# Impacts of 4R Nitrogen Management on Crop Production and Nitrate-Nitrogen Loss in Tile Drainage

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## I. Background

Corn and soybean producers in Iowa and throughout much of the U.S. Corn Belt are increasingly challenged to maximize crop production to supply feed, fiber, and more recently biofuels (especially ethanol from corn) while at the same time managing soils by utilizing fertilizers and animal manures efficiently and minimizing negative impacts on water quality. In particular, there is concern about nutrient export from subsurface drainage and surface water runoff to water systems in Iowa and the Gulf of Mexico. In addition to local impacts on receiving waters, nitrogen (N) and phosphorous (P) loads from U.S. Corn Belt are suspected as primary drivers of hypoxia in the Gulf of Mexico (Dale et al., 2010). The EPA SAB's 2007 hypoxia reassessment identified both N and P as major contributors to Gulf hypoxia and the 2008 Action Plan called for a dual nutrient strategy of 45% reductions in both N and P loads.

Relative to N loss, nitrate-N is the predominant form in many agricultural watersheds due to subsurface drainage or shallow subsurface flow (Baker et al., 2008). Nitrate-N loading from the Mississippi River is suspected to be a main contributor to the hypoxic zone in the Gulf of Mexico (Rabalais et al., 2001), and the main source of nitrate-N in the Mississippi River Basin has been linked to subsurface drainage in the Midwest (Lowrance, 1992; Keeney and DeLuca, 1993; David et al., 1997; Zucker and Brown, 1998). Based on the need for nitrate-N reductions to meet water quality goals, new management practices are needed that have the potential to significantly reduce nitrate-N losses at minimal cost and/or provide economic benefits. Practices are needed that will address the right source at the right rate in the right place. In addition, there is a need to quantify the water quality and crop yield impacts of some traditionally recommended best nutrient management practices such as timing of N application The Iowa Nutrient Reduction Strategy Science Assessment has indicated nitrate-N loss improvement with certain practices, such as time of application (spring versus fall) and nitrification inhibitor. However, the published data available for the science assessment was limited for those practices, especially from Iowa research. Also, the practice of split or in-season application had indication of limited benefit to tile drainage nitrate-N reduction. Among other practices, the Iowa Nutrient Reduction Strategy specifically identified in-season sensor-based nitrogen application and nitrogen inhibitors needing of future research that would concurrently document crop production and water quality (nitrate-N loss) effects.

## II. Project Objectives

As part of this field research and demonstration project, we propose to evaluate various promising N management methods and technologies by documenting the nitrate-N export and crop yield from several systems (Table 1). The specific objectives of this project are to:

1. Determine the effects of N fertilizer application and N fertilizer application timing on nitrate-N leaching losses along with potential impacts on crop yield.
2. Determine the effects of N fertilizer application and N fertilizer application timing on crop yield.
3. Disseminate project findings through peer-reviewed journal articles, Extension fact sheets, Extension presentations, and other outlets as appropriate; and provide needed scientific information for on-going review and adjustment of the Nutrient Reduction Strategy Science Assessment.

Table 1. Treatments at the Northwest Iowa Tile Drain Water Quality Study Site.

| Treatment Number | Tillage | Nitrogen Application Time | Nitrogen Application Rate (lb N/acre)* |
|---|---|---|---|
| 1 | Conventional tillage** | Fall (Anhydrous Ammonia with nitrapyrin) | 135 |
| 2 | Conventional tillage | Spring (Anhydrous Ammonia) | 135 |
| 3 | Conventional tillage | Split with variable N at sidedress (40 lb/acre of UAN at planting plus in-season adjusted rate no later than mid-vegetative growth stage) | Yearly variable based on in-season adjusted rate |
| 4 | Conventional tillage | None | 0 |

***** For corn plots only. The 135 lb N/acre rate is based on the Corn Nitrogen Rate Calculator output for corn following soybean in Iowa at a 0.10 price ratio (http://extension.agron.iastate.edu/soilfertility/nrate.aspx).
** Fall chisel corn stalks with spring disk/field cultivate, and spring disk/field cultivate soybean stubble.

We believe there is a need for direct water quality measurements associated with these practices as there is currently a lack of adequate water quality assessment. This project would specifically address the Right Time and Right Rate of N application and would be conducted in northwestern Iowa which is a nutrient hotspot in the Upper Mississippi River Basin (Figure 1). To assess site response to nitrogen and the overall limit of nitrate-N reduction that might be achievable with nitrogen management we have included a treatment with no nitrogen application (treatment 4). We have a history of publishing information from similar sites and this information was heavily used by decision makers in assessments of the potential impacts of various management practices (Lawlor et al., 2008; Qi et al., 2011; Lawlor et al., 2011; and Helmers et al., 2012).

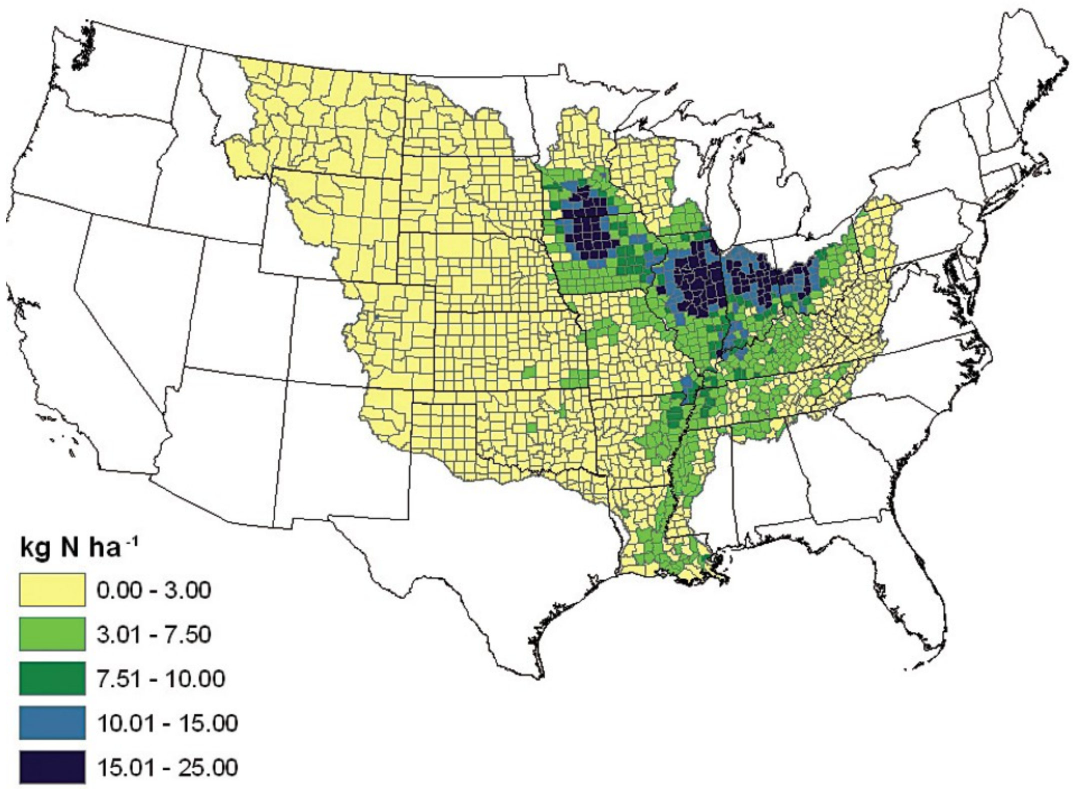



Figure 1. Predicted average riverine nitrate N yield, January to June, for all counties in the Mississippi River basin for the period from 1997 to 2006 (from David et al. 2010)

## III. Project Methods

The project objectives would be implemented at a new drainage facility in northwest Iowa (near Sutherland, Iowa, Figure 2). The site had tile drainage installed in 2013. In 2014, the study site will be uniformly cropped, with treatments implemented for the 2015 growing season. The cost of the site development, tile installation, and tile drainage/sampling equipment was provided by funds from the Iowa State University Department of Agronomy Endowment. Therefore, this project will capitalize on that investment. Each treatment is replicated four times and the treatments listed in Table 1 will be implemented in the fall of 2014 and spring of 2015. The treatments would consist of a corn-soybean rotation with each phase of the rotation present in each year. The N rate for treatments 1 and 2 are based on the Corn N Rate Calculator (http://extension.agron.iastate.edu/soilfertility/nrate.aspx) recommendation for a corn-soybean rotation in Iowa, with N at $0.50/bu and corn at $5.00/bu. Relative to phosphorus management, all plots would be managed the same where routine soil sampling would be conducted to assess soil test phosphorus (STP) levels and phosphorus would be added based on these STP values to maintain STP in the optimal range.

In 2013, the site was instrumented for replicated studies of drainage water quality. The site has 32 individually subsurface drained plots for subsurface drainage water quality evaluation. Drainage lines from individual plots were directed to separate sumps within culverts. Drainage water is pumped through plastic plumbing fitted with a common plated sprayer orifice nozzle and a water meter. Back pressure created by the meter forces a small constant fraction of all drainage to be diverted to a glass sampling bottle so that a flow-proportional water sample is collected. Subsamples (125 ml) will be collected from the composite water samples in glass jars during each drainage period and volume measurements will be recorded as dictated by actual drainage patterns. Additional information on this sampling strategy is described in Lawlor et al. (2008). Samples will be preserved by acidification with sulfuric acid and analyzed for nitrate-N using second derivative spectroscopy (Crumpton et al., 1992). Based on the nitrate-N concentration of the water sample, and the volume of water during the period from when water was collected, a mass of nitrate-N loss will be computed. While the water quality focus of this proposal is on documenting nitrate-N loss, we will analyze the water samples for total phosphorus (TP) so that the TP loss can be documented. Although we would not expect a treatment effect of the systems on TP we believe it is important to document the TP export via subsurface drainage.

In addition to sampling and quantifying nitrate-N loss we will also document crop yield for each treatment. Grain samples will be collected at harvest and will be analyzed for N to evaluate N export with the grain and to assess N use efficiency by N inputs, nitrate-N outputs and N outputs with grain. To measure residual nitrate-N present in the soil, soil cores will be sampled after corn or soybean harvest in late fall. In each plot, twenty push-probe (2cm) soil samples will be extracted at three depths (0-30, 30-60, and 60-90cm) with samples from each depth being composited. Nitrate-N will be extracted from soil samples and measured by a colorimeter (Lachat QuickChem 8000 Automated Ion Analyzer, Milwaukee, WI). To assess the corn N status, an active canopy sensor (model yet to be determined) will be used to determine NDVI and/or chlorophyll index, no later than mid-vegetative corn growth stage, and possibly multiple determinations in the early growing season. This sensing will also be used to help determine the variable in-season adjusted sidedress N rate application. Also, lower plant corn stalk samples will be collected at the end of the growing season to determine the concentration of nitrate-N in the lower corn stalk (20cm segment from 15 to 35 cm above the ground), specifically to determine if excess N had been applied in each system studied. Fifteen segments will be collected and composited from each plot.

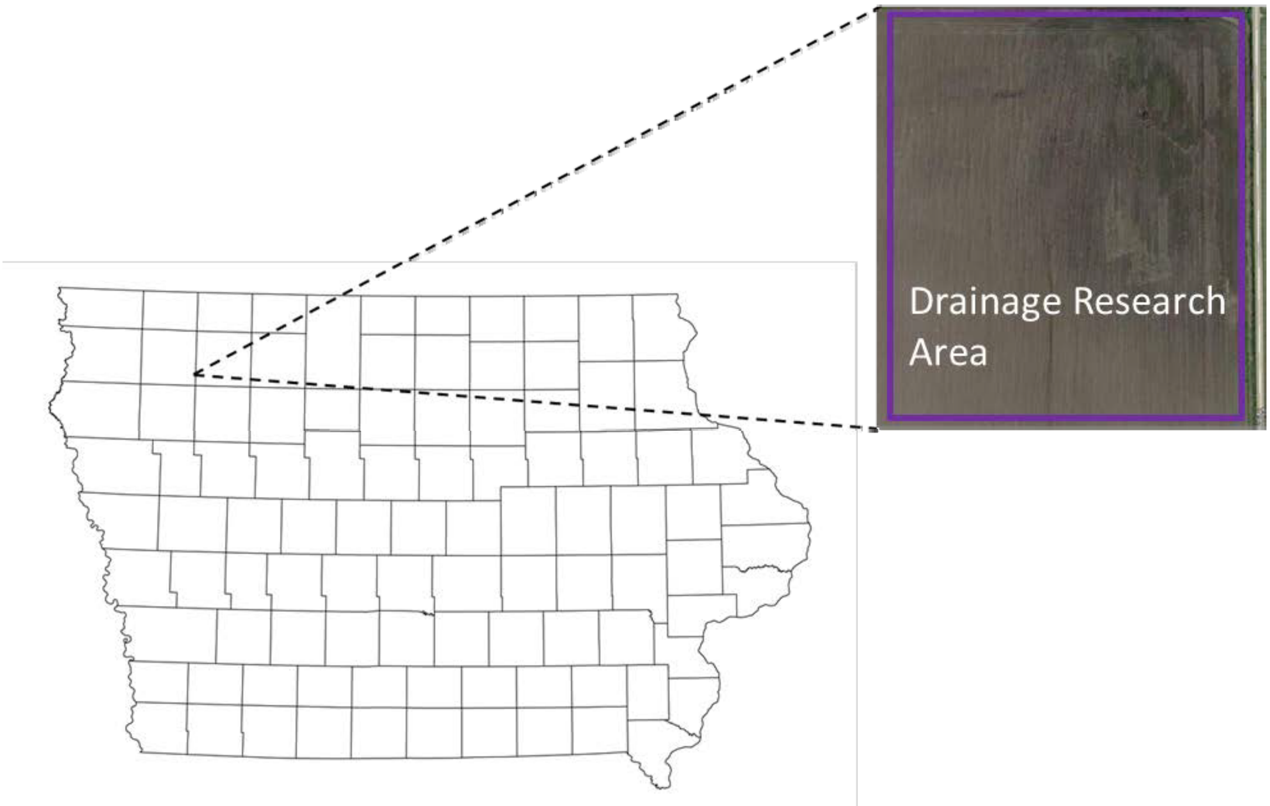



Figure 2. Study site near Sutherland, Iowa.

**Location and Size of the Project Area Including Relative Size and Scope**

The project area is located near Sutherland, IA in O'Brien County Iowa (Figure 2). The project site is on the Northwest Iowa Research and Demonstration Farm managed by Iowa State University. The total area is approximately 32 acres of which 26 acres are used as experimental plots and the remainder as border and buffer (Figure 3). A total of 32 experimental plots are available which are 160 ft x 225 ft (Figure 4). Subsurface drainage lines were installed in 2013 parallel to the long dimension through the center of each plot and on the borders between plots (80 ft spacing).

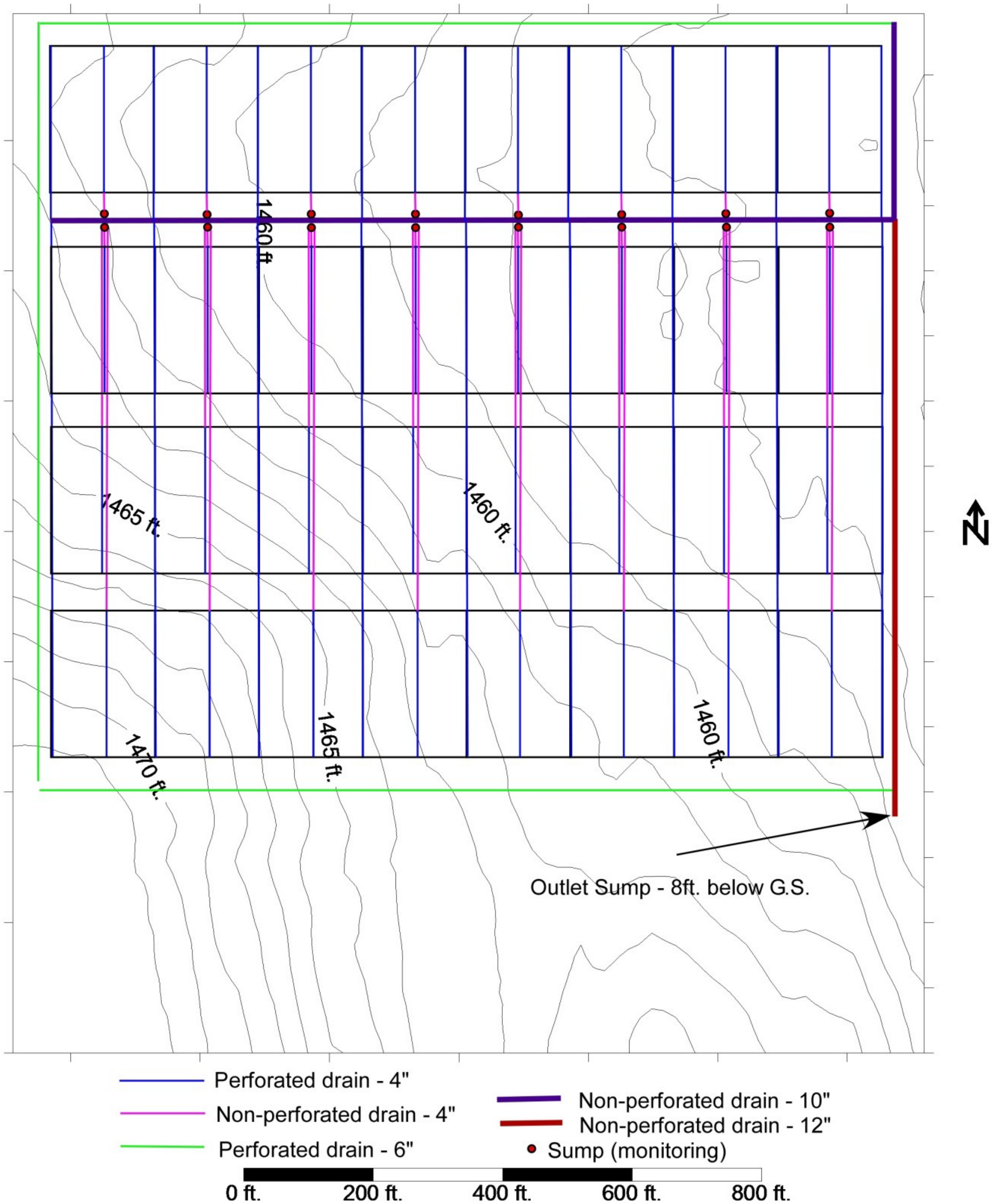
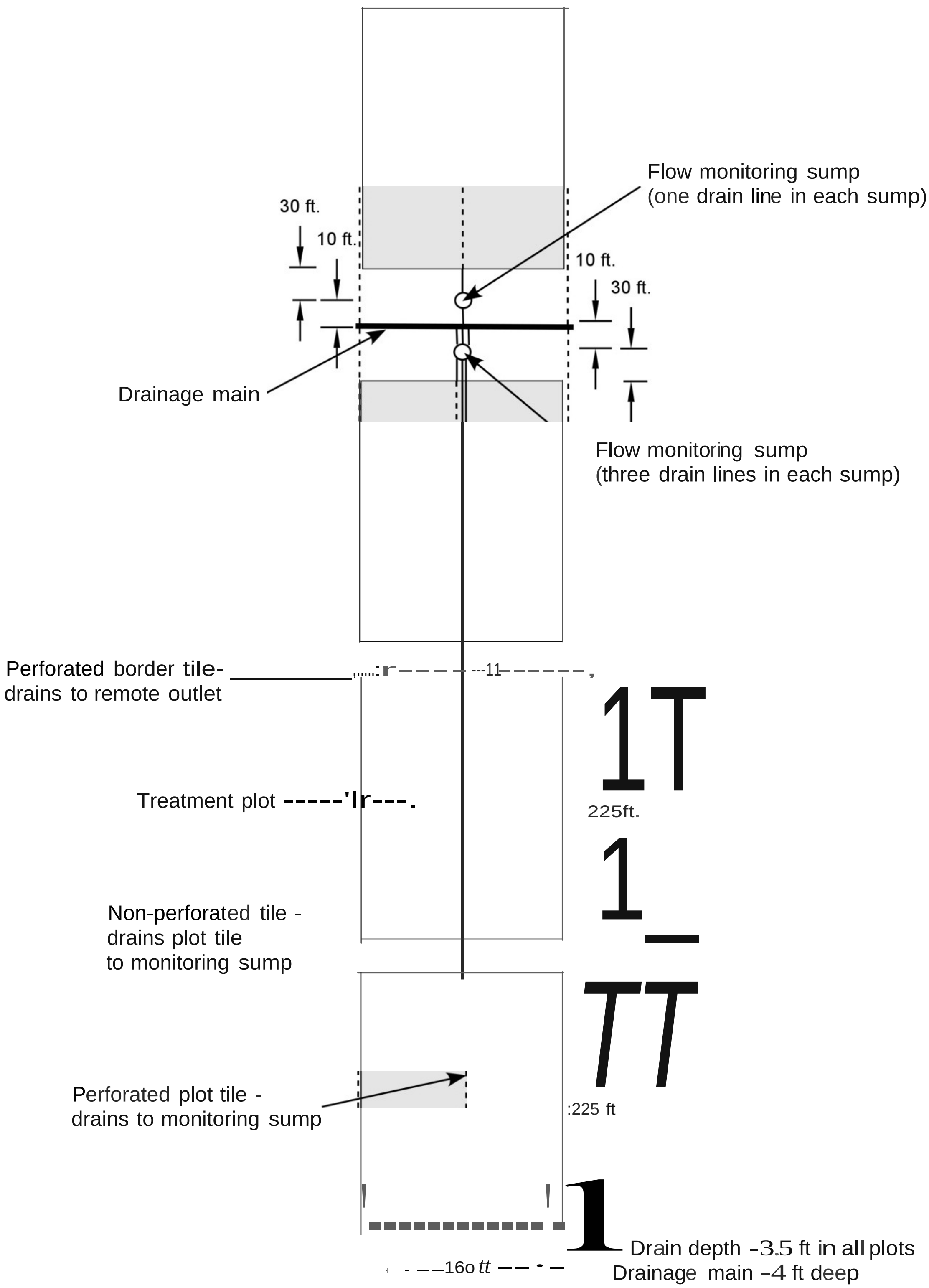



Figure 3. Example subsurface drainage layout for study site




**Plot Layout**

Figure 4. Example subsurface drainage layout for four plots

**IV. Project Products and Deliverables**

A primary product of this project will be a complete analysis of the impacts of the treatments on nitrate-N concentrations and loss from the drainage plots, crop yield, and soil nitrate at the end of the growing season. This will allow for an assessment of how the N management practices impact water quality, N cycling within the soil system, and crop yield. This information will be summarized in annual project reports, in the final completion report, and at 4R Fund Review meetings. Data will also be submitted for inclusion in the 4R Fund project database. Extension fact sheets, Extension presentations, and conference and stakeholder presentations will also be generated to share this information. Results will be utilized to further inform decisions for the Iowa Nutrient Reduction Strategy on-going Science Assessments. In addition, one or more peer-reviewed journal articles will be prepared that summarize project findings.

**V. Project Outcomes**

The expected outcomes will have both economic impact and environmental effects beyond the field. It is expected that at least some of the N management practices implemented will reduce nitrate-N concentrations and loss in subsurface drainage while maintaining or perhaps increasing crop yield. This information would be transferable to corn-soybean producers throughout much of the Upper Midwest where subsurface drainage is a common practice. This information would be of benefit to producers who are looking for practices that can reduce the downstream impacts of agricultural production while maintaining or increasing crop productivity and profitability. Also, because this project will evaluate water quality, specifically nitrate-N, it will address a range of N management practices. Many of these practices have the potential to reduce downstream nitrate-N loss and as a result, there is the potential for a positive environmental impact. In addition, we will be assessing post-harvest soil nitrate levels and whether the N management practices reduce those levels. This too has the potential for positive environmental impact.

**VI. Partnerships and Industry Involvement**

This project would support water quality assessments of specific 4R nitrogen management practices and as such would have applicability to industry partners. The Northwest Research Farm Association, which has membership from farmers and industry partners, have been instrumental in the establishment of this site and continue to be interested in what will be studied at the site and upcoming results. As noted by the letters of support the proposed studies would provide vitally needed information in support for the Iowa Nutrient Reduction Strategy for which there is broad support from the agricultural community.

**VII. Outreach**

Several strategies will be used to communicate to appropriate audiences and disseminate information. The information will be included in Dr. Helmers' and Dr. Sawyer's statewide and regional Extension education programs. These programs regularly interact with at least 2000+ producers and certified crop advisors each year on issues specifically related to water quality and N management in agricultural systems. The information would be shared through statewide field days, state and regional stakeholder meetings, as well as regional and national conferences and committees in which Dr. Helmers and Dr. Sawyer participate. Extension fact sheets will be developed to disseminate the information and leave information with producers and stakeholders. Additionally, project team members will develop scientific papers to make the information accessible for further research.

**VIII. Project Management** Achieving the goals and objectives of this project will take expertise in drainage and nutrient cycling. The project team consists of engineers and scientists who have experience evaluating, coordinating, and administering programs related to nitrate-N loss from drainage systems and impacts on crop yield and nutrient cycling. The project team has successfully completed several water quality projects together. To ensure that project activities are completed in a timely manner the project team will meet at least monthly and informally more often than monthly. Dr. Helmers will meet on a weekly basis with Carl Pederson to coordinate activities during the growing seasons. The role and qualifications of the primary project team are listed in Table 2. On-site plot management (tillage, planting, weed control, harvesting), treatment applications, and water collection will be conducted by the Northwest Research Farm Superintendent and the farm personnel. The project personnel will interact directly with the research farm personnel and assist with plot maintenance, cropping decisions, and drainage equipment maintenance.

Table 2. Role and qualifications of primary project team.

| **Name** | **Title** | **Role** | **Qualifications** |
|---|---|---|---|
| Matthew J. Helmers, Ph.D. | Assoc. Prof., ISU Dept. of Agricultural and Biosystems Eng. | • Manage work activities and reporting of work status<br>• Assist in summarizing and interpreting data<br>• Disseminate project information to stakeholders in Iowa and Corn Belt | 10+ yr. experience at Iowa State; Experience in drainage design, monitoring of drainage system performance including crop production and nutrient inputs, and outreach to landowners and agency personnel |
| John E. Sawyer, PhD. | Professor, ISU Dept. of Agronomy | • Assist in summarizing and interpreting data<br>• Review of data and methods for quality control<br>• Assist in dissemination of project information to producers | 16+ yr. experience at Iowa State; Experience in soil fertility management, efficient crop nutrient utilization and economically and environmentally sound fertilizer and manure nutrient management systems research and extension education |

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|---|---|---|---|
| Carl Pederson | Assistant Scientist,<br>ISU Dept. of Agricultural and Biosystems Engineering | • Provide maintenance, and troubleshooting of monitoring equipment<br>• Coordinate field sampling activities<br>• Summarize and interpret data | 23+ yr. experience at Iowa State; Experience in research farm management, maintenance and trouble-shooting of monitoring equipment, coordination of field sampling, and summarizing and interpreting field data |

**IX. Evaluation**

This project will evaluate the water quality, specifically, nitrate-N impacts of the treatments implemented along with N cycling and crop yield. The primary evaluation of the project will be what impacts these N management practices have on water quality and crop yield. This water quality site was implemented as a result of input and request from the Northwest Research Farm association. Implementation and on-going results will be shared with the association and their input and review will be used to help evaluate the project progress. As appropriate, we would also survey participants at Extension presentations to assess whether participants would consider practice changes based on the project results and information presented.

## X. Timeline and Deliverables

| | 2015 | | | | | | | | | | | | 2016 | | | | | | | | | | | | 2017 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
| Objective 1: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Install drainage monitoring equipment and monitor during non-freezing conditions | | | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X | X | X | X | X | |
| Summarize nitrate-N and total phosphours loss with drainage | | | | | | | | | | | X | X | X | | | | | | | | | | X | X | X | | | | | | | | | | X | X |
| Objective 2: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Apply nitrogen (fall nitrogen would first be applied in fall 2014) | | | | X | X | X | X | | | | X | | | | | X | X | X | X | | | | X | | | | | X | X | X | X | | | | X | |
| Plant crops | | | | X | X | | | | | | | | | | | X | X | | | | | | | | | | | X | X | | | | | | | |
| In-season N sensing | | | | | | X | X | | | | | | | | | | | X | X | | | | | | | | | | | X | X | | | | | |
| Stalk nitrate sampling | | | | | | | | | | X | | | | | | | | | | | | X | | | | | | | | | | | | X | | |
| Harvest crops | | | | | | | | | X | X | | | | | | | | | | | X | X | | | | | | | | | | | X | X | | |
| Soil sampling | | | | | | | | | | X | X | | | | | | | | | | | X | X | | | | | | | | | | | X | X | |
| Summarize crop yields and soil and plant sample information | | | | | | | | | | | X | X | X | | | | | | | | | | X | X | X | | | | | | | | | | X | X |
| Objective 3: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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| Outreach | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Extension factsheets | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X |
| Field days (NW Farm field day annually; other field days as they arise) | | | | | | X | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | |
| Crop Advantage Series meetings | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | | | | | | |
| Integrated Crop Management Conference | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | | | | | | | | X |
| Project Activities | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Annual report | | | | | | | | | | | | x | | | | | | | | | | | | | x | | | | | | | | | | | | | x |
| Final Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| Presentation @ 4R Fund Review meeting | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | | |
| Peer-Reviewed publication submitted | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X |

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