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RED RIVER SUBWATERSHED PLAN

SCOPING REPORT FOR THE NORTH DAKOTA PILOT

A large-scale demonstration of the benefits of comprehensive water planning

SUMMARY: NORTH DAKOTA RED RIVER SUBWATERSHED PLANNING PILOT

This proposal provides the framework for development of a subwatershed plan designed to serve as a model for subwatershed planning in the Red River Valley, an area periodically ravaged by devastating floods and threatened by increasing concentrations of nutrients and sediment in its waterways.

A collaborative planning effort incorporates objectives and missions of ag producers, local entities, ag suppliers, researchers, conservation agencies, and ag commodity groups into a comprehensive areawide plan equipped for speedy implementation.

The Red River Basin Commission (RRBC), a multi-jurisdictional, International Non-profit organization, will coordinate and facilitate the planning process of the project contributors. The effort formally began in September of 2018 with the completion of a final scoping report in the late fall of 2019. Collaborators have contributed financial and technical assistance to watershed landowners during this period to test the plan's applicability to its clients.

There are multiple phases to the Red River Sub-Watershed Plan listed below. This report represents the conclusion of Phase 1: Planning and Scoping.

1. Planning and Scoping
    a. Identification of Sub-watershed
    b. Engineering evaluation of surface drainage
    c. Evaluation of existing subsurface drains and planning for installation of controls and new drains
    d. Integration of stakeholder objectives
    e. Outreach to Landowners
    f. Development of research objectives
2. Implementation of Pilot
    a. Modification and integration of surface drains
    b. Modification and integration of control in existing subsurface drains
    c. Installation of new subsurface drains
3. Evaluation of results recommendations for expansion to other watersheds

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ACKNOWLEDGEMENTS

Landowners – Of course there can be no project without these people, many took time out of their busy lives to participate in public meetings and some offered additional time to ensure appropriate producer perspectives were included in the concepts of the proposal.

Natural Resources Conservation Service (ND) – the NRCS has been an invaluable partner from funding the scoping to providing expertise and access to some their network of stakeholders.

All Cass County Water Resource Districts -The Cass County Joint WRD district has been a committed partner in the efforts thus far to include funding for Engineering support as well as having significant participation in working groups as well as public outreach. The Rush River WRD has been even more actively involved in the same efforts.

Red River Retention Authority – The retention aspects of this proposal are more challenging to quantify but the advice and participation of the RRRA has been invaluable in expanding the concepts and formulation of research concepts.

Moore Engineering – Chad Engels and Kurt Lysne have been great partners and very responsive to needs ensuring graphics and big picture engineering requirements are embed in the plan.

Ellingson Water Management – in considering a project of this scale it has been critical to have the insights and relationships of the company behind the idea. The donation of time for two executive level employees has be exceptional.

NDSU and Extension – The RRBC has great access to stakeholders but having a plan in place to truly capture the outcomes of the proposed project could not have been accomplished without the continued engagement of these two team members.

ND Department of Environmental Quality – The ND DEQ has been a valued partner in analysis of the water quality in the area, the steady and reasoned approach to stakeholder definition of solutions is a cornerstone of the organizational culture that has enabled important considerations of the project.

ND Soybean Council – The Council has demonstrated great foresight in funding the continuation of the water quality baseline study for a second year. We look forward to working with them in communicating the hard work of producers to maintain high productivity and conserve or precious natural resources.

INTRODUCTION

The Project: **North Dakota Red River Subwatershed Planning Pilot**, will be administered by the Red River Basin Commission (RRBC). The RRBC is a regionally recognized leader in water issues for the entire basin from South Dakota, through North Dakota and Minnesota and into Manitoba. Through extensive basin-wide dialogue and consultation with citizens, land users, organizations, and governments, the RRBC developed the Natural Resources Framework Plan (NRFP). The NRFP was designed as a tool for moving the Basin forward in achieving common goals for water protection and management within the Basin.

The NRFP contains 13 goals. The first four focus on encouraging communication, research, and coordination across political jurisdictional boundaries. The remaining nine focus on improvements in water quality; water supply; flood damage reduction; drainage; conservation; and fish, wildlife, and outdoor recreation. The RRBC believes that if basin residents work together in dealing with land and water management challenges, we can maintain and improve the quality of life for present and future generations in the Red River Basin.

The Project enabled collaborators to expedite planning efforts for comprehensive natural resource planning in a subwatershed that contributes runoff towards peak Red River floods. Flood reduction will be realized by timely management of water holding capacity of the watershed soil profile and drainage water management on subsurface drainage systems.

This facilitated planning effort incorporates objectives and missions of ag producers, local entities, ag suppliers, researchers, conservation agencies, and ag commodity groups into a comprehensive areawide plan equipped for speedy implementation.

Subwatershed selection will be based on the effectiveness in providing flood protection to the mainstream of the Red River and the readiness of agricultural producers to implement conservation measures, and finally to determine the feasibility of management of nutrient reduction in the waters of the basin. The plan will prescribe conservation measures consistent with the landform and producer cropping practices. As a sub-watershed was identified and analyzed the following conservation measures were integrated into the planning as appropriate. The various stretches of the watershed are subject to a variety of conservation practices including residue management, cover crops, water and sediment control structures, permanent vegetation, salinity management, and wetland restoration, drainage water management, nutrient management, and integration of surface and subsurface drainage.

The project will realize the following benefits to the Red River Valley community: reduced downstream flooding, improved water quality, increased crop production, enhanced soil health, lower Federal crop insurance claims, lower future Federal Emergency Management claims, reproducible planning and implementation in other subwatersheds of the Red River Valley. In addition, the advent of the subwatershed plan will pave the way to realize full implementation as funding opportunities surface.

NEEDS ASSESSMENT

During the last two to three decades, agricultural producers in the Red River Basin have experienced unprecedented precipitation and elevated groundwater owing to excessive soil moisture, overland flooding, and out-of-bank flows. This phenomenon has affected agricultural production, as the water table reaches the root zone, increasing saline induced soils and causing crop loss.

Runoff from land surfaces occurs generally during spring snow melt across frozen ground, or during excessive rain events. During these times, soil profiles are often saturated and therefore do not provide sufficient storage and infiltration capacity. The resulting runoff event contributes towards downstream flooding. In addition, overland runoff has caused deteriorating water quality conditions in streams and rivers as dissolved solids become mobile in the watershed.

The implementation of well-planned water management and natural resource conservation measures will reduce soil saturation, enhance soil quality, and ready saturated soils for crop production the next growing season. Lands will have addition water retention capacity, thus reducing groundwater and overland water movement toward the main waterbodies.

The project will align agricultural producers with technical and financial assistance in addressing excess runoff and flooding, soil health, soil compaction, proper nutrient management, and improved plant and crop production.

PROGRAM OBJECTIVES

There are three key objectives that have been achieved through the scoping of the project

1) Integrated drainage planning- the development of a full understanding of water transport across and entire sub watershed enables development of flood damage reduction opportunities through short term retention on the surface and within the soil profile.

2) Nutrient management - the employment of reduced-till practices, cover crops, split application profiles, and other management practices that could include, but are not limited to, remote monitored lift stations and/or drainage control structures, bioreactors in the drains, or filter strips.

3) Development of research options – long term research projects have been formulated to more effectively understand what the result is of greater than field scale adoption of subsurface water management systems. Ample research has been conducted at the field level but scaling to the sub-watershed level is problematic since there are not currently implemented drainage plans at that level.

METHODS

The collaborating project partners have selected a Red River subwatershed to pilot the concept. The subwatershed was selected based on flood control needs and opportunities, soil conduciveness towards subsurface drainage, and agricultural producer's readiness for participation.

Project sponsors developed needs assessment based on the natural resources of the subwatershed. Hydraulic analysis and flood models will be developed as part of the implementation and balanced with producer practices to determine applicable conservation practice implementation in the watershed. The resource assessment for implementation was be divided into three regions based on the impact it has to water quality and quantity of flows into the mainstem of the Red River.

Regions of the subwatershed that were to be considered were:

- Upper watershed. This is a region of diverse landuse. Conservation measures in this landform will concentrate on enhancing water quality, water management and retention, and natural resource sustainability. Practices likely would have included vegetation establishment, cover crops, residue and nutrient management.
- Mid-Watershed. This region's landuse in nearly all cropland. The landscape includes areas subject to wind/water erosion. Subsurface drainage is primarily water management. Conservation practices will include residue, nutrient, salinity, irrigation, and drainage water management; filter strips; cover crops; subsurface drainage, water control structures; and etc.. This region may harbor water retention locations for overall reduced flow to the Red River and wetland compliance mitigation.
- Lower Watershed. This region the floodplain of the Red River. It consists of highly productive cropland that is susceptible to flooding, salinity from perched water tables, and excess tillage operations to evaporate spring soil moisture and increase soil temperature. Practices will include subsurface drainage and compatible management practices of residue, nutrient, salinity and drainage water management.

This strategic land management plan will allow the project area to realize reduced runoff to the Red River, increased soil health, proper nutrient management, and sustained natural resource and economic viability and reduced reliability on USDA safety nets for ag production and crop insurance.

The collaborative planning effort was facilitated by the RRBC with input by ag industry, engineering firms, ag commodity leaders, NRCS, water resource boards, soil conservation districts, county and township commissioners, and local constituents. The plan includes financial and technical assistance needs for implementation. Collaborators have identified potential contributors to implementation of the project and continue to seek other partnerships.

Community outreach will continue following the completion of the plan in order to communicate opportunities for implementation. It is anticipated that the plan will lead toward local, commodity group and corporate contributors. Consultation with multiple entities and agencies is ongoing to seek funding and agreements to help chart a course for adoption of conservation practices at l low cost in time and resources for producers. success. More comprehensive implementation may be sought through the Regional Conservation Partnership Program (RCPP).

FINALIZE STUDY GEOGRAPHIC AREA

Identification of a subwatershed posed multiple challenges. Existing drains and both surface and subsurface were considered as well as known water quality concerns. With the partnership of the Cass County Joint WRD the search was limited to subwatersheds within the county. Additionally, there is significant uncertainty for the future as final plans for the Fargo Moorhead Diversion are being developed. A short review of the proposed footprint for that projects allowed the team to focus in on the northern portions of the county. A after refined analysis the initial results suggest that the 16,600 acre subwatershed of the Rush River that drains into Cass County Drain 13 before flowing into the Red River was likely the best candidate subwatershed. A depiction of the final proposed study area is included below as Figure 1: Proposed Pilot Project Location.

There are six key reasons that this drainage area was selected:

- There is a more robust legal drain system that will not require extensive upgrades to accommodate flows from subsurface drainage.
- The four parallel drains that flow into drain 13 provide opportunities for enhanced long-term research of different water quality management practices simultaneously with varied treatments and control groups to have better determination of significance in the results.
- In consideration of prevailing weather patterns, the narrow north-south cross sections of the four drains will indicate similar weather patterns across the distinct practice areas, further reinforcing the various impacts of the management practices.
- There were very few parcels in the area that already have subsurface water management systems.
- Upon engagement it was not a significant challenge to achieve 50% landowner support for the concept. From a research perspective that 50% mark is required to ensure that changes are statistically significant.
- Location near NDSU and Fargo facilitates research as well as potential future outreach and education activities in the project area.

This drainage area does present a few difficulties worth noting; however, they can be mitigated through other aspects of the proposal or during implementation.

1. The preferred subwatershed would include areas representing the Upper watershed, Mid-Watershed, and Lower Watershed for maximum research

potential. In nearly all of the Red River Basin this is not possible without expanding the acreage of the project area to the point that it would not be feasible to finance the project due to topography.

2. The cropping patterns are uniform throughout the subwatershed with almost all the cultivation being wheat, corn, and soybeans. Some of the other crops that are prevalent in the basin may require different practices than will be employed in the pilot.
3. Drain 13 has been upgraded and retrofitted in the recent past, however, it extends less than half a mile into the study area and drains the largest acreage in the of the four drains. While this may lead to increase costs for improvement of that drain, this combination of drains will require the least improvement of all the subwatersheds that were considered.
4. Many of the watersheds in Cass County encounter significant overland flooding that can move across the watershed boundaries. This drainage area has significantly less likelihood of that occurring in the absence of exceptional circumstance based on topography and existing infrastructure.

While known water quality issues was a consideration in selection of a proposed location, it was not a determining factor. Very little water quality monitoring has been done on Legal Drainage Systems anywhere in Cass County. The Water Quality Baseline Study initiated in this scoping effort appears to be a first of its kind regionally.

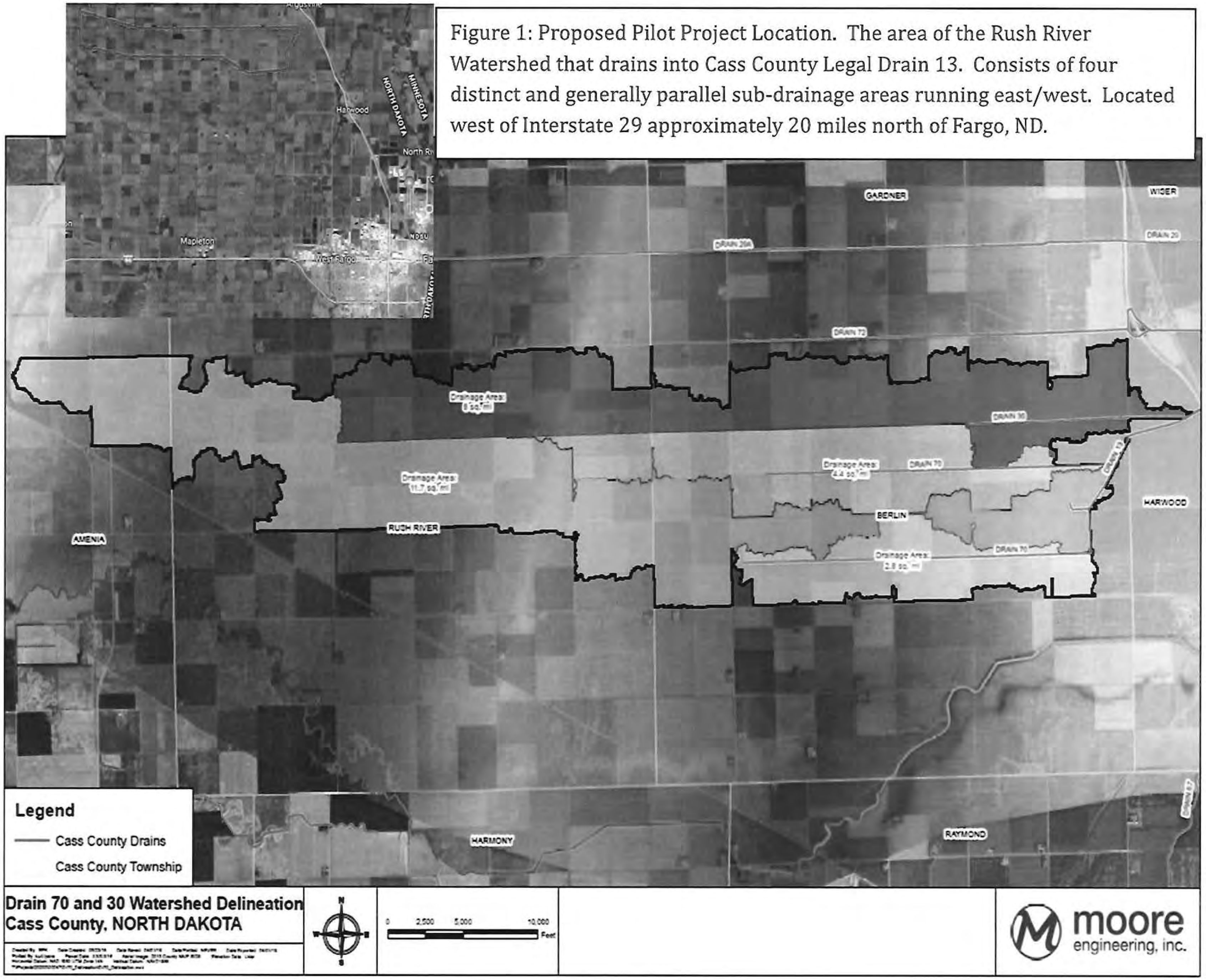


Figure 1: Proposed Pilot Project Location. The area of the Rush River Watershed that drains into Cass County Legal Drain 13. Consists of four distinct and generally parallel sub-drainage areas running east/west. Located west of Interstate 29 approximately 20 miles north of Fargo, ND.

EXISTING DRAIN RECONNAISSANCE

Drainage infrastructure as mentioned above is fairly robust in the subwatershed of the Rush River. Of the four legal drains that enter Cass county Legal Drain 13 three (drains 70North, 70 South and 30) all have sufficient capacity to accept the drainage water for their entire drainage area.

Cass county legal drain 13 is not as well developed in the proposed study area. Much of the drainage area travels through swales and road ditches. The solution for this drainage area will require significant engineering consultation and design work once the final landowner input is made for management practices during the implementation phase. Solutions have been discussed that involve lengthening drain 13 which is currently extends less than a ½ mile into eastern end the proposed study area. The proposed project area has a drainage that extends approximately 8 miles in the east west direction. This solution is less popular with landowners as it would remove acres from production. An alternate solution would be some enhanced form of buried drain in the existing ditches. This could be a 36 inch buried pipe; however the cost to conduct detailed engineering work on this is beyond the funding ability of the scoping project and will have to be included in implementation funding.

One additional complication that may have to be addressed is the assessment district for Drain 70 south. The landowners in the area voted on an assessment for themselves to upgrade the drain several years ago. If any portion of the project would add additional water to that drain, the landowners have expressed that they may wish to receive some compensation for that additional water. At this point it is not anticipated that any additional water would be directed to drain 70 South, however, on conducting more detailed engineering work for Drain 13 it may be considered as a possibility and that assessment would have to be taken into consideration.

EXISTING TILE SURVEY

The survey has been completed. There are only 6 small parcels in the study area that have been tiled. This contributed to the selection of this subwatershed as there will be more demonstrable and quantifiable change in an area with limited tile. Four of the six parcels are on pumping systems and two system is gravity fed. Those parcels are depicted in black on Figure 2: Landowner Participation Analysis.

The one significant concern these parcels present is how to integrate them into research efforts moving forward. There are several programs that would offset the cost of upgrading to controlled drainage for the gravity systems. Any effort to gather research data on those parcels will have to address alternate compensation for the existing tile.

NDSU – RESEARCH METHODOLOGY

As the scoping of the project was initiated, there were two primary tasks in developing the research methodology.

- Identification of short medium and longer term actions that will be proposed for understanding of nutrient and water management in project area.
- Primary areas of focus for research in general priority are: 1. Water Quality 2. Water quantity management 3. Better field management practices

Dr Christina Hargiss from the NDSU Natural Resources Management Program was consulted as the topics would need a multi-disciplinary approach. Much of her current research is on Water Quality in Urban infrastructure. She was able to rapidly identify that these two topics are too broad for an initial look at the pilot project. Establishing an understanding of current hydrology in the drainage area as well as a basic understanding of water quality in the legal drainage systems would be imperative. In consultation with the working group the Water Quality Baseline Study was initiated as described in the next section.

Once a general understand of this issues was addressed Dr Hargiss recommended adding key researchers from Agriculture and BioSciences Engineering to consult on hydrology and larger scale social and economic impacts and a researcher from Soil Science to advise on soil physiology.

Dr. Aaron Daigh from Soil Sciences and Dr. Zhulu Lin from Agriculture and Biosystems Engineering were added to the team to generate a concept for long term research on what changes result from adoption of water and nutrient management practices at the subwatershed scale. Their comprehensive multidisciplinary research concept is outlined in the appendices under "Research Plan".

WATER QUALITY BASELINING

As mentioned in the finalize geographic study area section above; project developers intended to identify a sub-watershed with a known water quality challenge. At this scale very little work has been conducted to identify water quality issues. As a result, the Water Quality Baseline study was taken up as a key factor in developing a research methodology that would have good mathematical findings after changes were initiated in the watershed.

Many members of the working group had concerns that significant spring overland flooding in the proposed project area as well as the unusual precipitation patterns this summer unusually wet year could skew the results of the study. As a result, the RRBC presented the concept to the ND Soybean council and requested that they fund a second year of the study. At their Board Meeting on the fifth of September 2019, they agreed to do so. This second year of data will both improve the understanding flows and nutrient loading in varying flow conditions.

Water quality baselining is under way. NDSU Natural Resource Management Program (NRM) has a graduate student using automated sampling on the four individual drains as well as the consolidated drain 31 to identify current conditions. The highlights of the study are:

Evaluation of current water quality conditions in a headwater watershed of the Red River Watershed that currently is not dominated by tile drainage. This information provides an accurate baseline for further studies to determine changes in water quality once tile is implemented and to determine how conservation measures may or may not have an impact on those changes. It also provides a new approach to tile studies, as to our knowledge no study has captured a before/after comparison at a watershed scale. The specific objectives of this study are as follows:

1.) Analyze P, N, and TSS contributions from the sub-watershed that contribute to the Red River during different spring runoff and different types of precipitation events.

2.) Assess velocity and flow of water coming from each drain in the sub-watershed during spring runoff and precipitation events to determine how sub-watershed contributes to Red River

A full text description of the Water Quality baseline study is available in the appendices. Initial data from the study is also included in the appendices. The North Dakota State lab is still analyzing water samples from the summer of 2019. A full report will be published once that analysis is completed.

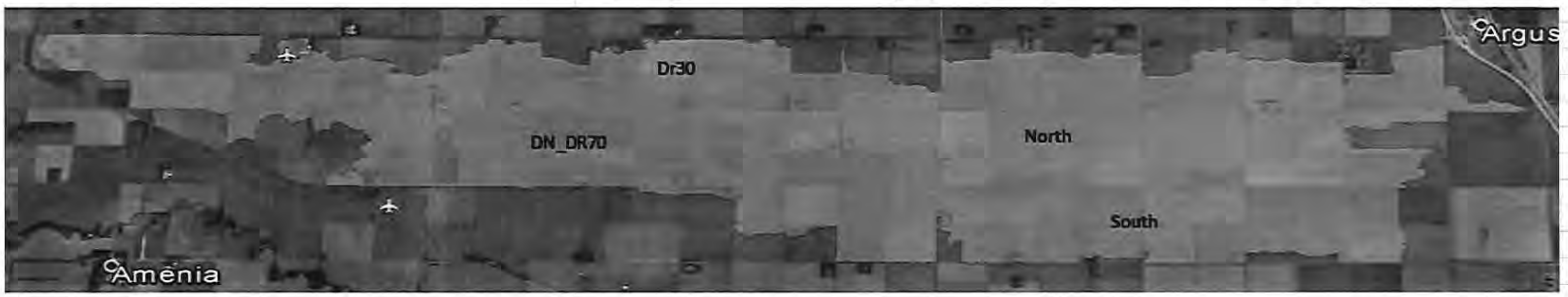
GENERALIZED ECONOMIC BENEFIT ANALYSIS

At the scale of producers, Table 1 Generalized Economic Benefit Analysis outlines that simple conversion in the proposed study area to Sub-Surface water based on broad area soil types and county crop averages will realize an increase in productivity of more than one million dollars annually. The added benefit to peripheral businesses from increased economic activity, increased land value with drainage improvements and increase in tax revenues from increased productivity are also more challenging to asses.

There are a series of indirect benefits to the producers that do not lend themselves to a generalized analysis. Many of these benefits are projected to be included in the social and economic elements of the long-term research concept. Some of those benefits are reduced fuel cost and CO_2 emissions from better drained fields, reduced input costs for nutrients that are retained on the landscape, reduced crop losses to excess water during precipitation events and higher organic content of the soil based on reduced tillage.

Table 1: General Economic Benefit analysis. Using county crop averages the expected yield increases by soil type, revenue increases by $1.4Million/year

					Crop	DM Yield increases (%)			Crop Acres		
Map Code	Map Unit	Acres	Drainage Class	CPI	Coverage (%)	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat
I371A	Bearden-Kindred silty clay loams, 0 to 2 percent slopes	3569.1	Somewhat poorly drained	91	92.5%	21.8	16.5	18.5	551.2	2263.3	487.1
I473A	Hegne-Fargo silty clay loams, 0 to 1 percent slopes	2609.4	Poorly drained	87	95.4%	24.5	18.7	20.7	1101.4	1289.8	98.4
I490A	Glyndon-Tiffany silt loams, 0 to 2 percent slopes	2583.1	Somewhat poorly drained	89	92.3%	35.1	15.4	17.1	495.6	1803.1	85.9
I229A	Fargo silty clay, 0 to 1 percent slopes	1678.8	Poorly drained	86	90.4%	37.3	18.9	21.0	184.1	1305.7	27.0
I373A	Kindred-Bearden silty clay loams, 0 to 2 percent slopes	1636.5	Somewhat poorly drained	92	89.6%	21.9	16.6	18.6	438.6	992.3	34.8
I238A	Fargo-Hegne silty clays, 0 to 1 percent slopes	1506.4	Poorly drained	84	79.5%	37.3	18.9	21.0	561.9	577.4	58.6
I469A	Fargo silty clay, moderately saline, 0 to 1 percent slopes	1002.3	Poorly drained	52	90.1%	23.6	18.3	20.3	333.9	560.8	8.2
I492A	Bearden-Lindaas silty clay loams, 0 to 2 percent slopes	689.6	Somewhat poorly drained	92	94.7%	22.2	16.5	18.5	18.9	488.0	146.1
I235A	Fargo silty clay, depressional, 0 to 1 percent slopes	386.2	Poorly drained	86	86.8%	37.3	19.1	21.0	71.0	263.2	1.1
I491A	Galchutt-Fargo silty clay loams, 0 to 2 percent slopes	355.4	Somewhat poorly drained	91	92.7%	21.8	16.8	18.9	220.8	108.6	0.0
I211A	Wyndmere loam, 0 to 2 percent slopes	283.2	Somewhat poorly drained	76	88.7%	24.6	9.3	21.1	8.0	155.3	87.9
I244A	Galchutt silt loam, 0 to 2 percent slopes	228	Somewhat poorly drained	89	94.3%	21.3	15.4	17.5	31.8	183.2	0.0
I233A	Fargo silty clay loam, 0 to 1 percent slopes	220.6	Poorly drained	94	90.1%	35.1	15.4	17.1	160.3	38.6	0.0
I202A	Gardena silt loam, 0 to 2 percent slopes	183.2	Moderately well drained	95	98.4%	24.5	18.7	20.7	0.0	180.3	0.0
I119A	Bearden silty clay loam, 0 to 2 percent slopes	124	Somewhat poorly drained	90	98.0%	21.9	16.6	18.6	41.6	80.0	0.0
I376A	Colvin silty clay loam, 0 to 1 percent slopes	74.7	Poorly drained	68	99.9%	21.9	16.6	18.6	44.7	21.7	8.3
I231A	Dovray silty clay, 0 to 1 percent slopes	30.2	Very poorly drained	64	86.6%	37.3	18.9	21.0	0.3	25.8	0.0
I472A	Perella silty clay loam, 0 to 1 percent slopes	21.6	Poorly drained	88	95.2%	21.9	16.6	18.6	15.1	5.4	0.0
I241A	Fargo-Ryan, thick solum silty clays, 0 to 1 percents slopes	1.2	Poorly drained	78	25.9%	37.3	18.9	21.0	0.0	0.3	0.0
		17,183.50		86	91.2%	27.8	17.2	19.3	4279.29	10342.77	1043.43



Base Yield		Price	Units
Corn	183.5	3.38	bu/ac
Soybeans	43.7	7.86	bu/ac
Wheat	58.4	4.8	bu/ac

	Undrained Revenue	Drained Revenue	Difference
DN_DR70	$ 2,819,385.42	$ 3,416,385.61	$ 597,000.19
Dr30	$ 1,893,533.42	$ 2,290,900.41	$ 397,366.99
North	$ 1,491,153.36	$ 1,737,454.58	$ 246,301.22
South	$ 1,040,218.84	$ 1,201,846.65	$ 161,627.81
Total	$ 7,244,291.04	$ 8,646,587.24	$ 1,402,296.21

SOIL SURVEY

The detailed soil surveys are no longer required for scoping of the proposed pilot. There are only a few minor variations in soil type across the landscape in this area. Individual soil analysis has been deferred to phase two of the project and will be important as landowners choose to have subsurface drainage installed.

The following six soil types account for over 14,000 acres in the proposed project area which is greater than 85%. Descriptions are from the USDA Official Soil Series Descriptions at https://soilseries.sc.egov.usda.gov/

Bearden-Kindred silty clay loams (approximately 5100 acres)

- The Bearden series consists of very deep, somewhat poorly drained, moderately to slowly permeable soils that formed in calcareous silt loam and silty clay loam lacustrine sediments. These soils are on glacial lake plains and have slopes of 0 to 3 percent. Mean annual air temperature is 39 degrees F, and mean annual precipitation is 18 inches.
- The Kindred series consists of very deep, somewhat poorly drained soils that formed in lacustrine sediments. Saturated hydraulic conductivity is moderate or moderately slow. These soils are on low flats and concave swales on glacial lake plains. Slopes range from 0 to 2 percent. Mean annual air temperature is 40 degrees F, and mean annual precipitation is 19 inches.

Hegne-Fargo silty clay loams (approximately 6700 acres)

- The Hegne series consists of very deep, poorly drained soils that formed in clayey calcareous lacustrine sediments on glacial lake plains. These soils have slow or very slow permeability. They have slopes of 0 to 2 percent. Mean annual precipitation is about 20 inches. Mean annual air temperature is about 42 degrees F.
- The Fargo series consists of very deep, poorly drained and very poorly drained, slowly permeable soils that formed in calcareous, clayey lacustrine sediments. These soils are on glacial lake plains, floodplains, and gently sloping side slopes of streams within glacial lake plains. Slopes range from 0 to 2 percent. Mean annual air temperature is about 5 degrees C, and mean annual precipitation is about 575 millimeters.

Glyndon-Tiffany silt loams (approximately 2600 acres)

- The Tiffany series consists of very deep, poorly drained soils that formed in glacial outwash. These soils have moderately high or high saturated hydraulic conductivity.

These soils are in depressions and on glaciolacustrine deltas and outwash plains. Slope ranges from 0 to 1 percent. Mean annual air temperature is 39 degrees F, and mean annual precipitation is 19 inches.

- The Glyndon series consists of very deep, somewhat poorly drained soils that formed in silty glacial lacustrine sediments and delta sediments on glacial lake plains. They have moderate permeability in the upper part and moderately rapid permeability in the lower part. They have slopes of 0 to 3 percent. Mean annual precipitation is about 20 inches. Mean annual air temperature is about 40 degrees F.

IDENTIFY CURRENT PRACTITIONERS

Several practitioners have been included in the working group and are informing the discussion of management practices to be recommended for producers. NDSU extension has been an active member of the working group and generally accepts that landowners and producers must be involved in recommending practices based on their cropping plans and other field scale choices.

These two pictures were taken from the same spot at the proposed study area in late October 2019. On the left, north of the road, is a tiled field that has been harvested and minimally tilled. On the right, facing south, an untilled field with water still standing between the rows of unharvested soybeans.

Three significant venues for engagement on practices were included in formulating the research concepts.

1. Feedback from the Discovery Farms projects in Minnesota
2. The 2019 NCERA 217- Agricultural Drainage Management Systems (ADMS) Task Force Annual Meeting in Moorhead on June 5-6 2019

3. The North Dakota Department of Environmental Quality led Cold Climate BMP workshop at the University of Minnesota Crookston Campus in on April 15-17, 2019. A technical report is due to be released in November of 2019 and will be consulted as implementation of the Pilot is considered.

Several landowners volunteered to join a working group that would look at proposed practices and determine what practices make sense for the soil and topography as well as the cropping patterns of local producers. A contract will be drafted by this group to outline what owners agree to try based on receiving cost share for tile installation.

TILE SPECIFICATIONS

While Ellingson Water Management company has actively participated on the scoping of this project, it has been acknowledged throughout he process, that landowners are welcome to employ any company they choose to install sub-surface water management systems. As part of the agreement to participate in the project and be eligible for cost share for those systems the following minimum standards are expected to be included in the design.

Minimum Standards for Installation

In our extensive analysis of the study area we have determined that the project should be designed and installed using a 3/8" drainage coefficient.

Drainage coefficient is defined as the capacity of a drainage system expressed as a depth of water removed in 24 hours(inches/day). The chosen drainage coefficient should economically remove excess water from the soil profile within 24 to 28 hours to minimize the yield impact of excess moisture. The chosen drainage coefficient is then used as an input in the Hooghhoudt formula to determine proper spacing and depth of the drainage laterals as well as proper sizing of the main lines.

To determine the drainage coefficient Ellingson performed a drainage assessment of the study area. Historical analysis of crop production and weather patterns along with detailed soil analysis and current market conditions is used to determine the drainage coefficient that provides the best economic benefit for the landowners. The goal is to maximize the yield potential of each farm while providing a positive return on investment. Our extensive history of installation and the subsequent results has confirmed the recommendation of the 3/8" coefficient.

Additionally in coordination with recognized best management practices across Agencies and researchers, water level control structures or other methods of controlling the drainage be installed with very few exceptions. Having the ability to manage the water table provides multiple benefits. Managed systems will have the ability to conserve water and also reduce nutrient loss. Location of these controls will be determined during the design process and a water management plan should be completed for each drainage system that is controlled.

LANDOWNER ENGAGEMENT

Landowner Engagement was the most deliberate element of the scoping. The timing of the engagement was critical in that there had to be enough of the concept to share with the landowners and not waste their time. However: it could not wait to give the perception that we had planned without them to make changes on their property. As such once the prospective watershed was identified and initial working group planning factors identified an active information plan was initiated.

Mailings went out to all landowners to provide general information. While those mailings did not generate significant comment there were a few landowners who stated they were "not interested" in any way. No additional outreach was made to those few landowners. Everyone else was sent a second mailing to announce the Public Meetings that were to be held on the Second and fourth of April at the Harwood Community Center in Harwood, ND. At those wo meetings the same information was presented to both and a variety of questions were answered. 32 different landowners out of 64 attended one of the two meetings, attendees' names are listed in the Appendix. Generally speaking, those meetings yielded favorable results.

After the public Meetings a third mailing was send with a return postage paid feedback postcard with the check boxes shown below for all people who attended the public meetings.

- ❑ I think the idea has merit, please let me know when you have secured funding to move forward to the implementation phase
- ❑ I 'm not interested in the project, do not contact me again.
- ❑ I like the idea and would like to discuss being involved in planning for implementation.

For landowners who were not in attendance at either meeting the feedback card had the following options

- ☐ I have discussed it with people who were at the meeting and am not interested, please do not contact me again.
- ☐ I would like more information about the proposal.
- ☐ Comments on the project or suggestions to improve the concept

If the card was returned with a positive response those landowners have been tracked as a "yes" response on all subsequent efforts. If it was a "No" the owners have been similarly tracked as not interested. All who have made telephonic contact have been placed in the maybe category as they generally did not state a "yes" or "no". After that effort to contact landowners the staff of the RRBC have made hundreds of phone calls and email attempts to contact landowners but roughly 28% of the landowners in the proposed study area have not responded to any of the attempted contacts.

A subsequent Landowner meeting was held on 14 August to share the status of the scoping project. Landowner were informed that Drains 30, 70 north and 70 South had reached the target 50% participation goal, but that outreach was still progressing for Drain 13. The landowners were able to assist in contacting several additional landowners which ultimately assisted in reaching a 50% participation threshold throughout the proposed pilot project study area.

ABSENTEE ENGAGEMENT

There are fourteen known landlords who rent their property to other producers. Four have stated they are not interested, and two have indicated they will participate. Two additional owners have indicated we should engage the renter which is underway. All those renters have been contacted and their interest in participation is included in the landowner analysis below.

LANDOWNER ANALYSIS

As of the close out of scoping efforts in September 2019, the owners/operators of 9,295 acres out of 16,600 production acres in the subwatershed have expressed interest in participation, if funding can be raised to offset their costs. There are approximately 2,700 acres that the owner has said "no, I will not be involved". There are still approximately 30% of the acres in which the owner has not responded to outreach. Carrying through the percentage that have said "yes" versus the percentage that have said "no" the working group is operating on the assumption that roughly 4,500 additional acres would participate if funds were available.

In Figure 2, on the next page, you can see the delineation of the four distinct drainage areas that correspond to the legal drains 30, 70 north, 13, and 70 south. The color coding on individual parcels indicate the owner/operator response to the proposal. Green stands for interested in participation, yellow indicates that level of cost offset would determine participation, red indicates they are opposed to participation at any level and black means that tile is already installed though conversion to controlled drainage is still a part of the proposal.

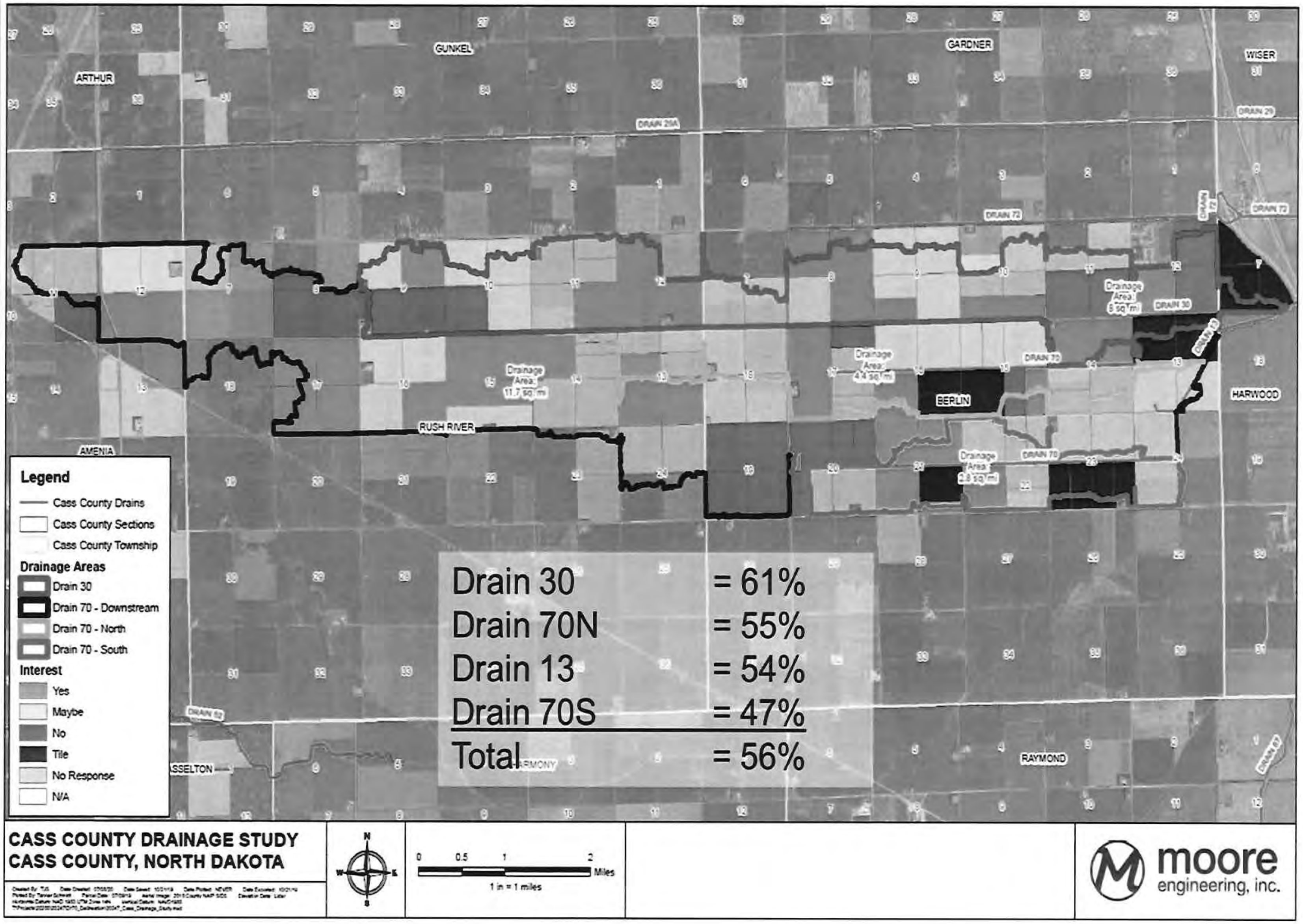
The working group and researchers have agreed that a threshold of 50% of the acres in and drainage area are required to be tiled in order to develop defensible results in research. With the current participation levels all four drains would meet that requirement. If one of the drains loses participation to the point of breaking the 50% threshold that drain would then be considered the control group for the research. In the event there are not negative changes in participation then Cass County Legal Drain 72 immediately north of the study are has been considered for use as a control group.

Two additional concerns have been addressed in detail that impact the privacy of the Landowners.

1. Wetland Delineation – A cursory review of the U.S. Department of Fish and Wildlife link below indicates that it is likely that there are a significant number of historical wetlands across the proposed study area. While many of those wereprobably addressed prior to the advent of the Food Security act of 1985 there will probably still be some in an area this large that will require a form AD-1026 process. Those records, however, are covered under privacy laws and it was outside the scoping process to secure appropriate privacy releases during this effort. https://www.fws.gov/wetlands/data/Mapper.html

2. Landowner production Data – The data that will be required to evaluate long term research is also covered by privacy laws. Landowners have been assured that no data will ever be released on an individual parcel to any organization outside of accredited researchers on the project. Aggregated results will be provided to organizations at the individual legal drain scale only (i.e. all of the parcels that contribute water to legal drain 70).

Figure 2: Landowner Participation Analysis. Percentages annotated include landowners who have agreed (green), are interested (yellow), or already have tile installed (black).



DEFINITION OF INSTRUMENTATION AND MONITORING REQUIREMENTS

There are several ways to address the instrumentation and monitoring requirements of transition to implementation for the Pilot project. The initial plan was to work with the USGS stream gauging office for a cooperative agreement, there several efforts ongoing to bring better more efficient gauging for volumes of flow as well as water quality monitoring to a variety of locations in the Red River Basin. Unfortunately, the programs can be costly. An initial communication from the USGS is included in the appendix that outlines the costs for water quality monitoring stations. With the design of the research project through NDSU these may be prohibitively expensive to monitor all five locations that are being sampled for the baseline study.

The alternative method is included in the research proposal from NDSU and included automates sampling equipment and then water quality analysis at another facility. This is the way the baseline study has been completed and since there is not an immediate need for real time information it may be more cost effective to plan to follow already established procedures.

PHASE II: IMPLEMENTATION INITIAL BUDGET

Table 2: General Budget Requirements to initiate Phase II: Implementation	
Total Production Acres	18446
Total Acres tiled and firm opposition to participation "no"	4161
Planning Acres	**14,285**
Project Funds = (Planning Acres X 50% x $1000/Acre)	$7,142,500
Infrastructure Improvement	$3,000,000
Research	$1,942,000
BMP implementation	$2,000,000
RRBC Project Management ($30,000/year)	$240,000
Total	**$14,324,500**

Installation of drain tile on someone's property is the most challenging and largest portion of the project proposal, but it also the most critical element as there are no benefits without it.

Infrastructure and engineering are a major element as well as one of the sub watersheds only has road ditches, a significant improvement will have to be made as well as some resizing of culverts throughout the watershed. There are some obvious partners and cost sharing opportunities at the County and State level for this work.

BMP Implementation naturally falls within the NRCS priorities and there are several different funding possibilities for this element.

Research, while very important, is one of the easier aspects of the project to fund as there are a wide variety of organizations that are interested in the potential outcomes of this project. **

Administration, Outreach, and Promotion is a small but crucial element of the overall project. The RRBC is a non-profit that is always working on these topics and has access to a diverse group of stakeholders, the greatest benefit of the project grows out of the possibilities for outreach and education from the findings of the research.

** As the concept for ongoing research has not been processed through the NDSU review boards it is not a proposal at this time.

FINANCING OPTIONS

Concepts have been mapped out in the working group and a financing sub-committee was established. Engagement at the ND capitol is being sought for July and corporate sponsors are being scheduled for August. The general concepts forwarded by the financing sub-committee are highlighted below.

Initial recommendations of Fundraising workgroup

Banks – In order for landowners to pay for the tile that is not covered in the project offset several local banks will be engaged to build a package of information for landowners. The Bank of North Dakota will use the AG Pace program to buy down interest. In general, the group suggested engagement of Bell Banks, Bremer Bank, and Choice Financial. Engagement is ongoing so that as landowner explore options there are financing option that are fully developed to minimize costs for the landowners.

NRCS – Finding options to have a broad funding of BMP implementation, most programs are relatively intensive at the landowner level. The RRBC attended the RCPP webinar on 26 September for proposals for the new RCPP funding package. The webinar seemed to suggest that this innovative concept would qualify with the caveat that funding commitments from all other contributors must be included in the application packet. This means that since fundraising has just started, the project cannot be submitted before the

December 3rd deadline. That is for funding under 2019 budgets and the webinar suggested that once all applications were processed through, a new announcement for 2020 funding would be made, with a goal of a June submission deadline.

Syngenta – Working group members are still working on connecting the RRBC (Ted) to the leadership in order to provide an overview of the project. This will be heavily focused on the research aspect. There is a strong possibility that successful engagement of the company would lead to other connections to subsidiary and partner corporations.

Department of Environmental Quality – The executive Director of the RRRA has offered that Federal 319 Funding could be applied to several aspects of the Water Quality Work. The DEQ is already involved in the analysis for the baseline WQ study and the RRBC has worked with the 319 program several times in the past. Will try to set a meeting in October.

Cass County Flood Tax – There are two distinct funding possibilities for this project. First, this project has definite applications to overland flooding in the area, some infrastructure improvements would certainly be eligible and the retention aspect of the storage in the spring could be a further opportunity for eligibility. Secondly. The retention of water on the landscape could reduce the peak at the Halstead Gauge which has a separate funding authority with the Tax committee. The RRBC Chair also sits on this committee and since the RRBC has already applied for funding on a different project it is not likely the committee would consider a request from the RRBC. Water Board members said they would start conversations with other county commissioners to see if there might be interest in the project.

State Water Commission – A cost share for elements of the project would likely qualify at some level. That discussion needs to be started at the ND Joint Water Resource District which the RRBC regularly participates in. Will have initial conversation at the October Meeting of the board.

Commodity Groups – The ND Soybean Council has funded the continuation of the Water Quality Baseline Study for an additional year. The group suggested a meeting with the Grain Growers association and provided contact information to several of the members, this is especially valuable as Cass County produces more beans and wheat than any other county in the state.

Crystal Sugar – The research board is always looking for ways to improve their processes and Kirsten Stibbe is on that board and is active in the Red River Valley Sugar Beet Growers Association. Initial contacts have been cordial however most people involved with sugar beets are consumed with the lift for the foreseeable future and Ms Stibbe said she would contact the RRBC once those concerns had been alleviated.

EPA funds – Adaptive management is of distinct interest to several elements of the EPA, RRBC will reach out to contacts to share the project concept and determine if there is any potential funding.

AG Implement companies - Connections to John Deere/RDO and others may be valuable any insights into the right folks to talk to are appreciated.

Governor – The RRBC is still trying to present to the Governor and will contact his Natural Resource Policy advisor to find opportunities. Securing an "endorsement" of the project from the governor could facilitate requests to the major funding foundations like Bush, Gates, and Bremmer. The Executive Director was also able to present to the ND Agriculture Commissioner and has asked Commissioner Goehring for a similar endorsement. RRBC will apply to those foundations in the coming months as applications windows open.

An initial sponsorship packet highlighting levels of contributions and benefits of being a sponsor has been drafted and will continue to be refined as contributors suggest efforts of interested.

EVALUATION

The project will be evaluated across three anticipated outcomes:

1) Integrated drainage planning

2) Nutrient management

3) Development of research options

The evaluation of benefits and potential in terms of all three areas will be included in the planning and scoping of phase of the project.

APPENDICES

Budget for Scoping

Expenditure Report

Listing of Contributors to the Scoping Effort

Water Quality Baseline Study and Preliminary Results

Research Plan

USGS Water Monitoring Cost Estimates

Landowners Who Participated in Public Meetings

Economic Analysis of Increased Productivity

BUDGET

The initial project budget for the scoping was submitted as listed in the table below.

		Estimate
I. Personnel		
RRBC project coordinator	2/5 FTE for the 12 months of the Project ($65000/yr)	$26,000
RRBC Outreach	1/4 FTE for final 6 months ($45,000/yr)	$5,625
II. Consultants & Contract Services		
NDSU	Develop research plan for integrated surface and subsurface drainage	$20,000
Ellingson Companies	Evaluation of existing subsurface drains and planning for installation of controls and new drains (does not include in kind contribution)	$25,000
III. Non-Personnel		
Travel/Mileage	RRBC integration activities (25,000 @ $.55) (12hotel and meals @ 150)	$15,550
Meeting spaces	RRBC integration activities (4 @ $250)	$1,000
Tour support	(2 tours@1500)	$3,000
Document services	RRBC integration activities (10,000 @ $.20)	$2,000
Meals and incidentals	RRBC integration activities	$2,500
III. Non-Federal contributions	Cass County Joint Water Resource District contribution through Moore Engineering	$20,000
Total costs		$120,675

EXPENDITURE REPORT

Expenditures on the scoping project are listed below. A more detailed report has been submitted to the Natural Resource Conservation office and is available as needed.

		Expenditures
I. Personnel		
RRBC project coordinator	2/5 FTE for the 12 mo. (Staff salary @$65,200/yr. plus Benefits)	$20,819.17
RRBC Outreach	1/4 FTE for final 6 months (Staff salary $47,800/yr. plus Benefits)	$2,612.62
II. Consultants & Contract Services		
NDSU	Develop research plan for integrated surface and subsurface drainage	$27,411
Ellingson Companies	Evaluation of existing subsurface drains and planning for installation of controls and new drains (does not include in kind contribution)	$40,000
III. Non-Personnel		
Travel/Mileage	RRBC integration activities (Approx. 4500 miles @ $.545) + (4 extended trips for 2 staff – include hotel and meals @ 150 plus) + (staff day trip meals to project sites)	$1,153.82
Meeting spaces	RRBC integration activities (4 @ $250)	$225
Tour support	(2 tours@1500)	$0
Document services	RRBC integration activities (10,000 @ $.20)	$941.70
Meeting Meals & Other Project Incidentals	RRBC integration activities	$552.68
III. Non-Federal contributions	RRJWD contribution through Moore Engineering	$20,000
Total costs		$113,715.99

LISTING OF CONTRIBUTORS TO THE SCOPING EFFORT

Ted Preister	Executive Director	Red River Basin Commission
Jake Gust	Manager	Rush River WRD
Jerry Melvin	Vice-Chairman	Maple River WRD
Wes Ecker	Chairman	North Cass WRD
William Hejl	Member	Rush River WRD
Keith Weston	Executive Director	Red River Retention Authority
Thomas Scherer	Ph.D. Agricultural Engineering	NDSU Extension
Christina Hargiss	Ph.D.	NDSU NRM
Chad Engels	Senior Project Manager	Moore Engineering
Kurt Lysne	Water Engineer	Moore Engineering
Derrek Ellingson	Sales	Ellingson Water Management
Levi Otis	Government Affairs	Ellingson Water Management
Rochelle Nustad	Hydrologist	U.S. Geological Survey

WATER QUALITY BASELINE STUDY AND PRELIMINARY RESULTS

NDSU NORTH DAKOTA STATE UNIVERSITY

By Zachary Anderson, candidate for Masters of Natural Resource Management, Dr. Christina Hargiss, Dr. Jack Norland

Literature Review

Tile drainage, otherwise known as subsurface drainage is utilized extensively in North American and Europe to lower the water table in soils that are seasonally or perpetually wet. This practice is necessary for water management in agricultural fields with naturally poorly drained soil; however, it contributes to water quality issues (Saadat et al., 2018). Tile drainage infrastructure includes privately owned perforated pipes installed in parallel configurations at a field scale. These pipes eventually discharge into ditches and streams (Ikenberry et al. 2014). These systems have significantly impacted watershed hydrology, nutrient fate and transport over the past 50 years (Blann et al., 2009; Christianson et al., 2016; King et al., 2014). Nitrogen (N) and Phosphorous (P) are the most common and troublesome nutrients brought on by these changes.

Aquatic ecosystems can be sensitive to anthropogenic additions of N and dissolved P, which are major contributors to the environmentally degrading processes of eutrophication and hypoxia (Nash et al., 2014). Phosphorus, which exists in aquatic environments as phosphate, organic P compounds, or sediment-bound P, is one of the primary contributors to harmful algal blooms in lakes (Davis et al., 2009; Downing et al., 2001) such as those observed in the western basin of Lake Erie and Lake Winnipeg. Nitrogen exports from headwater watersheds has been directly linked to the water quality conditions in downstream waters (Alexander et al., 2007). High profile cases such as the seasonal hypoxic zone in the Gulf of Mexico are linked to non-point source pollution in the Mississippi Basin.

It is well understood that tile drainage is one of the primary N loss pathways from agricultural fields (Amado et al., 2017; Goswami et al., 2009), because of this many studies exploring nutrient transport via tile drainage focus on N exports. Nitrogen is highly mobile in the soil surface, with much of that coming from fertilizer for crops. Plant uptake eliminates a percentage of N applied, leaving excess N to normal denitrification or nitrification processes. Denitrification is of particular interest as it is an anaerobic process normally caused by water logged soil. Tile drainage lowers the water table limiting what denitrification can take place. This residual N is soluble and moves into tile drains during precipitation events. Rainfall volume has shown to be correlated to N exports from tile systems, with large exports occurring during large events and vice versa, unless other factors favor N export during smaller events (David et al., 1997; Goswami et al., 2009; Mager et al., 2004). It has been observed that these exports can account for significant percentages of N loads for the given watershed. Williams et al. (2015) found that 14-100% ($\bar{x}$ = 29%) of NO4-N in the watershed originated from tile drainage. In a more recent study Amado et al., (2017), found that at least 50% of N load measured in an Iowa watershed originated from tile drains. To truly understand N movement within a watershed onsite monitoring is necessary.

Inversely, P leaching through tile drainage has only become recognized in more recent publications (King et al., 2014; Kleinman et al., 2015; Saadat et al., 2018; Smith et al., 2015; Vidon and Cuadra, 2011; Woodley et al., 2018). Prior to this P in drainage waters, particularly subsurface drains such as tile lines were often mistakenly assumed to be a minor contributor of P losses from agricultural fields (Kleinman et al., 2015). Phosphorous, normally thought of as a surface runoff issue is able to access tile lines through soil macropores, cracks, and fissures allowing P to move down the soil profile. During precipitation events, macropores act as a direct linkage from the tile lines to the soil surface, precipitation transports P from the surface down the these macropores to the tile system. Vidon and Cuadra (2011) found a correlation between high P fluxes and export rates were associated with high tile discharge events. A study by Enright and Madramootoo (2004) found that tile contributed 40% of the total P exported from agricultural fields located along the Pike River in Quebec. Likewise, Smith et al. (2015) concluded that as much as 50% of the P loads in the tributary of Indiana's St. Joe Watershed may be derived from tile drainage. Given that P is often the limiting factor in freshwater ecosystems, and is associated with harmful algal blooms throughout North America. Understanding the dynamics between P and tile drainage is essential if we are to control P exports moving forward.

Much like N and P, tile drains have a profound effect on stream flow. Woodley et al. (2018) found that tile drainage was the dominant avenue for water flow in a test plot scenario. This added connectivity allows for changes in total water yields, timing, and shape of hydrographs in a given watershed (Blann et al., 2009). Several studies show significant contributions from tile in regards to total watershed discharge, Drain 30-45%, 51%, 56% were found by Amado et al. (2017), King et al. (2014), and Williams et al. (2015) respectively. Understanding the correlation and effects of tile drain contribution to watershed discharge is essential to understanding the total hydrology of the watershed.

Introduction

Prior research on tile drainage contributions to watersheds have primarily focused on comparing nutrient load exports and discharge from tile outlets to measurements downstream, or a side by side comparison of two fields one tiled, one not. These studies did find an impact from tile on watershed processes, but lack a baseline or reference condition to build upon. Total suspended solids (TSS) is analyzed in very few studies (Ghane et al., 2016; Jarvie et al., 2017; Nash et al., 2014; Poirier et al., 2012; Renwick et al., 2018), and is not measured as a change in stream turbidity, but as a means to measure mineral bound nutrients. These studies are also primarily conducted in states such as Ohio (King et al., 2014; Smith et al., 2015; Williams et al., 2015), Illinois (David et al., 1997), Minnesota (Mager et al., 2004), Missouri (Nash et al., 2014), and Indiana (Saadat et al., 2018) with minimal research coming from far northern climates such as the Red River of the North Watershed (Red River Watershed). The utilization of tile drainage has rapidly expanded in the Red River Watershed allowing earlier planting dates and higher crop yields (Pates, 2011). Areas within the Red River Watershed without tile drainage are becoming increasingly difficult to find. The Red River Watershed flows north and eventually drains into Lake Winnipeg in central Manitoba, Canada. Schindler et al. (2012) found that the Red River Watershed supplied 70% of the P load and 35% of the N load entering the lake causing harmful algal blooms to double in size since the 1990's. The Red River also supplies several major North Dakota cities with their drinking water (Fargo, Grand Forks, and Wahpeton), changes to Red River water quality could cause increased purification costs for a substantial proportion of the state's population.

This study evaluated current water quality conditions in a headwater watershed of the Red River Watershed that currently is not dominated by tile drainage. This information provides an accurate baseline for further studies to determine changes in water quality once tile is implemented and to determine how conservation measures may or may not have an impact on those changes. It also provides a new approach to tile studies, as to our knowledge no study has captured a before/after comparison at a watershed scale. The specific objectives of this study are as follows:

1.) Analyze P, N, and TSS contributions from the sub-watershed that contribute to the Red River during different spring runoff and different types of precipitation events.

2.) Assess velocity and flow of water coming from each drain in the sub-watershed during spring runoff and precipitation events to determine how sub-watershed contributes to Red River

Methods

Site Description

The study watershed is located in eastern North Dakota, immediately south and west of the town of Argusville, ND (Figure 1). The estimated area of the watershed is, roughly calculated via USGS StreamStats website, around 18,943.15 ha (StreamStats). The primary soil types are clay and silty clay loams with slopes ranging from 0.1% to 20.8% (Web Soil Survey). Primary land use is agricultural production, with few other major land uses occurring within the watershed. Primarily tile drainage is not utilized in the watershed though there is an unknown area that is drained through this practice, this is thought to be a small percentage of the overall watershed area. Existing drainage within the study area is made up of shallow surface drains that feed into larger open ditch drains. There are four large open ditch drains (from north to south are Drain 30, Drain 70-N, Drain Little 13, and Drain 70-S) flowing to the east, all four drain into a larger open ditch drain (Drain 13) before passing east under Interstate 29 (Figure 1) and eventually flowing into the Red River.

Sample Collection

Samples were collected at five sites (Figure 1) within the study area, four sites were located on 167th Ave SE at each crossing of four smaller open ditches. These sites were named for the given ditch at which they sampled (Drain 30, Drain 70-N, Little 13, and Drain 70-S). A fifth sample site was placed along old highway 81 at the crossing of Drain 13, this site was referred to as 81 Cross. During the spring runoff period (April 6th – May 16th, 2019) grab samples and flow measurements were taken weekly at each of the five sites. Grab samples were taken via dip cup following North Dakota Department of Environmental Quality (NDDEQ) protocol. Post collection preservatives were added as needed to the sample, samples were cooled to 4^0C, and transported to the NDDEQ lab in Bismarck for analysis. Flow measurements were taken using a metered rod to measure the distance between the top of the culvert and the top of the water to use later to calculate flow and load using Manning's equation.

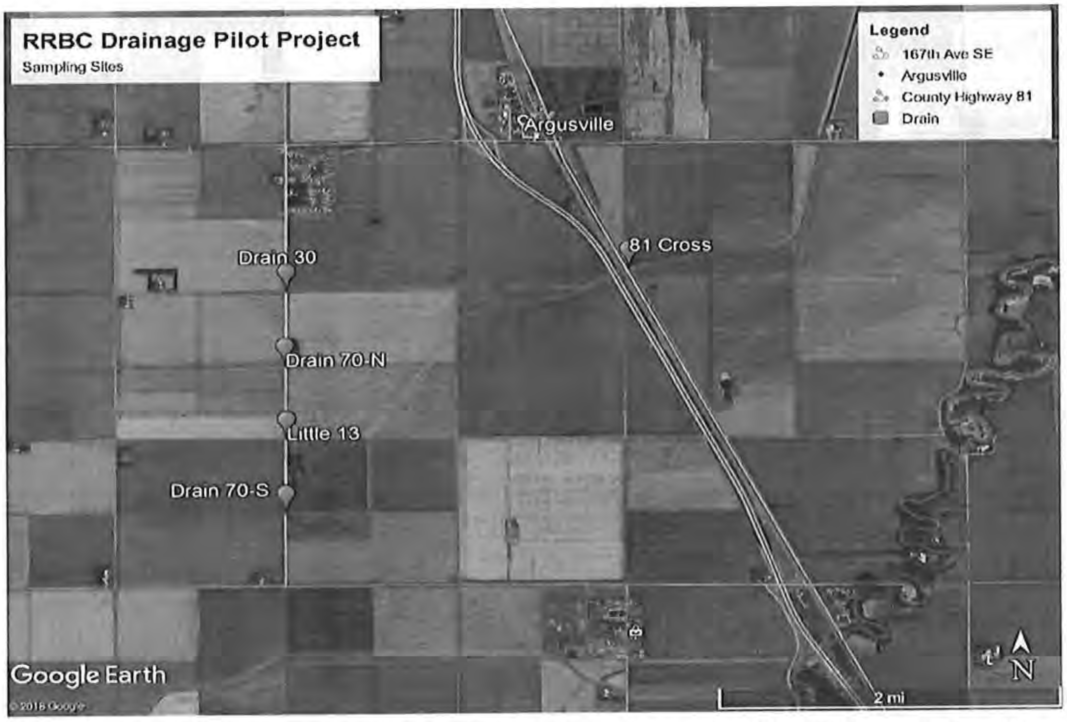


Figure 1: Study site location with sample sites indicated in blue with names in white.

Teledyne Isco Avalanche portable refrigerated samplers were used for storm event sampling following the completion of runoff sampling. Height measurements were collected using a Teledyne Isco model 720-submergible probe containing a pressure transducer. Intake lines were placed next to the pressure transducer approximately 4" off the bottom of the ditch within the primary current. Flow measurements were taken in 30-minute increments. A programed sample event with fourteen 800ml samples taken every hour following a rain event was utilized for each rain event. Once samples were taken, the sampler would cool the pulled samples to 4^0C ($\pm 1^0$c) and purge the intake line. Following completion of the sampling program, the hydrograph was retrieved from each sampler using Teledyne Isco Flowlink v5.0. The hydrograph was then used to identify what time the rising limb, peak, and falling limb occurred. These times were then used to choose what samples were taken during the given area of the hydrograph, as a sample report was generated for each program showing the date and time at which each sample was pulled. Samples that fell within the same area of the hydrograph were then composited to have water samples from the rise, peak and falling limb of the hydrograph. Composite samples were bottled and preserved according to NDDEQ specifications and shipped to the lab for analysis. Composite samples were analyzed for nutrients complete, major cations and anions, TSS, and ICP MS trace metals. All samples whether grab or from auto sampler were also analyzed with a YSI sonde (626870-1) for temperature, specific conductivity, dissolved oxygen, and pH.

Runoff Sampling

Flow during the runoff sampling period was greatest at the beginning of the six weeks and gradually fell over the following six weeks of grab samples. TSS in general was higher with larger amounts of water moving within the ditch (Figure 2). All five sites showed similar measurements in the first week of sampling (April 8th) with sites Drain 30, Drain 70-N, and Drain 70-S having 18 mg/L, Little 13 having 16 mg/L, and 81 Cross having 28 mg/L. The second week of sampling (April 15th) three drains showed similar measurements of TSS site Drain 30, Drain 70-N, and Drain 70-S had 14 mg/L, 16mg/L, and 15mg/L respectively. Little 13 dropped significantly in comparison to the other sites resulting in 9 mg/L, and 81 cross inversely had a significant jump in suspended solids containing 144mg/L the second week. 81 cross then dropped dramatically in the following two weeks with the 3rd week of sampling showing 33 mg/L and the 4th week showing 14 mg/L of suspended solids. The last two weeks of sampling 81 cross resulted in a non-detection from the laboratory. The NDDEQ has a non-detection limit of 5 mg/L for TSS, so we were unable to decipher if the sample contained any number of suspended solids less than 5 mg/L. This same result was returned for sites Drain 30, Drain 70-N, Little 13, and Drain 70-S for the four sampling dates following the April 15th date. These non-detect returns are displayed as 0 mg/L on the figure, but it is unknown if the result is higher then 0 mg/L and lower than 5 mg/L

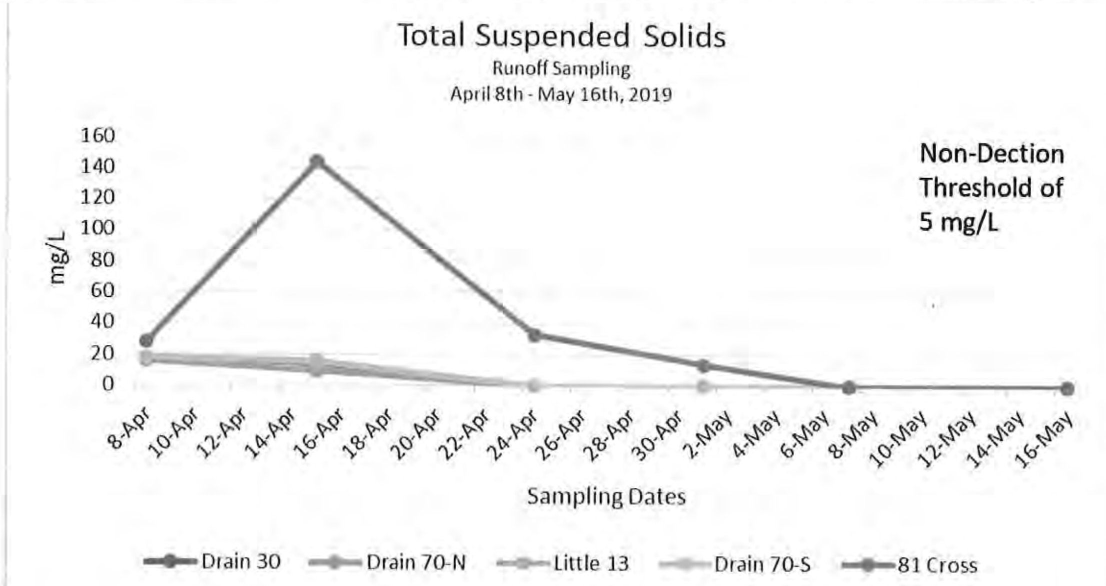


Figure 2: Total Suspended Solids results from runoff sampling taken from April 8th to May 16th.

Total Nitrogen (N) (Figure 3), inversely to TSS, was lower earlier in sampling than in later dates. In the initial sample date of April 8th all sites fell into a range between 1 mg/L and 2 mg/L. The next two sampling dates showed a similar trend of all sites having similar N counts. A slight downward trend in N continued for the April 24th date, only 81 cross experienced an increase in N. Following the April 24th sampling date all sites other than 81 cross showed increases in N counts until runoff sampling ended on May 16th. Total Nitrogen (N) at 81 cross decreased slightly from the May 8th sampling date to the May 16th date, resulting in 9.44 mg/L and 9.09 mg/L.

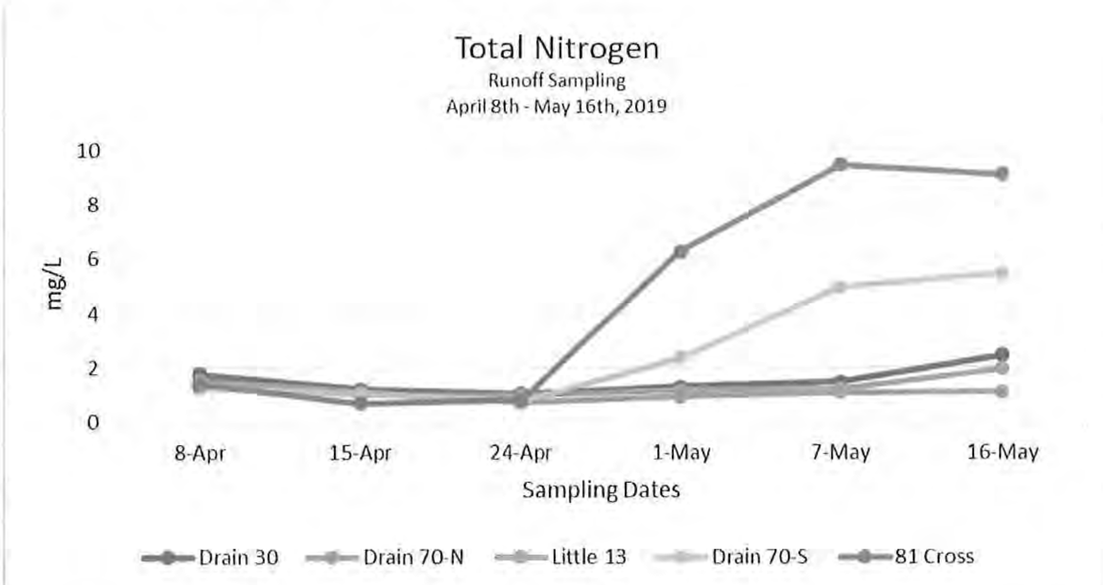


Figure 3: Total Nitrogen (N) measurements during runoff sampling, taken weekly from April 6th to May 16th.

Similarly to N, NO3-N tended to return similar results across all sites in early sampling dates (Figure 4). This continued until the April 24th sampling date at which time three sites (Drain 30, Drain 70-N, and Little 13) all fell below the NDDEQ non-dectection level of 0.03 mg/L for the duration of the runoff sampling dates. This data is displayed as 0 mg/L, but could fall between 0 mg/L and the non-detection level of 0.03 mg/L. Sites 81 cross and Drain 70-S both experenced rapid increses in NO3-N following the April 24th sampling date.

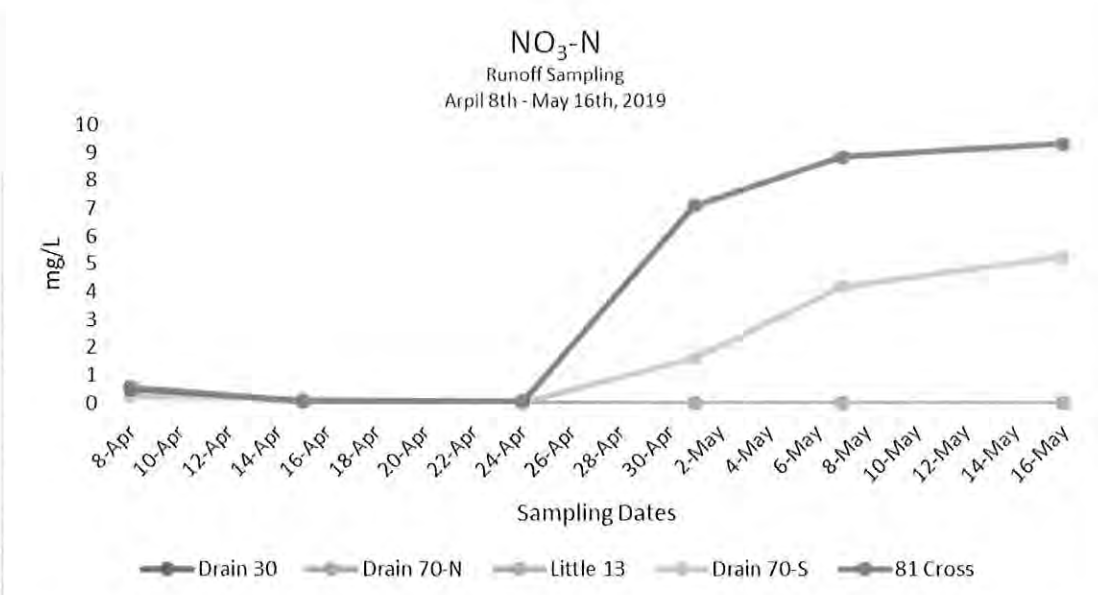


Figure 4: NO3-N measurements during runoff sampling, taken weekly from April 6th to May 16th.

Total phosphorus measurements for the first sample date varied greatly across all sites, and continued throughout the runoff sampling dates (Figure 5). Drain 70-S and Drain 70-N both started near 0.2 mg/L with Drain 70-S measuring 0.251 mg/L and Drain 70-N measuring 0.207 in the first sample date. The following date both sites increased in total phosphorous, site Drain 70-S measured 0.798 mg/L and Drain 70-N resulting in 0.655 mg/L. Following the April 15th sample date both Drain 70-S and Drain 70-N decreased until the final runoff sample was taken on May 16th, then both sites showed slight increases in total phosphorous for the first date since the April 15th sample date. Little 13 was the only site to show an overall trend in increased total phosphorous, with only one sample (May 8th) being lower than the previous weeks sample. Site Drain 30 lacked an apparent trend in total phosphorous, with only two sample dates (May 2nd and May 8th) showing any trend in increasing or decreasing total phosphorous. Site 81 cross held within a range of 0.27 mg/L to 0.37 mg/L through the first four sample dates, then decreased to 0.12 mg/L the fifth week of sampling then increasing slightly the final week of sampling to 0.14 mg/L.

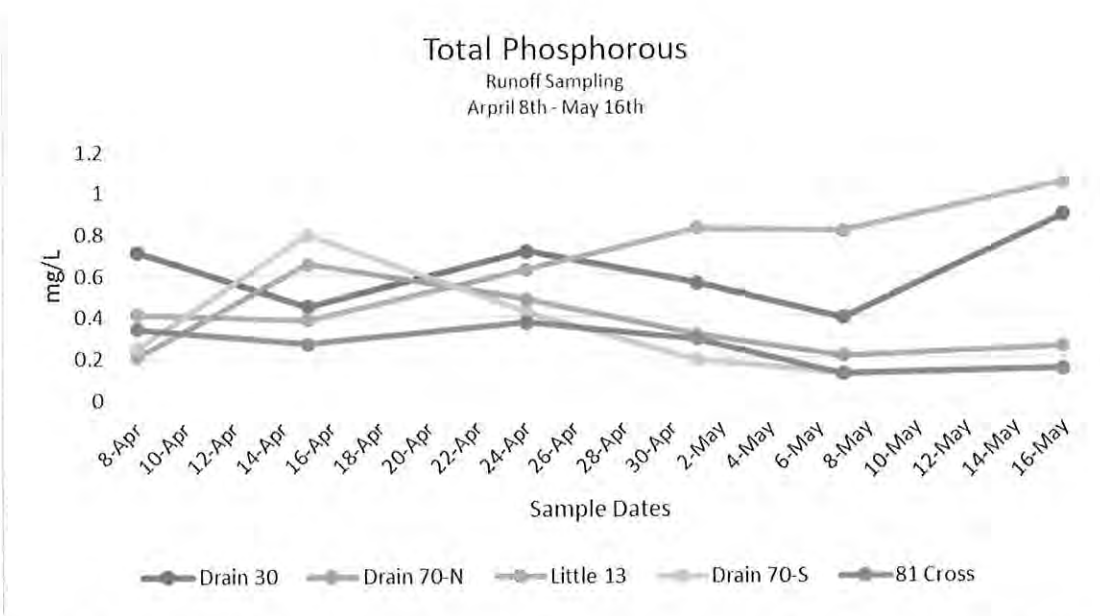


Figure 5: Total phosphorous measurements during runoff sampling, taken weekly from April 6th to May 16th.

Rain Event Sampling

All rain event data is taken from a rain event on June 20th that resulted in a total 24-hour rainfall of 0.74 inches recorded at the NDAWN station in Prosper, ND. Additional samples have been taken, but results were not available at time of report writing. Results are displayed as measures of composite samples taken during the rise, peak, and fall of the hydrograph. Prior to the storm. event heights at each site were recorded to be 7.8 inches at site Drain 30, 11.8 inches at site Drain 70-N, 9.1 inches at Little 13, 8.2 inches at Drain 70-S, and 8.0 inches at 81 cross. Hydrographs peaked at the following heights for each site, 8.8 inches at site Drain 30, 13.7 inches at Drain 70-N, 13.0 inches for Little 13, 13.4 inches at Drain 70-S, and 13.2 inches at 81 cross.

Total nitrogen (Figure 6) measurements for the rising limb of the hydrograph showed significant differences between the five sites, resulting in 5.06, 2.95, 1.79, 3.08, 8.8 mg/L for Drain 70-S, Little 13, Drain 70-N, Drain 30, and 81 cross respectively. All sites showed an increase in N during the peak of the hydrograph compared to the rising limb measurements. Peak measurements of N showed the greatest change from the rising measurements at Drain 70-N which increased to 6.84 mg/L, an increase of 5.05 mg/L. Drain 70-S and 81 Cross both increase similarly to each other with measurements of 7.95 mg/L and 11.5 mg/L respectively. Showing an increase from the rising measurements of 2.89 mg/L for Drain 70-S and 2.7 mg/L for 81 cross. Little 13 and Drain 30 both showed slight increases from their rising measurements. Little 13 had a peak measurement of 2.99 mg/L, a 0.04 mg/L increase from its rising measurement. Drain 30 had a peak measurement of 3.1, an increase of 0.02 mg/L of N. Four sites again showed an increase in N measurements during the falling limb samples in comparison to the peak measurements. Drain 70-S was the only site to show a decrease in N during the falling limb sampling measuring 7.05 mg/L a decrease by 0.16 mg/L compared to the peak measurement. Little 13, Drain 70-N, Drain 30, and 81 cross all increased with results of 8.58,16,259, and 12.3 mg/L respectively. Drain 30 showed the most significant change from the peak measurement with a difference of 255.9 mg/L. Drain 70-N resulted in an increase of 9.16 mg/L from the peak to falling limb sample. Little 13 also had a significant increase from peak to falling limb samples, increasing 5.59 mg/L. 81 cross increased the least out of the sites that showed an increase, only increasing 0.8 mg/L.

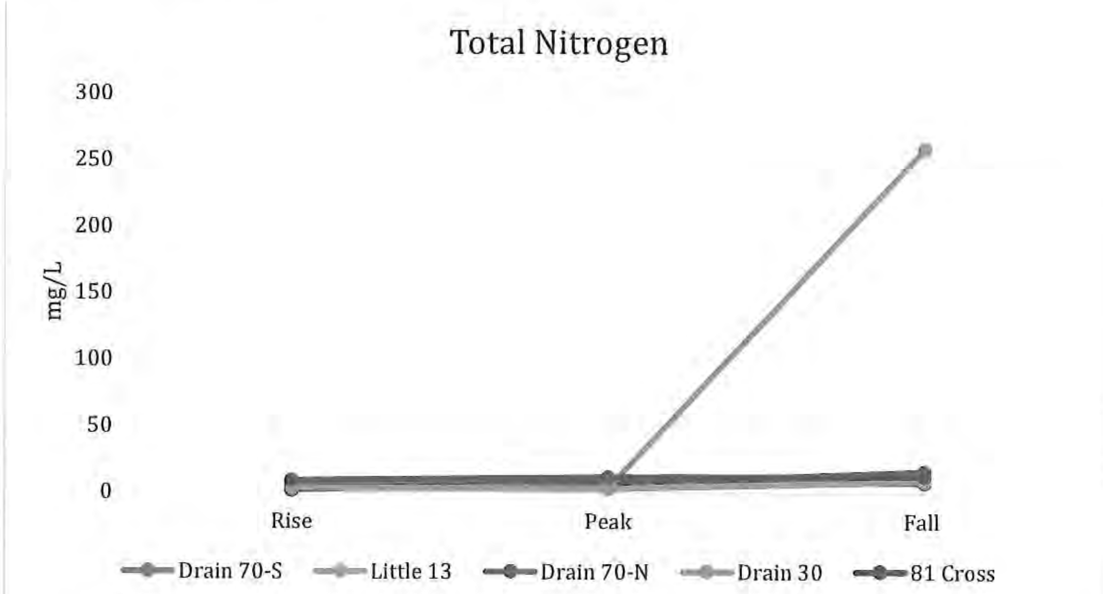


Figure 6a: Total nitrogen measurements taken during the rising limb, peak, and falling limb of the hydrograph for five drainage ditches during a rainfall event totaling 0.74 inches on June 20th, 2019.

Sample results for NO3-N (Figure 6a) showed a similar trend to the results found with N. Across all sites the lowest measure of NO3-N was taken during the rising limb of the hydrograph. Three sites (Little 13, Drain 70-N, and Drain 30) all had a rising limb result of a non-detect (0.03 mg/L), Drain 70-S measured 4.1 mg/L and 81 cross was 7.35 mg/L. Three sites showed an increase in NO3-N moving from the rising limb measurement to the peak measurement. Drain 70-S, Drain 70-N and 81 cross measured 7.21, 5.76, 10.7 mg/L of NO3-N respectively. An increase of 3.11 mg/L at Drain 70-S, 5.76 mg/L at Drain 70-N, and 3.35 mg/L at 81 cross. Little 13 and Drain 30 resulted in a non-detect during the peak measurement. Four sites showed an increase in NO3-N from the peak measurement to the falling limb measurement. Little 13, Drain 70-N, Drain 30, and 81 cross resulted in NO3-N counts of 6.74, 15.2, 81, and 11.1 mg/L respectively. An increase of 6.74 mg/L at Little 13, 9.44 mg/L at Drain 70-N, 81 mg/L at Drain 30, and 0.4 mg/L at 81 cross. Drain 70-S was the only site to show a decrease NO3-N measurement in its falling sample compared to its peak sample resulting in 7.05 mg/L in its falling, a decrease of 0.16 mg/L NO3-N. Figure 6b shows the same sampling event with the falling measurement of drain 30 removed to allow for a smaller scale, showing the changes of the other sites.

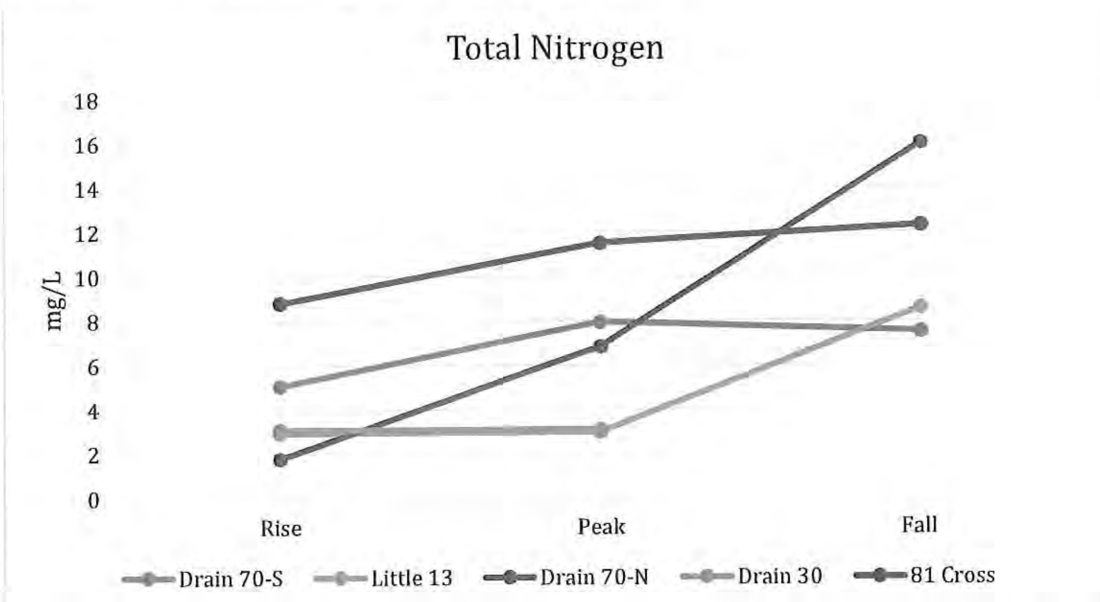


Figure 6b: Total nitrogen measurements taken during the rising limb, peak, and falling limb of the hydrograph for five drainage ditches during a rainfall event totaling 0.74 inches on June 20th, 2019 with drain 30 falling outlier removed.

Total phosphorus (Figure 8) overall lacked a definite trend across the five sample sites with rising limb measurements of 0.13, 1.66, 0.073, 0.902, 0.11 mg/L for Drain 70-S, Little 13, Drain 70-N, Drain 30, and 81 cross respectively. Little 13, Drain 70-N, and Drain 30 all showed increases in total phosphorus in their peak samples, resulting in 1.68, 0.11, and 0.921 mg/L of total phosphorus. This was an increase of 0.02 mg/L at Little 13, 0.037 mg/L at Drain 70-N, and 0.019 mg/L at Drain 30. Drain 70-S and 81 cross inversely resulted in a decrease in total phosphorus at their peak samples with 0.08 mg/L being found at Drain 70-S and 0.02 mg/L at 81 cross, a decrease of 0.05 mg/L and 0.09 mg/L respectively. Decreases in total phosphorus was found at Drain 70-S, Little 13, and Drain 70-N during the falling limb sample. Drain 70-S measured 0.02 mg/L at the falling limb sample, a decrease of 0.06 mg/L from the peak sample at that site. Little 13 significantly decreased from its peak sample of 1.68 mg/L to its falling limb sample of 0.9 mg/L, a decrease of 0.78 mg/L.

Measurements at Drain 70-N resulted in 0.2 mg/L at the falling sample, a decrease of 0.09 mg/L total phosphorus. 81 cross did not change between its peak sample and falling limb sample of 0.02 mg/L. Drain 30 was the only site to show an increase throughout the hydrograph with a falling limb sample of 16 mg/L, an increase of 15.079 mg/L.

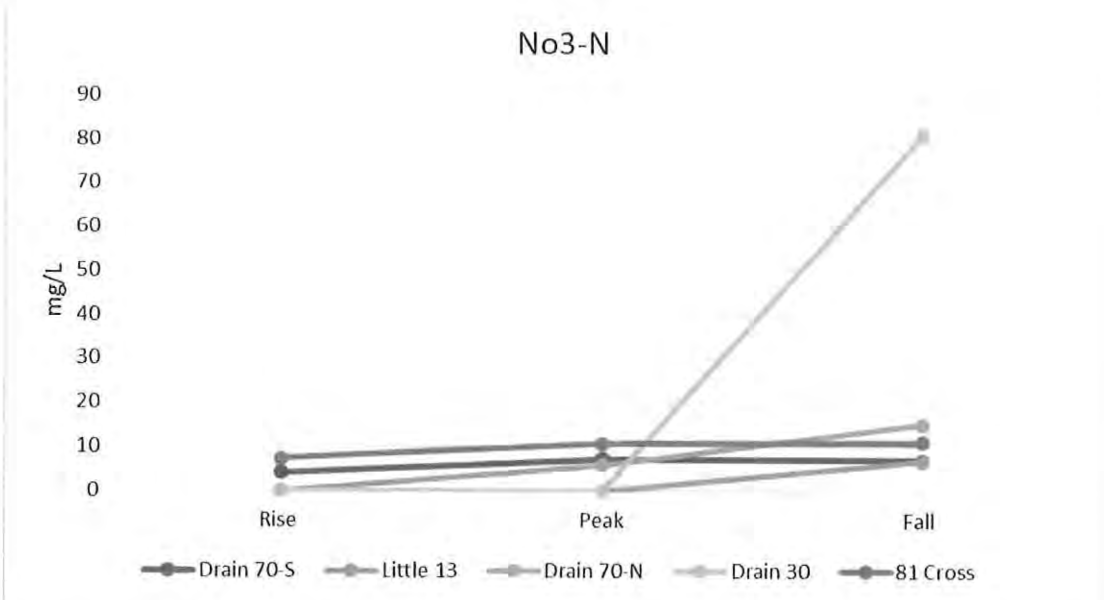


Figure 7: NO3-N measurements taken during the rising limb, peak, and falling limb of the hydrograph for five drainage ditches during a rainfall event totaling 0.74 inches on June 20th, 2019.

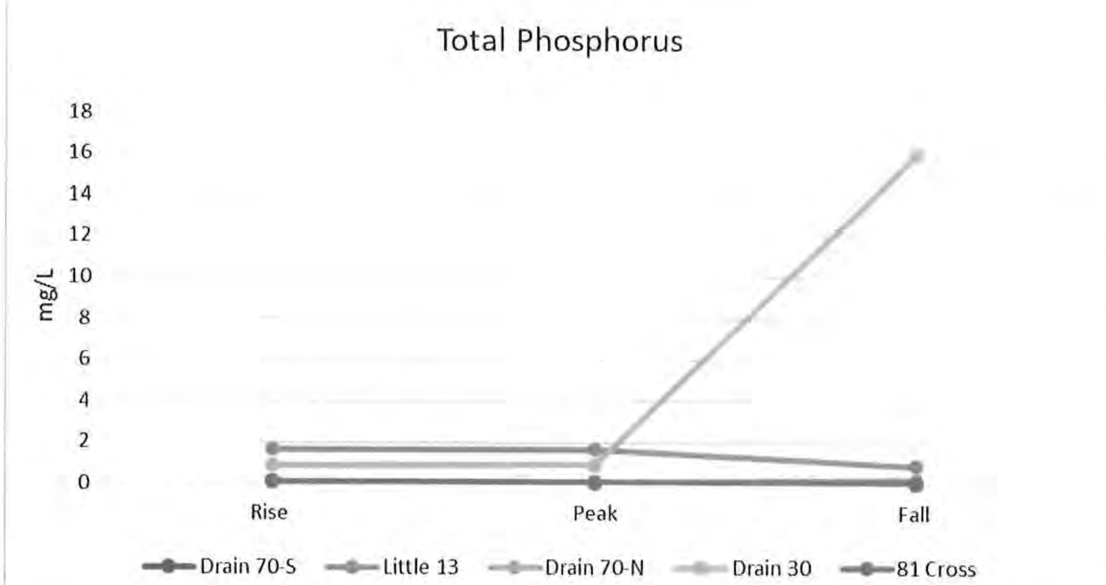


Figure 8: NO3-N measurements taken during the rising limb, peak, and falling limb of the hydrograph for five drainage ditches during a rainfall event totaling 0.74 inches on June 20th, 2019.

Total suspended solids (Figure 9) rising limb sample showed similar measurements at the four smaller drain sites. Drain 70-S, Little 13, Drain 70-N, and Drain 30 showed rising limb results of 17, 18, 15, and 16 mg/L of TSS. 81 cross showed a much lower result of 7 mg/L in comparison. The peak sample resulted in Drain 70-S, Drain 70-N, and 81 cross falling below the detection limit (<5.0 mg/L), and decreasing by 17, 15, and 7 mg/L respectively. Little 13 also decreased in TSS at its peak sample resulting in 13 mg/L, a decrease of 5 mg/L. Drain 30 was the only site to show an increase in TSS at the peak sample, 24 mg/L of TSS was found at the peak an increase of 8 mg/L from the rising limb sample. The falling limb sample resulted in all but one site staying above the detection threshold of 5 mg/L. Little 13 measured 5 mg/L at its falling limb sample, a decrease of 8 mg/L. Drain 70-S, Drain 70-N, and 81 cross all resulted in a non-detection resulting in no change from peak to fall sampling. Drain 30 fell below detection levels for the fall limb sample, resulting in a decrease of 24 mg/L TSS from peak to falling limb sampling.

Discussion

The hydrology of our site is one of extremes, with water moving within the drainage systems quickly following a rain event. Peak flow was routinely observed to occur between 3 and 4 hours following a significant rain fall of a half inch per hour or greater, especially in the early growing season before plants emerge. This creates a hydrograph with a rising limb that has a significant positive slope reaching a peak quickly, followed by a falling limb which decreases at half the rate of the rising limb. Runoff sampling indicated that N was introduced into the system around the same time, and it is our hypothesis that this could be caused by the thawing of the soil profile allowing these nutrients to leech into the surface water. A possibility why this was only observed in two of the five sites could be related to fall fertilizer application on certain fields and not others. This hypothesis is further strengthened by the levels of NO3-N in the same sample sites, NO3-N being a major part of inorganic fertilizers.

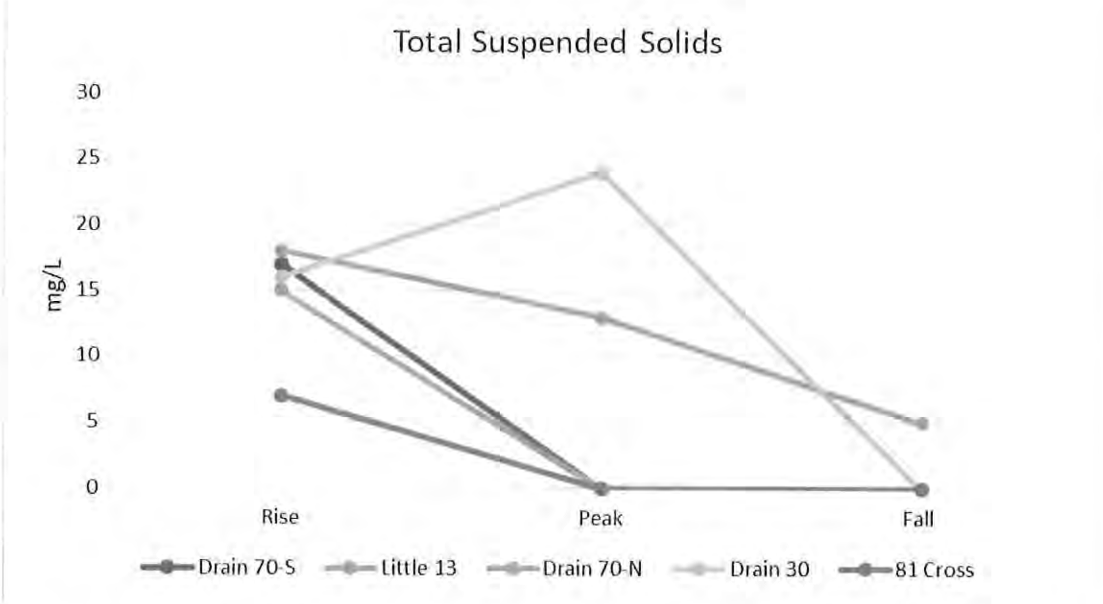


Figure 9: Total suspended solids measurements taken during the rising limb, peak, and falling limb of the hydrograph for five drainage ditches during a rainfall event totaling 0.74 inches on June 20th, 2019.

It is possible that late fall application could have locked in the levels until the spring thaw leading to elevated runoff levels. Total phosphorus levels in runoff sampling fluctuated greatly between each site and each sample date making it difficult to observe any trend in movement of this nutrient. It is well documented that phosphorus binds to sediment particles, so a correlation is often found between TSS and P. In our results we did not see this trend, which leads us to believe the primary species of phosphorus in the system is dissolved in solution and not bound to sediment particles. This is concerning, as the primary diver in harmful algal blooms in the Lake Winnipeg basin is soluble phosphorus (Schindler et al., 2012). To further assess this relationship future monitoring of dissolved phosphorus is being conducted in the watershed. Total Suspended Solids measurements were observed at their highest near the beginning of spring runoff which could have been elevated by the significant overland flooding in the study area, as it is unlikely the soil had begun to thaw at the initial two sampling dates.

Storm event sampling revealed trends for all analysis. Total nitrogen and NO3-N both tended to increase later in the hydrograph with the highest readings coming on the falling limb samples. Only one site did not follow this trend, site Drain 70-S saw a drop in N and NO3-N from its peak sample to its falling sample. Total phosphorus inversely was highest in rising and peak samples than in falling for four sites. Drain 30 was the only site that showed an increase with each sample taken. It is worth noting that the falling limb sample for TN, NO3-N, and TP for site Drain 30 were all analyzed using the same sample bottle so it is possible there was an error in the handling/analysis of this sample or by chance included a nutrient saturated soil particle. Further sampling data with help decipher if this is in fact an outlier or not. Total Suspended Solids showed significant results in the rising limb samples for all five sites, and a significant decrease in the peak samples for all but two sites. Little 13 and site Drain 30 were the only sites to have sample results above the non-detection threshold of 5.0 mg/L. Little 13 slightly decreased by 5 mg/L and Drain 30 increased by 8 mg/L. Flow at site Drain 30 increased the least of all sites only rising 1 inch from the initial pre-storm height to the peak flow height. Total suspended solids overall tended to be significantly higher in the rising limb of the hydrograph then in the following samples taken during the peak and falling limb.

Preliminary Conclusions

Based on the literature, soil types and conditions in the Red River Valley, and knowledge of tile drainage, it is expected that once subsurface drainage is implemented P will generally decrease in water quality samples, while N will generally increase. This study on average found pre-drainage water quality averages to be 7.03 mg/L for N, 5.37 mg/L for NO3-N, 0.49 mg/L for P, 7.67 mg/L for TSS, which can fluctuate with runoff, precipitation, and during the growing season. For the averages of N, P, and NO3-N the falling measure for drain 30 was not included, until we have more results showing a similar trend for the site we deemed that measure as an outlier. Further analysis of baseline pre-drainage conditions until tile is placed will be important to get a full picture of what is happening in the system to compare with post tile placement water quality. Additionally, it will be important to determine how on the ground conservation practices, once tile is placed, can help improve water quality factors that might be impacted within the system.

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Additional results to be published separately once the ND State lab can finish analysis of all samples for the study.

RESEARCH PLAN

NDSU NORTH DAKOTA STATE UNIVERSITY

Research Proposal: Subsurface Drainage and Conservation BMPs Effect on Water Quality, Hydrology, and Agronomics in a Red River Valley Sub-Watershed

Researchers – North Dakota State University:

Dr. Christina Hargiss – Natural Resource Management, School of Natural Resource Sciences

Dr. Aaron Daigh - Soil Science, School of Natural Resource Sciences

Dr. Zhulu Lin - Agriculture and Biosystems Engineering

Project Summary:

The purpose of this project is to monitor, quantify, model, and document various aspects (e.g., nutrient fate and transport, hydrology, and agronomics) of deploying subsurface drainage systems in the Red River Valley. The results and documentations will help inform agricultural producers, land and water managers, and government officials of the behaviors of nutrients and water on the landscape as producers implement subsurface drainage water management. Stakeholders will gain essential knowledge, from these documents, for creating realistic expectations for water management in the region.

A sub-watershed of the Red River watershed, just west of Argusville, North Dakota, has been chosen as the study area for the project. The study area is divided into four parallel drainage areas based on the surface topography: Drain 70 S (light green), Small drain (yellow), Drain 70 N (pink), and Drain 30 (blue) (Figure 1). Surface water flows from these four drainage areas converge at drain 13 near Interstate 29 and subsequently drains into the Red River.

Each of the four drainage areas will consist of its own specific set of land management practices; hereafter referred to as treatments. Specifically, treatments that will be worked through with landowners for applicability in their cropping plans are 1) conventional subsurface drainage systems with conventional land management practices, 2) conventional subsurface drainage systems with one or more conservation best management practices (BMP; see listed below), 3) subsurface drainage with control structures and with conventional land management practices, and 4), subsurface drainage with control structures and with one or more conservation BMP (see listed below). The BMP options may include: saturated buffers, cover crops, grassed waterways, reduced/no till, create/restore small wetlands to serve as nutrient sink, and bioreactors. Additional BMPs may be considered if the validity of the practice for improving water quality, as related to subsurface drainage, is documented in the scientific peer-review literature. The BMPs may be eligible for cost sharing in some way, such as through the NRCS or funding provided to Red River Basin Commission. Cost sharing for BMPs will not be supplied by NDSU. Cost estimates for the BMPs are NOT included in the budget estimates provided by NDSU; budget estimates only include research costs.

Project Goals:

1) determine how implementation of subsurface drainage changes the water quality and flow of water as it exits the watershed;

2) assess conservation practices (i.e., BMPs) implemented at the watershed level and subsequent impact on water quality;

3) verify individual conservation practices (BMPs) impacts at the field level on water quality and flow;

4) model flow and water quality at the field, watershed, and basin scales; and

5) assess impacts of subsurface drainage on agronomics such as planting dates, crop yields, and profits.

The *specific objectives* of the project are outlined and overviewed in 9+ focus areas (i.e., individual research studies) below. Study designs will be solidified upon project funding and methods may be subject to change based on available funds, scientific findings in the literature, and conditions/findings in the field. However, the information included here will provide a brief overview of each focus area/study and costs for the entire project (see attached budget).

Comparison of flow and water quality concentrations and loading in four treatment watersheds: assessing trends, changes during growing season, precipitation events, and over time, and potential influence on aquatic life uses (3+ studies)

This study would be the first of its kind to assess a watershed level area pre drainage and compare with post subsurface drainage implementation data to assess changes that occur with water quality, flow, and how conservation practices influence these on a watershed scale. The majority of studies conducted around the world are on a field scale, or multiple fields in a localized area, and often drainage has been in place for many years with no pre data (King et al. 2015).

Each drainage area (Figure 1) will be assigned a treatment (described above). During the summers of 2019 and 2020 water quality and flow will be assessed at drains 70 N, 70 S, small drain, and 30, as well as from drain 13 as these four drains combine, but before it enters the Red River. This pre drainage data will be compared to seven to eight years of data taken post subsurface drainage implementation to assess flow and water quality changes. Data measurements will be taken for flow including during different rain events and at different points during the growing season. At each of these times water quality samples will be taken and assessed for nitrate+nitrite, total kjeldahl nitrogen, ammonia (NH_3), total nitrogen, total suspended solids, total phosphorus, electrical conductivity, and dissolved phosphorus. Sampling will be conducted through use of flow meters, loggers, automatic samplers, grab samples and additional measurements taken in the field as well as laboratory analysis.

Literature has shown some water quality parameters change quickly post subsurface drainage installation, while others happen over time or are driven by seasonal or precipitation changes (Magner et al. 2004, Michaud et al. 2004, Goswami et al. 2009, Ikenberry et al. 2014, King et al. 2015). Data from the project will be analyzed for changes and trends in flow and water quality across precipitation events, during different growing season conditions; as well as, comparing pre and post drainage concentrations and loads across the sub-watershed and within the four individual drainage areas.

Aquatic ecosystems have been shown to be sensitive to additions of nitrogen and phosphorus, and these nutrients can be major contributors to eutrophication (Nash et al. 2015). Schindler et al. (2012) found that the Red River Basin supplies 70% of the phosphorus load and 35% of the nitrogen load entering Lake Winnipeg and contributing to harmful algal blooms. Farmers don't want to contribute to these problems and prefer to keep their soil amendments on the land to keep input prices down and profits up. The problem lies in the fact that it only takes a small amount of nitrogen and phosphorus to impact aquatic life. Total phosphorus concentrations as low as $\geq$0.02 mg/L can be considered problematic for aquatic life and lead to eutrophication (Correll 1998, King et al. 2014). Data from the study, as well as improvements through conservation practices will be analyzed to assess water quality concentration and load impacts to aquatic life uses.

The data and analysis from this portion of the study will inform producers, water managers, and government officials of the transformations that happen with the implementation of subsurface drainage, and changes over time. Additionally, the data and analysis will assess how conservation practices can improve water quality on a watershed level and what is or is not realistic to expect of these improvements.

Modeling of flow and water quality data at the field, sub-watershed, and Red River Basin levels (3 studies)

We will employ the SWAT (i.e., Soil and Water Assessment Tool) model to study the effects of subsurface drainage and conservation practices on flow generation and downstream water quality (N and P) in the Red River Basin (RRB). We plan to develop the SWAT models at three scales – field, sub-watershed, and basin scales. At the field scale, we will develop a SWAT model for each combination of drainage and conservation treatments. The SWAT model will first be calibrated against crop yields for crop growth parameters, then the model parameters related to specific drainage and conservation practices will be calibrated using daily or weekly observations of tile flow and nutrient (N and P) concentrations. The drainage treatments considered in this project include free (gravity) drainage and controlled drainage, while the conservation practices will include saturated buffers, cover crops, grassed waterways, no till, create/restore small wetland to serve as nutrient sink, and bioreactor.

At the sub-watershed scale, we will develop a SWAT model for the entire study area. The parameters related to plant growth, drainage, and conservation practices will be transferred from the field-scale models. Other model parameters will be calibrated with streamflow and nutrient (N and P) concentrations observed at the four sampling sites (i.e., Drain 70S, Drain 70N, Drain 30, and small drain). At the basin scale, we will develop a SWAT model for the entire RRB within the United States. Similarly, the model parameters related to drainage and conservation practices will be transferred from the field- and sub-watershed-scale models, while other model parameters will be calibrated against daily and monthly average streamflows measured at 16 USGS stream gage stations. After the model is satisfactorily calibrated against streamflows, then it will be calibrated against the observed sediment concentrations and estimated nutrient (N and P) loads at the USGS gage stations located at Fargo and Grand Forks.

SWAT model setup requires the following three types of data. 1) Spatial data includes 1 to 3-meter DEM, pre-defined watershed boundary data, pre-defined stream networks, major impoundments (lakes and reservoirs), SSURGO database, crop data layers. 2) Weather data includes, at the minimum, daily precipitation, maximum and minimum daily temperature time series. 3) Management data includes planting and harvest dates, fertilizer types, fertilization rates and dates, irrigation rates and dates, tillage types, conservation types, and drainage types. The management data may be obtained through farmers' survey.

SWAT model calibration requires the following data to be collected through field experiments: 1) crop yield data from each combination of drainage and conservation treatments, 2) daily tile flow observations from each combination of drainage and conservation treatments, and at the four sampling sites of the study area, and 3) weekly water quality observations and/or water quality data from precipitation hydrograph events from each combination of drainage and conservation treatments, and at the sampling sites of the study area. The water quality observations will at least include nitrate, total nitrogen, dissolved and total phosphorous concentrations. SWAT model calibration also requires the following publically available data: 1) crop yields estimated at the county-level, 2) daily and monthly average streamflows at 16 USGS stream gage stations in the Red River of the North Basin, and 3) sediment and nutrient (N and P) concentrations at the USGS gage stations located at Fargo and Grand Forks.

This portion of the project will deliver a well-calibrated SWAT model for field scale, subwathershed, and the entire RRB that may be used by farmers, watershed district managers, and decision-makers to understand how the adoption of farm management and conservation practices will affect streamflow and downstream water quality through scenario analysis.

Evaluation of targeted conservation practices for reducing nutrient losses (1+ study, variable based on conservation practices chosen amongst producers)

In the event that multiple producers *with subsurface drainage* also install or practice in-field (e.g., no-till, cover crop) or edge-of-field (e.g., saturated buffer, bioreactor) nutrient reduction practices, then we propose to perform a targeted evaluation and comparison of those practices. An experimental design of these targeted evaluations may involve the monitoring and data collection on two fields (with and without the nutrient reduction practice) for each producer. Many nutrient reduction strategies are well known to decrease either nutrient concentrations or loads from subsurface drainage outlets. Typically, producers can expect a 10-30% reduction for most nutrient reduction strategies during most years. This study will provide empirical data to verify these ranges in the frigid, clayey soils of the Red River Valley. These data will also be used for developing the water quality model (see modeling study descriptions above) and basin-scale scenario simulations.

These data and analyses will inform producers, water managers, and government officials of realistic expectations for nutrient reduction strategies to perform in the region.

Nutrient dilution effects along basin (1 study)

Nutrient concentrations in drainage-basin surface waters often change in time and space. Runoff and water tables from adjacent lands with lower concentrations often mix and dilute the highest concentration waters as flows converge down gradient. In the case of rowcropped landscapes, subsurface drainage outlets may reasonably be expected to contain the highest concentrations of nitrates in a watershed. Conversely, these same drainage waters may simultaneously contain some of the lowest concentrations of total phosphorus. Therefore, as additional runoff waters and water tables from non-drained areas are mixed with the subsurface drainage water, the concentrations in waters along the drainage basin are expected to change. These nutrient dynamics along a basin can have direct influences on aquatic life, drinking water quality, and environmental states.

Currently, we do not have a clear understanding of how much dilution (if any) is to be expected in the Red River Valley. Additionally, if substantial dilution does occur, we do not have clear knowledge if this is governed by the addition and mixing from runoff, water tables, or both. Therefore, we propose to monitor nutrient concentrations at multiple subsurface drainage outlets, along various locations in county level drainage ditches, and along the Red River to determine if nitrate and phosphorus concentration are constant (i.e., minimal dilution effects) or dynamic (i.e., evidence of mixing and dilution from adjacent waters). We will fractionate particulate and dissolved phosphorus fractions to infer if any substantial dilute is derived from the mixing with overland runoff waters or water tables.

These data and analyses will inform producers, water managers, and government officials of how nutrient concentrations are altered as water move downstream through the basin. Moreover, these data and analyses will provide insights of how these nutrient dynamics may shift if subsequent land management changes are deployed and cause changes in how precipitation is partitioned to runoff and water tables.

Agronomics and production practices of drained and undrained fields (1 study)

Subsurface drainage has many potential benefits for producers. Among them are improved trafficability for early season field operations and drier conditions for rapid plant emergence and seedling growth. These expectations are inferred from well-established concepts. However, there is a lack of data to verify when and how often these conditions result in notable increases in crop yields and, more importantly, producer profits. Therefore, we propose to use the attached annual survey for producers (Appendix A), crop yield maps of producer's fields throughout the sub-watershed, and producer focus groups/individual producer interviews to build a dataset for agronomic analyses and address the following questions: 1) Does installation of subsurface drainage result in earlier field operations? 2) When and where do crop yields and producer profits increase with earlier field operations? 3) Does crop choice shift among producers following installation of subsurface drainage? 4) Do specific field operations change in frequencies following installation of subsurface drainage? 5) Does deployment of additional conservation practices increase following installation of subsurface drainage? 6) Are producer's expectations from subsurface drainage met or change over time following installation?

These data and analyses will inform producers and government agency personnel of how subsurface drainage subsequently affects farm management practices and outcomes with farm profits.

Project Deliverables:

The following would be deliveriables provided by researchers on the project:

- Annual reports and briefings
- Final report at completion of the eight year project
- Recommendations to stakeholers
- Presentations at public and professional meetings on results
- Dissemination of information in journal articles and other formats such as newsletters if requested

Literature Cited:

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<u>Example of Annual Producer Survey</u> NOTE: Landowners and producers information will not be individually identified or released without the landowner's explicit written consent. Data and information provided in this survey will be used for watershed modeling purposes and agronomic analysis.

Items	Response	Additional notes (if needed)
Year:		
Field Township, Range, Section, Quarter:		
Surface drains (Yes/No):		
Subsurface drains (Yes/No) and type:		
Previous crop:		
Tillage implements used:		
Tillage dates for each implement:		
Fertilizer type:		
Fertilizer rate:		
Fertilizer application date:		
Other soil amendments (gypsum, etc.):		
Other soil amendment application date:		
Crop planted:		
Planting date:		
Replanting performed (Yes/No):		
Replanting date:		
Preventative plant (Yes/No):		
Irrigation Date:		
Irrigation Rate:		
Crop damage (hail, disease, etc.):		
Date of damage		
Harvest Date:		
Chopper (Yes/No)		
Crop yield:		
Any Conservation Practices (BMP's) Used:		
Cover crop (Yes/No):		
Cover crop type:		
Cover crop rate:		
Termination method (winter kill/chemical):		
Cover crop termination date:		

Tile Potential Budget - 7/10/19 2% inflation is included on full time employee salary

Tile Drainage and Conservation Practices (potentially cost shared by NRCS) are outside of the realm of what NDSU can provide and additional money should be sought for this portion of the project

Salary	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	
ABEN PhD Student			22000	22000	22000	22000			88000
SNRS PhD Student 1	22000	22000	22000	22000					88000
SNRS PhD Student 2					22000	22000	22000	22000	88000
Undergraduate field assistant ($13/hour)	7000	7000	7000	7000	7000	7000	7000	7000	56000
ABEN Faculty 1 month summer salary ($9,700	9700	9894	10092	10294	10500	10710	10924	11142	83255
Research Technician full time on project	50000	51000	52020	53060	54122	55204	56308	57434	429148
Fringe Benefits									
Graduate Student Fringe Benefits (@3%)	660	660	1320	1320	1320	1320	660	660	7920
Undergraduate Student Fringe (@3)	210	210	210	210	210	210	210	210	1680
ABEN Faculty Fringe benefits (@21%)	2037	2078	2119	2162	2205	2249	2294	2340	17484
Research Technician Fringe Benefits (@55%)	27500	28050	28611	29183	29767	30362	30969	31589	236032
Operating									
Travel to site and sample delivery	5000	5000	5000	5000	5000	5000	5000	5000	40000
Travel to national meetings to present results	5000	5000	7500	7500	7500	7500	7500	7500	55000
Equipment (Weather stations 5 X $6,000 each; Automatic samplers, solar panels, and batteries to operate 7 X $11,000 each)	107000								107000
Computer for Technician and Students ($1000 each X 4)	2000		1000		1000				4000
Consumables (probes, PVC, etc)	8000	8000	8000	8000	8000	8000	8000	8000	64000
Water Quality Analysis	50000	50000	50000	50000	50000	50000	50000	50000	400000
Total Directs	296107	188892	216872	217729	220623	221555	200865	202875	1765518
Total Indirects (@10%)	29611	18889	21687	21773	22062	22155	20087	20288	176551.8
Total Project Cost Per Year	**325718**	**207781**	**238559**	**239502**	**242685**	**243710**	**220952**	**223163**	1942070

Total Project Cost	**1942070**

Tile Drainage and Conservation Practices (potentially cost shared by NRCS) are outside of the realm of what NDSU can provide and additional money should be sought for this portion of the project

USGS WATER MONITORING COST ESTIMATES

The USGS would be interested in collaborating on this project. We understand you are in the scoping phase and are looking for input on what factors need to be investigated along with some preliminary costs. The Dakota WSC has published work as part of a Discovery Farms program that is similar to the proposed study but at a smaller scale (field vs. subwatershed scale). That investigation is available in the report Runoff and Water-Quality Characteristics of Three Discovery Farms in North Dakota, 2008–16.

Your scoping documents and subsequent conversations indicated a project design with a control subwatershed and a subwatershed with a drainage management plan. The outlet of each watershed would need a streamgage to provide flow data. Depending on the size of the watershed flow would be expected to cease during the winter months (dry or frozen). A real-time streamgage operating only during open water periods costs about $12,000-13,000 annually. If the subwatershed is large enough that flow occurs throughout the year, a 12-month gaging station would be required. A12-month gage costs $16,000-17,000 annually. For longer-term projects, generally 5 or more years, the USGS does not require additional funds for installation and equipment costs. Depending on the streamage location some channel modifications might be needed in order to get reliable and consistent flow results.

Collection of water-quality samples will allow loads and yields to be computed. Each discrete water-quality sample collected by the USGS is $800 plus lab analysis fees which will be determined by the constituents selected. For example, analysis of major ions, trace metals, nutrients, TOC, DOC, and sediment will cost about $650 per analysis. The inclusion of pesticides would be an increased cost (analyzing a suite of pesticides alone is $735 per analysis). For meaningful statistical analysis, a minimum of 30 samples are recommended over a range of conditions. The load and yield calculations can be improved by the inclusion of a real-time water-quality monitor with the streamgage. Costs will vary depending on the parameters that are monitored (temperature, pH, specific conductance, dissolved oxygen, and/or turbidity). Costs for a 2-parameter water-quality monitor operated during open water are $6,500 annually while a 5-parameter monitor operated for the same period would be closer to $18,000 annually. For longer-term projects, the combination of samples and real-time water-quality monitoring can be used to develop regressions that predict real-time water-quality parameters such as dissolved solids, chloride, sulfate, nitrate plus nitrite, total phosphorus and suspended sediment. See the equations for the Red River at Fargo (use the drop down box to change constituents).

The streamgage data collection platform is also capable of hosting other environmental sensors such as precipitation, soil moisture, and other water-quality sensors such as nitrate. The Dakota WSC has experience operating each of these types of sensors and costs can be provided if interested. Precipitation was of value in the Discovery Farms works and is relatively inexpensive. There may also be some value in an expanded network of sensors that incorporates edge of field monitoring to isolate the impact of specific practices.

As stated above, the USGS would be interested in collaborating on this project and more precise numbers can be provided with the further definition of the scope of work. The costs provided above are for data collection, review, storage, and publication of the data on the USGS webpage. An interpretative report similar to the Discovery Farms report would be an additional cost beyond the costs outlined above.

LANDOWNERS WHO PARTICIPATED IN PUBLIC MEETINGS

2 April 2019

Brady Backstrom

Rick & Tim Bergman

Karen A Bryn

Donald K Cramer

Dale & Jerri Rust

Larry Allen & Lois R Gangnes

Ken Hejl

Gary E Hoglund

Phyllis Kurtz

Karl D Langseth

Roger G Nelson

Bruce & Janice Nereson

Dennis P & Vicki R Rust

Kent Smith

James B & Ann Ueland

4 April 2019

Kenneth A & Virjean K Cramer

Rodney G Nelson

William Mattson

Brian D & Lisa M Roach

Peggy J Stibbe

D And M Zimmerman

Raymond Wolfer

14 August 2019

Brady Backstrom

Roy Gordon Blixt

Phyllis Kurtz

Karl D Langseth

Brian D & Lisa M Roach

Dennis P Rust

James B Ueland

Dale Weston

ECONOMIC ANALYSIS OF INCREASED PRODUCTIVITY

Report Prepared by Ellingson Water Management on following pages

ELLINGSON

WATER MANAGEMENT

DRAINAGE ASSESSMENT

Prepared For: Cass County Pilot Project October 15, 2019

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DRAINAGE ASSESSMENT: OVERVIEW MAP

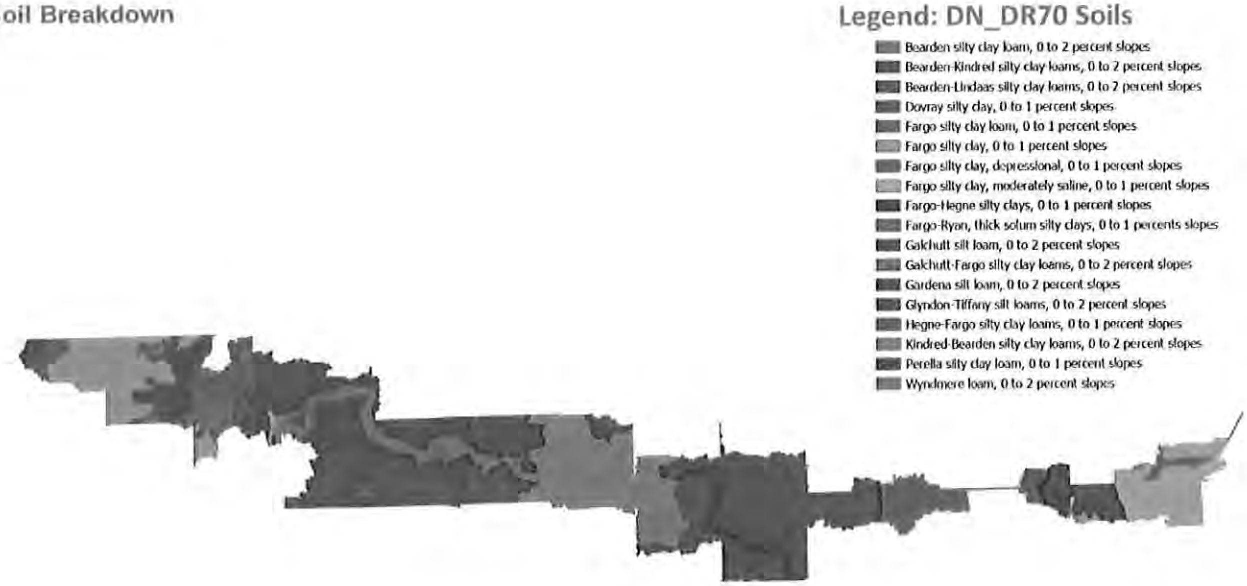
DRAINAGE – SOIL EVALUATION

DN_DR70
7,464 AC
Cass County, North Dakota

Drainage Class Breakdown

Legend: DN_DR70 Drainage Class

Soil Breakdown



Soil Code	Acres in AOI	Soil Description	Drainage Class	Sand/Silt/Clay	Ksat	Productivity Index	Element Index
I119A	124	Bearden silty clay loam, 0 to 2 percent slopes	Somewhat poorly drained	6.6-63.3-30.1	2.8	90	91
I202A	183.2	Gardena silt loam, 0 to 2 percent slopes	Moderately well drained	14-71.2-14.8	9.2	95	89
I211A	283.2	Wyndmere loam, 0 to 2 percent slopes	Somewhat poorly drained	51.8-38.7-9.5	66.2	76	83
I229A	623	Fargo silty clay, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	86	94
I231A	30.2	Dovray silty clay, 0 to 1 percent slopes	Very poorly drained	10.4-39.6-50	1.4	64	94
I233A	214.1	Fargo silty clay loam, 0 to 1 percent slopes	Poorly drained	9.4-46.8-43.9	0.9	94	94
I235A	59.7	Fargo silty clay, depressional, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	86	94
I238A	243.3	Fargo-Hegne silty clays, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	84	94
I241A	1.2	Fargo-Ryan, thick solum silty clays, 0 to 1 percents slopes	Poorly drained	4.2-45-50.8	0.7	78	89
I244A	228	Galchutt silt loam, 0 to 2 percent slopes	Somewhat poorly drained	23-55-22	3.1	89	91
I371A	1486.4	Bearden-Kindred silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.6-63.3-30.1	3.5	91	91
I373A	945.7	Kindred-Bearden silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.3-62.7-31	2.8	92	91
I469A	476.1	Fargo silty clay, moderately saline, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	52	83
I472A	6.6	Perella silty clay loam, 0 to 1 percent slopes	Poorly drained	6.3-62.1-31.6	7.2	88	94
I473A	322.8	Hegne-Fargo silty clay loams, 0 to 1 percent slopes	Poorly drained	10.2-46.6-43.2	0.9	87	94
I490A	1442.3	Glyndon-Tiffany silt loams, 0 to 2 percent slopes	Somewhat poorly drained	11.5-69.1-19.3	21.5	89	91
I491A	355.4	Galchutt-Fargo silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	19.2-50-30.8	3.1	91	91
I492A	439.4	Bearden-Lindaas silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.6-63.3-30.1	3.5	92	91
Total Acres	7464.6			Weighted Average		86.9	90.7

DRAINAGE – SOIL EVALUATION CONTINUED

DR30 5109
AC
Cass County, North Dakota

Drainage Class Breakdown

Legend: DR30 Drainage Class

Soil Breakdown

Legend: DR30 Soils

- Bearden-Kindred silty clay loams, 0 to 2 percent s
- Bearden-Lindaas silty clay loams, 0 to 2 percent s
- Colvin silty clay loam, 0 to 1 percent slopes
- Fargo silty clay loam, 0 to 1 percent slopes
- Fargo silty clay, 0 to 1 percent slopes
- Fargo silty clay, depressional, 0 to 1 percent slope
- Fargo silty clay, moderately saline, 0 to 1 percent
- Fargo-Hegne silty clays, 0 to 1 percent slopes
- Glyndon-Tiffany silt loams, 0 to 2 percent slopes
- Hegne-Fargo silty clay loams, 0 to 1 percent slope
- Kindred-Bearden silty clay loams, 0 to 2 percent s
- Perella silty clay loam, 0 to 1 percent slopes

Soil Code	Acres in AOI	Soil Description	Drainage Class	Sand/Silt/Clay	Ksat	Productivity Index	Element Index
I229A	925.8	Fargo silty clay, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	86	94
I233A	6.5	Fargo silty clay loam, 0 to 1 percent slopes	Poorly drained	9.4-46.8-43.9	0.9	94	94
I235A	232.9	Fargo silty clay, depressional, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	86	94
I238A	400.5	Fargo-Hegne silty clays, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	84	94
I371A	945	Bearden-Kindred silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.6-63.3-30.1	3.5	91	91
I373A	553.7	Kindred-Bearden silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.3-62.7-31	2.8	92	91
I376A	74.7	Colvin silty clay loam, 0 to 1 percent slopes	Poorly drained	7-63.6-29.4	1.9	68	89
I469A	7.9	Fargo silty clay, moderately saline, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	52	83
I472A	15	Perella silty clay loam, 0 to 1 percent slopes	Poorly drained	6.3-62.1-31.6	7.2	88	94
I473A	724.6	Hegne-Fargo silty clay loams, 0 to 1 percent slopes	Poorly drained	10.2-46.6-43.2	0.9	87	94
I490A	1140.8	Glyndon-Tiffany silt loams, 0 to 2 percent slopes	Somewhat poorly drained	11.5-69.1-19.3	21.5	89	91
I492A	81.6	Bearden-Lindaas silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.6-63.3-30.1	3.5	92	91
Total Acres	5109			Weighted Average		88.0	92.3

DRAINAGE – SOIL EVALUATION CONTINUED

North 2813
AC
Cass County, North Dakota

Drainage Class Breakdown

Legend: North Drainage Class

ELLINGSON
WATER MANAGEMENT

DRAINAGE ASSESSMENT – Cass County Pilot

Soil Breakdown

Legend: North Soils

- Bearden-Kindred silty clay loams, 0 to 2 percent slopes
- Bearden-Lindaas silty clay loams, 0 to 2 percent slopes
- Fargo silty clay, 0 to 1 percent slopes
- Fargo silty clay, depressional, 0 to 1 percent slopes
- Fargo silty clay, moderately saline, 0 to 1 percent slopes
- Fargo-Hegne silty clays, 0 to 1 percent slopes
- Hegne-Fargo silty clay loams, 0 to 1 percent slopes
- Kindred-Bearden silty clay loams, 0 to 2 percent slopes

Soil Code	Acres in AOI	Soil Description	Drainage Class	Sand/Silt/Clay	Ksat	Productivity Index	Element Index
I229A	25.5	Fargo silty clay, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	86	94
I235A	77.6	Fargo silty clay, depressional, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	86	94
I238A	499	Fargo-Hegne silty clays, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	84	94
I371A	911.2	Bearden-Kindred silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.6-63.3-30.1	3.5	91	91
I373A	137.1	Kindred-Bearden silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.3-62.7-31	2.8	92	91
I469A	143	Fargo silty clay, moderately saline, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	52	83
I473A	851.8	Hegne-Fargo silty clay loams, 0 to 1 percent slopes	Poorly drained	10.2-46.6-43.2	0.9	87	94
I492A	168.5	Bearden-Lindaas silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.6-63.3-30.1	3.5	92	91
Total Acre	2813.7					86.5	92.1

DRAINAGE – SOIL EVALUATION CONTINUED

South 1796
AC
Cass County, North Dakota

Drainage Class Breakdown

Legend: South Drainage Class

Soil Breakdown

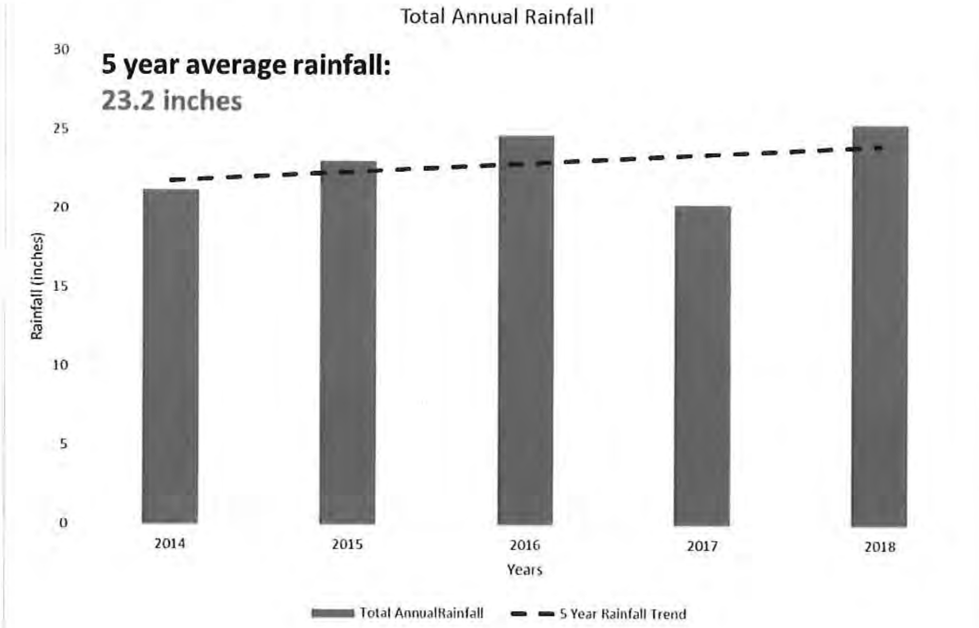
Legend: South Soils

- Bearden-Kindred silty clay loams, 0 to 2 percent slopes
- Fargo silty clay, 0 to 1 percent slopes
- Fargo silty clay, depressional, 0 to 1 percent slopes
- Fargo silty clay, moderately saline, 0 to 1 percent slopes
- Fargo-Hegne silty clays, 0 to 1 percent slopes
- Hegne-Fargo silty clay loams, 0 to 1 percent slopes

Soil Code	Acres in AOI	Soil Description	Drainage Class	Sand/Silt/Clay	Ksat	Productivity Index	Element Index
I229A	104.5	Fargo silty clay, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	86	94
I235A	16	Fargo silty clay, depressional, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	86	94
I238A	363.6	Fargo-Hegne silty clays, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	84	94
I371A	226.5	Bearden-Kindred silty clay loams, 0 to 2 percent slopes	Somewhat poorly drained	6.6-63.3-30.1	3.5	91	91
I469A	375.3	Fargo silty clay, moderately saline, 0 to 1 percent slopes	Poorly drained	4.3-45.8-49.9	0.9	52	83
I473A	710.2	Hegne-Fargo silty clay loams, 0 to 1 percent slopes	Poorly drained	10.2-46.6-43.2	0.9	87	94
Total Acres	1796.1					79.5	91.3

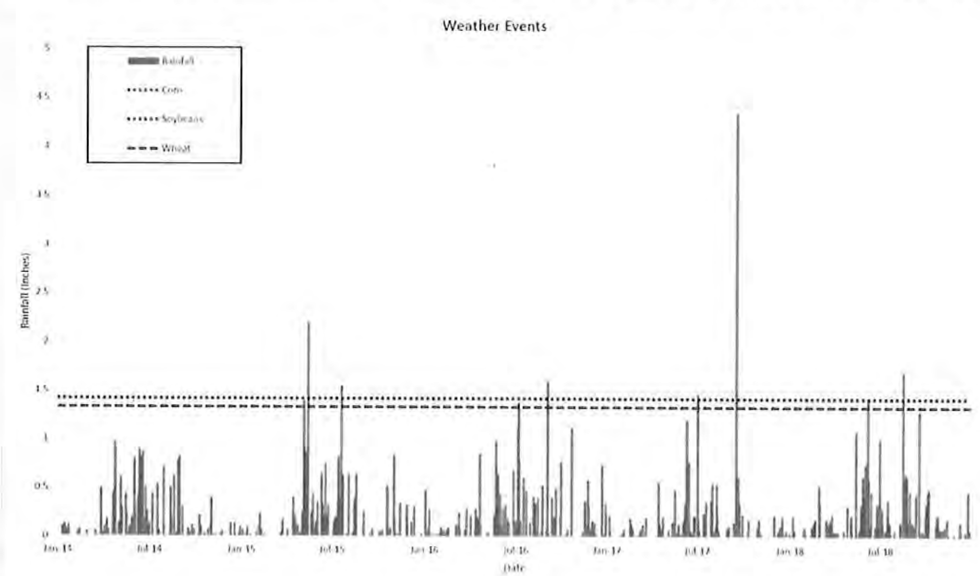
HISTORICAL RAINFALL INFORMATION

5-Year Annual Rainfall*



5-Year Rainfall Event History*

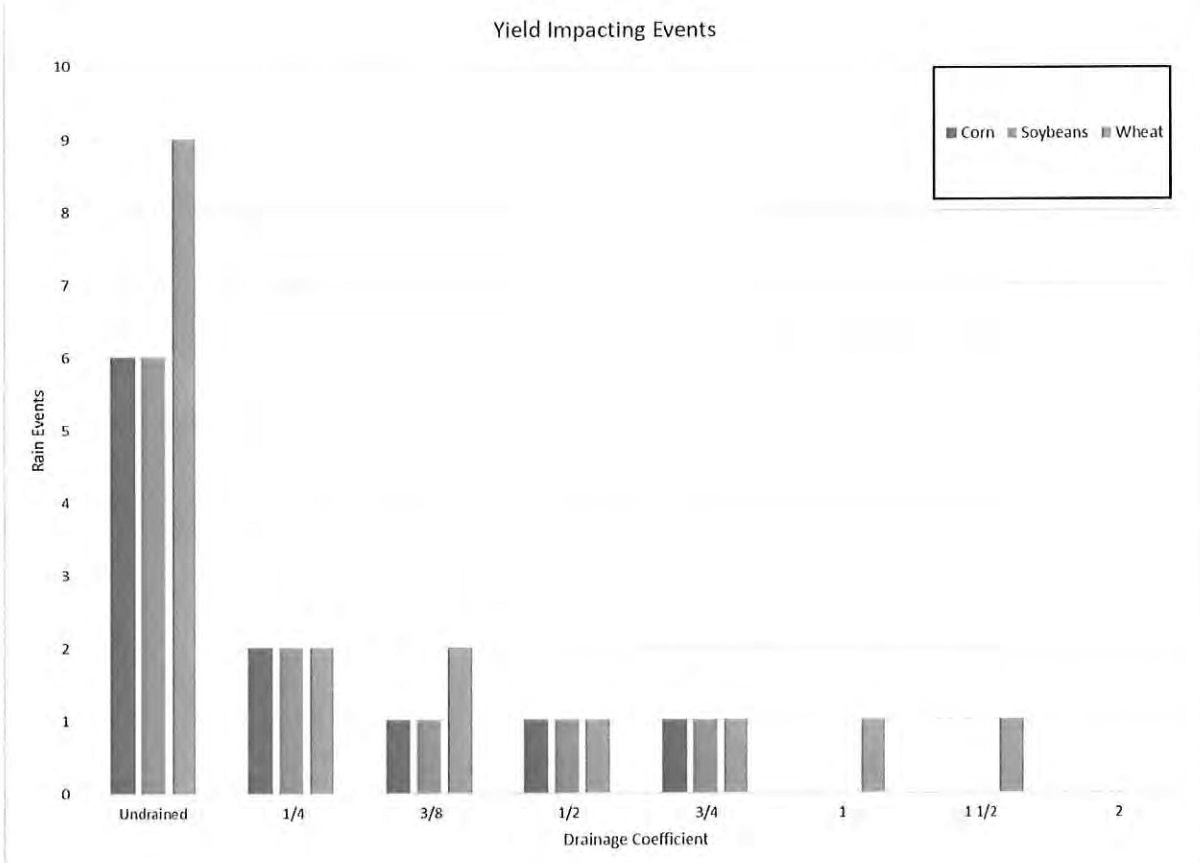
The Horizontal lines represent how much rainfall a crop can withstand before the yield is negatively impacted



***Weather provided by DTN**

YIELD IMPACTING EVENTS

The number of significant, negative yield-impacting rainfall events over the five-years on this field and the difference in impact if the field were to remain undrained as well as if tiled with different drainage coefficients.



ELLINGSON
WATER MANAGEMENT

DRAINAGE ASSESSMENT SUMMARY

DN_DR70, DR30, North, South 17,183.5 AC
Cass County, North Dakota

ELEMENT
91.5
INDEX (EI)

3/8

Your recommended drainage coefficient

Crop Initial Yield, and Price

Crop	Base Yield	Price	Units
Corn	183.5	3.38	bu/ac
Soybeans	43.7	7.86	bu/ac
Wheat	58.4	4.8	bu/ac

***Crop data from National Agricultural Statistics Service (NASS)**

Revenue Breakdow n

	Undrained Revenue	Drained Revenue	Difference
DN_DR70	$ 2,819,385.42	$ 3,416,385.61	$ 597,000.19
Dr30	$ 1,893,533.42	$ 2,290,900.41	$ 397,366.99
North	$ 1,076,688.27	$ 1,322,989.49	$ 246,301.22
South	$ 709,581.45	$ 871,209.25	$ 161,627.81
Total	**$ 6,499,188.56**	**$ 7,901,484.76**	**$ 1,402,296.21**

Total Annual Profit:
$1,402,296

Yield Increase s by Soil Type

			Yield Increases (%)		
Map Code	Map Unit	Acres	Corn	Soybeans	Wheat
I371A	Bearden-Kindred silty clay loams, 0 to 2 percent slopes	3569.1	21.8	16.5	18.5
I473A	Hegne-Fargo silty clay loams, 0 to 1 percent slopes	2609.4	24.5	18.7	20.7
I490A	Glyndon-Tiffany silt loams, 0 to 2 percent slopes	2583.1	35.1	15.4	17.1
I229A	Fargo silty clay, 0 to 1 percent slopes	1678.8	37.3	18.9	21.0
I373A	Kindred-Bearden silty clay loams, 0 to 2 percent slopes	1636.5	21.9	16.6	18.6
I238A	Fargo-Hegne silty clays, 0 to 1 percent slopes	1506.4	37.3	18.9	21.0
I469A	Fargo silty clay, moderately saline, 0 to 1 percent slopes	1002.3	23.6	18.3	20.3
I492A	Bearden-Lindaas silty clay loams, 0 to 2 percent slopes	689.6	22.2	16.5	18.5
I235A	Fargo silty clay, depressional, 0 to 1 percent slopes	386.2	37.3	19.1	21.0
I491A	Galchutt-Fargo silty clay loams, 0 to 2 percent slopes	355.4	21.8	16.8	18.9
I211A	Wyndmere loam, 0 to 2 percent slopes	283.2	24.6	9.3	21.1
I244A	Galchutt silt loam, 0 to 2 percent slopes	228	21.3	15.4	17.5
I233A	Fargo silty clay loam, 0 to 1 percent slopes	220.6	35.1	15.4	17.1
I202A	Gardena silt loam, 0 to 2 percent slopes	183.2	24.5	18.7	20.7
I119A	Bearden silty clay loam, 0 to 2 percent slopes	124	21.9	16.6	18.6
I376A	Colvin silty clay loam, 0 to 1 percent slopes	74.7	21.9	16.6	18.6
I231A	Dovray silty clay, 0 to 1 percent slopes	30.2	37.3	18.9	21.0
I472A	Perella silty clay loam, 0 to 1 percent slopes	21.6	21.9	16.6	18.6
I241A	Fargo-Ryan, thick solum silty clays, 0 to 1 percents slopes	1.2	37.3	18.9	21.0
		17183.5	**27.8**	**17.2**	**19.3**

*Yield increases were determined using DrainMod

ELLINGSON
WATER MANAGEMENT

DRAINAGE ASSESSMENT - Cass County Pilot

DRAINAGE ASSESSMENT DN_DR70

DN_DR70
7,464 AC
Cass County, North Dakota

ELEMENT
90.7
INDEX (EI

3/8

Your recommended drainage coefficient

Revenue Breakdow n by Soil Type

		Undrained Revenue			Drained Revenue			Difference		
Soil Code	Acres	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat
I119A	124	$ 25,776.76	$ 27,471.69	$ -	$ 31,421.87	$ 32,031.99	$ -	$ 5,645.11	$ 4,560.30	$ -
I371A	1486.4	$ 105,290.24	$ 341,757.72	$ 41,697.60	$ 128,243.52	$ 398,147.74	$ 49,411.66	$ 22,953.27	$ 56,390.02	$ 7,714.06
I492A	439.5	$ 823.35	$ 125,562.48	$ 16,981.79	$ 1,006.14	$ 146,280.29	$ 20,123.42	$ 182.78	$ 20,717.81	$ 3,141.63
I231A	30.2	$ 188.82	$ 8,875.90	$ -	$ 259.25	$ 10,553.44	$ -	$ 70.43	$ 1,677.54	$ -
I233A	214.1	$ 95,515.42	$ 13,189.71	$ -	$ 129,041.33	$ 15,220.92	$ -	$ 33,525.91	$ 2,031.22	$ -
I229A	623	$ 58,376.05	$ 155,982.05	$ 42.05	$ 80,150.31	$ 185,462.65	$ 50.88	$ 21,774.27	$ 29,480.61	$ 8.83
I235A	59.7	$ -	$ 19,475.43	$ -	$ -	$ 23,195.24	$ -	$ -	$ 3,719.81	$ -
I469A	476.1	$ 71,988.63	$ 114,264.13	$ -	$ 88,977.95	$ 135,174.46	$ -	$ 16,989.32	$ 20,910.34	$ -
I238A	243.3	$ 101,009.08	$ 20,972.08	$ -	$ 138,685.46	$ 24,935.81	$ -	$ 37,676.39	$ 3,963.72	$ -
I241A	1.2	$ 7.62	$ 102.44	$ -	$ 10.46	$ 121.81	$ -	$ 2.84	$ 19.36	$ -
I244A	228	$ 19,718.45	$ 62,934.07	$ -	$ 23,918.48	$ 72,625.92	$ -	$ 4,200.03	$ 9,691.85	$ -
I491A	355.4	$ 136,946.78	$ 37,312.45	$ -	$ 166,801.18	$ 43,580.94	$ -	$ 29,854.40	$ 6,268.49	$ -
I202A	183.2	$ -	$ 61,937.59	$ -	$ -	$ 73,519.92	$ -	$ -	$ 11,582.33	$ -
I490A	1442.3	$ 202,712.13	$ 330,941.47	$ 13,332.02	$ 273,864.09	$ 381,906.46	$ 15,611.79	$ 71,151.96	$ 50,964.99	$ 2,279.78
I473A	322.8	$ 87,995.62	$ 51,600.51	$ -	$ 109,554.55	$ 61,249.81	$ -	$ 21,558.93	$ 9,649.30	$ -
I373A	945.7	$ 208,034.66	$ 173,527.46	$ -	$ 253,594.25	$ 202,333.01	$ -	$ 45,559.59	$ 28,805.56	$ -
I472A	6.6	$ 4,095.99	$ -	$ -	$ 4,993.02	$ -	$ -	$ 897.02	$ -	$ -
I211A	283.2	$ 4,955.17	$ 53,342.75	$ 24,647.25	$ 6,174.14	$ 58,303.63	$ 29,847.81	$ 1,218.97	$ 4,960.88	$ 5,200.57
sum 7464.7		**$ 1,123,434.78**	**$ 1,599,249.94**	**$ 96,700.70**	**$ 1,436,696.00**	**$ 1,864,644.05**	**$ 115,045.56**	**$ 313,261.22**	**$ 265,394.11**	**$ 18,344.86**
Total Revenue		**$ 2,819,385.42**			**$ 3,416,385.61**			**$ 597,000.19**		

Total Annual Profit:

$597,000

Annual Profit Per Acre:

$79.9

DRAINAGE ASSESSMENT DR30

DR30 5,109
AC
Cass County, North Dakota

LEMENT
92.3
INDEX (EI

3/8

Your recommended drainage coefficient

Revenue Breakdow n by Soil Type

		Undrained Revenue			Drained Revenue			Difference		
Soil Code	Acres	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat
I371A	945	$ 125,577.97	$ 177,119.93	$ 54,011.38	$ 152,953.97	$ 206,344.72	$ 64,003.49	$ 27,376.00	$ 29,224.79	$ 9,992.11
I492A	81.6	$ 184.42	$ 22,448.58	$ -	$ 225.36	$ 26,152.60	$ -	$ 40.94	$ 3,704.02	$ -
I376A	74.7	$ 27,705.67	$ 7,436.39	$ 2,329.46	$ 33,773.22	$ 8,670.83	$ 2,762.74	$ 6,067.54	$ 1,234.44	$ 433.28
I233A	6.5	$ 3,907.45	$ 54.96	$ -	$ 5,278.96	$ 63.42	$ -	$ 1,371.51	$ 8.46	$ -
I229A	925.8	$ 22,053.77	$ 285,517.80	$ 126.66	$ 30,279.83	$ 339,480.66	$ 153.26	$ 8,226.06	$ 53,962.86	$ 26.60
I235A	232.9	$ 26,855.96	$ 50,203.33	$ -	$ 36,873.23	$ 59,792.16	$ -	$ 10,017.27	$ 9,588.84	$ -
I469A	7.9	$ -	$ 2,462.77	$ -	$ -	$ 2,913.45	$ -	$ -	$ 450.69	$ -
I238A	400.5	$ 92,222.00	$ 79,938.57	$ 120.54	$ 126,620.80	$ 95,046.95	$ 145.85	$ 34,398.81	$ 15,108.39	$ 25.31
I490A	1140.8	$ 104,676.22	$ 288,394.36	$ 10,741.86	$ 141,417.57	$ 332,807.09	$ 12,578.72	$ 36,741.35	$ 44,412.73	$ 1,836.86
I473A	724.6	$ 162,145.36	$ 153,204.09	$ -	$ 201,870.98	$ 181,853.26	$ -	$ 39,725.61	$ 28,649.17	$ -
I373A	553.7	$ 38,646.53	$ 138,536.60	$ 9,755.14	$ 47,110.12	$ 161,533.67	$ 11,569.59	$ 8,463.59	$ 22,997.07	$ 1,814.46
I472A	15	$ 5,290.56	$ 1,865.11	$ -	$ 6,449.19	$ 2,174.72	$ -	$ 1,158.63	$ 309.61	$ -
sum	5109	$ 609,265.91	$ 1,207,182.47	$ 77,085.04	$ 782,853.23	$ 1,416,833.53	$ 91,213.65	$ 173,587.32	$ 209,651.06	$ 14,128.61
Total Revenue		$ 1,893,533.42			$ 2,290,900.41			$ 397,366.99		

Total Annual Profit:

$397,366

Annual Profit Per Acre:

$77.7

DRAINAGE ASSESSMENT – Cass County Pilot

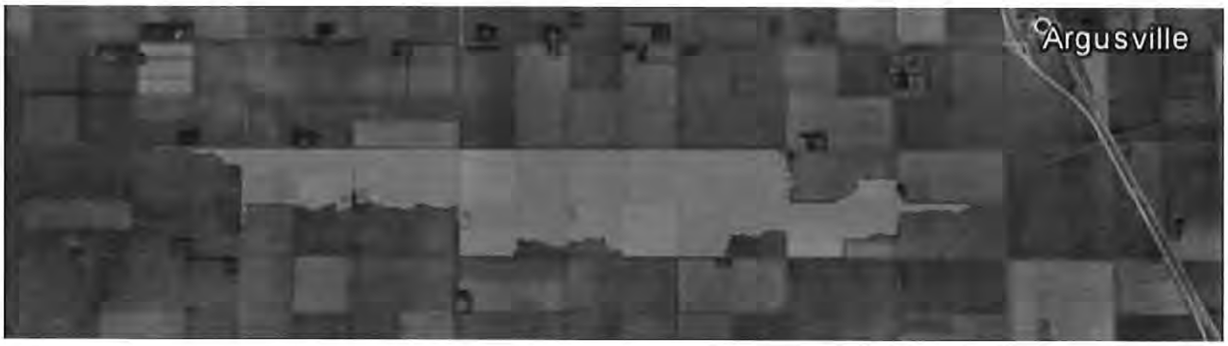
DRAINAGE ASSESSMENT NORTH

North 2,813
AC
Cass County, North Dakota

ELEMENT
92.1
INDEX (EI

3/8

Your recommended drainage coefficient



Revenue Breakdow n by Soil Type

		Undrained Revenue			Drained Revenue			Difference		
Soil Code	Acres	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat
I371A	911.2	$ 110,109.43	$ 187,767.87	$ 36,343.49	$ 134,113.29	$ 218,749.57	$ 43,067.03	$ 24,003.86	$ 30,981.70	$ 6,723.55
I492A	168.5	$ 10,686.56	$ 19,612.82	$ 23,958.95	$ 13,058.98	$ 22,848.94	$ 28,391.36	$ 2,372.42	$ 3,236.12	$ 4,432.41
I229A	25.5	$ 5,271.96	$ 37.78	$ 1,264.24	$ 7,238.39	$ 44.92	$ 1,529.73	$ 1,966.44	$ 7.14	$ 265.49
I235A	77.6	$ 11,821.58	$ 18,201.11	$ 299.94	$ 16,231.03	$ 21,677.52	$ 362.93	$ 4,409.45	$ 3,476.41	$ 62.99
I469A	143	$ 18,984.39	$ 33,274.24	$ 2,300.19	$ 23,464.71	$ 39,363.43	$ 2,767.13	$ 4,480.32	$ 6,089.19	$ 466.94
I238A	499	$ 134,292.20	$ 2,177.68	$ 3,033.06	$ 184,383.19	$ 2,589.26	$ 3,670.01	$ 50,090.99	$ 411.58	$ 636.94
I473A	851.8	$ 282,284.32	$ 115,757.70	$ 5,102.82	$ 351,443.98	$ 137,404.39	$ 6,159.11	$ 69,159.66	$ 21,646.69	$ 1,056.28
I373A	137.1	$ 25,341.22	$ 28,764.70	$ -	$ 30,890.94	$ 33,539.64	$ -	$ 5,549.73	$ 4,774.94	$ -
sum 2813.7		$ 598,791.66	$ 405,593.90	$ 72,302.70	$ 760,824.52	$ 476,217.67	$ 85,947.30	$ 162,032.85	$ 70,623.76	$ 13,644.60
Total Revenue		$ 1,076,688.27			$ 1,322,989.49			$ 246,301.22		

Total Annual Profit:

$246,301

Annual Profit Per Acre:

$87.55

DRAINAGE ASSESSMENT SOUTH

North 1,796
AC
Cass County, North Dakota

ELEMENT
91.3
INDEX (EI)

3/8

Your recommended drainage coefficient

Revenue Breakdow n by Soil Type

		Undrained Revenue			Drained Revenue			Difference		
Soil Code	Acres	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat
I371A	226.5	$ 921.82	$ 70,741.62	$ 4,502.86	$ 1,122.78	$ 82,413.98	$ 5,335.89	$ 200.96	$ 11,672.37	$ 833.03
I229A	104.5	$ 28,511.97	$ 6,941.77	$ 6,147.42	$ 39,146.94	$ 8,253.77	$ 7,438.38	$ 10,634.97	$ 1,311.99	$ 1,290.96
I235A	16	$ 5,371.19	$ 2,517.72	$ -	$ 7,374.65	$ 2,998.61	$ -	$ 2,003.45	$ 480.89	$ -
I469A	375.3	$ 116,150.47	$ 42,612.38	$ -	$ 148,858.45	$ 50,005.62	$ -	$ 32,707.97	$ 7,393.25	$ -
I238A	363.6	$ 21,008.15	$ 95,245.96	$ 13,269.09	$ 28,844.19	$ 113,247.45	$ 16,055.60	$ 7,836.04	$ 18,001.49	$ 2,786.51
I473A	710.2	$ 150,685.04	$ 122,468.54	$ 22,485.44	$ 187,602.87	$ 145,370.16	$ 27,139.93	$ 36,917.83	$ 22,901.62	$ 4,654.49
sum	**1796.1**	**$ 322,648.65**	**$ 340,527.99**	**$ 46,404.81**	**$ 412,949.87**	**$ 402,289.59**	**$ 55,969.79**	**$ 90,301.23**	**$ 61,761.60**	**$ 9,564.98**
Total Revenue		**$ 709,581.45**			**$ 871,209.25**			**$ 161,627.81**		

Total Annual Profit:

$161,627

Annual Profit Per Acre:

$89.99

DRAINAGE ASSESSMENT: TERMS DEFINED

Find key water management terms used throughout the assessment defined and explained further below:

Drainage Coefficient: **The design capacity of a drainage system expressed as a depth of water removed in 24 hours (inches/day). For example, a ½ drainage coefficient means the system can remove ½ of an inch of water in a day. A drainage coefficient should be chosen that will economically remove excess water from the top part of the root zone within 24 to 48 hours.**

Crop Productivity Index (CPI): **A 1-100 rating comes from the Natural Resources Conservation Service to provide a relative ranking of soils based on their potential for intensive crop production. This productivity index can be used to rate the potential yield of one soil against that of another over a period of time.**

Element Index (EI): **Our 1-100 index that quantifies each field's potential drainage benefit based off its soil properties, yield potential, and other agronomic factors.**

Spacing: **The distance between lateral drain tiles. Drain spacing is determined based on the following fac tors: soil type, soil permeability and stratification, crop rotation, the desired drainage coefficient, and the degree of surface drainage.**

K SAT: **Hydraulic conductivity (K) or saturated hydraulic conductivity is a measurement of the soil's ability to transmit water, or how easily the water is permitted to move through the pores of saturated soil.**

Yield Impacting Event: **A weather event that causes a crop to become saturated long enough to cause harm and forfeit yield potential. While agriculture in the United States continues to achieve enhanced productivity, it is also experiencing greater variability in crop yields and associated farm income in recent decades. This increased yield variability is, in part, directly related to increases in extreme weather events during critical growth phases of crop development.**

% Yield Increase: **Yield gains accumulated from proper drainage. Yield can be increased by proper drainage enabling timely planting in a wet spring, or by factors like less yield-loss potential during wet periods in the growing season, fewer plant diseases and less soil compaction.**

Drainage Classes: Natural drainage class refers to the frequency and duration of wet periods under conditions similar to those under which the soil developed. Alteration of the water regime by man, either through drainage or irrigation, is not a consideration unless the alterations have significantly changed the morphology of the soil. The classes follow:

i. Excessively Drained – Water is removed very rapidly. The occurrence of internal free water commonly is very rare or very deep. The soils are commonly coarse-textured and have very high hydraulic conductivity or are very shallow.

ii. Somewhat Excessively Drained – Water is removed from the soil rapidly. Internal free water occurrence commonly is very rare or very deep. The soils are commonly coarse-textured and have high saturated hydraulic conductivity or are very shallow.

iii. Well Drained – Water is removed from the soil readily but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Water is available to plants throughout most of the growing season in humid regions. Wetness does not inhibit growth of roots for significant periods during most growing seasons. The soils are mainly free of the deep to redoximorphic features that are related to wetness. Sometimes

well drained soils can be subject to a high-water table in the Spring and Early Summer and may still require tile drainage.

iv. Moderately Well Drained – Water is removed from the soil somewhat slowly during some periods of the year. Internal free water occurrence commonly is moderately deep and transitory through permanent. The soils are wet for only a short time within the rooting depth during the growing season, but long enough that most mesophytic crops are affected. They commonly have a moderately low or lower saturated hydraulic conductivity in a layer within the upper 1 m, periodically receive high rainfall, or both.

v. Somewhat Poorly Drained – Water is removed slowly so that the soil is wet at a shallow depth for significant periods during the growing season. The occurrence of internal free water commonly is shallow to moderately deep and transitory to permanent. Wetness markedly restricts the growth of mesophytic crops, unless artificial drainage is provided. The soils commonly have one or more of the following characteristics: low or very low saturated hydraulic conductivity, a high-water table, additional water from seepage, or nearly continuous rainfall.

vi. Poorly Drained – Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods. The occurrence of internal free water is shallow or very shallow and common or persistent. Free water is commonly at or near the surface long enough during the growing season so that most mesophytic crops cannot be grown, unless the soil is artificially drained. The soil, however, is not continuously wet directly below plow-depth. Free water at shallow depth is usually present. This water table is commonly the result of low or very low saturated hydraulic conductivity of nearly continuous rainfall, or of a combination of these.

vii. Very Poorly Drained – Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season. The occurrence of internal free water is very shallow and persistent or permanent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soils are commonly level or depressed and frequently ponded. If rainfall is high or nearly continuous, slope gradients may be greater.

Undrained Scenario: A scenario in which soil drains naturally without the aid of installed drainage practices.

RED RIVER BASIN
COMMISSION