AUG 18 2006 

**2003 Project Abstract**
For the Period Ending June 30, 2006

FINAL REPORT

**TITLE: Native Plants and Alternative Crops for Water Quality**
**PROJECT MANAGER: Linda Meschke**
**ORGANIZATION: Blue Earth River Basin Initiative**
**ADDRESS: 426 Winnebago Avenue, Suite 100, Fairmont, MN 56031**
**WEB SITE ADDRESS:** www.berbi.org
**FUND: Minnesota Environment and Natural Resources Trust Fund**
**LEGAL CITATION:** ML 2003, Ch. 128, Art. 1, Sec. 14, Subd. 09

**APPROPRIATION AMOUNT: $ 622,000.00**

Overall Project Outcome and Results

Incorporation of crops that do not require annual tillage [3rd Crops] on riparian areas and strategically targeted uplands has the potential to improve water quality in the Minnesota River while providing economic opportunities for farmers and rural communities. However, information and incentives are lacking to accelerate the widespread use of these plants/ crops in agricultural systems. This project examines farm production differences and the hydrologic and water quality differences among selected 3rd cropping systems and a traditional corn/ soybean rotation in the Blue Earth River Basin. Key objectives are to 1] establish, demonstrate and evaluate plantings of native plants and 3rd crops for agronomic, water quality, and economic benefit; 2] determine economic and water quality impacts; and 3] accelerate implementation of native plant and 3rd crop production systems with demonstration, market identification, coordination and promotion.

Results include conversion of 271.9 acres of land, at 33 sites, in a corn/ soybean rotation to a variety of 3rd crops; establish four 3rd crop demonstration sites in the Blue Earth, Chippewa, Roseau and Lower MN watersheds; establish and monitor research sites for agronomic assessment of landscape position on soybean, alfalfa and willow yield; establish and monitor water quality improvements from a 3rd crop system versus conventional system in the Elm Creek Watershed [Blue Earth Basin]; hydrologic modeling indicating reduced peak stream flows in watersheds with 3rd crop systems; identified economic significance to adoption of perennial cropping systems for landowners and society; provided over 110 outreach events that reached at least 10,000 people; developed a book of stories about each 3rd crop easement farmer titled "Native Plants and 3rd Crops for Water Quality"; and established a significant outreach, demonstration, collaboration, and marketing programs that has significantly elevated the awareness, adoption and mindset for alternative cropping systems and their significance to agriculture, environment and community.

Project Results Use and Dissemination

Throughout the project all project partners have worked tirelessly to disseminate information about native plants and 3rd crop benefits to the traditional agricultural system, improvement to water quality, reduction in peak stream flows, and the potential economic advantage for producers and rural communities. Over 110 presentations have been made by various team members across the state. There are many additional partners, who are not official project partners, who have contributed to the growth and advancement of an alternative crop mindset, beyond our original expectations, such as Green Lands, Blue Waters, Productive Conservation, Agroforestry Coalition, MISA, Institute for Agriculture and Trade Policy, MN Project, Land Stewardship Project, MN Department of Agriculture – Sustainable Ag and Diversification Divisions, MN Dept. of Natural Resources, and NRCS ad the State Technical Committee.

AUG 18 2006

**Date of Report:** August 15, 2006
**LCMR Final Work Program Report**

**FINAL REPORT**

**Date of Work program Approval:** June 25, 2003
**Project Completion Date:** June 30, 2006

# I. PROJECT TITLE: Native Plants and Alternative Crops for Water Quality

| | | |
|---|---|---|
| **Project Manager**: | Linda Meschke | Dean Current |
| **Affiliation:** | Blue Earth River Basin Initiative | U of MN |
| **Mailing Address:** | 426 Winnebago Avenue, Suite 100 | 115 Green Hall, 1530 Cleveland Ave N |
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| | | |
|---|---|---|
| **Total Biennial LCMR Project Budget:** | **LCMR Appropriation:** | **$622,000.00** |
| | **Minus Amount Spent:** | **$591,344.71** |
| | **Equal Balance:** | **$ 30,655.29** |

**Legal Citation: MN Laws 2003, Chapter 128, Article 1, Section 14, Subd.09.**

**Appropriation Language:**
Subd. 9. Native Plants and Alternative Crops for Water Quality
$311,000 the first year and $311,000 the second year are from the trust fund to the board of water and soil resources for agreements with the Blue Earth River Basin Initiative and the University of Minnesota to accelerate the use of native plants and alternative crops through easements, demonstration, research, and education. This appropriation is available until June 30, 2006, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

## II. and III. FINAL PROJECT SUMMARY

Incorporation of crops that do not require annual tillage [3rd Crops] on riparian areas and strategically targeted uplands has the potential to improve water quality in the Minnesota River while providing economic opportunities for farmers and rural communities. However, information and incentives are lacking to accelerate the widespread use of these plants/ crops in agricultural systems. This project examines farm production differences and the hydrologic and water quality differences among selected 3rd cropping systems and a traditional corn/ soybean rotation in the Blue Earth River Basin. Key objectives are to 1] establish, demonstrate and evaluate plantings of native plants and 3rd crops for agronomic, water quality, and economic benefit; 2] determine economic and water quality impacts; and 3] accelerate implementation of native plant and 3rd crop production systems with demonstration, market identification, coordination and promotion.

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## IV. OUTLINE OF PROJECT RESULTS

**Result 1:** We will use easements to establish, demonstrate and evaluate plantings of native plants and 3rd Crops for agronomic, water quality and economic benefit.

### 3rd Crop Easements

Demonstration plantings of various third crops have been established on thirty three sites totaling 271.9 acres [10 acres is the maximum size] across the greater Blue Earth River Watershed. These sites illustrate a variety of potential 3rd crop options a landowner has in south central Minnesota. All of the sites are conversion of land in a corn/ soybean rotation to a 3rd crop. Efforts were made to have the demonstration sites dispersed throughout the watershed region, reflect a variety of soil types and conditions, demonstrate a variety of crops, and a range of ecological services. Each site is committed to a ten year easement that is recorded in the county the project is located in.
BERBI worked collaboratively with local Soil and Water Conservation Districts [SWCD] to implement this section of the project. Each SWCD promoted the program to landowners in their jurisdiction. They worked with interested landowners to identify appropriate species, complete necessary paperwork and ensure the project was completed according to project guidelines. This was a very effective and efficient delivery mechanism for this program.

In addition, we worked with the University of Minnesota, University of North Dakota, University of South Dakota, University of Wisconsin – Stevens Point, University of Iowa, University of Minnesota Research and Outreach Centers, University of Minnesota Extension Service, Natural Resources Conservation Service, Minnesota Department of Agriculture, Minnesota Department of Natural Resources and private partners in order to get necessary technical information to meet the landowners needs.

Response from the landowners was very high. We could have enrolled many more acres if we had additional funding. Agricultural producers are looking for alternative crops. The replacement crop must have a viable market and minimal risk for the landowner to grow it. The growth of renewable energy is a great driver for perennial crops on the landscape. As the bioenergy industry evolves, with strong leadership toward perennial crops as a feedstock, we will see thousands of acres planted. Producers in south central Minnesota are experiencing decreasing soybean yield trends, threats of Asian soybean rust, and depressed markets. This is helping to drive farmers toward other crops.

The following chart indicates the landowner/ operator name; 3rd crop type; rate paid; number of acres; and payment amount for the easements enrolled under this program.

| | Land Owner (LO) | Type of Crop | Rim Rate - 2003 | % of Rim rate | Total acres | LO Payment Total | 5% Dist Pmnt | Project TOTALs Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Ardis Perrine | Native Prairie | $1,969.00 | 70 | 10.0 | $ 13,780.00 | $ 689.00 | $ 14,469.00 |
| 2 | Shirley Riihl | Alfalfa | $1,767.00 | 50 | 3.4 | $ 3,002.00 | $ 150.00 | $ 3,152.00 |
| 3 | Jim Nickel | Alfalfa | $1,767.00 | 50 | 0.8 | $ 706.00 | $ 35.00 | $ 741.00 |
| 4 | Billey Rabbe | Native Prairie | $1,993.00 | 70 | 10.0 | $ 13,950.00 | $ 697.00 | $ 14,647.00 |
| 5 | Rodney Einck | Oats | $1,637.00 | 40 | 10.0 | $ 6,540.00 | $ 327.00 | $ 6,867.00 |
| 6 | David Krampitz | Native Prairie | $1,759.00 | 70 | 10.0 | $ 12,310.00 | $ 615.00 | $ 12,925.00 |
| 7 | Wayne Bloomquist | Native Grasses | $1,953.00 | 70 | 10.0 | $ 13,670.00 | $ 683.00 | $ 14,353.00 |
| 8 | Mark Rentz | Alfalfa | $1,349.00 | 50 | 10.0 | $ 6,740.00 | $ 337.00 | $ 7,077.00 |
| 9 | Norm & K. Penner | Hazel | $1,638.00 | 60 | 10.0 | $ 9,820.00 | $ 491.00 | $ 10,311.00 |
| 10 | John Malterer | Alfalfa | $1,775.00 | 50 | 5.5 | $ 4,878.00 | $ 243.00 | $ 5,121.00 |
| 11 | Dennis Hunstad | Pasture | $1,810.00 | 60 | 10.0 | $ 10,860.00 | $543.00 | $ 11,403.00 |
| 12 | Vivian Bradford - James Haaland | Perennial Native Grass/Flower | $1,779.00 | 70 | 10.0 | $ 12,450.00 | $ 622.00 | $ 13,072.00 |
| 13 | Lovella Rempel | Oats/Wheat/Flax Rotation | $1,490.00 | 40 | 10.0 | $ 5,960.00 | $ 298.00 | $ 6,258.00 |
| 14 | Richard Flohrs | Perennial Woody Vegetation | $1,810.00 | 70 | 10.0 | $ 12,670.00 | $ 633.00 | $ 13,303.00 |
| 15 | Donald Moritz | Clover/oats/woody ornamentals | $1,900.00 | 60 | 6.5 | $ 7,410.00 | $ 370.00 | $ 7,780.00 |
| 16 | Kermit Carlson | Native Grasses | $2,000.00 | 60 | 6.0 | $ 7,200.00 | $ 360.00 | $ 7,560.00 |
| 17 | Craig Peterson | Pasture Mix/Windbreak | $2,056.00 | 70 | 10.0 | $ 14,390.00 | $ 719.00 | $ 15,109.00 |
| 18 | John/Lloyd Olson | Pasture for Rotational Grazing | $2,056.00 | 60 | 10.0 | $ 12,330.00 | $ 616.00 | $ 12,946.00 |
| 19 | Walter Bettin | Pasture | $2,000.00 | 60 | 10.0 | $ 12,000.00 | $ 600.00 | $ 12,600.00 |
| 20 | Paul Berry | Oats/W.Wheat/Pumpkins | $2,039.00 | 40 | 10.0 | $ 8,150.00 | $ 407.00 | $ 8,557.00 |
| 21 | Howard Guse | Oats/W.Rye/Pasture | $1,930.00 | 40 | 10.0 | $ 7,720.00 | $ 386.00 | $ 8,106.00 |
| 22 | Russ Guse | Oats/W.rye/W.wheat | $1,930.00 | 40 | 10.0 | $ 7,720.00 | $ 386.00 | $ 8,106.00 |
| 23 | Melvin Guse | Oats/W.rye or W.wheat | $1,775.00 | 40 | 10.0 | $ 7,100.00 | $ 355.00 | $ 7,455.00 |
| 24 | Eugene Bauman | Mixed Grass Hay | $1,759.00 | 50 | 10.0 | $ 8,790.00 | $ 439.00 | $ 9,229.00 |
| 25 | Orlin & C. Bauman | Oats | $1,759.00 | 40 | 10.0 | $ 7,030.00 | $ 351.00 | $ 7,381.00 |
| 26 | Troy Schue | Native Grasses | $2,147.00 | 70 | 2.0 | $ 3,004.00 | $ 150.00 | $ 3,154.00 |
| 27 | Leon Gerken | Native Prairie - Pasture | $1,900.00 | 60 | 10.0 | $ 11,400.00 | $ 570.00 | $ 11,970.00 |
| 28 | Don Davis | Timothy | $1,390.00 | 50 | 9.0 | $ 6,255.00 | $ 312.00 | $ 6,567.00 |
| | Don Davis | Hazelnuts | $1,762.00 | 60 | 1.0 | $ 1,057.00 | $ 52.00 | $ 1,109.00 |
| 29 | Jane Olson | Native-Side oats Grama | $1,684.00 | 70 | 5.8 | $ 6,832.00 | $ 341.00 | $ 7,173.00 |
| 30 | Vern Arndt | Native Grasses | $2,085.00 | 60 | 10.0 | $ 12,509.00 | | $ 12,509.00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 31 | Wade Sagehorn | Natives & Living Snow fence | $1,811.00 | 70 | 2.0 | $ 2,534.00 | $ 126.00 | $ 2,660.00 |
| 32 | Alice Gaines | Native Grasses | $1,515.00 | 60 | 7.2 | $ 6,538.00 | $ 326.00 | $ 6,864.00 |
| 33 | Curt Olson | Native Grass & shrubs | $1,903.00 | 70 | 2.7 | $ 3,570.00 | $ 178.00 | $ 3,748.00 |
| | | | | | 271.9 | $ 280,875.00 | $13,407.00 | $ 294,282.00 |

## 3rd Crop Demonstration Plots

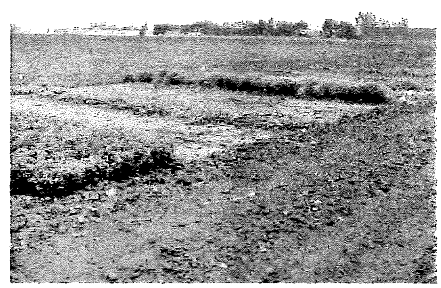
Establishment of 3rd crop demonstration sites at four locations across Minnesota was one of the goals of this project. To compliment ongoing efforts by project partners, two acre demonstration plantings were to be established within the greater Blue Earth, Chippewa, Lower Minnesota and Roseau watersheds. Each site would demonstrate at least ten species of 3rd crops.

Sites have been established at the following four locations:

- Heritage Acres, Fairmont [Blue Earth Watershed]
- Magnusson Farm, Roseau [Roseau River Watershed]
- Prairie Horizons Farm, Starbuck [Chippewa River]
- Seven Stories Farm, Belle Plaine [Lower Minnesota Watershed]

**Heritage Acres –** The Heritage Acres site was established in the spring of 2004 and is located on the western shore of Lake Sisseton at the Heritage Acres Agricultural Interpretive Center. The site consists of 50 species of various crops in 30 foot rows on one acre and then approximately ten acres of small grain that is used annually for their threshing day. Annual 3rd Crop Field Days have been held at the site. In 2005 the North American Temperate Agroforestry Conference stopped at the site as part of an agroforestry tour in south central Minnesota.

Ag Producers learning about 3rd Crops.



Demo Site in the first year.

Species included at the Heritage Acres site include:

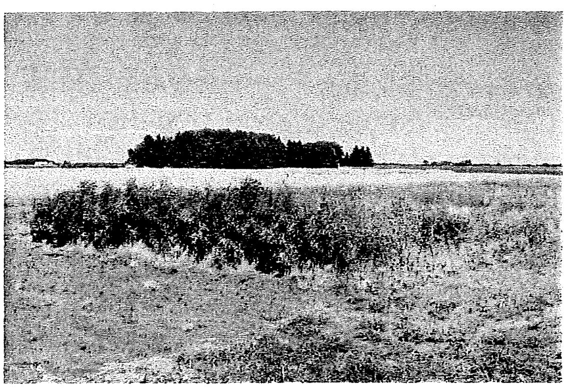
| | | |
|---|---|---|
| "Bison" Big Blue Stem | Switchgrass | "Itasca" Little Blue Stem |
| "Pierre" side oats grama | Buffalo grass | Purple Prairie Clover |
| Perennial flax | Buckwheat | Alfalfa [Fiber] CW 75046 |
| Illinois bundleflower | Lead Plant | Wild Senna |
| Blue Wild Indigo | False Indigo | Milk Vetch |

Canadian Wild Rye
Bittersweet
McDermond Pear
Highbush Cranberry
~~Black Chokeberry~~
Red Dogwood
Wild Hazelnuts
Buffalo Berry
American Elderberry
"Maiden's Bush" Lilac [lite pink]
Common Purple Lilac
"Villosa" lilac [legacy]

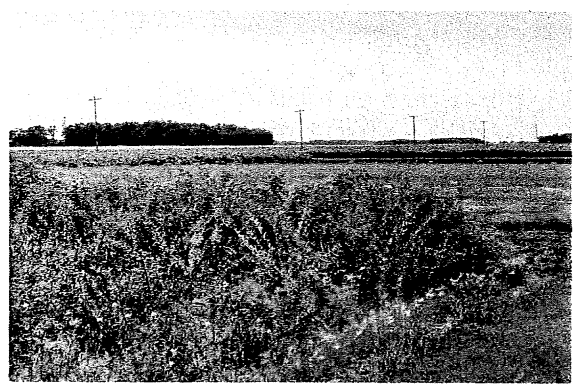
Mesic Forb Mix
Black Currents
Juneberry
Chokeberry
~~Nanny berry~~
Wild Grape
American Cranbush
Pin Cherry
Prairie Cordgrass
Magenta Lilac
Common White Lilac
Common Lilac

Slender wheatgrass
Badgersett Hazelnuts
American Plum
Forsythia
Cardinal Dogwood
Golden Current
Sand Cherry
French Pussy Willow
"Chinese" Lilac
"Sunday" Lilac [lite purple]
"Pekin" Lilac

**Magnusson Farm –** In the fall of 2003 twenty five native species were planted on the Magnusson Farm northwest of Roseau to evaluate and demonstrate the potential seed production of those species in the region. There is also interest in the plant potential for biomass energy from natives. The plantings consisted of perennial grasses, forbs and woody species. A field day is held each year in June for farmers, agricultural industry representatives, bankers, insurance brokers, seed processors and state and federal agency representatives. Annual attendance is about 120 people.



Roseau Demonstration Site



False Indigo, a native legume, in the foreground.

Species included at the Magnusson Farm are:

False Indigo
Lead Plant
American Vetch
Pale pea
Round Headed Bush Clover

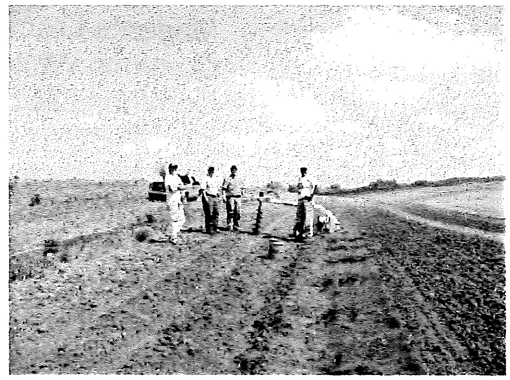
Perennial flax
Wild Senna
Showy Tick Trefoil
White Prairie Clover
Prairie Indigo

Blue Wild Indigo
Illinois Bundleflower
Canada Milkvetch
Purple Prairie Clover
Wild Lupine

**Prairie Horizons Farm --** Luverne and Mary Jo Forbord operate Prairie Horizons Farm near Starbuck in the Chippewa River watershed. The planting was established in the spring of 2006. Mats were put down to assist with weed control at the site. Species planted at the site include:

| | | |
|---|---|---|
| Hardy Apricot | Buffalo grass | Indian grass |
| Big bluestem | Switchgrass | Buffalo berry |
| Nanking cherry | Black chokeberry | Chokecherry |
| Golden current | Badgersett Hazelnuts | Native Hazelnuts |
| Magenta Lilac | Usarian pear | Curly willow |

Planting at Prairie Horizons Farm



Planting is 1320 feet long, 3 rows wide

**Seven Stories Farm --** Heidi Morlock lives with her family on Seven Stories Farm between Belle Plaine and Jordan. The farm, owned by Heidi's mother, is a great example of a working third crop farm. The farm is set up to capitalize on the near by urban market utilizing local Farmer's Markets or sales on site. In addition they host a Day Camp for kids to get connected with nature and they also host small musical events on their farm. Crops demonstrated include:

| | | |
|---|---|---|
| Hazelnuts | Black Beans | Alfalfa [in rotation] |
| Cut flowers | Curly Willow | Dogwood |
| Korean Pine Nuts | Strawberries | Blueberries |
| Wetland Restoration | Black Walnuts | June Berry |
| Raspberries | Native grasses | Day Camps for Kids |
| Music Events | Several varieties of vegetables | |

Field Day attendees learning from Heidi

Curly willows

We have compiled a book called "Native Plants and 3rd Crops For Water Quality – BERBI 3rd Crop Producers" of all the landowners and stories about why they choose to grow a third crop and how they are fitting it into their farming system. The book also includes information on the four demonstration sites. We plan to use this book in the future to inspire other growers who want to try a third crop. A copy of the book is included as a separate document with this report.

## Agronomic Assessment -- Landscape Position Experiments

## - Replicated Large Plot Field Research

**Waseca**: A study site was established in 2004 at the University of Minnesota Southern Research and Outreach Center's Agricultural Ecology Research Farm near Waseca. Corn, alfalfa, willow, poplar, and Illinois bundleflower/big bluestem were planted in a strip along a soil Catena typical of south-central Minnesota. Six landscape positions were identified within this study area using GIS terrain analysis; flat, east-facing hillslope, 2 west facing hillslope positions (differing by slope), depositional, and summit. Four replicates were established within each landscape position. Willow (SX64) cuttings were planted on May 19, 2004 in a high density twin row configuration. In a twin-row configuration, cuttings are spaced 60 cm apart within each row. The distance between rows is 75 cm with 150 cm between each twin row. This configuration results in a density of 14,332 cuttings/ha. The willow strip consisted of three double rows running the entire length of the study area. Poplar (NM-6) cuttings were planted on May 19, 2004 in a 4 ft x 4 ft foot grid configuration. Poplar strips consisted of four rows running the entire length of the study area. Each willow and poplar cutting was approximately 25 cm long and planted to a depth of 20 cm, leaving 1-2 buds above ground. A 10 ft strip of alfalfa (Garst 620) was broadcast planted at 20 lbs/a on April 17, 2004. Corn was planted at 32,000 seeds per acre on May 2, 2004. Soybeans were planted at 128,000 seeds per acre on June 3, 2005. Both corn and soybeans were planted in 30 inch row spacing and consisted of 4 rows running the entire length of the study area. Standard fertility and weed control practices were followed. Alfalfa was cut July 20 and August 28 in 2004; however, samples were only obtained on the August cutting date. Alfalfa was cut on June 30, August 1, and September 6 in 2005. Biomass samples were obtained after each cutting in 2005. Corn and soybean was harvested October 24, 2004 and October 10, 2005 respectively. Willows were coppiced on December 14, 2005 using a sickle mower. Alfalfa biomass samples were collected from 0.093 $m^{-2}$ quadrants from each replicate after each cutting. Basal stem diameter (measured 30 cm above ground level) and plant height were obtained from poplar and willow plants in each replicate after leaf drop in the fall. Plant density was also determined in each plot of the study. Terrain analysis was performed based on a DEM of the site to determine topographic features and surface water flow characteristics. Soil samples collected from each landscape position to characterize soil physical and chemical characteristics.

Discussion of 2004 data will be confined to alfalfa and corn data because both poplar and willow were in the establishment year and the Illinois bundleflower/big bluestem mix did not establish. Furthermore, limited disease/pest issues in 2004 confounded the results resulting in low interpretive value. In 2004, productivity of corn and alfalfa differed significantly between landscape positions. Alfalfa dry weight was reduced in deposition and west-facing hillslope position compared to all others. Corn also showed the same trend but also did poorly on site 6, which was a second west-facing hillslope with steeper slope that site 2. This data suggests that depositional areas and west-facing hillslope positions are less favorable for the corn and alfalfa in 2004.

In our short-rotation coppice system, willow was coppiced fall 2004. Coppicing essentially results in a plant with many stems instead of one main trunk. Therefore, the 2005 willow growth data represents new growth in the first year after coppice. Poplar was not managed as a coppice system and is presented as second year growth. In 2005, alfalfa, willow, and poplar productivity was significantly affected by landscape position. Alfalfa dry weight (averaged over four cuttings) was greatest on an east-facing hillslope, summit, and flat landscape positions. Alfalfa tended to be less productive in depositional and west-facing hillslope positions. Alfalfa stands were significantly reduced by wet conditions in the depositional areas. Conversely, willow productivity (stem diameter, shoots per plant, and height parameters) was greater in depositional areas when compared to an east-facing hillslope where alfalfa productivity was highest. For poplar, growth and productivity was high on most landscape positions with the exception of the depositional area. Soybean yield was reduced when grown in the depositional site as compared to other landscape positions.

**2005 –Strip Trial – Waseca**

**Table 1** - The effect of landscape position on soybean, alfalfa and willow yield

| Site | Description | Soybean | | | Alfalfa | | | Willow |
|---|---|---|---|---|---|---|---|---|
| | | | Cutting 1 | Cutting 2 | Cutting 3 | Cutting 4 | Total | |
| # | | ------------ | ------------ | ----------- | Kg/ha | ------------ | ------------ | ------------ |
| 1 | Flat | 3164 b | 2840 abc | 3260 a | 2680 a | 1140 bc | 10920 a | 2203 b |
| 2 | W Hillslope | 2827 c | 2420 c | 2480 b | 2860 b | 1020 c | 8780 c | 294 d |
| 3 | Deposition | 2683 c | 0 d | 0 c | 0 c | 22 d | 22 d | 4249 a |
| 4 | E Hillslope | 3269 ab | 3200 a | 3020 a | 3060 b | 1580 a | 10860 a | 882 cd |
| 5 | Summit | 3175 b | 3080 ab | 2940 a | 3180 b | 1640 a | 10840 a | 1735 bc |
| 6 | W Hillslope | 3559 a | 2700 bc | 2440 b | 3140 b | 1280 b | 9560 b | 4339 a |

**Table 2** - The effect of landscape position on willow height and number of shoots

| Site | Description | Soybean Density | Willow Height | Shoots |
|---|---|---|---|---|
| # | | plts/acre | cm | #/plant |
| 1 | Flat | 132422 bc | 160 bc | 10 a |
| 2 | W Hillslope | 141570 ab | 126 c | 3 d |
| 3 | Deposition | 114563 d | 204 ab | 4 cd |
| 4 | E Hillslope | 123275 dc | 140 c | 4 cd |
| 5 | Summit | 117176 d | 159 bc | 7 bc |
| 6 | W Hillslope | 143748 a | 231 a | 8 ab |

Seeding an alternative perennial crop that is adapted to wet and cool soil environments in lieu of typical corn and alfalfa crops may increase overall productivity of the field as well as address critical soil erosion and soil nutrient loss issues. We will extend these plantings to other landscape positions and consider other alternative perennial crops in the design of future research.

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**Fairmont**: The second landscape study was established in 2004 and 2005 at Fairmont, Minnesota. Procedures were modified from those described for Waseca. At Fairmont, Illinois bundleflower, switchgrass, alfalfa, cottonwood, hazelnut, and willow were established at two landscape positions (summit and toe slope) in 2004. Illinois bundleflower, switchgrass, and hazelnut were slow to establish because of poor growing conditions. Alfalfa yields were measured and willow and cottonwood stem diameter and height were measured in 2005. Growth and development data will be recorded in 2006-2008.

**Table 3** - 2006 Fairmont Hill Slope & Toe Slope data and height, diameter and stand counts

| **Average Height & Diameter** | | | | | | **Stand Counts per M$^2$** | | |
|---|---|---|---|---|---|---|---|---|
| | **Location** | | | **Location** | | | **Location** | |
| | **Hill Slope** | **Toe Slope** | | **Hill Slope** | **Toe Slope** | | **Hill Slope** | **Toe Slope** |
| | Average ht (cm) | | | Average Stem diameter (mm) | | | Average plants (m$^2$) | |
| **Poplar** | 293 | 339 | **Poplar** | 25 | 29 | **Alfalfa** | 305 | 133 |
| **Willow** | 124 | 169 | **Willow** | 7 | 9 | **IBF** | 7 | 4 |
| | | | | | | **Hazelnut** | 1 | 0.44 |

*Poplar & Willow diameter taken at 30cm.
*Poplar & Willow data taken fall of 2005, average of 10 plants per plot.
*Stand counts taken June 2006.
**Note**: Height and stem diameter data is shown for 2 landscape positions for poplar and willow as we did not want to destructively harvest. For both species it appears that there is a landscape position effect on height and stem diameter. For alfalfa, Illinois bundleflower (IBF), and hazelnut we measured plant populations. Alfalfa polulations were greatly affected by location and Illinois blundleflower and hazelnut to a lesser extent.

**Waseca and Rosemont**: The third landscape position study was initiated in 2005. From these initial experiments we have discovered that planting perennial species across a wide range of landscape positions is very risky. Many environments are ideal for plant development for only a short period of time and the plants become susceptible to stand loss under the less than ideal conditions. As a result of this observation, in 2005 an additional landscape position experiment was established in wetland areas at Waseca and Rosemount, we established willow, cottonwood, prairie cordgrass, and false indigo. The experiment was designed to evaluate the potential to establish plants in riparian areas that are characterized by having a wide range of moisture regimes, ranging from frequent flooding to drought. Beginning in 2006, we will measure the establishment success and biomass production potential of each perennial crop annually.

**Lower Minnesota River - Sand Creek**. The fourth landscape position study was initiated in 2004 to evaluate the establishment of Illinois bundleflower, switchgrass, big bluestem, little bluestem, and alfalfa in upland environments. The establishment of the plantings was evaluated in 2005. The stands that established were very sparse so we decided not to continue the experiment beyond the second year. This experiment continues to high-light one of the major issues that will face farmers as they try to diversify there cropping systems, many of the potential perennial 3rd crops have a risk associated with their establishment.

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## Elm Creek Watershed Study

Watershed monitoring suggests that the combination of wetlands with associated perennial vegetation reduces peak flow discharges and loading of nitrogen, total suspended solids (TSS), and total phosphorus to downstream locations in comparison with drained corn-soybean crops. The following summary is presented with details in Appendix A of this report.

Watershed monitoring stations were chosen to identify differences in water quality and quantity from row-crop dominated watershed versus those with significant areas of wetlands and/or perennial crops. Two watersheds are being monitored, the JD 73#2 (Kittleson) watershed, 1300 acres, and the Ditch 37 (SHEEK) watershed, 3700 acres. Parameters being measured are water discharge as channel flow, tile flow or wetland outflow, total phosphorous (TP), total suspended solids - TSS, nitrate + nitrite nitrogen, and orthophosphorous (ORP).

Results from 2005 represent the first year of monitoring following perennial crop and wetland establishment over 2003-2004. Water discharge measurements indicate that about 75-80% of the water flowing into the Kittleson wetland is tile flow. The two tile main outlets being monitored (W3 and W7) had relatively consistent flow, ranging from 0.01 cfs to 1.46 cfs at W3 with slightly less flow out of W7. Tile flow had nearly constant, high levels of nitrogen, with means of 21.4 and 17.4 mg/l for W3 and W7 respectively. TP and ORP was low from the tile mains, generally less than 0.05 mg/l with a maximum of near 0.2 mg/l.

In contrast, surface channels from the corn-soybean fields (W2 and W4) flowed intermittently for less than 15 days of the year. Flow occurred in response to intense rainfall and produced short-duration hydrographs, with peaks exceeding 100 cfs at stations W2 and W4. These runoff events had high velocities, exceeding 9 ft/second which contributed to gully erosion downstream of the outlets. Nutrient loads in surface water outflow were high for TP, ORP and TSS and moderately high in total nitrogen.

Water at the wetland outlet structure (station W5) discharged an average rate of 5 cfs, with a maximum of about 10 cfs. Flows are fairly constant from the outlet structure with gradual increases and long duration recession flows following rainstorms. Water quality samples at the wetland outlet were lower in nitrogen than the tile flow with a mean of 0.41 mg/l and a max of 4.5 mg/l; TP averaged 0.35 mg/l and ORP 0.31 mg/l. The majority of TSS samples were <2 mg/l although a maximum of 84 mg/l was recorded on 12 May 2006, on the rising limb of the hydrograph.

The Ditch 37/SHEEK wetland outlet produced similar results to the Kittleson wetland outlet, though discharge was significantly less from station S1, with a maximum of around 5 cfs. Water quality values were very similar to the Kittleson wetland outlet, with slightly lower nitrogen concentrations. Downstream at the JD 37 watershed outlet (Station S2), total nitrogen ranged from 1.75 to 10.6

mg/l, slightly less than tile outlets but much greater than the wetland outlets. Phosphorous levels were slightly greater than at the wetland outlet (S1) ranging from 0.1 to 0.5 mg/l for both TP and ORP. TSS was very low from the wetland outlet, usually less than 2 mg/l. In contrast, TSS at the watershed outlet (S2) was usually low (<10 mg/l) but rose greatly at high flow conditions, up to 73 m/l or more. These data represent a watershed which has approximately 650 acres of perennial vegetative cover – wetland complexes within a total area of roughly 3700 acres.

## Hydrologic Modeling

Hydrologic analysis and modeling research supported by CSREES (USDA) complemented the on-going research sponsored by the LCMR. The results of this research suggest that the transformation of mixed perennial cropping with wetlands to intensively drained corn-soybeans has increased streamflow levels in watersheds of the Minnesota River basin (Ennaanay 2006). Furthermore, hydrologic simulation suggests that by replacing annual crops on wet soils with a combination of wetlands (restored) and woody crops (such as hybrid poplar), peak flows associated with rainstorms and annual flow volumes can be reduced; the magnitude of reductions depends on the percentage of area in the watershed that is changed. These results are being reported here as they are integral to the overall objectives of the LCMR research.

The modeling study was prompted by the recognition that over a century of intensive agricultural development and wetland drainage in the Minnesota River Basin (MRB) has resulted in hydrologically unstable streams and polluted water bodies. This study focused on two aspects of stream flow regimes related to land use changes in the MRB: (1) the historical impacts of drainage and associated agricultural practices on the hydrologic regime of two tributary watersheds, the Lesueur and Cottonwood, having different levels of tile drainage densities, and (2) the response to conversions from corn to perennial vegetation and wetland restoration on portions of the Cottonwood watershed as simulated using the Hydrologic Simulation Program-FORTRAN (HSPF) model. Long term trend analysis of stormflow runoff, baseflow, and 7-day low flow indicated that all three increased over the period 1939-2002. Double-mass curve analysis suggests that baseflow and 7-day low flow were higher in the Lesueur than in the Cottonwood, presumably due to the greater density of tile drainage. Similar results have been found by researchers investigating several streams and rivers in Iowa (Schilling and Libra 2003, Schilling and Wolter 2005).

The hydrologic model, HSPF, was calibrated for the Cottonwood watershed and model parameters were developed for corn and hybrid poplar based on plot data from Waseca that was supported by the LCMR. Computer simulations indicated that conversions from annual corn crops to hybrid poplar and restored wetlands on wet soils reduced annual water yield, peak flows for small storm events, baseflows, and 7-day low flows. The results of this study suggest that converting wet soil areas to perennial woody crops and wetlands in the MRB can potentially improve hydrologic conditions, stream channel stability and water quality. The greater the area converted, the greater were the effects. It is important to note that when the wettest soils were converted back to wetlands and hybrid poplar, there were significant reductions in streamflow which has implications for reducing nutrient loading and sediment to tributaries in the Minnesota River.

**References:**

Ennaanay, D. 2006. Impacts of land use changes on the hydrologic regime in the Minnesota River Basin. PhD dissertation, University of Minnesota, St. Paul, MN.

Schilling, E.K. and R.D. Libra. 2003. Increased baseflow in Iowa over the second half of the 20th century. Journal of the American Water Resources Association 39(4):851-860.

Schilling, E.K. and C.F. Wolter, 2005. Estimation of streamflow, baseflow, and nitrate-nitrogen loads in Iowa using multiple linear regression models. Journal of the American Water Resources Association 41(6):1333-1346.

There is a balance of $15,974.07 for Result 1. This is the result of easement and SWCD technical and administrative slippage that occurred from two projects that had encumbered funds, but were not established. Notification to us was too late to re-encumber the funds.

| | | |
|---|---|---|
| **Summary Budget Information for Result 1:** | **LCMR Budget** | **$ 409,375.00** |
| | **Spent** | **$ 393,400.93** |
| | **Balance** | **$ 15,974.07** |

**Result 2:** Determine cumulative economic and water quality and quantity impacts of native plants and 3rd Crop systems at the watershed level and their relation to rural economic vitality.

## Surface runoff, sediment and water quality

We report runoff data for the first year of establishment (2004) at Waseca. Two replications of surface runoff plots were established for five crops: perennial flax (PF), Illinois bundleflower (IBF), hazelnuts seedlings (HN) with sod grass cover, hybrid willow seedlings (HW) without ground cover, and soybeans. In 2005 the soybean crop was replaced with corn. Comparisons of runoff, sediment, total phosphorus and nitrate-nitrogen are presented in Appendix B for 2004. From snowmelt in March through summer rains, HN and PF, with their high percentage of ground cover, had lower runoff (Table 1), total suspended solids (TSS), and phosphorus than soybean and HW plots (which were essentially bare soil plots with small willow seedlings present). Nitrate-nitrogen loadings were nearly equal during the runoff events for soybean, IBF, HN and PF, but less than HW. With less than 10% ground cover, the HW plots responded similarly to soybean during early summer storms. These results demonstrate the importance of soil cover as a best management practice to reduce runoff, soil erosion, and nutrients during establishment of perennial cropping systems.

**Table 4** - Monthly precipitation and runoff from willow, soybean, Illinois bundleflower, hazelnut, and perennial flax for 2004 at Waseca.

| | | Average runoff in mm per plot per month | | | | |
|---|---|---|---|---|---|---|
| Month | Total precipitation (mm) | Willow seedlings | Soybean | Illinois bundleflower (IBF) | Hazelnut – sod grass | Perennial flax |
| Feb | 40 | 34 | 15 | 48 | 32 | 23 |
| Mar | 71 | 25 | 26 | 9 | 1 | 1 |
| Apr | 45 | 0 | 0 | 3 | 0 | 0 |
| May | 143 | 9 | 4 | 10 | 12 | 1 |
| June | 163 | 16 | 21 | 21 | 5 | 2 |
| July | 180 | 82 | 82 | 33 | 22 | 38 |
| Aug | 146 | 78 | 16 | 18 | 20 | 1 |
| Sep | 176 | 82 | 14 | 38 | 10 | 19 |
| Oct | 62 | 31 | 18 | 3 | 1 | 4 |
| Totals | 1025 | 326 | 196 | 183 | 104 | 88 |

**Reference**: Colson, A. Runoff, sediment, and nutrients from newly established woody and herbaceous perennial crops and soybean. Master of Science Thesis, University of Minnesota, St. Paul.

**Note**: Runoff data was collected for 2005, but due to malfunctioning data loggers, the data are being re-analyzed. These data will be reported in subsequent progress reports of the continuing LCMR project (2005-2008).

## Subsurface drainage

Hydrology: Tile drainage at the Waseca plots is presented for 2004 and 2005. Perennial crops were planted in 2004. In 2005, the tree crops were fully established with good canopy growth for comparisons with herbaceous perennials and corn-soybean crops. Rainfall during the growing season in 2004 totaled 701 mm (Table 2). High levels of tile flow were observed for all plots with the lowest flow under Illinois bundleflower-big bluestem and the hazelnut – sod grass cover. The higher rainfall amounts in 2005 (1138 mm from 3/29 – 10/23) resulted in less tile flow than in 2004 (table 3). The corn plots had the highest level of tile line flow during the 2005 growing season, while the IBF/BB mixture, alfalfa and the hazelnut/grass mixture had the lowest flow. Hybrid poplar, willow and perennial flax were intermediate in tile line flow. Perennial flax had the earliest growth but did not produce a high level of biomass thus it did not have a high level of water use, although it provided good season-long ground cover. The cropping systems with the lowest tile line flow had early biomass production, which continued throughout the growing season, this resulted in high water use which resulted in reduced tile line flow.

**Table 5** - 2004 Cropping System Tile Line Flow and Season Totals.

**2004 Tile Flow l/week**

| Week of: | Rainfall (mm) | Alfalfa | IBF BB | Poplar | Willow | Hazel | Flax | Soybean |
|---|---|---|---|---|---|---|---|---|
| | | Average Weekly Tile Flow (L/week) | | | | | | |
| | | l/week | | | | | | |
| 3/21 | 28 | 22 | 42 | 27 | 57 | 11 | 16 | 0 |
| 3/28 | 0 | 296 | 216 | 83 | 204 | 162 | 204 | 0 |
| 4/4 | 0 | 14 | 10 | 1 | 7 | 0 | 24 | 0 |
| 4/11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 4/18 | 1 | 0 | 1 | 0 | 6 | 0 | 16 | 1 |
| 4/25 | 3 | 16 | 7 | 0 | 27 | 10 | 15 | 26 |
| 5/2 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 42 |
| 5/9 | 26 | 104 | 45 | 12 | 195 | 67 | 136 | 82 |
| 5/16 | 52 | 1527 | 505 | 1894 | 2828 | 1759 | 2354 | 1487 |
| 5/23 | 23 | 3479 | 1262 | 3365 | 3659 | 2447 | 3978 | 3619 |
| 5/30 | 10 | 1834 | 637 | 664 | 1715 | 1051 | 1200 | 2656 |
| 6/6 | 102 | 9005 | 3070 | 14619 | 17341 | 10908 | 15200 | 9966 |
| 6/13 | 3 | 2503 | 785 | 1523 | 2581 | 1229 | 1917 | 3833 |
| 6/20 | 10 | 238 | 23 | 31 | 270 | 25 | 279 | 1377 |
| 6/27 | 18 | 0 | 0 | 0 | 1 | 0 | 61 | 135 |
| 7/4 | 77 | 827 | 1121 | 1943 | 4324 | 2025 | 6033 | 2057 |
| 7/11 | 35 | 2961 | 1860 | 2163 | 4229 | 5100 | 7720 | 3587 |
| 7/18 | 10 | 330 | 120 | 216 | 777 | 379 | 472 | 1168 |
| 7/25 | 36 | 9 | 16 | 113 | 7 | 83 | 536 | 135 |
| 8/1 | 12 | 0 | 1 | 0 | 45 | 0 | 120 | 18 |
| 8/8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/15 | 57 | 120 | 940 | 1049 | 6314 | 1599 | 4094 | 51 |
| 8/22 | 23 | 1 | 0 | 13 | 39 | 0 | 42 | 2 |
| 8/29 | 18 | 1 | 1 | 1 | 8 | 0 | 10 | 4 |
| 9/5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9/12 | 127 | 4585 | 2399 | 4686 | 8627 | 6728 | 9164 | 2475 |
| 9/19 | 6 | 218 | 75 | 572 | 641 | 292 | 400 | 326 |
| 9/26 | 0 | 0 | 0 | 8 | 0 | 0 | 10 | 35 |
| **Annual Total** | 701 | 28,090 | 13,136 | 32,984 | 53,899 | 33,874 | 54,000 | 33,085 |

**Table 6** - 2005 Cropping System Tile Line Flow and Season Totals.

| Week of: | Rainfall (mm) | Alfalfa | IBF BB | Poplar | Willow | Hazel | Flax | Corn |
|---|---|---|---|---|---|---|---|---|
| | | Average Weekly Tile Flow (L/week) | | | | | | |
| | | L/week | | | | | | |
| 3/29 | 36 | 35 | 4 | 2,330 | 1,162 | 835 | 2,625 | 950 |
| 4/3 | 2 | 0 | 0 | 343 | 3 | 0 | 42 | 466 |
| 4/10 | 101 | 3,705 | 2,148 | 7,341 | 4,039 | 4,007 | 6,209 | 5,364 |
| 4/17 | 12 | 790 | 521 | 1,965 | 1,075 | 659 | 1,186 | 2,951 |
| 4/24 | 10 | 29 | 2 | 410 | 20 | 0 | 126 | 1,088 |
| 5/1 | 35 | 0 | 0 | 103 | 0 | 0 | 0 | 515 |
| 5/8 | 112 | 5,083 | 3,969 | 8,703 | 6,571 | 4,644 | 7,220 | 7,886 |
| 5/15 | 39 | 1,565 | 1,197 | 2,824 | 2,159 | 1,121 | 1,822 | 4,345 |
| 5/22 | 26 | 109 | 322 | 781 | 601 | 141 | 347 | 2,608 |
| 5/29 | 9 | 0 | 0 | 95 | 0 | 0 | 14 | 1,376 |
| 6/5 | 17 | 1 | 3 | 3 | 2 | 0 | 3 | 1,336 |
| 6/12 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 831 |
| 6/19 | 67 | 1 | 1 | 0 | 1 | 0 | 0 | 596 |
| 6/26 | 76 | 38 | 64 | 383 | 34 | 63 | 559 | 1,932 |
| 7/3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 733 |
| 7/10 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 219 |
| 7/17 | 66 | 2 | 3 | 16 | 2 | 0 | 62 | 98 |
| 7/24 | 23 | 0 | 0 | 0 | 1 | 0 | 0 | 9 |
| 7/31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/7 | 98 | 17 | 7 | 30 | 12 | 1 | 129 | 10 |
| 8/14 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/21 | 64 | 0 | 0 | 0 | 2 | 1 | 22 | 3 |
| 8/28 | 29 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9/4 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9/11 | 25 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 9/18 | 164 | 1,240 | 1,287 | 42 | 4,012 | 3,722 | 3,155 | 668 |
| 9/25 | 0 | 730 | 891 | 42 | 1,007 | 1,270 | 2,165 | 1,180 |
| 10/2 | 34 | 1 | 72 | 6 | 1 | 1 | 58 | 746 |
| 10/9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 564 |
| 10/16 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 303 |
| 10/23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 102 |
| Annual Total | 1,138 | 13,344 | 10,492 | 25,419 | 20,704 | 16,465 | 25,744 | 36,879 |

Total nitrogen loss in the tile line experiment was proportional to tile line flow. This would suggest that water use is an effective method to reduce the loss of nitrate nitrogen from cropping systems. Our data suggests that perennial 3rd crops have potential to reduce nitrate nitrogen losses from tiled agricultural landscape systems.

We will continue to conduct the tile line experiment for at least the next two years to determine if the pattern of tile line flow as measured during the establishment phase of the perennial cropping systems will change as the systems mature. We would expect the woody systems to become more effective as they mature while some of the herbaceous systems to be less effective as they experience stand loss.

## Soil Moisture

The first year following establishment of perennial crops on both the runoff and drainage plots exhibited little difference in soil moisture uptake. The root and crown systems of willow and hybrid poplar seedlings would not be expected to transpire large amounts of soil water until after 2-3 years of growth. During establishment, as indicated in the runoff differences between willow seedlings with no ground cover compared to hybrid hazelnut seedlings with sod-grass cover from the runoff plot data for 2004, ground cover is essential to minimize surface runoff and soil loss. Furthermore, during both 2004 and 2005, Waseca experienced high levels of rainfall that masked soil moisture differences between young perennial crops. Surface soil moisture measurements taken at the drainage plots also showed no differences among crops during 2005 (see below):

**Table 7 - Soil Moisture at Waseca Drainage Plots (2005)**

| Cropping system | Monthly Average Percent Soil Moisture | | | | | | |
|---|---|---|---|---|---|---|---|
| | Apr | May | Jun | July | Aug | Sept. | Oct |
| **Alfalfa** | 18 | 16 | 17 | 13 | 13 | 16 | 16 |
| **IBF & BB** | 18 | 16 | 17 | 16 | 13 | 16 | 19 |
| **Poplar** | 17 | 16 | 16 | 14 | 13 | 16 | 20 |
| **Willow** | 17 | 15 | 18 | 13 | 13 | 15 | 18 |
| **Hazel** | 18 | 16 | 19 | 12 | 12 | 16 | 19 |
| **Flax** | 17 | 16 | 20 | 13 | 14 | 16 | 20 |

*Soil moisture taken to a depth of 10cm.

Soil moisture in a 4-yr old established hybrid poplar (HP) stand was compared with soil moisture under corn grown in a soybean-corn rotation. In 2004, soil moisture in the late summer was lower under HP than under corn. The following year, when the understory was cleared, soil moisture differences under the 5-year old stand of hybrid poplar were similar to that of corn. Therefore, it appears that the understory component of the young HP stand is important in depleting soil moisture. Earlier research in northwestern Minnesota showed dramatic soil moisture differences between 12-year old HP, switchgrass and wheat, with HP exhibiting much lower soil moisture during the mid to late summer (Perry 1998).

As the tree crops become more mature during the following two years, we expect to see differences in soil moisture depletion with depth among crops early in the summer and throughout the growing season.

Detailed soil moisture and soil frost analyses are being summarized in a M.S. thesis by M. Byrne (see excerpts in Appendix C).

## Soil Frost

The presence of perennial vegetation on the landscape can affect soil frost in several ways. If perennial crops, and particularly woody tree crops, reduce soil moisture over the growing season more than annual crops, reduced soil moisture conditions in the fall can result in less concrete type soil frost which is common in bare soil – fallow conditions on annual croplands. Perennial vegetation also affects soil frost by influencing the deposition of snow. Snow fence effects, which trap snow and thereby cause deeper snow in certain locations, provide insulation of the soil, thus reducing the depth and thickness of soil frost. With less concrete frost, drier soils, and a shallow layer of soil frost, perennial cover can potentially reduce snowmelt runoff and/or the magnitude of flows from rain-on-snow events in the spring. Forest cover, hybrid poplar, and to a lesser extent, switchgrass cover in the Red River Valley of the North (Christopherson 2001) have been shown to reduce frost depth and the occurrence of concrete soil frost in comparison to bare fields associated with annual crops.

For the first year following the establishment of perennial crops in the tile drainage plots, soil frost under flax was consistently shallower than under the other crops. Soil frost under willow seedlings and no soil cover was consistently deeper. Soil frost under the corn/soybean field was only slightly shallower than willow.

In the landscape position plots and mature poplar stands, soil frost under the mature poplar stand and cornfield were similar, and shallower than under the other crops. Willow seedlings with no ground cover consistently had the deepest soil frost, although soil frost under the young poplar was only slightly shallower.

Concrete frost was observed in all the plots during the first winter following establishment of perennial crops. Details of this work are presented in Appendix C.

## Economic analysis

The primary objective of the economic analysis is to investigate the economic viability of introducing agroforestry and perennial vegetation systems in the Minnesota River Basin. To accomplish this objective, we identified the following economic benefit categories (Table 1 Column 2). Following the results of literature surveys, we have chosen a list of economic benefit categories to be included in our economic analysis (Table 1 Column 3). By conducting brief phone interviews with representatives from the Department of Public Health and Corps of Engineers St. Paul District, we have confirmed that (i) cost savings at water storage facilities from sediment reductions and (ii) cost savings at drinking water treatment facilities from reduced nutrient loads are likely to be insignificant.

We are now close to finalizing the benefit computation for three benefits in the list: (1) flood control benefit, (2) saving in dredging costs, and (3) recreational benefits. The Computerized Agricultural

Crop Flood Damage Assessment System (CACFDAS) model was used to analyze flood control benefit (1); the avoided cost method was used to analyze the benefit from reduced sedimentation (2); and benefit transfer method was used to compute freshwater recreational benefit (3). As a result of our analysis, we have obtained "per unit" benefit ranges (Table 2). For the benefit analysis to be complete, we still need to obtain the estimates of predicted physical changes from our hydrologist team. The estimated per unit benefits can be multiplied by the estimated physical changes to yield total economic benefits for each category. The figures for other categories, i.e. income generation, cost savings in ditch cleaning, and cost savings in TMDL scheme, are very crude estimates and are currently revised.

The economic analysis using the CACFDAS model demonstrates the strength and uniqueness of our study. The hydrologic impacts were first modeled by our hydrologist team and then translated into the hydrograph inputs for the CACFDAS analysis. Economics team prepared crop budget inputs by using the results of the unique survey conducted in the Cottonwood watershed. The hydrologic change has two distinct impacts, one on the expected frequency of flood events and the other on the timing of the flood events within a year cycle. The in-depth modeling efforts of our hydrologist team, combined with the detailed crop budget (with dates of operations), allow us to simulate the impacts of the proposed vegetation changes with reasonable precision. The results of our simulation for eight scenarios are presented in Table 3. As shown, flood damages per peak flood acre are significantly reduced. This result comes from two distinct sources: one from the aforementioned changes in hydrograph and the other from the fact that the corn-soybean rotation is replaced with flood-resilient perennials. The expected annual damage is relatively small in contrast to this large change, primarily because we only simulated on a small reach within 22 river miles at the mouth of Cottonwood River.

Lastly, we also initiated a unique survey utilizing our learning group. The next round of our study needs to focus on the feasibility of the proposed vegetation system. This survey will provide for an important input for this purpose. The survey will (i) obtain the reasonable estimates of costs of land conversion and risk premium required for growers to adopt alternative crops, and (ii) help evaluate the effects of learning groups. The survey is currently administered by Lin Huang under the supervision of William Easter.

**Table 8** - Coverage of Benefit Estimates

| Benefit Category | Economic Significance | Benefit Est Included |
|---|---|---|
| **Flood control** | yes | yes |
| **Income generation** | yes | in process |
| **Savings in dredging costs** | moderate | yes |
| **Savings in ditch cleaning costs** | yes | in process |
| **Recreational benefits** | yes | yes |
| **Savings in water treatment** | no | no |
| **Siltation control for water storage** | no | no |
| **Carbon sequestration** | uncertain | no |
| **Enhanced wildlife habitat & landscape** | uncertain | no |
| **Cost savings in TMDL scheme** | uncertain | in process |

**Table 9** - Benefit Estimates Per Unit

| Benefit category | Unit | Estimates Range | | |
|---|---|---|---|---|
| | | Low | Best * | High |
| **Flood control** | **$/acre** | 11.66 | 35.06 | 100.36 |
| **Income generation (net) **** | **$/acre** | < 0.00 | -- | 587.56 |
| **Savings in dredging costs** | **$/CY** | -- | 6.50 | -- |
| **Savings in ditch cleaning costs **** | **$/foot** | -- | -- | 65.00 |
| **Recreational benefits** | **$/household** | -- | 11.80 | 59.87 |
| **Cost savings in TMDL scheme **** | **$/kg** | < 0.00 | -- | 7.89 |

* "Best" or "most prefered" among our alternative estimates.
** These figures are obtained with very rough computations.

**Table 10** - Summary of CACFDAS Analysis Cottonwood Watershed

| | Scenarios | Ag. Damages Per Acre (US$) | Expected Annual Area Flooded (Acre) | Expected Annual Damage Reduced (US$) |
|---|---|---|---|---|
| [1] | **Existing Condition *** | 151.16 | 66.25 | --- |
| [2] | **86% Drained Corn *** | 151.41 | 65.48 | 100 |
| [3] | **86% Undrained Corn *** | 135.25 | 65.82 | 1,112 |
| [4] | **11% Hybrid Poplar** | 139.5 | 63.99 | 1,087 |
| [5] | **29% Hybrid Poplar** | 116.1 | 62.63 | 2,743 |
| [6] | **59% Hybrid Poplar** | 81.86 | 59.83 | 5,116 |
| [7] | **77% Hybrid Poplar** | 60.95 | 58.31 | 6,460 |
| [8] | **86% Hybrid Poplar** | 50.8 | 58.50 | 7,043 |

* Damages calculated as 50-50 corn-soybean rotation.

**Summary Budget Information for Result 2: LCMR Budget $ 127,975.00**
**Balance $ 0.00**

**Result 3:** Accelerate implementation of native plant and 3rd crop production with demonstration and market identification, coordination and promotion.

Throughout this project we have used diverse approaches to develop and disseminate agronomic, technical, and research information about a variety of third crops. A series of fact sheets were developed on Hazelnuts, Native Plants for Seed or Plant Production, Hay/ Grazing Crops, Biomass Crops, Woody Ornamentals, Herbs and Plants for Essential Oils and Cover Crops. These, along with other third crop information were inserted into packets and distributed throughout the grant period. Over 1500 packets of 3rd crop information has been distributed to landowners/ operators.

In addition, we have held field days [16]; organized producer meetings [14]; fair displays [22] newsletters/ mailings [10]; presented 3rd crop related information at meetings – local [23], state [6] and national [2]; and assisted with two third crop learning groups. The learning groups were on hazelnuts and native seed and plant production. In 2005 we hosted a tour of 3rd crop sites [agroforestry related] in the greater Blue Earth River Watershed as part of the North American Agroforestry Conference held at Rochester, MN. Field days, 3rd Crop Walk N Talks, and tours are held at our demonstration plots, easement sites or other sites that represent 3rd crops.

Additional outreach methods include news releases/ articles [13 +]; radio interviews [18 +]; websites [BERBI, CINRAM] and one on one landowner contacts. The BERBI office is contacted on a regular basis for information or advice about 3rd crops. These discussions can range from general agronomic information, technical information [such as harvest timing, seed cleaning, etc.], business planning, enterprise development, inventions, and markets.

We have had a marketing assistant on staff through out the grant. This position has been paid ½ with LCMR funds and ½ with Bush Foundation funds. Through this position we have been able to identify viable markets, coordinate growers with markets, provide assistance with market development, identify a few markets to avoid, and advance third crop thinking. We have also assisted private industry in the development of their products by providing input and ideas, coordinating with area farmers and assisting with product testing. We worked with farmers to form a group to try and develop a flax enterprise [application submitted but not funded]; explore hazelnut commercialization challenges, frustrations and opportunities; expand bioenergy thinking beyond ethanol and biodiesel [think cellulosic!] and assisted with testing for a methane digester.

In addition, efforts have been made to advance bioindustrial development in the region that supports third crops. Adding a higher value product and/or multiple revenue streams to agricultural crops results in stronger rural economies. Examples include derivatives, carbon credits, nutrient trading, water quality credits, premiums for sustainably grown crops, and being able to qualify for the Conservation Security Program. Examples of companies that have interest in 3rd crops include Phenix Biocomposites, New World Amaranth, Spectrum [flax], Aveda, Rahr Malting, Faribault Mills, Biosun, New Horizons Milling, and Whole Grain Milling. There are several local market opportunities with farmers markets, restaurants and schools.

The Madelia Model that is being developed can be a national model for what third crops represent: a diverse agriculture, improved ecological services, local agricultural processing with living wage jobs, and a stronger community. The model is centered around the concept of evolving a rural community into one that promotes a sustainable mindset through the establishment of a biobased industrial park that utilizes agricultural crops grown in the region for renewable energy and value added processing.

A renewable energy plant as the base for the Madelia Model will potentially use 380,000 acres of native polycultures for conversion to energy. This would equal 20 percent of the agricultural landscape, within a 25 mile radius of Madelia, converted to perennials. Native polycultures being considered is a mixture of switchgrass, big blue stem and Indiangrass. By using a mixture of plants, biomass yields can be increased.

We have developed a list of markets for several third crops. The list includes both non-organic and organic markets. Some markets are pretty stable and consistent while others are continually evolving. One of our goals is to establish a rapport with a variety of market opportunities so as we work with farmers we can advise them of the best opportunities for their situation.

Throughout our 3rd crop efforts we have had many partners. These include farmers, private industry, University experts, Extension, SWCD's, Research and Outreach Centers, nonprofit partners, community leaders, elected officials and others. Their support and assistance has helped advance third crops far beyond where we thought they might be at this point. Many farmers are willing to grow different crops if we can develop viable markets. Bioenergy presents a great opportunity to really elevated 3rd crops on the landscape and we need to be prepared to capitalize on it. Other opportunities will continue to evolve and become viable.

We have a balance of $14,681.22 left in this result. This is because we over budgeted the marketing position and the costs for website development were not allocated to the project.

| | | |
|---|---|---|
| **Summary Budget Information for Result 3:** | **LCMR Budget** | **$ 84,650.00** |
| | **Amount Spent** | **$ 69,968.78** |
| | **Balance** | **$ 14,681.22** |

## V. TOTAL LCMR PROJECT BUDGET:

| | | **Actual** |
|---|---|---|
| **All Results: Personnel:** | **$ 271,900** | **$259,218.78** |
| **All Results: Equipment:** | **$ 31,100** | **$ 31,100.00** |
| **All Results: Development:** | **$ 0** | **$ 0.00** |
| **All Results: Acquisition:** | **$ 301,250** | **$285,482.00** |
| **All Results: Other:** | **$ 17,750** | **$ 15,543.93** |
| **TOTAL LCMR PROJECT BUDGET:** | **$ 622,000** | **$591,344.71** |

**Explanation of Capital Expenditures Greater Than $3,500:** The University of Minnesota will be purchasing equipment as part of the research component. There is one item that will cost over $3,500 and that is a Campbell Data Logger – CR23X [climatic data].

All equipment purchased through this project will continue to be utilized for similar purposes beyond the timeframe of this project.

## VI. PAST, PRESENT AND FUTURE SPENDING:

### A. Past Spending:

BERBI has received a grant for $10,000 for coordination and promotion of 3rd crops.

University of Minnesota has received a grant from CSREES for research titled "Improving Water Quality and Enhancing Hydrologic Stability of the Minnesota River through Agroforestry and Other Perennial Cropping Systems".

### B. Current Spending:

**National Watershed Initiative- EPA**, includes some money for easements for 3rd Crops [Three Rivers RC & D, Counties, SWCD, BERBI, MSU-Mankato- WRC] funded $ 800,000 - not all for 3rd Crops

**Dept. Of Energy** for **Fostering Biomass Markets in SC MN@** [BERBI, OEA, Extn., IATP] Pending

**Dept. Of Energy** for **Bio Refining Biomass Research** [U of MN, OEA, BERBI ] Pending

**SARE** for **>Train the Trainer= Professional Development of 3rd Crop Service Providers** [Uof MN, BERBI] pending

SARE for **Farmer Discussion Groups** [IATP, BERBI, Center for Rural Affairs, NE, Extension] pending

**Bush Foundation**, funded the other half of the marketing position in this LCMR project. They also supported administrative costs in the BERBI office. $148,000 over 3 years. [BERBI]

**EPA 319 Grant** was funded for $671,250 for Innovative Easements [3rd Crops], Innovative Cost Share, Manure Pit Abatement Training and Implementation Coordination in the Greater Blue Earth Watershed. [BERBI & GBERBA]

**The McKnight Foundation is** supporting Rural Advantage with capacity building and administrative costs to continue the development of the 3rd Crop Initiative. 3 years, $141,000 [Rural Advantage]

**Xcel Energy** through the Renewable Development Fund is funding a study of the feasibility of growing miscanthus x giaganthus in Minnesota for bioenergy. 3 years, $318, 500 [Rural Advantage]

**Office of Environmental Assistance** is funding a study to determine the biomass supply within a 25 mile radius of Madelia; analyze the data and determine the type of renewable energy, and the process, best suited to supply the Madelia community with renewable energy. 1 year, $9,999.00 [Rural Advantage]

**National Fish and Wildlife Foundation** funding to establish additional 3rd crop acres focusing on native grasses and pasture renovations. 18 months, $140,000 – Pending [Rural Advantage]

**Bush Foundation** funding to support continued work on the 3rd crop initiative, development of the Madelia Model, to develop and hire a Conservation Agronomist position to advance the third crop mindset, and initial funding to develop a business plan for the Madelia Model. 3 years, $250,000 – Pending [Rural Advantage]

**C. Required Match (if applicable)***: A match is not required for this project.*

**D. Future Spending:**

This proposal is Phase I what is intended to be a three phase project to the LCMR. We ~~continue to look for and identify other sources of funding and apply for them as we can.~~

## VII. Project Partners:

### 1. Partners Receiving LCMR Funds*:*

**University of Minnesota**- The University of Minnesota will be receiving $218,850 for their portion of this project. Fiscally, both BERBI and the University will work directly with BWSR. The work plan will be submitted as one document. Team members are Dr. Dean Current, Center for Integrated Natural Resources and Agricultural Management; Dr. Don Wyse, Agronomy; Dr. Craig Sheaffer, Agronomy; and Dr. Ken Brooks, Hydrologist

### 2. Project Cooperators*:*

Joseph Magner, PCA; Bill Easter, Applied Economics, University of Minnesota; Gary Wyatt, Dave Pharr and Mike Demchik, University of Minnesota Extension Service; Local SWCD's

**VIII. DISSEMINATION:** We plan to disseminate the information via a written final report and oral presentations were applicable. The information will be posted on the BERBI website [berbi.org] and the University literature can be posted on the University website. We will also have field days and presentations during the course of the project.

**IX. LOCATION***:* The majority of this project will be carried out in the Greater Blue Earth River Watershed in south central Minnesota. In addition, there will be two acre demonstration plots in the Roseau River, Chippewa, and Lower Minnesota watersheds.

## X. REPORTING REQUIREMENTS:

**Periodic work program progress reports will be submitted not later than January 31 and July 31 of each year. A final work program report and associated products will be submitted by June 30, 2006.**

**XI. RESEARCH PROJECTS:** Attached

Appendix A – Monitoring in the Elm Creek Watersheds 2005
Chris Lenhart and Ken Brooks

Appendix B -- 2004 Results of Runoff Plots at Waseca
[Taken from Colson, M.S. Thesis 2006]

Appendix C -- Excerpts from Marin Byrne MS Thesis draft [June 2006]

Appendix D -- References for papers and presentations

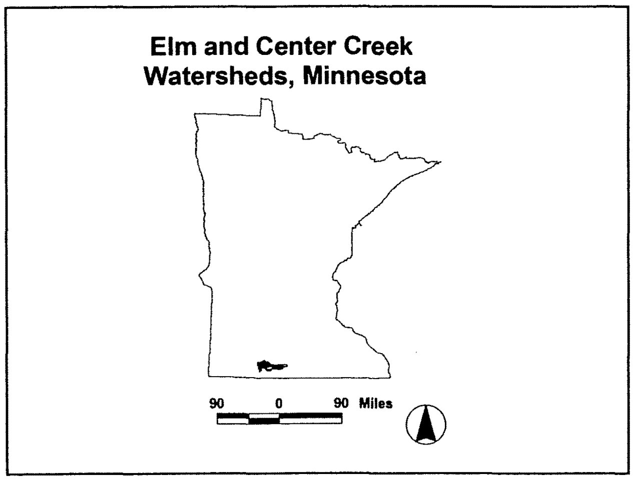
## APPENDIX A

## Monitoring in the Elm Creek Watersheds 2005[1]

**Chris Lenhart and Ken Brooks**

The project was designed to identify difference in the quantity and quality of runoff from small agricultural watersheds with different crop cover and wetland components at various spatial scales. This report covers the first year following wetland restoration and the establishment of perennial crops on a portion of the Sheek property, described below. The watersheds flow into Elm Creek which is a tributary of the Blue Earth River basin, located in south central Minnesota, near the towns of Trimont and Fairmont (Figure 1). The Elm Creek monitoring program focuses on the Judicial Ditch (JD) 73#2 (Kittleson) and JD 37 (Sheek) watersheds (Figures 2 & 3).

(Figure 1)




## Sampling Approach and Methodology

Watershed monitoring stations were chosen to find differences in water quality and quantity from row-crop dominated watershed versus those with significant areas of perennial (third) crops and wetland components. In the JD 73#2 (Kittleson) watershed, monitoring stations are located at surface channel outlets of corn-soy bean watersheds (stations W2 and W4), tile outlets from the same sub-watersheds (stations W3 and W7), a sub-watershed with a large, previously restored wetland (W1) and the mouth of the Kittleson wetland (W5), which was restored in November 2004. The goal of the project is to compare sediment and nutrient export from subwatersheds representing current corn-soybean farming with sub watersheds that have undergone partial wetland and perennial cropping and restoration. Hydrologic characteristics (seasonality, peak and duration of discharge) are also a key part of the data collection.

[1] This research is also supported by the Minnesota Pollution Control Agency as a research project of the TMDL program. We acknowledge the excellent support of Don Ide in collecting data and the support of the Mr. Kittleson and the SHEEK property owners for their cooperation. The Martin County SWCD and the St. Paul office of BWSR have been instrumental in getting this project established.

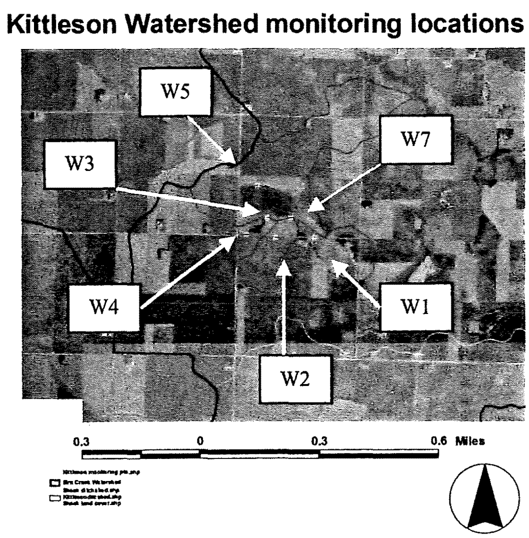
## 2005 Data: Hydrologic Monitoring of JD 73#2 Watershed

The 2005 data presented in this report represents the first year after perennial vegetation establishment and wetland restoration; therefore, a more complete picture of these effects will . is preliminary, as it has not ~~been thoroughly analyzed yet. Although the information here helps to provide an overall picture of the~~ hydrologic characteristics of these watersheds, some of the data may be edited as we further analyze the data. The location of the ditch 73#2 watershed is shown in figure 2. Results are presented below.

**Table 1: Summary of monitoring program in Elm Creek Basin, Minnesota**

| Watershed | Area of watershed at monitoring location | Percentage of watershed in wetland | Parameters monitored |
|---|---|---|---|
| Kittleson (Martin County JD #73#2) at wetland outlet | 1300 acres | 5.5% | TP, TSS, N - Nitrate + nitrite, OrthoPhos |
| Kittleson (Martin County JD #73#2- west branch) | 600 acres | 0% | TP, TSS, N - Nitrate + nitrite, OrthoPhos |
| Kittleson (Martin County JD #73#2- east branch) | 400 acres | 0% | TP, TSS, N - Nitrate + nitrite, OrthoPhos |
| Sheek (Ditch #37) watershed outlet | 3744 acres | 3.8% | TP, TSS, N - Nitrate + nitrite, OrthoPhos |
| Sheek (Ditch #37) restored wetland outlet | 1200 acres | 6.7% | |

Figure 2: JD 73#2 watershed (Kittleson wetland)




**West branch of JD 73#2 watershed**

**Flood peaks**

The flood peaks observed at the surface water channel (station W4) were significantly higher than from the tile main outlet (station W3). The maximum flow from station W3 was 1.46 cfs, with a minimum if 0.01 cfs and mean 0.47 cfs (Figure 3). In contrast, the surface channel had extremely flashy flow with a maximum discharge 64 cfs on 9/25/05 (Figure 4). Storm hydrographs lasted only about 2 days (50 hours). Both surface channels (stations W4 and W2) of the Kittleson watershed were intermittent streams than only flowed during large storm events. In contrast, tile flow was constant though at a much lower peakflow.

**Runoff velocity**

A maximum velocity of 9.25 ft/second was recorded by the ISCO 4150 area-velocity meter on May 13 for station W4. Velocities in excess of 3 ft/s lasted for several hours. The monitoring station was located on the upstream end of the culvert at this time, which tends to have lower velocities than the downstream end of a pipe. Hand measurements of velocity were taken the morning of May 13, on the falling limb of the hydrograph, using a Marsh-McBirney velocity meter. Values of 6.6 feet/second at the downstream end of the culvert and 4.5 feet/second in the surface channel just downstream of the culvert outlet were recorded at this time. In the September 25, 2005 storm, a maximum velocity of 10.36 feet/second was recorded by the area-velocity meter.

Velocities in excess of 3 feet/second are generally considered erosive of earth-lined channels not protected by rip-rap. It is apparent from these measurements, that highly erosive velocities occur at the outlets of these corn-soybean – dominated watersheds, as further evidenced by the five foot deep gully formed on the downstream end of these pipes.

**Seasonality of flow**

The surface channel monitored at station W4 only flowed for a total of about 5 days in 2005, from May 12-May 14 and September 25-26. In contrast, the tile main outlet, (Station W3) had relatively consistent, perennial flow, ranging from 0.01 cfs to 1.46 cfs. The W3 outlet flowed continuously since monitoring began, providing a constant input of baseflow to the Kittleson wetland. The volume of flow in W3 was much greater in the fall and spring storms than summer storms. For example the volume of runoff from an 8/17 storm had a peak of 0.87 cfs, with a runoff volume of approximately 7 acre feet of volume. In contrast, a fall storm on 9/25/05 also had a peak of 0.86 cfs, but produced 54 acre feet of runoff. The difference in runoff volume is presumed to be largely due to differences in evapotranspiration rates in the spring vs. summer.

**Volume of flow**

**Surface runoff from stations W4 + W4B**

Stations W4 and W4B were two side-by-side culverts both draining the Ditch 37 watershed. Despite intermittent nature of surface flow, because of the large flood peaks, surface runoff constituted a significant portion of the water discharging from the Kittleson (JD 37) Watershed. Two storms on May 13 and September 25, 2005 contributed virtually 100% of the annual surface water runoff for 2005. The September 25 storm yielded 29.5 acre-feet of runoff . The total volume of surface water runoff from the May 13 storm was not directly measurable, because we did not have a monitoring station installed at W4B (the east half of the side-by-side culverts). However given that the peak flow in station W4 was very similar to the September 25 (36.6 versus 36.7 cfs) it was assumed that the volume of runoff from this storm was similar, near 30 acre feet. Using these methods, the total annual volume of runoff from the watershed was estimated as 59 acre feet of runoff.

**Flow at tile outlet at station W3**

Monitoring of W3 occured from April 14 to November 15, 2005. Using interpolation to fill in missing data in late May to early June, the total volume of tile flow during the monitoring period was about 210 acre feet. The ratio of surface runoff to tile flow during the monitoring period for 2005 was about 22% to 78%. Given that there was no additional runoff events during the winter and the tile flow likely continued decreasing from November through March, the total annual ratio of surface to groundwater discharge volume was probably in the range of 10-20% surface to 80-90% tile flow for 2005.

**Water quality data:**

Water quality data was collected for the W3 station 19 times between 5/12/05 and 10/19/05 (Table 1). Results from this tile outlet indicate high levels of total nitrogen, with low numbers for TSS, Total phosphorous (TP) and orthophosphorous (OP). Mean levels of nitrate 21.37 exceeded the state standard of

10 mg/liter in all 19 samples. Nitrogen levels were very constant, with a low variance of 9.35. In contrast, TSS spiked more following the May storms with a high of 21 mg/liter. Most of the baseflow samples had negligible TSS, less than 2 mg/l. Similarly phosphorous levels were generally well below problematic levels* and reached maximum levels in May, with a maximum TP of 0.101 mg/L). 16 of 19 samples fell between 0.008 mg/L and 0.042 mg/L

[*Currently, there are no statewide standards for TP in rivers or streams. The US Environmental Protection Agency states a desired goal of 0.10 milligrams per liter (mg/L) for prevention of nuisance plant growth in streams. An analysis of algal productivity and total phosphorus (TP) concentration data for the Minnesota River has shown that TP must fall below 0.26 mg/L.to descrease algal productivity over current levels. ]

Water quality data was collected for the W4 station 19 times between 5/12/05 and 9/28/05 (Table 2). In contrast to the tile outlets, results from this surface channel indicate low levels of total nitrogen, with very numbers for TSS, Total phosphorous (TP) and orthophosphorous (OP). Mean levels of nitrate were (12.01 mg/L) but samples exceeded the state standard of 10 mg/liter in only 2 of 6 samples. Nitrogen levels ranged from 3.98 to 26 mg/L. In contrast, TSS levels were very high following the May storms with a high of 1040 mg/liter. Since this channel only flowed after large storm events, there were no baseflow samples. Total Phosphorous levels reached maximum levels on May 25 at 1.27 mg/L with a maximum OP of 0. 624 mg/L). All phosphorous samples were above 0.107 mg/L.

**Table 1: 2005 Water quality data for Site W3 - Kittleson West Tile outlet (JD 73#2- west branch) drainage area 600 acres**

| Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) |
|---|---|---|---|---|---|
| 5/12/2005 | 9:00 | 12 | 23.4 | 0.101 | 0.087 |
| 5/13/2005 | 10:00 | No data | 21.7 | 0.098 | |
| 5/25/2005 | 10:00 | 21 | 23.6 | 0.098 | 0.089 |
| 6/3/2005 | 13:00 | 2 | 25.7 | 0.018 | 0.014 |
| 6/7/2005 | 10:45 | 3 | 25.7 | 0.015 | 0.013 |
| 6/15/2005 | 8:30 | < 2 | 25.1 | 0.013 | 0.024 |
| 6/22/2005 | 11:30 | < 2 | 25.2 | 0.027 | 0.027 |
| 7/1/2005 | 9:00 | < 2 | 24.3 | 0.028 | 0.025 |
| 7/8/2005 | 8:45 | No data | 22.6 | 0.022 | 0.031 |
| 7/15/2005 | 9:00 | < 2 | 21.9 | 0.008 | 0.2 |
| 7/20/2005 | 9:00 | < 2 | 21.7 | 0.019 | 0.024 |
| 7/29/2005 | 9:15 | < 2 | 19.5 | 0.017 | 0.024 |
| 8/10/2005 | 8:15 | < 2 | 18.4 | 0.009 | 0.014 |
| 8/24/05 | 8:15 | < 2 | 19.1 | 0.026 | 0.032 |
| 9/9/2005 | 8:15 | < 2 | 18.4 | 0.018 | 0.018 |
| 9/21/2005 | 7:15 | < 2 | 15.7 | 0.015 | 0.016 |
| 9/28/2005 | 11:00 | < 2 | 17.2 | 0.042 | 0.034 |
| 10/6/2005 | 6:45 | < 2 | 20.2 | 0.027 | 0.02 |
| 10/19/2005 | 7:30 | < 2 | 19 | 0.026 | 0.025 |
| n | | 18 | 19 | 19 | 18 |
| max | | 21 | 25.7 | 0.101 | 0.200 |
| min | | 2 | 15.7 | 0.008 | 0.013 |
| mean | | 3.18 | 21.37 | 0.025 | 0.037 |
| variance | | 24.24 | 9.35 | 0.001 | 0.002 |

| Table 2: 2005 Water Quality Data from Station W4: Kittleson west surface channel (JD 73#2- west branch). drainage area 600 acres | | | | | |
|---|---|---|---|---|---|
| Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) |
| 5/12/2005 | 9:00 | 46 | 26 | 0.476 | 0.477 |
| 5/12/2005 | 20:30 | No data | 20.5 | 0.562 | No data |
| 5/13/2005 | 9:15 | 258 | 18.6 | 0.665 | 0.568 |
| 5/25/2005 | 10:00 | 1040 | 3.98 | 1.27 | 0.624 |
| 5/25/2005 | 10:30 | 264 | 17.8 | 0.268 | 0.159 |
| 5/25/2005 | 14:45 | 126 | No data | No data | 0.107 |
| 5/25/2005 | 15:00 | 19.5 | No data | No data | 0.220 |
| 9/28/2005 | 11:15 | 124 | 7.67 | 0.406 | 0.358 |
| n | | 7 | 6 | 6 | 7 |
| Max | | 1040 | 26 | 1.270 | 0.624 |
| Min | | 19.5 | 3.98 | 0.268 | 0.107 |
| mean | | 305.25 | 12.01 | 0.652 | 0.339 |
| variance | | 124672.65 | 68.75 | 0.123 | 0.042 |

**East branch of Ditch 73#2 watershed (station W2 and W7)**

Results for the east branch of Ditch 73#2 were very similar to the west branch, described in the previous section, as they both have >90% corn-soybean coverage, with no wetlands (surface water storage).

**Station W2 Summary**

**Flood peaks**

Station W2 had a very large peak on May 13, 2005 at approximately 100 cfs. Our monitoring station was washed out by this flood, which also partially undermined the dirt road. Therefore the peak was estimated by measurements of velocity obtained before the probe ripped off and cross-sectional measurements of the grass channel. The September 25$^{th}$ storm peaked at about 90 cfs with the hydrograph lasting about 50 hours.

**Runoff velocity**

Velocities exceeded 8 ft/s prior to washing out of the station in the May 13 storm. This is sufficient to erode any type of soil or vegetation coverage that is not protected by rip-rap or other armoring techniques. The highly erosive velocities are evidenced by the large scour holes at the downstream end of the culverts.

**Seasonality of flow**

As with station W4, the W2 surface channel has intermittent flow following large storms only. This channel flowed for approximately 6-8 days in 2005.

**Runoff volume**

The large peak on May 13, 2005 (about 100 cfs) washed out the monitoring station; therefore total runoff volumes were not measured for this storm. Given that the September 25th storm peaked at about 90 cfs with the hydrograph lasting about 50 hours, this watershed yielded more runoff than the west branch, despite a smaller watershed size (400 acres vs. 600 acres).

**Water Quality data (Table 3)**

TSS, TP, and Orthophosphorous levels collected at W2 were high during surface runoff events, while total nitrogen levels were moderate ranging from 3.69 – 21.3 mg/l. results were similar for the adjacent surface watershed.

Table 3: 2005 Water Quality Data from Station W2: Kittleson east surface channel (JD 73#2 - east branch) drainage area 400 acres

| Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) |
|---|---|---|---|---|---|
| 5/12/2005 | 9:00 | 747 | 5.56 | 0.849 | 0.966 |
| 5/12/2005 | 20:30 | No data | 8.62 | 1.12 | No data |
| 5/13/2005 | 8:45 | 352 | 5.96 | 0.748 | 0.513 |
| 5/25/2005 | 10:00 | 580 | 4.79 | 0.844 | 0.5 |
| 5/25/2005 | 10:00 | 216 | 14.4 | 0.678 | 0.477 |
| 5/25/2005 | 14:30 | 70 | No data | No data | 0.193 |
| 5/25/2005 | 14:30 | 9 | No data | No data | 0.319 |
| 6/7/2005 | 10:45 | 3 | 21.3 | 0.02 | 0.014 |
| 9/28/2005 | 10:45 | 2 | 3.69 | 0.181 | 0.174 |
| max | | 747 | 21.3 | 1.120 | 0.966 |
| min | | 2 | 3.69 | 0.020 | 0.014 |
| mean | | 175.93 | 9.79 | 0.599 | 0.313 |

Table 4: 2005 Water quality data for Site W7 - Kittleson east tile outlet (JD 73#2 - east branch). drainage area 400 acres

| Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) |
|---|---|---|---|---|---|
| Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) |
| 6/3/2005 | 13:00 | 2 | 20.8 | 0.017 | 0.016 |
| 6/15/2005 | 8:30 | 2 | 21.4 | 0.012 | 0.019 |
| 6/22/2005 | 11:30 | 2 | 22.4 | 0.015 | 0.018 |
| 7/1/2005 | 9:00 | 2 | 20.7 | 0.2 | 0.19 |
| 7/8/2005 | 8:30 | | 18.4 | 0.019 | 0.03 |
| 7/15/2005 | 9:00 | 2 | 18.7 | 0.015 | 0.02 |
| 7/20/2005 | 9:00 | 2 | 18.5 | 0.023 | 0.026 |
| 7/29/2005 | 10:00 | 2 | 16.9 | 0.012 | 0.021 |
| 8/10/2005 | 9:00 | 2 | 18.6 | 0.011 | 0.2 |
| 8/24/05 | 9:00 | 2 | 14 | 0.030 | 0.030 |
| 9/9/2005 | 9:00 | 2 | 10.4 | 0.043 | 0.042 |
| 9/21/2005 | 8:00 | 2 | 13.6 | 0.017 | 0.018 |
| 9/28/2005 | 12:30 | 2 | 14.4 | 0.032 | 0.032 |
| 10/6/2005 | 7:30 | 2 | 15.4 | 0.024 | 0.017 |
| 10/19/2005 | 7:15 | 2 | 16.5 | 0.017 | 0.019 |
| n | | 14 | 15 | 15 | 15 |
| max | | 2 | 22.4 | 0.2 | 0.2 |
| min | | 2 | 10.4 | 0.011 | 0.016 |
| mean | | 2.00 | 17.38 | 0.03 | 0.05 |
| variance | | 0.00 | 11.27 | 0.00 | 0.00 |

| Table 5: 2005 Water quality data for Site W5: Kittleson wetland outlet structure (JD 73#2 main branch). Drainage area 1300 acres | | | | | |
|---|---|---|---|---|---|
| Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) |
| 5/12/2005 | 9:00 | 84 | 3.53 | 0.164 | 0.026 |
| 5/13/2005 | 10:45 | | 3.49 | 0.194 | |
| 5/25/2005 | 11:00 | 3 | 4.53 | 0.122 | 0.085 |
| 6/3/2005 | 13:00 | 20 | 3.49 | 0.116 | 0.06 |
| 6/7/2005 | 10:45 a.m | 7 | 2.48 | 0.148 | 0.098 |
| 6/15/2005 | 8:30 | 6 | 0.7 | 0.224 | 0.208 |
| 6/22/2005 | 11:30 | 16 | 0.28 | 0.269 | 0.244 |
| 7/1/2005 | 9:00 | 2 | 0.2 | 0.382 | 0.324 |
| 7/8/2005 | 9:00 | | 0.2 | 0.491 | 0.506 |
| 7/15/2005 | 9:00 | 2 | 0.2 | 0.529 | 0.503 |
| 7/20/2005 | 9:00 | 10 | 0.2 | 0.676 | 0.649 |
| 7/27/2005 | 1200 | 3 | TKN 1.8 | 0.663 | 0.601 |
| 7/29/2005 | 9:30 | 2 | 0.2 | 0.742 | 0.686 |
| 8/10/2005 | 8:30 | 2 | 0.2 | 0.426 | 0.398 |
| 8/24/05 | 8:30 | 2 | 0.2 | 0.212 | 0.191 |
| 9/9/2005 | 8:30 | 2 | 0.2 | 0.118 | 0.076 |
| 9/21/2005 | 7:30 | 2 | 0.2 | 0.118 | 0.07 |
| 9/28/2005 | 11:30 | 2 | 0.74 | 0.17 | 0.125 |
| 10/6/2005 | 7:00 | 12 | 0.75 | 0.196 | 0.114 |
| 10/19/2005 | 7:45 | 2 | 1.25 | 0.057 | 0.027 |
| N | | 18 | 19 | 20 | 19 |
| max | | 12 | 1.25 | 0.742 | 0.686 |
| min | | 2 | 0.2 | 0.057 | 0.027 |
| mean | | 3.73 | 0.41 | 0.355 | 0.313 |
| variance | | 12.27 | 0.12 | 0.057 | 0.058 |

**W5 Kittleson wetland outlet (Outlet of Ditch 73#2 watershed)**

The Kittleson wetland was restored in October 2004. Following a large storm in October 2004, the pond filled up and the wetland has continuously discharged water from its outlet since that time.

The range of flows predicted by outlet structure modeling prior to installation was 0 to 9 cfs. Measured values were as follows: minimum was 0.7 cfs, maximum 10.0 cfs, and mean was 5.2 cfs. The wetland has been above the long-term "modeled" normal water level elevation of 1252.0 during the entire monitoring period (Figure 5)

**Flood peaks**

Flood peaks are considerably dampened by the wetland, as the maximum discharge was 10 cfs, compared to 100 cfs entering from one subwatershed only. If both surface channels (W2 and W4) plus tile outlets were combined, the peak inflow would have exceeded 150 cfs, as a conservative estimate.

**Seasonality of flow**

The wetland has flowed constantly since October 2004. If the wetland would drop to the predicted normal water level of 1252, discharge would stop, until it rose above that point again.

**Runoff volume**

Volume calculations for the W5 wetland have not been completed yet.

## HYDROLOGIC MONITORING OF THE JD 37 (SHEEK) WATERSHED FOR 2005

The data from stations S1 and S2 have not been completely analyzed yet.
S1 (Sheek wetland outlet) 1200 acre watershed

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**Water quantity data**

Discharge data has not been completely analyzed for this site. The modeled or predicted normal water level for the wetland was 1255 feet above sea level, with a flow range between 0 and 3.2 cfs. The wetland has been running high since it filled up with water in the spring of 2005. It began discharging water in mid-May, 2005 and has been above 1255 feet ever since that date.

**Water quality data**

It appears that TSS is low coming out of the Sheek wetland compared to surface channels W2 and W4 with a maximum of 15 mg/l. Phosphorous is considerably lower than the surface channels but higher than the tile flows, as would be expected. Nitrate levels were less than 0.2 mg/l in most samples, except following the May 13 and September 25 storms, when a maximum of 1.03 mg/l was reached.

Table 7. Site S1 – Sheek watershed outlet – JD 37 watershed. Drainage area = 1200 acres

| SITE | Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) |
|---|---|---|---|---|---|---|
| S1 | 5/18/2005 | 13:30 | | 1.03 | 0.245 | |
| S1 | 5/25/2005 | 10:00 | 6 | 0.89 | 0.218 | 0.114 |
| S1 | 6/3/2005 | 13:00 | 15 | < 0.2 | 0.261 | 0.221 |
| S1 | 6/7/2005 | 10:45 a.m | 7 | 0.61 | 0.26 | 0.229 |
| S1 | 6/15/2005 | 8:30 | 5 | < 0.2 | 0.25 | 0.221 |
| S1 | 6/22/2005 | 11:30 | 3 | < 0.2 | 0.264 | 0.247 |
| S1 | 7/1/2005 | 9:00 | 5 | < 0.2 | 0.315 | 0.272 |
| S1 | 7/8/2005 | 9:15 | | < 0.2 | 0.342 | 0.319 |
| S1 | 7/15/2005 | 9:00 | 4 | < 0.2 | 0.323 | 0.23 |
| S1 | 7/20/2005 | 9:00 | 9 | < 0.2 | 0.308 | 0.212 |
| S1 | 7/27/2005 | 11:15 | 9 | TKN 1.8 | 0.213 | 0.153 |
| S1 | 7/29/2005 | 10:15 | < 2 | < 0.2 | 0.22 | 0.176 |
| S1 | 8/10/2005 | 9:15 | 5 | < 0.2 | 0.165 | 0.107 |
| S1 | 8/24/05 | 9:15 | < 2 | < 0.2 | 0.093 | 0.056 |
| S1 | 9/9/2005 | 9:15 | < 2 | < 0.2 | 0.034 | 0.012 |
| S1 | 9/21/2005 | 8:15 | < 2 | < 0.2 | 0.05 | 0.019 |
| S1 | 9/28/2005 | 1:00 | < 2 | < 0.2 | 0.077 | 0.039 |
| S1 | 10/6/2005 | 7:45 | 14 | < 0.2 | 0.084 | 0.032 |
| S1 | 10/19/2005 | 8:00 | < 2 | < 0.2 | 0.037 | 0.011 |

**S2 – Sheek watershed oulet (Ditch 37) – 3744 acres**

**Water quantity data**

The S2 monitoring station represents the largest watershed unit that we are monitoring. Although data was missing from this site because our probe was cut three times in 2005, it appears that the hydrographs produced in response to storms in the watershed are somewhere in between the small tile outlets and the surface channel outlet. The volume of flow is considerably larger than the tile outlet stations, because the watershed is considerably larger, but the baseflow is quite constant, varying from 2 to 10 cfs. The flood peaks were not as flashy as the surface channels W2 and W4, with peaks in the range of 25-50 cfs.

**Water quality data (Table 8)**

The data for Site S2 has not been completely analyzed here – see table 8.

Table 8. Site S2 – Sheek watershed outlet – JD 37 watershed. Drainage area = 3700 acres

| Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) | SVS (mg/L) | TVS (mg/L) | Notes |
|---|---|---|---|---|---|---|---|---|
| 5/12/2005 | 9:00 | 36 | 10.6 | 0.204 | 0.193 | | | |
| 5/13/2005 | 12:30 | | 5.3 | 0.637 | | | | |
| 5.19.2005 | | 32 | | | | | | |
| 5.25.2005 | | 16 | | | | | | |
| 5/25/2005 | 10:00 | 8 | 3.41 | 0.284 | 0.211 | | | |
| 6/3/2005 | 13:00 | 7 | 1.92 | 0.245 | 0.212 | | | |
| 6/7/2005 | 10:45 | 16 | 2.67 | 0.327 | 0.313 | | | |
| 6/15/2005 | 8:30 | 8 | 2.14 | 0.428 | 0.388 | | | |
| 6/22/2005 | 11:30 | 11 | 3.06 | 0.371 | 0.351 | 6 | | |
| 7/1/2005 | 9:00 | 28 | 5.72 | 0.255 | 0.191 | | | |
| 7/8/2005 | 9:30 | | 4.42 | 0.286 | 0.265 | | | |
| 7/14/2005 | 13:30 | 73 | | | | | | |
| 7/15/2005 | 9:00 | 2 | 6.33 | 0.243 | 0.206 | | | |
| 7/18/2005 | | 3.2 | | | | | | |
| 7/20/2005 | 9:00 | 3 | 3.45 | 0.275 | 0.206 | | | |
| 7/25/2005 | | 8 | | | | | | |
| 7/29/2005 | 9:45 | 2 | 4.61 | 0.206 | 0.199 | | | |
| 8/3/2005 | | 0 | | | | | | |
| 8/3/2005 | | 0 | | | | | | |
| 8/10/2005 | 8:45 | 6 | 3.83 | 0.204 | 0.178 | | | |
| 8/24/05 | 8:45 | 5 | 2.83 | 0.171 | 0.155 | | | |
| 9/9/2005 | 8:45 | 5 | 3.29 | 0.193 | 0.175 | | | |
| 9/21/2005 | 7:45 | 6 | 5.09 | 0.111 | 0.092 | | | |
| 9/28/2005 | 12:00 | 12 | 2.37 | 0.339 | 0.296 | | | |
| 10/6/2005 | 7:15 | 4 | 1.75 | 0.494 | 0.412 | | | |
| 10/19/2005 | 8:15 | 6 | 2.21 | 0.227 | 0.178 | | | |
| n | | 24 | 19 | 19 | 18 | | | |

Table 8. Site S2 – Sheek watershed outlet (cont.)

| Date | Time Sampled | TSS (mg/L) | Nitrate + Nitrite (mg/L) | TP (mg/L) | OP (mg/L) | SVS (mg/L) | TVS (mg/L) | Notes |
|---|---|---|---|---|---|---|---|---|
| max | | 73 | 10.6 | 0.494 | 0.412 | | | |
| min | | 0 | 1.75 | 0.111 | 0.092 | | | |
| mean | | 12.43 | 3.95 | 0.28 | 0.24 | | | |
| variance | | 271.96 | 1.91 | 0.01 | 0.01 | | | |

**Summary of 2005 Analysis to Date**

Preliminary findings of interest include the extremely flashy nature of runoff from the surface channels draining the corn-soybean watersheds. Flood peaks and velocities were much greater than would be expected from relatively small watershed (400-600 acres). Tile outlets had very constant baseflows in the range of 0 – 1.5 cfs, and had consistently high nitrate levels in the range of 15-25 mg/l.

Flood peaks and nutrient concentrations were considerably reduced in the outflow of the Kittleson wetland (station W5), compared to both surface channel and tile inflows. Volumetric (loading) calculations have not been completed yet, but it is expected from preliminary calculations that considerable reductions in nitrate, phosphorous and TSS will be found.

**Problems and issues with 2005 monitoring**

There were difficulties with monitoring equipment being vandalized three times at station S2. Station W2 was washed out in the flood of May 13, destroying one of our ISCO water samplers. In addition, the automatic water samplers did not work most of the time, so we relied on grab samples for water quality data. This was particularly problematic for the surface channels- W2 and W4 because they would only flow for a day or two following large storms. This monitoring season we will try to get the automatic samplers to work more regularly so that we can get more water quality samples during storms, across the entire hydrograph.

**Future work and data collection**

A water budget for inflowing water and nutrients to the Kittleson wetland will be completed in 2006. In addition we have a whole set of turbidity and TSS data for the Elm Creek basin that was not presented in the report, but was summarized in a poster presentation at the 2006 CSREES conference. The Elm Creek in-channel data will continue for 2006 so that we will have information on turbidity, sediment and nutrient loading at a variety of scales ranging from the 400 acre corn-soybean watersheds to the 200 square mile Elm Creek watershed.

## Appendix B

2004 Results of Runoff Plots at Waseca

(Taken from Colson, M.S. Thesis 2006)

**Seasonal Precipitation and Runoff - 2004**

Precipitation from February to October 2004 accounted for approximately 96 percent of the annual total and was about 150 mm (6 in.) above normal (Table 1). April and October had below normal precipitation, whereas May through September received above normal precipitation. February precipitation was a mix of rain and snow on top of January's snow pack. The average water equivalent of the snow measured from all plots was 37 mm (1.5 in.) with a maximum water equivalent of 52 mm (2.0 in.) measured in the Illinois bundleflower plots. Very little infiltration occurs during snowmelt since the soil moisture content was close to saturation on the frozen or recently thawed soils and because freezing temperatures still occurred during night. Night time snow melt did not occur until March. The higher amount of runoff from Illinois bundleflower in February may have been due to the higher snow water equivalent retained by the treatment. Much of the snowmelt runoff from the soybean plot occurred in early March, which was possibly a result of soil surface roughness from tillage that may have delayed runoff earlier during snowmelt.

Based on estimations, more than 40 percent of the snowmelt runoff from the hazelnut and perennial flax plots may have occurred prior to equipment installation. Other observations indicate that the runoff volume from willow plots increased dramatically after removal of the grass cover in June table2, The soybean and willow treatments had similar run off in July, but at soybean maturity (August), runoff was similar to that of Illinois bundleflower, hazelnut, and perennial flax plots. For the February to October period, runoff was greatest for willow and least for perennial flax. Soybean and Illinois bundleflower had similar runoff,.

Table 1: Monthly precipitation and runoff from willow, soybean, Illinois bundleflower, hazelnut, and perennial flax for 2004.

| | | Runoff in mm per plot per month | | | | |
|---|---|---|---|---|---|---|
| Month | Total precipitation (mm) | Willow | Soybean | Illinois bundleflower | Hazelnut | Perennial flax |
| Feb | 40 | 34 | 15 | 48 | 32 | 23 |
| Mar | 71 | 25 | 26 | 9 | 1 | 1 |
| Apr | 45 | 0 | 0 | 3 | 0 | 0 |
| May | 143 | 9 | 4 | 10 | 12 | 1 |
| June | 163 | 16 | 21 | 21 | 5 | 2 |
| July | 180 | 82 | 82 | 33 | 22 | 38 |
| Aug | 146 | 78 | 16 | 18 | 20 | 1 |
| Sep | 176 | 82 | 14 | 38 | 10 | 19 |
| Oct | 62 | 31 | 18 | 3 | 1 | 4 |
| Totals | 1025 | 326 | 196 | 183 | 104 | 88 |

An analysis of variance (ANOVA) was conducted on total runoff produced from April through October. The treatments did not show any significant difference, P = 0.1090. However, a LSD comparison of the means (Table 2) shows that the willow cropping treatment had a significantly different ($\alpha$= 0.05) mean than hazels and flax. Runoff from soybean and IBF was not different from the other treatments. Nonetheless, the data clearly indicated the greatest average amount of runoff occurred on the willow plots and the least was on the perennial flax plots.

Table 2: LSD (T) comparison of means of total millimeters of runoff by treatment.

| TRT | MEAN | GROUPS |
|---|---|---|
| --------- | ---------- | ----------- |
| Willow | 289.68 | I |
| Soybean | 155.32 | I I |
| IBF | 128.08 | I I |
| Hazel Nut | 71.84 | I |
| P. Flax | 63.72 | I |

**Runoff from Snowmelt and Rainfall Events**

During 2004, snowmelt produced the greatest amount of runoff for all but the willow plots (Table 3). Water quality measurements were determined from snowmelt runoff and from five rainfall storms. Of all rainfall events, the two-hour storm of 49 mm (1.93 in.) on 11 July 2004 had the highest intensity. The greatest volume of runoff (63 mm) occurred from the willow plots as a result of the 127 mm (5 in.) rainfall event of 14 - 15 September. When the herbaceous perennials were actively growing, runoff volumes from rainfall were generally greatest for willow and soybean than from the other perennials. Hazelnut was consistently among the crops producing the least amount of total runoff for all six events, which was due to the sod grass ground cover (the hybrid hazelnuts plants were seedlings and exhibited minimal growth the first year).

A simple linear regression analysis of rainfall events using Weisberg and Bartlett's Test (Statistix 7.0) indicated that runoff from soybeans, IBF, and PF was similar, but lower than willow seedlings (HW) and higher than the hazelnut-sod grass system (HN). Runoff from HW plots was substantially higher than from the HN plots. Therefore, three groups exist: 1)CSR, IBF, and PF; 2)HW, and 3)HN. The slopes of the regression differed among the cover conditions. Hybid willows (HW) had the steepest slope (runoff = 3.2 + 0.32*rain), most runoff, and least cover throughout the season. Hazelnuts (HN) had the most gentle slope (runoff = 0.6 + 0.03*rain), least runoff, and most cover throughout the season. The final group, CSR, IBF, and PF, had an intermediate slope (runoff = 4.4 + 0.094*rain) and cover conditions. It is worth noting that the regression shows P = 0.052 for the CSR, IBF, and PF group, and P = 0.08 for HW, which may be an indication of the reliability of the results. For HN, the simple linear regression was not significant (there was little runoff response from any rainfall event).

Comparisons of snow water equivalent (SWE) and snowmelt runoff indicate that the snowpack was uneven and highly variable within and between plots. For example, the average 37 mm SWE for all plots was far below the 52 mm SWE measured in the Illinois bundleflower plots. This is problematic for snowmelt events in this location, since the effects of vegetative structure, landscape position, and the plot boundaries can influence snow accumulation and drifting, resulting in highly variable SWE. More intensive SWE sampling is needed within plots to improve snowmelt-runoff relationships for the various crops, and more snowmelt events must be analyzed to determine statistical significance among cropping treatments.

Table 3: Summary of precipitation and runoff volumes from snowmelt and rainfall events in 2004, Waseca, MN.

| | Runoff in millimeters | | | | | Precipitation |
|---|---|---|---|---|---|---|
| Event Date | Willow seedlings | Soybean | Illinois bundleflower | Hazelnut – sod grass | Perennial flax | millimeters |
| 2-Mar-04 | 34 | 41 | 54 | 32 | 23 | 37* |
| 9-Jun-04 | 13 | 13 | 14 | 0.1 | 2 | 109 |
| 11-Jul-04 | 28 | 27 | 13 | 6 | 23 | 49 |
| 22-Aug-04 | 4 | 3 | 0.3 | 0.1 | <.1 | 9 |
| 15-Sep-04 | 63 | 10 | 20 | 7 | 19 | 127 |
| 7-Oct-04 | 14 | 8 | <.1 | 0.1 | 1 | 32 |

* Water equivalent of snow averaged from all plots; for the Illinois bundleflower plots, the snow water equivalent averaged 52 mm.

**Sediment Production from Snowmelt and Rainfall Events**

The ANOVA indicated no significant difference, P = 0.2345, among cropping treatments for the sediment production that occurred during storm runoff events. However, the runoff data show that the willow plots had the highest TSS loadings followed by soybeans, Illinois bundleflower, hazel nuts, and perennial flax with the lowest loading (Table 4). Total suspended solids (TSS) from all the rainfall events were highest from the willow plots than all others most likely due to the lack of ground cover that was removed in early June. The highest TSS was measured from the willow plots for the intensive rainfall event of 11 July (Table 4), although the total runoff for that event was less than from March snowmelt and from the 15 September rain storm. These same plots exhibited low TSS from snowmelt prior to the removal of the sod grass ground cover. The hazelnut plots consistently exhibited lower sediment loss as a result of a continuous grass cover.

Table 4: Summary of total suspended solids for snowmelt and rainfall events in 2004, Waseca, MN.

| | Average TSS loadings in kg/ha per treatment | | | | |
|---|---|---|---|---|---|
| Event Date | Willow | Soybean | Illinois bundleflower | Hazelnut | Perennial flax |
| 2-Mar-04 | 21 | N/A | 57 | 55 | 16 |
| 9-Jun-04 | 1750 | 297 | 441 | N/A | 58 |
| 11-Jul-04 | 3017 | 1194 | 348 | 96 | 248 |
| 22-Aug-04 | 160 | 97 | 10 | 9 | 0 |
| 15-Sep-04 | 1968 | 204 | 257 | 11 | 128 |
| 7-Oct-04 | 498 | 192 | 0 | 0 | 11 |
| Total | 7414 | 1983 | 1112 | 171 | 461 |

A simple linear regression analysis using Weisberg and Bartlett's Test (Statistix 7.0) shows from the TSS production data that three groups can be identified: 1) IBF, HN, and PF; 2) CSR; and 3) HW. The $r^2$ values are very low ($r^2 < 0.11$) indicating more data and other factors may help explain the observations. Also, the intense rainfall from 11 July 2004 when the greatest production of TSS occurs greatly influences the outcome of the regression analysis resulting in a slightly negative slope from the CSR data. Hybrid willow had the greatest slope, which is probably due to the lack of cover. The results of the regression analyses were significant for group 1 (IBF, HN, and PF; P = 0.04) but not for HW or HN.

Sediment loss, and the volume of runoff from the treatments in this experiment are comparable with previous research results and are dependent on rainfall, cover conditions, and cropping system (Mamedov et al. 2000, Zemenchik et al. 2002, Tabbara 2003). Sediment loss during snowmelt and rainfall events was in the range that has been reported previously (Ginting et al. 1998, Sharpley and Kleinman 2003, Tabbara 2003). The amount of sediment loss from agricultural fields during snowmelt runoff is generally minor compared to rainfall events (Ginting et al. 1998).

**Total Phosphorus Production from Snowmelt and Rainfall Events**

Total phosphorus (P) values can be expected to increase with higher TSS values; P content in particulate form has been reported to account for more than 90 percent total P content (Abu-Zreig 2003). The observed values of total P loss were similar to measured values of total P loss from the annual and perennial systems that have been reported (Zemenchik et al 2002; Sharpley and Kleinman 2003). The runoff data show that the willow plots had the highest total P loadings followed by soybeans, Illinois bundleflower, hazel nuts, and perennial flax with the lowest loading. Total phosphorus loadings from all the rainfall events were higher from the willow plots than all others, most likely due to the lack of ground cover. The highest total P was measured from the willow plots for the rainfall event of 9 June (Table 5), probably due to the recent removal of the turf grass cover which left the soil surface devoid of cover. The hazelnut plots consistently exhibited lower total P loss as a result of a continuous grass cover. However, the ANOVA indicated no significant difference, P-value = 0.1961, among cropping treatments for the total P production that occurred during the storm runoff events. The highest total P losses for soybean occurred approximately one month after planting when cover was less than 75 percent (Table 1) during the intense storm of 11 July, which were the highest losses of total P of any crop for all events (Table 6) excluding willows.

The linear regression analysis indicated three groups: 1)CSR, IBF, and PF; 2) HW; and 3) HN. The regression equation for CSR, IBF, and PF is TP = 0.1515 + 0.00403*Rain and the result is significant, P = 0.0742. The regression equation for hybrid willow is TP = 0.6162 + 0.275*rain. The result was not significant, P = 0.1251. The regression equation for hazel nut is TP = 0.0267 + 0.0002437*rain and the result was not significant P = 0.65. The slopes are an indication of the amount of cover with the least amount of cover belonging to hybrid willows, which had the greatest slope of 0.275. The greatest cover was on the hazel nut plots and the slope is very small, $2.437 \times 10^{-4}$. Although approaching significance, except for the hazelnut treatment, r-square values are very small ($r^2 < 0.18$) indicating that more replications were needed for this study, and other factors may help explain the observations.

Table 5: Summary of total phosphorus production for snowmelt and rainfall events in 2004, Waseca, MN.

| | Average TP loadings in kg/ha per treatment per event | | | | |
|---|---|---|---|---|---|
| Event Date | Willows | Soybeans | IBF | Hazels | Perennial Flax |
| 2-Mar-04 | 0.13 | N/A | 0.27 | 0.18 | 0.16 |
| 9-Jun-04 | 4.04 | 0.99 | 1.02 | 0.00 | 0.14 |
| 11-Jul-04 | 2.26 | 1.47 | 0.11 | 0.11 | 0.27 |
| 22-Aug-04 | 0.37 | 0.20 | 0.02 | 0.02 | 0.00 |
| 15-Sep-04 | 3.59 | 0.48 | 0.56 | 0.08 | 0.33 |
| 7-Oct-04 | 1.79 | 0.43 | 0.00 | 0.00 | 0.03 |

**Nitrate Production from Snowmelt and Rainfall Events**

The ANOVA on total plot $NO_3^-$-N runoff for the season indicated no significant difference, P-value = 0.3736, among cropping treatments for the $NO_3^-$-N production that occurred during the storm runoff events. The runoff data show that the willow plots had the highest $NO_3^-$-N loadings followed by Illinois bundleflower (Table 6). Perennial flax, hazel nuts, and soybeans had approximately equal total nitrates losses for the season. However, excluding willows, soybean had consistently higher loadings during storm events except for the 15 September event. The hazel nut plots had consistently lower loadings during storm runoff events, which is probably the result of the continuous cover condition.

The linear regression equation for HW, CSR, IBF, and PF is
$NO_3^- = -3.91*10^{-5} + 1.54*10^{-3}*rain$, and the regression analysis was highly significant, P = 0.0013. The linear regression for hazel nut is $NO_3^- = 8.84*10^{-3} + 4.53*10^{-5}*rain$, but the regression was not significant, P = 0.80. The slope for HW, CSR, IBF and PF regression is steeper than HN regression possibly due to greater cover conditions of the HN plots. The HN plots had the greatest cover and the HN regression indicates the most gentle slope. The $r^2$ values were very small indicating more replications from future data collection and other factors may help explain the observations.

Table 6: Summary of nitrate production for snowmelt and rainfall events in 2004, Waseca, MN.

| | Average NO-3 loadings in kg/ha per treatment per event | | | | |
|---|---|---|---|---|---|
| Event Date | Willows | Soybeans | Illinois bundleflower | Hazels | Perennial Flax |
| 2-Mar-04 | 0.644 | N/A | 0.114 | 0.354 | 0.238 |
| 9-Jun-04 | 0.029 | 0.036 | 0.051 | 0.000 | 0.005 |
| 11-Jul-04 | 0.131 | 0.089 | 0.035 | 0.037 | 0.052 |
| 22-Aug-04 | 0.055 | 0.043 | 0.002 | 0.003 | 0.000 |
| 15-Sep-04 | 0.276 | 0.222 | 0.314 | 0.031 | 0.358 |
| 7-Oct-04 | 0.172 | 0.071 | 0.000 | 0.000 | 0.006 |

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# Appendix C

**Excerpts from Marin Byrne MS thesis draft (June, 2006)**

## Runoff Plots

Total water content in the soil profile was remarkably consistent between crops on the run off plots for both 2004 and 2005 (Table 5). In both years, there were no significant differences in soil moisture between any of the crop types. The willow seedlings were beginning to establish crown development in 2005, but the willow plots still had low vegetative ground cover.

For 2004 and the beginning of 2005, total soil moisture showed no distinct trends, and no crop had consistently drier soil than any other. However, beginning in June of 2005, soil water content showed a fairly consistent decline over the rest of the season, likely due to the low rainfall in July and normal rainfall in August. During this period of drydown, the soil under the corn was consistently (although not significantly) drier than that under the other crops as well, perhaps because the corn was growing very rapidly during this period, especially during July and August.

## Tile Drainage Plots

Total water content in soil water profile was also remarkably consistent between crops on the tile drainage plots (Table 5). Once again, there were no significant differences in soil moisture between crop types, with the exception of a significant ($\alpha$=0.05) difference between soy and willow on August 10, 2004. As in the run off plots, no crop showed consistently drier soils than any other.

The drying trend observed on the runoff plots during the second half of the 2005 season was not as apparent in the tile drainage plots. Perhaps this is due to the tile drainage on these plots, which provides some inherent soil moisture regulation on these plots, such that conditions were drier than on the runoff plots at the beginning of the season, leaving less room for additional drying.

## Hillslope

A slightly different picture emerged on the hillslope, where in 2004 the soil under the mature poplar was consistently and significantly drier than that under the field, which was planted in corn (Table 5b). In 2005, the field was planted in soy, and the soil under poplar was significantly drier ($\alpha$=0.10) only on the first sampling date in April and at the end of May.

At first glance, it might be assumed that the lack of significant difference in soil moisture measured in 2005 might be due to the reduced sampling size in these locations (from 8 samples in each in 2004 to 5 samples in each in 2005), as the 95% confidence intervals were, in fact, larger. While this may have contributed, it is also worth noting that the differences between the two were much smaller in 2005 (with an average difference of 8.2 cm water over a 130 cm profile) than in 2004 (when the average difference between the two locations was only 3.2 cm of water over a 130 cm profile). Some of this might be attributable to the switch in the field from corn to soy. However, a change in the poplar grove seems more likely to be the cause. In 2004, there was a thriving understory of weeds, many of which reached four to five feet in height. In early 2005, an herbicide was applied between rows of poplars, such that the weedy understory only existed in narrow bands along each row of trees. The weeds in the understory certainly also consume soil water, and it seems reasonable that removing the weeds would reduce water consumption in the grove. Sandral et al

(2006) saw the impact that weed can have on soil moisture, when in their study, uncontrolled weeds extracted more water from a soil profile than clover pasture.

The drying trend observed on the runoff plots in late 2005 was also observed on the hillslope plots, with the driest soil measured at the end of August on the last date sampled.

**Comparison of Locations**

Although the tile drainage plots, run off plots and hillslope have different slopes, have crops of slightly varying developmental stage, and likely experienced slightly different climatic conditions, rendering direct comparison somewhat difficult, it is still interesting to compare soil water under the same crops between the locations (Figure 12a, 12b).

Not surprisingly, there are no significant differences in soil moisture under the same crops in different locations ($\alpha$=0.10). However, with very few exceptions, soil on the tile drainage plots was drier than soil on the corresponding run off plots. Given that the purpose of tile drainage is to remove water from the soil, this is not surprising.

When comparing only the agroforestry crops, the mature poplar showed generally drier soils than the immature agroforestry crops on the run off plots (Figure XXX). This is not surprising, as one would assume mature trees would use more water than immature. However, the mature poplar soil was not consistently drier than that on the tile drainage plots. This seems to indicate that artificial drainage can more than make up for the reduced water usage of younger trees.

When considered together, this implies, not surprisingly, that both crop cover and drainage status influence soil water.

**Discussion**

As shown above, there was very little difference between the soil moisture regimes beneath the annual, perennial and agroforestry crops in the tile drain plots and run off plots.

In 2004, this might be partly attributed to the relatively rainy season. In an average summer, the area receives 49.91 cm of rain between May and September. During the same period of 2004, 80.67 cm of rain fell. There was no period between sampling dates in which rain did not fall, and most periods experienced at least one reasonably sized storm (Figure 13). This frequent rainfall may have prevented the effects of differing water use to become manifested in soil moisture by keeping the soil continuously wet, as a longer dry period might be necessary for the effects of consumptive differences to become apparent. Norwood (2001) saw similar results in a study of soil water depletion under various management systems of dryland corn. In the study, soil water varied with management system, except during one year during which frequent rainfall refreshed the profile throughout the season.

However, 2005 was much less rainy, especially in June and July, but significant differences were still not seen between crops on the two sets of experimental crops, indicating that wet weather was not the only factor at play.

The lack of distinct differences in these two locations might also be attributed to the fact that the perennial and agroforestry crops were still in the establishment phase, and the agroforestry crops in particular showed little growth over the course of the 2004 season, and the hazel in particular were still underdeveloped at the end of the 2005 season (Figure BBB). The data from the mature poplar stand and nearby corn field support this idea, as the soil under the mature poplar was consistently drier than that in the corn field during 2004.

As discussed above, the lesser difference observed in 2005 might be the result of weed management among the poplars. It is worth noting, however, that the poplar grove was significantly drier than the field in the earliest part of 2005, when the threat of flooding from run off would be greatest. Fully mature field crops do evapotranspire a considerable amount of water, making the convergence of soil moisture measurements in the hillslope area not unexpected either, given the weed removal in 2005.

It is also possible that the spatially variable nature of soil moisture combined with the small sample size meant that the measurements taken were simply not refined enough to pick up differences (an idea once again supported by the corn/poplar data, where larger sample sizes resulted in smaller margins of error). In their 2004 study and analysis of spatio-temporal variability of ET in a corn field, Hupet and Vanclooster concluded that hydrologic processes are so spatially variable, even in a homogeneous field, that using random sampling to achieve estimates of any useful precision would be unrealistic as it would require an onerously burdensome number of samples.

Other studies with more refined sampling methods, such as a two-year study of soil water under a variety of alternative cropping systems in western Canada (Izaurralde et al 1994), observed consistently drier soils under the one perennial scenario than any of the annual cropping systems. This difference varied between a 1.8 cm and 0.2 cm of difference in soil water in an 80 cm profile, and thus it might be argued that even if additional measurements proved any observed differences to be statistically significant, differences of that size might be of little practical importance

If we assume that hydrologic benefits from perennial and agroforestry crops will result from differences in consumptive water use resulting in increased water storage capacity, the observations from this study do not show such benefits occurring during the establishment phases of such alternative crops, as no significant difference in soil moisture between the crops on the experimental plots was observed. However, a significant difference in soil moisture beneath the mature poplar stand and corn in 2004 indicates that mature agroforestry crops might provide hydrologic benefits through additional available water storage, although the reduced differences observed on the hillslope in 2005 reinforce the importance of overall management practices in taking advantage of this potential benefit.

**Soil Frost**

Soil frost monitoring was done from December 2004 to April 2005 on three sites at the SROC, Waseca. The first two, which were the mature poplar grove and experimental plots underlain by tile drainage, were also monitored for soil moisture, and are described above. The third site was a series of crop strips just north of the mature poplar grove (which will be referred to as the landscape position plots).

Eight frost tubes were placed at random within the mature poplar grove, although site selection was limited to locations at least two feet from a tree trunk, as that was the minimum required by the installation equipment (Figure 7).

In the tile drain plots, four frost tubes were placed at random in each of two plots of six crops (willow, poplar, hybrid hazelnut, Illinois bundleflower, perennial flax, and corn/soybean rotation) (Figure 3). The willow on the tile drain plots was cut to the ground in November, to simulate the conditions of willows grown for biomass.

The landscape position plots consisted of four 3 meter wide strips of different perennial crops, running approximately east-west approximately perpendicular to topographic lines over a small valley between two highpoints, thus traversing a continuous spectrum of landscape position (Figure 26). The strips of perennial crops were abutted on both sides by large fields in corn/soybean rotation, which had just come out of corn and had been disc plowed. Frost tubes were placed in the willow, IBF, and poplar strips, as well as in the section of field directly south of the strips. Willow on these plots was also trimmed to the ground in November of 2004. Six tubes were put in each crop, in groups of two each on the foot, backslope and topslope of the east-facing slope. The tubes were placed down the center of the perennial crop strips, and in a line approximately 2.5 meters from the crop strips in the cornfield.

The frost tubes were constructed following the methodology described by Christopherson (2001), although 75 percent of the tubes constructed for this study extended120 cm below the surface, and the remaining tubes went 137 cm below the soil surface. The tubes were installed in the fall of 2004. An initial soil frost measurement was taken December 15, followed by bi-weekly measurements until the beginning of March. Once it became apparent that the soil had begun to thaw, the measuring frequency was gradually increased, with measurements taken every other day during the first ten days of April. Measurements were recorded to the nearest 0.5 cm.

Snow depth and snow water equivalent were also measured next to each frost tube on each sampling date. Snow depth was measured with a ruler, and a snow sample was collected and taken bag to the lab to be weighed for snow water equivalent. Using a shovel to excavate soil on each plot, soil frost type was determined and visually.

**Results:**

The 2004-2005 winter was, on average, warmer than a typical winter, with less than average snowfall (Table 2). The winter still saw considerable periods of cold, including several extended periods where the temperature barely exceeded freezing, if at all, and several days with bitterly cold temperatures (Figure 5). However, these cold periods were sandwiched around periods of unseasonable warmth, including highs above 10°C on New Year's Eve, February 5, 6 and 13, and a high of 17°C on March 7.

During an average winter at the field site, there are 128 cm of snowfall, and 92 days with at least 2.54 cm of snow on the ground. The study winter was considerably less snowy, with only 90 cm of snowfall and 72 days with at least 2.54 cm of snow on the ground. Even these numbers are somewhat deceptive, as February and March were much snowier than normal, meaning that the early part of the winter, December in particular, was much less snowy than usual (Table 2). In fact, until January 6, there were only a total of 10 days during which any snow cover at all was recorded (Figure 5). In addition to snow, there were several rainfall events during the winter, the most significant of which were 1.24 cm of rain on January 2, and 2.84 cm of rain on March 31.

Snow was first observed on the sample sites on January 12, and last observed on March 26 (Table 3). Snow cover on all the sites was minimal throughout the winter, although some accumulation was observed, with a maximum of 15.6 cm observed in the tile drainage poplar on March 25. On January 28, the poplar, flax and IBF on the tile drainage plots and mature poplar grove and on March 25, the same crops plus the corn/soy field in the tile drainage plots had noticeably more snow than the other locations, largely due to drifting, although these differences all disappeared by the next sampling date.

It is also worth noting that during each of the warm periods of the winter, melted snow and rain accumulated in the surface of the soil and froze into a solid ice layer at the soil surface, which persisted until the soil began to thaw in March.

The soils in all sampling locations were very wet prior to freezing. With the heavy snowfall in late March followed immediately by days with highs between the 10 and 15°C and lows above freezing, surface conditions were also extremely wet at the end of winter just prior to frost disappearance.

At the time of the first measurements (December 15), a thin (less than 10 cm) layer of frozen soil had begun to develop in all sampled locations. The maximum soil frost depth was measured in all locations on January 28 when average soil frost depth exceeded 60 cm in all sample locations, exceeding 80 cm in the landscape position willows. While the soil remained frozen to the surface for the next six weeks, the lower extent of soil frost retreated slightly, plateauing between 50 and 70 cm deep from the end of February through mid-March.

During this time of persistent soil frost, in the tile drainage plots, soil frost under flax was consistently shallower than under the other crops, and soil frost under willow was consistently deeper. Soil frost under the corn/soy field was only slightly shallower than willow.

In the landscape position plots and poplar grove, soil frost under the mature poplar stand and cornfield were similar, and shallower than under the other crops. Willow consistently saw the deepest soil frost, although soil frost under the young poplar was only slightly shallower.

On March 17, the first signs of thawing at the surface were observed, and by March 25, soil frost under the willows in both locations and the young poplar on the landscape position plots had melted to a depth of more than 4.5 cm. After March 25, thawing proceeded rapidly in all sampled locations. In all cases, thawing was faster from the surface downward than from the bottom of the soil frost layer up. In fact, all locations showed minimal bottom-up thawing. All sampled locations showed similar rates of thawing.

On April 8, soil frost had disappeared from under the flax and IBF on the tile drainage plots, as well as from under the corn/soy field and IBF on the landscape position plots. On April 10, soil frost had disappeared everywhere.

When the data from the landscape position plots was separated by landscape position instead of crop type, a similar pattern was observed, and minimal differences between he landscape positions. Soil frost disappeared from all landscape positions on the same date. Soil frost type was visually examined on March 17, and on all plots, concrete soil frost was observed.

Table 5. Soil moisture in the Waseca runoff plots for 2004-2005.

| | 2004 | | | | | | | | | | 2005 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5/18 | 6/2 | 6/20 | 7/6 | 7/21 | 8/9 | 8/25 | 9/9 | 9/23 | 10/21 | 4/21 | 5/5 | 5/22 | 6/1 | 6/15 | 7/12 | 7/27 | 8/9 | 8/23 |
| Willow | 50.6 | 51.0 | 49.4 | 51.1 | 50.6 | 49.2 | 48.7 | 49.3 | 53.4 | 49.1 | 55.0 | 52.7 | 54.4 | 53.3 | 50.6 | 48.7 | 48.0 | 49.5 | 45.9 |
| Corn/Soy | 48.4 | 48.8 | 49.5 | 46.9 | 52.6 | 45.4 | 45.6 | 46.2 | 55.4 | 46.8 | 53.9 | 51.9 | 53.5 | 56.0 | 52.5 | 44.9 | 42.5 | 42.5 | 38.0 |
| IBF | 49.1 | 46.6 | 49.5 | 48.7 | 50.8 | 45.9 | 49.9 | 50.4 | 54.4 | 51.4 | 53.6 | 51.2 | 56.7 | 52.4 | 54.6 | 48.2 | 49.3 | 48.2 | 40.5 |
| Hazel | 46.0 | 47.5 | 49.5 | 49.0 | 53.2 | 49.3 | 48.2 | 47.8 | 54.2 | 50.8 | 54.3 | 49.3 | 54.5 | 54.3 | 51.7 | 47.2 | 48.5 | 47.7 | 44.1 |
| Flax | 47.2 | 46.4 | 45.5 | 44.3 | 50.2 | 46.6 | 48.6 | 47.6 | 53.5 | 48.6 | 54.2 | 51.7 | 54.2 | 55.6 | 52.4 | 47.8 | 45.8 | 44.9 | 42.4 |

## APPENDIX D

**References of articles presentations related to LCMR project Research**

Publications and presentations developed as part of the UMN-BERBI coordination on improving water quality and storage in the Minnesota River Basin through the introduction of perennial vegetation. These articles and presentations presented work that received funding from the LCMR as well as leveraged funding from USDA-CSREES and MN PCA.


Brooks, K.N., D. Current and D. Wyse. 2003. Restoring Hydrologic Function of Altered Landscapes: An Integrated Watershed Management Approach. Pp 101-114 in Invited Keynote Paper, FAO International Conference *Water Resources for the Future*, Porto Cervo, Sassari, Sardinia, Italy; 22-24 October, 2003, Watershed Management & Sustainable Mountain Development Working Paper 9, FAO, United Nations, Rome.

Bryne, M. And K.N. Brooks. 2005. Soil moisture regimes under annual and perennial crops as components of agroforestry systems. In: Brooks, K.N., and P.F. Ffolliott. 2005. (eds.) *Moving agroforestry into the mainstream.* The 9th North American Agroforestry Conference Proceedings, June 12-15, CINRAM and Dept. of Forest Resources, University of Minnesota, St. Paul, MN.

Colson, A., K. Brooks, D. Wyse, G. Johnson and C. Sheaffer. 2005. Runoff and sediment from woody and herbaceous perennial crops and an annual crop. In: Brooks, K.N., and P.F. Ffolliott. 2005. (eds.) *Moving agroforestry into the mainstream.* The 9th North American Agroforestry Conference Proceedings, June 12-15, CINRAM and Dept. of Forest Resources, University of Minnesota, St. Paul, MN.

Ennaanay, D. 2006. Impacts of land use changes on the hydrologic regime in the Minnesota River Basin. PhD Dissertation, University of Minnesota, St. Paul, MN.

Ennaanay, D., L. Aniskoff and K.N. Brooks. 2005. Modeling hydrologic response of converting annual crops to agroforestry and other perennial cropping systems: an assessment of SWAT and HSPF capabilities. In: Brooks, K.N., and P.F. Ffolliott. 2005. (eds.) *Moving agroforestry into the mainstream.* The 9th North American Agroforestry Conference Proceedings, June 12-15, CINRAM and Dept. of Forest Resources, University of Minnesota, St. Paul, MN.

Magner, J.A. and K.N. Brooks. 2005. Assessing agroforestry options for water quality using regional hydraulic geometry curves. In: Brooks, K.N., and P.F. Ffolliott. 2005. (eds.) *Moving agroforestry into the mainstream.* The 9th North American Agroforestry Conference Proceedings, June 12-15, CINRAM and Dept. of Forest Resources, University of Minnesota, St. Paul, MN.

Morse, S. And D. Current. 2005. Green Lands, Blue Waters – Project description. In: Brooks, K.N., and P.F. Ffolliott. 2005. (eds.) *Moving agroforestry into the mainstream.* The 9th North American Agroforestry Conference Proceedings, June 12-15, CINRAM and Dept. of Forest Resources, University of Minnesota, St. Paul, MN.

Sheaffer, C.C., G.A. Johnson, D.L. Wyse and L.R. DeHaan. 2005. Perennial vegetation for strategic placement on agricultural landscapes. In: Brooks, K.N., and P.F. Ffolliott. 2005. (eds.) *Moving agroforestry into the mainstream.* The 9th North American Agroforestry Conference Proceedings, June 12-15, CINRAM and Dept. of Forest Resources, University of Minnesota, St. Paul, MN.

**Selected Talks and Papers Presented (not published as papers above):**

Brooks, K.N. 2005. Improving Water Quality and Enhancing Hydrologic Stability of the Minnesota River through Agroforestry and other Perennial Cropping Systems. Presentation at the USDA -CSREES National Water Quality Conference. San Diego, CA, Feb. 7-9, 2005.

Brooks, K.N. 2003. Nitrogen farming: Potential Field Sites in Minnesota. Presentation at Nitrogen Farming Workshop. Wetlands Initiative and EPA, Chicago, Illinois, Feb. 21, 2003.

Ennaanay, D. , Y. Konishi, K.N. Brooks, and W.K. Easter. 26 Oct. 2005 Impacts of perennial vegetation on the hydrologic stability and the economic viability in watersheds of the Minnesota River Basin. Minnesota Water 2005 and Annual Water Resources Joint Conference, Earle Brown Heritage Center, Brooklyn Center, MN.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Attachment A: Budget Detail for 2003 Projects - BERBI Portion Only** | | | June 30, 2006 | Final Report | | | | | | |
| **Proposal Title: Native Plants and Alternative Crops for Water Quality** | | | | | | | | | | |
| **Project Manager Name: Linda Meschke** | | | | | | | | | | |
| **LCMR Requested Dollars:** $ *403,150 BERBI Portion Only* | | | | | | | | | | |
| **2003 LCMR Proposal Budget** | **Result 1 Budget:** | **Amount Spent June 30, 2006** | **Balance June 30, 2006** | **Result 2 Budget:** | **Amount Spent** *(date)* | **Balance** *(date)* | **Result 3 Budget:** | **Amount Spent June 30, 2006** | **Balance June 30, 2006** | |
| | *Establish, demonstrate and evaluate plantings of native plants and 3rd crops for agronomic, water quality and economic benefit* | | | *Determine cumulative economic and water quality and quantity impacts of native plants and 3rd crop systems at the watershed level and their relation to rural economic vitality.* | | | *Accelerate implementation of native plant and 3rd crop production with demonstration and market identification, coordination and promotion.* | | | |
| **BUDGET ITEM** | | | | | | | | | | **TOTAL FOR BUDGET ITEM** |
| **Personnel:** | | | | | | | | | | |
| **BERBI: Marketing Person – 0.5 FTE** $20/ hr x 1040 hr/yr x 3 years, includes 3% cost of living increase per year Note: the other half of this person is intended to be paid with a grant from the Bush Foundation. | | | | | | | $ 64,291.00 | $6,315.95 | $11,451.17 | $ 64,291.00 |
| **BERBI: Marketing Person benefits – 27%** includes FICA 6.2%; Med. 1.45%; PERA 5.1 %; and health insurance 14.25% | | | | | | | $ 17,359.00 | $2,270.20 | $1,230.05 | $ 17,359.00 |
| **BERBI: Martin SWCD- Fiscal Agent** | $ 2,000.00 | | $0.00 | | | | | | | $ 2,000.00 |
| **BERBI: Clerical** | $ 2,000.00 | | $ - | | | | | | | $ 2,000.00 |
| **BERBI: SWCD Technical Assistance 5% of the BERBI easements** | $ 14,800.00 | | $ 1,393.00 | | | | | | | $ 14,800.00 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| **Signage 30 signs @ $15** | $ 450.00 | $ 243.93 | $ 206.07 | | | | | | | $ 450.00 |
| | | | | | | | | | | |
| **Printing** | | | | | | | $ 1,000.00 | $749.67 | $0.00 | $ 1,000.00 |
| **BERBI Easements 200 acres @ $1450** | $ 295,250.00 | $ 3,004.00 | $ 14,375.00 | | | | | | | $ 295,250.00 |
| **Small Demonstration Plots- 4 sites x 2 acres x 3 years x $250** | $ 6,000.00 | $3,000.00 | $0.00 | | | | | | | $ 6,000.00 |
| | | | | | | | | | | |
| **COLUMN TOTAL** | $ 320,500.00 | $ 6,247.93 | $ 15,974.07 | $ - | | | $ 82,650.00 | $ 9,335.82 | $ 12,681.22 | $ 403,150.00 |

**Attachment A: Budget Detail for 2003 Projects - UMN Portion only** June 30, 2006 - Final Report

**Proposal Title: Native Plants and Alternative Crops for Water Quality [C-5] 16**

**Project Manager Name: Dean Current**

**LCMR Requested Dollars: $ 218,850** *University of Minnesota Portion*

| 2003 LCMR Proposal Budget | Result 1 Budget: | Revised Result 1 Budget: (6/06/06) | Amount Spent *through 06/30/06* | Balance *6/30/2006* | Result 2 Budget: | Revised Result 2 Budget: (6/06/06) | Amount Spent *through 06/30/06* | Balance *6/30/2006* | Result 3 Budget: | Amount Spent *through 06/01/06* | Balance *06/01/06* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Establish, demonstrate and evaluate plantings of native plants and 3rd crops for agronomic, water quality and economic benefit* | | | | | *Determine cumulative economic and water quality and quantity impacts of native plants and 3rd crop systems at the watershed level and their relation to rural economic vitality.* | | | *Develop community based education to accelerate implementation of native plant and 3rd Crop production and marketing to improve water quality.* | | | |
| **BUDGET ITEM** | | | | | | | | | | | | **TOTAL FOR BUDGET ITEM** |
| **PERSONNEL: Staff Expenses, wages, salaries -** | | | | | | | | | | | | |
| Research Assistant (50% time x 1.75 years - may be divided between more than one) | 14,450 | | 0 | 14,450 | 14,450 | | 11,154 | 3,296 | | | | 28,900 |
| Res. Asst. Fringe (76%) | 10,983 | | 0 | 10,983 | 10,983 | | 6,286 | 4,697 | | | | 21,966 |
| Research Associate (25% time x 2years) | 18,997 | | 33,789 | -14,792 | 18,997 | | 1,269 | 17,728 | | | | 37,994 |
| Res. Assoc. Fringe (31/6%) | 6,003 | | 10,917 | -4,914 | 6,003 | | 91 | 5,912 | | | | 12,006 |
| Research Technician (75% time x 2 years) | 27,002 | | 34,301 | -7,299 | 27,002 | | 49,946 | -22,944 | | | | 54,004 |
| Res. Tech Fringe (30.7%) | 8,290 | | 8,147 | 143 | 8,290 | | 17,000 | -8,710 | | | | 16,580 |
| | | | | | | | | | | | | |
| **Total Personnel** | | 85,725 | 87,154 | -1,429 | | 85,725 | 85,746 | -21 | | | | |
| | | | | | | | | | | | | |
| **Equipment / Tools** | | | | | | | | | | | | |
| Campbell Weather Station CR10 | | | | | | | | | | | | |
| Water Level Recorders [Solonist] 9 @ $855 | | | | | | | | | | | | |
| Cables for loggers [9 @ $25] | | | | | | | | | | | | |
| Optical reader [Solonist] and Loader | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| 9 flumes @ 1200 each | | | | | | | | | | | | |
| Subsurface Drainage Collectors 21 @ $310 | | | | | | | | | | | | |
| Field and Lab Supplies | | | | | | | | | | | | |
| | | | | | | | | | | | | 0 |
| **Total Equipment / tools - Supplies** | | | | | 31,099 | 31,407 | 31,386 | 21 | | | | 31,407 |
| | | | | | | | | 0 | | | | 0 |
| **Water Analysis** | | | | | | | | 0 | | | | 0 |
| **Soil Analysis** | | | | | | | | 0 | | | | 0 |
| **Lab Services** | | | | | 8,000 | 10,325 | 10,325 | 0 | | | | |
| **Printing** | | | | | | | | 0 | 2,000 | | 2,000 | 2,000 |
| **Travel expenses in Minnesota** | 3,150 | 3,150 | 1,721 | 1,429 | 3,150 | 518 | 518 | 0 | | | | 6,300 |
| | | | | | | | | 0 | | | | 0 |
| **COLUMN TOTAL** | 88,875 | 88,875 | 88,875 | 0 | 127,974 | 127,974 | 127,974 | 0 | 2,000 | | 2,000 | 218,849 |