Annual Report

# Water and Nutrient Research: In-field and Offsite Strategies


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## NUTRIENT AND WATER MANAGEMENT PROJECT 2010-2014

Much of Iowa is characterized by relatively flat, poorly-drained areas which with extensive subsurface drainage, have became some of the most valuable, productive land in the State. However, this drained land has also become a source of significant $NO_3$ loss because of the changes in land-use and hydrology brought about by tile drainage. While surface runoff is decreased with subsurface drainage (resulting in decreased losses of sediment, ammonium-nitrogen, phosphorus, pesticides and micro-organisms), subsurface flow and leaching losses of $NO_3$ are increased. This is due mostly to an increase in volume and the "short-circuiting" of subsurface flow, but also in part to the increased aeration of organic-rich soils with potentially increased mineralization and formation of $NO_3$ (and less denitrification) in the soil profile.

The problem of excess nutrient loads can probably be ameliorated by a combination of in field and off site practices, but the limitations and appropriateness of alternative practices must be understood and outcomes must be measurable. Promising in field practices include nutrient management, drainage management, and alternative cropping systems. Nitrate-removal wetlands are a proven edge-of-field practice for reducing nitrate loads to downstream water bodies and are a particularly promising approach in tile drained landscapes. Strategies are needed that can achieve measurable and predictable reductions in the export of nutrients from tile drained landscapes. The principal objectives of this project are (1) to evaluate the performance of nutrient management, drainage management, and alternative cropping systems with respect to profitability and export of water and nutrients (nitrate-nitrogen and total phosphorus) from tile drained systems and (2) to evaluate the performance of nitrate-removal wetlands in reducing nitrate export from tile drained systems.

This annual report describes activities related to objectives 1 and 2 along with outreach activities that were directly related to this project. Results for crop year 2013 are described.

### Gilmore City Project Site

*Treatments*

The specific treatments investigated at the Gilmore City Research Facility are listed in Table 1. All treatments except the forage and kura treatments (Table 1) consist of 8 plots with 4 in soybeans and 4 in corn each year. The forage and kura treatments have 4 plots each.

Table 1. Treatments at the Gilmore City Research Facility for Crop Years 2010-2014.

| Treatment Number* | Tillage | Cover Crop | Nitrogen Application Time | Nitrogen Application Rate (lb/acre) |
|---|---|---|---|---|
| 1,2 | Conventional tillage | – | Fall (Aqua-Ammonia) | 150 |
| 3,4 | Conventional tillage | – | Spring (Urea) | 150 |
| 5,6 | Conventional tillage | – | Spring (Aqua-Ammonia) | 150 |
| 7,8 | Conventional tillage | Rye planted after harvest of corn and beans | Spring (Aqua-Ammonia) | 150 |
| 9,10 | No-till | – | Spring (Aqua-Ammonia) | 150 |
| 11,12 | No-till | Rye planted after harvest of corn and beans | Spring (Aqua-Ammonia) | 150 |
| 13,14 | Conventional | – | Spring – Poly coated urea | 150 |
| 15,16 | Conventional | – | Late season side-dress | 150 |
| 17 | Kura clover - Corn | | - | 150 |
| 18 | Orchardgrass + Red/Ladino clover | | - | no fertilizer |

* within the corn and soybean rotation treatments, odd numbers are soybean and receive no nitrogen.

The specific objectives of this project component are to:

1. Determine the effects of nitrogen fertilizer application timing on nitrate-N leaching losses along with potential impacts on crop yield.
2. Determine the effects of nitrogen fertilizer source on nitrate-N leaching losses along with potential impacts on crop yield (examining aqua-ammonia, urea, and a poly-coated urea).
3. Determine the effects of cover crops (annual and perennial) on nitrate-N leaching losses and crop yield.
4. Compare the nitrate-N leaching losses and crop yield in a no-till system to a conventional tillage system (treatment 3 vs 5).
5. Disseminate project findings through peer-reviewed journal articles, Extension fact sheets, Extension presentations, and other outlets as appropriate.

The concentration and loading of nutrients exiting the various treatments will be monitored and evaluated on an annual basis and for the five year study period, 2010-2014 with 2010 serving as a transition year from previous treatments at the site. In addition, crop yield will be documented each year to evaluate treatment effects on yield, specifically whether there are declines in annual yield at the lower nitrogen rate applications. The evaluation of the treatment effects will be for the study period but each year will be analyzed to evaluate treatment effects on a yearly basis and after the completion of this phase of the research study. It is understood that climatic variability plays a significant role in the leaching of nutrients in the tile drained landscape. Based on this, it is important to have numerous years of leaching data to evaluate the treatment effects both from a production (crop yield) perspective and a nutrient leaching perspective. The multiple years of data allows for evaluating how the treatments respond under varying climatic conditions and after subsequent years with similar cropping practices. Also, these multiple years of data allow for additional characterization of tile flow under varied precipitation conditions and allow for further understanding of the hydrology of the site.

*Agronomic Activities*
Cereal rye for 2013 was seeded on October 8, 2012. Fall fertilization was completed on November 16, 2012. Chisel plowing was performed on November 13, 2012.

Agronomic field activities in 2013 were delayed due to excessive precipitation and colder temperatures earlier in the crop season. Rye cover crop in corn plots was sprayed to terminate rye on April 25. Urea and ESN was applied and incorporated on May 13. Seedbed preparation for corn and soybean was completed on May 13, 2013. Corn was planted on May 14 and soybean planting was finished on June 7. Soybean rye cover crop plots were sprayed to eliminate rye on May 23. Aqua-ammonia was side-dress applied on June 13. Soybean harvest was started on October 10 and delayed due to rain. Soybean harvest was completed on October 21, 2013. Corn was harvested on October 29, 2013.

*Weed Control*
Glyphosate resistant crops were used at the site. SureStart and Touchdown were used for post weed control and were broadcast on June 1. Application of Authority herbicide was on June 7 for soybean. Row cultivation for weed control was not incorporated into the weed management system in 2013.

*Precipitation*
Precipitation was recorded by the weather station at the site. Total precipitation was lowest in 2012 (Table 2) but all three years are drier than the long-term average. However, April and May in 2013 had nearly twice the long-term average monthly precipitation. This rainfall followed a long dry period in 2012.

Table 2. Precipitation in 2011-2013 at the research site and comparisons to norms and amounts at local NOAA weather stations.

| | 2011 | 2012 | 2013 | Normal* |
|---|---|---|---|---|
| | ------------------------------ inches ------------------------- | | | |
| Jan | 0.01 | 0.09 | 0.17 | 0.91 |
| Feb | 1.15 | 1.56 | 0.28 | 0.70 |
| Mar | 0.25 | 1.84 | 0.67 | 2.20 |
| Apr | 3.39 | 4.04 | 7.42 | 3.09 |
| May | 4.01 | 2.85 | 7.6 | 3.94 |
| Jun | 7.29 | 3.69 | 3.26 | 4.37 |

| | | | | |
|---|---|---|---|---|
| Jul | 2.89 | 1.16 | 1.83 | 4.37 |
| Aug | 0.86 | 0.98 | 1.3 | 4.60 |
| Sep | 0.93 | 2.05 | 0.55 | 3.16 |
| Oct | 0.17 | 1.52 | 2.1 | 2.17 |
| Nov | 0.30 | 0.47 | 1.41 | 1.86 |
| Dec | 1.00 | 0.56 | 0.02 | 1.37 |
| Total | 22.25 | 20.81 | 26.61 | 32.74 |

* From: Climatological Data for Iowa, National Climate Data Center for Pocahontas Iowa 1971-00.

*Drainage*

The drainage monitoring sumps are in place for monitoring from late March through the end of November in most years. Freezing conditions from late November through late March prevent monitoring in the sumps but since the soils are frozen there is very little if any flow during this period. Of the monitoring years, 2011 had the greatest overall drainage (Table 3). Since 2010 was a very wet year the soil water content in spring 2011 was likely fairly high such that nearly all the early spring precipitation resulted in drainage. There was very little drainage in 2012 due to little rainfall in the fall of 2011 and little rainfall throughout much of 2012. The early spring rainfall in 2013 replenished the soil profile which led to drainage in early 2013. These flow values are preliminary and the project team is doing a thorough review of flow information to assess high flows during some extensive wet periods.

Table 3. Subsurface drainage volumes with statistical differences at p=0.05, by treatment in 2011-2013.

| Treatment | Description | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | | ---------------- | inches | ----------------- |
| 1 | CP-FA-150-S | 8.6b | 0.8bcde | 5.3b |
| 2 | CP-FA-150-C | 8.0b | 0.4de | 8.9b |
| 3 | CP-SPUREA-150-S | 7.7b | 1.4abcd | 5.0b |
| 4 | CP-SPUREA-150-C | 10.4ab | 0.5de | 7.6b |
| 5 | CP-SP-150-S | 10.3ab | 1.8ab | 8.6b |
| 6 | CP-SP-150-C | 10.2ab | 1.2abcd | 10.0ab |
| 7 | CP-rye-150-S | 15.3a | 1.6abc | 7.7b |
| 8 | CP-rye-150-C | 9.6ab | 0.7cde | 7.6b |
| 9 | NT-SP-150-S | 9.3ab | 1.1abcde | 9.8ab |
| 10 | NT-SP-150-C | 8.5b | 2.0a | 9.4ab |
| 11 | NT-rye-150-S | 10.5ab | 0.6cde | 7.4b |
| 12 | NT-rye-150-C | 11.3ab | 0.9bcde | 9.7ab |
| 13 | CP-SPPOLY-150-S | 7.9b | 0.5de | 17.3a |
| 14 | CP-SPPOLY-150-C | 9.5ab | 0.5de | 6.9b |
| 15 | CP-SIDEDRESS-150-S | 10.2ab | 1.3abcd | 6.3b |
| 16 | CP-SIDEDRESS-150-C | 10.0ab | 0.9bcde | 7.9b |
| 17 | Kura clover | 8.4b | 0.1e | 4.9b |
| 18 | Orchard grass + Red/Ladino clover | 11.4ab | 0.4de | 7.3b |
| LSD | | 6.7 | 1.0 | 8.0 |

*Nitrate Concentrations and Losses*
In general, nitrate-N concentrations exceeded 10 mg/L in all years from systems where corn and soybeans are grown without cover crops (Table 4). While no nitrogen is applied in the soybean year the nitrate-N concentration is near the concentration from the corn phase of the treatment. Overall during the three years studied to date there is little difference due to the source of nitrogen fertilizer (aqua-ammonia, urea, or poly-coated urea). However, perennial or annual cover crop show the potential to reduce nitrate-N concentration due to lower nitrate-N concentrations than the similar treatment without cover crops. Also, the no-till systems have nitrate-N concentrations that are trending lower than the conventional tillage systems.

Table 5 shows $NO_3$-N losses by treatment in 2013. Losses were calculated by multiplying subsurface drainage effluent concentration by drainage volume. Due to plot-to-plot flow variability, in general there are few significant differences in nitrate-N losses between the treatments and flow-weighted nitrate-N concentrations are likely a better measure of treatment performance. Also, the loads are subject to change as the project team continues to review the drainage flow.

*Reactive Phosphorus Concentrations and Losses*
Total reactive phosphorus (TRP) concentrations were measured in tile drainage samples that were also tested for $NO_3$-N. Table 6 lists flow-weighted TRP concentrations for each treatment. Table 7 lists loss by year and treatment in grams per acre. The measured TRP includes both dissolved and suspended orthophosphate. This test measures the form most available to plants and is a useful indicator of potential water quality impacts such as algae blooms and weed growth in surface waters. Overall, the levels of phosphorus leaving the plots and limits were low, ranging from 4.6- 127.0 $\mu g\ L^{-1}$ (Table 6). Due to the large variation among plots there was no significant difference in TRP concentrations among the treatments. The loads are subject to change as the project team continues to review the drainage flow.

*Stalk Nitrate Test*
Corn stalk nitrate test sampling protocols were followed to determine nitrate-N concentrations in corn stalk tissue from each plot. Results are listed in Table 8. Stalk nitrate values can be divided into four categories: low (less than 250 mg/L-N), marginal (250-700), optimal (700 and 2000 mg/L-N), and excess (greater than 2000 mg/L-N). In general all samples have been in the optimal range with some samples in the marginal range and one treatment in the low range in 2011.

Table 4. Average annual flow-weighted nitrate concentrations by treatment in 2011-2013 with statistical significance at p=0.05.

| Treatment | Description | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | | -------------- nitrate N (mg/L) ------------ | | |
| 1 | CP-FA-150-S | 10.1bcde | 9.2abcd | 15.8efg |
| 2 | CP-FA-150-C | 11.4bcd | 10.7abc | 25.5a |
| 3 | CP-SPUREA-150-S | 12.1abc | 13.0ab | 23.1ab |
| 4 | CP-SPUREA-150-C | 11.7bcd | 10.8abc | 19.6bcde |
| 5 | CP-SP-150-S | 12.7ab | 14.9a | 21.9abc |
| 6 | CP-SP-150-C | 15.4a | 14.3a | 21.3abcd |

| | | | | |
|---|---|---|---|---|
| 7 | CP-rye-150-S | 9.3cde | 4.9cde | 17.5cdefg |
| 8 | CP-rye-150-C | 8.4de | 8.4abcd | 10.5h |
| 9 | NT-SP-150-S | 11.1bcd | 7.1bcde | 17.7cdefg |
| 10 | NT-SP-150-C | 7.4e | 10.7abc | 12.8gh |
| 11 | NT-rye-150-S | 8.9cde | 9.0abcd | 15.9efg |
| 12 | NT-rye-150-C | 8.8cde | 10.0abc | 15.8efg |
| 13 | CP-SPPOLY-150-S | 10.6bcde | 10.4abc | 16.8defg |
| 14 | CP-SPPOLY-150-C | 11.5bcd | 9.6abcd | 19.0bcde |
| 15 | CP-SIDEDRESS-150-S | 12.1abc | 9.7abcd | 23.7ab |
| 16 | CP-SIDEDRESS-150-C | 9.2cde | 9.8abcd | 17.8cdef |
| 17 | Kura clover | 8.3de | 3.2de | 13.2fgh |
| 18 | Orchard grass + Red/Ladino clover | 2.4f | 1.0e | 0.7i |
| LSD | | 3.4 | 6.8 | 4.9 |

Table 5. Average annual flow-weighted nitrate losses by treatment in 2011-2013 with statistical significance at p=0.05.

| Treatment | Description | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | | ------------ nitrate-N (lbs/acre) ---------- | | |
| 1 | CP-FA-150-S | 18.5bc | 1.2de | 20.4cde |
| 2 | CP-FA-150-C | 17.7bc | 1.2de | 48.5ab |
| 3 | CP-SPUREA-150-S | 20.8abc | 3.9abc | 28.8bcd |
| 4 | CP-SPUREA-150-C | 25.7ab | 1.5de | 36.5abc |
| 5 | CP-SP-150-S | 29.7ab | 5.2a | 46.0ab |
| 6 | CP-SP-150-C | 34.8a | 3.3abcd | 50.9a |
| 7 | CP-rye-150-S | 30.9ab | 1.6de | 29.7bcd |
| 8 | CP-rye-150-C | 17.0bc | 1.7cde | 19.3cde |
| 9 | NT-SP-150-S | 21.7abc | 2.4bcde | 39.2abc |
| 10 | NT-SP-150-C | 18.6bc | 4.5ab | 27.9bcd |
| 11 | NT-rye-150-S | 21.1abc | 1.3de | 28.7bcd |
| 12 | NT-rye-150-C | 21.6abc | 1.6de | 35.4abc |
| 13 | CP-SPPOLY-150-S | 19.9abc | 1.3de | 24.2cd |
| 14 | CP-SPPOLY-150-C | 23.5abc | 1.1de | 30.2abcd |
| 15 | CP-SIDEDRESS-150-S | 26.4ab | 2.7bcd | 36.2abc |
| 16 | CP-SIDEDRESS-150-C | 19.8abc | 2.0cde | 33.9abcd |
| 17 | Kura clover | 15.4bc | 0.1e | 12.9de |
| 18 | Orchard grass + Red/Ladino clover | 8.1c | 0.2e | 1.2e |
| LSD | | 15.5 | 2.3 | 21.1 |

Table 6. Average annual flow-weighted TRP concentrations by treatment in 2011-2013 with statistical significance at p=0.05.

| Treatment | Description | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | | ----------- TRP (ug/L) ------------ | | |
| 1 | CP-FA-150-S | 14.2ab | 81.2ab | 37.4abc |
| 2 | CP-FA-150-C | 22.6ab | 51.6ab | 42.9ab |
| 3 | CP-SPUREA-150-S | 7.4b | 15.1b | 5.1c |
| 4 | CP-SPUREA-150-C | 15.3ab | 8.0b | 15.0bc |
| 5 | CP-SP-150-S | 8.4b | 7.4b | 11.1bc |
| 6 | CP-SP-150-C | 11.6b | 13.1b | 6.6c |
| 7 | CP-rye-150-S | 9.2b | 22.4ab | 17.4bc |
| 8 | CP-rye-150-C | 42.4a | 5.0b | 28.6bc |
| 9 | NT-SP-150-S | 7.1b | 4.9b | 15.4bc |
| 10 | NT-SP-150-C | 7.3b | 13.4b | 24.4bc |
| 11 | NT-rye-150-S | 8.3b | 126.7a | 9.5bc |
| 12 | NT-rye-150-C | 8.8b | 127.0a | 16.5bc |
| 13 | CP-SPPOLY-150-S | 33.3ab | 4.5b | 64.8a |
| 14 | CP-SPPOLY-150-C | 9.3b | 10.8b | 15.8bc |
| 15 | CP-SIDEDRESS-150-S | 5.4b | 18.3ab | 22.0bc |
| 16 | CP-SIDEDRESS-150-C | 9.1b | 33.8ab | 16.2bc |
| 17 | Kura clover | 7.7b | 38.8ab | 10.6bc |
| 18 | Orchard grass + Red/Ladino clover | 6.0b | 1.9b | 4.6c |
| LSD | | 28.3 | 109.2 | 34.4 |

Table 7. Average annual flow-weighted TRP losses by treatment in 2011-2013 with statistical significance at p=0.05.

| Treatment | Description | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | | ----------- TRP (g/acre) ------------ | | |
| 1 | CP-FA-150-S | 14.4b | 3.4ab | 22.7abc |
| 2 | CP-FA-150-C | 10.0b | 1.5bc | 26.9ab |
| 3 | CP-SPUREA-150-S | 5.5b | 1.4bc | 2.8c |
| 4 | CP-SPUREA-150-C | 14.2b | 0.5c | 12.5abc |
| 5 | CP-SP-150-S | 7.8b | 1.3bc | 10.4abc |
| 6 | CP-SP-150-C | 12.4b | 0.8c | 7.0bc |
| 7 | CP-rye-150-S | 17.5b | 3.9a | 5.4c |
| 8 | CP-rye-150-C | 61.5a | 0.4c | 21.7abc |
| 9 | NT-SP-150-S | 6.0b | 0.8c | 15.2abc |
| 10 | NT-SP-150-C | 8.5b | 2.1abc | 9.0bc |
| 11 | NT-rye-150-S | 9.0b | 0.9c | 8.7bc |
| 12 | NT-rye-150-C | 9.8b | 1.2bc | 17.1abc |
| 13 | CP-SPPOLY-150-S | 33.4ab | 0.2c | 31.6a |
| 14 | CP-SPPOLY-150-C | 9.1b | 0.7c | 11.5abc |
| 15 | CP-SIDEDRESS-150-S | 5.2b | 2.2abc | 17.4abc |
| 16 | CP-SIDEDRESS-150-C | 7.5b | 0.8c | 14.5abc |
| 17 | Kura clover | 7.2b | 0.4c | 2.6c |

| | | | | |
|---|---|---|---|---|
| 18 | Orchard grass + Red/Ladino clover | 6.7b | 0.1c | 3.7c |
| LSD | | 39.5 | 2.4 | 21.3 |

Table 8. Stalk nitrate test concentrations in 2011-2013.

| Treatment | Description | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | | --------- nitrate-N* (mg/kg) ----- ---- | | |
| 2 | CP-FA-150-C | 199 | 1694 | 410 |
| 4 | CP-SPUREA-150-C | 1092 | 1262 | 1780 |
| 6 | CP-SP-150-C | 671 | 384 | 443 |
| 8 | CP-rye-150-C | 623 | 1161 | 765 |
| 10 | NT-SP-150-C | 614 | 1222 | 1064 |
| 12 | NT-rye-150-C | 411 | 891 | 451 |
| 14 | CP-SPPOLY-150-C | 1146 | 716 | 1276 |
| 16 | CP-SIDEDRESS-150-C | 225 | 646 | 452 |
| 17 | Kura | 424 | 1629 | 410 |

* low (less than 250 mg/L-N) marginal (250-700) optimal (700-2000 mg/L-N).

*Yields*

Corn and soybean yields, by treatment, are listed in Tables 9 and 10. Corn and soybean yields were impacted by the severe drought in 2012 and early season wet conditions followed by fairly dry conditions in 2013. Corn yields from the kura clover treatment were close to zero in 2012 and 2013. This system with the perennial cover crop has proven difficult for corn production. Competition for moisture and nutrients began early in the season and the corn did not overcome the competition of the growing perennial cover crop (kura clover). Corn yields of other treatments in 2012 ranged from 127 to 161 bu/acre (Table 9). The highest corn yield in 2013 was for the spring poly coated urea application with conventional tillage treatment while the lowest corn yield was for the rye cover crop with conventional tillage treatment. Soybean yields in 2013 ranged from 36-42 bu/acre (Table 10). The conventional tillage with fall applied nitrogen to the previous corn crop treatment had highest soybean yield of 42 bu/ac while the no-till spring nitrogen application to the previous corn crop treatment had the lowest yield at 36 bu/ac.

Table 9. Corn yield by treatment in 2011-2013 with statistical significance at p=0.05.

| Treatment | Description | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | | --------- yield (bu/acre) ------- -- | | |
| 2 | CP-FA-150-C | 161abc | 159a | 162ab |
| 4 | CP-SPUREA-150-C | 175ab | 161a | 160ab |
| 6 | CP-SP-150-C | 180a | 141ab | 157ab |
| 8 | CP-rye-150-C | 150c | 145ab | 132c |
| 10 | NT-SP-150-C | 159abc | 131b | 136c |
| 12 | NT-rye-150-C | 154bc | 127b | 145bc |
| 14 | CP-SPPOLY-150-C | 177ab | 145ab | 165a |
| 16 | CP-SIDEDRESS-150-C | 168abc | 148ab | 140c |
| 17 | Kura | 64d | / | 0d |

| | | | | |
|---|---|---|---|---|
| | LSD | 25 | 25 | 17 |

Table 10. Soybean yield by treatment in 2011-2013 with statistical significance at p=0.05.

| Treatment | Description | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | | --------- yield (bu/acre) ---------- | | |
| 1 | CP-FA-150-S | 45a | 24b | 42a |
| 3 | CP-SPUREA-150-S | 42abc | 31ab | 38ab |
| 5 | CP-SP-150-S | 42abc | 33ab | 39ab |
| 7 | CP-rye-150-S | 42abc | 24ab | 41ab |
| 9 | NT-SP-150-S | 37c | 27ab | 36b |
| 11 | NT-rye-150-S | 37bc | 28ab | 37ab |
| 13 | CP-SPPOLY-150-S | 45a | 36ab | 39ab |
| 15 | CP-SIDEDRESS-150-S | 43ab | 39a | 41ab |
| | LSD | 7 | 14 | 6 |

*Summary*

The total precipitation during 2011-2013 has been lower than the long-term average with particularly dry conditions in 2012. While 2013 had lower than average annual precipitation the early season was quite wet which delayed crop planting at the site. Overall, the nitrate-N concentrations generally exceeded the drinking water standard of 10 mg/L under the treatments with corn and soybean production without a cover crop. This was especially evident in 2013 which was a wet spring that was preceded by an extremely dry year in 2012. The use of the winter cereal rye cover crop showed potential to reduce nitrate-N concentrations in the subsurface drainage. Also, the nitrate-N concentrations tended lower in the no-till systems. Of note is that nitrate-N concentrations are similar between the corn and soybean phase of the corn-soybean rotation at the nitrogen application rates used in this study. Overall the total reactive phosphorus concentrations in the subsurface drainage were fairly low with concentrations ranging from 4.6- 127.0 µg $L^{-1}$. Overall, corn yields were generally better on the chisel plow treatments without rye cover crop. The corn yields were nearly 17 bushels less on the no-till corn plots averaged over the three years. Average soybean yields in the no-till treatments were decreased by over 5 bu./ac. Part of the yield drag in the no-till plots on both crops may be due to increased herbicide resistance weed pressure. Changes in herbicide management are ongoing to eliminate this variable.

**Wetlands Monitoring and Evaluation**

A unique aspect of the Iowa CREP is that nitrate reduction is not simply assumed based on wetland acres enrolled, but is calculated based on the measured performance of CREP wetlands. As an integral part of the Iowa CREP, a representative subset of wetlands is monitored and mass balance analyses performed to document nitrate reduction. By design, the wetlands selected for monitoring span the 0.5% to 2.0% wetland/watershed area ratio range approved for Iowa CREP wetlands. The wetlands also span a 2 to 3 fold range in average nitrate concentration. The wetlands thus provide a broad spectrum of those factors most affecting wetland performance: hydraulic loading rate, residence time, nitrate concentration, and nitrate loading rate. In addition to documenting wetland performance, this will allow continued refinement of modeling and analytical tools used in site selection, design, and management of CREP wetlands.

**Summary of 2013 Monitoring**

Seven wetlands were monitored for the Iowa CREP during 2013 (Figure 1). These include AA, DD65, GF, JM, KS, LICA, and SS wetlands. Wetland monitoring included wetland inflow and outflow measurements, wetland pool elevation and water temperature measurements, and collection of weekly grab samples and daily composite samples. Daily composite samples were collected using automated samplers programmed to collect and composite four six-hour subsamples at wetland inflows and outflows when temperatures were sufficiently above freezing to allow the equipment to function properly. The GF, JM, LICA, and SS wetlands were drawn down approximately 1 to 1.5 feet below full pool to help establish vegetation in the shallow portions of the wetland pools. The winter of 2013 was relatively dry thereby extending the drought of 2012, but the 2013 flow was relatively high during spring and early summer, followed again by relatively dry conditions after July. Accordingly, those wetlands that were drawn down to establish vegetation remained one to two feet below full pool into the winter of 2013. Daily sampling at the GF site, which had not been historically monitored for daily samples, was initiated during early June. Inflow and outflow ceased during August at each wetland where flow was monitored. In addition, preliminary water quality monitoring was initiated late in the year at six new wetlands in Clay, Palo Alto, Pocahontas, and Floyd Counties (sites DD 8, DD 15N, DD 48/81, DD 178, FCC1 and WW).

Wetland inflow and/or outflow stations were instrumented with submerged area velocity (SAV) Doppler flow meters and stage recorders for continuous measurement of flow velocity. The SAV measurements were combined with cross-sectional channel profiles and stream depth to calculate discharge as the product of water velocity and wetted cross-sectional area. Wetland water levels were monitored continuously using stage recorders in order to calculate pool volume, wetland area, and discharge at outflow structures. The pool discharge equations and SAV based discharge measurements were calibrated using manual velocity-area based discharge measurements collected during weekly site visits during 2013 and prior monitoring years. Manual velocity-area discharge measurements were determined using the mid-section method whereby the stream depth is determined at 10 cm intervals across the stream and the water velocity is measured at the midpoint of each interval. Velocity was measured with a hand held Sontek Doppler water velocity probe using the 0.6 depth method where the velocity at 0.6 of the depth from the surface is taken as the mean velocity for the interval. The product of the interval velocity and area is summed over intervals to give the total discharge.

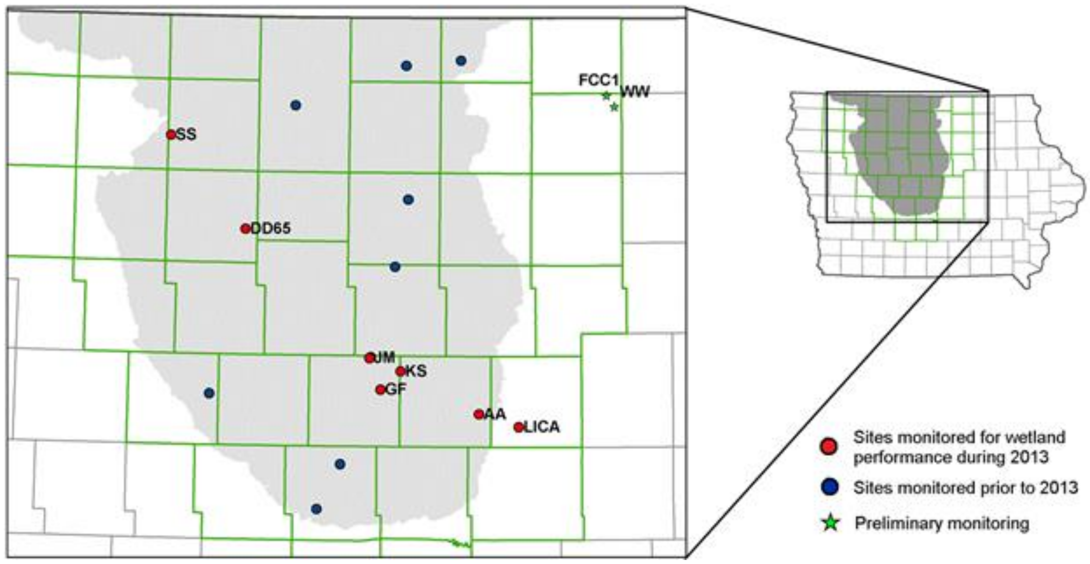


Figure 1. Wetlands monitored during 2013 and wetlands monitored during prior years and utilized for performance evaluation (see Figures 3 and 4). The shaded area represents the Des Moines Lobe in Iowa.

*Patterns in Nitrate Concentrations and Loads*

Despite significant variation with respect to nitrate concentration and loading rates, the wetlands display similar seasonal patterns. Historically, nitrate concentrations have generally been low to moderate during the winter, but water was not flowing at most sampling locations during the winter of 2012-2013 so no water samples were collected until March (Figure 2). The spring snow-melt often results in increased flow during late February or March but nitrate concentrations in the melt water and associated surface runoff are typically low to moderate. The AA and LICA sites showed elevated discharge during March of 2013 while only low snow-melt runoff was observed at the other monitored sites. During 2013, nitrate concentrations increased to their highest levels during increased flow periods generally from mid-April or May through the end of June or early July, and generally declined with declining flow in July. Nitrate concentrations were generally higher during the spring of 2013 than had historically been observed at the monitored wetlands. This is likely due to flushing of excess soil nitrate stored in the soil during the drought conditions of 2012 and early 2013. No flow into or out of any of the wetlands monitored was observed between early August and the end of December 2013. A nitrate concentration decline is sometimes observed during very high summer flow events and is thought to be associated with surface runoff having low nitrate concentration; this effect was observed during late May and early June of 2013 at all but the JM wetland. These nitrate concentration and flow patterns are consistent with those of CREP wetlands monitored in prior years and represent the likely patterns for future wetlands restored as part of the Iowa CREP.

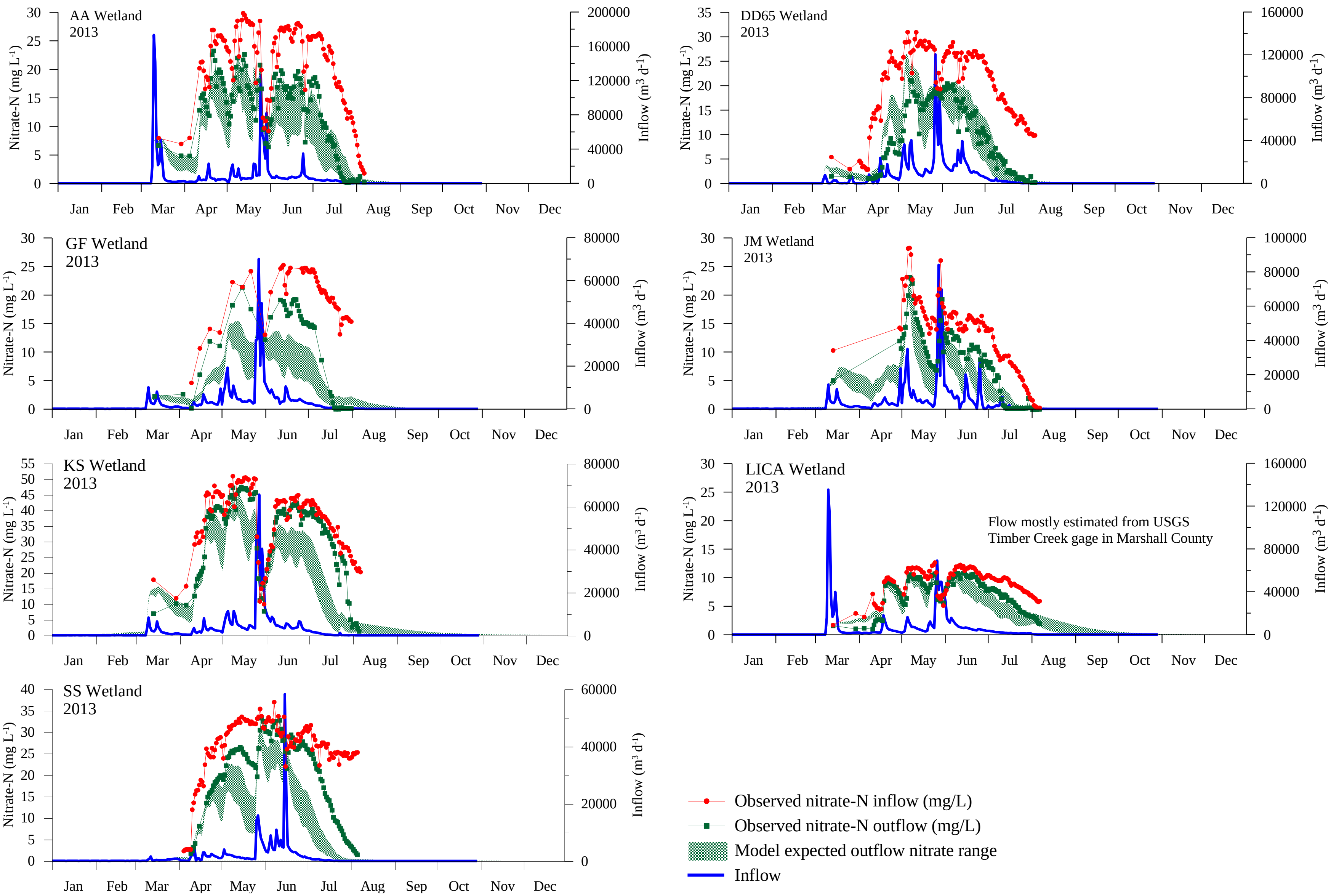


Figure 2. Measured and modeled nitrate concentrations and flows for wetlands monitored during 2013.

*Patterns in Nitrate Loss from Wetlands*

Wetland performance is a function of hydraulic loading rate, hydraulic efficiency, nitrate concentration, temperature, and wetland condition. Of these, hydraulic loading rate and nitrate concentration are especially important for CREP wetlands. The range in hydraulic loading rates expected for CREP wetlands is significantly greater than would be expected based on just the four fold range in wetland/watershed area ratio approved for the Iowa CREP. In addition to spatial variation in precipitation (average precipitation declines from southeast to northwest across Iowa), there is tremendous annual variation in precipitation and even greater annual variation in water yield. The combined effect of these factors means that annual loading rates to CREP wetlands can be expected to vary by more than an order of magnitude, and will to a large extent determine nitrate loss rates for individual wetlands.

Mass balance analysis and modeling were used to calculate observed and predicted nitrate removal for each wetland. Wetland bathymetry data were used to characterize wetland volume and area as functions of wetland depth. Wetland bathymetry for wetlands which had not previously been monitored by ISU was determined by ISU on the basis of wetland construction plans. These bathymetric relationships were used in numeric modeling of water budgets and nitrate mass balances to calculate nitrate loss, hydraulic loading, and residence times. Wetland water depth and temperatures were recorded at five minute intervals for numerical modeling of nitrate loss.

The monitored wetlands generally performed as expected with respect to nitrate removal efficiency (percent removal) and mass nitrate removal (expressed as kg N $ha^{-1}$ $year^{-1}$). In addition to measured inflow and outflow nitrate concentrations, Figure 2 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling using 2013 water budget, wetland water temperature, and nitrate concentration as model inputs.

Variability in wetland performance is in part due to differences in wetland characteristics and condition and partly due to differences in loading rates and patterns. At a given HLR, differences in wetland condition and in patterns of load can result in significant differences in performance. Mass balance analysis and modeling was also used to examine the long term variability in performance of CREP wetlands including the effects of spatial and temporal variability in temperature and loading patterns. In addition to the calculating the percent mass removal observed for wetlands monitored from 2004 through 2013, the percent nitrate removal expected for CREP wetlands was estimated based on hindcast modeling over the period from 1980 through 2005. The results illustrate reasonably good correspondence between observed and modeled performance and demonstrate that HLR is clearly a major determinant of wetland performance (Figure 3). Further analysis of the performance of wetlands monitored from 2004 through 2013 illustrates the combined effect of HLR and temperature and clearly shows the decline in percent nitrate loss with increasing hydraulic loading rate and the increase in percent loss when loading occurs during warmer periods (Figure 4).

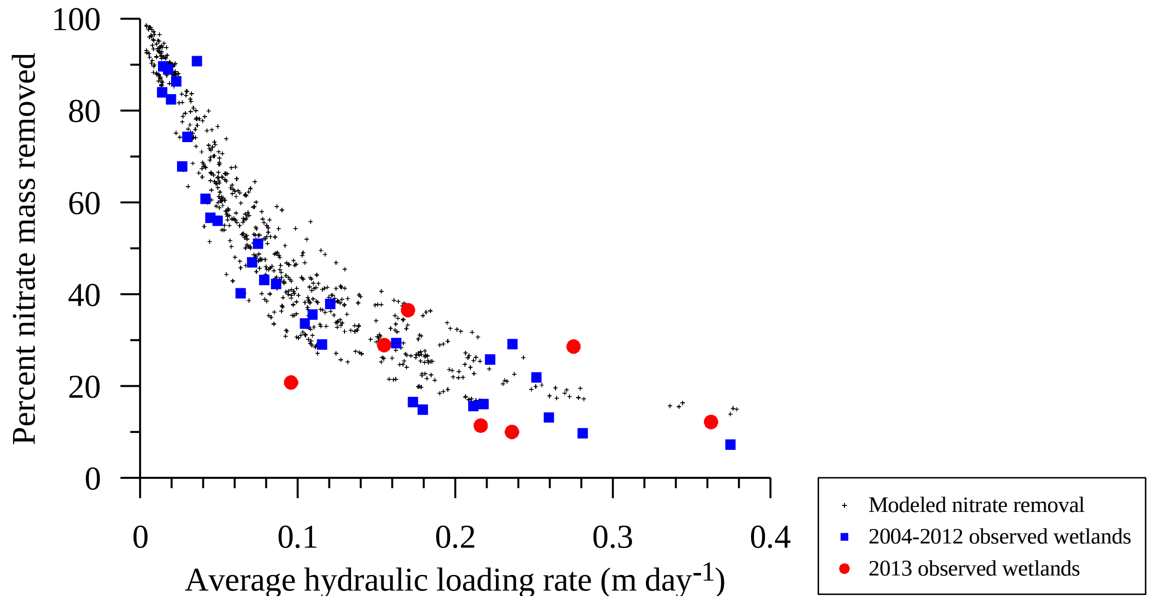


Figure 3. Modeled nitrate removal efficiencies for CREP wetlands based on 1980 to 2005 input conditions and measured nitrate removal efficiencies for CREP wetlands during 2004 to 2013. (*The visible outlier having 21 percent removal and HLR near 0.95 m day$^{-1}$ is the GF wetland which was drawn down for much of 2013.)*

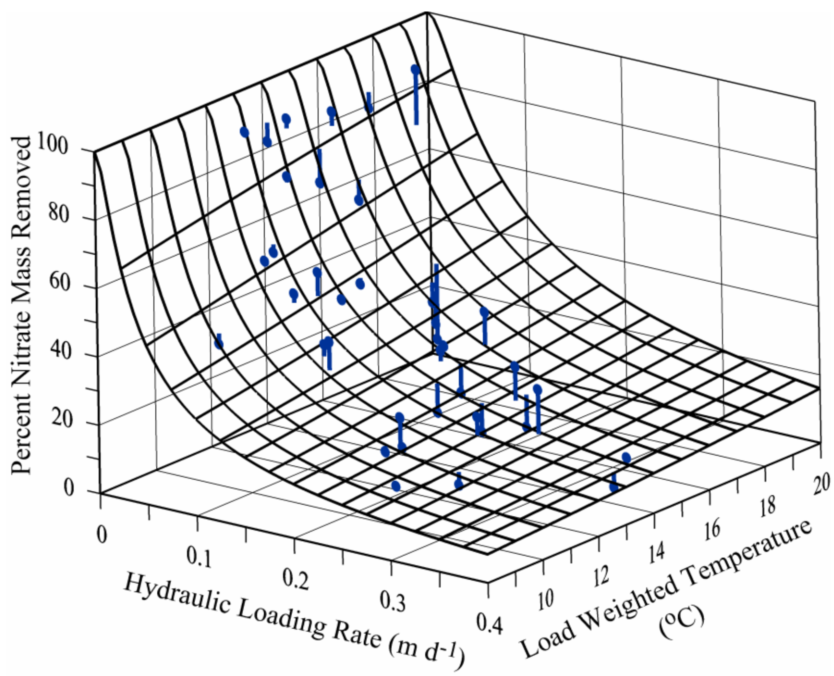


Figure 4. Percent nitrate mass loss versus hydraulic load rate and temperature ($R^2$ = 0.947).

**Outreach Activities**

In addition to the evaluation that is taking place at the project site in Gilmore City we have an active outreach program associated with this project. This includes presentations at technical and Extension related meetings. The activities and publications that are directly associated with the outreach component of this project are described below. Many of the presentations in 2013 were related to the Iowa Nutrient Reduction Strategy Science Assessment but data generated from Gilmore City and the Wetlands element were shared as part of these presentations.

*Oral Presentations at Extension Related Meetings*

1. December 11, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment" at Farmers Coop Society Elite Crop regional meeting in Sioux City, IA (85 attendees)
2. December 10, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment" at Golden Furrow regional meeting in Fairfield, IA (55 attendees)
3. December 5, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment: One Farm Many Practices" at the Integrated Crop Management Conference in Ames, IA (375 attendees)
4. December 4, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment" at the Iowa Farm News Expo in Fort Dodge, IA (85 attendees)
5. November 12, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment" at the Iowa Learning Farms Field Day near Plainfield, IA (65 attendees)
6. November 8, 2013 – Presentation on "Iowa Nutrient Reduction Strategy: Science Assessment" at Lunch and Learn at Pioneer in Johnston, IA (45 attendees)
7. November 6, 2013 – Presentation on "Iowa Nutrient Reduction Strategy: Science Assessment" at Hypoxia Lunch and Learn at the Crops Science Society of America, Soil Science Society of America, and Agronomy Society Annual meeting in Tampa, FL (65 attendees)
8. September 27, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment" at the Nature Conservancy and John Deere meeting in Fort Dodge, IA (20 attendees)
9. September 25, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment" at the NRCS Regional Training near Greenfield, IA (40 attendees)
10. September 24, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment" at the NRCS Regional Training near Armstrong, IA (45 attendees)
11. September 12, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment" at the Lake Rathbun Watershed Association Annual Meeting (150 attendees)
12. September 5, 2013 – Presentation on "Iowa Nutrient Reduction Strategy Science Assessment: One Farm Many Practices" at the Conservation Districts of Iowa Annual Meeting in West Des Moines, IA (45 attendees)

13. August 13, 2013 – Presentation on “Iowa Nutrient Reduction Strategy Science Assessment” at the Premier Crop Services Annual Meeting in West Des Moines, IA (125 attendees)
14. July 17, 2013 – Presentation on “Iowa Nutrient Reduction Strategy Science Assessment” at the Iowa Learning Farms Field Day near Otho, IA (55 attendees)
15. June 25, 2013 – Presentation on “Drainage water quality” at the Northern Research Farm Spring field day in Kanawha, IA (75 attendees)
16. June 11, 2013 – Presentation on “Iowa Nutrient Reduction Strategy” at Western Iowa No-Till Field Day (85 attendees)
17. April 22, 2013 – Presentation on “Iowa Nutrient Reduction Strategy” at Northeast Iowa NRCS Nutrient Management training in West Union, IA (45 attendees)
18. April 2, 2013 – Presentation on “Iowa Nutrient Reduction Strategy” at Cover Crop field day near Ames, IA (45 attendees)
19. April 1, 2013 – Presentation on “Iowa Nutrient Reduction Strategy” at Cover Crop Iowa Learning Farms field day near Sioux Center, IA (55 attendees)
20. March 20, 2013 – Presentation on “Water quality impacts of drainage” at Drainage Workshop in Storm Lake, IA (25 attendees)
21. February 12, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Agribusiness Association of Iowa Expo in Des Moines, IA (75 attendees)
22. January 24, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Crop Advantage Series in Waterloo, IA (125 attendees
23. January 22, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Crop Advantage Series in Carroll, IA (125 attendees)
24. January 17, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Crop Advantage Series in Atlantic, IA (125 attendees)
25. January 16, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Environmental Protection Commission meeting in Des Moines, IA (15 attendees)
26. January 11, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Practical Farmers of Iowa Annual Conference in Ames, IA (35 attendees)
27. January 10, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Crop Advantage Series in Mason City, IA (125 attendees)
28. January 9, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Crop Advantage Series in Okoboji, IA (65 attendees)
29. January 8, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Crop Advantage Series at Honey Creek Resort in Southern Iowa (95 attendees)
30. January 3, 2013 – Presentation on “Iowa’s Nutrient Reduction Strategy Science Assessment” at the Crop Advantage Series in Sheldon, IA (115 attendees)

*Oral Presentations at Technical Meetings*

1. Helmers, M.J., X. Zhou, and C. Pederson. 2013. Use and benefits of perennials and cover crops in agricultural production systems. American Society of

Agricultural and Biological Engineers (ASABE) 2013 Annual International Meeting. Kansas City, MO. July 21-24, 2013. [Oral presentation – Helmers]

2. Crumpton, W.G. 2013. *Potential of Wetlands as Nutrient Sinks in Agricultural Landscapes of the Upper Midwest.* Society of Wetland Scientists Annual Meeting, Duluth, MN, June 2013. Invited presentation.
3. Crumpton, W.G. 2013. *Water Quality Performance of Wetlands Receiving Nonpoint Source Loads: Nitrate Removal Efficiency and Mass Load Reductions Using Targeted Wetland Restorations.* Soil and Water Conservation Society Annual Conference. Reno, NV, July 2013. Poster Presentation.
4. Crumpton, W.G. 2013. *Potential Impact of Targeted Wetland Restoration on Nitrate Loads to Mississippi River Subbasins: Performance Forecast Modeling of Loads and Load Reductions.* Soil and Water Conservation Society Annual Conference. Reno, NV, July 2013. Poster Presentation.

*Extension Events Organized*

1. 14th Annual IA-MN-SD Drainage Research Forum
   November 24, 2013 – Coordinated with Dr. Gary Sands from the University of Minnesota and Chris Hay from South Dakota State University the forum in Waseca, MN. There were 75 attendees consisting of producers, contractors, and agency
2. Drainage Water Quality Field Day
   September 10, 2013 – Organized a field day at the Gilmore City Drainage Research and Demonstration project site. There were 25 attendees consisting of producers and agency representatives.

Publications:

1. Zhou, X., M.J. Helmers, and Z. Qi. 2013. Field scale modeling of subsurface tile drainage using MIKE SHE. *Applied Engineering in Agriculture* 29(6): 865-873.
2. Goeken, R., X. Zhou, and M.J. Helmers. In review. Comparison of timing and volume of subsurface drainage under perennial forage and row crops in a tile-drained field in Iowa. Submitted to *Trans. ASABE*.
3. Daigh, A.L., M.J. Helmers, E. Kladivko, X. Zhou, R. Goeken, J. Cavadini, D. Barker, and J. Sawyer. In press. Soil water during the drought of 2012 as affected by rye cover crop in fields in Iowa and Indiana. *Journal of Soil and Water Conservation.*