

# Byron #1 Field Study

## Groundwater Monitoring Report

February 2022

Minnesota Department of Agriculture  
Pesticide and Fertilizer Management Division

# Introduction

## Background and Partners

The Byron #1 Field Study began in 2014 and includes the monitoring of nitrate movement below an irrigated agricultural field recently transitioned from managed timberland. This field is located in Byron Township, Cass County, Minnesota. The project is supported by a core group of partners from both the private and public sectors (see box below).

The property is managed cooperatively by CLC and the landowner with each raising crops throughout the rotation. The remaining partners fill supporting roles that help inform management decisions. The MDA monitors soil pore water and groundwater nitrate concentrations below and around the field, NWATS monitors groundwater quality, movement, and water levels and provides related consultation, the U of M has been involved in irrigation management, and SFA advises the group about soil health matters including cover crops.

The core project team members are:

- Central Lakes College, Staples (CLC)
- The Minnesota Department of Agriculture (MDA)
- University of Minnesota Extension (U of M)
- Northwest AqwaTek Solutions (NWATS)
- Sustainable Farming Association of Minnesota (SFA)
- The cooperating landowner

Monitoring for nitrate concentrations in the soil and shallow groundwater of Byron #1 began in 2014, the first year of crop production. Nitrate in groundwater is of interest because it can be detrimental to the health of infants if consumed in water or formula at concentrations above 10 mg/L for nitrate as nitrogen. Nitrate is a common form of plant-available nitrogen and can come from nitrogen fertilizer, manure, or the breakdown of soil organic matter. If not utilized by plants or retained in soil organic material, nitrate can be moved by water through the soil profile and into the groundwater.

## Purpose and Objectives

The overall mission of the partnership is to “design and execute a land management plan that fosters soil health and provides adaptive management options that can be replicated to ultimately balance financial and environmental sustainability.”

Specific to the study at Byron #1, the purpose of the work is to help researchers, the ag industry, and government better understand the potential for groundwater quality impacts from irrigated agriculture on loamy sands with shallow water tables. This is being accomplished by monitoring nitrate concentrations and movement under careful agronomic management over time and throughout the crop rotation. This directly ties in with the overall project objectives:

1. Maintain a healthy and balanced ecosystem.
2. Utilize agricultural best management practices.
3. Monitor groundwater flow and quality.
4. Study changes in quality of soil pore water under various cropping rotations.

Currently, the work at Byron #1 is focused on scientific monitoring, environmental sustainability, and less on economic profitability. However, the long-term goal is for the work to be both economically profitable and environmentally sustainable.

## Factors in Nitrate Movement

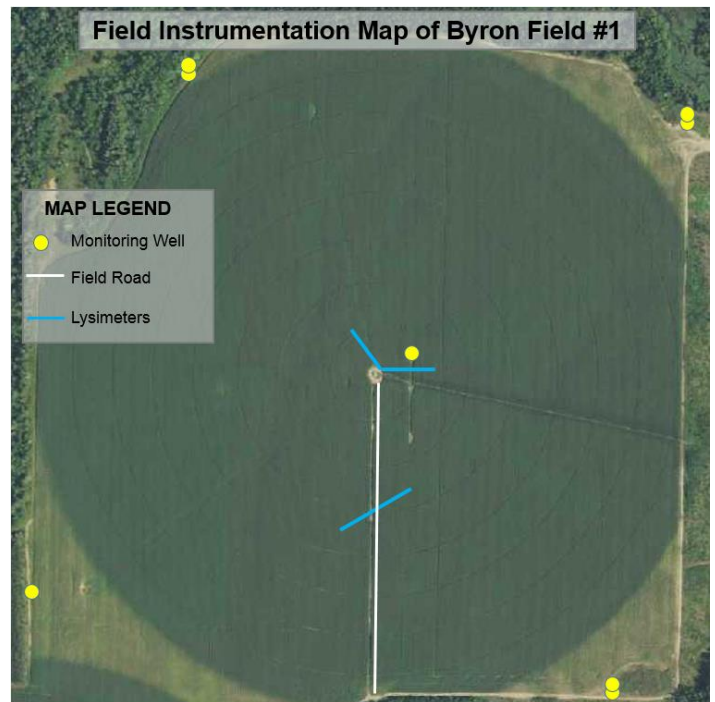
Nitrate is highly soluble in water and moves with the water within the soil. Groundwater is typically more vulnerable to nitrate contamination under coarse-textured soils than finer textured soils. Coarse-textured sandy soils can hold less water and have faster water movement compared to finer textured soils. Some factors impacting soil water movement and nitrate loss such as timing and intensity of precipitation or the soil texture conditions are outside the control of the farm manager. Other factors impacting water and nitrate movement include soil moisture monitoring and irrigation water management which aim to provide adequate water without over application.

Nitrate movement is also impacted by the crop being grown—the crop’s nitrogen needs, its efficiency in nitrogen uptake, and the timing of its growth. Weather and available soil moisture impact crop growth and, therefore, impact efficiency of nitrogen uptake. Weather also impacts mineralization, the breakdown of soil organic matter resulting in the release of nitrogen and other plant nutrients to the soil. Mineralization continues after the primary crop is no longer actively taking up nutrients, leaving unutilized nitrogen in the soil that can be lost as nitrate below the crop root zone. Cover crops can help manage nitrate movement by capturing and recycling nutrients present in the soil profile outside the growing season. Additionally, cover crops can utilize soil moisture when the primary crop is not actively growing—and potentially reduce the risk of nitrate loss.

## Materials and Methods

### Site Characteristics

Byron #1 has been established on 160 acres that was previously managed for timber production and most recently harvested in 2012. After timber harvest, the land was purchased for irrigated agricultural production, and a drop-nozzle, center pivot irrigation system covering 129 acres was installed in the field in 2014. The irrigation system has telemetric control capabilities that allow operators to monitor, start, or stop its operation remotely from a computer or smart phone. The soil at the site is predominantly Friendship loamy sand and Menahga loamy sand. Groundwater is 10-20 feet below the field’s surface. Meteorological information is available from a weather station from the Central Minnesota Agricultural Weather Network located at the CLC campus, within 15 miles of the site. Rainfall information is collected using manual rain gauges at the site.



Nitrate movement in Byron #1 is being monitored using suction tube lysimeters to collect water from soil pores at a four-foot depth and monitoring wells in the shallow aquifer around the field.

### Cropping History and Nitrogen Management

Because of the characteristics of Byron #1, farm operators maintain a crop rotation, nitrogen management and other agronomic management decisions focused on reducing nitrate loss beneath the field. The team is using an adaptive approach to management—actively using monitoring data to inform decisions on crop type and to fine-tune nitrogen management.

Crop rotation and environmental sustainability have been focal points for agronomic management. As the transition to row crop agriculture was finalized, the land was cleared in 2013, and the following crops have been grown.

In addition to these crops, CLC and the landowner were able to establish cover crops in 2016, 2017, 2018, and 2020 following harvest of the primary crop. Beginning in 2016, the management team decided to focus the crop rotation exclusively on crops with low nitrogen fertilizer requirements such as rye, seed potatoes, peas, barley, and soybeans.

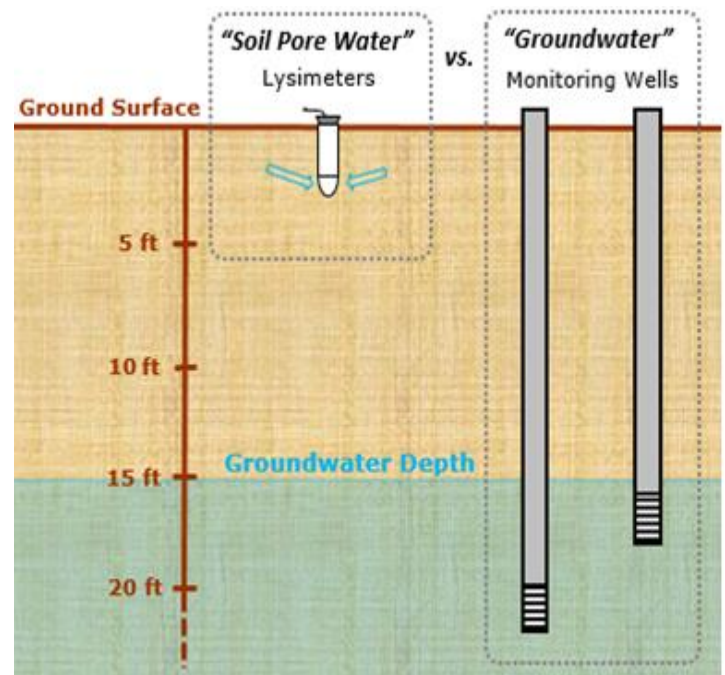
In addition to a specialized crop rotation, agronomic management has included the use of nitrogen fertilizer Best Management Practices (BMPs): following U of M nitrogen rate guidelines, using split applications of nitrogen fertilizer, and incorporating nitrogen fertilizer into the soil with tillage or irrigation. The project includes cover crops to promote soil health and to capture and hold nitrogen for the following season.

Year	Crop Type
2014	Soybeans
2015	Corn
2016	Soybeans
2016 Fall	Cover Crop Planted
2017	Rye
2017 Fall	Cover Crop Planted
2018	Peas
2018 Fall	Cover Crop Planted
2019	Soybeans
2020	Barley
2020 Fall	Cover Crop Planted
2021	Soybeans

The work at Byron #1 has included irrigation management tools and has incorporated support from the University of Minnesota's irrigation specialist. Irrigation management has been done by experienced operators examining the soil to assess irrigation needs during the growing season. The project has also utilized soil moisture sensors and the irrigation checkbook method to help inform irrigation management decisions.

### Soil Water Monitoring: Suction Tube Lysimeters

Suction tube lysimeters in Byron #1 are used to collect water from the soil's unsaturated zone beyond the reach of crop roots. Fifteen lysimeters were installed in 2014 at a depth of four feet. The tips of the lysimeters are made of a porous ceramic material. When vacuum is applied to lysimeters, water from the soil is drawn in through these ceramic tips. From April through November, water is collected from the lysimeters weekly and analyzed for nitrate concentration using an ultraviolet spectrophotometer. Results are averaged to account for variability and to gain more representative information. For quality assurance, 10% of the samples are tested by a certified lab in addition to being tested with the spectrophotometer.

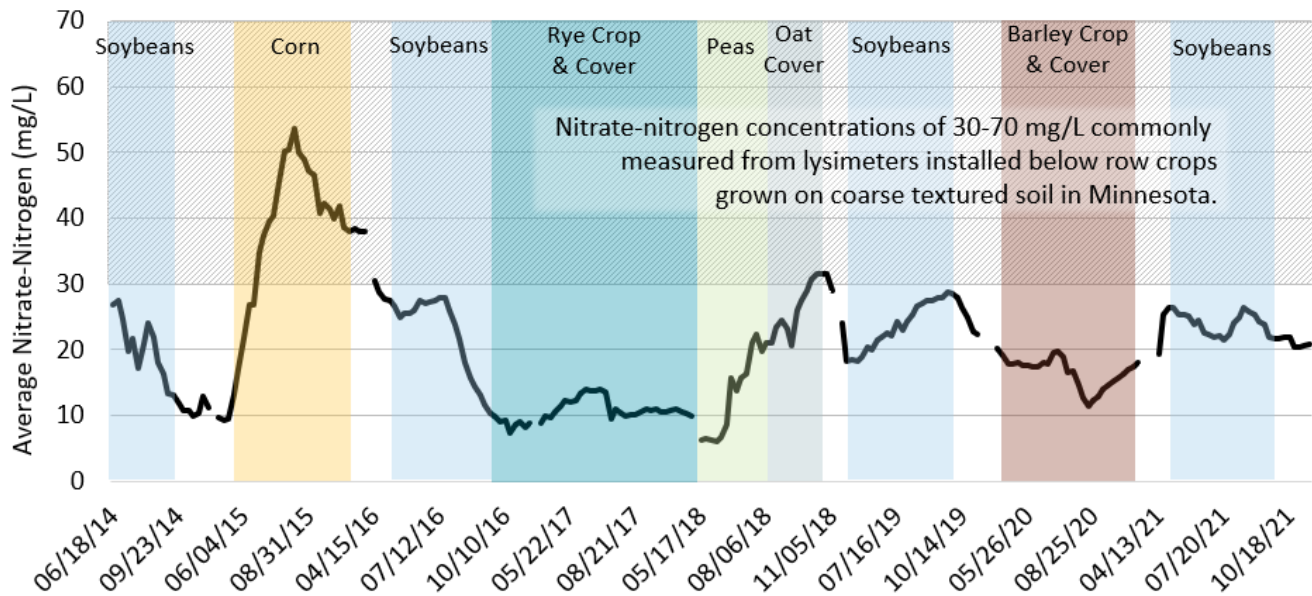


This image illustrates the vertical difference between soil pore water collected in lysimeters versus groundwater collected in monitoring wells.



## Byron #1 Soil Pore Water Nitrate-Nitrogen Concentration Data

Soil water collected from lysimeters placed 4 feet below the field surface

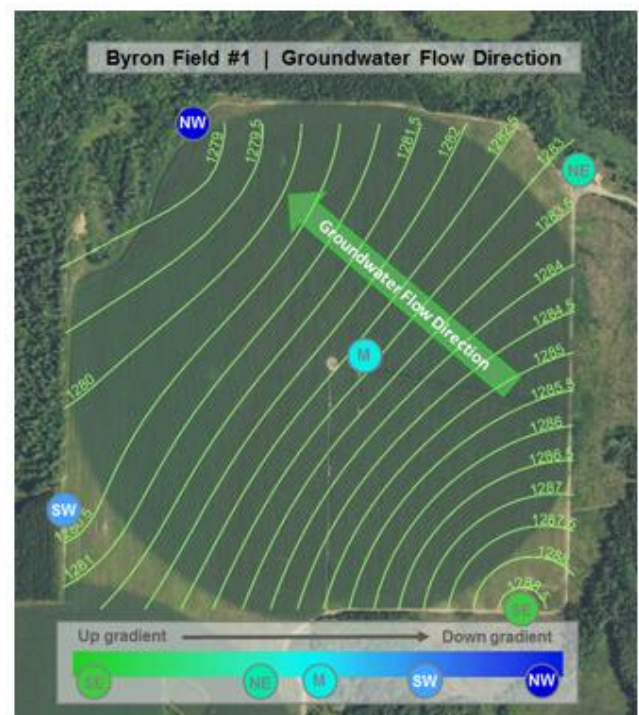


The black line in the graph above shows the average soil pore water nitrate-nitrogen concentrations observed at four feet below the field surface of Byron #1 from 2014 through 2021. Nitrate-nitrogen measured below other similar field demonstration sites throughout Central Minnesota has ranged from 30-70 mg/L throughout rotations that include corn, soybeans, potatoes, and edible beans.

## Groundwater Monitoring

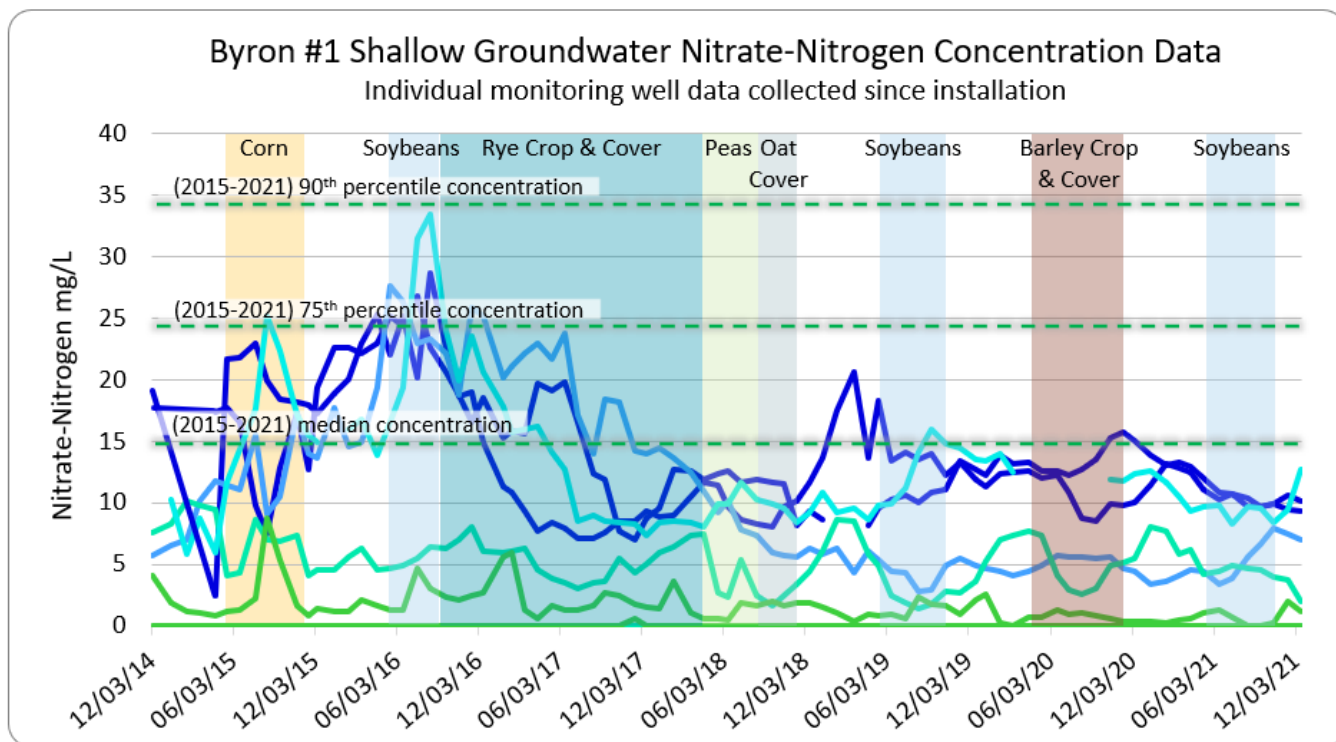
The Minnesota Department of Agriculture worked with the Minnesota Department of Natural Resources to install seven shallow monitoring wells around the perimeter of Byron #1, and partners have provided access to an additional well near the center of the field. Depths of these wells range 8-22 feet. Wells are paired, where possible, with one positioned to collect water from near the water table and the other 4.5 feet deeper in the aquifer. Groundwater monitoring in the field began in December 2014 following the first year of crop production. Groundwater samples are collected each month and analyzed for nitrate concentrations.

The location and depth of the eight monitoring wells used in this study are illustrated in the image and table shown on the right. The nitrate-nitrogen data collected from these wells is shown in graphic form on the following page.



Byron #1 monitoring well depth in feet

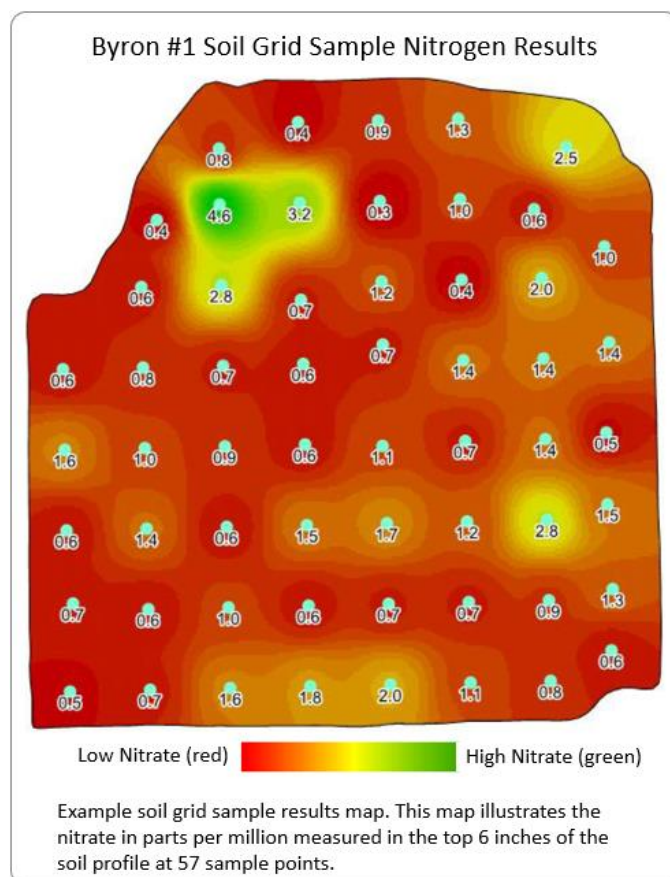
Southeast Wells	Northeast Wells	Middle Well	Southwest Well	Northwest Wells
SE	NE	M	SW	NW
11.4	17.7	22.0	16.2	8.1
16.2	22.2			12.7



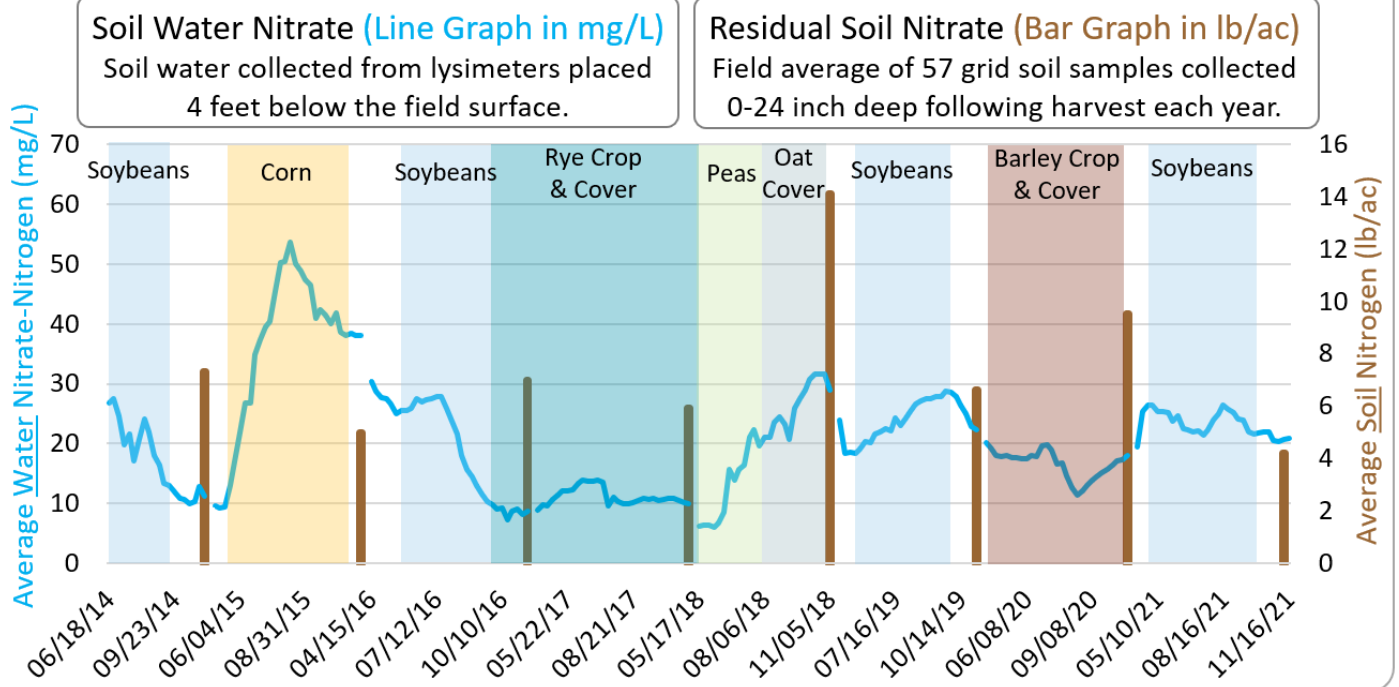
The solid lines in the graph above show the nitrate-nitrogen concentrations measured from individual monitoring wells placed around the perimeter of Byron #1. The dashed horizontal lines illustrate statistical benchmarks for comparable nitrate-nitrogen data collected from Minnesota Department of Agriculture monitoring wells in central Minnesota in 2015-2021. This monitoring network employs shallow wells at the edge of agricultural fields very similar to the wells placed near Byron #1. This comparable dataset includes information from 88 well sites and 578 samples collected throughout a 14-county area in central Minnesota that includes Cass County where the Byron #1 field is located. 85% of the groundwater nitrate-nitrogen samples collected at Byron #1 fall below the median concentration of samples collected from this central Minnesota monitoring network.

## Soil Grid Sampling

Byron #1 has had soil grid sampling done each year after harvest since 2014. For the sampling, the field is divided into 2.5-acre grids, and a composite sample is collected from each of the 57 grids. The soil is sent to a lab and analyzed for organic matter, nitrate-N, phosphorus, and potassium. This analysis provides useful information about nitrate concentration, transformation and movement in the soil and is used by farm operators to manage soil fertility.



### Byron #1 Soil Pore Water AND Residual Soil Nitrogen Data



The figure above illustrates the relative difference between nitrate-nitrogen concentrations in soil pore water during the season and in the soil following harvest. Soil pore water concentration (mg/L) is measured at a discrete point in the soil profile four feet below the soil surface. The soil nitrate concentration (lb/ac) is a composite of the top two feet of the soil profile. Because of the relationship between soil nitrate content and nitrate concentration in the water a relative comparison can be made. However, it should not be assumed that all of the soil nitrate measured at the end of the growing season will be lost to the groundwater during the late fall and early spring. Many factors including soil texture, organic matter, temperature, moisture, crop type and rooting system influence nitrate concentration and movement. The soil nitrate levels measured in this field following harvest are relatively low.

### Byron #1 Post-harvest Soil Grid Sample Results

(Field average measured from 0-6 and 6-24 inch depths)

Year	Organic Matter (%) 0-6 inch	Organic Matter (%) 6-24 inch	Nitrogen (lb/acre) 0-6 inch	Nitrogen (lb/acre) 6-24 inch	Nitrogen (lb/acre) 0-24 inch
2014	1.7	0.5	3.5	3.8	7.3
2015	1.0	0.4	1.8	3.2	5.0
2016	1.0	0.6	3.3	3.7	7.0
2017	1.3	0.4	1.9	4.0	5.9
2018	1.2	0.4	6.7	7.4	14.1
2019	1.1	0.5	2.3	4.3	6.6
2020	1.4	0.4	7.2	2.3	9.5
2021	1.1	0.3	3.3	0.9	4.2

# Summary

The study underway at Byron #1 is intended to further our understanding about nitrogen fertilizer impacts to groundwater in this landscape. Researchers, the ag industry, government agencies, and the public need scientific data like this to inform their conversations on the topic. In the first few years of the study, the shallow groundwater monitoring data collected indicates some impact from row crop production on the land's surface. More recently, however, that same groundwater monitoring data has shown improvement in water quality that is associated with changes in the cropping and fertilizer management practices.

Careful cropping and nitrogen fertilizer management decisions that balance both economic and environmental considerations are critical to reducing the risk of nitrogen fertilizer loss to groundwater. Study data from Byron #1 shows that management efforts have reduced impacts to water quality, but financial data shows a negative net return in six out of the first eight years (see Appendix). Additional study is needed as the project team works to balance economic and environmental goals. The groundwater monitoring at this field is intended to be a long-term effort lasting ten years or more. Ongoing monitoring of water quality data will allow future discussion and project conclusions following observation under varied weather patterns and repeated cropping rotations.

For questions related to the data summarized in this report you may contact:

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### Financial Appendix

#### Byron #1 Financial Data\*

Year	Crop	Yield Bu/Acre	Total Direct Expenses	Total Overhead Expenses	Total Expenses	Total Gross Return	Net Return Per Acre
2014	Soybeans	22	\$310.58	\$154.44	\$465.02	\$230.00	-\$235.02

2014 financial data is listed but not included in project totals because it was an atypical agronomic and financial year. There were additional transition costs to remove woody debris and prepare the field for planting; and because soil conditions were acidic, the field needed lime to optimize nutrient uptake.

Year	Crop	Yield Bu/Acre	Total Direct Expenses	Total Overhead Expenses	Total Expenses	Total Gross Return**	Net Return Per Acre**
2015	Corn	170	\$658.49	\$30.94	\$689.43	\$569.50	-\$119.93
2016	Soybeans	50	\$399.47	\$45.33	\$444.80	\$501.00	\$56.20
2017***	Rye	39	\$145.98	\$70.17	\$216.15	\$133.77	-\$82.38
2018***	Peas	32.5	\$184.08	\$58.87	\$242.95	\$225.43	-\$17.52
2019	Soybeans	39	\$402.73	\$12.78	\$415.51	\$404.74	-\$10.77
2020	Barley	70	\$351.49	\$20.77	\$372.26	\$331.80	-\$40.46
2021	Soybeans	46	\$429.88	\$19.37	\$449.25	\$529.00	\$79.75
2015-2021	All crops						-\$135.11†

\*Provided by Central Lakes College (CLC) Ag and Energy Center

\*\*CLC is a public entity and not eligible for federal farm payment programs; examples include Paycheck Protection Program, Coronavirus Food Assistance Program, Market Facilitation Program. If eligible, these payments would increase the net return.

\*\*\*Based on area averages; CLC was not the operating entity

†Agronomic practices have been performed with environmental sustainability as the primary consideration; financial return has been second

The direct expenses entered in the crop budgets are expenses that are directly related to the number of acres on the farm. Direct expenses for Byron #1 include seed, fertilizer, chemicals, irrigation expenses, marketing, land rent, and crop insurance. In some cases, the term "Variable Expenses" is used as these expenses vary from year to year.

The overhead expenses, sometimes referred to as "Fixed Expenses," are those types of expenses for an enterprise that tend to occur annually. That is, they are more of a fixture to the farming operation as a whole and need to be allocated to an enterprise for payment. Fixed expenses for Byron #1 include depreciation on buildings and equipment, staff salaries, and other CLC Farm overhead costs such as maintenance.

The website [www.finbin.umn.edu](http://www.finbin.umn.edu) is where all the data collected on individual farms across the state of Minnesota and beyond is "binned." One can access an enterprise and query a search regarding many areas such as row width comparisons, impact of technologies employed, tillage methods and so on. The data is thoroughly reviewed annually for accuracy and comes from the producers themselves that are enrolled in the Farm Business Management program.