I+S GROUP

FINAL REPORT PREPARED FOR:
MINNESOTA LEGISLATIVE-CITIZENS COMMISSION ON MINNESOTA RESOURCES

MAPLETON AREA AGRICULTURAL + URBAN RUNOFF ANALYSIS

SOUTHERN MINNESOTA - BLUE EARTH COUNTY DITCH NO. 57 (CD 57)

AUGUST 14, 2015

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

BLUE EARTH COUNTY

ISG

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PREPARED ON BEHALF OF:
THE BLUE EARTH COUNTY DRAINAGE AUTHORITY

PREPARED BY:
ISG

AUGUST 14, 2015

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City of Mapleton, MN

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EXECUTIVE SUMMARY

Water quality is being improved through an innovative approach to agricultural drainage. Incorporating conservation methods enhances conditions for crop production while protecting natural resources. Blue Earth County Ditch No. 57 (CD 57) is an extremely successful project, providing increased production and yields in the watershed while decreasing peak flows, sediment and nutrients downstream. Reductions for pollutants were as high as 50% with averages near 25%. Over 70 dump truck loads of sediment were kept out of public waters. If more projects like this were implemented, nutrient reduction goals could be met while keeping our agricultural based economy strong, feeding the world.

This innovative project addresses water quality and serves as a model for drainage projects now and into the future. This project report includes the drainage improvement process, incorporation of Minnesota Environment and Natural Resources Trust Fund (ENTRF) grant funding for water quality **Best Management Practices** (BMPs)*, and results from monitoring the system to quantify the BMP's effectiveness.

There is significant interest by government agencies, landowners and environmental advocates, in finding BMPs that are efficient at reducing peak flows and removing nutrients, as well as being cost effective. CD 57 serves as a pilot project and a model for constructing, combining and monitoring several BMPs. This process is necessary to determine their effectiveness and overall feasibility when incorporated into an improvement project for installation in other agricultural drainage systems. These improvements include modifications to the existing **open ditch** system, additional **storage** and water quality BMPs, and replacing portions of the existing deteriorating **county tile** system.

This project serves as a model of cooperation and coordination between landowners who were interested in an improved drainage system that protects water quality by incorporating environmentally sound practices. The existing CD 57 system had insufficient capacity in several portions, primarily those in the upper half of the watershed and was in a severely degraded state. Landowners in this area had experienced flooding and crop loss due to the undersized and failing system that was deteriorated to the point of needing replacement.

Through many meetings and workshops, **landowners**, **drainage engineers** and agencies came together to identify a better way to approach agricultural drainage. With a concerted effort at the local level, together they came up with an innovative approach that would provide a means to accomplish the goal of improving water quality while addressing agricultural drainage needs.

INTRODUCTION

HISTORY

Perhaps the most dramatic human modification to Minnesota hydrology was the conversion of prairie to farmland and the straightening of streams into ditches, thereby changing water storage, surface flow and the flow of water through soil. As settlers moved west to the Minnesota region, they found the land to contain fertile topsoil that was prime for agricultural production. However, much of the land was covered with wetlands and **prairie pothole** lakes.

Since these areas were highly suitable for crop growth, they were intensely drained to make farming more practical, productive, and economical during the late 1800s and early 1900's. This practice was encouraged by local agencies to drain water from the landscape as quickly as possible and has made the Prairie Pothole region some of the most productive farm land. This was also encouraged by officials for public health reasons, namely to reduce mosquito populations and the diseases they carried. This agricultural region became the backbone of the rural economy by providing grains and raw food products throughout the United States and later to a global market.

This transformation to the rural community infrastructure and agriculture would not have been possible without **artificial drainage**. Due to increasing awareness of water quality concerns, landowners and producers are beginning to recognize their social responsibility. They realize their impact on Minnesota's natural resources and areas downstream of modifications or repairs to these systems.

DRAINAGE INTRODUCTION

Traditional agricultural drainage consists of deep open ditches and underground county tile systems designed to rapidly drain the water from the landscape. Although the method is effective and results in a drained landscape, it also results in increased peak flows, higher nutrient loading in the water, and a restructured habitat regime. Today, there is a more efficient, economical, and environmentally friendly practice available. This report outlines an alternative conservation drainage method that can be applied to a broad area throughout the Midwest.

The efficiency of today's agricultural cropland is due in part to its drainage. The ability to control the water on the landscape improves yields and makes planting and harvesting more predictable. Most drainage systems were installed over 100 years ago and they are deteriorating quickly. This condition of disrepair is relatively common, making the planning process a timely event for drainage improvement and environmental protection.

Today, many of these systems are being replaced due to a number of reasons. First, they have exceeded their usable lifespan. Second, in some years, low crop prices deterred improvements as they were not considered cost effective due to low landowner profits. Third, the increase in private tiling and **system tiling** has maximized the capacity of the systems and increased their rate of deterioration; as a result, their efficiency decreases. The photographs in *Figures 1 and 2* show examples of issues found today with aging drainage systems. *Figure 1* shows a damaged county tile main that is failing. A section of the tile

Figure 1 - Existing Damaged Tile Main

Figure 2 - Open Ditch Slough

collapsed and the flow of water pulled soil into the line and caused erosion. *Figure 2* shows a portion of the open ditch that has eroded away causing sediment accumulation in the ditch.

CD 57 OVERVIEW

The Mapleton Area Agricultural Urban Runoff Analysis focuses on a County Ditch watershed in Southern Minnesota – Blue Earth County Ditch No. 57 (CD 57).

The CD 57 drainage system is a 6,041 acre watershed located in southern Minnesota and is comprised of agricultural farmland and urban runoff from the City of Mapleton. Located in southern Blue Earth County, CD 57 was in a state of disrepair, common to many systems in the area. As a public system since 1921 with portions of the system installed privately by landowners prior to 1900, the first and only improvement was completed in the mid-1970s. By 2007, portions of the system had deteriorated and failed. Landowners acknowledged this failure and requested that the degraded system be addressed via a **petition** to the **Drainage Authority**. As the petition was being developed, flooding concerns were voiced by downstream landowners.

CONCERNS WITH THE PETITION

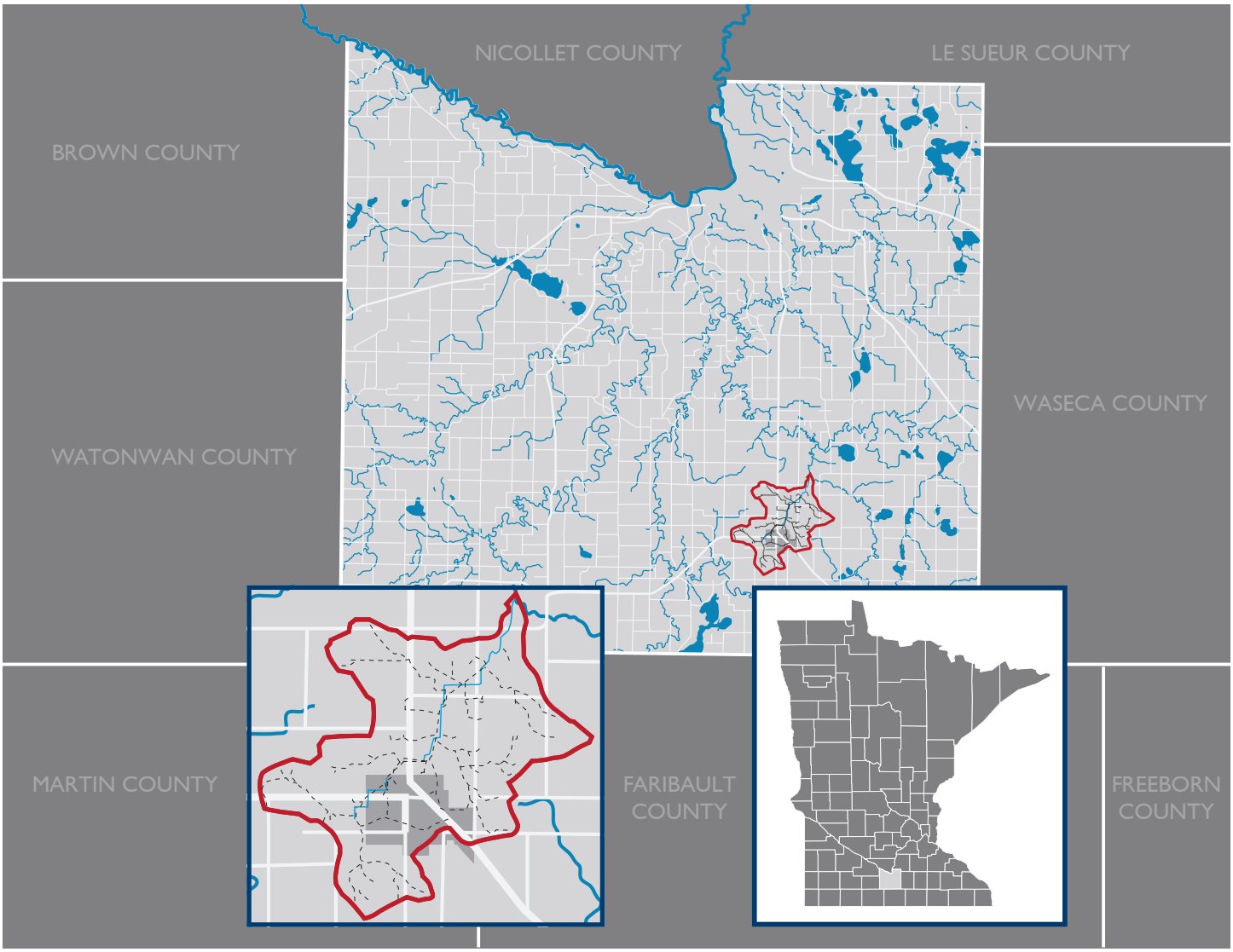
Through landowner meetings and personal communication between county staff and landowners, concerns were addressed in the petition process with a statement of intent that indicated water storage would be included to protect downstream landowners from flooding. Through this interactive process, a set of conservation drainage practices were evaluated. The initial designs were crafted and presented to landowners for the petition process and feedback. The CD 57 improvement provided an opportunity to include and assess the effectiveness of BMPs on water quality.

FUNDING SOURCES

Funding to monitor BMP effectiveness was provided through a grant from the Legislative-Citizen Commission on Minnesota Resources (LCCMR) Environmental and Natural Resources Trust Fund. This grant provided funding for the construction of BMPs and three years of water quality monitoring to determine their effectiveness. This report outlines the following:

- The history and background of CD 57
- Multi-purpose drainage management and Minnesota Drainage Law
- The BMPs installed in the CD 57 System
- The timeframe and partners involved in the project
- Water quality outcomes
- Challenges to the project and recommendations on moving forward with BMPs in drainage systems throughout the region

The *CD 57 Water Quality Report* specifically analyzes the water quality monitoring results and is a separate document from this report.



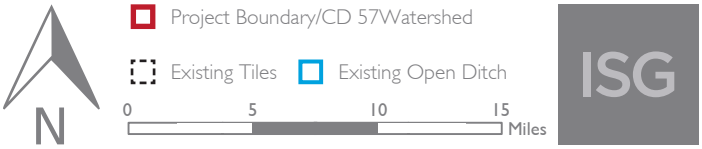
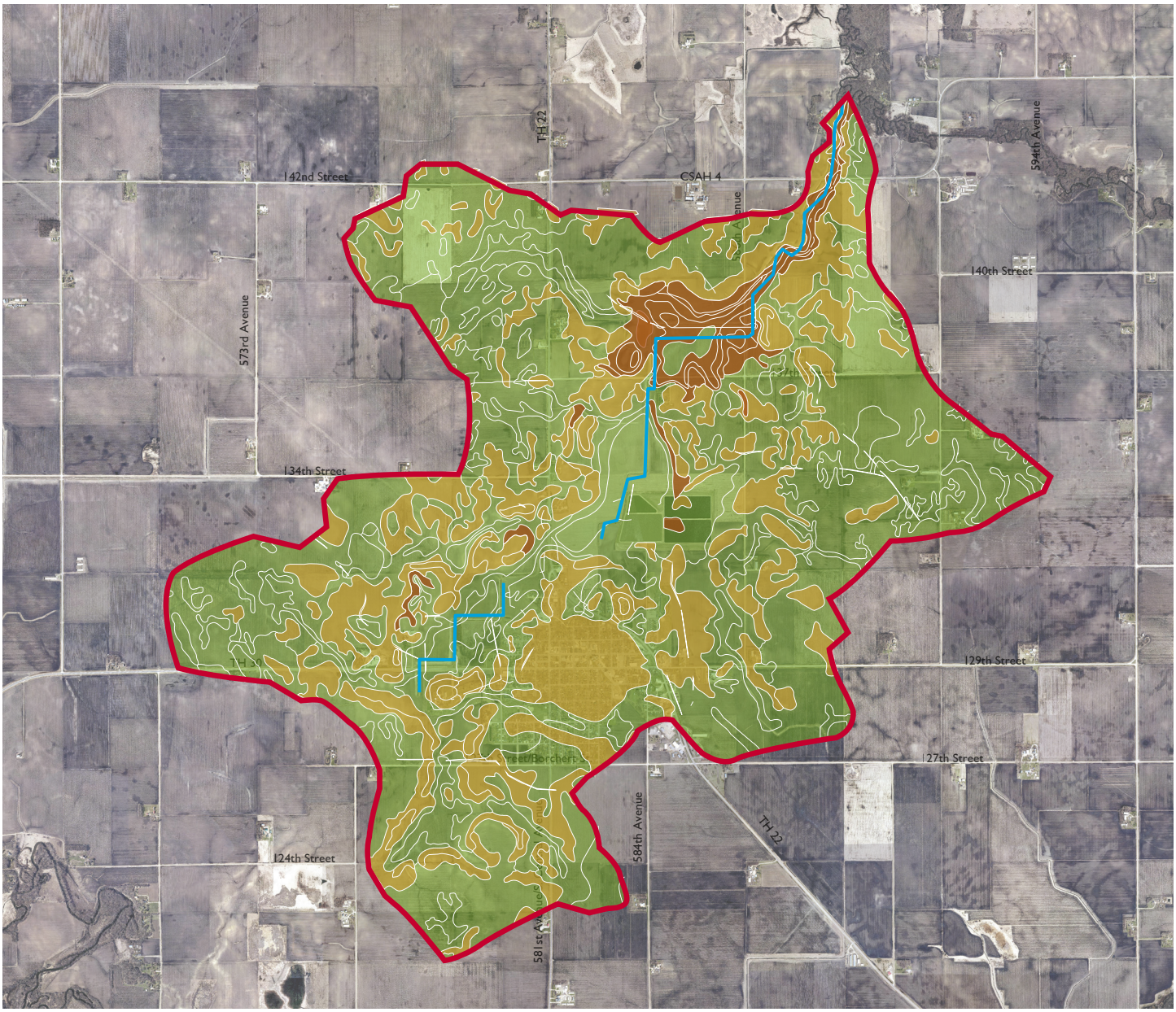


Figure 3 - CD 57 Watershed location and boundary

CD 57 BACKGROUND

WATERSHED

CD 57 is part of the Le Sueur River Minor Watershed of the Minnesota River and discharges into the Big Cobb River in Section 22 of Beauford Township. The watershed consists primarily of agricultural land use (approximately 87%), and of that crop land, approximately 93% is in two year corn-soybean rotation (Minnesota Pollution Control Agency, 2012). The remaining portions of the watershed include the City of Mapleton (400 acres, 7% of watershed), farmsteads and roads. The population of Mapleton in 2010 was 1,162. *Figure 3* shows the CD 57 watershed boundary and its location. Elevations within the watershed range from approximately 970 to 1,040 feet above Mean Sea Level (MSL).



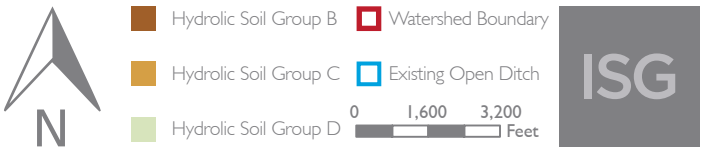


Figure 4 - Soils Map of County Ditch 57 - Blue Earth County, MN

SOILS

The Natural Resources Conservation Service (NRCS) classifies four hydrologic soil groups (A-D); Group A consists primarily of sandy soil with low runoff potential, Group B consists of sandy-silt loams with moderately low runoff potential, Group C consists of silty-clay loams with moderately high runoff potential, and Group D consists of clay loams with high runoff potential. The soil groups identified in the CD 57 watershed (*Figure 4*) predominantly include type B to type D soils, all of which are considered prime farmland if adequately drained. Soil textures include silt loam, silty clay loam, clay loam, silty clay, and clay.

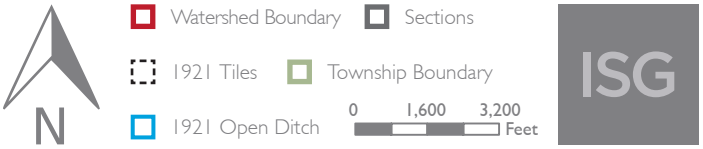


Figure 5 - 1921 Original Tiled System

HISTORY

The CD 57 system was originally constructed in 1921 as a primarily tiled system incorporating previously private tile with an open ditch outlet. The open ditch extended southwesterly from the Big Cobb River to 586th Avenue in the center of Section 27, Beauford Township (*Figure 5*).

The improvement constructed in the mid 1970's, extended the open ditch from 586th Avenue southwesterly to a point in the southern portion of the southeast 1/4 of Section 33, Beauford Township. An open ditch was also constructed from a point in the northern portion of the northwest 1/4 of Section 4, Mapleton Township, southwesterly, across Minnesota Trunk Highway (TH) 30, to a point in the northern portion of the southeast 1/4 of Section 5, Mapleton Township. Both ditch segments generally followed the alignment of the original mainline tile. These open ditches replaced failing tiles that were constructed under the original 1921 improvements. The two ditches were connected by the two tile lines including the existing mainline concrete tile and a supplemental corrugated metal tile.

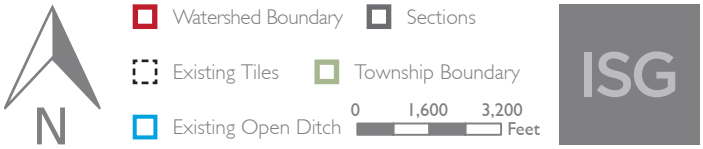
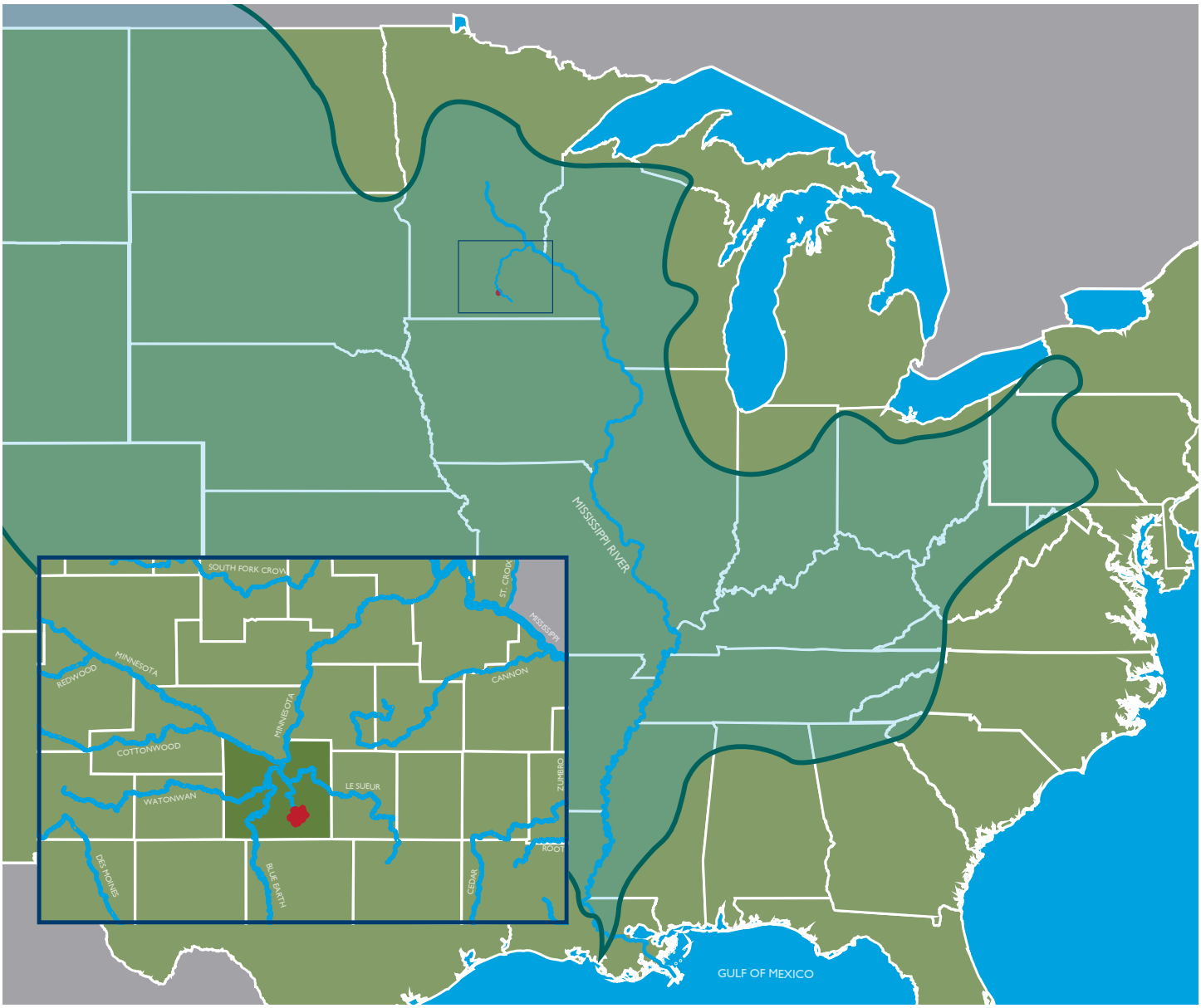


Figure 6 - Existing CD 57 System

As development progressed within the City of Mapleton, portions of the CD 57 system within the City were abandoned or integrated into the municipal storm sewer system. The majority of the City of Mapleton discharges to the CD 57 system in three locations. Flows from the southern portion of the City were routed around a stormwater pond that stored water when the system backed up and were discharged to the open ditch segment south of TH 30 via a county tile branch. A stormwater pond serving a small residential development in the northwest portion of the City discharges to the open ditch segment in the northwest 1/4 of Section 4, Mapleton Township. As part of a routine maintenance, the City of Mapleton discharges treated wastewater from the treatment lagoons to the open ditch twice a year in the eastern portion of the southeast 1/4 of Section 33, Beauford Township. *Figure 6* shows the existing layout of the CD 57 system.



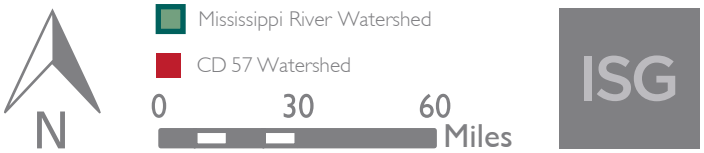


Figure 7 - CD 57 Flow Path to Gulf of Mexico

EXISTING CONDITIONS

CD 57 has an important influence on the water quality of other downstream watersheds. It drains northeast into the Big Cobb River, then flows west into the Le Sueur River and eventually into the Blue Earth River. The Blue Earth River converges with the Minnesota River and drains into the Mississippi River and terminates at the Gulf of Mexico. This area of the Gulf contains extremely low dissolved oxygen levels that cannot support aquatic life, a condition referred to as **hypoxia**. This condition is impacted by the level of water quality that flows from other rivers into the Mississippi River. *Figure 7* shows the flow path of CD 57 to the Gulf of Mexico.

CATEGORIES OF AGRICULTURAL BMPs

PREVENTATIVE	CONTROL	TREATMENT
Residue Management	Rate Control Weir	Buffer Strip
Nutrient Management	Alternative Intake	Wetland Restoration
Crop Rotation	Culverts	Surge Basin
Cover Crops	Two-Stage Ditch	Woodchip Bioreactor
	Grassed Waterways	
	Riparian Vegetation	
	Controlled Subsurface Drainage	
	Toe-wood Sod Mats	

Figure 8 - Preventative Measure - Cover Crop

MULTI-PURPOSE DRAINAGE MANAGEMENT

Laws and regulations put in place to protect the health of **public waters** are an important consideration for agricultural producers. Recently, there has been an increase in the awareness of social responsibility to protecting water quality. The improvement process requires environmental considerations for the health of public waters. However, implementation is not well defined in the process.

Farmers are incorporating more conservation drainage methods to protect the environment and to make drainage financially and environmentally sustainable. While every farm and every field may have different conservation needs, the primary pollutants found in agricultural settings include sediment and nutrients, primarily phosphorus and nitrogen. Although some nutrient discharge may be necessary for agricultural production, there are various agricultural practices to mitigate adverse effects. These beneficial practices are called Agricultural Best Management Practices (BMPs) as defined in *The Agricultural BMP Handbook for Minnesota*, published by the Minnesota Department of Agriculture (2012), and address specific water quality impairments such as sediment, nitrogen or phosphorus.

AGRICULTURAL BMPS

Agricultural BMPs can be divided into three major categories: *preventative measures, control measures*, and *treatment measures*.

Preventative measures are practices that can be applied to the existing landscape without dramatically changing its current land use. These practices can be used by any landowner through educated decisions based on guidance from Soil and Water Conservation Districts (**SWCD**), in regards to the crops and the land area in which they are planted. These measures will contribute towards increased water quality through erosion control, soil stability, and nutrient management. Examples of preventative measures include **residue management**, **nutrient management**, **crop rotation**, and **cover crops**. *Figure 8* shows a cover crop used as a preventative measure for winter erosion.

Control measures are practices that either convey water, control flow direction and rate, or maintain a desired water level. These practices are typically installed in existing drainage ditches, ponds, or wetlands and require agreements by several landowners or ditch systems. These BMPs are expected to reduce peak flow rates, sediment, and nutrient loading. Examples of control measures include rate control weirs, **alternative intakes**, **culverts**, **two-stage ditches**, **grassed waterways**, **riparian vegetation**, **controlled subsurface drainage**, and **toe-wood sod mats**. *Figure 9* shows a rate control weir used to reduce peak flow rates from an open ditch system.

Treatment measures are practices designed to improve the water quality of either surface runoff or water being carried through drainage systems. They are primarily aimed at treating sediment or nutrient loaded water. Examples of treatment measures include filter strips—often referred to as **buffer strips**—wetland restorations, **surge basins**, water and sediment control basins (WASCOBs), **woodchip bioreactors**, and **saturated buffers**. *Figure 10* shows a wetland restoration within an agricultural drainage system.

Figure 9 - Control Measure - Rate Control Weir

Figure 10 - Treatment Measure - Wetland restoration

MINNESOTA DRAINAGE LAW

In 1883, the first drainage laws were established and eventually became the framework for **Minnesota Drainage Statute 103E**, which outlines the requirements for establishing, repairing, improving and all other items related to **public drainage systems** in Minnesota. County commissioners were the first government authority group to accept and approve petitions to create public drainage systems. These systems were established to effectively drain the landscape for agricultural production, develop a cost share agreement for benefited owners along the system, and maintain the outlet through repairs and improvements. Today, the process is nearly the same, but primarily focuses on repairing damaged systems and improving undersized systems.

Early drainage systems established between 1880 and 1920 were designed to drain vegetated wetlands, or swamp lands which held water between depths of 1 to 6 feet. These systems primarily drained the low, wet areas for agricultural production. During this time, rainfall routinely caused the landscape to become flooded and therefore wasn't conducive for practical farming without artificial drainage.

From the 1920s through the 1930s, drainage activity slowed as rainfall amounts lessened during the time of the Depression and Dust Bowl. Existing drainage systems were able to handle the rainfall. After 1940, normal rainfall amounts returned and repair and improvement projects became routine due to the fact that the existing systems were becoming damaged and were undersized.

The 1950s and 1970s brought the first political influence from the public to address conservation. The creation of watershed districts helped influence conservation and changed the authority from the county board to applicable watershed districts. Many people from the public including wildlife groups brought up issues dealing with the function of wetlands as they relate to wildlife and waterfowl production. State programs were developed in the late 1970s to establish payment programs to farmers who committed to not drain the wetlands and leave them as wildlife areas. These programs are often referred to as state conservation easements.

Again, in the 1980s and 1990s rainfall amounts decreased and slowed drainage projects. Also during this time, land prices declined and it was difficult for drainage projects to show enough benefits for the desired project. The 1980s also brought the involvement of the Department of Natural Resources to drainage projects. At this time, one-rod buffers (16.5 feet) were required on all public drainage systems that had a **redetermination of benefits**. In 1991, the Minnesota Wetland Conservation Act established that existing wetlands could no longer be artificially drained without mitigating the impacts to a wetland.

During the late 1990s and into the 2000s, drainage projects substantially increased as existing drainage systems were damaged, aging, and in most cases beyond repair. This period also brought higher land prices while newer technologies made the land much more economical to farm. System tiling began to increase dramatically and resulted in more improvements because existing systems could no longer handle the amount of water draining from the landscape.

Historically, the main objective of a drainage project was to drain the land in the most economical way possible. Storage and water quality were not considered for drainage projects. In 2000, a portion of Minnesota Drainage Statute 103E was modified to allow for the use of external sources of funding to assist in the addition of wetland preservation, wetland restoration, water quality improvements, and flood control. This allowed for drainage systems to have the ability to use grants or other funding sources to add storage and water quality practices.

Drainage projects progressed through the 2000s and 2010s with more environmental and political pressure regarding water quality. Agencies began to strongly assess drainage and water quality and the impacts that public drainage systems have on public waters. The DNR began reviewing public drainage projects and providing feedback to the Drainage Authorities. Many requests were made by the DNR to address water quality in improvement projects. At this time, water quality was not the primary focus of drainage improvements throughout most of the State.

Due to inadequacies of the original drainage systems constructed 100 years ago, the costs to bring them up to today's standards is relatively high. In order to improve a drainage system, the benefits realized throughout the watershed must have a greater value than the cost to improve it. This leaves very little room to fund BMPs in accordance with Minnesota Drainage Statute 103E.

In 2014, the Drainage Statue was modified to include water quality multi-purpose drainage management options on projects. This put more emphasis on water quality in drainage projects. It requires the drainage authority to investigate the potential use of external sources of funding and technical assistance (Subd.1a). The following tasks are required to complete a **drainage improvement**:

- Develop a Petition with at least 26% of the affected or crossed over landowners in the system
- Submit the Petition to the Drainage Authority for approval and appointment of an Engineer
- Engineer Prepares Survey of the system and **Preliminary Engineering Report (PER)**
- Multi-purpose drainage management and water quality are reviewed by Engineer, **affected landowners**, and the drainage authority and are addressed in the PER
- PER is reviewed, public comments are received and the Drainage Authority approves or denies report
- **Ditch viewers** are assigned to complete a **redetermination of benefits** for the existing system and the proposed improvement
- A **Final Engineering Report (FER)** is prepared and submitted to the Drainage Authority
- A public meeting is established to Review the FER and **Improvement Determination of Benefits**.
- The project is approved if the benefits outweigh the costs, the outlet is adequate, the system is of public benefit, is feasible and cost effective along with meeting the other requirements of Minnesota Drainage Statute 103E
- After approval, the project is constructed, and then finally accepted by the Drainage Authority

DRAINAGE IMPROVEMENT PROCESS: REPAIR VS. IMPROVEMENT

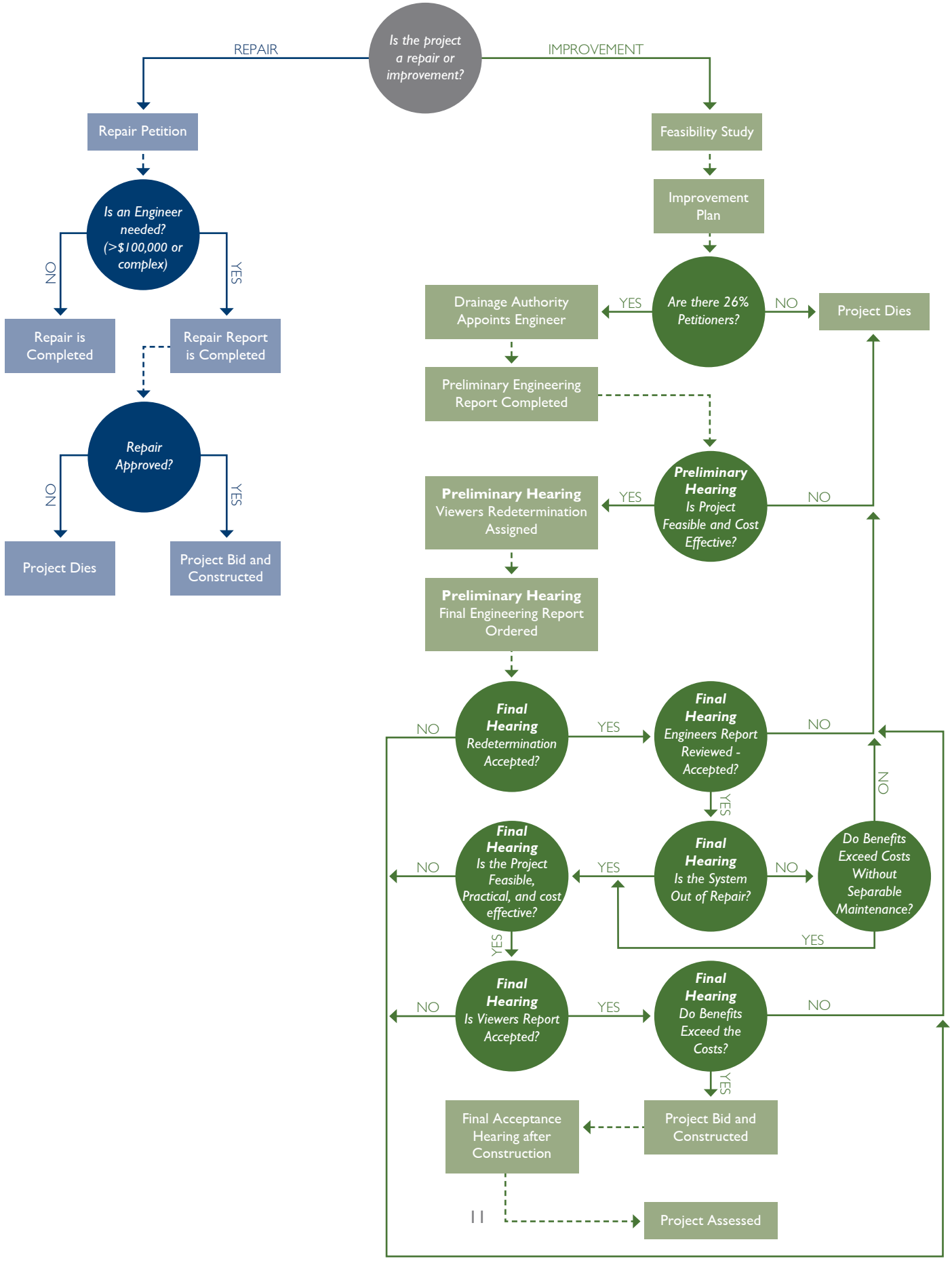


Figure 11 - Collapsed Existing County Tile

Figure 12 - Accumulated Sediment in Ditch

CD 57 IMPROVEMENTS

The CD 57 improvement project was developed because the existing system was damaged, needed repair, and had undersized county tile mains contributing to poor drainage. There were areas in the watershed where the system was at the point of failure. The tile connecting the open ditch segments under TH 22 was failing and causing significant flooding. The system needed increased drainage capacity and storage. Since the proposed goal was to provide an improvement to the drainage system, Minnesota Drainage Statute 103E requires that the landowners must recognize a benefit from the project.

Figures 11 and 12 show the existing deteriorating CD 57 system with collapsing county tile mains (*11*) and accumulated sediment in the open ditch (*12*).

INCREASED CAPACITY

The soil profile can be described as a 'sponge', as it absorbs and stores water between each individual soil particle. Areas where artificial drainage exists lower the **groundwater table** and in turn remove water from the sponge, thus allowing more water to be stored in the soil rather than ponding on the surface. This method of artificial drainage has proven to be very effective as less water is ponded in agricultural fields, thus it allows for farmers to more consistently maneuver equipment through the land and puts less stress on crops during the growing season.

Increased capacity describes the method where artificial drainage is increased through any of the following:

- Larger system tile lines to effectively drain more water below the surface
- Additional tile lines, sometimes placed lower in the ground to create a larger area of soil to absorb water. This is considered the sponge effect.
- Larger public drainage systems (either large ditches or tile main lines) to reduce the amount of backwater on the sponge and the associated system tile lines draining that area
- Any other alternative in which the water table is effectively lowered and drained more quickly

The most common way to describe **drainage capacity** is through the **drainage coefficient**. The drainage coefficient is a method used to measure flow through system tiling and public drainage systems. The units of the drainage coefficient are in inches per day. This describes the depth of water (inches) that can be drained in a 24 hour period (day). Today's standards recommended by the NRCS are a minimum of 0.50 inches/day for system tiles and public tiling systems, and 1.0 inches/day for public open ditch systems. Most original public drainage systems installed had designed drainage coefficients of 0.10 inches per day for public tiling systems and 0.25 for public open ditch systems. The existing CD 57 drainage coefficients ranged from 0.24 to 0.39 inches per day due to the improvements implemented in the 1970's.

To provide increased capacity to the system, the project improved

Figure 13 - Downstream CD 57 Open Ditch with Flooding

CD 57 between the two existing open ditch segments and south of the existing southern open ditch segment. NRCS recommendations indicate that these segments need a minimum capacity of 0.75 inches per day or greater. Landowner negotiations resulted in a petition to the Drainage Authority, which proposed an increase to the capacity of the system to 0.60 inches per day with supplemental storage to account for additional drainage. Also, it was originally recommended to construct an improvement south of Trunk Highway (TH) 30 as a replacement of the original tile. However, since the original tile was still functioning, the decision was made to construct improvements south of TH 30 to supplement the existing tile.

INCREASED STORAGE

It was also important to incorporate storage in the upper half of the watershed to protect the downstream landowners from flooding. Due to the limited capacity of the ditch system downstream, landowners feared that flooding would consistently occur downstream with a ditch improvement. By implementing BMPs in the upper half of the watershed to provide storage, the downstream landowners would be protected from higher peak flow rates and flooding. *Figure 13* shows a portion of the downstream ditch that experienced periodic flooding.

TIMEFRAME AND PARTNERS

Landowners recognized that they would need to provide a portion of funding for storage, however outside funding was needed to provide additional water quality BMPs and monitoring. The results could be useful in promoting ongoing use. The benefit of these costs could not be justified via the existing Statute without outside funding. Interest in water quality and available funding sources to improve water quality provided an opportunity to work with federal, state and local governments to incorporate BMPs into the drainage system improvement. This process provided an opportunity to include different BMPs and demonstrate how they can fit into existing Minnesota drainage law.

Outside funding sources would be used to construct BMPs that would provide more capacity to the system and reduce soil erosion and nutrient loading to downstream water bodies. This was primarily accomplished through creating storage, constructing improved open ditches, and ensuring adequate vegetative buffers were present.

The results from this project provided a unique opportunity to demonstrate the ability to work with multiple collaborators in a

concerted effort to provide valuable data on how BMPs affect water quality in a southern Minnesota drainage system.

This project also provided an opportunity to leverage grant funding to demonstrate a number of potential BMPs that would not have been cost effective otherwise. In addition to the qualitative results from this effort, such as BMP constructability and longevity, this project included monitoring of the system for both flow and water quality data. This monitoring provides insight into the effectiveness of each BMP and reflects the potential for use in other systems that may have similar impairments.

The following organizations collaborated to differing degrees on the development and implementation of this project:

- The *Blue Earth County Drainage Authority* reviewed and approved the project, served as the project manager and a conduit to landowners, and provided project administration. They also acted as the funding mechanism for the drainage improvement.
- The *Blue Earth County SWCD* provided support of the project by reviewing the water quality BMPs.
- The *City of Mapleton, MN* provided land for the City Pond and funding towards the project The Greater Blue Earth River Basin Alliance provided a letter of support.
- *ISG*, acting as engineer for the Blue Earth County Drainage Authority, provided design services, assistance with project administration, monitoring, technical memorandum, and presentations.
- *Land Owners* in Blue Earth County Ditch No. 57 outlined the needs of the project through landowner meetings, led the project from the improvement to include the water quality components, and provided the majority of the funding for construction. They also received the drainage benefits of the drainage improvement.
- The *Legislative-Citizen Commission on Minnesota Resources (LCCMR)* provided funding for the implementation of the BMPs and monitoring.
- The *Minnesota Department of Agriculture (MDA)* served as a co-sponsor of the project and assisted with design, monitoring, technical memorandum, and presentations.
- The *Minnesota Department of Natural Resources (DNR)* provided review of the proposed improvements and water quality BMPs.
- *Minnesota State University, Mankato* Departments of Civil and Mechanical Engineering and Chemistry and Geology, provided technical assistance and water quality monitoring.

Together, the collaborators worked to implement the Minnesota Drainage Statute 103E, which outlines the specific requirements for work involving drainage in the State:

- Landowners petition Drainage Authority.
- Drainage Authority appointed Engineer (ISG).
- ISG developed preliminary engineering report meeting 103E requirements.
- Drainage Authority approved preliminary engineering report and ordered ISG to find grant money to do the project.
- ISG consulted with Minnesota Department of Natural Resources (DNR), Minnesota Pollution Control Agency (MPCA), Blue Earth County Soil and Water Conservation District (SWCD), Greater Blue Earth River Basin Alliance (GBERBA), Minnesota Department of Agriculture (MDA), Blue Earth County, and others on grants.
- Funding for the project came primarily from drainage beneficiaries (landowners draining into the system) as described in drainage law, but also applied for funds with ENRTF for BMPs and analysis of water quality on improved system.
- Through this process ISG consulted/collaborated with landowners, agency representatives, the MN Drainage Workgroup and other drainage experts to review the storage and treatment options that were proposed and how to monitor their effectiveness.
- The final engineering report was developed by ISG and the viewers determined the benefits.
- The Blue Earth County Drainage Authority approved the project and ordered bids and construction.
- The project was constructed.
- Monitoring began and was implemented for 3 growing seasons.
- Three agricultural drainage workshops were completed during the project to outline the design, construction and results.
- This final report and results will be presented to the LCCMR

IMPROVEMENT TIMELINE COMPARISON

STANDARD DITCH PROJECT

2007
- Landowners experience flooding and system failures
- Landowners hire ISG feasibility study (BEDA, ISG)
- Informational meeting on improvement; LOA bring lawyers, LOF bring lawyers, BEDA, ISG

2007-2008
- Petition develops; Storage included; $30,000 cap

2008
- BEDA appoint ISG, redetermination, and PER
- Survey, hydroanalysis, and PER developed; Costs determined that more than $30,000 needed for storage

2009
- PER complete and approved

2009-10
- Construction; Record snowfall; Spring 2011 wet - delayed project

2010
- **Construction Complete**

BLUE EARTH COUNTY DITCH 57 PROJECT

2007
- Landowners experience flooding and system failures
- Landowners hire ISG feasibility study (BEDA, ISG)
- Informational meeting on improvement; LOA bring lawyers, LOF bring lawyers, BEDA, ISG
- LOA meet with DNR

2007-2008
- Meetings with LOA and LOF, BEDA, ISG, and lawyers; Compromise achieved; Storage provided

2008
- Petition develops; Storage included; $30,000 cap
- BEDA appoint ISG, order redetermination, and PER
- Survey, hydroanalysis, and PER developed; Costs determined that more than $30,000 needed for storage

2008-2009
- BEDA, ISG, and LOF pursued grant funding - denied; MPCA 3/9 clean water, GERBA, ENRTF

2009
- 1st drainage workshop by ISG and CD 57 discussed
- PER completed and approved; Multiple storage options included

2009-10
- ENRTF again - added BMP's and monitoring; Monitoring began by ISG with no funding

2010
- ENRTF approved!
- Storage options reviewed - #1 is a no go; #2 and #3 are approved
- PER complete and approved

2010-2011
- Construction; Record snowfall; Spring 2011 wet - delayed project

2012
- Newly installed drainage system with BMP's; Began monitoring water quality and stage
- 2nd drainage workshop on CD 57

2012-2014
- Monitored multiple presentations on project

2014
- 3rd drainage workshop on CD 57

2015
- Final report to LCCMR
- 4th drainage workshop

2016-Future
- Future monitoring

COSTS WITHOUT FUNDING	COSTS WITH ENRTF
$1,311,600 - Project Cost	$1,311,600 - Project Cost (ENRTF - $485,000)
$1,148,200 - Project Cost without Monitoring	$826,600 - Project Costs After Grant Removed
$856,600 - Separable Maintenance	$856,600 - Separable Maintenance
$291,600 - Net Cost per 103E (Project cost minus Separable Maintenance)	$0 (-30,000) - Net Cost per 103E (Project cost minus Separable Maintenance)
$240,000 - Net Benefits	$240,000 - Net Benefits
$240,000 (Net Benefits) - $291,600 (Net Cost per 103E) = **-$51,600**	$240,000 (Net Benefits) - $0 (Net Cost per 103E) = **+$240,000**

*Project does not meet Minnesota Drainage Statute 103E as Costs are higher than Benefits

*Project meets Minnesota Drainage Statute 103E

Table 1 - CD 57 Costs

COSTS

Multiple options were considered for improving the system. During the feasibility stage, the landowners within the watershed understood that they were going to have to pay for the project due to the existing Statute, however the downstream landowners didn't believe they would benefit. This made the process very difficult. Many of those landowners now understand how the system was improved and how the storage benefited their properties. The added storage reduced flooding throughout the system.

During the project, it was determined that repairs necessary to the existing system in the project area would cost approximately $856,600. The downstream landowners wanted to limit their costs to this amount. The cost for the improvement without storage was estimated at $800,000. Landowners decided that they would contribute $30,000 for storage. To accomplish the landowner's request for water storage to protect downstream areas from flooding, the $30,000 contribution was not sufficient. The ENRTF grant of $485,000 provided the additional funding to add storage to effectively reduce peak flows downstream and provide a project in which water quality could be improved. After the ditch viewers reviewed the project, the net benefits were calculated at $240,000 for the project. Without the ENRTF, landowners could have contributed up to $245,000 for storage and water quality. This would have constructed some of the storage, but not all of the water quality features would have been incorporated and no monitoring would have been conducted. The additional funds from the ENRTF made the results that were found with this project possible. *Table 1* summarizes the costs for the project with and without the ENTRF grant.

To summarize, without the ENRTF grant, the project as designed and implemented would not have been cost effective and thus not feasible per Minnesota Drainage Statute 103E. Portions of the water quality improvements and storage areas would have been eliminated or reduced in size to provide the required benefits to meet the requirements of the Statute. Monitoring would not have been included in the project and the effectiveness of the BMP's would not have been documented. The contributions from the ENRTF grant allowed for a good project to become a great project as it maximized the water quality BMPs effectiveness, which has a larger effect on water quality in Minnesota.

ENRTF GRANT

INITIAL EFFORTS

A major component of the success of the CD 57 project was the ability to find outside funding to allow for adequate storage and water quality practices to be constructed in the system. Multiple sources were approached for funding. At the time, there were many opportunities, but each time an application was made, it was denied. Some of the comments received stated that the project was a "good project" but was denied because the project was considered an "improvement project". The following funding opportunities were applied for and denied:

- MPCA 319 Grant
- 2009 NRCS Clean Water Legacy Grant
- NRCS RIM/WRP Wetland Restoration Programs
- 2009 ENRTF Grant
- Cobb River Watershed Grant
- DNR Streambank Funding
- MPCA Nature Conservancy Funds
- NRCS Watershed Work Group

After these denials, a review of outside funding for the project was taken upon Blue Earth County Drainage Authority, ISG, and others. It was decided that instead of focusing just on storage, that it was time to address the improvements with a broader approach that included a combination of BMPs in order to obtain a more significant improvement to water quality and a reduction in peak flow. This led to the development of a work plan combining several methods including storage, water quality, reduced peak flows, and monitoring. This combination of goals would later serve as a model project on how to improve water quality on a drainage system.

ENRTF GRANT AWARD

An ENRTF grant was applied for, and denied in 2009. In 2010, a second application for the ENRTF was submitted and the project was selected for an interview. The feedback provided important information for the application to be resubmitted and awarded a ENRTF grant in 2010. The interview with the legislative and citizen panel provided the opportunity to discuss the fact that funding sources other than landowners were unavailable. While landowners were interested in providing an investment in the improvements, they expressed a need for outside funding to implement BMPs that had costs that were in addition to the cost of improving the ditch system. According to the team that submitted the application, there was a great project idea, but no outside sources of funding would support it. The case was made at the legislative hearing that the project was an innovative approach to address drainage and water quality that may result in a potential change for the future of agricultural drainage. During the ENRTF presentation, one of the legislators asked the committee, "This seems like a great project, but aren't there other funding avenues to support this?" The committee responded that many other potential sources of funding were identified, applied for, and denied because funding groups thought the project was merely an improvement for landowners.

PROJECT GOALS

The main goals for the improvement project were to:

- Increase drainage capacity to the CD 57 drainage system;
- Provide storage to protect land downstream;
- Improve water quality by reducing soil erosion and nutrient loading by providing storage, thus increasing system capacity;
- Enhance ecological value and increase critical land and habitat by adding vegetative buffer strips with native grass species;
- Provide an innovative demonstration project following Minnesota drainage law that provides alternative strategies that satisfy the collective needs of public waters and property owners by considering both economic and environmental costs and benefits; and,
- Develop a tool for landowners, land managers, planners, and conservationists as a model for future agricultural drainage projects across the state as many outdated and failing ditch systems require upgrades and repairs.

PROPOSED CONDITIONS

Based on the existing conditions and impairments of the drainage system and the downstream reaches, specific BMPs were selected to be incorporated during the design of the overall project. These BMPs are described below and include the following:

- Surge Basins
- Two-Stage Ditch
- Buffer Strips
- Rate Control Weir
- Over-dug Ditch

Figure 14 on the next page shows each of these water quality BMPs and where they were installed within the CD 57 watershed.

SURGE BASINS

Surge basins, also referred to as sediment or storage ponds, are used as a primary method of runoff retention, rate control, and increased water quality through the temporary storage of runoff. This technique has been used for many years in urban settings with much success. Rate control is achieved through providing storage with a reduced outlet size, thus allowing water to temporarily pond in the basin. The primary process through which sediment and the attached nutrients are removed is through gravity. Therefore, having adequate time for ponding is critical as it allows sediment to drop out of the water and not travel downstream. Primary drawbacks of storage are finding willing landowners, the cost of land, a high likelihood of significant earthwork, and locating the facility as to not back water into the existing system.

Several potential locations were initially identified in the CD 57 watershed based on topography and location with respect to the system. The landowners in the system did not want to force storage upon any landowner and thus the most effective location option was not chosen due to landowner resistance. The identified landowner was hesitant to take land out of production since they were a small farming operation. This landowner felt the impacts of a storage easement would be too significant since the operation was less than 100 acres. Based on

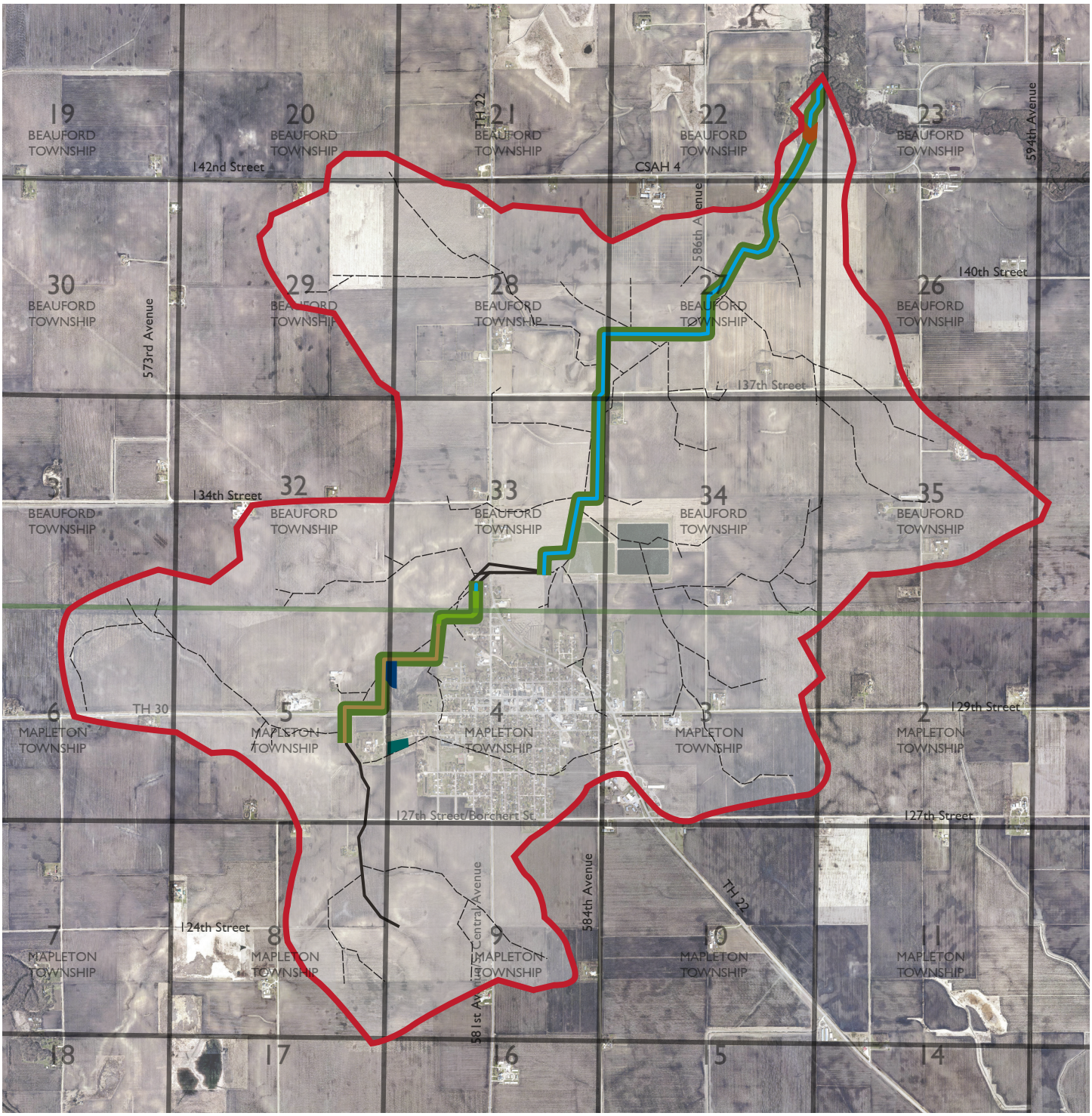


Figure 14 - Water Quality BMPs Intalled

N

0 1,600 3,200 Feet

Watershed Boundary
Existing Tiles
Overdug Ditch
City Stormwater Pond
Tile Improvements
Existing Open Ditch
Klein Surge Basin
Rate Control Weir
Two-Stage Ditch
Native Buffer Strips

ISG

Figure 15 - Inlet structures to Klein Pond

Figure 16 - City Pond

other potential sites, meetings were held with landowners to determine if there was interest in providing land for this basin. Ultimately the Klein Pond site was selected north of TH 30 adjacent to the ditch.

KLEIN POND

This surge basin is referred to as the Klein Pond because the Klein family was the landowner at the time of construction. This landowner was receptive to the project because they were aware of, and supportive of the concept behind social responsibility for water quality. The Klein Pond was constructed by excavating the existing low area to provide for 26.3 acre-feet of storage over a 4 acre area. Flow from the ditch is routed to this basin by a diversion weir and 48 inch culvert placed in the ditch. Once the pond reaches maximum capacity, the water flows over the weir and into the ditch downstream. Flow exits the pond through a 15-inch outlet, which reduces outgoing flow rates. The basin is planted with native vegetation to increase nutrient uptake and decrease the time the basin is saturated. The majority of the pond was designed as a detention basin with a small section that was over-dug to act as a sediment trap. It was over-dug below the 15-inch outlet and has a slight amount of permanent water in it. *Figure 15* shows the inlet structures into the sediment trap (pooled water section in the foreground) and Klein Pond (extra storage area in the background).

CITY POND

A second surge basin was constructed by expanding the existing City of Mapleton regional stormwater pond, thus it is referred to as the City Pond. The City of Mapleton allowed the CD 57 system to expand a pasture area that was previously utilized for flood storage. This basin is located south of the Klein Pond adjacent to Troendle Street SW. The existing pond was expanded to provide additional storage, capacity, and residence time to further remove sediment from the urban runoff. This pond was designed as a retention pond, thus it has a designed maintained water elevation. The City Pond provides storage of 23 acre-feet. The primary outlet of this pond is a 24-inch concrete pipe which eventually drains into the open ditch south of TH 30. Flow to the outlet is first routed through an 18-inch pipe, which is placed at a lower elevation than the 24-inch pipe. This provides a skimming effect within the pond to prevent debris and less dense oils and particles from traveling downstream. Like the Klein Pond, the City Pond was planted with native vegetation to increase nutrient uptake. *Figure 16* shows the expanded City Pond.

TWO-STAGE DITCH

A two-stage ditch is a specially constructed open ditch intended to provide water quality improvements while maintaining good flow characteristics that mimic natural fluvial process. The two-stage ditch is designed with a smaller inner channel that provides low flow and baseflow hydraulic capacity to prevent aggradation and erosion over a significant period of time. This channel controls the meandering capability, resulting in shorter flow lengths, faster velocities, and less sediment buildup in the inner channel making the two-stage ditch a self-sustaining system. The inner channel also keeps the saturated area away from the ditch banks and thus reduces the chance for sloughing and erosion. Benches provide hydraulic capacity for larger flow events, allow

Figure 17 - Two Stage Ditch

Figure 18 - Over-dug Ditch

for sedimentation and nutrient uptake, and also provide critical habitat area and increased vegetation, resulting in greater slope stability. Finally, vegetated buffers with native vegetation provide stormwater filtering and nutrient uptake for surface flow.

The location selected for the two-stage ditch was downstream of the surge pond and upstream of the tiled section across TH 22. The ditch section included a 2-foot wide inner channel, 2:1 side slopes, and 10-foot wide benches. The two-stage ditch spans 1,409 linear feet upstream from the tiled section west of TH 22 behind Casey's General Store in Mapleton. *Figure 17* shows the two-stage ditch behind Casey's General Store.

OVER-DUG DITCH

In-channel sediment storage was constructed on the existing open ditch north and south of TH 30 upstream of the two-stage ditch. This over-dug, in-channel storage consists of lowering the existing ditch bottom to provide approximately three feet of maintained water which allows sediment to settle out of suspension. The water elevation of the over-dug ditch section is maintained by several culvert crossings in the ditch. This allowed the system to gain depth creating more capacity for tile branches entering the system. *Figure 18* shows the over-dug ditch section of CD 57.

BUFFER STRIPS

Buffer strips are an area of vegetation planted between fields and surface waters to minimize organics, nutrients, and sediment in runoff from entering nearby surface waters. Per Minnesota Drainage Statute 103E, areas adjacent to public open ditch systems require 16.5 foot wide (1-rod) buffers along the top of the open ditch. Approximately 75% of the existing open ditch did not have the required buffer prior to the improvement. In lieu of typical buffer grasses, these areas were planted with native grasses and native vegetation to provide additional wildlife habitat and increase erosion protection. Deep rooted vegetation such as Big Bluestem, Canada Wildrye, and Switchgrass were planted to increase soil stability and nutrient uptake in runoff. *Figure 19* shows the native buffers planted throughout the system.

RATE CONTROL WEIR

Exiting peak flow rates are a major issue in every agricultural drainage ditch improvement. Per Minnesota Drainage Statute 103E, each drainage improvement needs to ensure an adequate outlet, thus protecting downstream landowners. One strategy of protecting downstream landowners is to reduce peak flow rates through a rate control weir. With the increase in drainage capacity of the system, peak flow rates are likely to increase without the use of a hydraulic weir.

The rate control weir was placed at the outlet of the ditch system and utilized a concrete section restricting flows to a narrow 18-inch opening for a depth of 5 feet. This weir created temporary ponding in the existing ditch for a lengthy linear section. This in turn reduced existing peak flow rates, allowed for storage, sedimentation, and nutrient removal for the entire system. *Figure 20* shows the rate control weir installed at the outlet of the system.

Figure 19 - Native Buffer Strips

Figure 20 - Rate Control Weir at System Outlet

WILDLIFE DIVERSITY

One parameter that was not formally tested, but rather was observed through field visits and the onsite cameras was the wildlife diversity provided by this project. Numerous different species were observed throughout the watershed. At the rate control weir, several species were observed from the onsite camera which included raccoons, deer, birds, cats, and fish. The weir provided perennial flows for fish to navigate, but also provided an ideal location for predators to feed and hunt. It also provided a more navigable pathway for these animals to cross the waterway.

The native buffers installed throughout the system also provide a significant habitat area that would otherwise have been in agricultural production. Several species of birds and mammals were observed in these areas including:

- Mallard (Anas platyrhynchos)
- Great Egret (Ardea alba)
- Great Blue Heron (Ardea herodias)
- Blue Winged Teal (Anas discors)
- Double Crested Cormorant (Phalacrocorax auritus)
- Wood Duck (Aix sponsa)
- Belted Kingfisher (Ceryle alcyon)
- Canada Goose (Branta canadensis)
- Raccoon (Procyon lotor)
- White-tailed Deer (Odocoileus virginianus)

The surge basins and two-stage ditch provided both an area of maintained water and a perennial flow area for birds and migrating water fowl species. Many different species of birds and waterfowl were observed in these areas. Without the creation of these water storage features, these areas would have been in agricultural production and would not have provided the diversified wildlife habitat. *Figure 21* shows several species of diversified wildlife that were captured on the onsite time-lapse cameras.

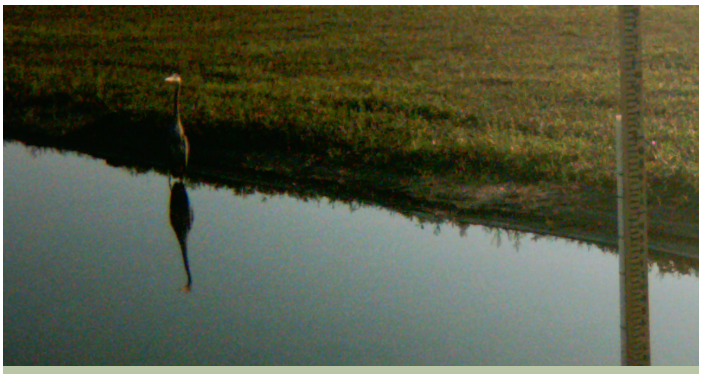


Figure 21.1 - Great Blue Heron (Ardea herodias)

Figure 21.2 - Wood Duck (Aix sponsa)

Figure 21.3 - Great Egret (Ardea alba)

Figure 21.4 - Belted Kingfisher (Megaceryle alcyon)

Figure 21.5 - Racoons (Procyon lotor)

Figure 21.6 - White-tailed Deer (Odocoileus virginianus)

Figure 22 - 54-inch RCP under TH 22

Figure 23 - Construction of two-stage ditch in wet conditions

Figure 24 - Final construction of two-stage ditch

Figure 25 - Area of Klein Pond flooded due to wet conditions

CONSTRUCTION

The CD 57 project was bid in two parts in October 2010. One part included the tile and ditch improvements and the other included all of the BMP's and water quality improvements. This was done to separate the ENRTF funding portion of the project from the landowner portion of the project. Holtmeier Construction was the low bidder for each publicly bid project. The project was awarded in early November 2010 and construction began immediately thereafter. It included construction of the two-stage ditch and the over-dug ditch, the grading of the Klein Pond and City Pond, the construction of the rate control weir, construction the supplemental 24-inch mainline in the upper end of the watershed, seeding of the native buffers, and installing the 54-inch reinforced concrete pipe (RCP) under TH 22 connecting the two open ditch segments (*Figure 22*), along with all of the other portions of the project.

Record rain and snowfall during the fall and winter of 2010 created extremely wet and difficult working conditions (*Figure 23*). This slowed and delayed the overall construction of the project. By the end of December, the two-stage ditch construction was complete (*Figure 24*), but the construction of the Klein Pond had halted.

Construction continued in the spring of 2011 with the Klein Pond and over-dug ditch. However, a very wet spring further delayed construction (*Figure 25*). Due to severe flooding in the Klein Pond area, construction of the project moved to the City Pond which was complete by mid-July (*Figure 26*).

Figure 26 - Construction of City Pond

Figure 28 - Rate Control Weir

Figure 27 - Completed Klein Pond

In late August and early September 2011, construction of the over-dug ditch and Klein Pond resumed. The dry conditions allowed the equipment to maneuver throughout the area to complete the Klein Pond. Spoils from the Klein Pond were spread in the adjacent field, raising the entire field by 2 to 3 feet. This minimized the flood damage to the area and created an excellent area for crop production. By mid-October 2011, the Klein Pond was complete and began to store water (*Figure 27*).

The diversion weir and 48-inch diversion culvert for the Klein Pond were completed in November 2011. The construction crew then moved on to the last two portions of the project. This included the rate control weir (*Figure 28*), seeding and mulching of the ponds and ditches. By December 2011, the entire improvement project was complete. Seeding the native grass buffers was completed and monitoring equipment was installed along the newly constructed structures and BMPs throughout the system in spring 2012.

The native grasses were maintained and mowed in 2012 and 2013 to control weed growth.

Figure 29 - Increased Storage Capacity Provided by Klein Pond

WATER QUALITY REPORT AND OUTCOMES

The *Water Quality Report* analyzes the water quality monitoring results that are summarized here.

WATER QUALITY HIGHLIGHTS

There were many benefits to water quality in the CD 57 system based on the six total years of monitoring. The following are the major water quality benefits.

- Increased Storage Capacity: The Klein Pond provided a substantial amount of storage to the upper half of the CD 57 watershed. During rain events, the Klein Pond would store water up to an area 650 feet by 250 feet and nearly 12 feet in depth, equaling 26.3 acre-feet of storage. This is equivalent to 13 Olympic sized swimming pools which is equivalent to 0.20 inches of rainfall across the contributing watershed. With a reduced outlet of a 15-inch pipe, water backed up into the pond, dramatically slowing the water flow. This allowed water downstream to drain out prior to water in the upper watershed from draining, preventing flooding. (*Figure 29*)

- Reduced Peak Flow: With an increase in drainage capacity, protecting downstream landowners and the receiving waters was a major concern in the design of the system. It was essential to the landowners to record the depth of water, thus flow throughout the system to insure that peak flow rates were protected. Peak flows also contribute to the highest pollutant loading. Therefore, reducing peak flow rates also reduced pollutant loading. Peak flow rates in the CD 57 system reached nearly 500 cfs after large rain events and may have been higher prior to the installed BMPs. The peak flow rates were reduced at two points as the flow travels through the watershed, once in the Klein Pond and once at the outlet of the system. Peak flow reductions at the Klein Pond ranged between 10 and 50 percent throughout the three years of monitoring and averaged 28 percent reduction for all monitoring storms. The rate control weir had a top reduction in peak flow of 25 percent and averaged 6 percent in reduction for the monitored rain events. The Klein Pond had more than 4 times the storage than the rate control weir, thus had a higher peak flow reduction. (*Figure 30*)

- BMP Water Quality Improvements: Water quality of the passing water had dramatic improvement in reductions of pollutants. Each BMP installed had a function to reduce the loading of TSS, TP, and TN to improve the overall water quality throughout the ditch system. While a traditional

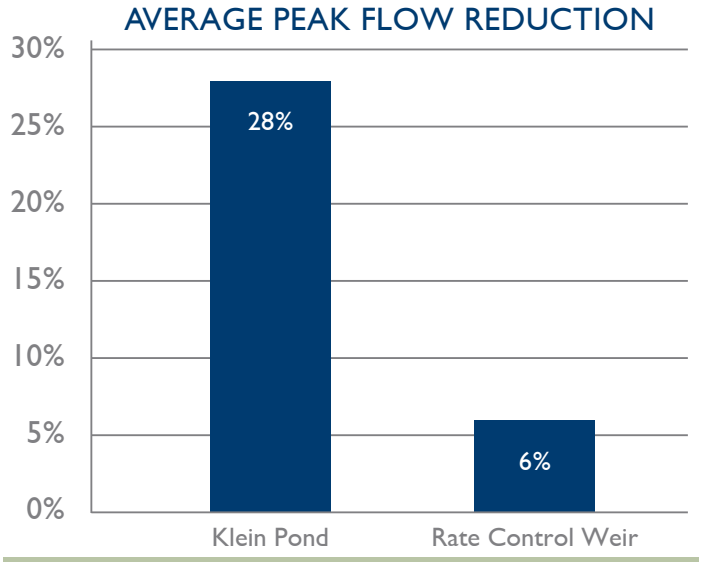


Figure 30 - Reduced Peak Flow

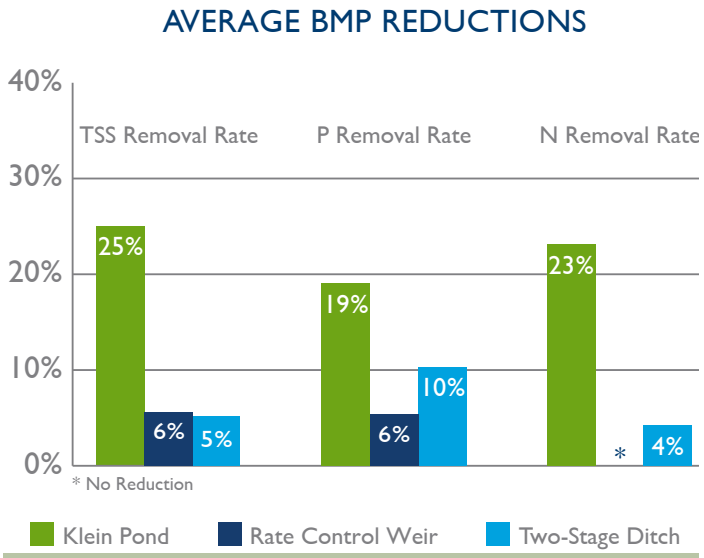


Figure 31 - BMP Water Quality Improvements

ditch increases its loading as it travels downstream, the CD 57 system decreased loading as the water passed through the treatment train of each BMP. The Klein Pond, two-stage ditch, and rate control weir were analyzed to determine how effective they were at reducing the total loading of TSS, TP, and TN. All three BMPs showed reductions, thus improving the overall water quality of the ditch. Reduction of each pollutant ranged between 15 and 50 percent for the Klein Pond, averaging nearly 25 percent for each. The two-stage ditch and rate control weir had reductions between 2 and 10 percent, averaging nearly 5 percent. Pre-BMP installation monitoring showed that the pollutants increased on average 30 percent as the water moved downstream. This is more than a 50 percent difference and substantially improves the water quality of the ditch. The installation of these BMPs are making a difference in the water quality downstream. (*Figure 31*)

- Trapped Sediment: Yearly topographic surveys were performed on the CD 57 system. After the completion of the 3 years of post-BMP installation monitoring, the Klein Pond was surveyed to determine how much sediment had accumulated in the pond. The survey revealed over 725 cubic yards of sediment had accumulated, equivalent to over 70 dump truck loads. The Klein Pond was the most effective at removing pollutants as over 230,000 pounds of sediment, 415 pounds of phosphorus, and 23,000 pounds of nitrogen were removed. Together, all three BMPs removed a total of 251,000 pound of sediment, equivalent to nearly 75 dump truck loads of sediment. (*Figure 32*)

- Baseflow Water Quality Improvements: During baseflow conditions, wildlife utilize waterways for their habitat. However, many waterways have degraded water quality and cannot support aquatic life. Therefore it is very important to provide a healthy environment for wildlife to thrive. Pre- and post- BMP installation monitoring was performed to determine the water quality changes during baseflows as a result to the installed BMPs. On average, the TSS and TP concentrations were reduced by more than 33 and 16 percent from the installed BMPs respectively. This provides a significant change in water quality and makes the CD 57 system a thriving place for a variety of species to live. Without the BMPs, it is likely that the CD 57 system would not support a diverse wildlife habitat for many species. Improving water quality during rain events impacts the natural resources on a national scale, however, improved water quality during baseflow conditions impacts natural resources on a local scale. (*Figure 33*)

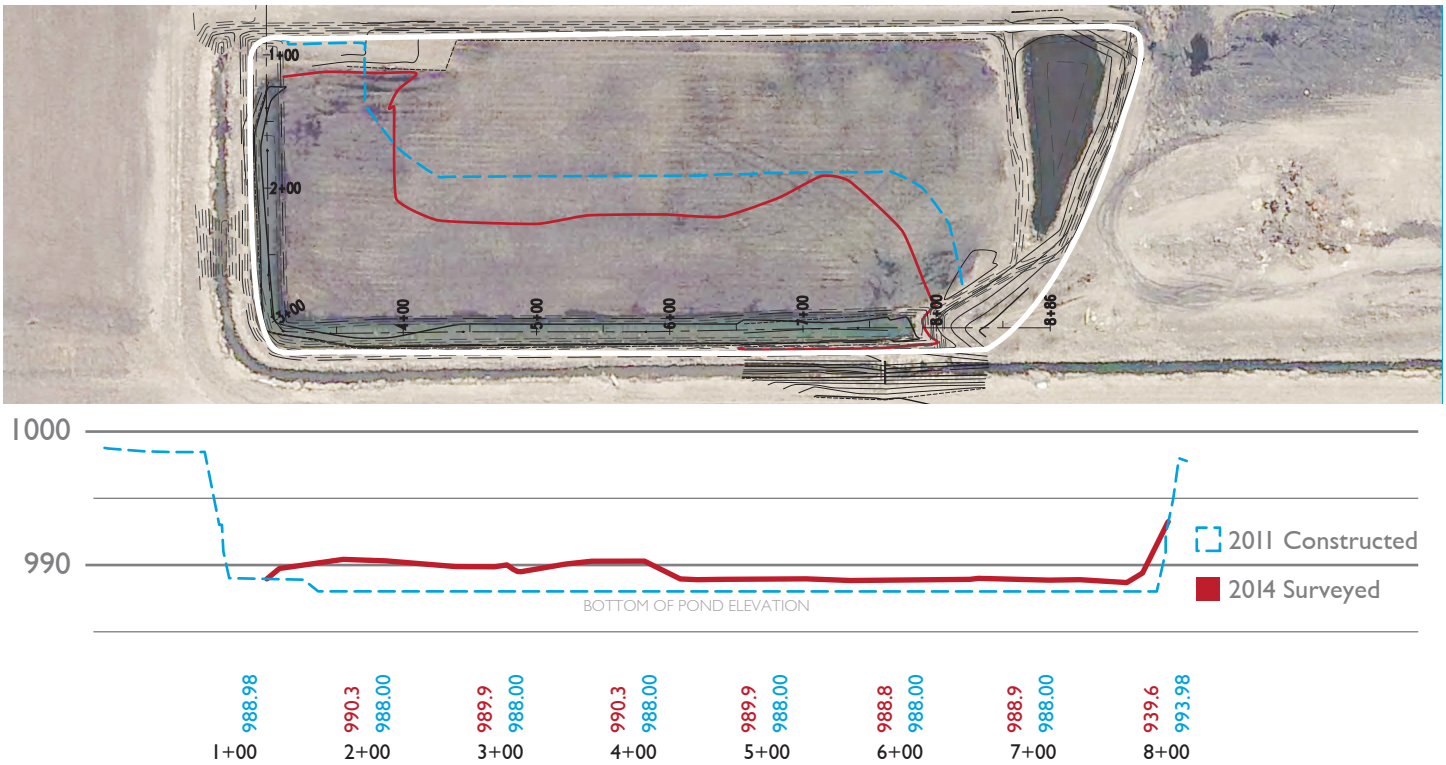


Figure 32 - Trapped Sediment

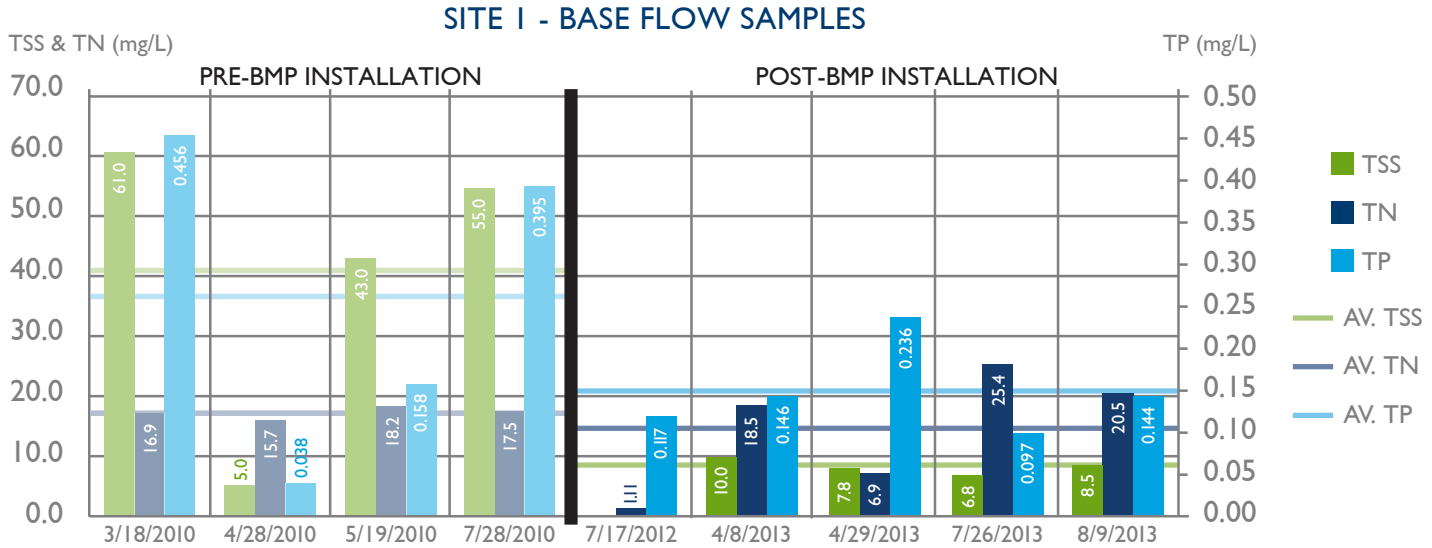


Figure 33 - Base Flow Water Quality Improvements
(Bars indicate date specific measurements; Lines indicate average measurement)

TSS Reduction = 33% TN Reduction = 3% TP Reduction = 12%

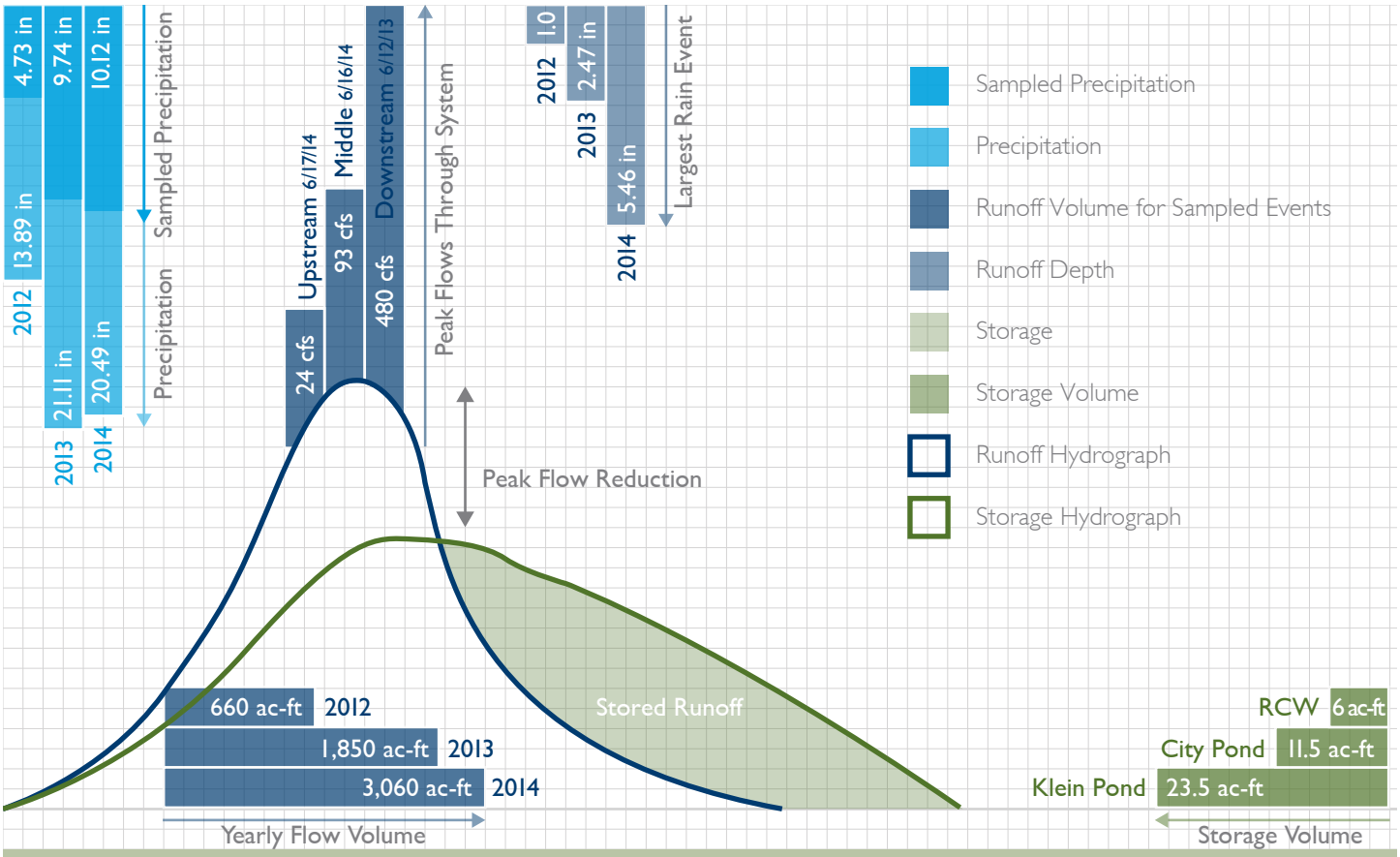


Figure 34 - Hydrograph Summary

FLOW

Flow monitoring for the CD 57 system was interpolated using stage (depth) data collected utilizing data logging devices. There were 19 rain events over 0.5-inches of rainfall that were sampled and analyzed for both flow and water chemistry. The data logging devices used collected rainfall depth, barometric pressure, and stage was used to determine the following: total rainfall and sampled rainfall depths, runoff depth, peak flow rates, and total flow volumes.

Rainfall was measured for every 0.01 inch of rain and was recorded with an onsite rain gauge and data logger. Rainfall was recorded at one location in the middle of the CD 57 watershed.

The total flow volume of a rain event at a given point is defined as the cumulative volume of water that passes through a point for a rain event. It is found by calculating the area under the hydrograph curve.

The runoff depth is calculated from the total flow volume recorded throughout the watershed. Compared to rainfall, runoff depth is less in depth due to infiltration of the soil.

Peak flow rates are the highest recorded flow rate and are the top most point of the hydrograph curve. Peak flow rate are generally linked to the highest pollutant loading that a watershed contributes.

Peak flow rates and total flow volume generally increase moving from upstream to downstream as the watershed size increases. Rainfall depth and runoff depth are generally similar throughout the watershed, but can vary as rainfall intensity varies. (*Figure 34*)

EDUCATION

One of the benefits of this project is the way it is being used as an educational tool. There have been many opportunities where the project was showcased as a model. They include workshops, publications, seminars, presentations and conferences. Audiences have included landowners from various ditch systems, government agencies, land managers, drainage authorities and members of the public.

AGRICULTURAL DRAINAGE WORKSHOPS

Three educational drainage workshops were held on behalf of Blue Earth County Drainage Authority, LCCMR, MNDNR, and MDA, with ISG and others to present this project to a diversified audience. The workshops contained a history, background, and overview of this project and the effort it took to achieve the outcome. It also included guest speakers with different perspectives to create an unbiased atmosphere for those in attendance. A tour of CD 57 was provided at two of the workshops. The 2014 event was attended by nearly 200 people.

PUBLICATION

The CD 57 project was also featured in the 2015 Gislason and Hunter Law Firm's agricultural law newsletter *DIRT Magazine*. The article titled, "Conservation Drainage" described the impacts that BMPs can have on agricultural drainage and water quality.

OTHER PRESENTATIONS

On behalf of Blue Earth County, ISG has presented this project to several other audiences since it began in 2007. Presentations were given to the following audiences:

- Minnesota State University, Mankato Department of Civil Engineering (2010)
- American Society of Civil Engineers (2011)
- Faribault County Drainage Authority (2013)
- Minnesota Water Resources Conference (2014)
- Iowa Water Conference (2014)
- Blue Earth County Soil and Water Conservation District (2014)
- Sibley County Drainage Authority (2015)

It addition to presentations, handouts were distributed to landowners across southern Minnesota. This includes a summary of the CD 57 project and a Fun Facts Brochure which highlights the major outcomes from monitoring this project.

CONCLUSION

Agencies and landowners were seeking proof that agricultural production could be enhanced and water quality could be improved by implementing a combination of BMPs. This project provided proof that these goals can be accomplished simultaneously. Storage and drainage capacity were improved resulting in reduced flooding which resulted in improved field conditions for crop yields. Water quality was also improved by reducing sediment and nutrient loading throughout the system.

It is evident that with proper planning, community and agency collaboration, and incorporation of innovative engineering, increased drainage capacity can be designed while also protecting water quality. This project demonstrated a unique circumstance of a degrading drainage system, protection of downstream landowners, water quality concerns, implementation of BMPs using outside funding, and an overall improved drainage system.

There were many benefits from the CD 57 Project including collaboration between many agencies and landowners, improved drainage and water quality through BMPs, and a unique tool to use in the future when dealing with similar projects.

Overall the project was successful. All parties involved learned how to work together to achieve a common goal for those impacted by the CD 57 Project. With the implementation of BMPs to the system, drainage was improved to the watershed while also enhancing water quality. The water quality benefits to this project are a significant bonus to the project. On a small scale these benefits can be applied in a variety of ways to all drainage systems in southern Minnesota. Together, they can affect a large scale watershed environment. This project provided an exceptional demonstration on how BMPs can be used in conjunction with improvements to agricultural drainage systems.

This project serves as a guide to others located in the area that are experiencing degraded drainage systems and water quality concerns. This project will help the future of agricultural drainage design and will make it easier to incorporate BMPs to improve the water quality in these systems. Hypoxia in the Gulf of Mexico continues to be a concern at a national scale. By implementing these type of projects throughout the agricultural community in the Midwest, sediment and nutrient levels can be reduced and lead to an overall water quality improvement throughout the Mississippi River Watershed.

CHALLENGES

There were several challenges during the 2009-2014 project construction and water quality monitoring of the CD 57 Project. During the pre-construction monitoring, limited data was collected due to lack of funding. Funding for water quality monitoring was not determined until late 2010,

Figure 35 - Damaged Camera due to High Water Levels

which limited the amount of samples that could be obtained. Pre-BMP installation samples only included grab samples during baseflow conditions and were not taken after rain events. The following were the major challenges associated with monitoring the CD 57 system for water quality:

- Costs
- Equipment
- Weather
- Maintenance
- Vandalism
- Agencies
- Funding
- Time

COSTS

Very few ditch systems in Minnesota have been monitored for flow and water quality. The main reason for this is due to the difficulty in monitoring. Major difficulties in ditch monitoring include backwater effects, inconsistent soil conditions, water quality variations with peak flows, and flow variations between open ditches and culvert crossings. To accurately monitor water quality and flow with varying site conditions requires higher quality equipment and additional monitoring sites in specific locations based on conditions. The high cost of this equipment would be more than the cost for constructing the BMPs. Therefore, it was not feasible to purchase the higher cost equipment.

One of the main focuses of the project was determining how the BMPs affected the system and water levels adjacent to the ditch. The theory was to use data loggers to record depth to show the improvements didn't negatively impact the adjacent farmland. Landowners needed assurance that the water levels in the ditches would not exceed the ditch banks.

EQUIPMENT

Post-BMP installation water chemistry sampling and testing was done through the Minnesota State University (MSU), Mankato, Departments of Civil and Mechanical Engineering and Chemistry and Geology and occurred during the peak flow, following 1-inch rain events and baseflow. This provided a unique opportunity for students to learn the methods needed to properly test for multiple water chemistry parameters. This combined effort allowed for a general analysis of the BMPs installed and how effective they were during rain events.

If sufficient funding was available for equipment, several changes would have been made to the monitoring approach. Data loggers would have been replaced by flow-velocity meters to monitor flow (cubic feet per second (cfs)) versus depth. In addition, rather than one grab sample at the peak flow of the storm, a real time portable sampler would be installed at each monitoring site. This sampler would take water quality samples from the ditch at different intervals of a storm, providing more measurements on water quality associated with different flows throughout a storm event. Water chemistry would also be tested through a certified testing lab. This would provide a validated water quality analysis of the tested parameters.

WEATHER

A major difficulty came from the unpredictability of severe weather in the area. The project started in the fall and winter of 2010-2011. Record rainfall and record snow fall during this time delayed some of the construction and added additional costs for pumping water, erosion control and other increased time for completion. Several storm events damaged monitoring equipment including staff gauges, data loggers, cameras, and rain gauges. With high winds and high flows, several of the staff gauges became loose and tipped over in the ditch. Cameras were also susceptible to flood damage since they needed to be placed within 20 feet of the staff gauge for a clear picture. Several cameras were flooded out during high flow periods. High winds also damaged the rain gauge and weather station. The rain gauge was periodically blown off the mount and needed to be remounted. *Figure 35* shows a camera that was damaged due to high water levels.

MAINTENANCE

Regular maintenance is required to make sure the equipment is

functioning correctly. This includes trimming vegetation around cameras, removing debris from staff gauges, ensuring data loggers and rain gauges are correctly reading pressure and depth, and routine inspection for damage after rain events. Maintenance costs were not included in the grant amount and future requests for funding would include ongoing maintenance, along with improved monitoring strategies.

VANDALISM

Vandalism and theft periodically occurred to the monitoring equipment. Cameras, staff gauges, and data loggers were consistently tampered with at three monitoring locations. Due to the limited visits, the incidents were not noticed until the next scheduled collection. A multi-functioning weather station valued at $10,000—provided at an in-kind contribution by MSU—was stolen and was never replaced.

AGENCIES

This project could not have happened without agency involvement. Specifically, there were individuals who were instrumental in moving the project forward. Leo Getsfried, Minnesota Department of Natural Resources was able to see how the BMPs could both improve water quality while also enhance crop conditions for landowners. This combination is essential in making agricultural drainage projects with combined BMPs so effective. Mark Dittrich, Minnesota Department of Agriculture, provided consistent, effective feedback and guidance that maximized the water quality improvements. Al Kean, Minnesota Board of Water and Soil Resources and staff ensured the best interests of the State while also helping to move the project forward as efficiently as possible with timely responses and solutions. Other agencies and staff from the DNR, BWSR, NRCS, and SWCD also contributed meaningful input to maximize the water quality benefits.

While input from agencies resulted in a successful project there were several challenges. These challenges sometimes impeded efforts to improve water quality. Below is a list of the challenges of the project.

- Too many agencies: There were several agencies and several groups of agencies that were involved in the drainage improvement process. This made for a confusing process.

- Lack of Communication: The responsibility of communication was not handled among agencies. Rather, the engineer appointed by the Drainage Authority was required to communicate between agencies and different departments in each agency to relay information between landowners, the drainage authority, and agencies. This slowed the process.

- Variety of Goals: Each agency has its own list of priorities and goals related to improving water quality. In many cases, the priorities conflicted with each other.

- Different Requirements: In the event that goals of the project aligned among agencies, the requirements for the goals did not align.

- Delays: Different requirements and policies lead to a delay in the implementation of the project since all agencies had to review the project and had their own timelines for review. This process significantly delayed the overall project from the petition stage to the final construction to 5 years. If there were a more streamlined process for collaborating with multiple agencies, this process could have been completed in two to three years.

- Added Costs: The delay time resulted in unnecessary costs to fulfill the needs and requirements of each agency. The added costs would have been better spent on water quality BMPs.

- Landowner reluctance to deal with agencies: Due to the time, costs, and requirements of agencies, many landowners are reluctant to work with agencies to achieve water quality goals. This requires additional time with landowners to build trust in order to move forward in working with agencies.

- Financial Support: Agencies do not provide enough financial incentives to implement BMPs within their existing budgets. This is due in part to the belief that the BMPs only benefit the landowners rather than benefitting the public waters and the landowners. Without LCCMR funding, water quality projects like CD 57 are difficult to get implemented.

- Lack of Implementation: The challenges listed above contribute to the lack of implementation of more BMP projects throughout Minnesota.

FUNDING

Another difficulty was the limited outside funding sources available for projects dealing with water quality in agricultural drainage systems. Many federal, state, and local governments strive for water quality improvements while supporting the agricultural economy. However, there are limited sources for funding for BMPs. BMPs associated with agricultural drainage can be very costly and in some cases, implementing these would not prove cost effective for the system. This results in many drainage improvement projects that are constructed as less effective, traditional style ditches with limited water quality aspects associated with them.

TIME

Drainage improvement projects happen when there is a failure or near failure of the system. In order to prevent additional system failure, crop loss, erosion and other damage, there is significant pressure on the drainage authority to rush through the process. The engineer must then

move quickly to meet all requirements for construction. This puts more focus on completing the project rather than considering water quality improvements.

RECOMMENDATIONS

Although this project was a success in terms collaboration between agencies, increased system capacity, and water quality improvements, there were several lessons learned throughout the process that make for valuable recommendations to future projects.

COST EFFECTIVENESS AND DRAINAGE LAW

In early phases of this project, several locations were targeted for wetland restorations. While wetland restorations add incredible valuable to water quality and wildlife habitat, they were difficult to incorporate into this drainage project due to high associated costs with little benefit to the drainage system (i.e., landowners). This nearly eliminates the potential for wetland restorations throughout southern Minnesota drainage systems without outside funding. While the overall goal of many agencies is to restore as many wetlands as possible, it is difficult to include them as part of drainage projects. In order for wetlands to be incorporated into drainage systems, outside funding is needed to make the project cost effective. The current rules for utilizing this funding when available should be reviewed. They do not allow a drainage system to obtain funding through RIM/WRP and thus this option is eliminated without 100% landowner support.

A similar issue arose when incorporating BMPs into this drainage system. Without funding from the LCCMR, the water quality BMPs installed in this system would not have been cost effective to the system. Even with willing landowners to contribute more money to storage within the watershed, the benefit amount fell short of what the costs were to improve the system. This is also a common mishap in drainage systems throughout southern Minnesota. While many landowners are open and willing to incorporate BMPs into their drainage systems, funding allocations limit the availability and practicality of these practices. Again, outside funding is needed to help implement these practices into southern Minnesota drainage systems.

MONITORING

This project was one of the first drainage systems with BMPs that included monitoring for water quality. Although monitoring for this project provided great results, many strategies were learned throughout the monitoring process that need to be taken into consideration for the next similar project.

More monitoring is needed prior to the construction of agricultural BMPs or an improvement to a ditch system. Monitoring should occur during baseflow conditions and also within 24 hours of a rainfall event, primarily those events greater than 1-inch. This will help provide a comparison of data. In addition to pre-BMP installation monitoring, it would also be beneficial to model sediment transport throughout each BMP and compare results to the post-BMP installation water quality data. This could be used in the future to calibrate sediment transport models.

While data loggers and grab samples were adequate to assess the water quality throughout the CD 57 system, more sophisticated equipment would better gauge and depict the water quality of the system. Real time flow and water quality devices would provide a more accurate depiction of the flow and water quality of the system. This would also reduce the amount of ambiguities within the data collected for monitoring.

Throughout the three years of post BMP-installation monitoring, the CD 57 system experienced snow melts, ice outs, and heavy rainfalls that damaged or destroyed monitoring equipment. Higher quality equipment that can handle extreme conditions would save money through reduced maintenance and replacement costs and would also reduce the risk of losing valuable data.

DESIGN AND INSTALLATION

Water quality results for the two-stage ditch in this system indicated it was much less effective than what was anticipated. However, this was likely due to the nature of this project and the location of the two-stage ditch in relation to the other BMPs. The two-stage ditch was constructed immediately downstream of the surge pond, which effectively reduced the sediment and nutrient loading. Since the two-stage ditch was receiving already treated water, the two-stage ditch appeared to be less effective at reducing the sediment and nutrient loading. Future monitoring would incorporate a system where a two stage ditch can be monitored independently to better gauge the effectiveness of this practice.

OVER-DUG DITCH

The concept behind the over-dug ditch was to create a long linear sediment trap in the existing ditch and also gain depth throughout the system. However, many portions of the over-dug ditch contained silty, unstable soils with steep bank slopes. This caused several areas of the over-dug ditch to slough, and added to the erosion potential of the ditch. It is recommended not to construct over-dug ditches in these situations. *Figure 36* shows a part of the over-dug ditch where erosion occurred.

MAINTENANCE

Monitoring showed that the BMPs analyzed had significant sediment removals. Specifically, the Klein Pond accumulated 725 cubic yards of sediment in the pond. At this rate, maintenance and sediment removal is necessary and should be budgeted for in the future. Consistent with its design intent and the current rate of sediment accumulation, the Klein Pond will need to be cleaned in a period of 10 years per MPCA recommendations. Portions of the over-dug ditch contained highly organic and silty soils. In some areas, erosion and sloughing occurred

Figure 36 - Erosion in Over-dug Ditch

Figure 37 - Removing Sediment from Pond

and periodic maintenance will be required for these areas. The buffer strips have been mowed and maintained over the past three years and ongoing maintenance will need to continue for these areas. Sediment in the City Pond was not monitored for sediment accumulation, however it is anticipated the sediment will need to be removed in 10 years per MPCA recommendations. (*Figure 37*)

LANDOWNER PARTICIPATION

There were instances where, for legitimate reasons, a landowner chose not to participate in a land easement for water quality improvement, even when it was the most ideal site to impact water quality. This was typically due to lost revenue and/or a significant percentage loss of productive land. For example, one property was identified as the most cost effective location for storage; however after multiple attempts involving the drainage authority, engineer, and other landowners, the property owner chose not to take the land out of production. The CD 57 petitioners didn't want to force a taking since this landowner only had 80 acres of tillable farmland. Taking this land out of production was a significant impact on the farmer. In the future, landowners may be more willing to participate in water quality BMPs if they are more adequately compensated for taking land out of production.

AGENCIES

There are many opportunities to improve the process of collaborating with agencies.

- One point of contact/decision making: Assign one agency to serve as the main contact to landowners.
- Improve Communication: Determine a more efficient process for interagency communication. Implement a step-by-step process between agencies rather than a back and forth process.
- Streamline and Prioritize Goals: Identify similar needs of each agency and prioritize BMPs based on these similarities.
- Review Process: Require a faster turn-around time for agencies to provide feedback on projects.
- Reduce Delays: By having fewer points of contact, improved communication, prioritized goals, and a more efficient review process will result in reduced delays.
- Financial Support: Consider the benefits to the receiving waters and those impacted as a result of the water quality improvements when allocating funding.

TIME

In order to include water quality improvements to systems, proper planning, watershed management and prioritizing is needed prior to the point of failure. This requires multi-purpose drainage management plans to be developed for each ditch system.

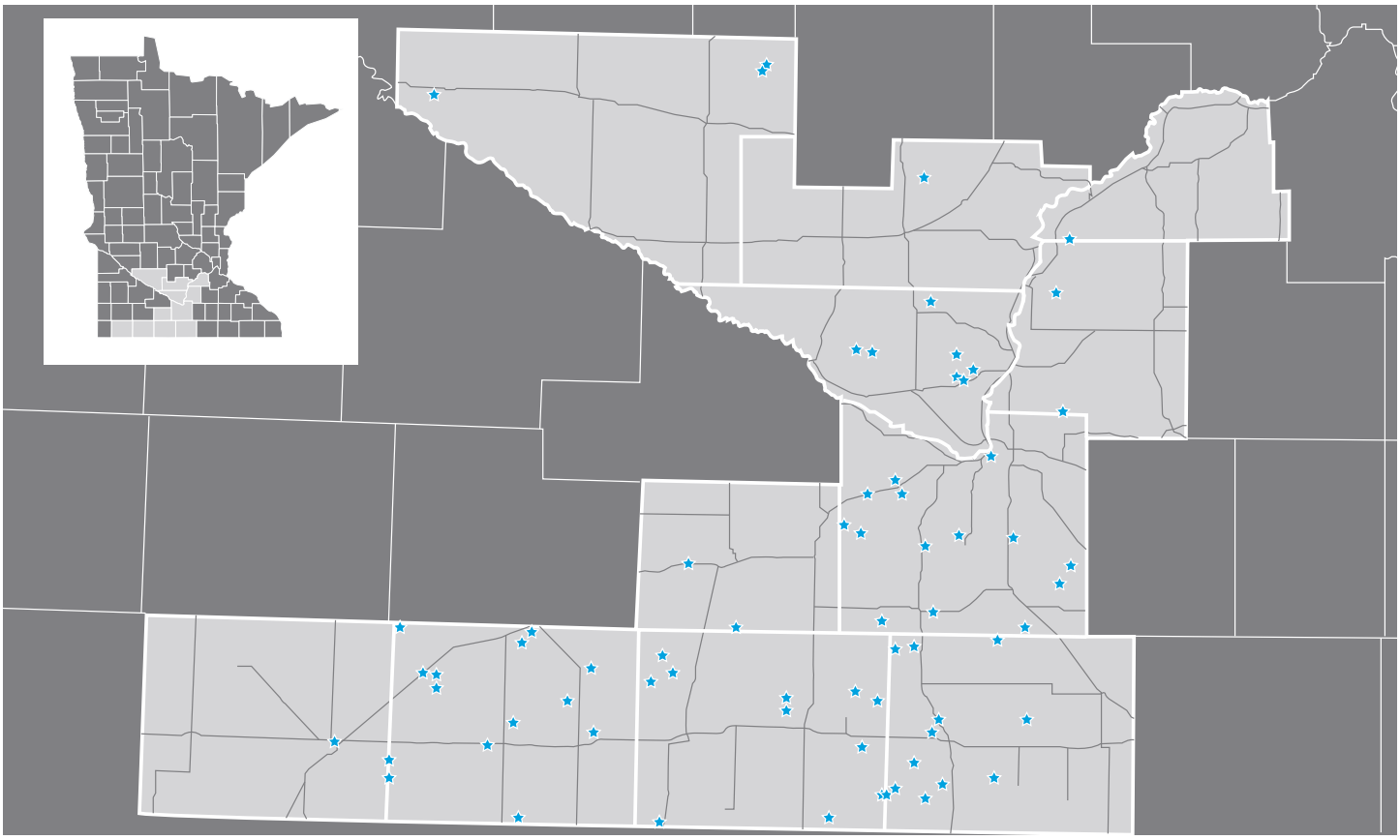
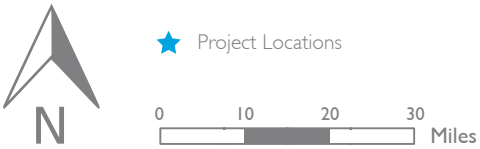


Figure 38 - Map of ISG Projects that have or will encorporate BMPs



ISG

MOVING FORWARD

Most agricultural drainage systems in southern Minnesota do not have an effective plan to address the watershed. Many of these BMPs are not one size fits all projects and need to be evaluated based on several factors including watershed size, watershed slopes, soil types, rainfall frequencies and many other factors within the watershed. Each drainage system needs to have its own Multi-Purpose Drainage Management Plan which identifies areas where BMPs are most effective. This allows each system to develop a strategy at implementing each practice. These plans will be helpful in seeking outside funding sources.

There are also very few systems that have both BMPs and monitoring with them which makes it difficult to design for desired water quality outcomes and to be able to quantify their impacts. More research and monitoring is needed to determine the effectiveness of these practices within their given circumstances. However, without funding for these type of projects, it is difficult for ditch systems to do these projects based on their cost effectiveness.

There are nearly 40 current agricultural drainage projects throughout southern Minnesota currently underway that have an opportunity to implement water quality BMPs to improve water quality (*Figure 38*).

REFERENCES

Gupta, Ram S. 2008. Hydrology and Hydraulic Systems, Third Edition. Long Grove, Illinois. Waveland Press, INC.

ISG. (2008). Preliminary Engineering Report for Blue Earth County Drainage Authority, Mankato, MN: Brandel.

ISG. (2010) Final Engineering Report for Blue Earth County Drainage Authority, Mankato, MN: Brandel.

ISG. (2014) Martin County Multipurpose Drainage Management Plan, Martin County, MN: Brandel.

https://drive.google.com/folderview?id=0B5UU3OzxBQV_fnJCMGplUS1kNVd3LTZ1MnpyNVVDc1Fzd)zNQnFZMGNuVVQ0alVnLW1kWU)&usp=drive_web

Understanding Minnesota Public Drainage Law. (2002) Association of Minnesota Counties. St. Paul, MN. Retrieved from http://www.mnwatershed.org/vertical/sites/%7B8075FBF0-4136-414E-99AC-FC56C14C0AC9%7D/uploads/%7BE8F70722-253E-453F-AFD5-97EBF3355241%7D.PDF

Smith, Louis, N., Holtman, Charles B. Smith and Partners, PLLP, Minnesota Drainage Law Analysis and Evaluation. Final Report. (2011). Retrieved from: http://www.bwsr.state.mn.us/drainage/Drainage_Law_Eval_Smith_Partners_LCCMR_Final_Report_08-15-11.pdf

Miller, T. P. (2012). The Agricultural BMP Handbook for Minnesota. Minnesota Department of Agriculture. Minnesota Pollution Control Agency. (2012). Le Sueur River Watershed Monitoring and Assessment Report. MPCA Document number: wq-ws3-07020011b.

Minnesota Department of Agriculture (MDA). 2011. Conservation practices Minnesota conservation funding guide: Grass filter strips. Date accessed: September 15, 2011. http://www.mda.state.mn.us/protecting/conservation/practices/buffergrass.aspx.

Minnesota Office of the Revisor of Statutes. 2012(b). Minnesota Administrative Rules. MN Rule 7050.0140 Use classifications for waters of the state. Date accessed: September 15, 2011. https://www.revisor.mn.gov/rules/?id=7050.0140.

MPCA. 2012 Le Sueur River Watershed Monitoring and Assessment Report. Date accessed: June 18, 2015
http://www.pca.state.mn.us/index.php/view-document.html?gid=17609

GLOSSARY

Affected Landowner: A landowner who owns property that is in some way influenced by a public drainage system.

Alternative Intake: Any method of replacing open surface intakes that are flush to the ground with an alternative method that temporarily ponds water, thus preventing sediment from entering. They include a variety of perforated risers, rock inlets, dense pattern tile, or any alternative of these.

Artificial Drainage: Any means of underground tiling or open ditches to effectively lower the groundwater table for adequate crop growth and to allow for proper workability of farm equipment.

Benefit: The financial value allocated to a parcel of land based on its capability to adequately drain water.

Best Management Practices (BMPs): Any method or practice that is used in an agricultural landscape to effectively reduce peak flow rates, sediment loading, erosion, and nutrient loading.

Buffer Strips: An area of perennial vegetation planted between agricultural fields and waterways. They are located adjacent to the top of both sides of any waterway. Buffer strips are required to be a distance of 16.5 feet (one rod) from the top of an open ditch for a Public Drainage System and 50 feet from the top of a public water. Buffer strips are often referred to as buffers or filter strips.

Controlled Subsurface Drainage: A practice used to manipulate the ground water elevation through the use of control structures located on a private tile line. This method allows water to be held higher in the soil profile during the growing season for better crop uptake while draining the water table during the planting and harvesting seasons.

County Tile: A county tile refers to a network of subsurface tiling that conveys water off the landscape and is part of a public drainage system. A county tile is comprised of a network of mainlines, branches, and laterals that are all part of the public drainage system. County tile is often referred to as a tile, tile main, county main, branch, or any variation of these.

Cover Crops: A non-perennial plant that is grown between the main crop in a rotation to enrich the soil through added organic matter, reduced leaching, and reduced soil erosion. They include a variety of small grains including wheat, rye, oats, and barley.

Crop Rotation: Crop rotation is defined as a system for growing several different crops in a planned succession on the same field. It includes the rotation of a small grain such as hay, oats, barely, or alfalfa.

Culvert: A device used to convey water under a roadway or crossing. They include a variety of round, square, or arched pipes made of either concrete, corrugated metal, wood or any other material.

Ditch Viewers: Ditch viewers provide an unbiased approach of determining benefits and damages to affected landowners of a drainage system.

Drainage Authority: Local unit of government that acquires jurisdiction over the land in which public drainage systems pass over. This jurisdiction allows the drainage authority to access the land in which a public drainage system passes for maintenance, repairs, and improvements to that system. It also enables the drainage authority to assess costs through the county treasury for projects related to public drainage systems. A drainage authority is comprised of the county board, joint county board, or watershed district.

Drainage Capacity: Drainage capacity refers to the amount of water than can be stored in the landscape and effectively drained through a public drainage system. It often associates how much water can be drained and how fast that water can be drained from the landscape.

Drainage Coefficient: A method used to measure flow through system tiling and public drainage systems. It is defined as the depth of water (inches) that can be drained in a 24-hour (day) period.

Drainage Engineer: Licensed engineer who is responsible for designing efficient and cost effective drainage systems to adequately convey water from an agricultural landscape. The engineer provides surveys, studies, and reports on the drainage system and the associated findings with designs. The drainage engineer is often referred to as the appointed engineer or engineer.

Drainage Improvement: Improvement of an existing drainage system involves enlarging, extending, deepening, or straightening of the legally established drainage system. The work typically consists of widening, deepening, or enlarging an open ditch or installing a larger tile size in underground tiling systems.

Drainage Repair: Minor or major work on an existing drainage system to maintain the designed drainage capacity. The work typically consists of removing debris, weeds, or sediment deposits from open ditches or replacing portions of damaged tiles.

Final Engineering Report: A document prepared by the drainage engineer that incorporates survey, design, modeling, reviews by the drainage authority, landowners, and ditch viewers for any repairs or improvements to a system. It is the final document of the proposed project including costs, designs, viewers report. It is presented to the drainage authority for approval for construction.

Grassed Waterways: Vegetative channels through agricultural land which provides a means for concentrated flows to drain from the surface while minimizing soil erosion.

Groundwater Table: The depth below the ground surface in which the ground is completely saturated with water. Is this better?

Hypoxia: A condition where a body of water contains extremely low dissolved oxygen levels that cannot support aquatic life.

Hypoxic Water Body: A body of water containing extremely low dissolved oxygen levels that cannot support aquatic life. This condition is also referred to as a hypoxic condition or hypoxia.

Landowner: Any person that owns property connected to the drainage system. This includes farmers, residents, or road authorities that pay an assessment to the drainage system.

Minnesota Drainage Statute 103E: Legal statue in which Minnesota Public Drainage projects must follow the outlined process to work on drainage projects. This process involves the drainage authority, ditch viewers, affected landowners, and the drainage engineer.

New Drainage System: The creation of a public drainage system through use of either underground tile or open ditches to effectively drain the landscape. It also involves establishing legal boundaries of the system and affected landowners.

Nutrient Management: The process of applying and adequate amount of fertilizer to a cropped field taking into consideration soil type, infiltration rate, and application rate.

Open Ditch: In an agricultural setting, an open ditch is referred to as a man-made waterway that was dug to convey water effectively off the surrounding landscape. An open ditch is often referred to as a ditch, dredge, channel, or any variation of these. The majority of open ditches are part of a public drainage system.

Prairie Pothole: Depressional or shallow wetlands that are not connected by stream networks.

Petition: A formal and legal request by landowner(s) to act upon an issue in which the governing agent has authority over. In drainage law, a petition is most commonly a request by landowners to establish, repair, or improve a drainage system.

Preliminary Engineering Report (PER): A document prepared by the drainage engineer that incorporates survey, design and modeling for any repairs or improvements to a system. It is the first draft of the proposed project that is presented to the drainage authority.

Public Drainage System: Public drainage systems, often referred to as drainage systems, ditch systems, or systems, include underground tile and/or open ditches through which water is conveyed off the landscape and crosses over multiple parcels of land. The system is designed to manipulate the water table for agricultural production. The system is owned by the property owners of the land areas affected, but it is governed by the drainage authority, in accordance with Minnesota Statute 103E.

Public Water: Any waterway in which the Minnesota Department of Natural Resources has jurisdiction. These waters consist of lakes, rivers, streams, and wetlands.

Rate Control Weir: A structure that is designed to convey water while control flow rate and direction. Most rate control weirs are constructed with either concrete or steel and are placed in a waterway creating a vertical wall to effectively hold water behind it.

Re-determination of Benefits: The process in which ditch viewers assess the land value involved in a public drainage system. This process is ordered by the drainage authority when a petition for drainage improvements is submitted. The total benefits (increase in land value) that the system receives must exceed the total cost of the project.

Residue Management: A practice in which materials left from harvest including stems, leaves, stalks, and seed ponds are left on the land and are not fully turned over into the ground.

Riparian Vegetation: A mix of grasses, forbs, sedges, and trees that serve as an intermediate zone between upland and aquatic environments. Riparian vegetation is typically planted in the banks of an open ditch or waterway, or on upper portions of buffer strips.

Saturated Buffer: An area in which water from a tile line is released below the surface through an area of perennial vegetation such as a buffer strip or riparian vegetation.

Separable Maintenance: The cost to fully repair the entire drainage system to the currently designed size and grade. In drainage law, separable maintenance can be subtracted from the improvement cost when comparing costs and benefits in the existing system can be proven to be out of repair. A system is out of repair if drainage repairs would not fully fix damages to the system.

Soil and Water Conservation District: SWCDs are political subdivisions of the State established under Minnesota Statute 103C. Each SWCD is governed by a board of elected supervisors to provide land and water conservation services to owners of private lands.

Sponge: The soil is sometimes referred to as a sponge, as it absorbs and stores water in each individual soil particle. The sponge is affected by the soil type and if it contains artificial drainage. Artificial drainages lowers the water table in the soil which allows for a large sponge to absorb more water.

Storage: Designated areas for water to temporarily pond, reducing peak flow rates, flooding and increase capacity to a drainage system.

Surge Basin: An excavated area designed to store large volumes of water during a rain event and slowly release that water through an outlet such as a culvert, tile, or rate control weir.

System Tiling: System or pattern tiling is a method to increase the drainage to private farmland to make the farming more practical, economical, and productive. This typically involves installing private tiling throughout an agricultural field with 4-8 inch perforated tiles which outlet into a public drainage system.

Tile: An underground pipe with holes or perforations that allow groundwater to drain. Tiles are typically installed on private lands by the landowner and range between 3 and 12 inches in diameter.

Toe-wood Sod Mats: A method of river or streambank stabilization and erosion control that utilizes woody debris such as tree branches, logs, or limbs. The wood debris is placed in areas that experience erosion and are covered topsoil, sod, and shrubs.

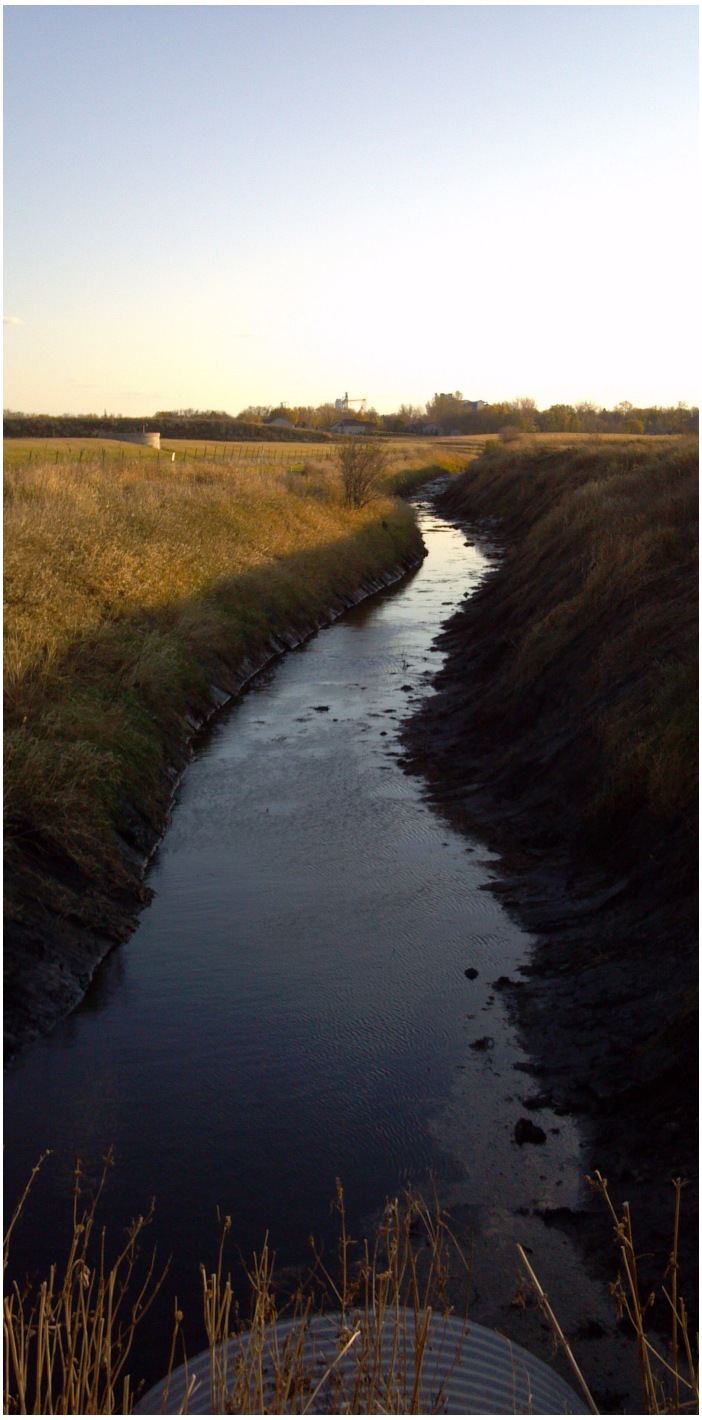
Two-Stage Ditch: A two-stage ditch is a low flow channel inside a high flow channel. The low flow channel is small and carries the perennial baseflows while the outer channel serves as the floodplain for high flows.

Viewers Report: A document prepared by the ditch viewers that assess the current land value and the re-determined value involved in a public drainage system. It is included in the Final Engineering Report and compares the cost of the proposed project and the benefits to the system.

Water and Sediment Control Basin (WASCOB): An earthen embankment installed perpendicular to the surface flow of water on a hillside, creating a linear pond area to temporally store water.

Watershed: A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place.

Waterway: Waterways refer to either an open ditch, stream, river, or other channel that conveys water.

Wetland Restoration: The reestablishment of natural hydrology and/or vegetative to a former wetland basin that has either been drained, farmed, or modified beyond its original state.

Woodchip Bioreactor: An excavated, underground trench filled with woodchips in which water from a tile is directed into the trench for nutrient removal.