2005 Project Abstract
For the Period Ending June 30, 2009

PROJECT TITLE: 7(j) Improving Impaired Watersheds: Conservation Drainage Research

PROJECT MANAGER: Mark Dittrich
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WEBSITE: www.mda.state.mn.us
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION:
2005 First Special Session Appropriation Language: 7 (j) Improving Impaired Watersheds: Conservation Drainage Research. $150,000 the first year and $150,000 the second year are from the trust fund to the commissioner of agriculture to analyze conservation drainage systems at University of Minnesota research and outreach centers for opportunities to retrofit drainage infrastructure with water quality improvement technologies. This appropriation is available until June 30, 2008, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

"Improving impaired watersheds conservation drainage research" to June 30, 2009 as stated below:

<u>Legal Citation: ML 2008, Chap. 367, Sec. 2, Subd. 15 Carryforward</u>

Appropriation Language: (a) The availability of the appropriations for the following projects are extended to June 30, 2009: (2) Laws 2005, First Special Session chapter 1, article 2, section 11, subdivision 7, paragraph (j), improving impaired watersheds conservation drainage research.

APPROPRIATION AMOUNT: $300,000

Overall Project Outcome and Result
Rural drainage systems are being repaired and replaced in Minnesota at an increasing rate. This provides a unique opportunity to simultaneously install conservation designs and practices with drainage repairs and improvements. This project measures the efficacy of three conservation practices with in-field methods and computer simulation of their performance in southern Minnesota. These innovative conservation practices may play a vital role in improving water quality in Minnesota and the hypoxic zone in the Gulf of Mexico.

Measuring the Efficacy of Three Conservation Practices:
1. Managed Drainage: Water control structures in drainage pipe designed to retain soil moisture by seasonally elevating the water table in the crop field within 2 feet from the soil surface.
2. Shallow Drainage: Drainage pipe installed at 2.5-3ft depth, rather than the traditional 4-5 ft depth.
3. Woodchip Bioreactor: Connecting drainage outlet pipe to an excavated area filled with woodchips, then area is capped with 12-18” of topsoil.

Results for Managed and Shallow Drainage: Field-based Studies

The field-based studies occurred in Nicollet and Mower County with fully instrumented flow measurement devices and weekly nitrate-nitrogen grab samples. There were two research plots, each approximately 10 acres for each site. Findings showed a 20% reduction in the flow discharge from managed drainage compared to conventional drainage. Nitrate concentrations between plots were very similar, and nitrate load reduction in managed drainage plots compared to conventional subsurface drainage practices were associated with the total amount of flow discharged, not the nitrate concentration.

Computer Simulation for Managed and Shallow Drainage

Computer modeling can help understand the range of impacts where field based studies may be cost prohibitive. Important site specific parameters for modeling subsurface drainage include soil and climate factors such as rainfall, temperature, and evapotranspiration. Together these dictate the range of potential effects a drainage system and the associated designs have upon the receiving water body. Also, simulations can associate the size and timing of the associated benefits with these two conservation management practices: managed and shallow drainage.

Three sites were chosen for simulation, as they provided needed baseline information for climate, soils and associated drainage management practices (managed and shallow drainage). The sites included were located in Redwood, Waseca and Mower counties, which provided a range of climate and soil parameters.

Results from Computer Simulation

- Redwood County site exhibited the greatest drainage volume reduction for shallow and managed drainage compared with conventional drainage: 18% and 38% respectively. The Mower County site exhibited the least volume reduction for shallow and managed drainage: 7% and 26% respectively.
- Managed drainage provided a 15% volume reduction beyond shallow drainage at each of the three site locations.

Woodchip Bioreactor: Rice and Dodge County Sites

The primary focus at these two sites was to measure the efficacy of a woodchip bioreactor, which is an excavated area intercepting subsurface drainage and retaining drainage water long enough to significantly reduce nutrient and bacteria concentrations. The two sites and infrastructure will be used for ongoing analysis of herbicide remediation in 2010-2011.

Results for Woodchip Bioreactor

- 50% of nitrate-nitrogen load was reduced within the woodchip trench in less than 32 hours, 30% of the load was reduced in 22 hours, and nearly 100% in 50 hours.
- Phosphorus concentrations were reduced by about 50%.

Project Results Use and Dissemination

The results from this study were disseminated through USDA and USEPA task force and coalition meetings that included industry in public-private partnerships with the research and field-based studies. Leadership and program development was provided primarily with the USDA - Natural Resources and Conservation Service (NRCS) and the USDA - Agricultural Research Service (ARS), beginning in 2003. Related activities included presentations to more than 32 groups, and delivering 2,200 publications to interested stakeholders and agency staff. These activities occurred in concert with Dr. Gary Sands's University of Minnesota "Drainage Outlet" website that has been redesigned to increase information delivery and overall ease-of-access.

Full reports are located at www.mda.state.mn.us/

Trust Fund 2005 Work Program Final Report

Date of Report: June 30, 2010
Trust Fund 2005 Work Program Final Report
Date of Workplan Approval: July 1, 2005
Project Completion Date: June 30, 2009

I. PROJECT TITLE: Improving Impaired Watersheds: Conservation Drainage Research

Project Manager: Mark Dittrich,
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Location: Statewide

- **A.** University of Minnesota Southern Research and Outreach Center - Waseca.
- **B.** University of Minnesota Southwest Research and Outreach Center - Lamberton.
- **C.** Mower County, Bennington Township, southeast of Grand Meadow.
- **D.** Nicollet County, Traverse Township, west of St. Peter.
- **E.** Clay County, Morken Township, east of Moorhead.
- **F.** Rice County, Bridgewater Township, west of Dundas.
- **G.** Dodge County, Ellington Township, north of Claremont.

Total Trust Fund Project Budget:	**LCMR Appropriation:**	**$300,000**
	Minus Amount Spent:	**$292,470**
	Equal Balance:	**$ 7,530**

Legal Citation: ML. 2005 First Special Session: Chp. 1, Art. 2, Sec. 11 Subd, 7 (j)

2005 First Special Session Appropriation Language: 7 (j) Improving Impaired Watersheds: Conservation Drainage Research. $150,000 the first year and $150,000 the second year are from the trust fund to the commissioner of agriculture to analyze conservation drainage systems at University of Minnesota research and outreach centers for opportunities to retrofit drainage infrastructure with water quality improvement technologies. This appropriation is available until June 30, 2008, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

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II. and III. FINAL PROJECT SUMMARY

Rural drainage systems are being repaired and replaced in Minnesota at an increasing rate. This provides a unique opportunity to simultaneously install conservation designs and practices with drainage repairs and improvements. This project measures the efficacy of three conservation practices, with in-field methods, and with computer simulation of their performance in southern Minnesota. These innovative conservation practices may play a vital role in improving water quality in Minnesota and the hypoxic zone in the Gulf of Mexico.

Measuring the Efficacy of Three Conservation Practices.

1. Managed drainage: water control structures in drainage pipe designed to retain soil moisture by seasonally elevating the water table in the crop field within 2 feet from the soil surface.
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Results for Managed Drainage: Field-based Studies.

Results for managed drainage field-based study occurred in Nicollet and Mower County, with fully instrumented flow measurement devices, and weekly nitrate-nitrogen grab samples. There were two managed drainage plots, each approximately 10 acres for each site. The finding for these field-based plots show a 20% reduction in the flow discharge from managed drainage compared to conventional drainage. Nitrate concentrations between plots were very similar, and nitrate load reduction in managed drainage plots compared to conventional subsurface drainage practices were associated with the total amount of flow discharged, not the nitrate concentration.

Computer Simulation for Managed and Shallow drainage:

For conservation practices to be most effective, site-specific information must be used. Where field based studies maybe cost prohibitive computer modeling can help understand the range of impacts, in this case measuring impacts of conservation practices associated with drainage.

Important site specific parameters for modeling subsurface drainage include climate (rainfall, temperature, ET). Together, soils and climate dictate the range of potential effects a drainage system and the associated designs have upon the receiving water body. Also, simulations can associate the size and timing of the associated benefits with these two conservation management practices: managed and shallow drainage.

Three sites were chosen for simulation, as they provided needed baseline information for climate, soils and associated drainage management practices (managed and shallow drainage). The sites included were located in Redwood, Waseca and Mower County; SW, SC, and SE Minnesota with climate and soil parameters.

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Authors include: Dr. Gary Sands, Dr. Jeffery Strock, Dr. John Moncrief, Dr. Andry Ranaivoson, Dr. Rodney Venterea and Mark Dittrich.

Full reports are located at www.mda.state.mn.us/

IV. OUTLINE OF PROJECT RESULTS: OVERVIEW

This project quantified environmental benefits from three conservation drainage practices and the associated designs. These project results used drainage research infrastructure provided by, and developed at the University of Minnesota Research and Outreach Centers. Field-based studies used four demonstration farms in Nicollet, Mower, Rice and Dodge Counties.
Due to the absence of average weather patterns and associated flows from field plots, project also included computer simulations to determine the average flows and nutrient loads from subsurface drainage leaving the edge of field to ditches and streams.

- Convened diagnostic teams: conferred with multiple land grant institutions, convened meetings at the UofM (Waseca, Lamberton and St. Paul), MDA – St. Paul, Minnesota Corn Growers - Shakopee and Gustavus Adolphus – St. Peter, with project coordinators and representatives.
- Developed methodology for measuring flows and water quality – Extensive research and planning was done to determine best method for measuring the rate of flow from the drainage plots. Techniques for measuring flow proved to be economical, reliable, and with the capacity to measure a wide range of flow rates. Also the configuration of equipment fit into the confined space of the sampling wells, except for the Clay County site.
- Reviewed existing data sets, designs, control structures, sampling wells, and monitoring equipment. Selected the criteria and experimental frameworks most likely to succeed. Coordinated with other land grant institutions staff that included: Dr. Richard Cooke – University of Illinois, Dr. Don Pitts – USDA NRCS, and Dr. Dan Jaynes – USDA ARS Ames Iowa to garner advice and avoid common pitfalls in designs, methods and equipment constraints.

- Selected demonstration sites in cooperation with the Minnesota Corn and Soybean Growers, Minnesota Land Improvement Contractors Association, USDA-NRCS, and associated LGU's (Mower SWCD, and Brown Nicollet Cottonwood Water Quality Water Board).
- Developed and implemented field-scale designs, pretested the equipment configurations in a laboratory setting, calibrated and installed the monitoring equipment. Recalibrated equipment when flow data diverged from precipitation and associated predicted flow rates.
- Provided outreach and education to/with research, conservation and farming community. Also garnered strong stakeholder feedback on the concerns regarding localized flooding, streambank instability, and associated impacts to aquatic communities.
- In concert with the University of Minnesota, local, state and federal partners developed a literature review regarding the impacts from surface and subsurface drainage. Literature review was under the direction of University of Minnesota – Water Resources Center, and authored by Dr. Kristin Blann.

Clay County Site: Flow Data Issues.

Problems were encountered with flow monitoring placement and the equipment at Nicollet and Mower County demonstration sites, however due to the nature of the landscape setting, and absence of frequently flooded conditions, these issues were addressed quickly and efficiently. These small gaps in data didn't affect our confidence in the plot design, total flows and relative magnitude of the results. In contrast, flow monitoring problems at the Clay County site were created by frequent ongoing high water / flooding conditions. Due to the lack of confidence in the data, Clay County site values were not reported. The MDA continues to investigate this site, the flow monitoring equipment designs, and complex trigger points to insure confidence in flow data. Efforts are underway (nearly completed) to upgrade the flow monitoring equipment, methods for triggering backup systems, and develop a new design embedded with inherent redundancy.

Result 1a. Field-based studies

Description:

The field-based component of the project was designed to show the potential impacts of subsurface drainage systems to the receiving water bodies, their designs and associated management practices on water quality, flows and crop yield.

Representative, uniform sites were selected in areas where new and existing subsurface drainage systems were being repaired or improved. These sites were located in suitable areas where local cooperators and local organizations were willing and able to modify their workloads and priorities to accommodate the needed resources for supporting these activities. During the siting process it was[MD1] important the monitoring equipment allowed for easy access to the dedicated farm fields and the outlets (tile mains and ditches) for weekly sampling and troubleshooting. Subsequently, after garnering the needed drainage designs from land-grant university staff and contractors, and the regulatory approval from state and federal agencies regarding the installation of subsurface drainage, new subsurface drainage systems were installed using typical and current equipment and materials. The exception to the typical drainage installation was the required, dedicated field plot outlet pipes for each plot.

At each demonstration site two plots were installed for each practice (conventional, shallow and managed drainage). Each plot was about 10 acres in size and was developed for each of the following drainage system designs:

- Conventional subsurface drainage installed at a depth of four feet and recommended spacing of eighty feet.
- Shallow subsurface drainage installed at a depth of three feet and the recommended spacing of fifty feet.
- Managed subsurface drainage installed at a depth of four feet and a spacing of fifty feet, with water control structures to manage the flows and water table within two feet of soil surface.

The function of the control structure is to manage the water table within the crop field during the growing season and then again through the winter within two feet from the soil surface, lowering the water table during planting (April to mid May) and harvesting (mid September through October) as needed for tillage, planting and harvesting. When early spring soil conditions are dry, farmers may not need to lower the water table for field activities, which enables the storage of precious soil moisture for crop use. This was done in the spring of 2009.

Each site was installed and designed with electromagnetic flow meters to measure flows. Also, each site required a nested rain gauge tipping bucket for rainfall; both were connected to a datalogger. Water samples were collected when flow occurred each week, and analyzed for nitrate concentrations. Crop yields were measured with a combine yield monitor. The field crops for these plots were either corn or soybeans.

Summary Budget Information for Result 1:
Trust Fund Budget: $193,000
Amount Spent: $185,470
Balance: $ 7,530

Deliverable **Completion Date: June 30, 2009**

1. **Measure, evaluate and model effectiveness of conservation drainage practices. June 30, 2009**

Completion Date: June 30, 2009.

Final Report Summary: Results for Nicollet and Mower County Sites

Annual flows from each plot are shown in the table below
Annual water flows in all plots ranged from 1.0 to 19.9 inches of flow.
Nitrate losses correspond closely to the drainage flow and are typical for the corn/soybean rotation.

Nicollet County: Nitrate losses (lbs/acre) ranged from 2.8 to 30.4 for all plots. Conventional drainage losses (lbs/acre) were generally higher than managed drainage.

Mower County: Nitrate losses (lbs/acre) ranged from 4.1 to 7.0 for all plots. Conventional drainage losses (lbs/acre) were consistently higher than managed drainage plots.

The differences in nitrate load between the two sites (lbs/acre) were due to soil type, nutrient management treatment / timing, primary tillage and planting systems employed by each cooperator.

Results:

Annual Flow and Nitrate Load			**Conventional**		**Shallow**		**Managed**	
			2007	**2008**	**2007**	**2008**	**2007**	**2008**
Nicollet County Site	Drainage (inches)	Site #1	6.6	4.7***	6.6	5.5	5.4	4.9
		Site #2	6.0	6.9	1.5	2.0	1.0**	1.2**
	NO3-N loss (lb/acre)	Site #1	26.4	20.4	25.8	30.4	16.8	22.2
		Site #2	19.7	23.7	2.8	8.5	8.1	6.6

Annual Flow and Nitrate Load			**Conventional**		**Shallow**		**Managed**	
			2007	**2008**	**2007**	**2008**	**2007**	**2008**
Mower County Site	Drainage (inches)	Site N	14.5	5.7	19.9	8.7	10.4	5.8
		Site S	9.2	4.8	14.8	6.6	11.3	5.1
	NO3-N loss (lb/acre)	Site N	6.0	6.7	5.4	7.0	4.4	5.3
		Site S	4.9	4.1	4.1	5.4	4.4	4.5

** Due to unknown factors, the water table was not effectively maintained.
***Equipment failure caused considerable loss of water flow data.

Crop Yield Results:

Crop yield responses between plots were uniform across both sites in 2008~~,~~; significant differences in crop yields were not observed in this study.

Conclusions

Managed drainage designs and water table management shows potential in reducing flows and nitrate loss in subsurface drainage water, as well as can provide additional moisture for crops in dry years. There was an approximately 20% reduction in flow and nitrate load in these plots. This potential benefit comes with an additional 5-10% installation cost compared to conventional subsurface drainage, for shallow and managed drainage, due to more material, structures and design resources.

New control structures, water table management designs (water gates) and installation methods may help transfer to farmfields beyond the traditional areas for managed drainage. New prototype control structure designs (water gates) are being field tested in SW Minnesota near Windom, and will likely be available for commercial use in the fall of 2010. More information can be found at websites AgriDrain Inc, and Agricultural Drainage Management Coalition www.agridrain.com or www.admcoaliton.com.

Result 1b: Modeling Subsurface Drainage in Southern Minnesota.

Description:

Designing and managing drainage systems to achieve both crop production and nitrogen reduction goals presents a challenging task for agricultural drainage designers and practitioners. Skaggs *et al*.

(2006, 2007), and Skaggs and Chescheir (2003) presented a rationale and framework for drainage design with a two-pronged, production-environment approach.

Dinnes *et al*. (2002) suggested that a combination of management practices might be necessary to achieve nitrate load-reduction goals, including drainage design and management. Sands *et al*. (2008) presented data supporting the effectiveness of shallow-drainage systems for south-central Minnesota.

For drainage practices to be most effective, site-specific information must be used for design and management decisions. Thorp *et al*. (2008) demonstrated through modeling how location (climate) is an important determinant of efficacy for the practice of managed drainage. Whereas numerous field-based studies can be cost prohibitive, computer-modeling studies can help us understand the range of effects of local soils and climate on the efficacy of drainage design and management practices.

Final Report Summary: DRAINMOD NII. Simulations for Three Southern Minnesota Landscapes. The field-scale drainage model – DRAINMOD (Skaggs, 1978) was used to assess the impacts of three subsurface drainage practices:

- Conventional pattern-tile drainage (four ft depth),
- Shallow pattern-tile drainage (three ft depth), and
- Managed pattern-tile drainage (seasonally controlled water table at two ft depth).

Three Minnesota location/soil combinations were selected: Waseca (SC MN), Mower Co. (SE MN), and Lamberton (SW MN). Long-term simulations of 90 yrs (Waseca), 70 yrs (Lamberton) and 50 yrs (Mower), were conducted to illustrate the effects of three tile drainage practices on:

- Drained volumes of tile water,
- Evapo-transporation (ET),
- Surface runoff, and
- Crop yield.

Model calibration was performed with observed data at each location. The simulations predicted that shallow (three ft) drainage reduced drainage volumes compared to conventional (four ft) drainage for all locations. Managed drainage provided even greater reduction of drainage volumes than shallow drainage.

Drainage volumes followed average annual precipitation for the three locations: Mower, Waseca and Lamberton exhibited decreasing drainage volumes, in that order, irrespective of drainage practice.

Annual drainage volume decreased with increasing drain spacing, for all locations and practices. Averaged over all drain tile spacing, on a percentage basis, Lamberton exhibited the greatest drainage volume reduction for shallow and managed drainage of 18 and 38%, respectively. Waseca showed the second largest percent volume reductions for shallow and managed drainage of 17 and 30%, respectively. Mower's percent drainage volume reductions were the least with 7% and 26% respectively, for shallow and managed drainage. Managed drainage provided 15% or greater additional drainage volume reduction, beyond that achieved for shallow drainage, at each location.

Figure 9 Simulated average percent drainage reduction for shallow and controlled drainage at Waseca, Lamberton and Mower, 1958-2007 average

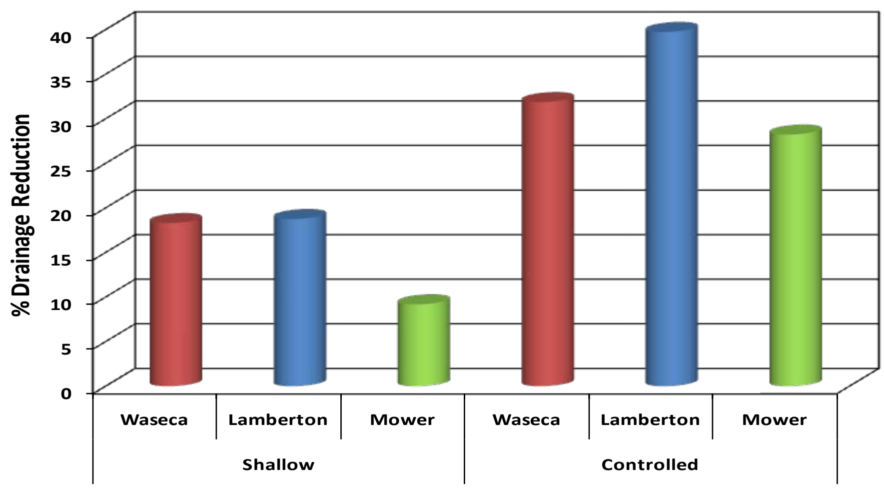


Figure 10 Simulated average percent drainage reduction at Waseca, Lamberton and Mower for shallow and controlled drainage, 1958-2007 average

Nitrate losses were not simulated for the Mower and Lamberton locations due to model instability. However, potential reductions in nitrate loss can be inferred from drained volume reductions and shown in Part I of the two part DRAINMOD report[MD2].

As expected, crop ET showed much more sensitivity to location than drainage practice. The largest ET amounts were predicted for managed drainage, followed by shallow, then conventional drainage. Crop ET increased with increasing drainage spacing for all locations and practices.

Managed drainage exhibited the largest simulated surface runoff, followed by shallow, then conventional drainage. Annual runoff depths were small, the largest of which was two inches.

Runoff at Waseca was much more sensitive to drain spacing than the other two locations. Runoff at Mower and Lamberton was significantly lower than Waseca, and not particularly sensitive to drain spacing.

The DRAINMOD-NII results produced good agreement when compared with observed values for the Lamberton and Mower locations. Hydrology simulations were conducted for a 70-year period (1938-2007) for Lamberton, and a 50-year period (1958-2007) for Mower Co. Nitrate loss simulations were not performed for Lamberton and Mower Co. due to unforeseen model stability problems. Newer model versions should address these concerns. Nitrate losses for these two locations were estimated from simulated drainage volumes based on the drainage vs. nitrate loss regression of Waseca.

Location/soil combination played a strong role in drainage volumes, ET, runoff, and crop yield. Differences among locations can be attributed to the combined effects of weather and soil properties for each location.

The Lamberton site (Normania, a clay loam soil) exhibited the smallest drainage volumes, ET, and surface runoff: this was predictable given that it had the lowest annual precipitation of the three locations. However, the Lamberton site had a greater reduction in drainage volume through shallow and controlled drainage than Mower and Waseca. This latter effect is likely attributable to soil type.

Conclusions:

Drainage practice (i.e., conventional, shallow and managed drainage) exhibited a strong effect on drainage and runoff volumes and a weaker effect on crop yield. Long-term average annual drainage volumes were highest for conventional drainage, followed by shallow and controlled drainage, for all drain spacing and locations. Conversely, managed drainage exhibited the largest annual ET, followed by shallow and conventional drainage.

Drainage intensity (drain tile depth and spacing) had a variable effect on model outputs. Drainage volumes decrease steadily as drain tile spacing increases, while annual ET and drainage volume reductions enlarge. The parameter of exception was surface runoff, which displayed minimal sensitivity to drainage intensity at Lamberton and Mower.

Relative crop yields did not appreciably increase as drain tile spacing narrowed less than 60 ft for all locations, but decreased markedly for wider drain spacing.

The simulations reveal an economic “break-point” for drain spacing at all locations. This break point appears when a yield advantage (net profit /acre) is generated over conventional drainage spacing (40-60 ft spacing). The economic break-point for drain spacing appears at 60 to 80 ft spacing, depending on location. A full economic analysis for drain spacing should be conducted for these drainage practices.

Location plays a strong role in drainage hydrology due to specific soil and weather conditions. Managed drainage appears to be the most effective drainage practice to reduce drainage volume and increase crop yield. Drain spacing is very important, particularly in the 60-80ft range, within this range drainage volumes can be reduced without adversely affecting crop yield.

Result 2: Demonstration and Education. $5,000
Description:

Develop a workshop and educational material for target audiences including anyone who works in the field of drainage, water quality and quantity. A publication on the conservation drainage designs, management, standard protocols, and measured environmental and economic benefits. June 30th 2008

- Sponsor a field day to accelerate adoption within high-impact areas. January 1, 2008
- Work in concert with regional extension offices, to address producers' challenges in accomplishing water quality goals and load reductions for impaired waters. January 1, 2008.

Summary Budget Information for Result 2:
Trust Fund Budget: $5,000
Amount Spent: $5,000
Balance: $ 0

Deliverable

1. **Workshops, education medium and field days developed with regional extension offices.**

Completion date: June 30, 2009

Final Report Summary:

Leadership and program development at the national level for conservation drainage practices and designs was provided through the USDA - Natural Resources and Conservation Service (NRCS) and the USDA - Agricultural Research Service (ARS), beginning in 2003. This national leadership occurred partly due to the activities in the Midwest Land Grant Institutions regarding water quality and the hydrologic alterations in the traditional corn-belt states, and the growing size of the hypoxic zone in the Gulf of Mexico.

The MDA and the University of Minnesota, along with conservation and agricultural stakeholders, supported legislative funding to establish conservation drainage research at the University of Minnesota Research and Outreach Centers in 2000 and 2004. These resources provided the infrastructure and associated monitoring framework to harness data for the DRAINMOD NII simulations described in the previous section Result 1b.

Regular updates and results from this study were disseminated through USDA and USEPA task force and industry coalition meetings from 2006 to 2009, and among the working partnership with the other Midwest Land Grant Institutions. The working partnership included the following Land Grant institutions: Ohio State, Iowa State, North Carolina State, Illinois and Purdue Universities. The forums provided a setting to collaborate and build relationships regarding existing methods, monitoring equipment, and information on grants for education, training and outreach. These working partnerships provided NRCS with knowledge, contacts, and on-the-ground experience to develop or refine USDA conservation practice standards for water management (#554) and for woodchip bioreactors (#747).

Related activities included presentations to more than 32 groups, delivering 2200 publications to interested stakeholders and agency staff. These activities occurred in concert with the redesign of Dr. Gary Sands', University of Minnesota "Drainage Outlet," website to increase information delivery and overall ease-of-access. Structural improvements associated with MDA activities included the design and installation of in-ditch and retention basin treatments at the University of Minnesota Southwest Research and Outreach Center in Lamberton. These activities provided the working knowledge and data within an education workshop, or field day setting. Forums often were effective for garnering feedback with diverse, emotional, motivated stakeholders. Stakeholders at these activities included representatives of the environmental community: MN Chapter of The Nature Conservancy, Clean Up Our River Environment, Friends of the Minnesota River, and The Freshwater Society.

Result 3. Evaluation of Woodchip Bioreactor System.

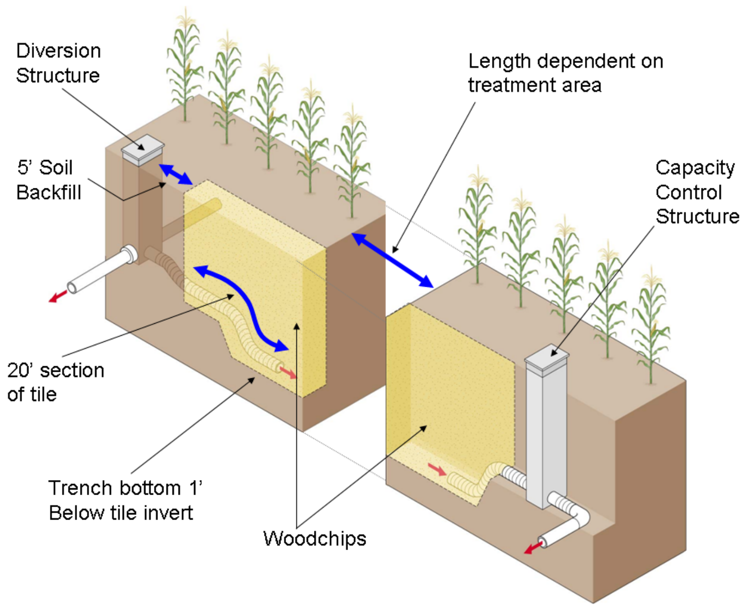
Description:

Nitrate (NO_3^-) is a critical pollutant in drainage water as it flows through waterways to the hypoxia zone in the Gulf of Mexico.

Bioreactors have shown promise in reducing nitrate concentrations in the upper Midwest with field scale trials. Drainage water from agricultural fields can be treated for nitrate contamination via biological reactions (Blowes *et al.*, 1994);

Denitrification with the WBS converts nitrate to harmless nitrogen gas (N_2), as well as a small amount of nitrous oxide (N_20), a potent greenhouse gas. Nitrous oxide gas discharges into the soil column in the topsoil above the woodchips, and then escapes to the atmosphere. Portions of the nitrous oxide gas also dissolve into the water and leave the system with the outlet flow. Both atmospheric and dissolved forms of nitrous oxide remain at low concentrations measured to date, thus WBS does not represent a significant threat as a source for greenhouse gas emissions (Forster et al., 2007).

An anaerobic woodchip bioreactor system (WBS) consists of a rectangular-shaped excavated area in which woodchip materials are buried under a layer of top soil and through which water from subsurface drainage flows through inlet and outlet control boxes. This system can be installed on nearly any drainage system, at the edge of a field and can leave the cropping area intact.



Design by Richard Cooke, University of Illinois

Purpose

The primary purpose of this project is to measure the efficacy of two bioreactor systems in Minnesota at reducing nutrient and pathogenic bacteria contaminants, determine performance criteria and key factors of the existing trench design. The study includes a detailed physical and chemical characterization as to the suitability of the environment for bacterial activity.

Summary Budget Information for Result 3:
Trust Fund Budget: $102,000
Amount Spent: $102,000
Balance: $ 0

Deliverable **Completion Date**

1. Report measurements of critical constituents in drainage water entering and leaving the woodchip bioreactor: nutrients, nitrogen gas, and bacteria.
2. Measure physical, spacial and chemical factors relevant to in-situ biological reaction.

Final Report Summary:

Rice and Dodge County bioreactor sites and associated structures were chosen and installed in 2006 and 2007. The process included selecting uniform material size (woodchips), and executing improved install protocols with contractor. Below in Table 1 it shows the physical site characteristics for these sites.

Subsurface drainage flows for SC MN can be described as typical when 75% of the total discharge occurs during spring and early summer (March, April, May and June). Typical flows occurred at both sites in 2008, though fewer number of flow events occurred at the Rice County site.

Rice County Site has two subsurface drainage plots: one plot contributes 6.6 acres of subsurface flow to the bioreactor, the conventional subsurface drainage plot discharges directly into the ditch. The Dodge County Site has one bioreactor, and it contributes 26 acres to the bioreactor.

Rice County conventional subsurface drainage plot is monitored for flow and pollutant loadings.

Table 1. WBS and Contributing Area Characteristics

Sites	Dimensions LxWxD (ft)	Contrib. Areas (ac)	Field Slope (%)	Fert. Mgmt.	Crop Rotation	Ditch Location	Flow in 2009
Rice County	90 x 3.0 x 6.0	6.6	Flat	Manure	Corn/ Bean	Adjacent	Very low
Dodge County	240 x 4.0x 6.0	26.0	> 1%	Comm. Fert.	Corn/ Corn/ Bean	0.5 mile away	Abundant/ Steady

Two key water quality issues emerged: subsurface drainage nitrate losses at both sites, and bacteria losses in subsurface flow after a single fall manure application at Rice County site.

The objectives of this research are:

- Verify and refine flow parameters and recalibrate existing in-field measurements.
- Measure critical constituents in drainage water: nutrients, nitrogen gas conversion; and bacteria from animal manures.
- Measure physical, spatial, and chemical factors relevant to in-situ biological reaction.

Monitoring Designs

Flows at the two sites were measured hourly with electromagnetic flow meters or weir heights converted to flow rates. Automated samplers extracted water volume for contaminant testing during flow events. Rainfall was measured throughout the season. Another essential parameter, hydraulic residence time (HRT) was resolved by computation, to determine the adequate length of time to denitrify the incoming water. Nitrate concentration (daily) and loading were the primary focus at both sites and, secondarily, E. Coli and fecal coliform bacteria at the Rice County site. Phosphorus and total suspended solids were also measured. At both sites, nitrous oxide gas was measured every two weeks during the growing season; measurements were taken above (actual) and beside (as controls) the bioreactor; the dissolved form of the gas was sampled from the drainage water leaving the WBS.

Results from Rice County Site

The two following tables summarize the results from the Rice County site for 2008 under limited sampling conditions.

Table 2. Amount of tile flow and rainfall for three events (inches).
MngDr = Managed Drainage/ ConvDr = Conventional Drainage

Start Date	End Date	MngDr	ConvDr	Rainfall
4/20/08	5/2/08	1.08	0.77	2.02
5/2/08	5/11/08	0.36	0.42	1.72
6/4/08	6/22/08	0.92	1.37	2.91

Table 3. Reduction of pollutant load through WBS compared to conventional drainage.

Contaminant	Units	% Reduction
TSS	Lbs/ac	85
N-NO3	Lbs/ac	45
Tot P	Lbs/ac	82
Ortho-P	Lbs/ac	85
Fecal Coliform	Cfu/ 100 mL	69
E. Coli	Cfu/ 100 mL	61

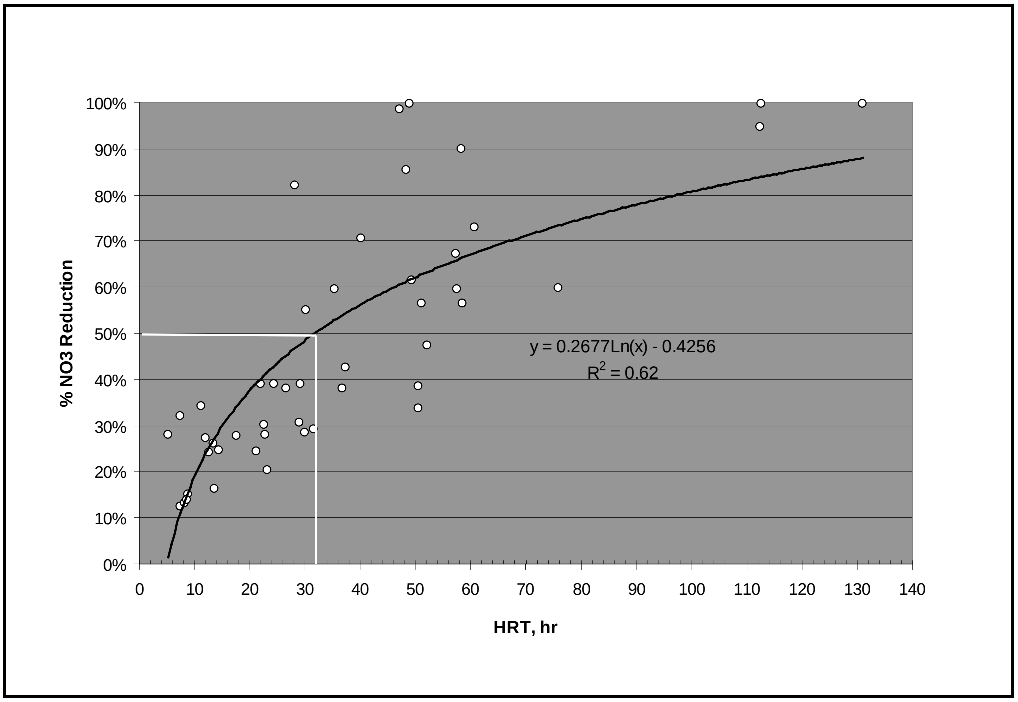
TSS: total suspended solids; NO3: nitrate; TOT-P: total phosphorus; ORTHO-P: soluble phosphorus;

Results from Dodge County Site

The range of nitrate concentrations (NO_3^-) in the inlet flow extended between 8.5 mg/L to 28 mg/L for 2008 and 2009. The primary focus at this site was to determine the adequate length of time (HRT) for the WBS to denitrify the incoming water. To determine this specific length of time, a log-regression was used (Figure 2). This log-regression determined that 50% of nitrate concentration reduction was completed in 32 hours. The graph at Figure 2 shows all reduction points with a regression coefficient of 0.62, meaning that 62% of the nitrate reduction in the WBS is explained by only one factor: HRT (hrs). By taking into account the data scatter in the graph, we can obtain a nitrate concentration reduction between 20% and 40 % and between 30% and 100% with a HRT of 22 hours and 50 hours, respectively. These data cover the period of late April to mid-July 2009. Based on loading, phosphorus concentration was also reduced by about 50%. Another intermediate product of the denitrification process was nitrite (NO_2^-); its concentration increased five times higher going through the WBS, but at a much lower concentration compared to nitrate (0.10 mg/L to 0.85 mg/L).

Nitrous oxide gas (N_20) may accumulate in the WBS as an intermediate compound in case of incomplete conversion of nitrate (NO_3^-) to nitrogen gas (N_2). The gas fluxes measured from these sites remain in the typical range of non-fertilized agricultural soil. Similarly, water-soluble nitrous oxide concentrations also remained at or below the ambient concentrations. The data suggest that the WBS is not generating elevated nitrous oxide that is escaping to the atmosphere.

Figure 2. Log-regression of percent reduction of nitrate concentration against HRT



Longevity of WBS

Based on the literature review, determining the WBS longevity is to determine the rate of change for carbon to nitrogen ratio over time by sampling the woodchip materials (Saliling et al, 2007). As carbon is consumed by the microorganisms, carbon to nitrogen ratio will decrease within the woodchips. Anecdotal reports give longevity of more than ten years for a WBS. Dr. Dan Jaynes – USDA ARS reported in March 2010, that their oldest WBS (9 years) continues a 60% denitrification rate.

Conclusions and Future Actions

Over two cropping seasons, the WBS has shown an ability to reduce contaminant concentrations based upon anaerobic metabolism with the appropriate HRT. Through an evaluation of concentration and loading, several contaminants including nitrate, phosphorus (total and soluble), total suspended solids, E. Coli, and fecal coliform were reduced. Emission of nitrous oxide was limited and WBS does not pose a threat as a potential source of this gas. Under Minnesota conditions, water quality issues such as nutrients and pathogens in subsurface drainage were reduced with the WBS.

The monitoring of these sites will continue for two more growing seasons: 2010-2011. Other important parameters such as temperature profile, oxidation-reduction potential, dissolved oxygen concentration, and pH will be continuously measured across the WBS. Actual field measurement of

HRT will be conducted using bromide tracer. These parameters will bring additional information regarding the timing and conditions under which denitrification and reduction of other contaminants occur. Degradation of pesticides will also be evaluated based on the same principles of anaerobic metabolism and associated conditions in the WBS.

V. TOTAL LCMR PROJECT BUDGET: $300,000.

MDA - $27,887

All Results: Personnel: $26,709 *(1BO)*

All Results: In-state and Out-of-state Travel: $106 *(2GO, 2HO)*

All Results: Employee Development *(2LO)* Other direct operating expenses: $1072

University of Minnesota Pass-Through - $264,583

All Results: Professional Technical: $235,443 *(2DO)*

All Results: Laboratory analysis and supplies $24,140 *(2DO)*

All Results: Workshops and Printing: $5,000

TOTAL LCMR PROJECT BUDGET: $292,470

Explanation of Capital Expenditures Greater Than $3,500: No capital expenditures will be greater than $3,500 for facilities, equipment and other capital assets.

VI. OTHER FUNDS & PARTNERS:

- USDA NRCS Conservation Innovation Grant.
- USDA Ag Drainage Systems Management Task Force, and Ag Drainage Management Coalition.

A. Project Partners Organizations and Individuals:

- Minnesota Land Improvement Contractors, Agricultural Drainage Systems Management Coalition, Minnesota Corn and Soybean Growers, Farm Bureau, and Farmers Union.
- Ellingson Drainage (West Concord MN), AgriDrain (Adair IA), Prinsco (Prinsberg MN), Hancor (Burnsville MN). $17,500
- University of Minnesota: Water Resources Center; Research and Outreach Centers; Bioproducts and Biosystems Engineering Department; Soil, Water and Climate Department; and Extension $264,583
- Primary authors and investigators include: Dr Gary Sands, Dr Lowell Busman, Dr Craig Schrader, Dr. John Moncrief, Dr. Andry Ranaivoson, Dr. Rodney Venterea, Twyla Hill, Dr. Inhong Song, Brad Hansen, Mark Dittrich, Wan Luo, Jeff Strock, and Dario Canelon.
- Cooperating Farmers: Donna and Ray Cerise, Brad and Jane Pake, Don and Ruth Wenner, Wenner – Underwood Farms, Eric Schrader, and Ed Smith.
- Local Support – Kevin Kuehner, Bev Nordby, Rick Morrison, Ed Hohnenstein, Jack Bovee, and Matt Taylor,
- Infrastructure and Communication Support: Leonard Binstock and Jeanne Hansen – Agricultural Drainage Management Coalition, Charlie Schafer – Agri-Drain Inc., Roger and Kevin Ellingson – Ellingson Drainage, Joe Kelley – Kelley Drainage, Sheryl Kunickis – USDA NRCS, John Brach – USDA NRCS,

- In-field designs, field surveys, troubleshooting, data processing, outreach and stakeholder feedback. Dr. Lowell Busman, Twyla Hill and Dr. Craig Schrader.

B. Other Funds being Spent during the Project Period: USDA – NRCS Conservation Innovation Grant. The equipment support (tiling and dirt moving), related professional / technical advice and support via UofM, drainage industry, and local agencies support.

C. Required Match (if applicable): No match required.

D. Past Spending: MDA has not received previous Trust Fund resources for this project.

E. Time: Completion date was June 30, 2009.

VII. DISSEMINATION: University of Minnesota's "The Drainage Outlet" website provides plans, presentations, and related documentation.

VIII. REPORTING REQUIREMENTS: MDA submitted eight reports during the project reporting period. The dates of these reports are: 1-31-06, 8-1-06, 1-31-07, 8-1-07, 1-31-08, 8-1-08, 1-31-09, 8-1-09

IX. RESEARCH PROJECTS: See Attachment B

Modeling Conservation Drainage Practices with DRAINMOD.
Part I: Model Calibration and Application – Waseca.
Gary Sands, Wan Luo, Jeff Strock, and Dario Canelon. Dec. 2009.

Modeling Conservation Drainage Practices with DRAINMOD.
Part II: Application of Model at Waseca, Lamberton, and Mower Co.
Gary Sands, Wan Luo, Jeff Strock, and Dario Canelon. Dec 2009.

Evaluation of Woodchip Bioreactors: Dodge and Rice County.
John F. Moncrief, Andry Z. Ranaivoson, Dr. Rodney Venterea, and Mark A. Dittrich. Jan 2010.

Full reports in PDF files located at ________________.

Attachment A: Budget Detail for 2005 Projects

End Date

Jun-09

030-2841-T09

Proposal Title: 7(j) Improving Impaired Watersheds: Conservation Drainage Research

Project Manager Name: Mark Dittrich **MFR. 03/05/10**
PI's: Faye Sleeper. Gary Sands. John Moncrief.
LCMR Requested Dollars: $300,000
1) See list of non-eligible expenses, do not include any of these items in your budget sheet
2) Remove any budget item lines not applicable

2005 LCMR Proposal Budget	Result 1 Budget: (Revised 08/01/06)	New Result 1 Budget (Revised 05/07/08)	Amount Spent	Balance Result 1	Result 2 Budget:	Amount Spent	Balance Result 2	New Result 3 Budget	Amount Spent	Result 3 Balance	Total Balance	TOTAL FOR BUDGET ITEM
	Diagnostic Team to Select Practices & Research Farm.				*Demonstration and Education*			*Woodchip Bioreactor*				
BUDGET ITEMS												
PERSONNEL: Staff Expenses, wages, salaries – Mn Dept of Ag. 2/3% FTE. Senior Planner unclassified coordiator position. 3yrs	**93,000**	**34,417**	**26,709**	**7,708**								**34,417**
PERSONNEL: Staff benefits – Fringe at 11.65%, and $12,000/ yr for insurance (*.67)	**35,417**	**0**		**0**								**0**
Travel expenses in Minnesota: MDA unclassified coordinator position. Per commissioners' plan. Meals = $1000. Lodging = $200. Travel = $1800	**3,000**	**500**	**106**	**394**								**500**
Other direct operating costs: Payments to producer for cooperation and use of farm field for research and demonstration = $1,500 per year ($15 per acre/yr for 100 acres for two full growing seasons, and fall season for early harvest, design work, surveying, installing tile and structures ($5K) a total of 3 payments.) Meals and Travel expenses for diagnostic team per commissioners' plan...Mileage and Meals = $3,000. (3 trips for ten people. 184 miles per round trip at 37.5 cents per mile. $31 per trip for meals.)	**6,000**	**500**	**1,072**	**-572**								**500**
Contracts				**0**								**0**
Professional/technical: P-T contract with Univeristy of Minnesota for Conservation drainage practices and infrastructure, layout and designs (redesign) at a Research and Outreach Center, and research / demonstration farm. Report: Evaluation, Recommendations, Publication. $94,000 Travel, Laboratory testing and supplies. $42,500. Dr. Song and Brad Hansen.	**136,500**	**137,083**	**137,083**	**0**				**0**	**0**	**0**		**137,083**
Professional/technical: P-T contract with Univeristy of Minnesota (Moncrief) for Conservation drainage on farm monitoring in southern MN. Travel $5,260, labor and equipment $93,100, total $98,360								**98,360**	**98,360**	**0**		**98,360**
Laboratory Analysis and Supplies: Analysis of water, soil and plant samples.	**21,083**	**20,500**	**20,500**	**0**				**3,640**	**3,640**	**0**		**24,140**
Education and Outreach: Develop and print educational fact sheet , update website, and assist with field days and workshops.				**0**	**5,000**	**5,000**	**0**			**0**		**5,000**
COLUMN TOTAL	**295,000**	**193,000**	**185,470**	**7,530**	**5,000**	**5,000**	**0**	**102,000**	**0**	**102,000**		**300,000**