Education, Research
- ☐ TMDL Implementation

Grant Funding

Final grant amount: $167,666.42 Final total project costs: $310,712.65

Matching funds: Final cash: $0 Final in-kind: $143,046.23 Final Loan: $0

Contract number: B42183 MPCA project manager: Mark Hanson

Executive Summary of Project

This study quantified the surface water quantity and quality and soil hydrologic characteristics of perennial vegetation on undisturbed soils in southwest Minnesota, and measured the changes that occurred following the conversion of a portion of the perennial vegetation to cropland utilizing a paired watershed design. Two small watersheds were instrumented with H-flumes and monitored year-round for four years. The perennial vegetation did not produce run-off during non-frozen soil conditions; however, it did have run-off associated with snowmelt over frozen soils. The water quality of the snowmelt run-off did have elevated levels of total phosphorus (TP), primarily in the dissolved molybdate reactive phosphorus (DMRP) form, and contained various forms of nitrogen, along with low sediment levels. The water leaving the perennial vegetation did carry nitrogen, phosphorus, and sediment although the run-off volumes were very low resulting in minimal pollutant exports.

One of the watersheds was converted from perennial vegetation to cropland in May 2013. Four run-off events from the cropland were observed in June of 2013. These were the only run-off events on non-frozen soils over the duration of the project. The conversion to cropland did result in additional total nitrogen (1.8 lb./acre), total phosphorus (0.24 lb/acre), and sediment (953 lb/acre) being exported from the watershed compared to the control in June 2013. These increased losses are more reflective of a shift in hydrology rather than a shift in pollutant concentrations, due to the lack of run-off observed from the perennial vegetation during non-frozen soil conditions.

An above and below design was also used to monitor non-point source agriculture run-off as it entered and exited the perennial vegetation. The vegetation effectively captured pollutants and run-off with high infiltration rates on a transition zone between a highly productive agriculture zone and the river valley floodplain.

Goals

1st Goal: Water quality and quantity characterization of perennial vegetation (including CRP) systems

2nd Goal: Quantification of natural background contributions from soil and perennial vegetation to current water quality impairments related to turbidity, excess nutrients, and bacteria

3rd Goal: Comparison of water quality characteristics among differing land management practices including: perennial vegetation and conventional row crop agriculture

Results that Count

1st Result: Three factors were determined to be important in affecting watershed hydrology, surface runoff, erosion and nutrient loss during the experiment: 1) precipitation (timing, intensity, frequency and duration); 2) frozen versus non-frozen soil conditions, and 3) land management (cultivated versus perennial vegetation).

2nd Result: No run-off occurred from perennial vegetation during periods with non-frozen soils; therefore no export of sediment or nutrients were measured from the perennial vegetation during non-frozen periods. Lack of run-off on non-frozen soil was attributed to the high infiltration capacity of the perennial vegetation. Sediment yields and flow-weighted mean concentrations (FWMC) were low for all events that occurred on frozen soils. Nitrogen losses were small in surface run-off, as anticipated, since most nitrogen losses occur through leaching. Total phosphorus (TP) FWMC ranged from 0.68 to 7.73 mg/L from perennial vegetation, however,, export loads were low when combined with run-off volumes. The dominant form of phosphorus was in the dissolved form (range of 16 to 80 percent, averaged 52 percent). E. coli bacteria counts in run-off from watersheds with perennial vegetation over frozen soils ranged from <1 to 1046 MPN/100mL, and averaged 375.2 MPN/100mL.

3rd Result: No run-off occurred from perennial vegetation during periods with non-frozen soils; four run-off events occurred in June of 2013 following conversion to cropland. When comparing the water quality of perennial vegetation to the recently converted cropland, the recently converted cropland had higher surface losses (yields) and FWMC for nitrogen, phosphorus, and sediment, along with much higher E. coli bacteria counts. A change in hydrology (run-off volumes) was the primary difference. Perennial vegetation provided better soil cover in May and June when the largest precipitation events occurred.

Site Photos

Description/location:

Monitoring site following hay cutting, shows slope of the land leading to the sites.

Monitoring site during the winter. Sites were maintained through the winter to ensure accurate results during snowmelt events.

Monitoring site facing upslope. The H-flume and instrument shelter are visible.

Nested monitoring site located below agricultural field and above the perennial vegetation. Another site captured runoff below the perennial vegetation for the "Above and Below" assessment.

Acronyms

BMP: Best Management Practice

BWSR: Board of Water and Soil Resources

CEC: Cation exchange capacity

CRP: Conservation Reserve Program

DEM: Digital Elevation Model

DMRP: Dissolved molybdate reactive phosphorus

EC: Electrical conductivity

FWMC: Flow weighted mean concentration

LIDAR: Light detection and ranging

MDA: Minnesota Department of Agriculture

NH4-N: Ammonium-nitrogen

NO3-N: nitrate-nitrogen

NVe: Eastern-most watershed in paired watershed design (see Figure A).

NVm: Middle watershed; "below" watershed in above and below design (see Figure A).

NVm-field: Upper middle watershed; "above" watershed in above and below design (see Figure A).

NVw: Western-most watershed in paired watershed design (see Figure A).

SWROC: Southwest Research and Outreach Center

TC: Total carbon

TN: Total nitrogen

TP: Total phosphorus

TSS: Total suspended solids

U of MN: University of Minnesota

USDA: United States Department of Agriculture

Partnerships

Brian Hicks: Landowner/operator

BWSR: Vegetation assessment and reporting

MDA : Project management and reporting

SWROC: Site installation, data collection, data management, laboratory analysis, outreach, and reporting

Section I – Work Plan Review

Two change orders were approved for this project. The first change order was needed to adjust the timelines due to wet conditions that delayed the start of the project. In early 2014 a second change order was needed due to the lack of runoff that delayed project plan. Modifications to the monitoring systems were necessary to account for unanticipated flow conditions. The addition of a fourth site was installed using in-kind and the re-distribution of some of the grant funds within an objective to various task. The total grant funding and estimated in-kind did not change. The additional site was utilized to provide a nested monitoring location within one of the watersheds. The third watershed allowed for assessment of the effect of the native prairie vegetation located on the hillslope to treat water leaving the row cropped portion of the watershed situated at the top of the hillslope. This watershed was evaluated using an above-and-below design consisting of two watersheds that are monitored, one nested within the other. It provided useful information on the effectiveness of perennial vegetation as a treatment or BMP. The site will be used to quantify the water quality benefits from the targeted placement of native vegetation in critical landscape positions.

Objective 1: Fiscal Management and Planning.

Task 1: Track Project Grant and Matching Funds and Expenditures.
Project budget and fiscal management were tracked and bills paid on-time.

Task 2: Required Reporting and Data Management.
Required reports were submitted and all data was recorded, organized and tracked in spreadsheets. A Final Research Report is attached in Appendix 1.

Objective 2: Conduct Soil and Water Monitoring of 3 Watersheds

(modification was made to the monitoring system to install a nested monitoring site (4) within one of the watersheds per change order).

Task 1: Installation of Monitoring Equipment.

A digital elevation model (DEM) was completed at the site and the locations for background soil sampling and infiltration measurements were identified. Monitoring equipment, wingwalls and H-flumes were installed in autumn 2010 for all three experimental sub-watersheds. Each watershed had a plywood wing wall installed perpendicular to flow near the bottom of the drainage (Stuntebeck, et al, 2008.). Flow was concentrated and forced through a pre-calibrated 1.5 foot H-flume that was equipped with a datalogger and bubbler to record water level, discharge, rainfall, soil moisture, and soil temperature. Run-off events were recorded on a 1-minute interval to examine hydrologic characteristics of the watershed. An ISCO 6712 automated water sampler was used to collect flow-based composite samples into 24 1-L bottles. Water samples were analyzed for ammonium, nitrate, total nitrogen, dissolved reactive phosphorus, total phosphorus, total suspended solids, and *E. Coli* (Appendix 1). This information was used to calculate pollutant export (loads) and flow weighted mean concentrations (FWMC) from the watersheds.

Task 2: Soil Sample each of the Watersheds.

During summer 2011, 32 soil sampling points were identified and geo-referenced across the study area. Soil samples were collected during fall of 2012 near the geo-referenced points using a Giddings probe and were separated into discrete depth intervals for physical (bulk density) and chemical analysis. A subset of these samples, from the 0-10 cm and 10-20 cm depths, were ground and sent to the University of Minnesota Research Analytical Laboratory for chemical analysis including: organic matter, pH, cation exchange capacity (CEC), total nitrogen (N), total carbon (C), and total phosphorus (TP) and textural analysis. These data provided background information on soil physical and chemical characteristics of the site before treatments were prescribed. They were also used to determine potential cause and effect of sediment and nutrient loss after treatment assignment. Infiltration measurements planned for summer 2011 were postponed until spring 2012. The reason for the postponement was due to excessive wet conditions in May and June, 2011 followed by extreme dry conditions the remainder of 2011. Infiltration was successfully measured during 2012 in close proximity (1-2 m) of the 32 geo-referenced sampling points. After treatment in the NVe watershed and in NVm-field, 15 soil sample points were resampled and analyzed for bulk density and infiltration.

Task 3: Water Quality Sampling and Laboratory Analysis.

Pre-treatment (calibration) and post-treatment water samples were collected and analyzed for temperature, electrical conductivity (EC), total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN), nitrate-nitrogen (NO3-N), ammonium-nitrogen (NH4-N), and *E. Coli.* Occasionally temperature was not recorded because samples were not retrieved from the field site within reasonable amount of time after collection. Dissolved oxygen was not measured for any of the samples because there was no instrument available for in-field or lab measurement. The number of samples collected was less than anticipated in the original work plan because runoff events from the perennial vegetation were limited. 159 water samples were collected for laboratory analysis in this project.

Objective 3: Compare and Contrast Water Quality and Quantity Characteristics of Alternative Land Management Strategies to Native Prairie Systems.

Task 1: Data Analysis of Treatment Effects using Paired and Above and Below Watershed Protocols.

During 2010, a field-scale site consisting of perennial vegetation with no history of artificial drainage or conventional row crop production agriculture was selected at the Hicks Family Farm near Tracy, MN. The farm is located within the Cottonwood River Watershed, a tributary of the Minnesota River. The soil at the site was mapped as a Storden loam with 7-8% slope.

Conversion (treatment) to conventional row crop system occurred in one of the watersheds in 2013 following the calibration period while the control watershed was maintained in native prairie vegetation. Due to limited runoff from the perennial vegetation limited calibration data was collected. The treatment watershed was converted to conventional row crop (corn) common for the region. Tillage and site-specific nutrient management practices were employed and documented in the treatment watershed. Year-round monitoring was completed from 2011 – 2014. During 2012 an additional monitoring system was also deployed to monitor a cultivated crop field contributing runoff to one of the sub-watersheds. The calibration period began in 2011 and ended in April of 2013. Sub-watershed treatment was initiated in May 2013 and continued through 2014. During the study period, extreme variability in monthly precipitation was observed. It was not uncommon to observe moderate to extreme drought and flooding conditions in the same year.

During some years no snowmelt runoff was observed. It was hypothesized that a lack of frost beneath the snow coupled with slow snowmelt resulted in a lack of measureable runoff. It was also hypothesized that the infiltration capacity of the soil under the perennial vegetation was very high, which also would have likely contributed to a lack of runoff. Subsequently, field measurements of infiltration capacity verified this hypothesis. During 2011 no snowmelt runoff was recorded and NVm ran once in June. No other runoff was recorded in 2011. In 2012, run-off over frozen soils occurred 3 times each at NVw and 5 times at NVm. No other run-off was observed in 2012 at NVw or NVe (both entirely in perennial vegetation). NVm had 6 events in April and of May of 2012. The occurrence of these events, led to the installation of the NVm-field to monitor an agricultural field that was releasing water onto NVm. NVm-field was installed in October of 2012. With the discovery of the agricultural field contribution, NVm was removed from the paired analysis, and an above and below design was implemented. NVw did not have run-off in 2013, NVe had 4 run-off events in June after conversion to cropland. NVw only had 3 run-off events on frozen soils, NVe only had 1 run-off event on frozen soils.

There were no challenges or setbacks with implementation of this aspect of the project. The native vegetation was plowed in the eastern treatment watershed (NVe) and the site was brought into production in May of 2013. Corn (Zea mays L.) was planted perpendicular to the hill slope in 2013 and fertilized with 120 lbs N/acre in 2013. No additional phosphorus or potassium inputs occurred. Corn was harvest by the farmer but yield data for 2013 was not available from the combine yield monitor. Corn was planted in 2014 using no-till methods and fertilized with 180 lbs N/acre. All nitrogen applications were in the form of urea and were broadcasted in June. Run-off volume from flow events was monitored as described in Section II of this report. Post-treatment water samples were analyzed for the same constituents as during the calibration period. Soil infiltration was re-measured in replicate at 15 locations in the NVe and NVm-field sub-watersheds after planting operations in June 2014. Soil bulk density was re-determined near the same 15 locations as the infiltration measurements.

Section II – Grant Results

Measurements:
This project collected many different parameters related to hydrology, water quality, GIS spatial analysis, and soil properties. While two experimental designs (paired watershed and above and below) were used to meet our goals, the same parameters were measured in both designs. Each of the parameters will be discussed briefly; a summary of the data and/or results will be presented in each experimental design section below. A complete analysis of the data and associated discussion and graphics are presented in the Final Research Report in Appendix 1 of this report.

Site Characterization Results:
Native vegetation specialists from the Board of Water and Soil Resources (BWSR) conducted a vegetation survey of the sites in 2013 (Figure 1). Vegetation was determined to be a mixture of native and non-native (including smooth brome grass (Bromus thermis) and Kentucky bluegrass(Poa pratensis) among others) vegetation. The native vegetation present was found as forbs in the understory of a predominantly smooth brome grass stand. Stem densities in the upper portions of the watershed were between 150 and 177 stems per square foot. Stem densities near the outlets of the watersheds were between 77 and 144 stems per square foot. The complete vegetation report is included in Appendix 1.

Figure 1. Photos of vegetation survey.

GIS Spatial Analysis Results:
The drainage area for each of the four watersheds was calculated in ArcGIS using the NRCS Engineering Toolbox, "Watershed Delineation" process. The "Watershed Delineation" process is a three step process that uses a Digital Elevation Model (DEM) to create a contour map that can be used to create a hydrologically correct DEM (Figure 2). The hydrologically correct DEM is used to calculate the drainage area and slope of a user defined outlet. After the "Watershed Delineation" process is completed, the user is provided with several shape files that provide a detailed assessment of the topography, hydrology, slope and drainage user defined outlets. A one-meter DEM was used as the input to the "Watershed Delineation" process. These data were retrieved from: http://www.mngeo.state.mn.us/chouse/metadata/lidar_swmn2010.html.

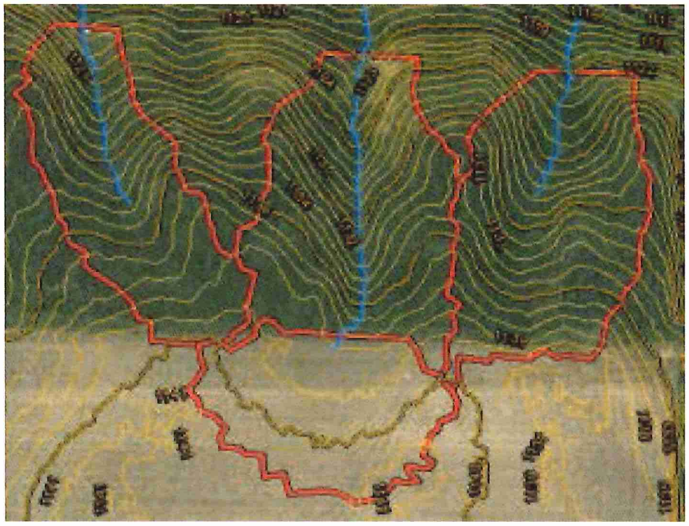

Figure 2. Digital elevation model for study sites.

A map of the study area is provided below for reference (Figure 3). The watershed outlets are shown with yellow stars, watershed boundaries are shown as red lines and stream lines were added to represent a drainage area greater than 0.25 acre. Following the precipitation section, data will be presented based on the experimental design type: paired watershed and above and below. This presentation will allow for the relevant information to be presented in a logical order.

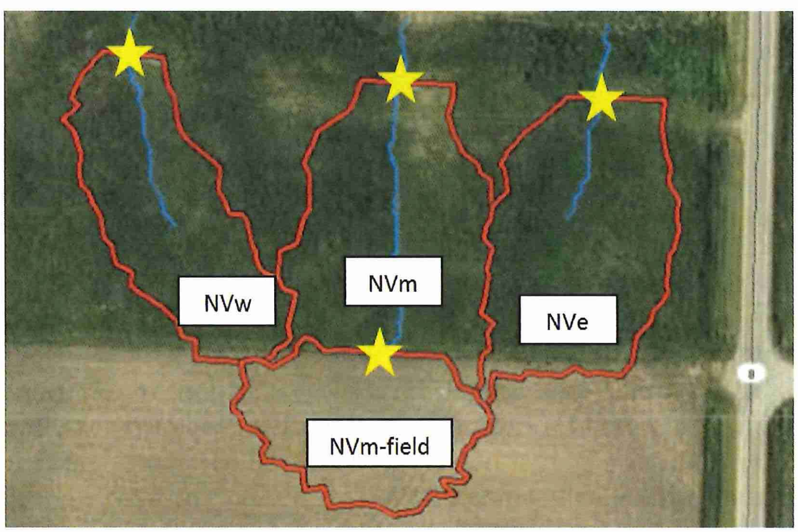

Figure 3. Watersheds included in the Cottonwood River Native Vegetation Water Quality Study.

The paired watershed design sites (NVw and NVe) were comparable in size (Table 1), slope, and slope length. The above and below design sites represent two different landscapes and land uses. The above field (NVm-field) is flatter, and is used for row crop production while the below field (NVm) has an average slope of 6.3% and is a mixture of cropland (NVm-field) with perennial vegetation separated by the NVm-field monitoring station.

Table 1. Watershed characteristics of the project area.

Paired Watershed Design			
	Watershed Size (acres)	Average Slope (%)	Slope Length (ft)
NVw	0.79	7.22	266
NVe	0.98	8.41	277
Above and Below Design			
	Watershed Size (acres)	Average Slope (%)	Slope Length (ft)
NVm-field (above)	0.67	2.82	151
NVm (below) (includes NVm-field)	1.70	6.3	394

Cottonwood River Watershed Examination of Comparable Lands

An analysis was completed to find areas within the Cottonwood River Watershed that have a similar slope as the project monitoring sites. The greater Cottonwood River Watershed consists primarily of land with slopes under 6 percent, and this analysis compares how much of the total watershed is comparable to our watersheds included in this study. The initial analysis was completed using the SSURGO Soils database (Soil Survey Staff 2014) and querying the areas that were defined as having similar slopes as the monitoring sites (6-12 percent slopes). The area of each polygon in the SSURGO shape file was deemed too great for a comparison between the project sites as many areas were greater than one acre. It was decided to complete additional analysis to compare the slope of areas at a one acre scale over greater Cottonwood River Watershed.

In order to complete this analysis, six three-meter Digital Elevation Models (DEMs) were downloaded from MnTOPO (http://arcgis.dnr.state.mn.us/maps/mntopo/) to encompass the entire CRW. The six DEMs were combined into one DEM using the Mosaic tool in ArcToolbox and were clipped to the Cottonwood River Watershed. The watershed shape file was downloaded from the MnDNR Deli. Slope was then calculated for each cell in the watershed wide DEM.

In order to calculate the slope for each one acre plot, the Grid Index Feature was used to create a one acre grid over the entire Cottonwood River Watershed (a total of 845,225 individual features) and this shape file was clipped to the watershed boundary. The Grid Index shape file had too many individual features to calculate Zonal Statistics so the Grid Index shape file was subdivided into twenty sections. Zonal statistics for the mean was calculated as a table for each of the twenty subsections of the Grid Index and exported as a text file. The twenty text files were combined into one table in Microsoft Excel and saved as a .csv file. The .csv file was converted to a geodatabase table using the Table to Table tool. The geodatabase table was then joined to the original Grid Index shape file for the entire Cottonwood River Watershed to provide the mean slope for each one acre parcel within the watershed.

The Cottonwood River Watershed was composed primarily of land with slopes under 6 percent (88.2 %) and land with slopes of greater than 12 percent made up 2.8 percent of the watershed. Land within the watershed with similar slopes (6-12 %) to our project sites composed 9.0 percent of the total watershed. This analysis shows that the results from this study should be applied to the greater Cottonwood River Watershed; however, there are over 75,000 acres with similar slopes (Figure 4). Land similar to our project sites will be critical in the future as these sensitive areas may be targeted for BMP's to mitigate agriculture pollution given their topography and proximity to the river valley.

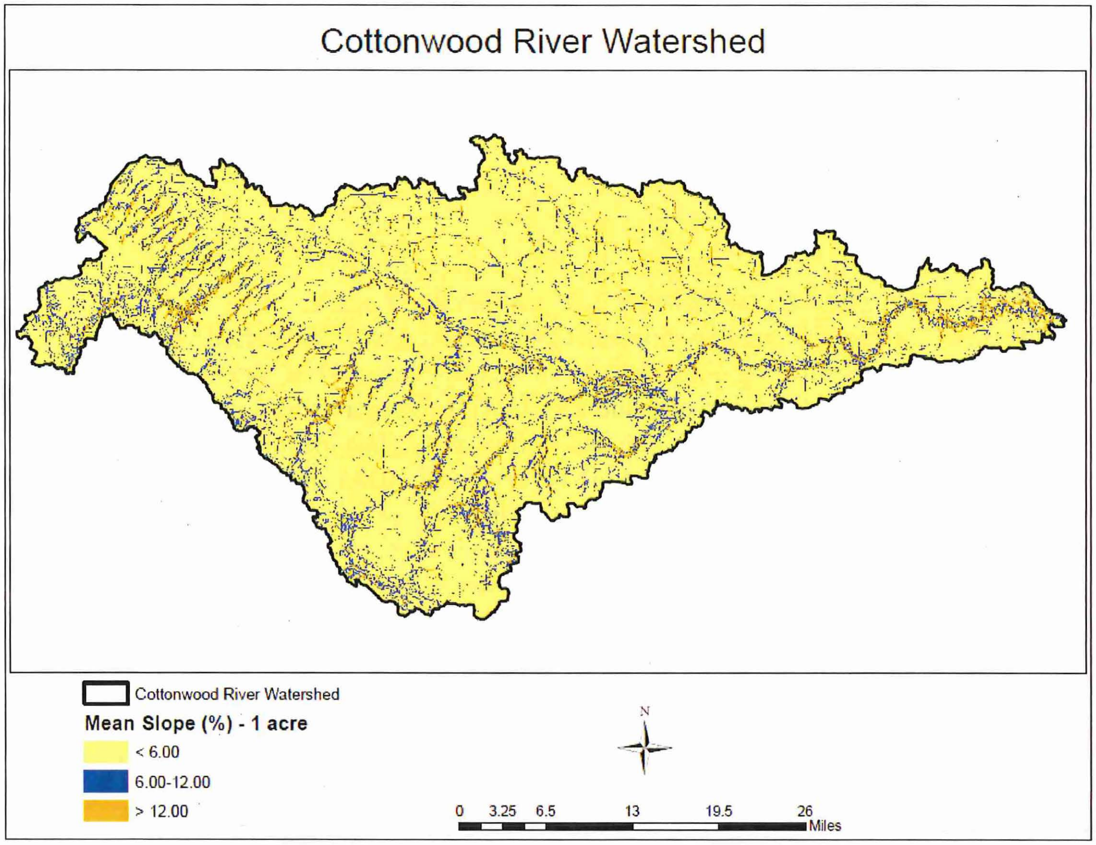

Figure 4. One acre average slopes for land within the Cottonwood River Watershed.

Precipitation

Monthly precipitation data were collected at the experimental site for the study period (2011-2014) and compared to the 30-year long-term (1980-2010) averages at the Southwest Research and Outreach Center (SWROC) in Lamberton (Figure 5). SWROC is located approximately 15 miles east/southeast of the study area. Monthly precipitation values in the winter were also taken from SWROC. Annual precipitation totals in 2011 through 2013 ranged from 20.2 to 23.0 inches compared to the annual average of 26.4 inches (13% to 24% below normal). The United States Drought Monitor classified the study sites as being in severe drought in the fall of 2011, extreme drought in the fall of 2012, and moderate drought in the fall of 2013. The distribution of rainfall was skewed to April through July every year from 2011 through 2014, and precipitation was below normal for most months from August through December from 2011 through 2013. Even with the below average annual totals, there were several months with above average precipitation including May and June of 2011, May of 2012 (the wettest May on record for SWROC), June of 2013 and June of 2014. In each year of monitoring, there was at least 1 daily rainfall total in May or June between 1.96 and 2.27 inches.

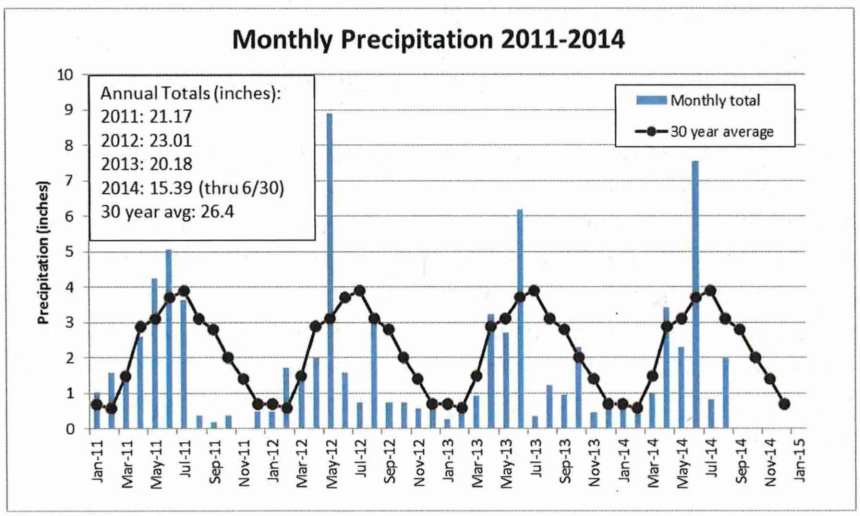

Figure 5. Monthly precipitation totals compared to the 30-year averages.

Watershed Study Experimental Design Methods

Two watershed study experimental designs were used in this study: paired watershed and above and below (Tollefson et al, 2014). From this point forward, the results from each design will be presented individually. Each section will include a summary of the experimental design, information from the study sites, and results.

Paired Watershed Design

This section describes the main experimental components of the paired watersheds research project. The project was designed to monitor surface run-off from perennial vegetation and recently converted perennial vegetation to cropland at the Hick's family farm near Tracy, MN. Infrastructure (wing walls, H-flumes, etc.) was installed in October of 2010 and electronic monitoring equipment was installed in February of 2011 prior to snowmelt. The sites were managed by the University of Minnesota, Southwest Research and Outreach Center (SWROC).

Two small watersheds (0.79 and 0.98 acres, respectively) were instrumented to monitor surface run-off. These watersheds are located in the southeast corner of a 160-acre field that was composed of a mixture of native and nonnative (including smooth brome grass (Bromus inermis) and Kentucky bluegrass(Poa pratensis) among others) perennial vegetation and was never cultivated for crop production. Cattle were grazed on the field until 2000, and since then, the field is harvested for forage in mid-summer. No artificial drainage was installed. The field was mapped as a Storden loam, a well-drained soil, with moderately high to high permeability on 7.2 and 8.4% slope. Slope lengths were 266 and 277 feet, respectively. The field is a transition between flat, highly productive agricultural fields to the south and lowland riparian land to the north. This transitional area is similar to other nearby lands that hold potential as treatment zones for received run-off, but is not representative of all fields in the region.

The watersheds were monitored utilizing a paired watershed design (Clausen and Spooner, 1993). Each watershed was managed in the perennial vegetation condition during 2011 and 2012 to conduct calibration of the paired watersheds. The vegetation was plowed in the eastern treatment watershed (NVe) and the site was brought into production in May of 2013. Corn (Zea mays L.) was planted perpendicular to the hill slope in 2013 and fertilized with 120 lbs N/acre in 2013. Corn was planted in 2014 using no-till methods and fertilized with 180 lbs N/acre. All nitrogen applications were in the form of urea and were broadcasted in June. The western watershed (NVw) was managed in perennial vegetation condition throughout the project (2011-2014) as the control site.

Hydrology and Run-off

Run-off was limited during the entire study period. During the calibration period (February 2011- April 2013), both NVw and NVe only recorded run-off on three days in 2012. All three of these events occurred when the soils were frozen and included run-off generated from snowmelt and from rainfall on frozen ground. The NVw site recorded 0.08 inches of run-off/acre (242 cubic ft) and NVe recorded 0.22 inches of run-off/acre (814 cubic ft) over the three events in 2012. No run-off was observed from either NVw or NVe during non-frozen soil conditions in the calibration period. Following the treatment (NVe converted to cropland), NVe had 4 run-off events in June of 2013 that totaled 0.73 inches of run-off/acre (2610 cubic ft). NVw (perennial vegetation control site) did not record run-off in 2013. Run-off occurred at both NVw and NVe in 2014 during the snowmelt when soils were frozen. No run-off was observed when the soils were non-frozen in 2014. The NVw site recorded 0.14 inches of run-off/acre (406 cubic ft) in 3 run-off events and NVe recorded 0.08 inches of run-off/acre (290 cubic ft) in a single run-off event in 2014. Snowmelt was only recorded in years associated with deep frost levels. Run-off was infrequent and of short duration: the average event on frozen soils lasted 5.4 hours; the average event on non-frozen soils (after NVe converted to cropland only) was 42 minutes.

Sediment

Event sediment yields at NVw averaged 0.24 lb/acre and flow weighted mean concentrations (FWMC) averaged 40.7 mg/L. All NVw events occurred during frozen soil conditions. A total of 1.12 lbs of sediment was exported from NVw from 2011 through June 2014. The NVe pre-treatment (perennial vegetation) event sediment yields averaged 0.22 lbs/acre and FWMC averaged 64.5 mg/L. All NVe pre-treatment events occurred on frozen soils. The NVe post-treatment (after conversion to cropland) sediment characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded sediment at 1.94 lb/acre and FWMC was 106.8 mg/L. Event sediment yields at NVe post-treatment over non-frozen soils averaged 238.2 lb/acre and FWMC averaged 5,075 mg/L. A total of 0.64 lbs of sediment was exported from NVe in 2011 and 2012; a total of 935.8 lbs of sediment was exported from NVe in 2013 and 2014 after conversion to cropland. Sediment yields and FWMC were low for all events that occurred on frozen soils. Sediment yields and FWMC were much greater at NVe after conversion to cropland on non-frozen soils. No run-off occurred from the perennial vegetation during non-frozen soils; therefore no export of sediment was measured from the perennial vegetation during non-frozen periods.

Nitrogen

Event total nitrogen (TN) yields at NVw averaged 0.07 lb/acre and FWMC averaged 5.2 mg/L. Total nitrogen speciation included 2.1% ammonium, 17.7% nitrate-nitrite, and 80.2% organic nitrogen. All NVw events occurred during frozen soil conditions. NVe pre-treatment (perennial vegetation) event TN yields averaged 0.24 lbs/acre and FWMC averaged 31.1 mg/L. Total nitrogen speciation included 5.7% ammonium, 3.2% nitrate-nitrite, and 91.1% organic nitrogen. NVe post-treatment (after conversion to cropland) nitrogen characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded TN at 0.15 lb/acre and FWMC was 8.1 mg/L. Event TN yields at NVe post-treatment over non-frozen soils averaged 0.45 lb/acre and FWMC was 9.5 mg/L. Total nitrogen speciation included 7.0% ammonium, 8.2% nitrate-nitrite, and 84.8% organic nitrogen (Appendix 1). The largest nitrogen losses were associated with the 4 non-frozen soil events at NVe post-treatment (after conversion to cropland). Large nitrogen losses through surface run-off were not anticipated as most nitrogen losses occur through leaching or through artificial drainage (if present) (*Minnesota Discovery Farms 2012 Water Year Monitoring Report, 2013)*.

Phosphorus

Event total phosphorus (TP) yields at NVw averaged 0.01 lb/acre and FWMC averaged 0.5 mg/L (Table 1). Approximately 40% of the TP was in the dissolved molybdate reactive phosphorus (DMRP) form. All NVw events occurred during frozen soil conditions. The NVe pre-treatment (perennial vegetation) event TP yields averaged 0.03 lbs/acre and FWMC averaged 4.7 mg/L. Approximately 79% of the TP was in the DMRP form. All NVe pre-treatment events occurred on frozen soils. NVe post-treatment (after conversion to cropland) phosphorus characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded TP at 0.02 lb/acre and FWMC was 1.0 mg/L. Event TP yields at NVe post-treatment over non-frozen soils averaged 0.06 lb/acre and FWMC was 1.2 mg/L. Approximately 6% of the TP was in the DMRP form for all events at NVe post treatment.

The watersheds managed in perennial vegetation did have elevated TP concentrations; however, the export loads were low when combined with run-off volumes. The watersheds managed in perennial vegetation also had a higher fraction of the TP in the DMRP form than from NVe after conversion to cropland. The events with the largest TP export loads occurred at NVe in 2013 after conversion to cropland. No run-off occurred from the perennial vegetation during non-frozen soils; therefore no export of TP was measured from the perennial vegetation during non-frozen periods.

Soil Bulk Density

Soil bulk density increased from 1.25 to 1.40 g/cm^3 in first 10 cm depth (Figure 6) following the conversion from perennial vegetation to cropland (Appendix 1). Soil bulk density also increased at each interval from 10 to 40 cm below the surface. In the perennial vegetation, soil bulk density decreased at the 40 to 60 cm depths and normalized around 1.44 g/cm^3 from 60 to 100 cm depth. After conversion of perennial vegetation to cropland, the soil bulk density increased at the 40 to 60 cm depth and normalized around 1.75 g/cm^3. Soil bulk density measurements of an adjacent field (NVm-field) with a long history of crop production were collected as a reference point. The recently converted cropland had soil bulk densities that fell between the perennial vegetation and NVm-field at the 0-40 cm depth. Soil bulk density in the lower 40-100 cm depth was similar for the recently converted cropland and NVm-field. It is anticipated that long-term production in the recently converted cropland would result in greater soil bulk densities in the 0-40 cm depth over time likely effecting physical soil properties.

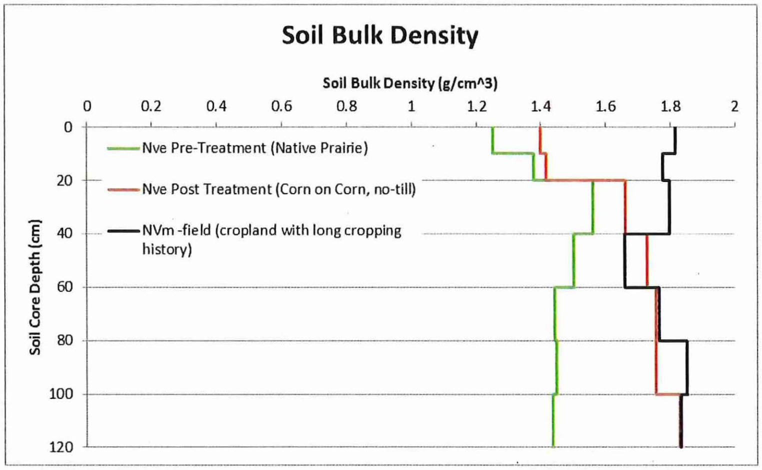

Figure 6. Soil bulk density of NVe pre-treatment (perennial vegetation) and NVe post-treatment (corn on corn, no-till in second year of crop production).

Infiltration

Hydraulic conductivity was determined at NVe during the control (perennial vegetation, 2012) and treatment (corn on corn, no-till, 2014). Measurements of the infiltration at NVe pre-treatment were consistent with hydraulic conductivity of the adjoining perennial vegetation sites (Figure 7); measurements of the infiltration at NVe post-treatment were consistent with the hydraulic conductivity of the adjoining field that has been in production for many decades (Figure 8). These measurements indicate a dramatic decrease in the amount of water that can infiltrate the soil after conversion to cropland.

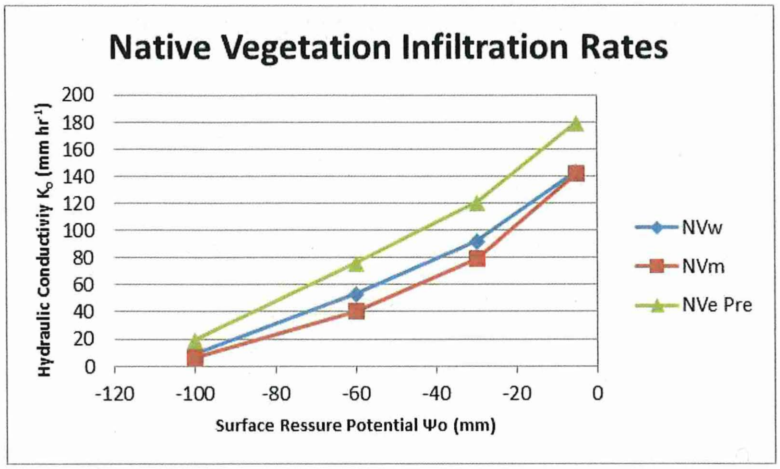

Figure 7. Watershed infiltration rates of three watersheds of native vegetation.

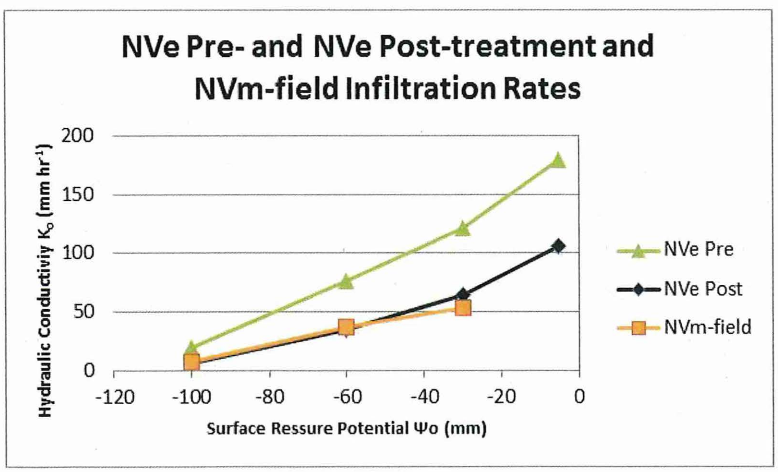

Figure 8. Watershed infiltration rates of NVe pre-treatment (perennial vegetation), NVe post-treatment (corn on corn, no-till), and NVm-field (crop field with long cropping history).

Conclusions

This study characterized the hydrology and water quality of perennial vegetation on undisturbed soils in southwest Minnesota. On the perennial vegetation, lack of run-off during non-frozen soil conditions was a significant factor in overall run-off losses. Snowmelt run-off from the perennial vegetation during frozen soil conditions did carry nitrogen, phosphorus and sediment from the watersheds. After conversion to cropland, the NVe watershed did experience four run-off events in June of 2013. The observed run-off and associated pollutant loads are likely a result of the change in land use. Increases in soil bulk density, and lowered infiltration rates were associated with the conversion into cropland. Additional years of crop production would likely continue to change the soil properties, and ultimately the hydrology of this site.

Above and Below Design

An above and below watershed design is used to isolate differences in land management, such as a BMP. The above and below watersheds are actually nested within a single watershed. The above watershed has the same monitoring equipment and objectives as the below. The water quantity and quality are measured from the above watershed, and then releases the water onto the below watershed. The below watershed is then monitored at the outlet. The difference between the water quantity and quality of the above and below monitoring stations is related to the treatment in the below watershed. The nested design elevates the need for a calibration period *(USDA, National Water Quality Handbook, 2003).*

At the beginning of our paired watershed study in 2011, it was unknown that NVm had 0.67 acres of row crop contributing to it. Significant differences in run-off volumes occurred between NVw, NVe, and NVm in 2011 and 2012. Further site investigation in 2012, as well as the availability of the high resolution LIDAR data, allowed for the above and below design to be implemented in October of 2012.

This section describes the main experimental components of the above and below watershed research project. The project was designed to monitor surface run-off from native vegetation and row crops at the Hick's family farm near Tracy, MN. Infrastructure (wing walls, H-flumes, etc.) was installed in October of 2010 at NVm and in October of 2012 at NVm-field. Monitoring began at NVm in February of 2011 prior to snowmelt and in October of 2012 at NVm-field, however, data analysis can only be completed since October 2012. The sites were managed by the University of Minnesota, Southwest Research and Outreach Center (SWROC).

Two nested watersheds (0.67 and 1.70 acres, respectively) were instrumented to monitor surface run-off. One watershed (NVm-field) was located within NVm (Figure 9). NVm-field (0.67 acres) had a slope of 2.82% and has a long history of row crop production. The field is mapped as Ves loam, a well-drained soil, with moderately high to high permeability. This is representative of many agricultural fields in the Cottonwood River Watershed. NVm-field watershed drains into NVm. NVm was composed of the NVm-field contributing area that drains into a mixture of native and nonnative (including smooth brome grass (Bromus thermis) and Kentucky bluegrass(Poa pratensis) among others) perennial vegetation and was never cultivated for crop production. Cattle were grazed on the perennial vegetation until 2000, and since then, the field is harvested for forage in mid-summer. No artificial drainage is present on the NVm hills lope. NVm's hills lope was mapped as a Storden loam, a well-drained soil, with moderately high to high permeability on 6.3% slope. NVm hills lope is a transition between flat, highly productive agricultural fields to the south and to lowland riparian land to the north.

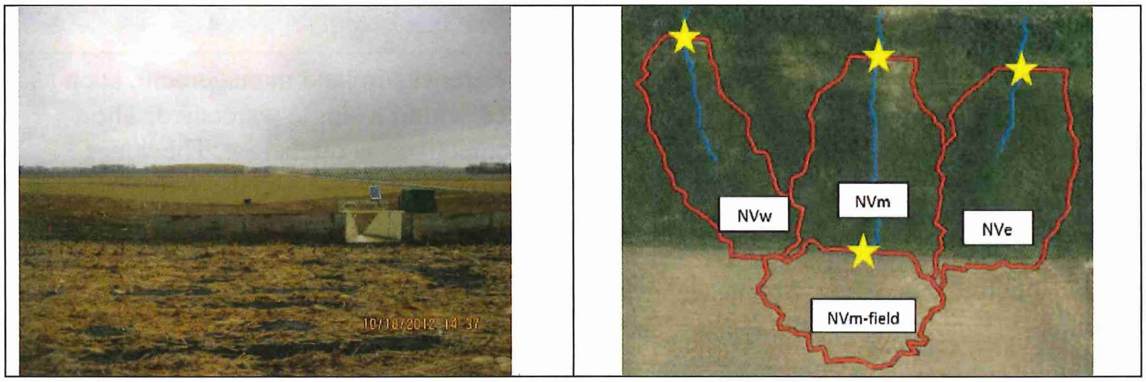

Figure 9. Photograph and map of NVm and NVm-field. In photo, NVm-field is in the foreground, and NVm is visible from the green shelter at the bottom of the hillslope.

The watersheds were monitored utilizing an above and below watershed design (*National Water Quality Handbook*). NVm-field was used for corn (Zea mays L) production since 2012, and NVm hillslope was in perennial vegetation. The hill slope vegetation was harvested in early July each year for forage. NVm-field was managed for high yielding corn production throughout the study, and would be representative of corn field in southwest Minnesota. NVm-field made up approximately 40% of the NVm watershed; meaning that the contributing area of the corn field was smaller than the treatment zone of the perennial vegetation.

Water Quality and Quantity Monitoring

Each watershed had a plywood wing wall installed perpendicular to flow near the bottom of the drainage (Stuntebeck, et al, 2008.). Flow was concentrated and forced through a pre-calibrated 1.5, or 2.5, foot H-flume that was equipped with a data logger and bubbler to record water level, discharge, rainfall, soil moisture, and soil temperature. Run-off events were recorded on a 1-minute interval to examine hydrologic characteristics of the watershed. An ISCO 6712 automated water sampler was used to collect flow-based composite samples into 24 1-L bottles. Water samples were analyzed for ammonium, nitrate, total nitrogen, dissolved reactive phosphorus, total phosphorus, total suspended solids, and E. Coli. This information was used to calculate pollutant export (loads) and flow weighted mean concentrations (FWMC) from the watersheds. No water quality or quantity monitoring of vadose zone or ground water was completed.

Soil Properties - Above and Below Evaluation

Soil properties at 15 locations were measured using a 0.1 acre grid pattern sampling design. Soil cores were analyzed in replicate at the 0-10 cm and 10-20 cm intervals for organic matter, pH, total organic carbon, total nitrogen, total phosphorus, cation exchange capacity, calcium, potassium, magnesium, sodium, and aluminum prior to conversion to cropland. Soil bulk density was determined in replicate at each of the 15 locations from cores collected at intervals of 0-10, 10-20, 20-40, 40-60, 60-80, 80-100, and 100-120 cm. Soil bulk density was determined by slicing 100 cm cores at predetermined intervals and drying at 105° C for 24 hours (Klute, 1986). Soil bulk densities are reported as an average of the specific depths in each watershed. Soil infiltration was measured in replicate at each of the 15 locations in the fall of 2012 or June of 2014. Tension infiltrometers were operated at pressures of -10, -6, -3 and -0.5 cm. (Reynolds and Elrick, 1991).

Hydrology and Run-off

Run-off events were broken down into two categories for analysis: frozen soils and non-frozen soils. Each these categories exhibit different patterns for each watershed. On frozen soils, the amount of run-off is strongly correlated to the amount of snowpack in the watershed. These two fields trap snow differently over the winter. Limited snowpack is captured in NVm-field watershed because sits on top of the ridge and most snow blows off of the watershed. The lack of snow at NVm-field allows for deep frost, and limits infiltration during snowmelt. NVm captures a large amount of snow due to the perennial vegetation that traps the snowpack. In addition, the valley between NVm-field and NVm holds several feet of snow throughout the winter. NVm has much more snow water equivalent available when snowmelt begins.

The two watersheds also have dramatically different snowmelt periods. The NVm-field watershed had limited snowpack, allowing the high sun angle in March to penetrate the snow and expose black soil even before temperatures reach freezing. Much or most of the snow in NVm-field sublimates before it has the opportunity to run-off. NVm-field has a higher heating potential, and generally the snowmelt run-off process is shorter than in the NVm watershed. In 2013, NVm-field had 0.43 in/acre of snowmelt run-off that occurred on a single day and in 2014, NVm-field had 0.86 in/acre of snowmelt run-off that occurred on 3 days. The snowmelt at NVm is a slower process due to the deeper snowpack not allowing soil to be exposed with temperatures below melting and the north facing orientation of the slope that does not efficiently collect the sun's energy. The third factor is the influence of the perennial vegetation that limits the depth of the frost and established macropore pathways in the soil. These factors lead to a slower melt and limit the surface run-off due to infiltration. In 2013, NVm did not have snowmelt run-off and in 2014, NVm-field had 0.54 in/acre snowmelt run-off. The perennial vegetation on the NVm hill slope had very little run-off, and also trapped run-off from the NVm-field portion of the watershed (Figure 10a).

Non-frozen soil run-off events occurred more frequently at NVm-field, and had higher run-off volumes (Figure 10b). In 2013 at NVm-field a single event in June had 0.44 in/acre run-off, and in 2014 at NVm-field two events that totaled 0.23 in/acre of run-off. NVm only had two small run-off events in 2013 totaling 0.03 in/acre of run-off and no run-off was measured in 2014. All non-frozen soil events in 2013 and 2014 occurred in June. The overall lack of run-off during non-frozen soil periods at NVm aligns with the two adjoining perennial vegetation watersheds that did not record run-off from 2011-2014.

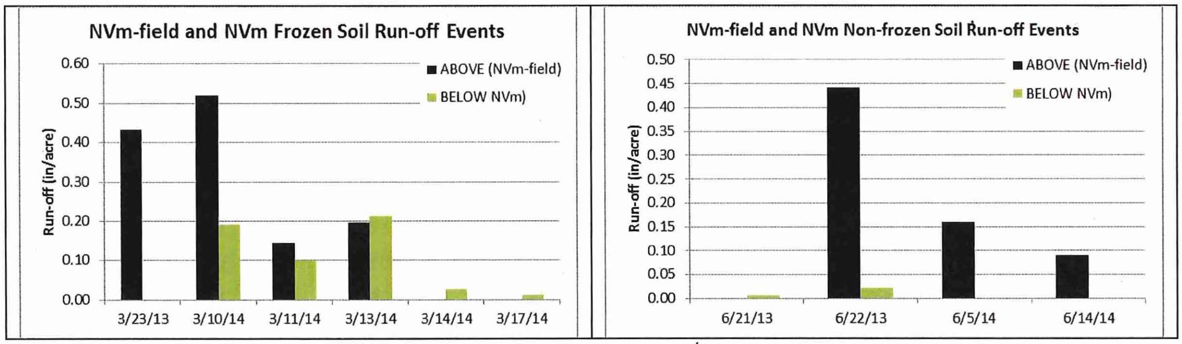

Figure 10. NVm-field and NVm a) frozen and b) non-frozen soil run-off events.

Sediment

TSS event yields and FWMC need to be broken down into two categories for analysis: frozen soils and non-frozen soils. Each these categories exhibit different sediment loss patterns for each watershed. In general, sediment losses on frozen soils are minimal. NVm-field lost between 0 - 27 lb/acre, and NVm lost between 0.2 – 6 lb/acre over 6 frozen soil events in 2013 and 2014 (Figure 11a). Event sediment FWMC for both NVm-field and NVm were similar for all 6 events and ranged from 0-180 mg/L (Figure 11b). Sediment losses from non-frozen soils have higher variability than frozen soils. NVm-field lost between 0-192 lb/acres and NVm lost between 0-1.8 lb/acre over four non-frozen soil events in 2013 and 2014 (Figure 12a). Total event losses were mitigated at NVm due to the small amount of surface water run-off compared to NVm-field (Figure 10a and 10b). Event sediment FWMC were higher for NVm-field (0-1,580 mg/L) than NVm (0-380 mg/L) during non-frozen soil conditions (Figure 12a and 12b). TSS event yields and FWMC were greatly influenced by the amount of run-off and the timing when the run-off event occurred.

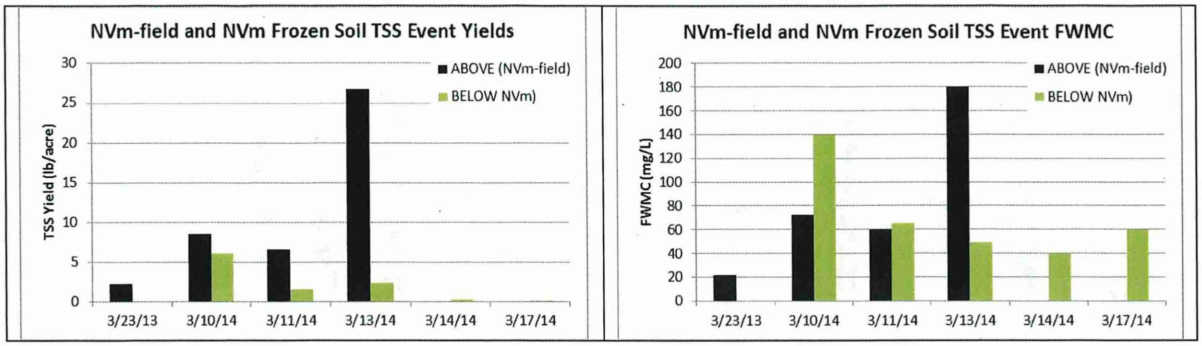

Figure 11. NVm-field and NVm frozen soil a) TSS event yields. b) TSS event FWMC.

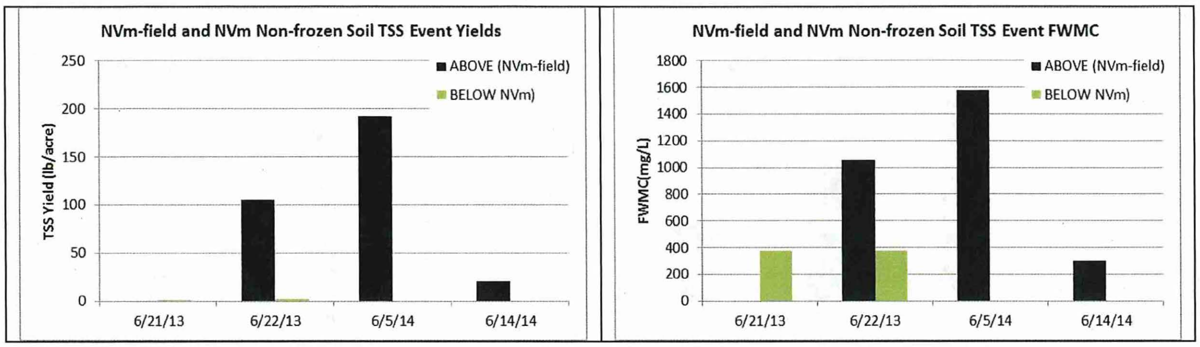

Figure 12. NVm-field and NVm frozen soil a) TSS event yields. b) TSS event FWMC

Phosphorus

Total phosphorus (TP) event yields and FWMC need to be broken down into two categories for analysis: frozen soils and non-frozen soils. Each these categories exhibit different TP loss patterns for each watershed. In general, TP yields and FWMC on frozen soils were higher for NVm-field for all events in which NVm-field had run-off measured. NVm-field lost between 0 – 0.4 lb/acre, and NVm lost between 0 – 0.06 lb/acre over 6 frozen soil events in 2013 and 2014 (Figure 13a). Event TP FWMC for NVm-field ranged from 0-2.2 mg/L and NVm from 0-1.5 mg/L (Figure 13b). TP losses from non-frozen soils were similar to frozen soils given run-off occurred. NVm-field lost between 0-0.12 lb/acres and NVm lost between 0-0.02 lb/acre over 4 non-frozen soil events in 2013 and 2014 (Figure 14a). Total event losses were mitigated at NVm due to the small amount of surface water run-off compared to NVm-field (Figure 10a and 10b). Event TP FWMC were lower for NVm-field (0-1.2 mg/L) than NVm (0-4.3 mg/L) during non-frozen soil conditions (Figure 14b); however NVm had very small TP event yields given the minimal volume of run-off occurring.

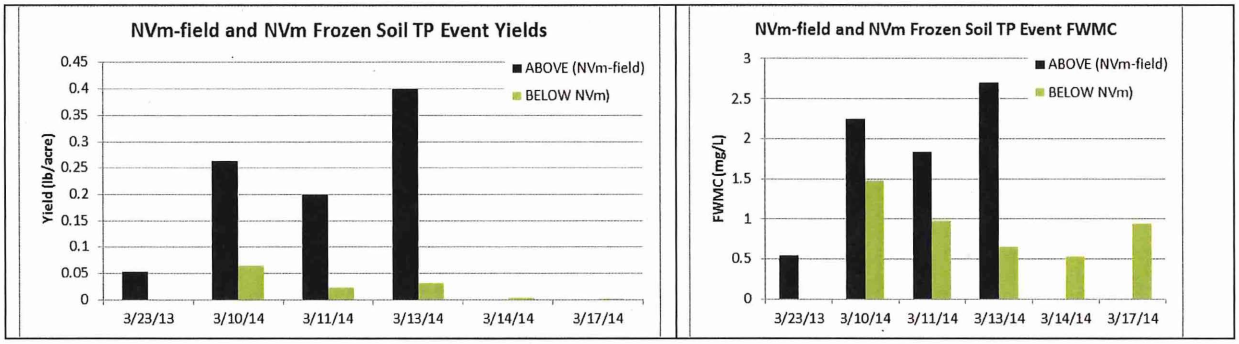

Figure 13. NVm-field and NVm frozen soil total phosphorus a) event yields and b) FWMC.

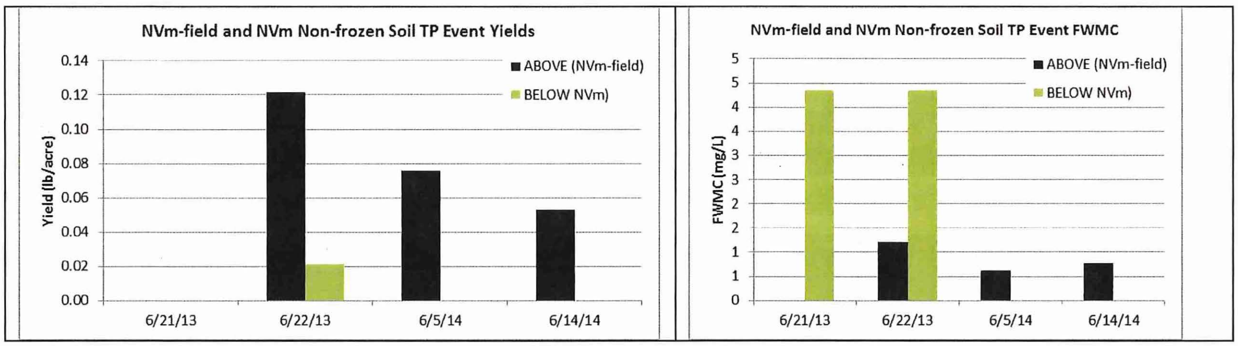

Figure 14. NVm-field and NVm non-frozen soil total phosphorus a) event yields and b) FWMC.

Dissolved molybdate reactive phosphorus (DMRP) concentrations were measured in addition to TP. The DMRP data will be presented as a fraction of the TP. During frozen soil conditions, most events at both sites had between 20 and 30 percent of the TP as DMRP (Figure 15a). The event on March 23, 2013 at NVm-field (above) had 80 percent of the TP as DMRP, however, this was the event with the lowest overall TP yield (Figure 13a) at NVm-above during frozen conditions. Events during non-frozen soil conditions resulted in a range of 23 to 49 percent TP as DMRP at NVm-field (above) and approximately 53 percent TP as DMRP at NVm (below) (Figure 15b).

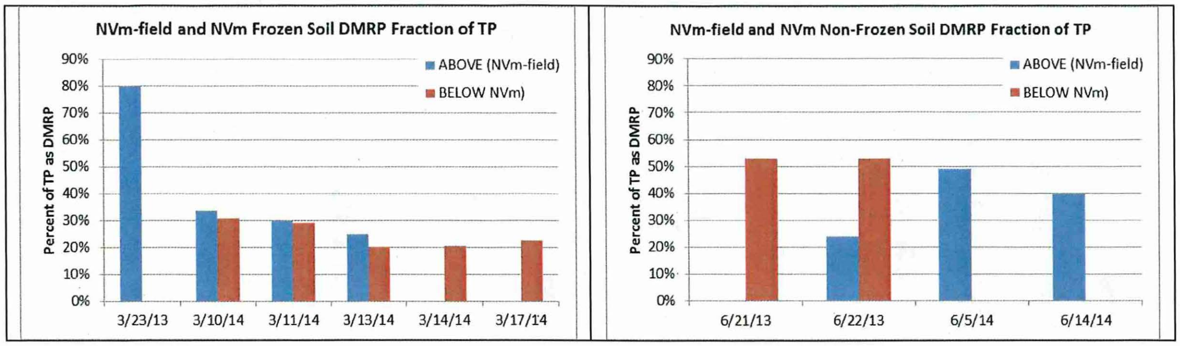

Figure 15. NVm-field and NVm DMRP fraction of TP on a) frozen soils and b) non-frozen soils.

Nitrogen

Total nitrogen (TN) event yields and FWMC need to be broken down into two categories for analysis: frozen soils and non-frozen soils. Each these categories exhibit different TN loss patterns for each watershed. In general, TN yields and FWMC on frozen soils were higher for NVm-field for all event in which NVm-field had run-off measured. NVm-field lost between 0 – 1.98 b/acre, and NVm lost between 0 – 0.41 lb/acre over 6 frozen soil events in 2013 and 2014 (Figure 16a). Event TN FWMC for NVm-field ranged from 0-18.2 mg/L and NVm from 0-9.4 mg/L (Figure 16b). TN losses from non-frozen soils were similar to frozen soils given run-off occurred. NVm-field lost between 0-1.0 lb/acres and NVm lost between 0-0.16 lb/acre over 4 non-frozen soil events in 2013 and 2014 (Figure 17a). Total event losses were mitigated at NVm due to the small amount of surface water run-off compared to NVm-field (Figure 10a and 10b). Event TN FWMC were lower for NVm-field (0-8.2 mg/L) than NVm (0-33.8 mg/L) during non-frozen soil conditions (Figure 17b); however NVm had very small TN event yields given the minimal volume of run-off occurring.

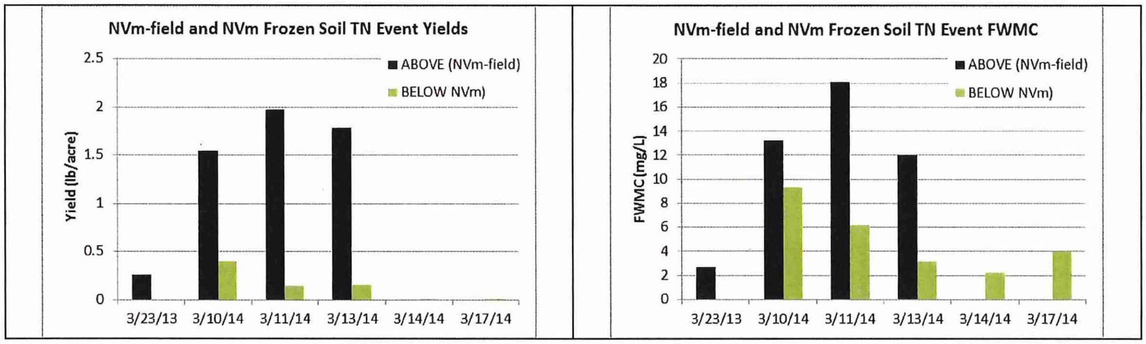

Figure 16. NVm-field and NVm frozen soil total nitrogen a) event yields and b) FWMC.

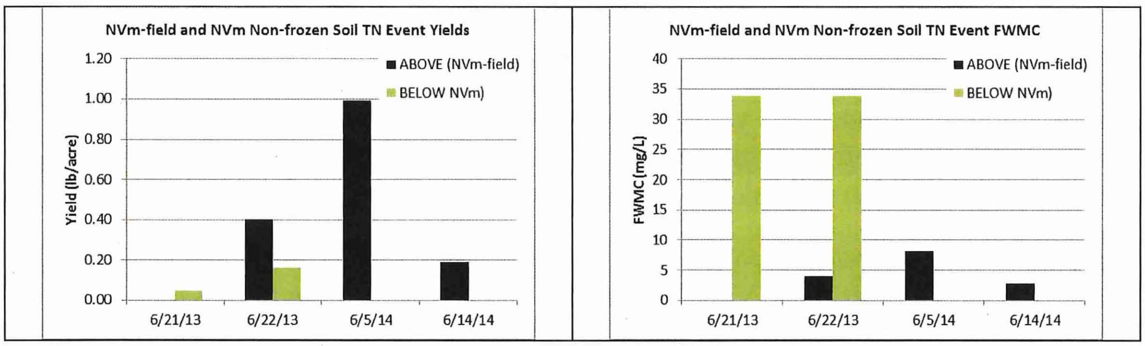

Figure 17. NVm-field and NVm non-frozen soil total nitrogen a) event yields and b) FWMC.

Soil Bulk Density

Soil bulk density was measured from the two watersheds (Figure 18). The data presented for NVm only includes the perennial vegetation portion (not the NVm-field watershed that is nested within NVm). NVm had lower bulk densities throughout the soil profile, especially in the uppermost 20 cm of the soil profile. NVm represents undisturbed soil conditions, while NVm-field has been used for crop production for decades effecting physical soil properties.

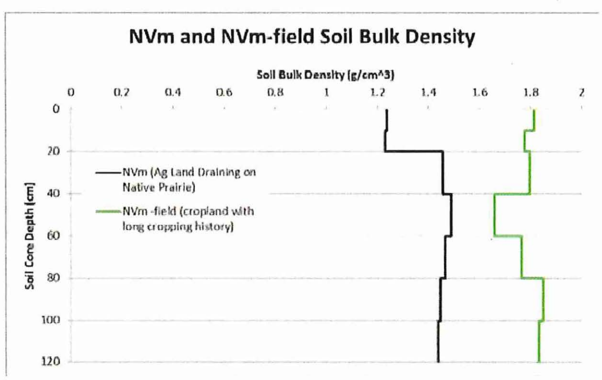

Figure 18. Soil bulk density of NVm (perennial vegetation portion only) and NVm-field (cropland with long cropping history).

Infiltration

Hydraulic conductivity was determined at NVm and NVm-field. Measurements of the infiltration at NVm were consistent with hydraulic conductivity of the adjoining perennial vegetation sites (Figure 7). Infiltration rates were similar between NVm and NVm-field at the highest surface pressure potentials; however, it appears the infiltration rates were separating as pressure potentials approached saturated conditions (Figure 19). These measurements indicate more water that can infiltrate undisturbed soils.

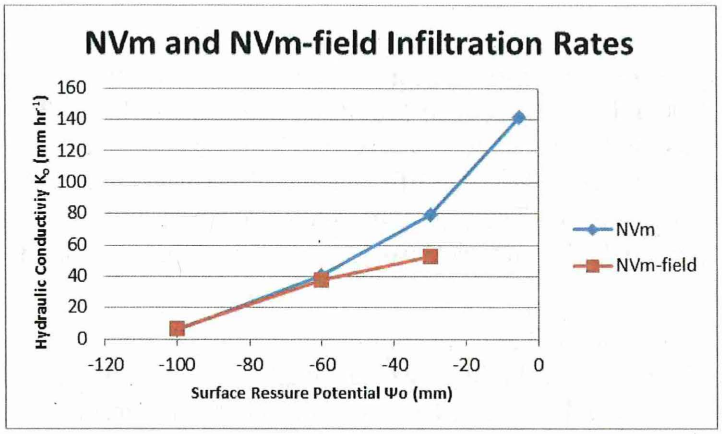

Figure 19. NVm and NVm-field infiltration rates.

Conclusions

This study used an above and below design to compare the quality and quantity of run-off from two different land uses. NVm-field represented a 0.67 acre watershed with a long history or row crop production and NVm was 1.7 acre watershed that included NVm-field with the remainder in perennial vegetation and undisturbed soils. Greater run-off volumes were observed at NVm-field than NVm on both frozen and non-frozen soils. NVm effectively captured the run-off and associated sediment and nutrients from NVm-field. NVm did occasionally have higher FWMC than NVm-field; however, the volume of run-off was minimal and therefore yields were low for NVm. NVm had undisturbed soils with lower bulk density and higher infiltration rates than NVm-field. The differences in water quality are a reflection of surface water run-off hydrology at these sites.

Public outreach and education

There were three primary public outreach and education components that where completed during the grant period. The first outreach and education component was completed on November 21st, 2012 and included a 30 minute PowerPoint presentation. This presentation was completed as part of the U of M's Department of Soils, Water, and Climate seminar class and was open to public. Approximately 20 students and U of M faculty attended the presentation that was focused primarily on project design and background as a result of low run-off occurrence in the 2010 and 2011 calendar years of monitoring. The presentation is attached, and no materials were distributed.

A field tour of a group of seven Scientists, Engineers, and graduate students from Agriculture and Agri-Food Canada and the University of Manitoba **was** held at the SWROC in 2011. One of the stops on the tour was the Cottonwood River Native Vegetation Water Quality monitoring stations. The tour was interested in the scientific design of the project, as well as the particular details of edge-of-field monitoring. The tour consisted of seven attendees that visited the sites and discussed the project goals. No materials were formally prepared or handed out at this event.

The primary project public outreach and education component of this project occurred as part of the 5th Soil and Water Management Field Day on July 23rd, 2014 on the Brian Hick's farm near Tracy, MN. As part of the field day, about 100 attendees heard an overview of the Cottonwood River Native Vegetation Water Quality monitoring design, visited the monitoring stations, and heard preliminary project results. Overview slides and a formal manuscript of the project was prepared and distributed to all attendees. The presentation and manuscript are attached, and the field day has a publically accessible website where these documents can be downloaded: http://swroc.cfans.umn.edu/ResearchandOutreach/SoilManagement/Outreach/index.htm

Future outreach and education will continue after the grant is completed. Planned activities include thesis preparation and defense, journal article submission, presentations on a local and state level and development of a guidance document.

Long-term results

This project increased knowledge regarding the potential influence of perennial vegetation and the removal of perennial vegetation for row crop agriculture on water quality and water quantity. Perennial vegetation may exist in undisturbed, managed or natural areas dating back to near pre-settlement times or in lands enrolled in conservation reserve program (CRP) easements. The former is rare while the latter is relatively common. Recent increases in crop prices paid to farmers along with the need to grow more food for a growing population, for direct or indirect consumption, and the expiration of CRP contracts has resulted in land formerly in perennial vegetation coming into crop production. To date, many total maximum daily load (TMDL) studies combine loads from human-induced nonpoint source pollution with the natural background contributions because of a lack of data to make this discernment. Furthermore, TMDL implementation plans often endorse the use of set aside programs which often utilize native vegetation to remediate the effects of human-induced nonpoint source pollution. To

achieve maximum water quality benefits, the position of the set aside acres is critical relative to the source of pollution and the receiving waterbody.
A better understanding of the vegetation, soil, management, and hydrologic controls that link spatially variable sediment and nutrient sources and sinks to transport processes at the watershed scale will help farmers be economically competitive while also inform development of tools and management approaches that can minimize their environmental impact. Finally, field-scale measurements can be used by systems analysts to parameterize and calibrate simulation models in order to link field-scale results to potential watershed-scale impacts.

There was some interest expressed by the Minnesota Agricultural Water Resources Center to possibly continue this project. No formal discussion or arrangements have occurred at this time. Interest was expressed in the need to continue water quality monitoring, and to collect more soil bulk density and infiltration data after a few years of corn production (no current plans to do so) as well as after the transition is made back to perennial vegetation from row crop production in NVe.

Lessons Learned

Although the research team was aware that weather variability could impact the project, we did not anticipate the extremes in precipitation and drought that occurred. It would be possible, although more expensive, to account for weather extremes, especially drought by being able to simulate runoff across the watersheds, or extending projects over longer periods of time.

It was very frustrating to our team that the contract execution took so long which inevitably delayed our project. Any way to expedite and make contract execution more efficient would be helpful.

Section III – Final Expenditures

The final project expenditure summary is presented below (Table 2). The detailed project budget summary is presented on the following page (Table 3).

Table 2. Final project expenditure summary.

Project Sponsors	**Cash Contribution To Project (2)**	**In-kind Contribution To Project (3)**	**Total Project Support (2+3)**
MPCA 319 Grant amount requested	**$183,766.00**		
Clean Water Partnership Loan (for 319 projects only)			
A. Project Sponsor - subtotals	$183,766.00		$0.00
State and/or Federal Contributing Sponsors:			
1. Minnesota Department of Agriculture	$32,943.13	$49,777.01	$82,720.14
2. Minnesota Board of Soil and Water Resources	$0.00	$3,100.00	$3,100.00
3. University of Minnesota Southwest Research and Outreach Station	$134,723.29	$90,169.22	$224,892.51
C. State and/or Federal Contributing Sponsors Subtotals:	$167,666.42	$143,046.23	$310,712.65
SUBTOTAL: All project sponsors (A+B+C)	$167,666.42	$143,046.23	$310,712.65
GRAND TOTALS	Total Cash $167,666.42	Total In-kind $143,046.23	Total Project Cost $310,712.65

Table 3. Final Project Budget

Cost Category	Revenue Source (Change Order #2 3/5/14) Grant	In-Kind	Total	Final Expenditures Grant	In-Kind	Total	Balances Grant	In-Kind	Total Remaining
OBJECTIVE 1: Fiscal management and planning.									
Task 1. Track project grant and matching funds and expenditures.									
MDA Project Coordinator		$ 17,287.63	$ 17,287.63	$ -	$ 17,287.63		$ -	$ -	$ -
Task 1 Subtotal	$ -	$ *17,287.63*	$ *17,287.63*	$ -	$ 17,287.63	$ *17,287.63*	$ -	$ -	$ -
Task 2. Required Reporting									
MDA Project Coordinator		$ 5,762.54	$ 5,762.54	$ -	$ 3,786.32	$ 3,786.32	$ -	$ 1,976.22	$ 1,976.22
Task 2 Subtotal	$ -	$ *5,762.54*	$ *5,762.54*	$ -	$ 3,786.32	$ 3,786.32	$ -	$ *1,976.22*	$ 1,976.22
Objective 1 Subtotal	**$ -**	**$ 23,050.17**	**$ 23,050.17**	**$ -**	**$ 21,073.95**	$ 21,073.95	**$ -**	**$ 1,976.22**	**$ 1,976.22**
OBJECTIVE 2: Conduct soil and water monitoring of 3 "watersheds." (4th site added within a watershed as in-kind)									
Task 1: Installation of monitoring equipment									
U of M SWROC Assistant Scientist	$ 13,449.80		$ 13,449.80	$ 13,449.80	$ -	$ 13,449.80	$ -	$ -	$ -
U of M SWROC Staff		$ 2,880.00	$ 2,880.00	$ -	$ 2,880.00	$ 2,880.00	$ -	$ -	$ -
MDA Staff		$ 7,013.09	$ 7,013.09	$ -	$ 7,013.09	$ 7,013.09	$ -	$ -	$ -
Monitoring Equipment for 3 Sites					$ -	$ -	$ -	$ -	$ -
ISCO 6712 Autosampler	$ 9,207.00		$ 9,207.00	$ 9,207.00	$ 3,000.00	$ 12,207.00	$ -	$ (3,000.00)	$ (3,000.00)
Sampler 24 Bottle Configuration	$ 1,056.00		$ 1,056.00	$ 1,056.00	$ 352.00	$ 1,408.00	$ -	$ (352.00)	$ (352.00)
External Battery Connect for Autosamplers	$ 204.00		$ 204.00	$ 204.00	$ 68.00	$ 272.00	$ -	$ (68.00)	$ (68.00)
Non-ISCO connector cable	$ 164.70		$ 164.70	$ 164.70	$ 54.83	$ 219.53	$ -	$ (54.83)	$ (54.83)
Site #4 Datalogger, solar panels, Logger Box, Radio Repair	$ -		$ -	$ -	$ 1,485.00	$ 1,485.00	$ -	$ (1,485.00)	$ (1,485.00)
Time Lapes Cameras (3), Soil Moisture Probes (15)	$ -		$ -	$ -	$ 5,310.00	$ 5,310.00	$ -	$ (5,310.00)	$ (5,310.00)
OTT CBS Bubbler and power/data cables	$ 7,056.00		$ 7,056.00	$ 7,056.00	$ 2,352.00	$ 9,408.00	$ -	$ (2,352.00)	$ (2,352.00)
Tubing (100 m length)	$ 48.00		$ 48.00	$ 48.00	$ -	$ 48.00	$ -	$ -	$ -
1L wedge shaped bottles (poly)	$ 802.00		$ 802.00	$ 802.00	$ 267.00	$ 1,069.00	$ -	$ (267.00)	$ (267.00)
H Flume (1.5 ft) w/ sampler tube and staff gauge	$ 5,125.00		$ 5,125.00	$ 5,125.00	$ 1,708.00	$ 6,833.00	$ -	$ (1,708.00)	$ (1,708.00)
T-316 Bubble Tube	$ 450.00		$ 450.00	$ 450.00	$ -	$ 450.00	$ -	$ -	$ -
Airlink CDMA Cellular Digital Modem for Verizon Systems, Mounting kit, Antenna, and Interface	$ 1,341.96		$ 1,341.96	$ 1,341.96	$ -	$ 1,341.96	$ -	$ -	$ -
RF401 900 MHz Spread Spectrum Radio w/ surge suppressor kit, and mounting kit	$ 1,794.00		$ 1,794.00	$ 1,794.00	$ 598.00	$ 2,392.00	$ -	$ (598.00)	$ (598.00)
900 MHz 3dBd Omni Antenna w/Type N Female and Mount Hardware and cable	$ 794.04		$ 794.04	$ 794.04	$ 264.00	$ 1,058.04	$ -	$ (264.00)	$ (264.00)
Enclosures for entire monitoring system	$ 1,800.00		$ 1,800.00	$ 1,800.00	$ 600.00	$ 2,400.00	$ -	$ (600.00)	$ (600.00)
100 Amp hour 12 volt deep cycle batteries	$ 390.00		$ 390.00	$ 390.00	$ 130.00	$ 520.00	$ -	$ (130.00)	$ (130.00)
Hardware for constructing flume wing walls and monitoring platforms for each of the sites	$ 2,474.00		$ 2,474.00	$ 2,474.00	$ 825.00	$ 3,299.00	$ -	$ (825.00)	$ (825.00)
Propane heaters for de-icing flumes	$ 200.00		$ 200.00	$ 200.00		$ 200.00	$ -	$ -	$ -
Shipping/handling/taxes	$ 3,100.43		$ 3,100.43	3,100.43	$ -	$ 3,100.43	$ -	$ -	$ -
Task 1 Subtotal	$ *49,456.93*	$ *9,893.09*	$ *59,350.02*	$ *49,456.93*	$ *26,906.92*	$ 76,363.85	$ -	$ *(17,013.83)*	$ *(17,013.83)*
Task 2. Soil sample each of the watersheds.									
U of M SWROC Assistant Scientist	$ 1,725.27		$ 1,725.27	$ 1,725.27	$ -	$ 1,725.27	$ -	$ -	$ -
Soil Sample Laboratory Analysis	$ 3,885.00		$ 3,885.00	$ 3,885.00	$ -	$ 3,885.00	$ -	$ -	$ -
Soil Sample Hydrologic parameters		$ 1,500.00	$ 1,500.00	$ -	$ 1,500.00	$ 1,500.00	$ -	$ -	$ -
Task 2 Subtotal	$ *5,610.27*	$ *1,500.00*	$ *7,110.27*	$ *5,610.27*	$ *1,500.00*	$ 7,110.27	$ -	$ -	$ -
Task 3. Water quality sampling and laboratory analysis									
U of M SWROC Grad Student	$ 35,544.00		$ 35,544.00	$ 35,544.00	$ -	$ 35,544.00	$ -	$ -	$ -
U of M SWROC Assistant Scientist	$ 18,978.00		$ 18,978.00	$ 18,978.00	$ -	$ 18,978.00	$ -	$ -	$ -
U of M SWROC Staff		$ 29,803.74	$ 29,803.74	$ -	$ 29,803.74	$ 29,803.74	$ -	$ -	$ -
MDA Staff		$ 1,000.00	$ 1,000.00	$ -	$ 1,000.00	$ 1,000.00	$ -	$ -	$ -
BWSR Staff		$ 862.40	$ 862.40	$ -	$ 862.40	$ 862.40	$ -	$ -	$ -
Compensation to Producer	$ 20,000.00		$ 20,000.00	$ 20,000.00	$ -	$ 20,000.00	$ -	$ -	$ -
Travel	$ 3,132.80		$ 3,132.80	$ 1,133.00	$ -	$ 1,133.00	$ 1,999.80	$ -	$ 1,999.80
Bacteria Analysis of Water Samples	$ 13,500.00		$ 13,500.00	$ 2,287.05	$ -	$ 2,287.05	$ 11,212.95	$ -	$ 11,212.95
Water Chemistry Laboratory Analysis		$ 14,634.00	$ 14,634.00	$ -	$ 6,280.75	$ 6,280.75	$ -	$ 8,353.25	$ 8,353.25
Task 3 Subtotal	$ *91,154.80*	$ *46,300.14*	$ *137,454.94*	$ *77,942.05*	$ *37,946.89*	$ 115,888.94	$ *13,212.75*	$ *8,353.25*	$ *21,566.00*
Objective 2 Subtotal	**$ 146,222.00**	**$ 57,693.23**	**$ 203,915.23**	**$ 133,009.25**	**$ 66,353.81**	**$ 199,363.06**	**$ 13,212.75**	**$ (8,660.58)**	**$ 4,552.17**
OBJECTIVE 3: Compare and contrast water quality and quantity characteristics of alternative land management strategies to native prairie systems.									
Task 1: Data analysis of treatment effects using paired watershed protocols									
U of M SWROC Grad Student	$ 37,544.00		$ 37,544.00	$ 34,657.17	$ -	$ 34,657.17	$ 2,886.83	$ -	$ 2,886.83
U of M SWROC Staff		$ 64,229.70	$ 64,229.70	$ -	$ 49,704.73	$ 49,704.73	$ -	$ 14,524.97	$ 14,524.97
MDA Staff		$ 12,387.85	$ 12,387.85	$ -	$ 3,676.14	$ 3,676.14	$ -	$ 8,711.71	$ 8,711.71
BWSR Staff		$ 3,621.05	$ 3,621.05	$ -	$ 2,237.60	$ 2,237.60	$ -	$ 1,383.45	$ 1,383.45
Task 1 Subtotal	$ *37,544.00*	$ *80,238.60*	$ *117,782.60*	$ *34,657.17*	$ *55,618.47*	$ 90,275.64	$ *2,886.83*	$ *24,620.13*	$ *27,506.96*
Objective 3 Subtotal	**$ 37,544.00**	**$ 80,238.60**	**$ 117,782.60**	**$ 34,657.17**	**$ 55,618.47**	$ 90,275.64	**$ 2,886.83**	**$ 24,620.13**	**$ 27,506.96**
OBJECTIVE 1 - TOTAL	$ -	$ 23,050.17	$ 23,050.17	$ -	$ 21,073.95	$ 21,073.95	$ -	$ 1,976.22	$ 1,976.22
OBJECTIVE 2 - TOTAL	$ 146,222.00	$ 57,693.23	$ 203,915.23	$ 133,009.25	$ 66,353.81	$ 199,363.06	$ 13,212.75	$ (8,660.58)	$ 4,552.17
OBJECTIVE 3 - TOTAL	$ 37,544.00	$ 80,238.60	$ 117,782.60	$ 34,657.17	$ 55,618.47	$ 90,275.64	$ 2,886.83	$ 24,620.13	$ 27,506.96
GRAND TOTAL	$ 183,766.00	$ 160,982.00	$ 344,748.00	$ 167,666.42	$ 143,046.23	$ 310,712.65	$ 16,099.58	$ 17,935.77	$ 34,035.35

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APPENDIX 1

(See attached "Final Research Report")

APPENDIX 1

Section 319 Nonpoint Source Pollution Control Program:
319 Demonstration, Education, Research
Final Research Report

Cottonwood River Native Vegetation Water Quality

By:
Mr. David Tollefson, University of Minnesota
Dr. Jeffrey Strock, University of Minnesota
Dr. Adam Birr, Minnesota Corn Growers Association
Mr. William VanRyswyk, Minnesota Department of Agriculture

Submitted October 2014

This Project Was Conducted In Cooperation with The State Of Minnesota And The United States Environmental Protection Agency, Region 5.

Grant #: B42183 (CFMS)

Contents

List of Figures

List of Tables

Executive Budget Summary

Project Title:	Cottonwood River Native Vegetation Water Quality
Project Start Date:	January 31st, 2010
Project Completion Date	August 29th, 2014

FUNDING:	
TOTAL BUDGET	$344,748.00
TOTAL EPA GRANT	$183,766.00
TOTAL EXPENDITURES OF EPA FUNDS	$167,666.42
TOTAL SECTION 319 IN-KIND ACCRUED	$143,046.23
BUDGET REVISIONS	$ 0.00
TOTAL EXPENDITURES	$310,712.65

Executive Summary of Project

To provide context and to better manage our water resources, this study quantified the surface water quantity and quality and soil hydrologic characteristics of perennial vegetation on undisturbed soils in southwest Minnesota, and measured the changes that occurred following the conversion of a portion of the perennial vegetation to cropland utilizing a paired watershed design. Two small watersheds were instrumented with H-flumes and monitored year-round for four years. The perennial vegetation did not produce run-off during non-frozen soil conditions; however, it did have run-off associated with snowmelt over frozen soils. The water quality of the snowmelt run-off did have elevated levels of total phosphorus (TP), primarily in the dissolved molybdate reactive phosphorus (DMRP) form, and contained various forms of nitrogen, along with low sediment levels. The water leaving the perennial vegetation did carry nitrogen, phosphorus, and sediment although the run-off volumes annually averaged less than 0.1 inches of runoff/acre resulting in low pollutant exports.

One of the watersheds was converted from perennial vegetation to cropland in May 2013. Four run-off events from the cropland were observed in June of 2013. These were the only run-off events on non-frozen soils over the duration of the project. The conversion to cropland did result in additional total nitrogen (1.8 lb/acre), total phosphorus (0.24 lb/acre), and sediment (953 lb/acre) being exported from the watershed compared to the control in June 2013. These increased losses are more reflective of a shift in hydrology rather than a shift in pollutant concentrations, due to the lack of run-off observed from the perennial vegetation during non-frozen soil conditions. Soil bulk density and hydraulic conductivity were used as indicators of changes in soil properties after conversion from perennial vegetation to cropland. It is anticipated that the hydrology and soil properties of this recently converted cropland would continue to change over time until a "new" equilibrium is reached that is consistent with lands in long-term crop production.

An above and below design was also used to monitor non-point source agriculture run-off as it entered the perennial vegetation, and monitored the run-off as it exited the perennial vegetation near the bottom of a hillside. These nested watersheds provided an opportunity to quantify the changes in water quantity and quality of non-point source pollution as it moved through a perennial vegetation. The vegetation effectively captured pollutants and run-off with high infiltration rates on a transition zone between a highly productive agriculture zone and the river valley floodplain. Similar areas exist within the Cottonwood River Watershed that hold potential to serve as a possible best management practice (BMP) treatment area for agriculture run-off.

A master's of science thesis report is in production and will be available in 2015.

Introduction

Land use/land cover and water resources are inextricably linked. Land use/land cover have a direct relationship with environmental characteristics and processes, including soil characteristics, productivity of the land, species diversity, climate, biogeochemistry and the hydrologic cycle. Changes in land use over the last century have resulted in observed concentrations of both sediments and nutrients in the Cottonwood River exceeding applicable water quality standards and guidelines (Minnesota River Basin Data Center, 2007).

In order to understand current questions about water quality and water quantity in the U.S. Northern Corn Belt, and specifically in Minnesota, it is necessary to examine the changes that have occurred in agriculture in the past two centuries. Briefly, the first major shift in land use began with the conversion of vast amounts of virgin prairie into what is now prime farmland and municipal uses. This conversion resulted in a shift in the hydrologic cycle, mainly due to the replacement of perennial vegetation with seasonal vegetation on the landscape. In the case of municipalities, expanding areas of impervious surface have also impacted water quantity and water quality. The second major shift in land use began with the installation of artificial drainage systems in the late 1800's. Because of drainage, areas which were once unsuitable for agricultural production, transportation, or municipal expansion could now be developed. In agricultural regions, many areas previously classified as too wet to farm were converted to row crop production. Following the Second World War, increased availability of inorganic fertilizers, primarily nitrogen, led to a separation of crop and livestock production with decreased reliance on animal manures and legumes to supply the necessary nutrients for crop production. These changes had a significant, long-lasting, positive impact on increased agricultural productivity and profitability. On the other hand, they drastically altered agronomic practices and have contributed to negative changes in soil properties and water quality impairments. Increased crop production possible under artificially drained, cultivated agricultural land, under some conditions, led to increased soil erosion, loss of soil carbon and degradation in water quality.

There is a lack of historical records quantifying the natural background levels of soil and nutrient losses from native prairie and perennial vegetation including conservation reservation reserve (CRP) lands. Moreover, there is a lack of data quantifying the loss of soil and nutrients when the native prairies were initially cultivated. To better manage our water resources, it critical to understand the potential hydrology and water quality impacts associated with our natural landscapes.

Project Goals and Objectives

Goal: **Quantify the water quality and quantity characteristics of native prairie systems and compare it to alternative land management systems endemic to the region.**

Objective 1: **Fiscal Management and Planning.**

Task 1: Track Project Grant and Matching Funds and Expenditures

- *Subtask 1: compile and organize invoices*
- *Subtask 2: pay bills*
- *Subtask 3: obtain in-kind documentation*
- *Subtask 4: prepare information for regular reports*

Task 2: Required Reporting and Data Management.

- *Subtask 1: maintain and organize data collected*
- *Subtask 2: prepare and complete interim progress reports*
- *Subtask 3: prepare and complete final report*

Objective 2: **Conduct Soil and Water Monitoring of 3 Watersheds.**

Task 1: Installation of Monitoring Equipment

- *Subtask 1: Survey and characterize drainage areas for each of the watersheds*
- *Subtask 2: Order and acquire monitoring equipment*
- *Subtask 3: Install water monitoring equipment in 3 watersheds*

Task 2: Soil Sample each of the Watersheds

- *Subtask 1: Collect 60 soil samples from the study area using a grid-based approach*
- *Subtask 2: Submit samples to U of M laboratory for various chemical and hydrologic parameters*

Task 3: Water Quality Sampling and Laboratory Analysis

- *Subtask 1: Collect water samples following runoff events.*
- *Subtask 2: Analyze samples for various water quality parameters including: pH, DO, conductivity, temperature, total suspended solids (TSS), total phosphorus (TP), dissolved reactive phosphorus (DRP), nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), total nitrogen (TN), E. Coli, fecal coliform, and dissolved organic carbon (DOC)*

Objective 3: **Compare and Contrast Water Quality and Quantity Characteristics of Alternative Land Management Strategies to Native Prairie Systems.**

Task 1: Data Analysis of Treatment Effects using Paired Watershed Protocols.

- *Subtask 1: Calculate flow and event loads for each of the analytes monitored.*
- *Subtask 2: Randomly implement alternative management practices in 1 of the 3 watersheds following an appropriate calibration period (anticipated 2 years).*
- *Subtask 3: Statistically evaluate treatment effects on water quality and quantity using standard paired watershed and above-and-below watershed protocols.*

Activities

A milestone table of objectives and tasks is presented below. All planned tasks were completed. Soil sampling was delayed due to dry and/or wet conditions, however, all planned sampling occurred within the project timeframe

A summary of the completed measurements/activates is provided below the milestone table. This project collected many different parameters related to hydrology, water quality, GIS spatial analysis, and soil properties. Each of the parameters will be discussed briefly, and the data and/or results will be evaluated in each experimental design section below.

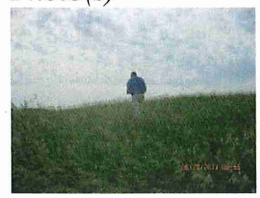
Table 1. Milestone Table

		2011												2012											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
OBJECTIVE 1:	Fiscal management and planning.																								
Task 1	Track project grant and matching funds and expenditures.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Task 2	Required Reporting.		X						X						X						X				
OBJECTIVE 2:	Conduct soil and water monitoring of 3 watersheds.																								
Task 1	Installation of monitoring equipment.	X																							
Task 2	Soil sample each of the watersheds.					X	X																		
Task 3	Water quality sampling and laboratory analysis.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OBJECTIVE 3:	Compare and contrast water quality and quantity characteristics of alternative land management strategies to native prairie systems.																								
Task 1	Data analysis of treatment effects using paired watershed protocols.												X	X	X										X

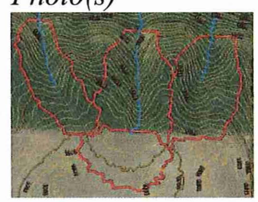
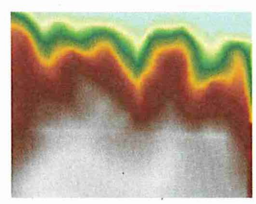
		2013												2014											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
OBJECTIVE 1:	Fiscal management and planning.																								
Task 1	Track project grant and matching funds and expenditures.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Task 2	Required Reporting.		X						X						X						X				
OBJECTIVE 2:	Conduct soil and water monitoring of 3 watersheds.																								
Task 1	Installation of monitoring equipment.																								
Task 2	Soil sample each of the watersheds.						X				X														
Task 3	Water quality sampling and laboratory analysis.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
OBJECTIVE 3:	Compare and contrast water quality and quantity characteristics of alternative land management strategies to native prairie systems.																								
Task 1	Data analysis of treatment effects using paired watershed protocols.	X	X									X	X	X	X	X	X	X	X	X	X				

Table 2. Activity Table

Site Characterization

Measurement	*Methods*	*Importance*	*Photo(s)*
BWSR Vegetation Survey	A plant expert from BWSR conducted a vegetation survey to determine: 1) vegetation species present 2) abundance of each vegetation species 3) stem density counts	This survey is important for interpreting the data and for expanding the knowledge learned to other landscapes. Vegetation species, and stem density is important when understanding the movement of water through vegetated areas and for applying our results to other areas.	 

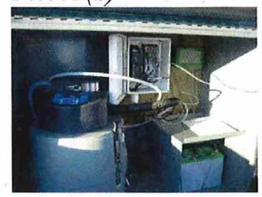
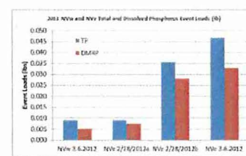
GIS Spatial Analysis

Measurement	*Methods*	*Importance*	*Photo(s)*
Watershed Characteri-zation	Each of the four watersheds was characterized using the NRCS Engineering Tools for watershed size, average slope, and slope length. The H-flumes were visible on the 2011 and 2013 imagery ensuring accurate placement of watershed outlets.	Without the use of these automated tools, watershed boundaries, average slope, and slope length had to be estimated. These tools ensure comparability between watersheds and allow for a better understanding of watershed dynamics.	
Cottonwood River Watershed Examination of Comparable Lands	To find similar landscapes in the broader Cottonwood River Watershed, 1 acre grids were created across the entire watershed and average slope was calculated in each 1 acre grid. The slopes from our hillside study were then used to find similar land in the broader watershed.	The hillside in this study is not comparable to the entire Cottonwood River Watershed, but it is comparable to many transitional areas between the highly productive agricultural land and the river valleys. This analysis was completed to determine how much land in the watershed has comparable slopes.	 

Hydrology based measurements

Measurement	*Methods*	*Importance*	*Photo(s)*
Precipitation	An electronic tipping bucket rain gage was installed at NVw and NVe to record rainfall on a 0.01 inch interval. Rainfall was recorded on a 15 minute interval on the data logger. Snowfall totals were taken from SWROC.	Surface run-off is driven by snowmelt run-off and rainfall. Rainfall was summarized on a monthly basis, as well as with each rainfall driven run-off event. Monthly snowfall values allow for snowpack estimates during the melt. These 2 parameters allow for comparison of the study period to historical precipitation records.	
Discharge (Run-off)	Run-off was concentrated using a plywood wing wall and forced through a pre-calibrated H-flume at the outlet of the watershed. A data logger and bubbler recorded water level, and calculated discharge every minute.	Discharge was used to calculate total run-off volumes and pollutant export (load) from each watershed. Instantaneous discharges were used to collect water quality samples on an equal-flow increment platform allowing for pollutant loads to be calculated.	 
Air Temperature	Air temperature was recorded on the data logger. Air temperature data is not presented in this report, but it was used extensively to correct discharge records.	Air temperature monitoring is critical for data processing during snowmelt periods. On-site temperature data allows for determination of ice formation in the flume. Without air temperature data there is no way to decipher ice in the flume from actual run-off during freeze/thaw periods associated with snowmelt.	

Water Quality based measurements

Measurement	*Methods*	*Importance*	*Photo(s)*
Water Quality Samples	Water quality samples were collected using an ISCO 6712 automated sampler and 24-bottle carousel. Twenty-four 1 liter bottles were composited with 5 equal-flow increment samples during run-off events. Samples were then collected by SWROC and were analyzed for various forms of nitrogen, phosphorus, sediment, and bacteria. pH, temperature and conductivity were measured at the lab bench.	Automated samplers are required to ensure a representative water quality sample is collected from each run-off event. Events are short duration, and often occur at night. Event pollutant export (load) is determined using the concentration determined in the laboratory. Water chemistry results from different land uses can also be examined for differences.	 
Annual and event pollutant export (loads)	After discharge records are verified, water chemistry results from the laboratory where used to calculate a total mass of each pollutant leaving the watershed. The pollutant mass was then normalized to the watershed area, to calculate a "yield" value (mass/acre).	Annual and event loads bring together the water quantity and quality leaving a watershed. Loads provide an opportunity to normalize pollutant export based on watershed size, and serve as the basis for comparison amongst different land uses.	

Soil Properties

Measurement	*Methods*	*Importance*	*Photo(s)*
Bulk Density	Ninety-four 5 cm diameter by 1 meter long cores were collected from 47 sites in the study area with a tractor operated soil probe. These cores were then sliced into 6 soil depth sections, and a core sample was sliced off. Samples were dried at 105° C for 24 hours.	Bulk density is the weight of soil in a given volume. Soils with high bulk density have slow infiltration rates and restrict root growth, and soils with low bulk density tend to have high infiltration rates and great aggregate soil structure. Changes in land use are reflected in a soil's bulk density.	 
Infiltration (hydraulic conductivity)	Infiltration measurements were taken with a tension infiltrometer at surface pressure potentials of 100, 60, 30, and 5 mm. This data was then analyzed to calculate: infiltration rate, sorptivity and unsaturated hydraulic conductivity function.	As precipitation falls onto or runs over soils with high infiltration capacity, much of this water may infiltrate prior to leaving the watershed. Different land uses affect the soil's natural ability to move water through its profile. Hydraulic conductivity represents a volume of water that can move through the soil profile in a defined period of time.	 
Soil chemistry	Ninety-four 5 cm diameter by 1 meter long cores were collected from 47 sites in the study area with a tractor operated soil probe. The cores were then sliced into 2 soil depth sections and analyzed for various components including organic matter percentage, total nitrogen, total phosphorus, and several cations.	This study site provided an opportunity to explore soil chemistry prior to conversion of perennial vegetation to cropland conversion.	

Evaluation of Goal Achievement

Goal #1:
Water quality and quantity characterization of Conservation Reserve Program (CRP) systems.

During 2010, a field-scale site consisting of perennial vegetation with no history of artificial drainage or conventional row crop production agriculture was selected at the Hicks Family Farm near Tracy, MN. The farm is located within the Cottonwood River Watershed, a tributary of the Minnesota River. The soil at the site was mapped as a Storden loam with 7-8% slope. Due to unexpected delays in contract execution, initiation of the project was delayed until autumn 2010. Consequently, no soil sampling or monitoring were done in 2010. A digital elevation model (DEM) was completed at the site and the locations for background soil sampling and infiltration measurements were identified. Monitoring equipment, wingwalls and H-flumes were installed in autumn 2010 for all three experimental sub-watersheds. Run-off volume from flow events were monitored as described in Section II of this report. Year-round monitoring was completed from 2011 – 2014. During 2012 an additional monitoring system was also deployed to monitor a cultivated crop field contributing runoff to one of the sub-watersheds. The calibration period began in 2011 and ended in April of 2013. Sub-watershed treatment was initiated in May 2013 and continued through 2014. During the study period, extreme variability in monthly precipitation was observed. It was not uncommon to observe moderate to extreme drought and flooding conditions in the same year.

During some years no snowmelt runoff was observed. It was hypothesized that a lack of frost beneath the snow coupled with slow snowmelt resulted in a lack of measureable runoff. It was also hypothesized that the infiltration capacity of the soil under the perennial vegetation was very high, which also would have likely contributed to a lack of runoff. Subsequently field measurements of infiltration capacity verified this hypothesis. During 2011 no snowmelt runoff was recorded and NVm ran once in June. No other runoff was recorded in 2011. In 2012, run-off over frozen soils occurred 3 times each at NVw and 5 times at NVm. No other run-off was observed in 2012 at NVw or NVe (both entirely in perennial vegetation). NVm had 6 events in April and of May of 2012. The occurrence of these events, led to the installation of the NVm-field to monitor an agricultural field that was releasing water onto NVm. NVm-field was installed in October of 2012. With the discovery of the agricultural field contribution, NVm was removed from the paired analysis and an above and below design was implemented. NVw did not have run-off in 2013; NVe had 4 run-off events in June after conversion to cropland. NVw only had 3 run-off events on frozen soils; NVe only had 1 run-off event on frozen soils.

Goal #2:

Quantification of natural background contributions from soil and perennial vegetation to current water quality impairments related to turbidity, excess nutrients, and bacteria.

During summer 2011, 32 soil sampling points were identified and geo-referenced across the study area. Soil samples were collected during fall of 2012 near the geo-referenced points using a Giddings probe and were separated into discrete depth intervals for physical (bulk density) and chemical analysis. A subset of these samples, from the 0-10 cm and 10-20 cm depths, were ground and sent to the University of Minnesota Research Analytical Laboratory for chemical analysis including: organic matter, pH, cation exchange capacity (CEC), total nitrogen (N), total carbon (C), and total phosphorus (TP) and textural analysis. These data provided background information on soil physical and chemical characteristics of the site before treatments were prescribed. They were also used to determine potential cause and effect of sediment and nutrient loss after treatment assignment. Infiltration measurements planned for summer 2011 were postponed until spring 2012. The reason for the postponement was due to excessive wet conditions in May and June, 2011 followed by extreme dry conditions the remainder of 2011. Infiltration was successfully measured during 2012 in close proximity (1-2 m) of the 32 geo-referenced sampling points. Run-off volume from flow events was monitored as described in Section II of this report. Pre-treatment, calibration water samples were collected and analyzed for temperature, electrical conductivity (EC), total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN), nitrate-nitrogen (NO3-N), ammonium-nitrogen (NH4-N), and E. coli. Occasionally temperature was not recorded because samples were not retrieved from the field site within reasonable amount of time after collection. Dissolved oxygen was not measured for any of the samples because there was no instrument available for in-field or lab measurement.

Goal #3:

Comparison of water quality characteristics among differing land management practices including: perennial vegetation and conventional row crop agriculture. Complete.

The native vegetation was plowed in the eastern treatment watershed (NVe) and the site was brought into production in May of 2013. Corn (Zea mays L.) was planted perpendicular to the hill slope in 2013 and fertilized with 120 lbs N/acre in 2013. No additional phosphorus or potassium inputs occurred. Corn was harvest by the farmer but yield data for 2013 was not available from the combine yield monitor. Corn was planted in 2014 using no-till methods and fertilized with 180 lbs N/acre. All nitrogen applications were in the form of urea and were broadcasted in June. Run-off volume from flow events was monitored as described in Section II of this report. Post-treatment water samples were analyzed for the same constituents as during the calibration period. Soil infiltration was re-measured in replicate at 12 locations in the NVe sub-watershed after planting operations in June 2014. Soil bulk density was re-determined near the same 12 locations as the infiltration measurements.

Long Term Results

This project increased knowledge regarding the potential influence of perennial vegetation and the removal of perennial vegetation for row crop agriculture on water quality and water quantity. Perennial vegetation may exist in undisturbed, managed or natural areas dating back to near pre-settlement times or in lands enrolled in conservation reserve program (CRP) easements. The former is rare while the latter is relatively common. Recent increases in crop prices paid to farmers along with the need to grow more food for a growing population, for direct or indirect consumption, and the expiration of CRP contracts has resulted in land formerly in perennial vegetation coming into crop production. To date, many total maximum daily load (TMDL) studies combine loads from human-induced nonpoint source pollution with the natural background contributions because of a lack of data to make this discernment. Furthermore, TMDL implementation plans often endorse the use of set aside programs which often utilize native vegetation to remediate the effects of human-induced nonpoint source pollution. To achieve maximum water quality benefits, the position of the set aside acres is critical relative to the source of pollution and the receiving waterbody.

A better understanding of the vegetation, soil, management, and hydrologic controls that link spatially variable sediment and nutrient sources and sinks to transport processes at the watershed scale will help farmers be economically competitive while also inform development of tools and management approaches that can minimize their environmental impact. Finally, field-scale measurements can be used by systems analysts to parameterize and calibrate simulation models in order to link field-scale results to potential watershed-scale impacts.

Monitoring Results

Surface Water Improvements

Watershed Study Experimental Design Methods:

Two watershed study experimental designs were used in this study: paired watershed and above and below (Tollefson et al, 2014). Site characterization, GIS analysis, and precipitation summary for the entire study area will be presented together and then the results from each design will be presented individually. Each section will include a summary of the experimental design, information from the study sites, and results.

BWSR Vegetation Survey

Vegetation was a mixture of native and non-native (including smooth brome grass (Bromus thermis) and Kentucky bluegrass(Poa pratensis) among others) vegetation. The native vegetation present was found as forbs in the understory of a dominant smooth brome grass stand. Stem densities in the upper portions of the watershed were between 150 and 177 stems per square foot. Stem densities near the outlets of the watersheds were between 77 and 144 stems per square foot. The complete vegetation report is included as Appendix 1.

GIS Spatial Analysis Results:

Watershed Characterization

The drainage area for each of the four watersheds was calculated in ArcGIS using the NRCS Engineering Toolbox, "Watershed Delineation" process. The "Watershed Delineation" process is a three step process that uses a Digital Elevation Model (DEM) to create a contour map that can be used to create a hydrologically correct DEM. The hydrologically correct DEM is used to calculate the drainage area and slope of a user defined outlet. After the "Watershed Delineation" process is completed, the user is provided with several shapefiles that provide a detailed assessment of the topography, hydrology, slope and drainage user defined outlets. A one-meter DEM was used as the input to the "Watershed Delineation" process. These data were retrieved from: http://www.mngeo.state.mn.us/chouse/metadata/lidar_swmn2010.html.

A map of the study area is provided below for reference (Figure 1). The watershed outlets are shown with yellow stars, watershed boundaries are shown as red lines and stream lines were added to represent a drainage area greater than 0.25 acre. Following the precipitation section, data will be presented based on the experimental design type: paired watershed and above and below. This presentation will allow for the relevant information to be presented in a logical order.

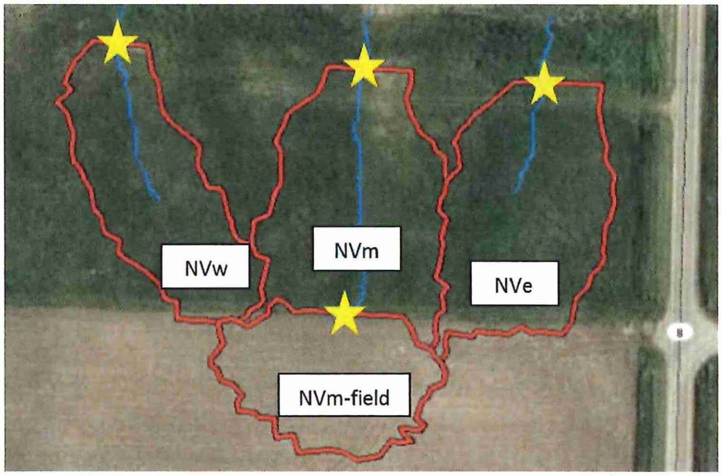


Figure 1. Watersheds included in the Cottonwood River Native Vegetation Water Quality Study.

The paired watershed design sites (NVw and NVe) were comparable in size (Table 1), slope, and slope length. The above and below design sites represent two different landscapes and land uses. The above field (NVm-field) is flatter, and is used for row crop production while the below field (NVm) has an average slope of 6.3% and is a mixture of cropland (NVm-field) with perennial vegetation separated by the NVm-field monitoring station.

Table 3. Watershed characteristics of the project area.

	Watershed Size (acres)	Average Slope (%)	Slope Length (ft)
Paired Watershed Design			
NVw	0.79	7.22	266
NVe	0.98	8.41	277
Above and Below Design			
NVm-field (above)	0.67	2.82	151
NVm (below) (includes NVm-field)	1.70	6.3	394

Cottonwood River Watershed Examination of Comparable Lands

An analysis was completed to find areas within the Cottonwood River Watershed that have a similar slope as the project monitoring sites. The greater Cottonwood River Watershed consists primarily of land with slopes under 6 percent, and this analysis compares how much of the total watershed is comparable to our watersheds included in this study. The initial analysis was completed using the SSURGO Soils database (Soil Survey Staff 2014) and querying the areas that were defined as having similar slopes as the monitoring sites (6-12 percent slopes). The area of each polygon in the SSURGO shapefile was deemed too great for a comparison between the project sites as many areas were greater than one acre. It was decided to complete additional analysis to compare the slope of areas at a one acre scale over greater Cottonwood River Watershed.

In order to complete this analysis, six three-meter Digital Elevation Models (DEMs) were downloaded from MnTOPO (http://arcgis.dnr.state.mn.us/maps/mntopo/) to encompass the entire CRW. The six DEMs were combined into one DEM using the Mosaic tool in ArcToolbox and were clipped to the Cottonwood River Watershed. The watershed shapefile was downloaded from the MnDNR Deli. Slope was then calculated for each cell in the watershed wide DEM.

In order to calculate the slope for each one acre plot, the Grid Index Feature was used to create a one acre grid over the entire Cottonwood River Watershed (a total of 845,225 individual features) and this shapefile was clipped to the watershed boundary. The Grid Index shapefile had too many individual features to calculate Zonal Statistics so the Grid Index shapefile was subdivided into twenty sections. Zonal statistics for the mean was calculated as a table for each of the twenty subsections of the Grid Index and exported as a text file. The twenty text files were combined into one table in Microsoft Excel and saved as a .csv file. The .csv file was converted to a geodatabase table using the Table to Table tool. The geodatabase table was then joined to the original Grid Index shapefile for the entire Cottonwood River Watershed to provide the mean slope for each one acre parcel within the watershed.

The Cottonwood River Watershed was composed primarily of land with slopes under 6 percent (88.2 %) and land with slopes of greater than 12 percent made up 2.8 percent of the watershed. Land within the watershed with similar slopes (6-12 %) to our project sites composed 9.0 percent of the total watershed. This analysis shows that the results from this study should be applied to the greater Cottonwood River Watershed; however, there are over 75,000 acres with similar slopes (Figure 2). Land similar to our project sites will be critical in the future as these sensitive areas may be targeted for BMP's to mitigate agriculture pollution given their topography and proximity to the river valley.

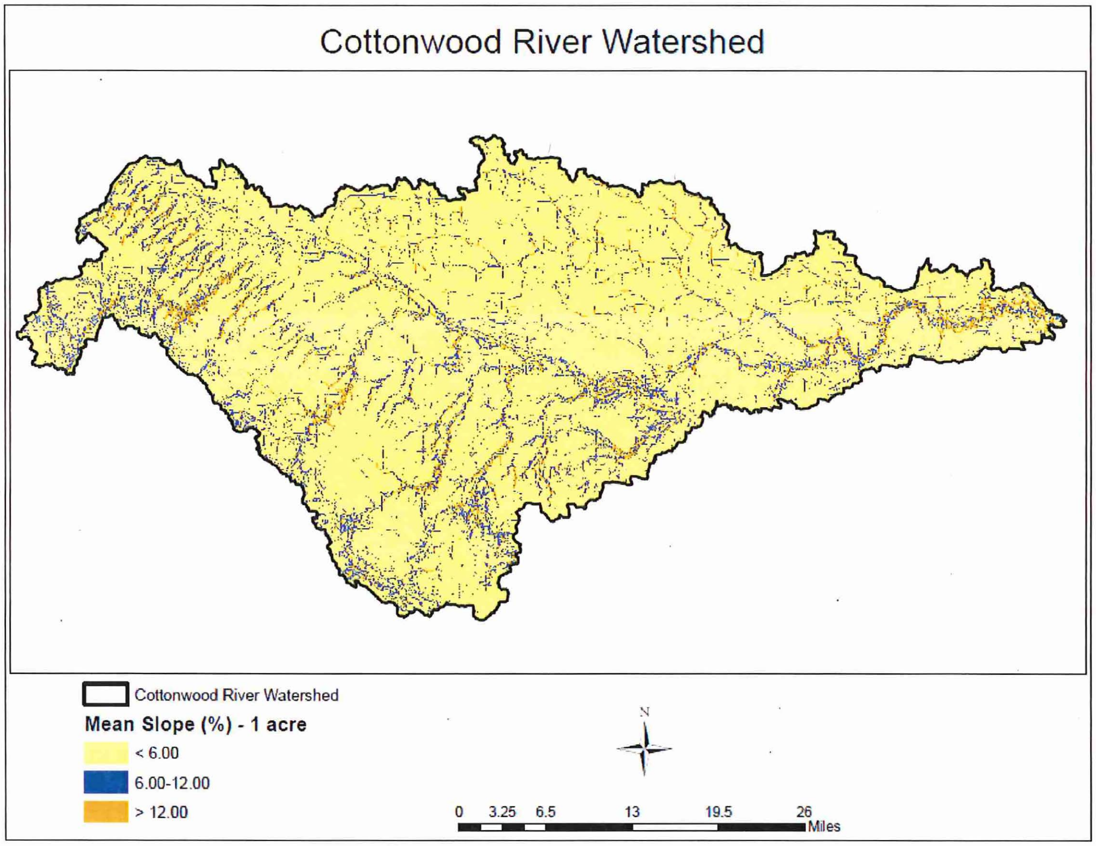


Figure 2 . One acre average slopes for land within the Cottonwood River Watershed.

Hydrology Based Measurements

Precipitation

Monthly precipitation data were collected at the experimental site for the study period (2011-2014) and compared to the 30-year long-term (1980-2010) averages at the Southwest Research and Outreach Center (SWROC) in Lamberton (Figure 3 and Appendix 2). SWROC is located approximately 15 miles east/southeast of the study area. Monthly precipitation values in the winter were also taken from SWROC. Annual precipitation totals in 2011 through 2013 ranged from 20.2 to 23.0 inches compared to the annual average of 26.4 inches (13% to 24% below normal). The United States Drought Monitor classified the study sites as being in severe drought in the fall of 2011, extreme drought in the fall of 2012, and moderate drought in the fall of 2013 (Appendix 3). The distribution of rainfall was skewed to April through July every year from 2011 through 2014, and precipitation was below normal for most months from August through December from 2011 through 2013. Even with the below average annual totals, there were several months with above average precipitation including May and June of 2011, May of 2012 (the wettest May on record for SWROC), June of 2013 and June of 2014. In each year of monitoring, there was at least 1 daily rainfall total in May or June between 1.96 and 2.27 inches.

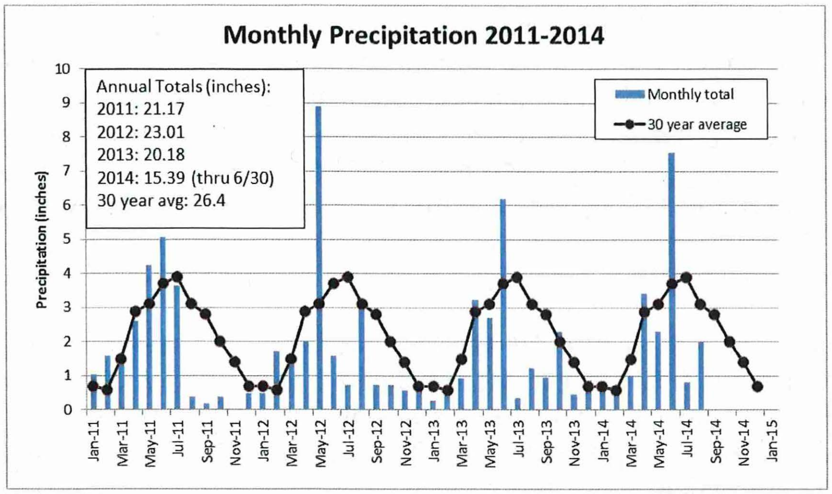


Figure 3. Monthly precipitation totals compared to the 30-year averages.

Paired watershed design:

A paired watershed design requires at least two watersheds, and at least two monitoring periods. One of the watersheds is called the control, and the other watershed is called the treatment; the first monitoring period is the calibration, and the second period is the treatment. The two watersheds are managed identically in the first monitoring period (calibration) to develop a relationship between the basins, and then one of the watersheds undergoes a treatment. The control watershed is managed the same through the calibration and treatment periods as a check over year-to-year or seasonal climate variation in management practices (*National Water Quality Handbook)*. Figure 4 presents the management of the two watersheds in our study.

Ideally, a large number of comparative events are observed during both the calibration and treatment periods. This scenario allows for strong statistical power, and the ability to report changes in land use as a reflection of land use (i.e. a 30% reduction in pollutant A was observed). In this study, run-off was extremely limited and a large event based population data was not available for analysis. To account for this, all event data is presented in each figure.

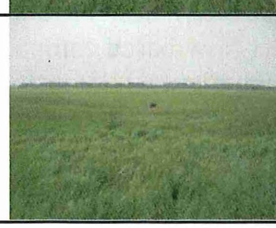
	Calibration Period (2011-2012)	Treatment Period (2013-2014)
NVw (Control Watershed)		
NVe (Treatment Watershed)		

Figure 4. Land management of NVw and NVe watersheds in the paired watershed study.

This section describes the main experimental components of the paired watersheds research project. The project was designed to monitor surface run-off from perennial vegetation and recently converted perennial vegetation to cropland at the Hick's family farm near Tracy, MN. Infrastructure (wing walls, H-flumes, etc) was installed in October of 2010 and electronic monitoring equipment was installed in February of 2011 prior to snowmelt. The sites were managed by the University of Minnesota, Southwest Research and Outreach Center (SWROC).

Description of Research Sites

Two small watersheds (0.79 and 0.98 acres, respectively) were instrumented to monitor surface run-off. These watersheds are located in the southeast corner of a 160-acre field that was composed of a mixture of native and nonnative (including smooth brome grass (Bromus inermis) and Kentucky bluegrass(Poa pratensis) among others) perennial vegetation and was never cultivated for crop production. Cattle were grazed on the field until 2000, and since then, the field is harvested for forage in mid-summer. No artificial drainage was installed. The field was mapped as a Storden loam, a well-drained soil, with moderately high to high permeability on 7.2 and 8.4% slope. Slope lengths were 266 and 277 feet, respectively. The field is a transition between flat, highly productive agricultural fields to the south and lowland riparian land to the north. This transitional area is similar to other nearby lands that hold potential as treatment zones for received run-off, but is not representative of all fields in the region.

The watersheds were monitored utilizing a paired watershed design (Clausen and Spooner, 1993). Each watershed was managed in the perennial vegetation condition during 2011 and 2012 to conduct calibration of the paired watersheds. The vegetation was plowed in the eastern treatment watershed (NVe) and the site was brought into production in May of 2013. Corn (Zea mays L.) was planted perpendicular to the hill slope in 2013 and fertilized with 120 lbs N/acre in 2013. Corn was planted in 2014 using no-till methods and fertilized with 180 lbs N/acre. All nitrogen applications were in the form of urea and were broadcasted in June. The western watershed (NVw) was managed in perennial vegetation condition throughout the project (2011-2014) as the control site.

Water Quality and Quantity Monitoring

Each watershed had a plywood wing wall installed perpendicular to flow near the bottom of the drainage (Stuntebeck, et al, 2008.). Flow was concentrated and forced through a pre-calibrated 1.5 foot H-flume that was equipped with a datalogger and bubbler to record water level, discharge, rainfall, soil moisture, and soil temperature. Run-off events were recorded on a 1-minute interval to examine hydrologic characteristics of the watershed. An ISCO 6712 automated water sampler was used to collect flow-based composite samples into 24 1-L bottles. Water samples were analyzed for ammonium, nitrate, total nitrogen, dissolved reactive phosphorus, total phosphorus, total suspended solids, and E. Coli (Appendix 4 and 5). This information was used to calculate pollutant export (loads) and flow weighted mean concentrations (FWMC) from the watersheds. No water quality or quantity monitoring of vadose zone or ground water was completed.

Soil Properties

Soil properties at 20 locations were measured using a 0.1 acre grid pattern sampling design. Soil cores were analyzed in replicate at the 0-10 cm and 10-20 cm intervals for organic matter, pH, total organic carbon, total nitrogen, total phosphorus, cation exchange capacity, calcium, potassium, magnesium, sodium, and aluminum prior to conversion to cropland (Appendix 8). Soil bulk density was determined in replicate at each of the 32 locations from cores collected in the fall of 2012 at intervals of 0-10, 10-20, 20-40, 40-60, 60-80, 80-100, and 100-120 cm. Soil bulk density was re-determined in replicate at the 12 locations in NVe (after conversion from perennial vegetation to cropland) in June 2014 following the second year of corn (Zea mays L) planting (first known disturbance of soil). Soil bulk density was determined by slicing 100 cm cores at predetermined intervals and drying at 105^{o} C for 24 hours (Klute, 1986). Soil bulk densities are reported as an average of the specific depths in each watershed. Soil infiltration was measured in replicate at each of the 20 locations in the fall of 2012, and re-measured in replicate at the 12 locations in NVe (after conversion to cropland) in June 2014 following the second year of corn (Zea mays L) planting. Tension infiltrometers were operated at pressures of -10, -7, -3 and -0.5 cm. (Reynolds and Elrick, 1991).

Results and Discussion

Hydrology and Run-off

Run-off was limited during the entire study period (Appendix 6). During the calibration period (February 2011- April 2013), both NVw and NVe only recorded run-off on three days in 2012. All three of these events occurred when the soils were frozen and included run-off generated from snowmelt and from rainfall on frozen ground. The NVw site recorded 0.08 inches of run-off/acre (242 cubic ft) and NVe recorded 0.22 inches of run-off/acre (814 cubic ft) over the three events in 2012. No run-off was observed from either NVw or NVe during non-frozen soil conditions in the calibration period. Following the treatment (NVe converted to cropland), NVe had 4 run-off events in June of 2013 that totaled 0.73 inches of run-off/acre (2610 cubic ft). NVw (perennial vegetation control site) did not record run-off in 2013. Run-off occurred at both NVw and NVe in 2014 during the snowmelt when soils were frozen. No run-off was observed when the soils were non-frozen in 2014. The NVw site recorded 0.14 inches of run-off/acre (406 cubic ft) in 3 run-off events and NVe recorded 0.08 inches of run-off/acre (290 cubic ft) in a single run-off event in 2014. Snowmelt was only recorded in years associated with deep frost levels. Run-off was infrequent and of short duration: the average event on frozen soils lasted 5.4 hours; the average event on non-frozen soils (after NVe converted to cropland only) was 42 minutes.

Sediment

Event sediment yields at NVw averaged 0.24 lb/acre and flow weighted mean concentrations (FWMC) averaged 40.7 mg/L (Appendix 7). All NVw events occurred during frozen soil conditions. A total of 1.12 lbs of sediment was exported from NVw from 2011 through June 2014. The NVe pre-treatment (perennial vegetation) event sediment yields averaged 0.22 lbs/acre and FWMC averaged 64.5 mg/L. All NVe pre-treatment events occurred on frozen soils. The NVe post-treatment (after conversion to cropland) sediment characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded sediment at 1.94 lb/acre and FWMC was 106.8 mg/L. Event sediment yields at NVe post-treatment over non-frozen soils averaged 238.2 lb/acre and FWMC averaged 5,075 mg/L. A total of 0.64 lbs of sediment was exported from NVe in 2011 and 2012; a total of 935.8 lbs of sediment was exported from NVe in 2013 and 2014 after conversion to cropland. Sediment yields and FWMC were low for all events that occurred on frozen soils. Sediment yields and FWMC were much greater at NVe after conversion to cropland on non-frozen soils. No run-off occurred from the perennial vegetation during non-frozen soils; therefore no export of sediment was measured from the perennial vegetation during non-frozen periods.

Nitrogen

Event total nitrogen (TN) yields at NVw averaged 0.07 lb/acre and FWMC averaged 5.2 mg/L. Total nitrogen speciation included 2.1% ammonium, 17.7% nitrate-nitrite, and 80.2% organic nitrogen. All NVw events occurred during frozen soil conditions. NVe pre-treatment (perennial vegetation) event TN yields averaged 0.24 lbs/acre and FWMC averaged 31.1 mg/L. Total nitrogen speciation included 5.7% ammonium, 3.2% nitrate-nitrite, and 91.1% organic nitrogen. NVe post-treatment (after conversion to cropland) nitrogen characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded TN at 0.15 lb/acre and FWMC was 8.1 mg/L. Event TN yields at NVe post-treatment over non-frozen soils averaged 0.45 lb/acre and FWMC was 9.5 mg/L. Total nitrogen speciation included 7.0% ammonium, 8.2% nitrate-nitrite, and 84.8% organic nitrogen (Appendix 4). The largest nitrogen losses were associated with the 4 non-frozen soil events at NVe post-treatment (after conversion to cropland). Large nitrogen losses through surface run-off were not anticipated as most nitrogen losses occur through leaching or through artificial drainage (if present) (*Minnesota Discovery Farms 2012 Water Year Monitoring Report, 2013).*

Phosphorus

Event total phosphorus (TP) yields at NVw averaged 0.01 lb/acre and FWMC averaged 0.5 mg/L (Table 1). Approximately 40% of the TP was in the dissolved molybdate reactive phosphorus (DMRP) form. All NVw events occurred during frozen soil conditions. The NVe pre-treatment (perennial vegetation) event TP yields averaged 0.03 lbs/acre and FWMC averaged 4.7 mg/L. Approximately 79% of the TP was in the DMRP form. All NVe pre-treatment events occurred on frozen soils. NVe post-treatment (after conversion to cropland) phosphorus characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded TP at 0.02 lb/acre and FWMC was 1.0 mg/L. Event TP yields at NVe post-treatment over non-frozen soils averaged 0.06 lb/acre and FWMC was 1.2 mg/L. Approximately 6% of the TP was in the DMRP form for all events at NVe post treatment.

The watersheds managed in perennial vegetation did have elevated TP concentrations; however, the export loads were low when combined with run-off volumes. The watersheds managed in perennial vegetation also had a higher fraction of the TP in the DMRP form than from NVe after conversion to cropland. The events with the largest TP export loads occurred at NVe in 2013 after conversion to cropland. No run-off occurred from the perennial vegetation during non-frozen soils; therefore no export of TP was measured from the perennial vegetation during non-frozen periods.

Soil Bulk Density

Soil bulk density increased from 1.25 to 1.40 g/cm^3 in first 10 cm depth (Figure 5) following the conversion from perennial vegetation to cropland (Appendix 9 and 10). Soil bulk density also increased at each interval from 10 to 40 cm below the surface. In the perennial vegetation, soil bulk density decreased at the 40 to 60 cm depths and normalized around 1.44 g/cm^3 from 60 to 100 cm depth. After conversion of perennial vegetation to cropland, the soil bulk density increased at the 40 to 60 cm depth and normalized around 1.75 g/cm^3. Soil bulk density measurements of an adjacent field (NVm-field) with a long history of crop production were collected as a reference point. The recently converted cropland had soil bulk densities that fell between the perennial vegetation and NVm-field at the 0-40 cm depth. Soil bulk density in the lower 40-100 cm depth was similar for the recently converted cropland and NVm-field. It is anticipated that long-term production in the recently converted cropland would result in greater soil bulk densities in the 0-40 cm depth over time likely effecting physical soil properties.

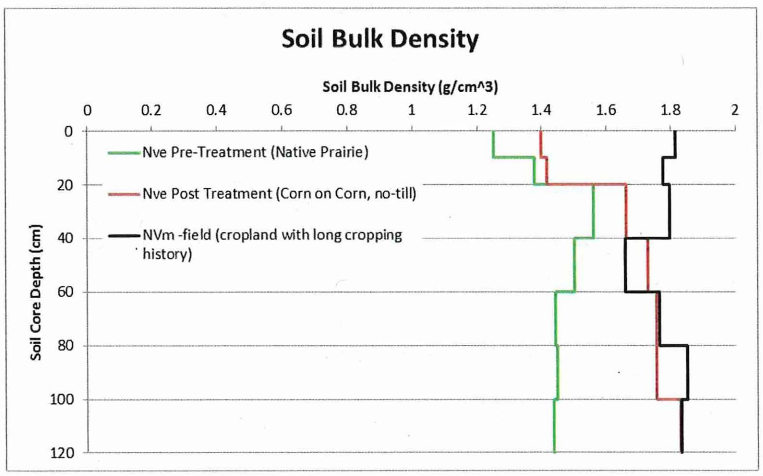


Figure 5. Soil bulk density of NVe pre-treatment (perennial vegetation) and NVe post-treatment (corn on corn, no-till in second year of crop production).

Infiltration

Hydraulic conductivity was determined at NVe during the control (perennial vegetation, 2012) and treatment (corn on corn, no-till, 2014). Measurements of the infiltration at NVe pre-treatment were consistent with hydraulic conductivity of the adjoining perennial vegetation sites (Figure 6); measurements of the infiltration at NVe post-treatment were consistent with the hydraulic conductivity of the adjoining field that has been in production for many decades (Figure 7). These measurements indicate a dramatic decrease in the amount of water that can infiltrate the soil after conversion to cropland.

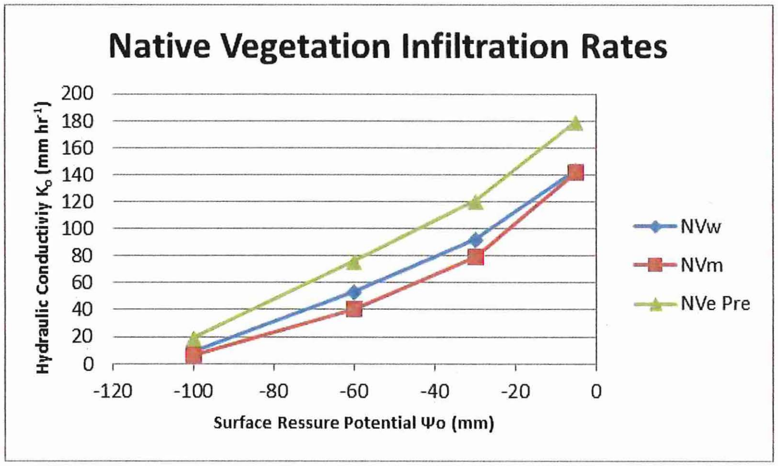


Figure 6. Watershed infiltration rates of three watersheds of native vegetation.

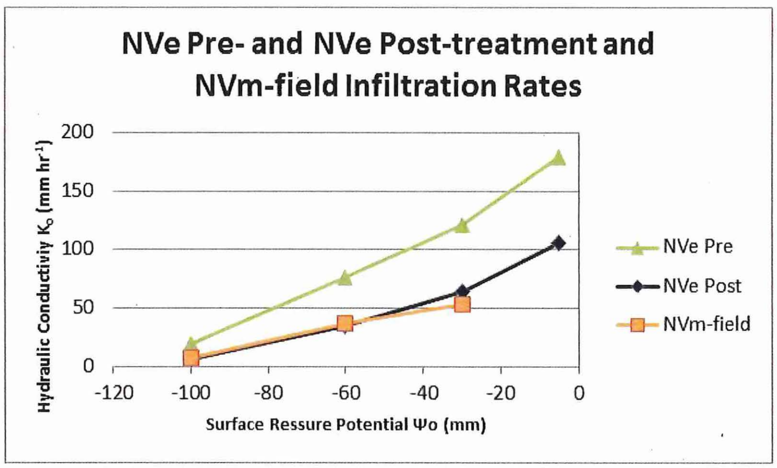


Figure 7. Watershed infiltration rates of NVe pre-treatment (perennial vegetation), NVe post-treatment (corn on corn, no-till), and NVm-field (crop field with long cropping history).

Conclusion

This study characterized the hydrology and water quality of perennial vegetation on undisturbed soils in southwest Minnesota. On the perennial vegetation, lack of run-off during non-frozen soil conditions was a significant factor in overall run-off losses. Snowmelt run-off from the perennial vegetation during frozen soil conditions did carry nitrogen, phosphorus and sediment from the watersheds. After conversion to cropland, the NVe watershed did experience four run-off events in June of 2013. The observed run-off and associated pollutant loads are likely a result of the change in land use. Increases in soil bulk density, and lowered infiltration rates were associated with the conversion into cropland. Additional years of crop production would likely continue to change the soil properties, and ultimately the hydrology of this site.

Other Monitoring: Edge of Field Data Context

Comparison of Annual Losses to Minnesota Discovery Farms Results:

Minnesota Discovery Farms has been collecting agricultural edge-of-field monitoring data since 2010 and their results allow for context to the data collected in this project. As of September 2014, there are 11 core farms that are monitoring a combination of surface and subsurface drainage systems. For more information about the individual farms, site descriptions, and agronomic information, please refer to http://www.discoveryfarmsmn.org/ .

For this analysis, the annual Minnesota Discovery Farms data from 2010-2013 (16 site years) are presented as an annual average for all surface run-off locations. The goal is to provide a relative data range to provide context for agricultural fields across greater Minnesota. Data is reported on an annual basis, and this section will focus on annual yields of run-off, total nitrogen, total phosphorus, and total suspended solids. To compare to the Minnesota Discovery Farms data, NVw and NVe data will be presented as three different groups: NVw perennial vegetation (2011-2014), NVe perennial vegetation (2011-2012), and NVe cropland (2013-2014).

The data range for Minnesota Discovery Farms for all parameters is much wider than observed in our study (Figure 8). This is expected due to the variety of site locations, differences in soils and geology, and differences in farming operations across Minnesota. The perennial vegetation at NVw (2011-2014) and NVe (2013-2014) resulted in annual yields of all parameters that were below the range of observed yields with the Minnesota Discovery Farms network. The NVe cropland (2013-2014) values for run-off, total nitrogen and total phosphorus fell on the lower end of the Minnesota Discovery Farms ranges. The NVe cropland (2013-2014) annual TSS yield range extended on either side of the Minnesota Discovery Farms interquartile range.

When comparing the edge of field annual yield data collected in this study to the data collected by Minnesota Discovery Farms, a few general inferences can be drawn. The perennial vegetation annual yields are far below the observed range on Minnesota Discovery Farms locations. The recently converted cropland at NVe fell on the low end of the data range for run-off, total nitrogen and total phosphorus. The recently converted cropland at NVe fell within the data range for total suspended solids.

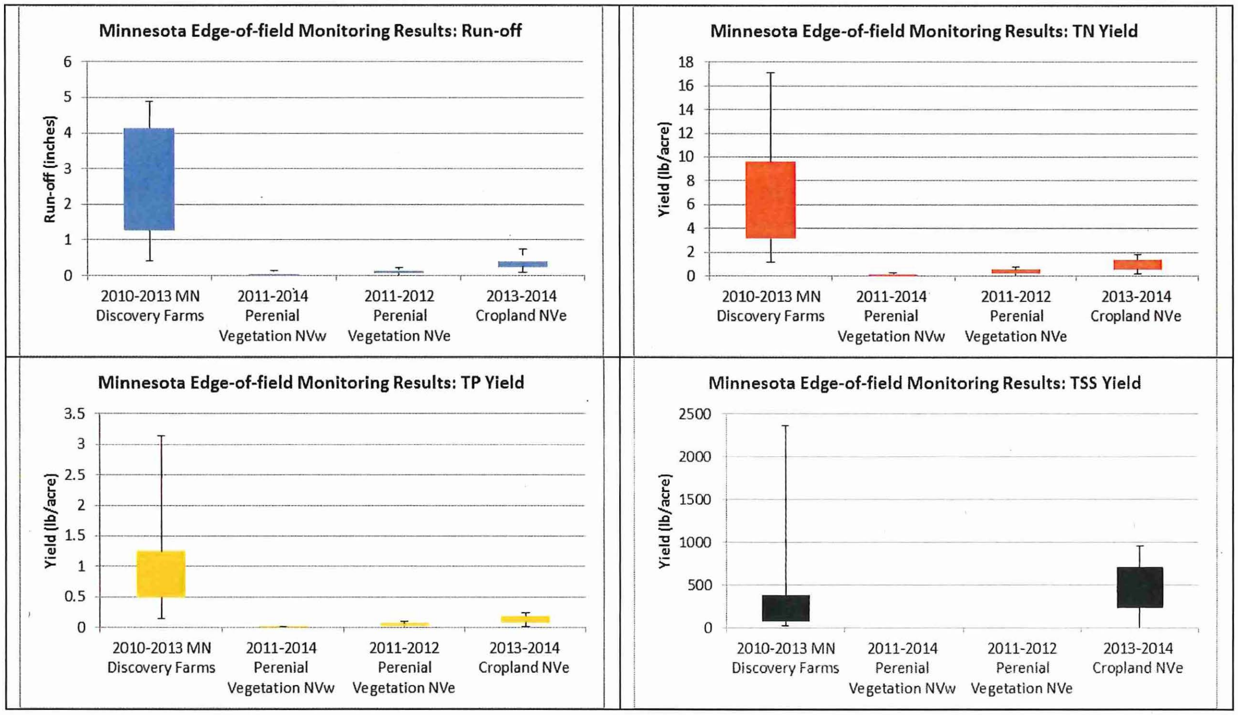


Figure 8. Minnesota Discovery Farms and Project Annual Run-off Yields.

Above and Below Design:

An above and below watershed design is used to isolate differences in land management, such as a BMP. The above and below watersheds are actually nested within a single watershed. The above watershed has the same monitoring equipment and objectives as the below. The water quantity and quality are measured from the above watershed, and then releases the water onto the below watershed. The below watershed is then monitored at the outlet. The difference between the water quantity and quality of the above and below monitoring stations is related to the treatment in the below watershed. The nested design elevates the need for a calibration period *(USDA, National Water Quality Handbook, 2003).*

At the beginning of our paired watershed study in 2011, it was unknown that NVm had 0.67 acres of row crop contributing to it. Significant differences in run-off volumes occurred between NVw, NVe, and NVm in 2011 and 2012. Further site investigation in 2012, as well as the availability of the high resolution LIDAR data, allowed for the above and below design to be implemented in October of 2012.

This section describes the main experimental components of the above and below watershed research project. The project was designed to monitor surface run-off from native vegetation and row crops at the Hick's family farm near Tracy, MN. Infrastructure (wing walls, H-flumes, etc) was installed in October of 2010 at NVm and in October of 2012 at NVm-field. Monitoring began at NVm in February of 2011 prior to snowmelt and in October of 2012 at NVm-field, however, data analysis can only be completed since October 2012. The sites were managed by the University of Minnesota, Southwest Research and Outreach Center (SWROC).

Description of Research Sites

Two nested watersheds (0.67 and 1.70 acres, respectively) were instrumented to monitor surface run-off. One watershed (NVm-field) was located within NVm (Figure 9). NVm-field (0.67 acres) had a slope of 2.82% and has a long history of row crop production. The field is mapped as Ves loam, a well-drained soil, with moderately high to high permeability. This is representative of many agricultural fields in the Cottonwood River Watershed. NVm-field watershed drains into NVm. NVm was composed of the NVm-field contributing area that drains into a mixture of native and nonnative (including smooth brome grass (Bromus thermis) and Kentucky bluegrass(Poa pratensis) among others) perennial vegetation and was never cultivated for crop production. Cattle were grazed on the perennial vegetation until 2000, and since then, the field is harvested for forage in mid-summer. No artificial drainage is present on the NVm hills lope. NVm's hills lope was mapped as a Storden loam, a well-drained soil, with moderately high to high permeability on 6.3% slope. NVm hills lope is a transition between flat, highly productive agricultural fields to the south and to lowland riparian land to the north.

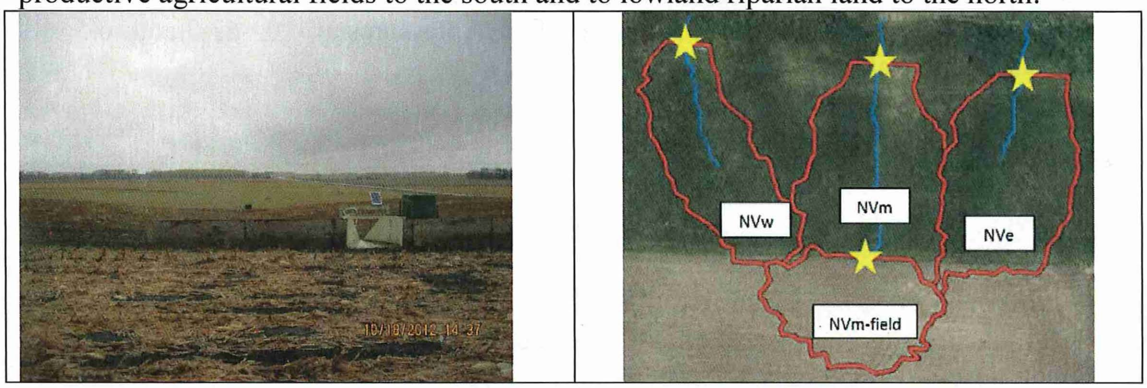


Figure 9. Photograph and map of NVm and NVm-field. In photo, NVm-field is in the foreground, and NVm is visible from the green shelter at the bottom of the hillslope.

The watersheds were monitored utilizing an above and below watershed design (*National Water Quality Handbook*). NVm-field was used for corn (Zea mays L) production since 2012, and NVm hillslope was in perennial vegetation. The hill slope vegetation was harvested in early July each year for forage. NVm-field was managed for high yielding corn production throughout the study, and would be representative of corn field in southwest Minnesota. NVm-field made up approximately 40% of the NVm watershed; meaning that the contributing area of the corn field was smaller than the treatment zone of the perennial vegetation.

Water Quality and Quantity Monitoring

Each watershed had a plywood wing wall installed perpendicular to flow near the bottom of the drainage (Stuntebeck, et al, 2008.). Flow was concentrated and forced through a pre-calibrated 1.5, or 2.5, foot H-flume that was equipped with a data logger and bubbler to record water level, discharge, rainfall, soil moisture, and soil temperature. Run-off events were recorded on a 1-minute interval to examine hydrologic characteristics of the watershed. An ISCO 6712 automated water sampler was used to collect flow-based composite samples into 24 1-L bottles. Water samples were analyzed for ammonium, nitrate, total nitrogen, dissolved reactive phosphorus, total phosphorus, total suspended solids, and E. coli. This information was used to calculate pollutant export (loads) and flow weighted mean concentrations (FWMC) from the watersheds. No water quality or quantity monitoring of vadose zone or ground water was completed.

Soil Properties

Soil properties at 15 locations were measured using a 0.1 acre grid pattern sampling design. Soil cores were analyzed in replicate at the 0-10 cm and 10-20 cm intervals for organic matter, pH, total organic carbon, total nitrogen, total phosphorus, cation exchange capacity, calcium, potassium, magnesium, sodium, and aluminum prior to conversion to cropland. Soil bulk density was determined in replicate at each of the 15 locations from cores collected at intervals of 0-10, 10-20, 20-40, 40-60, 60-80, 80-100, and 100-120 cm. Soil bulk density was determined by slicing 100 cm cores at predetermined intervals and drying at 105° C for 24 hours (Klute, 1986). Soil bulk densities are reported as an average of the specific depths in each watershed. Soil infiltration was measured in replicate at each of the 15 locations in the fall of 2012 or June of 2014. Tension infiltrometers were operated at pressures of -10, -6, -3 and -0.5 cm. (Reynolds and Elrick, 1991).

Results and Discussion

Hydrology and Run-off

Run-off events need to be broken down into two categories for analysis: frozen soils and non-frozen soils. Each these categories exhibit different patterns for each watershed. On frozen soils, the amount of run-off is strongly correlated to the amount of snowpack in the watershed. These two fields trap snow differently over the winter. Limited snowpack is captured in NVm-field watershed because sits on top of the ridge and most snow blows off of the watershed. The lack of snow at NVm-field allows for deep frost, and limits infiltration during snowmelt. NVm captures a large amount of snow due to the perennial vegetation that traps the snowpack. In addition, the valley between NVm-field and NVm holds several feet of snow throughout the winter. NVm has much more snow water equivalent available when snowmelt begins.

The two watersheds also have dramatically different snowmelt periods. The NVm-field watershed has limited snowpack, allowing the high sun angle in March to penetrate the snow and expose black soil even before temperatures reach freezing. Much or most of the snow in NVm-field sublimates before it has the opportunity to run-off. NVm-field has a higher heating potential, and generally the snowmelt run-off process is shorter than in the NVm watershed. In 2013, NVm-field had 0.43 in/acre of snowmelt run-off that occurred on a single day and in 2014, NVm-field had 0.86 in/acre of snowmelt run-off that occurred on 3 days. The snowmelt at NVm is a slower process due to the deeper snowpack not allowing soil to be exposed with temperatures below melting and the north facing orientation of the slope that does not efficiently collect the sun's energy. The third factor is the influence of the perennial vegetation that limits the depth of the frost and established macropore pathways in the soil. These factors lead to a slower melt and limit the surface run-off due to infiltration. In 2013, NVm did not have snowmelt run-off and in 2014, NVm-field had 0.54 in/acre snowmelt run-off. The perennial vegetation on the NVm hill slope had very little run-off, and also trapped run-off from the NVm-field portion of the watershed (Figure 10a).

Non-frozen soil run-off events occurred more frequently at NVm-field, and had higher run-off volumes (Figure 10b). In 2013 at NVm-field a single event in June had 0.44 in/acre run-off, and in 2014 at NVm-field two events that totaled 0.23 in/acre of run-off. NVm only had two small run-off events in 2013 totaling 0.03 in/acre of run-off and no run-off was measured in 2014. All non-frozen soil events in 2013 and 2014 occurred in June. The overall lack of run-off during non-frozen soil periods at NVm aligns with the two adjoining perennial vegetation watersheds that did not record run-off from 2011-2014.

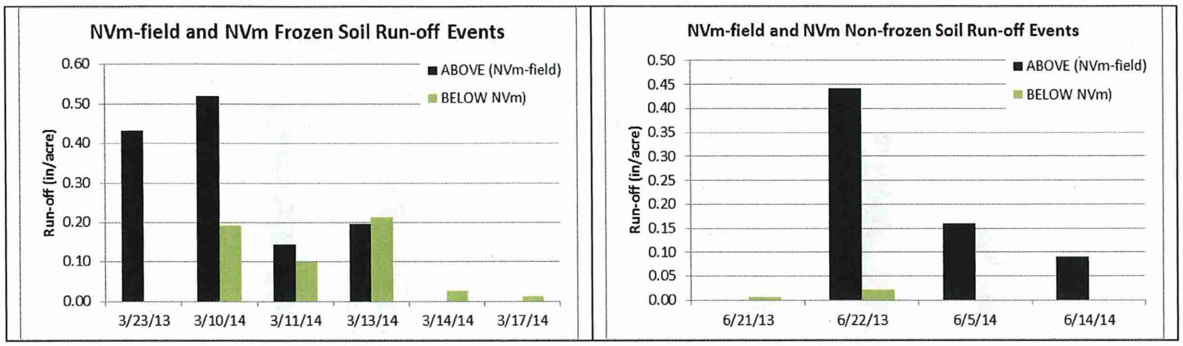


Figure 10. NVm-field and NVm a) frozen and b) non-frozen soil run-off events.

Sediment

TSS event yields and FWMC need to be broken down into two categories for analysis: frozen soils and non-frozen soils. Each these categories exhibit different sediment loss patterns for each watershed. In general, sediment losses on frozen soils are minimal. NVm-field lost between 0 - 27 lb/acre, and NVm lost between 0.2 – 6 lb/acre over 6 frozen soil events in 2013 and 2014 (Figure 11a). Event sediment FWMC for both NVm-field and NVm were similar for all 6 events and ranged from 0-180 mg/L (Figure 11b). Sediment losses from non-frozen soils have higher variability than frozen soils. NVm-field lost between 0-192 lb/acres and NVm lost between 0-1.8 lb/acre over four non-frozen soil events in 2013 and 2014 (Figure 12a). Total event losses were mitigated at NVm due to the small amount of surface water run-off compared to NVm-field (Figure 10a and 10b). Event sediment FWMC were higher for NVm-field (0-1,580 mg/L) than NVm (0-380 mg/L) during non-frozen soil conditions (Figure 12a and 12b). TSS event yields and FWMC were greatly influenced by the amount of run-off and the timing when the run-off event occurred.

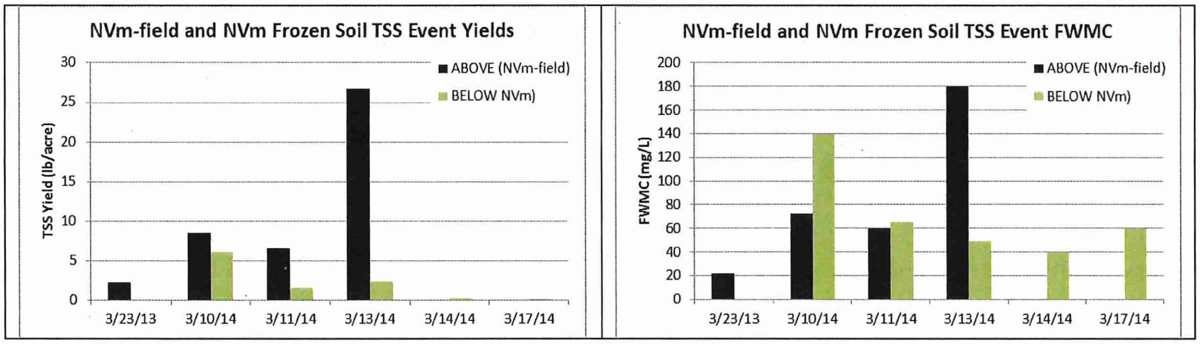


Figure 11. NVm-field and NVm frozen soil a) TSS event yields. b) TSS event FWMC

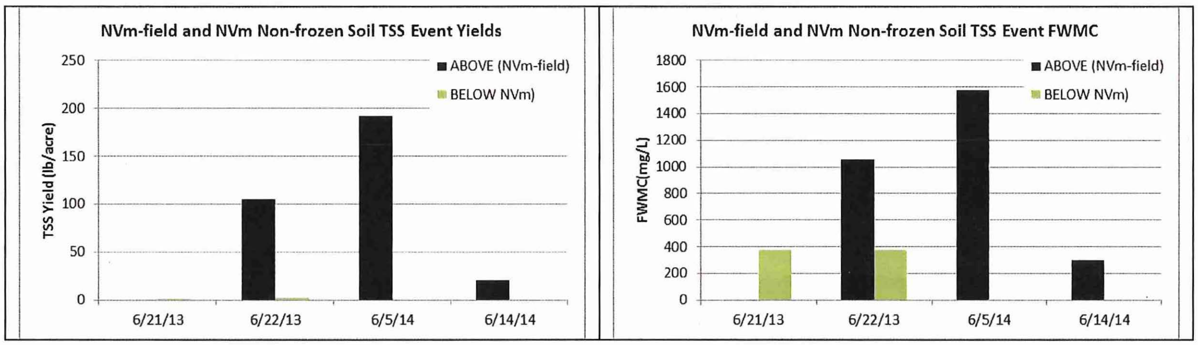


Figure 12. NVm-field and NVm non-frozen soil a) TSS event yields. b) TSS event FWMC

Phosphorus

Total phosphorus (TP) event yields and FWMC need to be broken down into two categories for analysis: frozen soils and non-frozen soils. Each these categories exhibit different TP loss patterns for each watershed. In general, TP yields and FWMC on frozen soils were higher for NVm-field for all events in which NVm-field had run-off measured. NVm-field lost between 0 – 0.4 lb/acre, and NVm lost between 0 – 0.06 lb/acre over 6 frozen soil events in 2013 and 2014 (Figure 13a). Event TP FWMC for NVm-field ranged from 0-2.2 mg/L and NVm from 0-1.5 mg/L (Figure 13b). TP losses from non-frozen soils were similar to frozen soils given run-off occurred. NVm-field lost between 0-0.12 lb/acres and NVm lost between 0-0.02 lb/acre over 4 non-frozen soil events in 2013 and 2014 (Figure 14a). Total event losses were mitigated at NVm due to the small amount of surface water run-off compared to NVm-field (Figure 10a and 10b). Event TP FWMC were lower for NVm-field (0-1.2 mg/L) than NVm (0-4.3 mg/L) during non-frozen soil conditions (14b); however NVm had very small TP event yields given the minimal volume of run-off occurring.

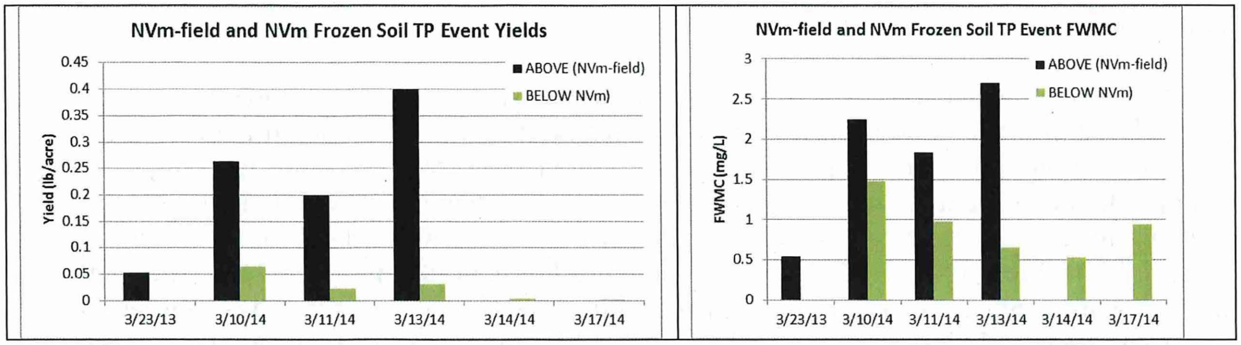


Figure 13. NVm-field and NVm frozen soil total phosphorus a) event yields and b) FWMC.

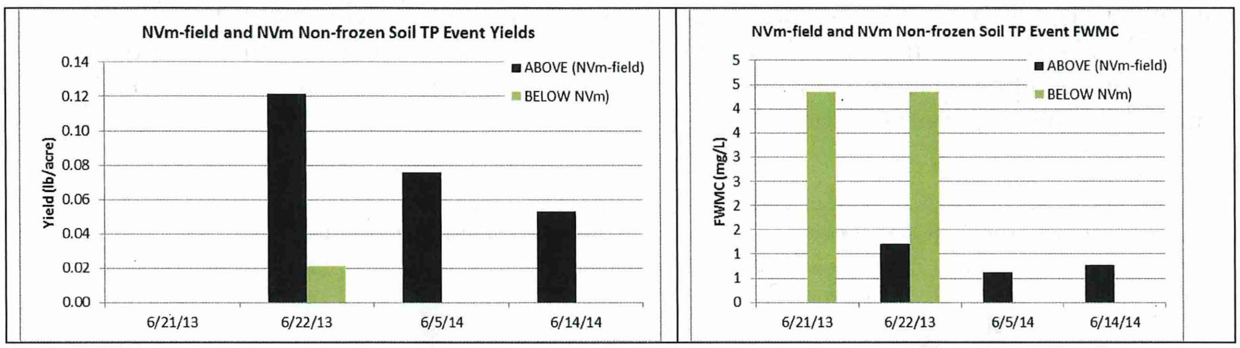


Figure 14. NVm-field and NVm non-frozen soil total phosphorus a) event yields and b) FWMC.

Dissolved molybdate reactive phosphorus (DMRP) concentrations were measured in addition to TP. The DMRP data will be presented as a fraction of the TP. During frozen soil conditions, most events at both sites had between 20 and 30 percent of the TP as DMRP (Figure 14a). The event on March 23, 2013 at NVm-field (above) had 80 percent of the TP as DMRP, however, this was the event with the lowest overall TP yield (Figure 15a) at NVm-above during frozen conditions. Events during non-frozen soil conditions resulted in a range of 23 to 49 percent TP as DMRP at NVm-field (above) and approximately 53 percent TP as DMRP at NVm (below) (Figure 15b).

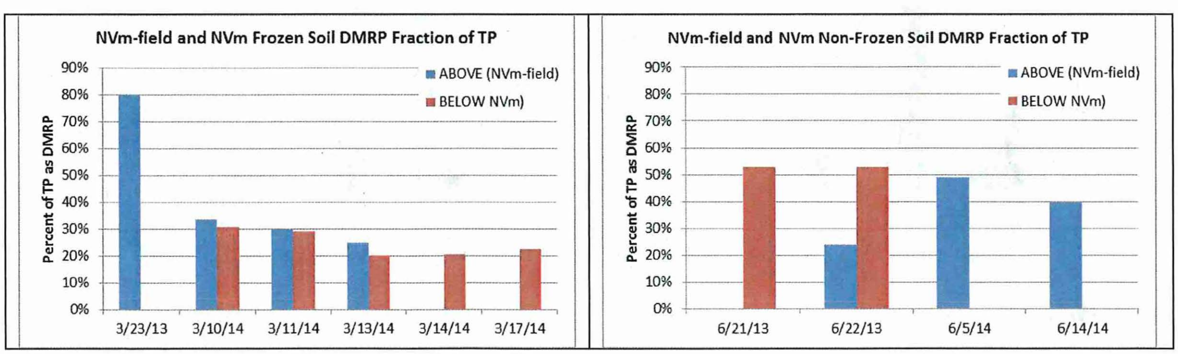


Figure 15. NVm-field and NVm DMRP fraction of TP on a) frozen soils and b) non-frozen soils.

Nitrogen

Total nitrogen (TN) event yields and FWMC need to be broken down into two categories for analysis: frozen soils and non-frozen soils. Each these categories exhibit different TN loss patterns for each watershed. In general, TN yields and FWMC on frozen soils were higher for NVm-field for all event in which NVm-field had run-off measured. NVm-field lost between 0 – 1.98 b/acre, and NVm lost between 0 – 0.41 lb/acre over 6 frozen soil events in 2013 and 2014 (Figure 16a). Event TN FWMC for NVm-field ranged from 0-18.2 mg/L and NVm from 0-9.4 mg/L (Figure 16b). TN losses from non-frozen soils were similar to frozen soils given run-off occurred. NVm-field lost between 0-1.0 lb/acres and NVm lost between 0-0.16 lb/acre over 4 non-frozen soil events in 2013 and 2014 (Figure 17a). Total event losses were mitigated at NVm due to the small amount of surface water run-off compared to NVm-field (Figure 9a and 9b). Event TN FWMC were lower for NVm-field (0-8.2 mg/L) than NVm (0-33.8 mg/L) during non-frozen soil conditions (Figure 17b); however NVm had very small TN event yields given the minimal volume of run-off occurring.

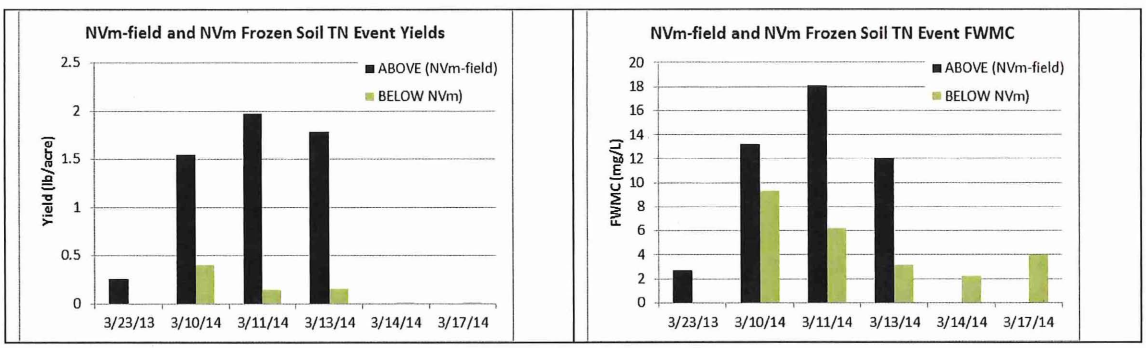


Figure 16. NVm-field and NVm frozen soil total nitrogen a) event yields and b) FWMC.

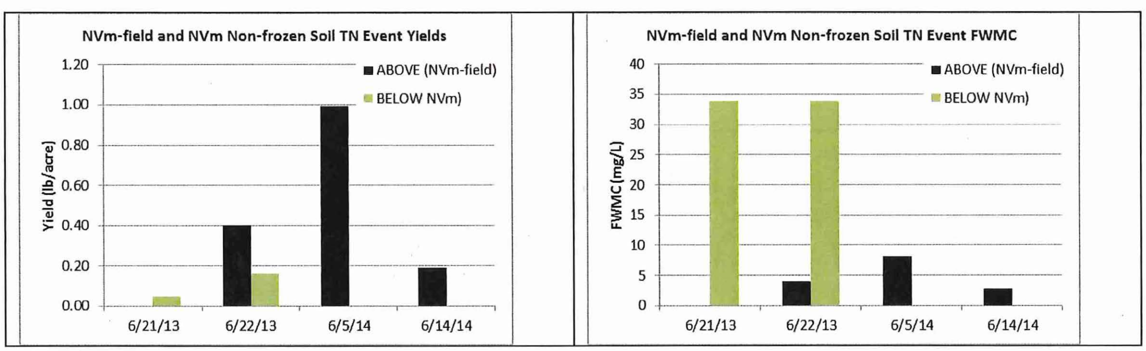


Figure 17. NVm-field and NVm non-frozen soil total nitrogen a) event yields and b) FWMC.

Soil Bulk Density

Soil bulk density was measured from the two watersheds (Figure 18). The data presented for NVm only includes the perennial vegetation portion (not the NVm-field watershed that is nested within NVm). NVm had lower bulk densities throughout the soil profile, especially in the uppermost 20 cm of the soil profile. NVm represents undisturbed soil conditions, while NVm-field has been used for crop production for decades effecting physical soil properties.

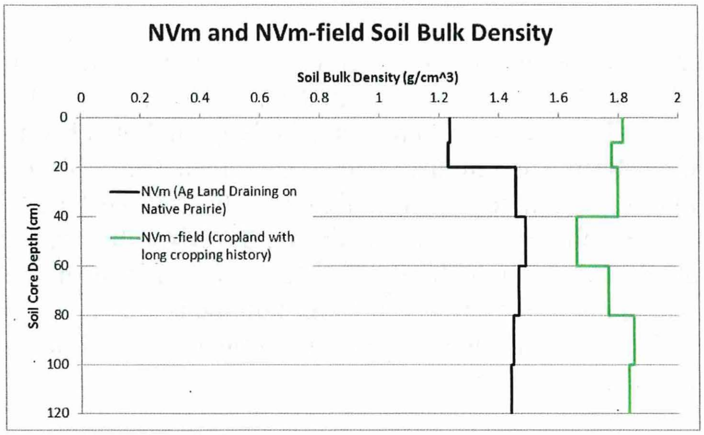


Figure 18. Soil bulk density of NVm (perennial vegetation portion only) and NVm-field (cropland with long cropping history).

Infiltration

Hydraulic conductivity was determined at NVm and NVm-field. Measurements of the infiltration at NVm were consistent with hydraulic conductivity of the adjoining perennial vegetation sites (Figure 6). Infiltration rates were similar between NVm and NVm-field at the highest surface pressure potentials; however, it appears the infiltration rates were separating as pressure potentials approached saturated conditions (Figure 19). These measurements indicate more water that can infiltrate undisturbed soils.

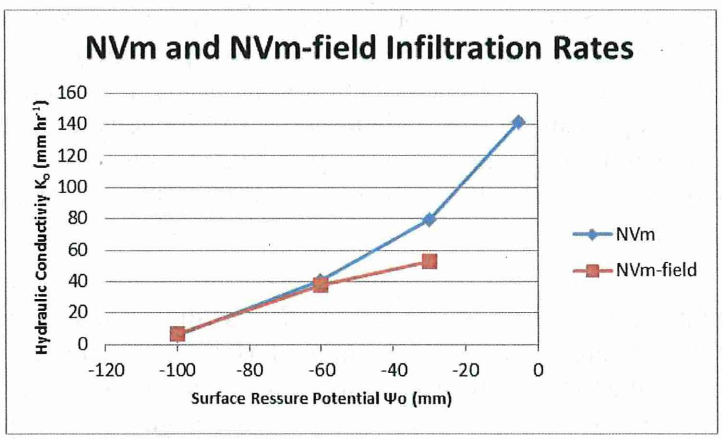


Figure 19. NVm and NVm-field infiltration rates.

Conclusion

This study used an above and below design to compare the quality and quantity of run-off from two different land uses. NVm-field represented a 0.67 acre watershed with a long history or row crop production and NVm was 1.7 acre watershed that included NVm-field with the remainder in perennial vegetation and undisturbed soils. Greater run-off volumes were observed at NVm-field than NVm on both frozen and non-frozen soils. NVm effectively captured the run-off and associated sediment and nutrients from NVm-field. NVm did occasionally have higher FWMC than NVm-field; however, the volume of run-off was minimal and therefore yields were low for NVm. NVm had undisturbed soils with lower bulk density and higher infiltration rates than NVm-field. The differences in water quality are a reflection of surface water run-off hydrology at these sites.

Coordination Efforts

Coordination with State Agencies

Several Minnesota state agencies were involve with this project including the Minnesota Department of Agriculture (project coordination/data analysis/reporting), Minnesota Pollution Control Agency (project coordination/equipment), and the Minnesota Board of Soil and Water Resources (plant identification/report). The University of Minnesota Southwest Research and Outreach Center provided support for the monitoring, data collection and laboratory analysis.

Summary of Public Participation

There were three primary public outreach and education components that where completed during the grant period. The first outreach and education component was completed on November 21st, 2012 and included a 30 minute PowerPoint presentation. This presentation was completed as part of the U of M's Department of Soils, Water, and Climate seminar class and was open to public. Approximately 20 students and U of M faculty attended the presentation that was focused primarily on project design and background as a result of low run-off occurrence in the 2010 and 2011 calendar years of monitoring. The presentation is attached, and no materials were distributed.

A field tour of a group of seven Scientists, Engineers, and graduate students from Agriculture and Agri-Food Canada and the University of Manitoba was held at the SWROC in 2011. One of the stops on the tour was the Cottonwood River Native Vegetation Water Quality monitoring stations. The tour was interested in the scientific design of the project, as well as the particular details of edge-of-field monitoring. The tour consisted of seven attendees that visited the sites and discussed the project goals. No materials were formally prepared or handed out at this event.

The primary project public outreach and education component of this project occurred as part of the 5th Soil and Water Management Field Day on July 23rd, 2014 on the Brian Hick's farm near Tracy, MN. As part of the field day, about 100 attendees heard an overview of the Cottonwood River Native Vegetation Water Quality monitoring design, visited the monitoring stations, and heard preliminary project results. Overview slides and a formal manuscript of the

project was prepared and distributed to all attendees. The presentation and manuscript are attached, and the field day has a publically accessible website where these documents can be downloaded:
http://swroc.cfans.umn.edu/ResearchandOutreach/SoilManagement/Outreach/index.htm

Future outreach and education will continue after the grant is completed. Planned activities include thesis preparation and defense, journal article submission, presentations on a local and state level and development of a guidance document.

Challenges of the Project

Although the research team was aware that weather variability could impact the project, we did not anticipate the extremes in precipitation and drought that occurred. Based on previous monitoring in Minnesota, it was anticipated that run-off would occur much more frequently than observed with this project. The overall lack of run-off proved to be challenging in terms of collecting a large dataset to run statistics. In addition, the project budget forecasted many events per year, with several samples per event to be analyzed. This lack of samples resulted in a lower than expected in-kind contribution to the project. The soil conditions, paired with the episodic drought pattern observed resulted in very limited run-off.

The project sites was instrumented with the correct equipment and operated in a similar manner to additional edge-of-field sites in Minnesota. Even given the monitoring experience and familiarity with equipment of project staff, edge-of-field monitoring in the Upper Midwest is extremely challenging. The most challenging, and staff intensive period occurs with snowmelt and the daily freeze/thaw cycle that requires site visits at least daily to ensure accurate data is collected. During non-snowmelt times, events are of short duration (average of 42 minutes) and occurred in the overnight hours. In addition, all events are extremely valuable given the scarcity of run-off adding pressure to ensure all equipment is functioning. Surface edge-of-field monitoring in this region is inherently challenging.

It was very frustrating to our team that the contract execution took so long which inevitably delayed our project. Any way to expedite and make contract execution more efficient would be helpful.

Future Activity Recommendations

As with any outdoor research study, a longer study period would be preferred to account for seasonal and annual variation in climate. As such, it would be preferable to have a back-up plan to simulate rainfall events, even on a smaller scale, to help produce run-off events. It is impossible to predict how individual watersheds will respond rainfall moving into a project.

Many of the measurements collected related to soil properties showed the benefits of perennial vegetation on the landscape. A study could be conducted that tracks the changes in disturbed soils that were converted to perennial vegetation to track how long it takes the soils to recover from disturbance. The soils in this project serve a target in terms of soil quality; however, the transformation of cropland soils to perennial vegetation is not well understood.

This would be important when planning future conservation planning, and the length of time in which it takes soil properties to improve back to pre-disturbance periods.

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Appendix List	
Appendix 1.	MDA Cottonwood River Water Quality Study – Vegetation Survey
Appendix 2.	Monthly precipitation at the experimental site compared to the 30-year mean near Lamberton, MN and percent departure from 30-year average.
Appendix 3.	USDA Drought Monitor for Minnesota, 2011-2014 ("U.S. Drought Monitor").
Appendix 4.	Water sample chemistry results.
Appendix 5.	Water sample field chemistry results.
Appendix 6.	Running Event Summary by Site.
Appendix 7.	Annual Loads, Yield and Flow Weighted Mean Concentration (FWMC) by site.
Appendix 8.	Soil Sampling Laboratory Results.
Appendix 9.	Pre-treatment Soil bulk density results from cores collected in 2012.
Appendix 10.	Post-treatment Soil bulk density results from cores collected in 2014.
Appendix 11.	Seminar presentation on November 12th, 2012.
Appendix 12.	Soil and Water Management Field Day Brochure
Appendix 13.	Soil and Water Management Field Day Presentation.
Appendix 14.	Soil and Water Management Field Day Manuscript

Appendix 1. MDA Cottonwood River Water Quality Study – Vegetation Survey		
Survey Conducted June 20th 2013 by Dan Shaw of BWSRSurvey Methods: A meander search was conducted in "upper" (side slopes) areas and "swale" areas of each study unit to develop a list of dominant species and percent cover for each species. Representative square-foot plots were placed in representative "upper" and "swale" portions of study units to determine the number of stems per square foot.		
NVm Upper Portion		
Common Name	Scientific Name	Percent
Smooth Brome Grass	(Bromus inermis)	90%
Kentucky Bluegrass	(Poa pratensis)	6%
Bare Areas with thatch		5%
Common Wood Sorrel	(Oxalis stricta)	2%
Canada Godenrod	(Solidago canadensis)	1%
Common Milkweed	(Asclepias syriaca)	1%
Alfalfa	(Medicago sativa)	1%
Heart-leaved Golden Alexanders	(Zizia aurea)	<1%
Snowberry	(symphoricarpos albus)	<1%
Purple Prairie Clover	(Dalea purpurea)	<1%
Porcupine Grass	(Stipa spartea)	<1%
Canada Milk Vetch	(Astragalus canadensis)	<1%
Sweet Clover	(Melilotus alba)	<1%
Yarrow	(Achillea millefolium)	<1%
Prairie Sage	(Artemisia ludoviciana)	<1%
Ground Cherry	(Physalis sp.)	<1%
Prairie Turnip	(Psoralea esculenta)	<1%
Black Medic	(Medicago lupulina)	<1%
Alsike Clover	(Trifolium hybridum)	<1%
Prairie Rose	(Rosa arkansana)	<1%
Dandelion	(Taraxacum officinale)	<1%
Field Thistle	(Cirsium discolor)	<1%
Common Ox-eye	(Heliopsis helianthoides)	<1%
Thimbleweed	(Anemone cylindrica)	<1%
Rough Pucoon	(Lithospermum caroliniensis)	<1%
NVm Upper Portion Stem Density (1 square foot)		
150 Stems per square foot		
Kentucky Bluegrass	(Poa pratensis)	55%
Smooth Brome Grass	(Bromus inermis)	45%
Forbs (mostly Black Medic)		5%
NVm Swale Portion		
Common Name	Common Name	Common Name
Smooth Brome Grass	(Bromus inermis)	98%
Quackgrass	(Elymus repens)	2%
Kentucky Bluegrass	(Poa pratensis)	5%
Canada Goldenrod	(Solidago canadensis)	1%
Common Milkweed	(Asclepias syriaca)	1%
Big Bluestem	(Andropogon gerardii)	<1%
Red Clover	(Trifolium pratense)	<1%
Alfalfa	(Medicago sativa)	<1%
Dandelion	(Taraxacum officinale)	<1%
Alsike Clover	(Trifolium hybridum)	<1%
Bare Areas/Thatch		<1%

Appendix 1. MDA Cottonwood River Water Quality Study – Vegetation Survey		
NVm Swale Portion Stem Density (1 square foot)		
71 Stems per square foot		
Smooth Brome Grass	(Bromus inermis)	80%
Kentucky Bluegrass	(Poa pratensis)	17%
Forbs (mostly Black Medic)		3%
NVw Upper Portion		
Common Name	Common Name	Common Name
Smooth Brome Grass	(Bromus inermis)	92%
Kentucky Bluegrass	(Poa pratensis)	10%
Alfalpha	(Medicago sativa)	2%
Snowberry	(symphoricarpos albus)	1%
Dicanthelium	(Dicanthelium sp.)	<1%
White Campion	(Silene latifolia)	<1%
Yellow Sweetclover	(Melilotus officinalis)	<1%
Yarrow	(Achillea millefolium)	<1%
Pasture Thistle	(Cirsium discolor)	<1%
Common Milkweed	(Asclepias syriaca)	<1%
Back Medic	(Medicago lupulina)	<1%
Hoary Vervain	(Verbena stricta)	<1%
Thimbleweed	(Anenome)	<1%
Yellow Coneflower	(Ratibida pinnata)	<1%
Big Bluestem	(Andropogon gerardii)	<1%
Prairie Rose	(Rosa arkansana)	<1%
Meadowrue	(Thalictrum dasycarpum)	<1%
Bare Areas and Thatch		<1%
NVw Upper Portion Stem Density (1 square foot)		
177 Stems per square foot		
Black Medic	(Medicago lupulina)	55%
Smooth Brome Grass	(Bromus inermis)	28%
Kentucky Bluegrass	(Poa pratensis)	7%
NVw Swale Portion		
Common Name	Common Name	Common Name
Smooth Brome Grass	(Bromus inermis)	98%
Kentucky Bluegrass	(Poa pratensis)	15%
Common Milkweed	(Asclepias syriaca)	4%
Alfalpha	(Medicago sativa)	2%
Lambs Quarters	(Chenopodium album)	<1%
Red Clover	(Trifolium pratense)	<1%
American Vetch	(Vicia Americana)	<1%
Prairie Sage	(Artemisia ludoviciana)	<1%
Bare Ground/Thatch		<1%
NVw Swale Portion Stem Density (1 square foot)		
144 Stems per square foot		
Kentucky Bluegrass	(Poa pratensis)	63%
Smooth Brome Grass	(Bromus inermis)	33%
Black Medic	(Medicago lupulina)	4%

Appendix 2. Monthly precipitation at the experimental site compared to the 30-year mean near Lamberton, MN and percent departure from 30-year average.

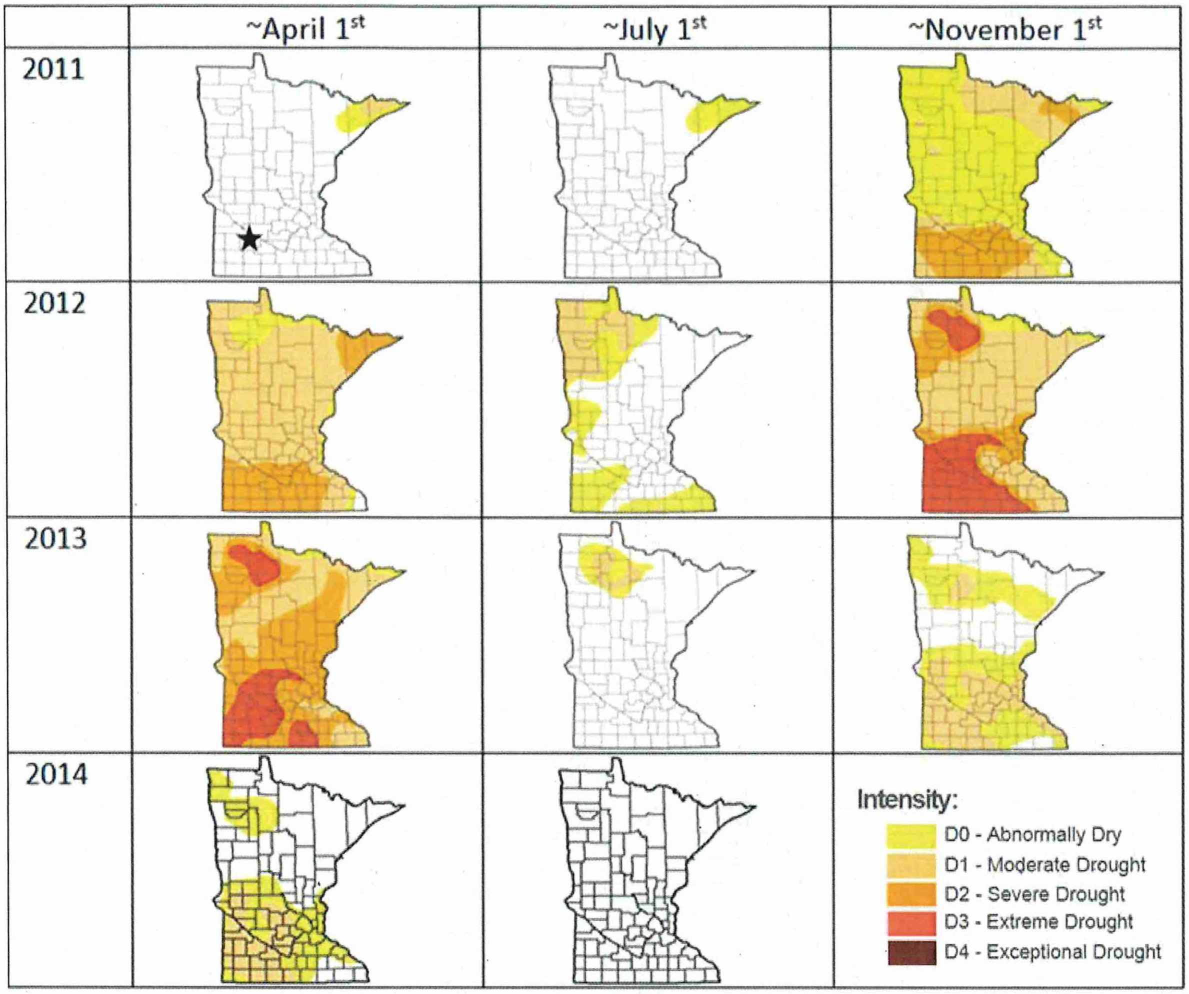
Month	30-year average	2011 Monthly Rainfall Total	2011 Percent departure from 30-year average	2012 Monthly Rainfall Total	2012 Percent departure from 30-year average	2013 Monthly Rainfall Total	2013 Percent departure from 30-year average	2014 Monthly Rainfall Total	2014 Percent departure from 30-year average
January	0.7	1.03*	47%	0.48*	-31%	0.27*	-61%	0.69*	-1%
February	0.6	1.58*	163%	1.73*	188%	0.62*	3%	0.51*	-15%
March	1.5	1.54	3%	1.43*	-5%	0.94*	-37%	1.00*	-33%
April	2.9	2.59	-11%	1.99	-31%	3.24*	12%	3.41*	18%
May	3.1	4.24	37%	8.9	187%	2.71	-13%	2.3	-26%
June	3.7	5.07	37%	1.58	-57%	6.19	67%	7.56	104
July	3.9	3.65	-6%	0.74	-81%	0.37	-91%	0.83	-79%
August	3.1	0.39	-87%	3.15	2%	1.24	-60%	2.00**	-35%
September	2.8	0.18	-94%	0.73	-74%	0.96	-66%		
October	2.0	0.39	-81%	0.75	-63%	2.31	16%		
November	1.4	0.01	-99%	0.58	-59%	0.46*	-67%		
December	0.7	0.5*	-29%	0.95*	36%	0.88*	26%		
Total	**26.4**	**21.17**	**-20%**	**23.01**	**-12%**	**20.18**	**-24%**	**18.80*****	**-31%*****

*Winter monthly precipitation value obtained from Lamberton, MN SWROC.

**Based on August 1-26, 2014

**Based on Jan. 1 through August 26, 2014

Appendix 3. USDA Drought Monitor for Minnesota, 2011-2014 ("U.S. Drought Monitor").



Appendix 4. Water sample chemistry results.

Field Bottle ID	Start Date	End Date	TSS (mg/L)	TS (mg/L)	TP (mg/L)	DMRP (mg/L)	TN (mg/L)	NO3-N (mg/L)	NH4-N (mg/L)	E. Coli (MPN/100mL)
NVM 11001	6/21/2011 12:13	6/21/2011 12:21	1300.0	na	0.9130	0.2200	4.3900	1.0800	0.0719	-
NVM 11002	6/21/2011 12:22	6/21/2011 12:41	860.0	na	0.6970	0.2370	3.2700	0.6670	0.0011	-
NVM 2/29/12 1	2/28/2012 15:58	2/28/2012 17:38	20	240	2.3790	1.815	25.242	6.953	0.2079	> 4839.2
NVM 2/29/12 2	2/28/2012 17:39	2/28/2012 17:59	20	180	1.4280	1.083	15.235	2.909	0.2808	> 4839.2
NVM 2/29/12 3	2/28/2012 18:00	2/28/2012 18:46	40	200	1.3250	1.035	13.604	2.623	0.1472	727.0
NVM 2/29/12 4	2/28/2012 18:47	2/28/2012 19:09	0	200	1.2370	0.886	13.722	2.683	0.1619	387.3
NVM 2/29/12 5	2/28/2012 19:10	2/28/2012 19:31	0	160	1.1570	0.784	12.387	2.253	0.1845	435.2
NVM 2/29/12 6	2/28/2012 19:32	2/29/2012 0:05	0	200	1.4140	0.758	12.528	2.225	0.1983	344.8
NVM 2/29/12 7	2/29/2012 0:06	2/29/2012 0:11	20	180	1.3500	1.068	12.393	2.146	0.2021	435.2
NVM 2/29/12 8	2/29/2012 0:12	2/29/2012 0:16	20	140	1.2240	0.825	12.067	2.049	0.1820	770.1
NVM 2/29/12 9	2/29/2012 0:17	2/29/2012 0:21	20	180	*1.0870*	0.762	11.506	1.972	*0.1685*	298.7
NVM 2/29/12 10	2/29/2012 0:22	2/29/2012 0:26	0	160	*1.0120*	0.714	11.13	1.914	*0.1777*	410.6
NVM 2/29/12 11	2/29/2012 0:27	2/29/2012 0:31	20	120	0.9729	0.644	10.918	1.919	0.1423	517.2
NVM 2/29/12 12	2/29/2012 0:32	2/29/2012 0:36	0	140	0.9365	0.535	11.359	1.945	0.1580	344.8
NVM 2/29/12 13	2/29/2012 0:37	2/29/2012 0:41	0	260	0.9370	0.54	11.063	1.94	0.1778	214.2
NVM 2/29/12 14	2/29/2012 0:42	2/29/2012 0:46	0	180	0.9296	0.587	11.156	1.81	0.1614	435.2
NVM 2/29/12 15	2/29/2012 0:47	2/29/2012 0:51	0	180	0.9181	0.529	11.406	1.849	0.1846	325.5
NVM 2/29/12 16	2/29/2012 0:52	2/29/2012 0:58	20	160	0.9336	0.544	11.388	1.895	0.2041	214.3
NVM 2/29/12 17	2/29/2012 0:59	2/29/2012 1:09	20	180	0.9805	0.632	12.038	1.998	0.1658	249.5
NVM 2/29/12 18	2/29/2012 1:10	2/29/2012 1:55	0	200	1.0780	0.701	13.001	2.117	0.1995	292.4

Appendix 4. Water sample chemistry results.

Field Bottle ID	Start Date	End Date	TSS (mg/L)	TS (mg/L)	TP (mg/L)	DMRP (mg/L)	TN (mg/L)	NO3-N (mg/L)	NH4-N (mg/L)	E. Coli (MPN/100mL)
NVE 2/29/12 1	2/28/2012 16:30	2/29/2012 0:22	120	500	7.7280	6.164	48.352	0.038	3.1830	410.6
NVE 2/29/12 2	2/29/2012 0:23	2/29/2012 0:58	0	60	1.4360	0.973	15.428	3.019	0.2558	517.2
NVE 3/8/12 1	3/6/2012 11:06	3/6/2012 13:05	0	100	0.9845	0.677	10.816	2.255	0.1661	209.8
NVE 3/8/12 2	3/6/2012 13:06	3/6/2012 13:47	0	80	0.8454	0.533	8.064	1.679	0.1602	298.7
NVE 3/8/12 3	3/6/2012 13:48	3/6/2012 14:22	0	60	0.8485	0.529	7.606	1.603	0.1825	456.9
NVE 3/8/12 4	3/6/2012 14:23	3/6/2012 15:02	0	120	0.9484	0.666	8.078	1.561	0.1452	135.5
NVE 3/8/12 5	3/6/2012 15:03	3/6/2012 16:03	0	60	1.1340	0.784	8.837	1.606	0.2081	648.8
NVE 3/8/12 6	3/6/2012 16:04	3/6/2012 21:05	0	100	1.5220	1.199	10.648	1.944	0.1826	343.6
NVE 3/8/12 7	3/6/2012 21:06	3/7/2012 2:14	0	180	1.6230	1.274	12.382	2.013	0.1263	1046.2
NVM 3/8/12 1	3/6/2012 11:23	3/6/2012 12:37	0	180	0.7607	0.441	10.913	2.134	0.2129	1046.2
NVM 3/8/12 2	3/6/2012 12:38	3/6/2012 12:58	0	140	0.6591	0.388	8.907	1.68	0.1517	435.2
NVM 3/8/12 3	3/6/2012 12:59	3/6/2012 13:13	0	140	0.6344	0.32	8.125	1.608	0.1837	488.4
NVM 3/8/12 4	3/6/2012 13:14	3/6/2012 13:28	0	140	0.6408	0.17	8.061	1.521	0.1847	461.1
NVM 3/8/12 5	3/6/2012 13:29	3/6/2012 13:39	0	120	0.6179	0.333	8.238	1.453	0.2021	228.2
NVM 3/8/12 6	3/6/2012 13:40	3/6/2012 13:49	20	100	0.6284	0.349	8.243	1.502	0.2702	204.6
NVM 3/8/12 7	3/6/2012 13:50	3/6/2012 13:59	20	160	0.5752	0.233	7.933	1.491	0.2523	204.6
NVM 3/8/12 8	3/6/2012 14:00	3/6/2012 14:09	20	120	0.3895	0.336	8.494	1.522	0.2106	178.9
NVM 3/8/12 9	3/6/2012 14:10	3/6/2012 14:19	0	80	0.6318	0.317	8.285	1.564	0.2319	201.4
NVM 3/8/12 10	3/6/2012 14:20	3/6/2012 14:29	20	120	0.6079	0.329	9.191	1.739	0.2221	129.6
NVM 3/8/12 11	3/6/2012 14:30	3/6/2012 14:39	0	100	0.5757	0.227	8.396	1.546	0.2481	166.4
NVM 3/8/12 12	3/6/2012 14:40	3/6/2012 14:49	20	180	0.5833	0.22	8.527	1.532	0.2249	124.6
NVM 3/8/12 13	3/6/2012 14:50	3/6/2012 14:59	0	140	0.5860	0.299	8.778	1.524	0.2307	84.2
NVM 3/8/12 14	3/6/2012 15:00	3/6/2012 15:09	0	160	0.6135	0.254	9.41	1.683	0.1866	123.6
NVM 3/8/12 15	3/6/2012 15:10	3/6/2012 15:23	20	140	0.6850	0.361	9.631	1.685	0.2164	115.3
NVM 3/8/12 16	3/6/2012 15:24	3/6/2012 15:38	0	140	0.4851	0.264	9.355	1.599	0.2081	131.4
NVM 3/8/12 17	3/6/2012 15:39	3/6/2012 16:02	0	180	0.6596	0.373	9.315	1.517	0.1498	107.1
NVM 3/8/12 18	3/6/2012 16:03	3/6/2012 16:55	0	180	0.7015	0.442	9.057	1.474	0.2313	235.9
NVM 3/8/12 19	3/6/2012 16:56	3/6/2012 20:57	0	140	0.7588	0.511	8.41	1.392	0.1762	228.2
NVM 3/8/12 20	3/6/2012 20:58	3/7/2012 3:21	0	180	0.9676	0.595	10.969	1.71	0.1552	178.5
NVW 3/8/12 1	3/6/2012 11:28	3/6/2012 14:01	20	100	0.9186	0.574	16.85	4.127	0.1548	39.9
NVW 3/8/12 2	3/6/2012 14:02	3/6/2012 17:16	20	100	0.4591	0.166	7.493	1.419	0.1263	20.3
NVM 5/7/12 1	5/5/2012 10:18	5/5/2012 11:07	3180	3400	2.3860	0.992	29.171	6.019	0.1498	-
NVM 5/7/12 2	5/5/2012 11:08	5/5/2012 11:15	1840	2100	1.9330	0.885	24.082	3.717	0.1885	-
NVM 5/7/12 3	5/5/2012 11:16	5/5/2012 23:03	1120	1320	1.9170	0.666	17.759	2.54	0.1891	-
NVM 5/7/12 4	5/5/2012 23:04	5/5/2012 23:08	900	1360	1.8050	0.606	17.075	2.66	0.1452	-
NVM 5/7/12 5	5/5/2012 23:09	5/5/2012 23:13	960	1120	1.3810	0.608	15.963	2.246	0.1339	-
NVM 5/7/12 6	5/5/2012 23:14	5/5/2012 23:21	820	980	1.2690	0.601	15.89	2.244	0.1300	-
NVM 5/7/12 7	5/5/2012 23:22	5/5/2012 23:27	1180	1380	1.8920	0.653	18.654	2.504	0.1887	-
NVM 5/7/12 8	5/5/2012 23:28	5/5/2012 23:32	1980	2680	2.2710	0.58	22.283	2.856	0.1647	-
NVM 5/7/12 9	5/5/2012 23:33	5/5/2012 23:37	2540	2860	1.8260	0.606	23.401	3.167	0.1570	-
NVM 5/7/12 10	5/5/2012 23:38	5/5/2012 23:42	2080	2380	2.0710	0.585	19.743	2.683	0.1210	-
NVM 5/7/12 11	5/5/2012 23:43	5/5/2012 23:47	1500	1900	1.9370	0.552	18.686	2.667	0.1279	-
NVM 5/7/12 12	5/5/2012 23:48	5/5/2012 23:52	1180	1480	1.8670	0.572	17.036	2.27	0.1890	-
NVM 5/7/12 13	5/5/2012 23:53	5/6/2012 0:03	620	1080	1.9090	0.131	20.57	3.411	0.1929	-
NVM 5/7/12 14	5/6/2012 0:04	5/6/2012 0:40	2380	2820	2.3780	0.408	21.718	3.02	0.1384	-
NVM 5/7/12 15	5/6/2012 0:41	5/6/2012 0:45	2700	3080	2.4520	0.628	22.682	3.031	0.1052	-
NVM 5/7/12 16	5/6/2012 0:46	5/6/2012 0:50	2100	2460	2.0000	0.598	20.9	2.69	0.1014	-
NVM 5/7/12 17	5/6/2012 0:51	5/6/2012 0:55	1540	1880	1.8750	0.598	19.212	2.491	0.1949	-
NVM 5/7/12 18	5/6/2012 0:56	5/6/2012 1:02	1160	1440	1.2600	0.05	29.905	3.419	0.7872	-
NVM 5/7/12 19	5/6/2012 1:03	5/6/2012 3:25	260	520	1.3880	0.667	11.02	1.886	0.1377	-
NVM 5/29/12 1	5/26/2012 6:41	5/26/2012 7:33	2040	4000	1.8420	0.087	17.475	1.026	0.1274	-
NVM 5/29/12 2	5/26/2012 7:34	5/26/2012 7:39	2380	3940	1.5330	0.079	13.779	0.93	0.2066	-
NVM 5/29/12 3	5/26/2012 7:40	5/27/2012 19:04	2400	3920	1.6500	0.072	14.615	9.036	0.2635	-
NVM 5/29/12 4	5/27/2012 19:05	5/28/2012 2:02	2140	4060	1.8820	0.425	16.953	2.159	0.2386	-
NVm-Field1	3/23/2013 10:45	3/23/2013 11:15	40	-	0.4400	0.354	1.75	1.46	0.0169	-
NVm-Field2	3/23/2013 11:15	3/23/2013 11:45	20	-	0.3990	0.316	2.1	1.48	0.129	-
NVm_Field3	3/23/2013 12:00	3/23/2013 14:30	0	-	0.7540	0.6	4.29	1.4	0.681	-
NVe1	6/21/2013 21:42	6/21/2013 21:47	10140	-	2.5700	0.16	16	0.286	1.61	> 2419.6
NVe2	6/21/2013 21:48	6/21/2013 21:52	4400	-	1.0600	0.0883	11	0.934	1.02	> 2419.6
NVe3	6/21/2013 21:53	6/21/2013 22:09	3640	-	1.2400	0.0966	12.3	1.29	1.05	> 2419.6
NVe4	6/21/2013 22:10	6/21/2013 22:16	4280	-	1.4400	0.0713	11	0.826	0.914	> 2419.6
NVe5	6/21/2013 22:17	6/21/2013 22:40	3520	-	1.1800	0.0694	8.36	1.49	0.656	> 2419.6
NVm-field1	6/21/2013 21:44	6/21/2013 21:52	2540	-	0.7950	0.337	8.94	1.92	0.114	172.3

Appendix 4. Water sample chemistry results.

Field Bottle ID	Start Date	End Date	TSS (mg/L)	TS (mg/L)	TP (mg/L)	DMRP (mg/L)	TN (mg/L)	NO3-N (mg/L)	NH4-N (mg/L)	E. Coli (MPN/100mL)
NVm-field2	6/21/2013 21:54	6/21/2013 22:06	1400	-	1.4600	0.326	6.17	1.45	0.0926	145.0
NVm-field3	6/21/2013 22:09	6/21/2013 22:18	1440	-	1.6500	0.321	5.47	1.06	0.059	146.7
NVm-field4	6/21/2013 22:21	6/21/2013 22:31	940	-	1.2800	0.349	4.68	1.11	0.0835	210.5
NVe1	6/22/2013 23:37	6/22/2013 23:47	6040	-	1.3200	0.0776	9.49	0.216	0.833	> 2419.6
NVe2	6/22/2013 23:48	6/22/2013 23:52	4640	-	0.8570	0.0695	8.04	0.454	0.526	> 2419.6
NVe3	6/22/2013 23:53	6/23/2013 0:16	3060	-	0.7490	0.0542	7.02	0.936	0.436	> 2419.6
NVe4	6/23/2013 0:17	6/23/2013 0:21	6620	-	1.4000	0.0678	8.67	0.235	0.564	> 2419.6
NVe5	6/23/2013 0:22	6/23/2013 0:48	3800	-	0.9510	0.0584	8.67	0.804	0.44	> 2419.6
NVe6	6/23/2013 0:49	6/23/2013 1:39	3800	-	0.8760	0.0422	8.45	1.48	0.357	1986.3
NVm-field1	6/22/2013 23:48	6/23/2013 0:12	1280	-	1.1600	0.312	4.29	0.893	0.0437	1732.9
NVm-field2	6/23/2013 0:13	6/23/2013 0:30	1420	-	1.4700	0.283	4.91	0.825	0.0357	2419.6
NVm-field3	6/23/2013 0:31	6/23/2013 1:00	760	-	1.1700	0.285	3.41	0.712	0.0521	980.4
NVm-field4	6/23/2013 1:01	6/23/2013 2:00	440	-	0.9280	0.275	2.89	0.734	0.0561	770.1
NVm1	6/23/2013 0:35	6/23/2013 1:14	380	-	4.3400	2.29	33.8	0.193	4.01	> 2419.6
NVE 3-11-14 1	3/11/2014 16:10	3/11/2014 16:10	180	-	0.428	0.037	13.3	3.91	0.203	< 1
NVE 3-14-14 1	3/13/2014 10:00	3/13/2014 14:18	100	-	1.07	0.058	8.1	0.756	0.206	< 1
NVE 3-14-14 2	3/13/2014 14:19	3/13/2014 17:01	120	-	0.891	0.011	8.1	0.861	0.184	< 1
NVM 3-11-14 1	3/10/2014 13:00	3/10/2014 14:28	140	-	3.34	0.884	17.7	4.83	0.408	< 1
NVM 3-11-14 2	3/10/2014 14:29	3/10/2014 14:33	80	-	1.06	0.275	6.3	0.574	0.275	< 1
NVM 3-11-14 3	3/10/2014 14:34	3/10/2014 14:38	40	-	0.941	0.257	5.5	0.523	0.252	< 1
NVM 3-11-14 4	3/10/2014 14:39	3/10/2014 14:43	20	-	0.979	0.289	5.1	0.482	0.249	< 1
NVM 3-11-14 5	3/10/2014 14:44	3/10/2014 14:59	60	-	1.07	0.319	5.0	0.477	0.256	< 1
NVM 3-11-14 6	3/10/2014 15:00	3/10/2014 15:32	0	-	1.02	0.360	5.4	0.636	0.261	< 1
NVM 3-11-14 7	3/10/2014 15:33	3/10/2014 16:18	60	-	1.36	0.458	6.6	0.978	0.324	< 1
NVM 3-11-14 8	3/10/2014 16:19	3/10/2014 17:14	120	-	1.84	0.628	8.3	1.13	0.372	< 1
NVM 3-11-14 9	3/10/2014 17:15	3/10/2014 18:31	100	-	2.26	0.738	10.4	1.22	0.465	< 1
NVM 3-11-14 10	3/10/2014 18:32	3/10/2014 19:57	60	-	0.887	0.233	8.0	1.21	0.266	< 1
NVM 3-11-14 11	3/10/2014 19:58	3/10/2014 22:23	380	-	1.22	0.307	13.6	2.46	0.398	< 1
NVM 3-11-14 12	3/10/2014 22:24	3/11/2014 5:15	300	-	1.07	0.298	11.2	2.27	0.33	< 1
NVM 3-12-14 1	3/11/2014 7:51	3/11/2014 11:31	80	-	1	0.277	8.5	1.59	0.295	< 1
NVM 3-12-14 2	3/11/2014 11:32	3/11/2014 14:32	40	-	0.992	0.277	6.2	0.986	0.254	< 1
NVM 3-12-14 3	3/11/2014 14:33	3/11/2014 16:39	60	-	0.973	0.296	4.8	0.658	0.216	< 1
NVM 3-12-14 4	3/11/2014 16:40	3/11/2014 19:19	80	-	0.951	0.296	4.6	0.65	0.212	< 1
NVM 3-12-14 5	3/11/2014 19:20	3/11/2014 19:37	40	-	0.87	0.293	4.7	0.643	0.229	< 1
NVM 3-14-14 1	3/13/2014 10:57	3/13/2014 12:43	80	-	0.454	0.055	3.5	0.311	0.155	< 1
NVM 3-14-14 2	3/13/2014 12:44	3/13/2014 13:32	80	-	0.451	0.061	3.1	0.244	0.149	< 1
NVM 3-14-14 3	3/13/2014 13:33	3/13/2014 14:13	40	-	0.426	0.078	2.8	0.225	0.159	< 1
NVM 3-14-14 4	3/13/2014 14:14	3/13/2014 14:53	40	-	0.553	0.114	3.1	0.228	0.16	< 1
NVM 3-14-14 5	3/13/2014 14:54	3/13/2014 15:33	20	-	0.641	0.144	3.0	0.245	0.17	< 1
NVM 3-14-14 6	3/13/2014 15:34	3/13/2014 16:16	0	-	0.731	0.169	3.2	0.267	0.176	< 1
NVM 3-14-14 7	3/13/2014 16:17	3/13/2014 17:10	40	-	0.845	0.156	3.2	0.283	0.181	< 1
NVM 3-14-14 8	3/13/2014 17:11	3/13/2014 18:34	80	-	0.99	0.227	3.2	0.291	0.176	< 1
NVM 3-14-14 9	3/13/2014 18:35	3/13/2014 21:08	80	-	1	0.240	3.1	0.273	0.144	< 1
NVM 3-31-14 1	3/14/2014 11:36	3/14/2014 19:02	40	-	0.533	0.110	2.2	0.183	0.113	< 1
NVM 3-31-14 2	3/17/2014 12:55	3/17/2014 17:24	60	-	0.937	0.212	4.0	0.148	0.216	< 1
NVM - Field 3-11-14 1	3/10/2014 14:40	3/10/2014 14:41	60	-	2.28	0.721	12.7	2.13	0.511	< 1
NVM - Field 3-11-14 2	3/10/2014 14:42	3/10/2014 14:43	80	-	2.16	0.697	11.7	2.04	0.511	< 1
NVM - Field 3-11-14 3	3/10/2014 14:44	3/10/2014 14:46	100	-	2.14	0.697	11.2	1.99	0.491	< 1
NVM - Field 3-11-14 4	3/10/2014 14:47	3/10/2014 14:49	80	-	2.19	0.698	11.3	1.9	0.484	< 1
NVM - Field 3-11-14 5	3/10/2014 14:50	3/10/2014 14:52	100	-	1.78	0.702	12.6	2.2	0.493	< 1
NVM - Field 3-11-14 6	3/10/2014 14:53	3/10/2014 14:55	60	-	2.45	0.760	12.3	2.13	0.5	< 1
NVM - Field 3-11-14 7	3/10/2014 14:56	3/10/2014 14:58	120	-	2.22	0.686	12.8	2.4	0.511	< 1
NVM - Field 3-11-14 8	3/10/2014 14:59	3/10/2014 15:01	40	-	2.47	0.798	13.2	2.52	0.516	< 1
NVM - Field 3-11-14 9	3/10/2014 15:02	3/10/2014 15:04	40	-	2.26	0.707	13.4	2.54	0.505	< 1
NVM - Field 3-11-14 10	3/10/2014 15:05	3/10/2014 15:07	60	-	2.44	0.781	13.4	2.56	0.486	< 1
NVM - Field 3-11-14 11	3/10/2014 15:08	3/10/2014 15:10	60	-	2.11	0.708	12.8	2.55	0.508	< 1
NVM - Field 3-11-14 12	3/10/2014 15:11	3/10/2014 15:13	80	-	2.41	0.788	13.1	2.51	0.5	< 1
NVM - Field 3-11-14 13	3/10/2014 15:14	3/10/2014 15:18	100	-	2.59	0.836	13.9	2.64	0.505	< 1
NVM - Field 3-11-14 14	3/10/2014 15:19	3/10/2014 15:23	80	-	2.22	0.718	13.8	2.69	0.509	< 1
NVM - Field 3-11-14 15	3/10/2014 15:24	3/10/2014 15:28	40	-	2.2	0.732	14.1	2.74	0.511	< 1
NVM - Field 3-11-14 16	3/10/2014 15:29	3/10/2014 15:33	60	-	2.29	0.742	14.4	2.85	0.526	< 1
NVM - Field 3-11-14 17	3/10/2014 15:34	3/10/2014 15:38	40	-	1.19	0.750	13.8	2.85	0.532	< 1
NVM - Field 3-11-14 18	3/10/2014 15:39	3/10/2014 15:43	20	-	2.46	0.787	14.5	2.89	0.521	< 1

Appendix 4. Water sample chemistry results.											
Field Bottle ID	**Start Date**	**End Date**	TSS (mg/L)	TS (mg/L)	TP (mg/L)	DMRP (mg/L)	TN (mg/L)	NO3-N (mg/L)	NH4-N (mg/L)	E. Coli (MPN/100mL)
NVM - Field 3-11-14 19	3/10/2014 15:44	3/10/2014 15:50	120	-	2.46	0.849	14.2	2.75	0.546	< 1
NVM - Field 3-11-14 20	3/10/2014 15:51	3/10/2014 16:16	80	-	2.46	0.862	14.4	2.94	0.546	< 1
NVM - Field 3-12-14 1	3/11/2014 13:15	3/11/2014 19:28	60	-	1.83	0.545	18.1	4.58	0.5	< 1
NVM - Field 3-14-14 1	3/13/2014 9:39	3/13/2014 13:52	180	-	2.02	0.411	10.7	1.1	0.381	< 1
NVM - Field 3-14-14 2	3/13/2014 13:53	3/13/2014 18:04	180	-	3.52	1.000	13.6	3.58	0.816	< 1
NVW 3-11-14 1	3/11/2014 8:05	3/11/2014 19:40	40	-	0.588	0.115	4.2	0.423	0.172	< 1
NVW 3-14-14 1	3/13/2014 11:55	3/13/2014 14:20	20	-	0.654	0.093	4.2	0.242	0.256	< 1
NVW 3-14-14 2	3/13/2014 14:21	3/13/2014 16:04	20	-	0.722	0.132	3.7	0.247	0.181	< 1
NVW 3-14-14 3	3/13/2014 16:05	3/13/2014 19:15	40	-	0.651	0.121	3.5	0.32	0.149	< 1
NVW 3-31-14 1	3/29/2014 13:28	3/29/2014 16:54	120	-	0.817	0.182	5.2	0.61	0.119	< 1
NVM - Field 6-6-14 1	6/5/2014 17:20	6/5/2014 17:50	1580	-	0.623	0.305	8.2	0.988	0.084	50.4
NVM - Field 6-6-14 2	6/5/2014 17:51	6/5/2014 18:08	-	-	-	-	-	-	-	26.2
NVM - Field 6-14-14 1	6/14/2014 4:34	6/14/2014 5:40	300	-	0.773	0.306	2.8	1.43	0.069	30.5

Appendix 5. Water sample field chemistry results.						
Field Bottle ID	**Start Date**	**End Date**	**pH**	**DO(%)**	**Cond(uS)**	**Temp(C)**
NVM 11001	6/21/2011 12:13	6/21/2011 12:21	-	-	-	-
NVM 11002	6/21/2011 12:22	6/21/2011 12:41	-	-	-	-
NVM 2/29/12 1	2/28/2012 15:58	2/28/2012 17:38	8.4	-	435	-
NVM 2/29/12 2	2/28/2012 17:39	2/28/2012 17:59	7.96	-	186	-
NVM 2/29/12 3	2/28/2012 18:00	2/28/2012 18:46	7.7	-	318	-
NVM 2/29/12 4	2/28/2012 18:47	2/28/2012 19:09	7.76	-	222	-
NVM 2/29/12 5	2/28/2012 19:10	2/28/2012 19:31	7.75	-	217	-
NVM 2/29/12 6	2/28/2012 19:32	2/29/2012 0:05	7.7	-	204	-
NVM 2/29/12 7	2/29/2012 0:06	2/29/2012 0:11	7.84	-	206	-
NVM 2/29/12 8	2/29/2012 0:12	2/29/2012 0:16	7.87	-	183.6	-
NVM 2/29/12 9	2/29/2012 0:17	2/29/2012 0:21	7.6	-	183.6	-
NVM 2/29/12 10	2/29/2012 0:22	2/29/2012 0:26	7.7	-	180.9	-
NVM 2/29/12 11	2/29/2012 0:27	2/29/2012 0:31	7.6	-	173.9	-
NVM 2/29/12 12	2/29/2012 0:32	2/29/2012 0:36	8.04	-	177.3	-
NVM 2/29/12 13	2/29/2012 0:37	2/29/2012 0:41	7.83	-	155.5	-
NVM 2/29/12 14	2/29/2012 0:42	2/29/2012 0:46	7.66	-	176.4	-
NVM 2/29/12 15	2/29/2012 0:47	2/29/2012 0:51	7.92	-	180.5	-
NVM 2/29/12 16	2/29/2012 0:52	2/29/2012 0:58	7.8	-	179.3	-
NVM 2/29/12 17	2/29/2012 0:59	2/29/2012 1:09	7.67	-	188.1	-
NVM 2/29/12 18	2/29/2012 1:10	2/29/2012 1:55	7.75	-	192.8	-
NVE 2/29/12 1	2/28/2012 16:30	2/29/2012 0:22	7.62	-	193.9	-
NVE 2/29/12 2	2/29/2012 0:23	2/29/2012 0:58	7.78	-	208	-
NVE 3/8/12 1	3/6/2012 11:06	3/6/2012 13:05	7.1	-	146.6	14
NVE 3/8/12 2	3/6/2012 13:06	3/6/2012 13:47	7.17	-	118.9	15.1
NVE 3/8/12 3	3/6/2012 13:48	3/6/2012 14:22	7.14	-	119.7	15
NVE 3/8/12 4	3/6/2012 14:23	3/6/2012 15:02	7.16	-	130.9	15
NVE 3/8/12 5	3/6/2012 15:03	3/6/2012 16:03	7.2	-	95.6	15.3
NVE 3/8/12 6	3/6/2012 16:04	3/6/2012 21:05	7.25	-	133.8	15.9
NVE 3/8/12 7	3/6/2012 21:06	3/7/2012 2:14	7.5	-	211	14.7
NVM 3/8/12 1	3/6/2012 11:23	3/6/2012 12:37	7.04	-	241	7.3
NVM 3/8/12 2	3/6/2012 12:38	3/6/2012 12:58	7.07	-	131.8	5.5
NVM 3/8/12 3	3/6/2012 12:59	3/6/2012 13:13	6.96	-	124.8	6.3
NVM 3/8/12 4	3/6/2012 13:14	3/6/2012 13:28	6.94	-	121.3	7.7
NVM 3/8/12 5	3/6/2012 13:29	3/6/2012 13:39	6.98	-	130.5	8
NVM 3/8/12 6	3/6/2012 13:40	3/6/2012 13:49	7	-	130	7.9
NVM 3/8/12 7	3/6/2012 13:50	3/6/2012 13:59	7.05	-	126.1	8.5
NVM 3/8/12 8	3/6/2012 14:00	3/6/2012 14:09	7.12	-	74.5	8.7
NVM 3/8/12 9	3/6/2012 14:10	3/6/2012 14:19	7023	-	99.8	8.7
NVM 3/8/12 10	3/6/2012 14:20	3/6/2012 14:29	7.13	-	127.8	8.9
NVM 3/8/12 11	3/6/2012 14:30	3/6/2012 14:39	7.13	-	128	8.5
NVM 3/8/12 12	3/6/2012 14:40	3/6/2012 14:49	7.25	-	127.5	9
NVM 3/8/12 13	3/6/2012 14:50	3/6/2012 14:59	7.29	-	131.2	8.5
NVM 3/8/12 14	3/6/2012 15:00	3/6/2012 15:09	7.31	-	148.9	8.8
NVM 3/8/12 15	3/6/2012 15:10	3/6/2012 15:23	7.2	-	153.1	9
NVM 3/8/12 16	3/6/2012 15:24	3/6/2012 15:38	7.34	-	87.3	8.3

Appendix 5. Water sample field chemistry results.

Field Bottle ID	Start Date	End Date	pH	DO(%)	Cond(uS)	Temp(C)
NVM 3/8/12 17	3/6/2012 15:39	3/6/2012 16:02	7.17	-	154.5	9
NVM 3/8/12 18	3/6/2012 16:03	3/6/2012 16:55	7.26	-	156	9.9
NVM 3/8/12 19	3/6/2012 16:56	3/6/2012 20:57	7.41	-	157.4	10.1
NVM 3/8/12 20	3/6/2012 20:58	3/7/2012 3:21	7.41	-	104.3	11.6
NVW 3/8/12 1	3/6/2012 11:28	3/6/2012 14:01	7.35	-	126.7	12.9
NVW 3/8/12 2	3/6/2012 14:02	3/6/2012 17:16	7.13	-	131.6	13.3
NVM 5/7/12 1	5/5/2012 10:18	5/5/2012 11:07	-	-	-	-
NVM 5/7/12 2	5/5/2012 11:08	5/5/2012 11:15	-	-	-	-
NVM 5/7/12 3	5/5/2012 11:16	5/5/2012 23:03	-	-	-	-
NVM 5/7/12 4	5/5/2012 23:04	5/5/2012 23:08	-	-	-	-
NVM 5/7/12 5	5/5/2012 23:09	5/5/2012 23:13	-	-	-	-
NVM 5/7/12 6	5/5/2012 23:14	5/5/2012 23:21	-	-	-	-
NVM 5/7/12 7	5/5/2012 23:22	5/5/2012 23:27	-	-	-	-
NVM 5/7/12 8	5/5/2012 23:28	5/5/2012 23:32	-	-	-	-
NVM 5/7/12 9	5/5/2012 23:33	5/5/2012 23:37	-	-	-	-
NVM 5/7/12 10	5/5/2012 23:38	5/5/2012 23:42	-	-	-	-
NVM 5/7/12 11	5/5/2012 23:43	5/5/2012 23:47	-	-	-	-
NVM 5/7/12 12	5/5/2012 23:48	5/5/2012 23:52	-	-	-	-
NVM 5/7/12 13	5/5/2012 23:53	5/6/2012 0:03	-	-	-	-
NVM 5/7/12 14	5/6/2012 0:04	5/6/2012 0:40	-	-	-	-
NVM 5/7/12 15	5/6/2012 0:41	5/6/2012 0:45	-	-	-	-
NVM 5/7/12 16	5/6/2012 0:46	5/6/2012 0:50	-	-	-	-
NVM 5/7/12 17	5/6/2012 0:51	5/6/2012 0:55	-	-	-	-
NVM 5/7/12 18	5/6/2012 0:56	5/6/2012 1:02	-	-	-	-
NVM 5/7/12 19	5/6/2012 1:03	5/6/2012 3:25	-	-	-	-
NVM 5/29/12 1	5/26/2012 6:41	5/26/2012 7:33	-	-	-	-
NVM 5/29/12 2	5/26/2012 7:34	5/26/2012 7:39	-	-	-	-
NVM 5/29/12 3	5/26/2012 7:40	5/27/2012 19:04	-	-	-	-
NVM 5/29/12 4	5/27/2012 19:05	5/28/2012 2:02	-	-	-	-
NVm-Field1	3/23/2013 10:45	3/23/2013 11:15	7.67	-	47.2	4.7
NVm-Field2	3/23/2013 11:15	3/23/2013 11:45	7.5	-	43.9	4.7
NVm_Field3	3/23/2013 12:00	3/23/2013 14:30	7.16	-	56.8	4.7
NVe1	6/21/2013 21:42	6/21/2013 21:47	7.8	-	115.5	-
NVe2	6/21/2013 21:48	6/21/2013 21:52	8.33	-	176.9	-
NVe3	6/21/2013 21:53	6/21/2013 22:09	8.37	-	102	-
NVe4	6/21/2013 22:10	6/21/2013 22:16	8.16	-	97.8	-
NVe5	6/21/2013 22:17	6/21/2013 22:40	8.41	-	154.7	-
NVm-field1	6/21/2013 21:44	6/21/2013 21:52	6.16	-	241	-
NVm-field2	6/21/2013 21:54	6/21/2013 22:06	6.11	-	43.1	-
NVm-field3	6/21/2013 22:09	6/21/2013 22:18	5.25	-	76.6	-
NVm-field4	6/21/2013 22:21	6/21/2013 22:31	5.98	-	110.5	-
NVe1	6/22/2013 23:37	6/22/2013 23:47	7.84	-	147.8	-
NVe2	6/22/2013 23:48	6/22/2013 23:52	7.97	-	100.1	-
NVe3	6/22/2013 23:53	6/23/2013 0:16	8.17	-	103.9	-
NVe4	6/23/2013 0:17	6/23/2013 0:21	7.81	-	103.5	-
NVe5	6/23/2013 0:22	6/23/2013 0:48	8.04	-	98.3	-
NVe6	6/23/2013 0:49	6/23/2013 1:39	7.97	-	106.2	-
NVm-field1	6/22/2013 23:48	6/23/2013 0:12	6.06	-	81.6	-
NVm-field2	6/23/2013 0:13	6/23/2013 0:30	6	-	56.9	-
NVm-field3	6/23/2013 0:31	6/23/2013 1:00	5.97	-	61.6	-
NVm-field4	6/23/2013 1:01	6/23/2013 2:00	6.16	-	45.8	-
NVm1	6/23/2013 0:35	6/23/2013 1:14	7.36	-	278	-
NVE 3-11-14 1	3/11/2014 16:10	3/11/2014 16:10	7.5	-	194.3	-
NVE 3-14-14 1	3/13/2014 10:00	3/13/2014 14:18	6.7	-	80.9	11
NVE 3-14-14 2	3/13/2014 14:19	3/13/2014 17:01	6.7	-	92.6	10.8
NVM 3-11-14 1	3/10/2014 13:00	3/10/2014 14:28	7.7	-	65.9	-
NVM 3-11-14 2	3/10/2014 14:29	3/10/2014 14:33	7.6	-	61.2	-
NVM 3-11-14 3	3/10/2014 14:34	3/10/2014 14:38	7.6	-	55.9	-
NVM 3-11-14 4	3/10/2014 14:39	3/10/2014 14:43	7.7	-	52.5	-
NVM 3-11-14 5	3/10/2014 14:44	3/10/2014 14:59	7.7	-	51.8	-
NVM 3-11-14 6	3/10/2014 15:00	3/10/2014 15:32	7.7	-	54.1	-
NVM 3-11-14 7	3/10/2014 15:33	3/10/2014 16:18	7.7	-	65.9	-
NVM 3-11-14 8	3/10/2014 16:19	3/10/2014 17:14	7.7	-	74.7	-
NVM 3-11-14 9	3/10/2014 17:15	3/10/2014 18:31	7.7	-	83.6	-

Appendix 5. Water sample field chemistry results.

Field Bottle ID	Start Date	End Date	pH	DO(%)	Cond(uS)	Temp(C)
NVM 3-11-14 10	3/10/2014 18:32	3/10/2014 19:57	7.7	-	71.4	-
NVM 3-11-14 11	3/10/2014 19:58	3/10/2014 22:23	7.2	-	134.5	-
NVM 3-11-14 12	3/10/2014 22:24	3/11/2014 5:15	7.6	-	146.2	-
NVM 3-12-14 1	3/11/2014 7:51	3/11/2014 11:31	7.3	-	100.6	-
NVM 3-12-14 2	3/11/2014 11:32	3/11/2014 14:32	7.1	-	72.4	-
NVM 3-12-14 3	3/11/2014 14:33	3/11/2014 16:39	7.5	-	60.1	-
NVM 3-12-14 4	3/11/2014 16:40	3/11/2014 19:19	7.3	-	54.8	-
NVM 3-12-14 5	3/11/2014 19:20	3/11/2014 19:37	7.4	-	62.9	-
NVM 3-14-14 1	3/13/2014 10:57	3/13/2014 12:43	6.8	-	31.9	11.3
NVM 3-14-14 2	3/13/2014 12:44	3/13/2014 13:32	6.8	-	27.4	10.2
NVM 3-14-14 3	3/13/2014 13:33	3/13/2014 14:13	6.8	-	25.6	9.9
NVM 3-14-14 4	3/13/2014 14:14	3/13/2014 14:53	6.8	-	26.4	9.6
NVM 3-14-14 5	3/13/2014 14:54	3/13/2014 15:33	6.9	-	26.6	9.6
NVM 3-14-14 6	3/13/2014 15:34	3/13/2014 16:16	6.9	-	28.2	9.7
NVM 3-14-14 7	3/13/2014 16:17	3/13/2014 17:10	6.9	-	31.4	10.2
NVM 3-14-14 8	3/13/2014 17:11	3/13/2014 18:34	6.9	-	34.8	10.9
NVM 3-14-14 9	3/13/2014 18:35	3/13/2014 21:08	6.9	-	36.3	11.7
NVM 3-31-14 1	3/14/2014 11:36	3/14/2014 19:02	7.9	-	30.7	16.2
NVM 3-31-14 2	3/17/2014 12:55	3/17/2014 17:24	7.5	-	32.7	16.8
NVM - Field 3-11-14 1	3/10/2014 14:40	3/10/2014 14:41	6.1	-	105.8	-
NVM - Field 3-11-14 2	3/10/2014 14:42	3/10/2014 14:43	6.1	-	103.2	-
NVM - Field 3-11-14 3	3/10/2014 14:44	3/10/2014 14:46	6.2	-	95.7	-
NVM - Field 3-11-14 4	3/10/2014 14:47	3/10/2014 14:49	6.2	-	94.4	-
NVM - Field 3-11-14 5	3/10/2014 14:50	3/10/2014 14:52	6.3	-	98.9	-
NVM - Field 3-11-14 6	3/10/2014 14:53	3/10/2014 14:55	6.3	-	97.6	-
NVM - Field 3-11-14 7	3/10/2014 14:56	3/10/2014 14:58	6.3	-	105.1	-
NVM - Field 3-11-14 8	3/10/2014 14:59	3/10/2014 15:01	6.3	-	105.9	-
NVM - Field 3-11-14 9	3/10/2014 15:02	3/10/2014 15:04	6.4	-	107.3	-
NVM - Field 3-11-14 10	3/10/2014 15:05	3/10/2014 15:07	6.4	-	106.7	-
NVM - Field 3-11-14 11	3/10/2014 15:08	3/10/2014 15:10	6.4	-	108	-
NVM - Field 3-11-14 12	3/10/2014 15:11	3/10/2014 15:13	6.4	-	108.1	-
NVM - Field 3-11-14 13	3/10/2014 15:14	3/10/2014 15:18	6.5	-	110.9	-
NVM - Field 3-11-14 14	3/10/2014 15:19	3/10/2014 15:23	6.5	-	112.2	-
NVM - Field 3-11-14 15	3/10/2014 15:24	3/10/2014 15:28	6.5	-	113.6	-
NVM - Field 3-11-14 16	3/10/2014 15:29	3/10/2014 15:33	6.5	-	115.8	-
NVM - Field 3-11-14 17	3/10/2014 15:34	3/10/2014 15:38	6.5	-	115.4	-
NVM - Field 3-11-14 18	3/10/2014 15:39	3/10/2014 15:43	6.5	-	115.9	-
NVM - Field 3-11-14 19	3/10/2014 15:44	3/10/2014 15:50	6.6	-	118.8	-
NVM - Field 3-11-14 20	3/10/2014 15:51	3/10/2014 16:16	6.6	-	121.7	-
NVM - Field 3-12-14 1	3/11/2014 13:15	3/11/2014 19:28	6.7	-	143.3	-
NVM - Field 3-14-14 1	3/13/2014 9:39	3/13/2014 13:52	6.7	-	105.9	11.6
NVM - Field 3-14-14 2	3/13/2014 13:53	3/13/2014 18:04	6.7	-	115.2	12.1
NVW 3-11-14 1	3/11/2014 8:05	3/11/2014 19:40	8.0	-	72.7	-
NVW 3-14-14 1	3/13/2014 11:55	3/13/2014 14:20	6.8	-	34.1	13.2
NVW 3-14-14 2	3/13/2014 14:21	3/13/2014 16:04	6.8	-	38.5	12.3
NVW 3-14-14 3	3/13/2014 16:05	3/13/2014 19:15	6.8	-	40.9	12.5
NVW 3-31-14 1	3/29/2014 13:28	3/29/2014 16:54	7.3	-	58.1	17.2
NVM - Field 6-6-14 1	6/5/2014 17:20	6/5/2014 17:50	5.62	-	241	-
NVM - Field 6-6-14 2	6/5/2014 17:51	6/5/2014 18:08	5.62	-	224	-
NVM - Field 6-14-14 1	6/14/2014 4:34	6/14/2014 5:40	5.6	-	658	-

Appendix 6. Event Summary by Site.

Paired Watershed Design

	NVw					NVe				
Event Date	Peak Flow (cfs)	Duration (min)	Total Flow (ft^3)	Total Run-off (in/ac)	Sample Pulses	Peak Flow (cfs)	Duration (min)	Total Flow (ft^3)	Total Run-off (in/ac)	Sample Pulses
Calibration (2011-May 2013)	NVw and NVe both managed as Perennial Vegetation									
2/28/2012	0.003	204	8.69	<0.01	0	0.008	176	18.9	0.01	1
2/29/2012a	0.031	90	42.06	0.01	2	0.057	65	107.2	0.03	5
3/6/2012	0.026	349	191.1	0.07	9	0.057	908	687.6	0.19	33
Treatment (June 2013-July 2014)	Control Perennial Vegetation Site (same as 2011-2012)					Treatment Site: Corn planted in 2013 (Perennial Vegetation 2011-2012)				
6/21/2013	0	0	0	0	0	1.967	61	1471.5	0.41	24
6/22/2013	0	0	0	0	0	0.808	45	539.22	0.15	15
6/23/2013a	0	0	0	0	0	0.988	25	450.24	0.13	10
6/23/2013b	0	0	0	0	0	0.351	41	149.22	0.04	4
3/11/2014	0.016	696	111.24	0.04	3	0	0	0	0	0
3/13/2014	0.046	440	278.82	0.10	14	0.051	418	290.16	0.08	9
3/29/2014	0.01	206	15.48	0.01	2	0	0	0	0	0
Maximum	0.031					1.967				
Totals		1545	368.57	0.23	16		1739	3714.04	1.04	101

Above and Below Design

	NVm (Below)					Nvm-Field (Above)				
Event Date	Peak Flow (cfs)	Duration (min)	Total Flow (ft^3)	Total Run-off (in/ac)	Sample Pulses	Peak Flow (cfs)	Duration (min)	Total Flow (ft^3)	Total Run-off (in/ac)	Sample Pulses
6/21/2011	0.284	45	176.1	0.03	6	NA	NA	NA	NA	NA
2/28/2012	0.111	251	578.94	0.09	26	NA	NA	NA	NA	NA
2/29/2012a	0.674	123	1916.04	0.31	62	NA	NA	NA	NA	NA
2/29/2012b	0.005	236	51	0.01	1	NA	NA	NA	NA	NA
3/1/2012	0.013	170	34.26	0.01	2	NA	NA	NA	NA	NA
3/6/2012	0.284	943	2600	0.42	100	NA	NA	NA	NA	NA
4/21/2012	0.005	157	24.48	<0.01	1	NA	NA	NA	NA	NA
4/27/2012	0.005	96	14.64	<0.01	1	NA	NA	NA	NA	NA
5/5/2012a	0.487	87	338.04	0.05	12	NA	NA	NA	NA	NA
5/5/2012b	1.154	310	2992	0.48	86	NA	NA	NA	NA	NA
5/26/2012	0.426	78	339.42	0.06	14	NA	NA	NA	NA	NA
5/27/2012	0.164	449	143.1	0.02	6	NA	NA	NA	NA	NA
Upper Site Installed	"Below" Site (same as 2011-2012)					"Above" Site (Installed October 2012)				
3/23/2013	0	0	0	0	0	0.372	195	1051.2	0.43	18
6/21/2013	0.07	83	39.1	0.01	2	0	0	0	0	0
6/22/2013	0.14	59	131.34	0.02	4	0.35	145	1073.2	0.44	19
3/10/2014	0.121	975	1120.92	0.18	60	0.68	96	1261.63	0.52	100
3/11/2014	0.031	706	620.94	0.10	23	0.1	373	349.62	0.14	6
3/13/2014	0.071	611	1316.76	0.21	43	0.019	505	475.02	0.20	10
3/14/2014	0.016	445	165.66	0.03	5	0	0	0	0	0
3/17/2014	0.008	269	79.2	0.01	2	0	0	0	0	0
6/5/2014	0	0	0	0	0	0.421	48	388.92	0.16	6
6.14.2014	0	0	0	0	0	0.109	66	219.78	0.09	4
Maximum	1.154					0.68				
Totals		6093	12681.94	0.56	454		1428	4233.687	1.98	163

Appendix 7. Annual Loads, Yield and Flow Weighted Mean Concentration (FWMC) by site.

		TSS			TS			TP			DMRP			TN			NO3-N			NH4-N		
	Run-off (In)	Load (lb)	Yield (lb/ acre)	FWMC (mg/L)	Load (lb)	Yield (lb/ acre)	FWMC (mg/L)	Load (lb)	Yield (lb/ acre)	FWMC (mg/L)	Load (lb)	Yield (lb/ acre)	FWMC (mg/L)	Load (lb)	Yield (lb/ acre)	FWMC (mg/L)	Load (lb)	Yield (lb/ acre)	FWMC (mg/L)	Load (lb)	Yield (lb/ acre)	FWMC (mg/L)
NVw	2011 and 2012: Control Period (Perennial Vegetation); 2013 and 2014: Treatment Period (Corn on Corn, no-till)																					
2011	0	0	0	0	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0.08	0.30	0.38	20.00	1.51	1.91	100.0	0.01	0.02	0.75	0.01	0.01	0.43	0.21	0.27	13.46	0.05	0.06	3.14	0.00	0.00	0.14
2013	0	0	0	0	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0.14	0.82	1.04	32.37	NA	NA	NA	0.02	0.02	0.66	0.00	0.00	0.12	0.10	0.13	4.02	0.01	0.01	0.32	0.00	0.01	0.19
NVe	2011, 2012, 2013, and 2014: Control Period (Perennial Vegetation)																					
2011	0	0	0	0	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0.23	0.64	0.65	12.53	6.83	6.97	134.4	0.09	0.09	1.80	0.07	0.07	1.34	0.69	0.71	13.66	0.09	0.09	1.68	0.02	0.03	0.49
2013	0.73	933.8	952.8	5731	NA	NA	NA	0.24	0.24	1.45	0.01	0.02	0.09	1.78	1.81	10.91	0.11	0.12	0.70	0.15	0.15	0.91
2014	0.08	1.94	1.97	106.9	NA	NA	NA	0.02	0.02	1.01	0.00	0.00	0.04	0.15	0.15	8.08	0.01	0.01	0.79	0.00	0.00	0.20
NVm	Bottom of Perennial Vegetation, includes both native vegetation and conventional row-crop in watershed																					
2011	-0.03	12.66	7.44	1151.	0.00	0.00	0.00	0.01	0.01	0.84	0.00	0.00	0.23	0.04	0.03	4.01	0.01	0.01	0.94	0.00	0.00	0.00
2012	1.46	442.0	260.0	785.6	612.2	360.1	1088	0.74	0.43	1.31	0.30	0.17	0.53	8.33	4.90	14.80	1.35	0.79	2.39	0.11	0.06	0.19
2013	0.03	4.04	2.38	380.0	NA	NA	0.00	0.05	0.03	4.34	0.02	0.01	2.29	0.36	0.21	33.80	0.00	0.00	0.19	0.04	0.03	4.01
2014	0.55	17.53	10.31	83.48	NA	NA	NA	0.21	0.12	1.00	0.06	0.03	0.27	1.23	0.72	5.86	0.18	0.10	0.85	0.05	0.03	0.24
NVm-field	Installed October 2012: watershed entirely conventional row-crop																					
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013	0.87	72.27	107.8	544.9	NA	NA	NA	0.12	0.17	0.88	0.05	0.07	0.36	0.45	0.67	3.36	0.15	0.22	1.12	0.02	0.03	0.15
2014	1.11	47.82	239.0	706.7	NA	NA	NA	0.11	0.53	1.56	0.03	0.16	0.47	0.59	2.97	8.77	0.11	0.55	1.62	0.02	0.10	0.30

Appendix 8. Soil Sampling Laboratory Results.

Plot Location	Depth (in)	LOI-OM (%)	pH (water)	TOC (%)	Total N (%)	Total P (ppm)	CEC NH4 meq/100g	CEC Summation meq/100g	Ca (ppm)	K (ppm)	Mg (ppm)	Na (ppm)	Al (ppm)
1	0 – 4	5.6	7.2	3.45	0.3095	966.38	21.82	30.01	5121.90	378.91	412.11	18.99	0.90
1	4 – 8	4.3	7.4	2.86	0.2299	882.06	18.75	27.73	4608.20	339.46	460.70	15.95	0.74
2	0 – 4	6.2	6.9	3.71	0.3642	885.63	24.02	22.54	3497.80	310.20	512.60	14.65	0.65
2	4 – 8	3.8	7.0	2.09	0.1793	734.18	19.51	18.30	2871.80	183.71	416.47	15.21	0.50
3	0 – 4	6.2	6.6	3.52	0.3357	938.66	23.83	20.65	3312.50	143.75	445.48	19.34	0.74
3	4 – 8	4.6	6.7	2.17	0.2044	859.00	20.45	18.52	2995.10	99.22	393.67	18.04	0.77
4	0 – 4	6.8	6.4	3.96	0.3529	880.63	24.01	22.39	3539.10	179.17	508.48	17.13	0.89
4	4 – 8	4.1	6.5	2.20	0.1986	779.01	21.24	20.35	3278.50	91.18	444.84	19.73	0.69
5	0 – 4	7.2	6.5	3.88	0.3649	893.30	27.13	25.09	4075.80	253.54	487.61	19.01	0.71
5	4 – 8	4.4	6.8	2.17	0.1954	697.60	22.18	25.19	4219.50	126.67	452.13	19.73	0.74
6	0 – 4	7.4	6.4	4.34	0.3763	931.78	25.25	22.53	3483.70	400.31	492.15	15.75	0.93
6	4 – 8	4.2	6.1	2.33	0.1962	715.67	18.26	16.02	2521.20	227.04	338.12	16.54	0.50
7	0 – 4	7.3	5.9	3.83	0.3511	921.16	25.18	20.36	3110.70	325.86	477.46	14.73	0.80
7	4 – 8	4.3	5.9	2.22	0.1952	745.06	22.20	17.40	2736.80	183.21	387.98	16.66	0.55
8	0 – 4	7.6	6.2	4.26	0.4048	897.49	27.38	27.10	4284.80	362.27	571.56	19.04	0.66
8	4 – 8	4.2	7.0	2.11	0.1826	672.89	27.55	29.27	4868.60	201.02	529.73	22.69	0.73
9	0 – 4	5.4	6.7	2.75	0.2708	745.57	22.90	24.25	3675.60	241.15	630.54	23.07	0.67
9	4 – 8	3.5	6.7	1.56	0.1518	711.24	22.93	20.95	3027.60	180.52	641.42	22.54	0.45
10	0 – 4	8.2	6.7	4.97	0.4535	1046.65	22.92	36.50	5921.50	683.73	620.65	20.31	0.93
10	4 – 8	4.9	6.3	2.67	0.2585	872.82	26.42	19.70	3011.60	345.34	449.89	18.16	0.51
11	0 – 4	7.0	6.3	3.70	0.3410	808.93	23.66	26.00	3959.40	379.95	628.18	22.51	0.59
11	4 – 8	3.9	6.2	1.93	0.1926	693.21	28.67	22.90	3476.10	261.14	578.01	29.21	0.52
12	0 – 4	7.4	7.0	4.31	0.4230	917.17	24.44	28.90	4691.40	369.93	541.65	18.40	0.71
12	4 – 8	4.5	7.2	2.56	0.2228	801.00	26.79	37.29	6588.40	225.07	454.04	22.28	0.78
13	0 – 4	8.7	6.5	4.74	0.4475	1037.70	20.90	27.94	4208.90	670.96	623.76	19.72	0.76
13	4 – 8	4.6	5.9	2.56	0.2254	833.30	28.90	19.01	2874.20	443.26	418.64	19.96	0.56
14	0 – 4	6.7	7.3	4.62	0.4414	866.29	25.59	42.78	7712.00	360.17	396.81	24.62	0.84
14	4 – 8	3.6	7.7	3.50	0.2067	772.25	18.38	23.40	3647.70	230.58	546.99	22.00	0.75
15	0 – 4	8.1	5.9	4.49	0.4142	858.67	26.73	20.05	3197.30	124.97	447.14	21.34	0.49
15	4 – 8	5.0	6.0	2.75	0.2332	720.21	21.91	21.60	3263.80	314.21	535.68	22.16	0.71
16	0 – 4	6.4	5.9	3.83	0.3561	913.73	27.31	17.43	2701.90	166.48	417.25	19.83	0.48
16	4 – 8	4.1	5.8	2.07	0.1868	794.77	21.06	28.55	4596.90	371.76	554.45	21.91	0.59
17	0 – 4	5.3	7.4	3.11	0.2907	710.04	23.30	35.34	6102.90	311.39	484.47	22.08	0.66
17	4 – 8	3.5	7.6	1.92	0.1586	633.88	19.62	25.88	3935.60	370.60	632.39	19.86	0.74
18	0 – 4	8.0	6.3	4.48	0.4324	903.90	28.78	18.72	2877.10	219.44	450.43	19.84	0.62
18	4 – 8	4.5	6.0	2.28	0.2012	676.74	20.64	30.95	4497.80	896.46	744.68	19.31	0.72
19	0 – 4	9.3	6.2	5.63	0.5501	943.94	30.19	27.57	4022.90	778.64	658.41	19.01	0.45
19	4 – 8	5.3	6.5	2.86	0.2717	681.78	27.39	20.03	3082.70	242.25	478.81	19.87	0.58
20	0 – 4	6.3	6.3	3.76	0.3397	877.64	23.68	16.61	2568.30	152.68	402.41	21.28	0.40
20	4 – 8	3.9	6.3	2.12	0.1951	696.09	22.72	27.04	4219.20	296.07	623.03	22.20	0.65
21	0 – 4	7.0	6.4	3.81	0.3481	818.16	25.48	45.27	8206.00	400.78	388.19	22.02	0.80
21	4 – 8	4.1	7.0	1.88	0.1806	611.03	17.75	26.44	4232.40	230.00	561.48	25.04	0.58
22	0 – 4	7.6	6.5	4.13	0.3904	865.47	23.09	26.39	3896.80	365.66	718.62	21.25	0.79
22	4 – 8	5.0	6.4	2.36	0.2403	734.55	26.10	22.18	3164.10	202.86	700.16	23.09	0.64
23	0 – 4	7.2	6.3	4.01	0.3795	813.84	25.52	23.49	3552.40	242.88	612.20	23.12	0.80
23	4 – 8	4.9	6.4	2.34	0.2123	752.01	26.13	19.32	2853.80	150.99	557.22	23.62	0.69
24	0 – 4	6.9	6.5	3.82	0.3775	747.34	22.50	27.43	4138.60	256.08	728.70	27.63	0.63
24	4 – 8	4.7	6.8	2.12	0.2132	589.68	29.34	24.57	3606.90	181.79	723.65	33.19	0.60
25	4 – 8	5.1	6.4	2.62	0.2394	736.40	26.07	22.00	3360.50	269.79	539.58	21.49	0.56
25	0 – 4	6.5	6.5	3.72	0.3520	844.88	22.79	24.45	3650.20	517.61	586.24	18.66	0.55
26	0 – 4	7.9	6.4	4.23	0.3965	840.51	24.64	26.62	3879.50	570.75	694.63	19.05	0.62
26	4 – 8	4.5	6.6	2.10	0.2188	637.67	28.18	24.40	3610.80	250.63	683.93	24.86	0.56
27	0 – 4	8.2	6.4	4.15	0.4028	1029.50	24.81	25.46	3665.40	644.49	660.11	19.80	0.62
27	4 – 8	4.9	6.4	2.37	0.2292	395.49	26.03	23.37	3398.80	380.76	649.12	19.61	0.68
28	0 – 4	7.0	6.3	4.04	0.4067	378.74	26.63	23.97	3311.60	953.83	597.68	18.48	0.61
28	4 – 8	5.1	6.2	2.65	0.2568	354.44	27.31	21.33	3027.20	586.98	564.17	17.36	0.61
29	0 – 4	7.0	6.7	4.08	0.3630	365.49	26.31	32.42	4809.40	503.24	850.88	29.14	0.69
29	4 – 8	5.0	6.5	2.63	0.2417	370.22	28.43	21.02	3221.90	319.67	490.18	20.91	0.57
30	0 – 4	5.5	6.5	3.01	0.3065	342.94	25.72	19.61	2966.20	377.43	456.68	18.59	0.55
30	4 – 8	4.4	6.6	2.55	0.2229	726.05	21.68	17.78	2767.50	220.06	403.61	18.54	0.50
31	0 – 4	5.8	7.3	2.82	0.2608	722.58	19.57	28.14	4412.60	354.76	623.06	19.78	0.60
31	4 – 8	3.9	7.5	2.06	0.1688	595.99	15.06	38.58	6663.50	209.52	574.87	12.93	0.76
32	0 – 4	5.5	7.4	3.19	0.3003	712.63	15.18	26.41	4233.90	396.64	513.57	7.57	0.58

Appendix 9. Pre-treatment Soil bulk density results from cores collected in 2012.

Sampling Location	Core	0-10 cm (0 -4 Inches)	10-20 cm (4 - 8 inches)	20-40 cm (8 - 16 inches0	40-60 CM (16 - 24 inches)	60-80 cm (24 - 32 inches)	80-100 cm (32 - 40 inches)	1000 + cm (>40 inches)
1	A	1.325	1.444	1.653	1.305	NA	NA	NA
1	B	1.223	1.433	1.861	1.257	NA	NA	NA
2	A	1.106	1.524	1.704	1.751	1.977	2.194	1.838
2	B	1.290	1.546	2.028	2.094	1.681	2.270	NA
3	A	1.338	1.466	1.838	1.674	1.572	1.674	1.207
3	B	1.322	1.470	1.407	1.696	1.674	1.517	NA
4	A	1.367	1.374	1.407	1.688	1.605	1.634	NA
4	B	1.210	1.206	1.561	1.630	1.306	1.747	1.159
5	A	1.122	1.476	1.802	1.769	1.517	1.513	NA
5	B	1.312	1.213	1.373	1.619	1.418	1.422	NA
6	A	1.436	1.081	1.601	1.400	1.553	1.224	1.473
6	B	1.012	1.195	1.656	1.407	1.378	1.487	1.436
7	A	1.338	1.294	1.265	1.444	1.422	1.535	1.835
7	B	1.107	1.040	1.297	1.513	1.338	1.327	1.619
8	A	1.335	1.471	1.399	1.447	1.561	1.476	1.677
8	B	1.151	1.199	1.542	1.360	1.089	1.329	NA
9	A	1.232	1.349	1.688	1.228	1.444	1.392	1.586
9	B	1.107	1.440	1.513	1.389	1.674	1.582	NA
10	A	1.455	1.546	1.455	1.294	1.363	1.572	1.685
10	B	1.221	1.048	1.747	1.342	1.498	1.648	NA
11	A	1.422	1.294	1.568	1.466	1.319	1.356	NA
11	B	1.261	1.122	1.534	1.341	1.414	1.618	NA
12	A	1.129	1.261	1.334	1.492	1.400	1.531	NA
12	B	1.195	1.137	1.480	1.758	1.475	1.398	NA
13	A	1.469	1.338	1.513	1.623	1.608	1.605	NA
13	B	1.268	1.450	1.663	1.615	1.396	1.569	1.411
14	A	1.142	1.367	1.619	1.568	1.422	1.156	NA
14	B	1.184	1.283	1.374	1.436	1.526	1.166	NA
15	A	1.129	1.188	1.429	1.466	1.561	1.553	1.718
15	B	1.038	1.243	1.417	1.360	1.308	1.261	1.418
16	A	1.484	1.371	1.409	1.385	1.217	1.312	1.425
16	B	1.126	1.206	1.569	1.230	1.169	1.512	1.501
17	A	1.221	1.455	1.699	NA	NA	NA	NA
17	B	1.283	1.212	1.926	NA	NA	NA	NA
18	A	1.491	1.297	1.791	1.743	1.444	1.593	1.582
18	B	0.896	1.107	1.597	1.853	1.875	1.618	NA
19	A	1.363	1.283	1.466	1.202	1.371	0.992	0.956
19	B	1.206	1.286	1.199	1.411	1.363	NA	NA
20	A	1.224	1.414	1.422	1.319	1.531	1.411	NA
20	B	1.213	1.162	1.140	1.279	1.182	NA	NA
21	A	1.126	1.308	1.466	1.480	1.035	1.213	NA
21	B	1.327	1.257	1.221	1.246	1.458	NA	NA
22	A	1.396	1.056	1.630	1.458	1.400	1.495	1.434
22	B	1.206	1.286	1.498	1.367	1.645	1.444	1.352
23	A	1.367	1.367	1.044	1.557	1.082	1.473	NA
23	B	1.348	1.487	0.976	1.319	1.531	0.985	NA
24	A	1.327	1.047	1.360	1.341	1.243	1.381	1.469
24	B	1.330	0.930	1.104	1.159	1.286	1.480	NA
25	A	1.254	1.466	1.274	1.371	1.316	1.102	1.113
25	B	1.097	1.504	1.298	1.253	1.356	1.456	NA
26	A	1.345	1.381	1.374	1.371	1.235	1.327	1.345
26	B	1.279	1.213	1.462	1.436	1.268	1.440	NA
27	A	1.093	1.100	1.400	1.425	1.520	1.097	NA
27	B	1.294	1.279	1.425	1.575	1.758	1.138	NA
28	A	0.965	1.031	1.294	1.422	1.440	1.619	NA
28	B	1.210	1.071	1.349	1.798	1.736	1.414	1.345
29	A	1.173	1.363	1.327	1.061	1.520	1.970	1.762
29	B	1.261	1.071	1.228	1.462	1.502	1.199	1.948
30	A	1.456	1.885	2.326	1.785	1.346	NA	NA
30	B	1.385	1.489	1.310	1.516	1.111	1.184	NA
31	A	1.356	1.520	0.971	1.396	1.593	NA	NA

Appendix 9. Pre-treatment Soil bulk density results from cores collected in 2012.

Sampling Location	Core	0-10 cm (0 -4 Inches)	10-20 cm (4 - 8 inches)	20-40 cm (8 - 16 inches0	40-60 CM (16 - 24 inches)	60-80 cm (24 - 32 inches)	80-100 cm (32 - 40 inches)	1000 + cm (>40 inches)
31	B	1.506	1.126	1.301	1.444	1.440	NA	NA
32	A	0.833	1.363	1.093	1.254	1.099	NA	NA
32	B	1.349	1.509	1.495	1.213	NA	NA	NA

Appendix 10. Post-treatment Soil bulk density results from cores collected in 2014.

Sampling Location	Core	0-10 cm (0 -4 Inches)	10-20 cm (4 - 8 inches)	20-40 cm (8 - 16 inches0	40-60 CM (16 - 24 inches)	60-80 cm (24 - 32 inches)	80-100 cm (32 - 40 inches)	1000 + cm (>40 inches)
1	A	1.425	1.491	1.378	1.309	1.352	1.430	NA
1	B	1.433	1.341	1.667	1.857	2.017	1.773	NA
2	A	1.180	1.904	1.473	1.667	1.670	1.783	2.109
2	B	1.692	1.498	1.458	1.879	1.751	1.699	1.963
3	A	1.517	1.458	1.677	1.875	2.156	2.123	2.112
3	B	1.677	1.699	1.751	1.904	1.714	2.043	2.123
14	A	1.279	1.451	1.696	1.780	1.685	1.582	1.849
14	B	1.096	1.469	1.546	1.612	1.608	1.926	1.838
15	A	0.998	1.126	1.484	1.327	1.642	1.465	NA
15	B	1.476	1.261	1.590	1.572	1.721	1.802	NA
16	A	1.389	1.692	1.692	1.911	1.641	1.703	1.926
16	B	1.553	1.180	1.725	1.875	1.681	1.539	2.149
17	A	1.685	1.498	1.941	2.142	1.879	1.868	1.714
17	B	1.389	1.049	1.484	1.802	1.900	1.729	1.725
18	A	1.177	1.305	1.593	1.710	2.080	2.087	NA
18	B	1.389	1.257	1.480	1.568	1.893	2.072	NA
19	A	1.513	1.546	2.215	1.531	1.575	1.816	2.032
19	B	1.374	1.118	1.984	1.429	1.670	1.919	2.109
30	A	1.100	1.736	1.528	1.933	1.732	0.999	NA
30	B	1.458	1.224	1.824	1.882	1.601	1.172	1.211
31	A	1.162	1.319	1.575	1.944	1.645	1.900	1.663
31	B	1.334	1.246	1.791	1.506	1.729	1.754	1.754
32	A	1.652	1.297	1.546	1.820	1.977	1.974	1.685
32	B	1.656	1.860	1.794	1.667	1.783	1.970	1.776
33	A	1.623	1.827	2.014	1.886	1.831	1.714	1.889
33	B	2.032	1.835	2.076	1.582	1.608	1.827	1.937
34	A	2.076	1.762	1.721	1.751	1.667	2.098	1.699
34	B	1.707	1.553	1.743	1.615	1.857	1.838	1.908
35	A	1.802	1.820	1.429	1.447	1.846	1.656	1.783
35	B	1.612	1.981	1.509	1.707	1.835	2.248	NA

Appendix 11. Seminar presentation on November 12^{th}, 2012.

COTTONWOOD RIVER NATIVE VEGETATION WATER QUALITY

DAVID TOLLEFSON

OVERVIEW

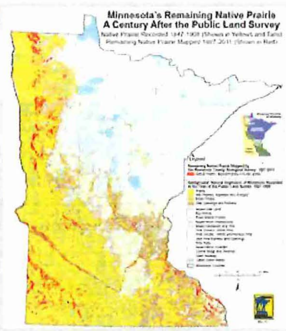
- Background
- Edge-of-field overview
- Site description
- Methods
- Results
- Conclusions
- Moving forward

ORIGINAL GRASSLAND VEGETATION VS. CONVERTED LAND COVER

Source: US EPA and Source: US Dept. of the Interior National Land Cover Database

MINNESOTA'S REMAINING PRAIRIE

- Less than 1% of native prairie remains in Minnesota
- "North America's most endangered ecosystem"

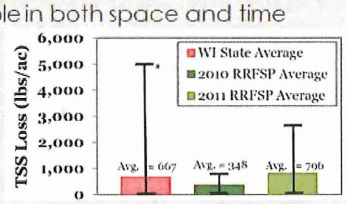


WHY IS THIS IMPORTANT?

- Increasing scrutiny of non-point source pollution in waters
  - Total Maximum Daily Load (TMDL)
    - "Natural Background" knowledge is limited
    - Non-point sources often grouped together
- Grassland conversion to cropland
- Precision conservation
- Compliments agricultural edge-of-field monitoring

EDGE OF FIELD MONITORING LESSONS LEARNED IN SOUTHEAST MINNESOTA

- Sediment and nutrient losses are highly variable in both space and time



EDGE OF FIELD MONITORING LESSONS LEARNED IN SOUTHEAST MINNESOTA

- Water movement reflects physical factors for each site

EDGE OF FIELD MONITORING LESSONS LEARNED IN SOUTHEAST MINNESOTA

- Timing of precipitation events is a major driver of surface run-off

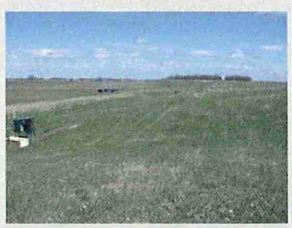
EDGE OF FIELD MONITORING LESSONS LEARNED IN SOUTHEAST MINNESOTA

- Snowmelt run-off can be a significant driver of water movement in a given year

PROJECT GOALS

1. Quantify natural background
2. Compare water quality
3. Measure effectiveness of targeted native prairie vegetation

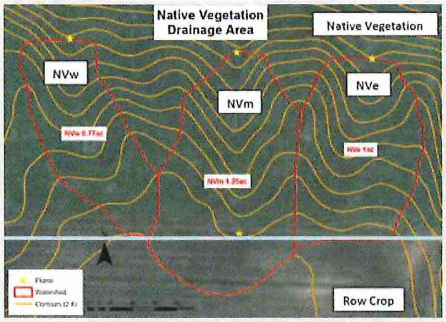
SITE LOCATION



SITE CHARACTERISTICS

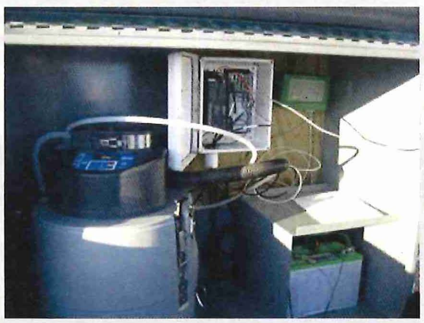
- Redwood County, MN
- Homesteaded in 1857
- No record of row crop/ subsurface drainage
- Grazing has not occurred for > 20 years
- Vegetation harvested once a year for forage
- Storden loam soils (7-10%) slopes

PROJECT DESIGN



INSTRUMENTATION

INSTRUMENTATION

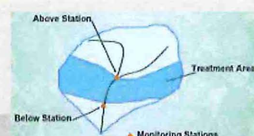


PAIRED WATERSHED DESIGN

- Calibration Period
- Treatment Period




ABOVE AND BELOW DESIGN

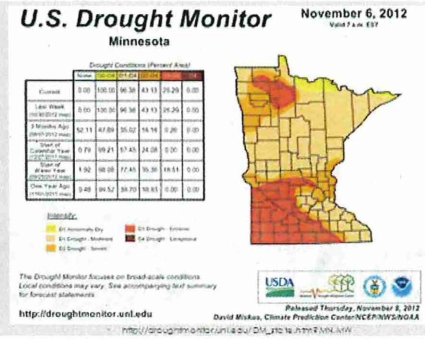
PARAMETERS MEASURED

- Water quantity
- Water quality
  - Total and reactive phosphorus
  - Nitrate, ammonia, and total nitrogen
  - Total suspended sediment
  - Bacteria
- Soil moisture
- In-situ infiltration
- Soil sampling
- Rainfall

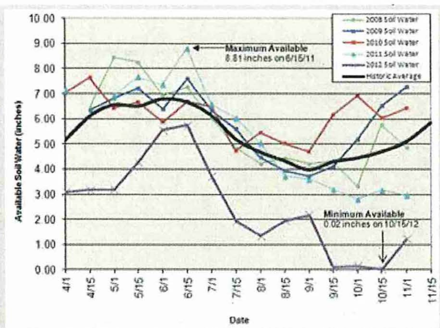
PRECIPITATION AND SOIL MOISTURE

- USDA drought status
- SWROC soil water graphics
- Soil moisture
- Monthly precipitation totals
- Infiltration draft results

CURRENT DROUGHT CONDITIONS

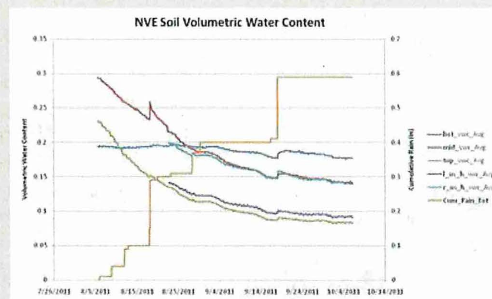


SWROC: 2008-2012 SOIL WATER VS. HISTORIC (1966-2011) AVERAGE



http://swroc.cfans.umn.edu/WeatherInformation/SoilMoisture/2005-2011SoilWatervsHistoricAverage/index.htm

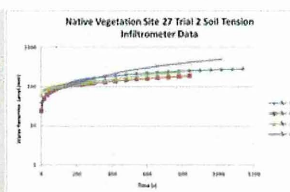
SOIL MOISTURE



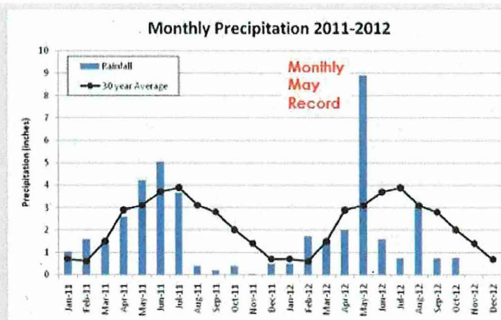
DRAFT INFILTRATION RESULTS

- 32 locations
- Raw data collected
- Need to process data by site

Pressure (-cm)	Median Rate (cm/hr)
10	40.5
6	112.9
3	449.2
0.5	443.2



PRECIPITATION SUMMARY



PAIRED WATERSHED DESIGN: WATER QUANTITY

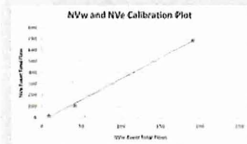
- 2011
  - 20.67 inches of precipitation
- No run-off observed

- 2012
  - 21.48 inches of precipitation
  - 3 small run-off events on **frozen soils**

PAIRED WATERSHED DESIGN: WATER QUANTITY

	NVw		NVe	
	Total Event Flow (ft^3)	Duration (hours)	Total Event Flow (ft^3)	Duration (hours)
2/28/2012	8.69	3.4	18.9	2.9
2/29/2012a	42.06	1.5	107.2	1.1
3/6/2012	191.1	5.8	687.6	15.1

Total Run-off = 0.09 inches/acre   Total Run-off = 0.22 inches/acre



Time ???

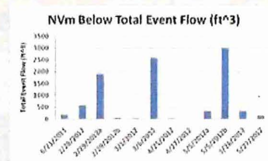
ABOVE AND BELOW DESIGN (ONLY BELOW SITE): WATER QUANTITY

- 2011: 1 run-off event
  - 20.67 inches of precipitation
    - 1 run-off event (June 21, 2012)
- 2012: 11 run-off events
  - 21.48 inches of precipitation
    - 5 frozen ground events Feb. 28 through March 6, 2012
    - 6 non-frozen ground events April 21 through May 27, 2012

ABOVE AND BELOW DESIGN (ONLY BELOW SITE): WATER QUANTITY

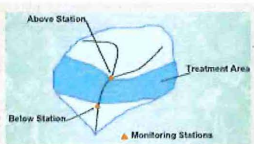
2011 Annual Yield (lb/acres)

Analyte	Yield (lb/acre)
Ammonia	0.000
Nitrate-Nitrogen	0.008
Total Nitrogen	0.033
Total Phosphorus	0.007
Dissovled phosphorus	0.002
Total Suspended Sediment	9.374



ABOVE AND BELOW DESIGN (ONLY BELOW SITE): WATER QUALITY

- Key notes:
  - Only "below" was monitored
  - Lack of overland flow from nearby native vegetation stations shows contribution of "above" watershed



Effect of treatment = 1- Below Station Run-off / Above Station Run-off

CONCLUSIONS

- To date, native prairie vegetation has resulted in:
  - Very little run-off observed
  - Very low pollutant loads
- Moving forward:
  - Calibration period will continue in paired design
  - Above and below sites will be active

Appendix 12.	Soil and Water Management Field Day Brochure

The objective of the Soil & Water Management Field Day is to convene farmers, researchers, stakeholders, and practitioners to interact on issues related to soil and water management for productivity and environmental enhancement. Drainage water management is a practice that allows a producer to exercise greater control over a drainage system in such a way as to reduce drainage during certain times of the year (when less drainage is needed) and provide for adequate drainage when needed most. Drainage water management has the potential to improve water quality by reducing the quantity of nutrient enriched drainage water leaving fields, and provide production benefits by extending the period of time when water is available to plants.

For more information, visit
swroc.cfans.umn.edu
or
call the SWROC at
507-752-7273.

Southwest Research and Outreach Center
University of Minnesota

College of Food, Agricultural and Natural Resource Sciences
University of Minnesota
Driven to Discover

Minnesota Department of Agriculture

SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE

Soil & Water Management Field Day

Wednesday, July 23, 2014

Brian Hicks Farm
19465 County Road 8
Tracy, Minnesota 56175

9:00 a.m.

Soil & Water Management Field Day
Wednesday, July 23, 2014

9:00 a.m. *Welcome*
- Jeff Strock, University of Minnesota
- Mark Dittrich, Minnesota Department of Agriculture

Farm History & Managment Objectives
- Brian Hicks, Owner/Operator

Farm Surveys on Crop Production & Climate Change
- Chad Ingles, Iowa State University
- Catherine Sereg, Heron Lake Watershed District
- Shawn Wohnoutka, Redwood-Cottonwood Rivers Control Area

Climate Change & Crop Production
- Dennis Todey, South Dakota State University

10:00 a.m. *Field Tour I*
- **Greenhouse Gas Emission**, John Baker, U.S. Department of Agriculture
- **Runoff**, David Tollefson, University of Minnesota

Field Tour II
- **Greenhouse Gas Emission**, Mike Castellano, Iowa State University
- **Drainage Water Management: Crop Production & Water Quality**, Jeff Strock, University of Minnesota

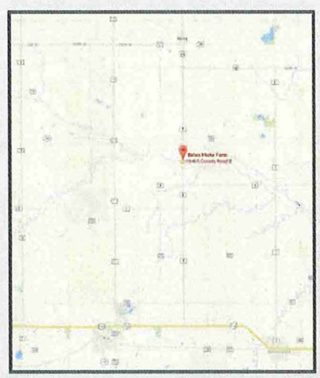
12:00 p.m. *Lunch*

Carbon Nitrogen, Water, & Climate Change
- Jerry Hatfield, USDA-ARS National Laboratory for Agriculture & the Environment

1:00 p.m. *Panel Discussion on Achieving Crop Production Environmental Quality Goals in the Face of Future Climate Change*
- Brian Hicks, Farmer
- Dave Frederickson, Minnesota Commissioner of Agriculture
- John Linc Stine, Commissioner of Minnesota Pollution Control Agency
- Jerry Hatfield, USDA-ARS National Laboratory for Agriculture & the Environment
- Warren Formo, Minnesota Agricultural Water Resources Center

The Field Day will be held rain or shine. In the event of inclement weather, the programs will be held in a tent on the Hicks farmsite.

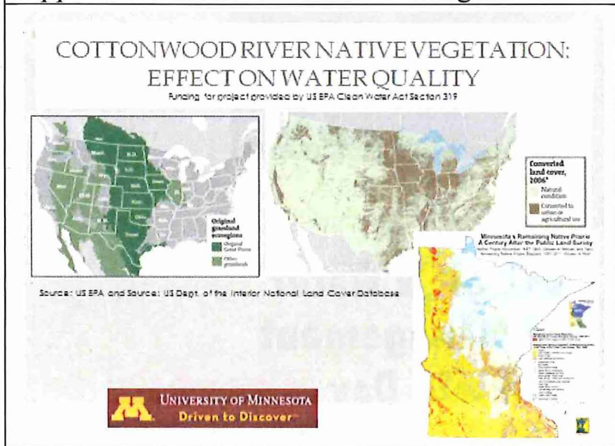
Brian Hicks Farm
19465 County Road 8
Tracy, Minnesota 56175
(watch for signs)

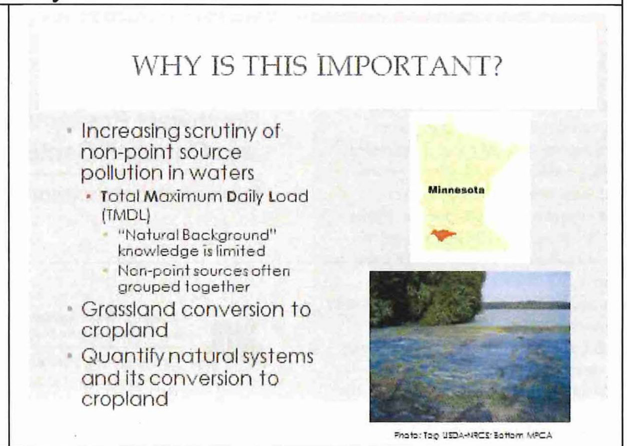


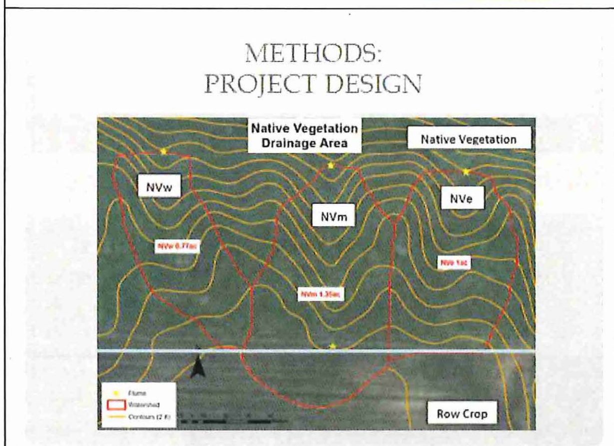
Please register online at:
goo.gl/x8YUND

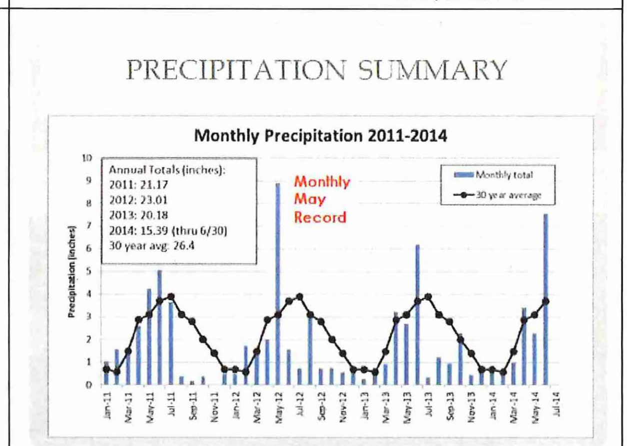
No registration fee is required.
Registration includes a proceedings of field day presentations and a noon lunch.

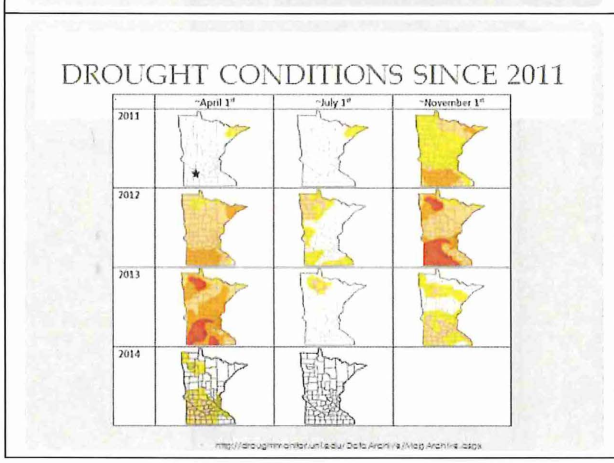
Appendix 13. Soil and Water Management Field Day Presentation.

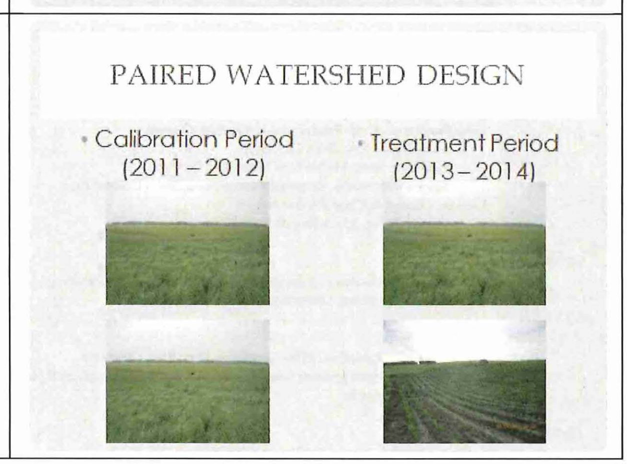












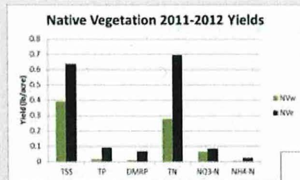
2011-2012 RESULTS: PAIRED WATERSHED DESIGN CALIBRATION PERIOD

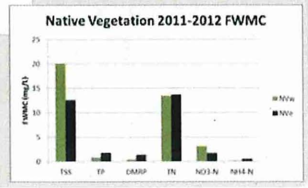
- **2011**
  - No run-off observed
  - Above average May and June rainfall
- **2012**
  - 3 small run-off events on **frozen soils**
  - Wettest May on record

2012 Events:

- NVw
  - 3 events
  - 0.09 inches RO
  - 242 cubic ft RO
  - ~10 hours of RO
- Nve
  - 3 events
  - 0.22 inches RO
  - 814 cubic ft RO
  - ~19 hours of RO
- Events occurred on Feb. 28, Feb. 29, and March 6, 2012

2011-2012 RESULTS: PAIRED WATERSHED DESIGN CALIBRATION PERIOD



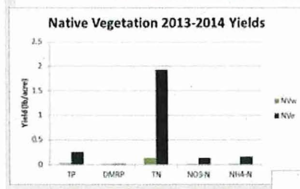


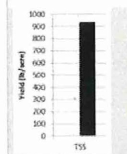
- Many events did not produce run-off at either site in 2011 and 2012

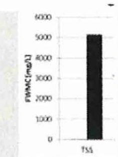
2013-2014 RESULTS: PAIRED WATERSHED DESIGN TREATMENT PERIOD

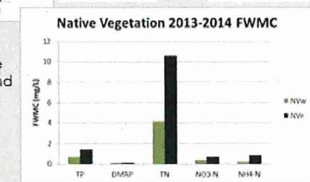
- NVw
  - No run-off in 2013
  - Snowmelt run-off in 2014 = 0.14 inches RO
- NVe
  - 4 run-off events in June 2013
  - 0.72 inches RO
  - June 21-23, 2013
  - <3 hours of RO (all between 9:30 PM and 1:30 AM)
  - Snowmelt run-off in 2014 = 0.08 inches RO

2013-2014 RESULTS: PAIRED WATERSHED DESIGN TREATMENT PERIOD



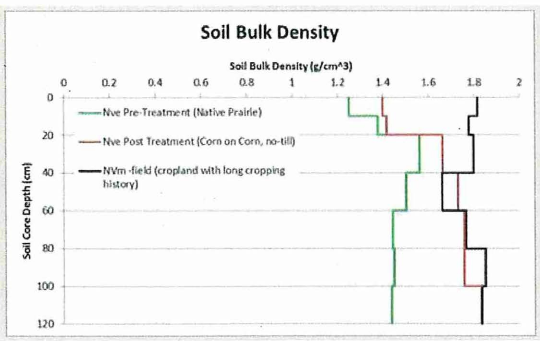




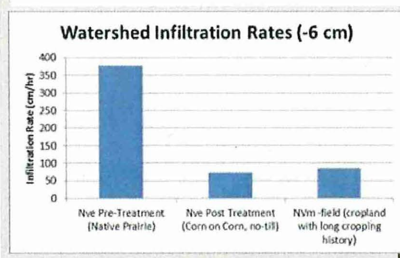


- Many events did not produce run-off at either site in 2013 and 2014

BULK DENSITY RESULTS



DRAFT INFILTRATION RESULTS



CONCLUSIONS

- Run-off is infrequent and short duration
- No run-off from native prairie during non-frozen soil conditions
  - Low pollutant yields, but elevated concentrations of N and P
- NVe was planted to corn in 2013
  - Four events occurred in June totaling
  - No associated run-off from native prairie
- Soil bulk density and infiltration changes were measured in 2nd year of crop production

COTTONWOOD RIVER NATIVE VEGETATION WATER QUALITY IN SOUTHWEST MINNESOTA

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EXECUTIVE SUMMARY

To provide context and to better manage our water resources, this study quantified the surface water quality and hydrology of a native prairie in southwest Minnesota, and measured the changes that occurred following the conversion of a portion of grassland to cropland utilizing a paired watershed design. Two small watersheds were instrumented with H-flumes and monitored year-round for four years. The native prairie did not produce run-off during non-frozen soil conditions; however, it did have run-off associated with snowmelt over frozen soils. The water quality of the snowmelt run-off did have elevated levels of total phosphorus (TP), primarily in the dissolved molybdate reactive phosphorus (DMRP) form, and contained various forms of nitrogen, along with low sediment levels. The water leaving the native prairie did carry nitrogen, phosphorus, and sediment although the run-off volumes annually averaged less than 0.1 inches of run-off/acre resulting in low pollutant exports.

One of the watersheds was converted from native prairie grassland to cropland in May 2013. Four run-off events from the cropland were observed in June of 2013. These were the only run-off events on non-frozen soils over the duration of the project. The conversion to cropland did result in additional nitrogen, phosphorus, and sediment being exported from the watershed compared to the control. These increased losses are more reflective of a shift in hydrology rather than a shift in pollutant concentrations, due to the lack of run-off observed from the native prairie during non-frozen soil conditions. Soil bulk density and infiltration rate were used as indicators of changes in soil properties after conversion from prairie to cropland. It is anticipated that the hydrology and soil properties of this recently converted cropland would continue to change over time until a "new" equilibrium is reached that is consistent with lands in long-term crop production.

INTRODUCTION

Land use/land cover and water resources are inextricably linked. Land use/land cover have a direct relationship with environmental characteristics and processes, including soil characteristics, productivity of the land, species diversity, climate, biogeochemistry and the hydrologic cycle. Changes in land use over the last century have resulted in observed concentrations of both sediments and nutrients in the Cottonwood River exceeding applicable water quality standards and guidelines (Minnesota River Basin Data Center, 2007).

In order to understand current questions about water quality and water quantity in the U.S. Northern Corn Belt, and specifically in Minnesota, it is necessary to examine the changes that have occurred in agriculture in the past two centuries. Briefly, the first major shift in land use began with the conversion of vast amounts of virgin prairie into what is now prime farmland and municipal uses. This conversion resulted in a shift in the hydrologic cycle, mainly due to the replacement of perennial vegetation with seasonal vegetation on the landscape. In the case of municipalities, expanding areas of impervious surface have also impacted water quantity and water quality. The second major shift in land use began with the installation of artificial drainage systems in the late 1800's. Because of drainage, areas which were once unsuitable for agricultural production, transportation, or municipal expansion could now be developed. In agricultural regions, many areas previously classified as too wet to farm were converted to row crop production. Following the Second World War, increased availability of inorganic fertilizers, primarily nitrogen, led to a separation of crop and livestock production with decreased reliance on animal manures and legumes to supply the necessary nutrients for crop production. These changes had a significant, long-lasting, positive impact on increased agricultural productivity and profitability. On the other hand, they drastically altered agronomic practices and have contributed to negative changes in soil properties and water quality impairments. Increased crop production possible under artificially drained, cultivated agricultural land, under some conditions, led to increased soil erosion, loss of soil carbon and degradation in water quality.

There is a lack of historical records quantifying the natural background levels of soil and nutrient losses from native prairie and perennial vegetation including conservation reservation reserve (CRP) lands. Moreover, there is a lack of data quantifying the loss of soil and nutrients when the native prairies were initially cultivated. To better manage our water resources, it critical to understand the potential hydrology and water quality impacts associated with our natural landscapes.

METHODS

This section describes the main experimental components of the research project. The project was designed to monitor surface run-off from native vegetation and recently converted grassland to cropland at the Hick's family farm near Tracy, MN. Infrastructure (wing walls, H-flumes, etc) was installed in October of 2010 and electronic monitoring equipment was installed in February of 2011 prior to snowmelt. The sites were managed by the University of Minnesota, Southwest Research and Outreach Center (SWROC).

Description of Research Sites

Two small watersheds (0.77 and 1.00 acres, respectively) were instrumented to monitor surface run-off. These watersheds are located in the southeast corner of a 160-acre field that was composed of a mixture of native and nonnative (including smooth brome grass (Bromus thermis) and Kentucky bluegrass(Poa pratensis) among others) vegetation and was never cultivated for crop production. Cattle were grazed on the field until 2000, and since then, the field is harvested for forage in mid-summer. No artificial drainage was installed. The field was mapped as a Storden loam, a well-drained soil, with moderately high to high permeability on 7 to 10% slope. The field is a transition between flat, highly productive agricultural fields to the south and to lowland riparian land to the north. This transitional area is similar to other nearby lands that hold potential as treatment zones for received run-off, but is not representative of the all fields in the region.

The watersheds were monitored utilizing a paired watershed design (Clausen and Spooner, 1993). Each watershed was managed in the native prairie condition for 2011 and 2012 to conduct calibration of the paired watersheds. The vegetation was plowed in the eastern treatment watershed (NVe) and the site was brought into production in May of 2013. Corn (Zea mays L.) was planted perpendicular to the hillslope in 2013 and fertilized with 120 lbs N/acre in 2013. Corn was planted in 2014 using no-till methods and fertilized with 180 lbs N/acre. All nitrogen applications were in the form of urea and were broadcasted in June. The western watershed (NVw) was managed in the native prairie condition throughout the project (2011-2014) as the control site.

Water Quality and Quantity Monitoring

Each watershed had a plywood wing wall installed perpendicular to flow near the bottom of the drainage (Stuntebeck, et al.). Flow was concentrated and forced through a pre-calibrated 1.5 foot H-flume that was equipped with a datalogger to record water level, discharge, rainfall, soil moisture, and soil temperature. Run-off events were recorded on a 1-minute interval to examine hydrologic characteristics of the watershed. An ISCO 6712 automated water sampler was used to collect flow-based composite samples into 24 1-L bottles. Water samples were analyzed for ammonium, nitrate, total nitrogen, dissolved reactive phosphorus, total phosphorus, total suspended solids, and E. Coli. This information was used to calculate pollutant export (loads) and flow weighted mean concentrations (FWMC) from the watersheds. No water quality or quantity monitoring of vadose zone or ground water was completed.

Soil Properties

Soil properties at 20 locations were measured using a 0.1 acre grid pattern sampling design. Soil cores were analyzed in replicate at the 0-10 cm and 10-20 cm intervals for organic matter, pH, total organic carbon, total nitrogen, total phosphorus, cation exchange capacity, calcium, potassium, magnesium, sodium, and aluminum prior to grassland conversion to cropland. Soil bulk density was determined in replicate at each of the 32 locations from cores collected in the fall of 2012 at intervals of 0-10, 10-20, 20-40, 40-60, 60-80, 80-100, and 100-120 cm. Soil bulk density was re-determined in replicate at the 12 locations in NVe (after conversion from grassland to cropland) in June 2014 following the second year of corn (Zea mays L) planting. Soil bulk density was determined by slicing 100 cm cores at predetermined intervals and drying at 105^{o} C for 24 hours (Klute, 1986). Soil bulk densities are reported as an average of the specific depths in each watershed. Soil infiltration was measured in replicate at each of the 20 locations in the fall of 2012, and re-measured in replicate at the 12 locations in NVe (after conversion from grassland to cropland) in June 2014 following the second year of corn (Zea mays L) planting. Tension infiltrometers were operated at pressures of -10, -7, -3 and -0.5 cm. (Reynolds and Elrick, 1991).

RESULTS AND DISCUSSION

Precipitation

Monthly precipitation data were collected at the experimental site for the study period (2011-2014) and compared to the 30-year long-term (1980-2010) averages at the Southwest Research and Outreach Center (SWROC) in Lamberton (Figure 1). SWROC is located approximately 15 east/southeast of the study area. Monthly precipitation values in the winter were also taken from SWROC. Annual precipitation totals in 2011 through 2013 ranged from 20.2 to 23.0 inches compared to the annual average of 26.4 inches (13% to 24% below normal). The United States Drought Monitor classified the study sites as being in severe drought in the fall of 2011, extreme drought in the fall of 2012, and moderate drought in the fall of 2013. The distribution of rainfall was skewed to April through July every year from 2011 through 2014, and precipitation was below normal for most months from August through December from 2011 through 2013. Even with the below average annual totals, there were several months with above average precipitation including May and June of 2011, May of 2012 (the wettest May on record for SWROC), June of 2013 and June of 2014. In each year of monitoring, there was at least 1 daily rainfall total in May or June between 1.96 and 2.27 inches.

Hydrology and Run-off

Run-off was limited during the entire study period (Table 1). During the calibration period (February 2011- April 2013), both NVw and NVe only recorded run-off on three days in 2012. All three of these events occurred when the soils were frozen and included run-off generated from snowmelt and from rainfall on frozen ground. The NVw site recorded 0.09 inches of run-off/acre (242 cubic ft) and NVe recorded 0.22 inches of run-off/acre (814 cubic ft) over the three events in 2012. No run-off was observed from either NVw or NVe during non-frozen soil conditions in the calibration period. Following the treatment (NVe converted from grassland to cropland), NVe had 4 run-off events in June of 2013 that totaled 0.72 inches of run-off/acre (2610 cubic ft). NVw (native prairie control site) did not record run-off in 2013. Run-off occurred at both NVw and NVe in 2014 during the snowmelt when soils were frozen. No run-off was observed when the soils were non-frozen in 2014. The NVw site recorded 0.15 inches of run-off/acre (406 cubic ft) in 3 run-off events and NVe recorded 0.08 inches of run-off/acre (290 cubic ft) in a single run-off event in 2014. No run-off was recorded during non-frozen soil conditions from either NVw or NVe when the watersheds were managed in native prairie. Snowmelt was only recorded in years associated with deep frost levels. Run-off was infrequent and of short duration: the average event on frozen soils lasted 5.4 hours; the average event on non-frozen soils (after NVe converted from grassland to cropland) was 42 minutes.

Sediment

Event sediment yields at NVw averaged 0.24 lb/acre and flow weighted mean concentrations (FWMC) averaged 40.7 mg/L (Table 1). All NVw events occurred during frozen soil conditions. A total of 1.22 lbs of sediment was exported from NVw from 2011 through June 2014. The NVe pre-treatment (native prairie) event sediment yields averaged 0.21 lbs/acre and FWMC averaged 64.5 mg/L. All NVe pre-treatment events occurred on frozen soils. The NVe post-treatment (after conversion of grassland to cropland) sediment characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded sediment at 1.94 lb/acre and FWMC was 106.8 mg/L. Event sediment yields at NVe post-treatment over non-frozen soils averaged 233.5 lb/acre and FWMC averaged 5,075 mg/L. A total of 0.64 lbs of sediment was exported from NVe in 2011 and 2012; a total of 935.8 lbs of sediment was exported from NVe in 2013 and 2014 after conversion to cropland. Sediment yields and FWMC were low for all events that occurred on frozen soils. Sediment yields and FWMC were much greater at NVe after conversion from grassland to cropland on non-frozen soils. No run-off occurred from the native prairie during non-frozen soils; therefore no export of sediment was measured from the native prairie during non-frozen periods.

Nitrogen

Event total nitrogen (TN) yields at NVw averaged 0.07 lb/acre and FWMC averaged 5.2 mg/L. Total nitrogen speciation included 2.1 % ammonium, 17.7% nitrate-nitrite, and 80.2% organic nitrogen. All NVw events occurred during frozen soil conditions. NVe pre-treatment (native prairie) event TN yields averaged 0.23 lbs/acre and FWMC averaged 31.1 mg/L. Total nitrogen speciation included 5.7 % ammonium, 3.2% nitrate-nitrite, and 91.1% organic nitrogen. NVe post-treatment (after conversion of grassland to cropland) nitrogen characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded TN at 0.15 lb/acre and FWMC was 8.1 mg/L. Event TN yields at NVe post-treatment over non-frozen soils averaged 0.44 lb/acre and FWMC was 9.5 mg/L. Total nitrogen speciation included 7.0 % ammonium, 8.2% nitrate-nitrite, and 84.8% organic nitrogen. The largest nitrogen losses were associated with the 4 non-frozen soil events at NVe post-treatment (after conversion of grassland to cropland). Large nitrogen losses through surface run-off were not anticipated as most nitrogen losses occur through leaching or through artificial drainage (if present).

Phosphorus

Event total phosphorus (TP) yields at NVw averaged 0.01 lb/acre and FWMC averaged 0.5 mg/L (Table 1). Approximately 40% of the TP was in the dissolved molybdate reactive phosphorus (DMRP) form. All NVw events occurred during frozen soil conditions. The NVe pre-treatment (native prairie) event TP yields averaged 0.03 lbs/acre and FWMC averaged 4.7 mg/L. Approximately 79% of the TP was in the DMRP form. All NVe pre-treatment events occurred on frozen soils. NVe post-treatment (after conversion of grassland to cropland) phosphorus characteristics varied greatly due to frozen and non-frozen soil conditions. During frozen soil conditions, a single event at NVe yielded TP at 0.02 lb/acre and FWMC was 1.0 mg/L. Event TP yields at NVe post-treatment over non-frozen soils averaged 0.06 lb/acre and FWMC was 1.2 mg/L. Approximately 6% of the TP was in the DMRP form. The watersheds managed in native prairie did have elevated TP concentrations; however, the export loads were low when combined with run-off volumes. The watersheds managed in native prairie also had a higher fraction of the TP in the DMRP form than from NVe after conversion of grassland to cropland. The events with the largest TP export loads occurred at NVe in 2013 after conversion of grassland to cropland. No run-off occurred from the native prairie during non-frozen soils; therefore no export of TP was measured from the native prairie during non-frozen periods.

Soil Bulk Density and Infiltration

Soil bulk density increased from 1.25 to 1.40 g/cm^3 in first 10 cm depth (Figure 2) following the conversion from native prairie to cropland. Soil bulk density also increased at each interval from 10 to 40 cm below the surface. In the native prairie, soil bulk density decreased at the 40 to 60 cm depths and normalized around 1.44 g/cm^3 from 60 to 100 cm depth. After conversion of native prairie grassland to cropland, the soil bulk density increased at the 40 to 60 cm depth and normalized around 1.75 g/cm^3. Soil bulk density measurements of an adjacent field (NVm-field) with a long history of crop production were collected as a reference point. The recently converted cropland had soil bulk densities that fell between the native prairie and NVm-field at the 0-40 cm depth. Soil bulk density in the lower 40-100 cm depth was similar for the recently converted cropland and NVm-field. It is anticipated that long-term production in the recently converted cropland would result in greater soil bulk densities in the 0-40 cm depth over time likely effecting physical soil properties. Preliminary Infiltration data at -6 cm pressure show a large reduction in infiltration rates at NVe when comparing the pre-treatment (native prairie) and post treatment (after conversion of grassland to cropland) (Figure 3). Infiltration rates were similar for the NVe post treatment watershed and the NVm-field watershed during the second year of crop production. Additional infiltration data analysis will occur.

SUMMARY

Preliminary results from this study characterized the hydrology and water quality of a native prairie in southwest Minnesota. On the native prairie, lack of run-off during non-frozen soil conditions drove the results. Snowmelt run-off from the native prairie during frozen soil conditions did carry nitrogen, phosphorus and sediment from the watersheds. After conversion from grassland to cropland, the NVe watershed did experience 4 run-off events in June of 2013. The observed run-off and associated pollutant loads are likely a result of the change in land use. Increases in soil bulk density were associated with the conversation into cropland. Additional years of crop production would likely continue to change the soil properties, and ultimately the hydrology of this site.

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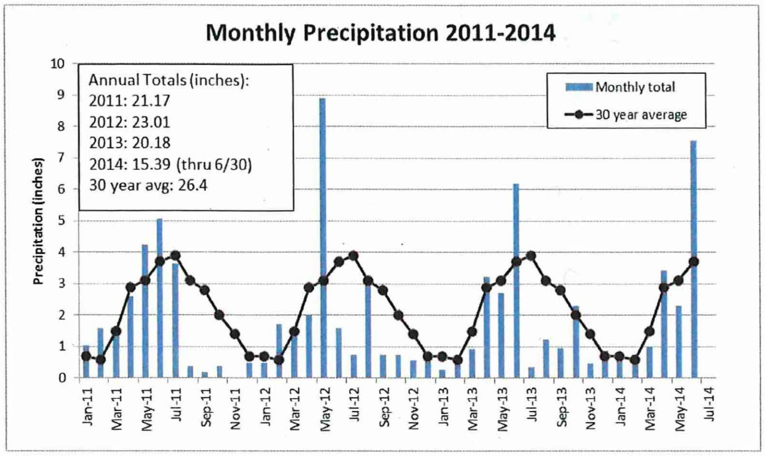

Figure 1. 2011-2014 monthly precipitation totals.

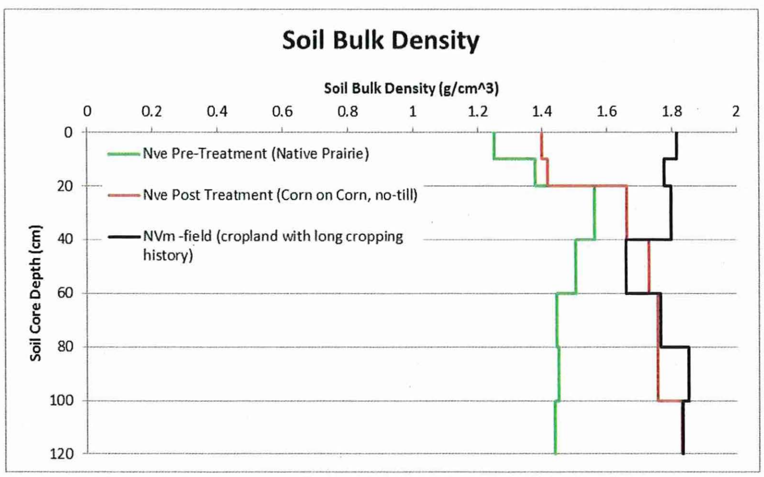

Figure 2. Soil bulk density results.

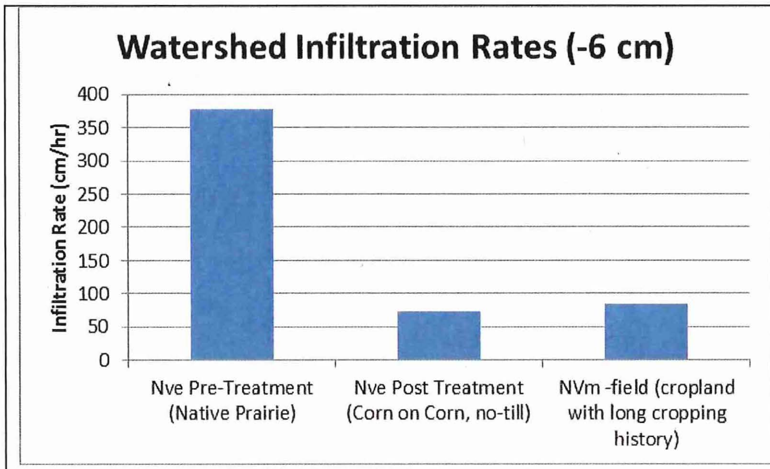

Figure 3. Watershed infiltration rates at -6 cm pressure.