Annual Report

2011 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance

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January 1, 2011 – December 31, 2011

Submitted to
Iowa Department of Agriculture and Land Stewardship

Submitted by
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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 2011 Monitoring

Five wetlands were monitored for the Iowa CREP during 2011 (Figure 1). These include AA, AL, JM, KS, and LICA wetlands. AA, AL, JM, and KS wetland monitoring included wetland inflow and/or outflow measurements, wetland pool elevation and temperature measurements, and collection of weekly grab samples and automated daily samples. Automated samplers were programmed to collect daily composite water samples composed of four six-hour subsamples collected at wetland inflows and outflows when temperatures were sufficiently above freezing to allow water to be pumped through tubing by the automated equipment. Grab samples were collected throughout the year during approximately weekly site visits at inflow and outflow locations and daily auto-samples were collected from about mid to late March through mid November. Inflow and outflow ceased during August at each wetland. Weekly to bi-monthly grab samples were collected at the LICA wetland. All water samples were assayed for nitrate-N concentration.

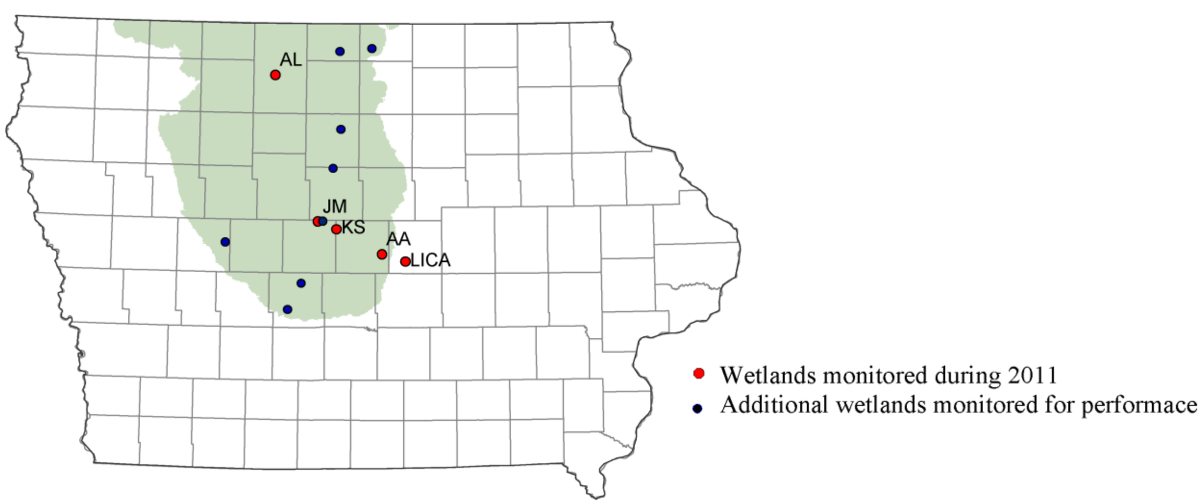

Figure 1. Wetlands monitored during 2011 and wetlands monitored during prior years and utilized for performance evaluation (see Figure 3).

Wetland inflow and/or outflow stations were instrumented with submerged area velocity (SAV) Doppler flow meters 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 velocity and wetted 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. 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 discharge. Depending on the stream width and depth, one manual discharge measurement takes about five to forty minutes to complete and provides an accurate measure of discharge at a known stream depth and time.

Wetland bathymetry data was used to characterize wetland volume and area as functions of wetland depth. These relationships are used in numeric modeling of water budgets and nitrate mass balances to estimate nitrate loss. Wetland water temperatures were recorded continuously for numerical modeling of nitrate loss.

Despite significant variation with respect to average nitrate concentration and loading rates, the wetlands display similar seasonal patterns. Nitrate concentrations are generally moderate to high during the winter, but flow is generally low so that mass loading is typically low during the winter (Figure 2). The spring melt often results in a high flow event during February or March but nitrate concentrations in the melt water and associated surface runoff are typically low. Nitrate concentrations increase to their highest levels during high flow periods in spring and early summer, may decline with declining flow in mid to late summer, and generally increase again if there is increased flow during late summer or fall. 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. These nitrate concentration and flow patterns are representative of the patterns that are expected for future wetlands restored as part of the Iowa CREP.

Nitrate Loss from Wetlands

Mass balance analysis and modeling were used to calculate observed and predicted nitrate removal for each wetland. Inflow and outflow nitrate concentrations for the wetlands are illustrated in Figure 2. In addition, Figure 2 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling using 2011 water budget, wetland water temperature, and nitrate concentration as model inputs.

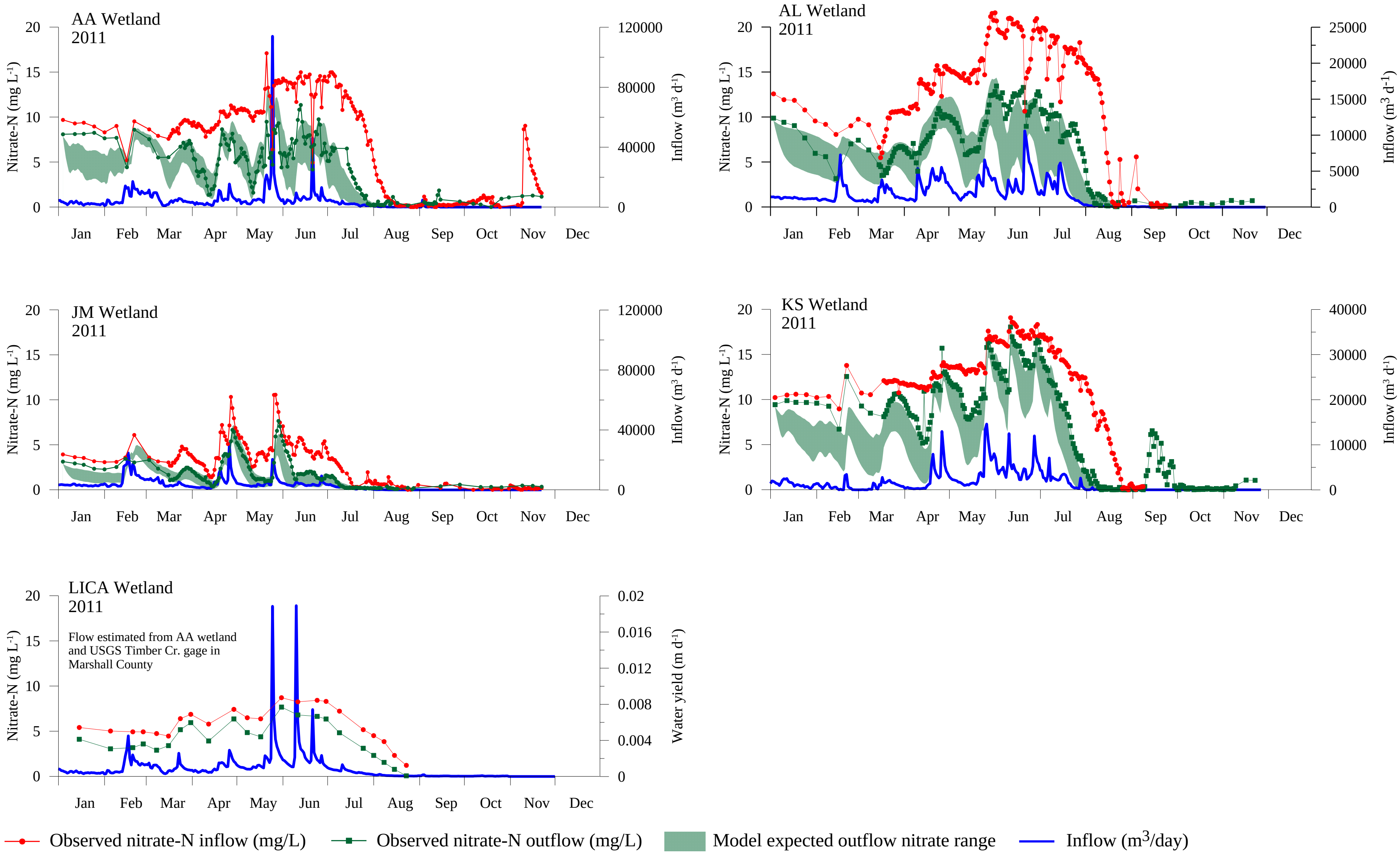

Figure 2. Measured and modeled nitrate concentrations and flows for wetlands monitored during 2011.

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} $year^{-1}$). 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. 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 modeling was used to estimate the variability in performance of CREP wetlands that would be expected due to spatial and temporal variability in temperature and precipitation patterns. The percent nitrate removal expected for CREP wetlands was estimated based on hindcast modeling over the 1980 through 2005 period (Figure 3). For comparison, percent nitrate removal measured for wetlands monitored during 2004 to 2011 illustrates reasonably good correspondence between observed and modeled performance. Figure 3 differs from prior performance plots because the average hydraulic loading rate for observed wetlands was recalculated to include only those days having inflow (and hence, nitrate loading) to the wetland. The percent nitrate removal and corresponding hydraulic loading are determined for the period of record having daily sample concentrations. Because discharge was not measured and daily samples were not collected at the LICA wetland, the percent removal could not be reliably estimated and is not shown in Figure 3; however, on the basis of weekly grab sample concentration data and estimated water yield, this wetland appears to have about 22% nitrate removal efficiency. Percent nitrate removal is clearly a function of hydraulic loading rate (Figure 3).

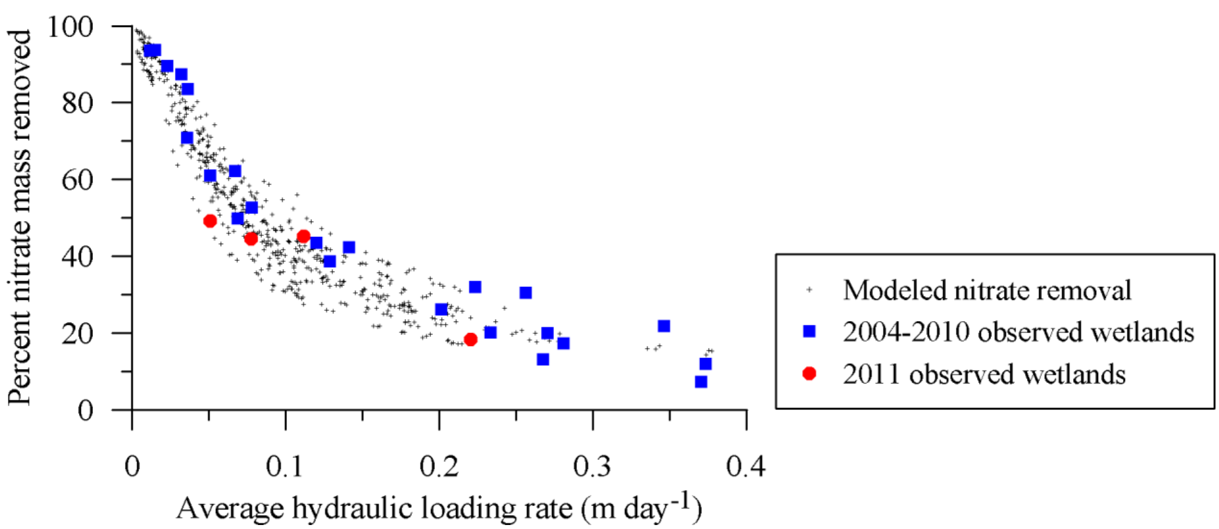

Figure 3. Modeled nitrate removal efficiencies for CREP wetlands based on 1980 to 2005 input conditions and measured nitrate removal efficiencies for CREP wetlands during 2004 to 2011.

Mass nitrate removal rates can vary considerably more than percent nitrate removal among wetlands receiving similar hydraulic loading rates. However, mass removal rates are predictable using models that integrate the effects of hydraulic loading rates, nitrate concentration, temperature, and wetland condition. Crumpton et al. (2006) developed and applied a model that explicitly incorporates hydraulic loading rate, nitrate concentration, and temperature to predict performance of US Corn Belt wetlands receiving nonpoint source nitrate loads. This analysis included comparisons for 38 “wetland years” of available data (12 wetlands with 1-9 years of data each) for sites in Ohio, Illinois, and Iowa, including four IA CREP wetlands (2 low load and 2 high load sites). The analysis demonstrated that the performance of wetlands representing a broad range of loading and loss rates can be reconciled by models explicitly incorporating hydraulic loading rates and nitrate concentrations (Crumpton et al. 2006). This model will be updated to include the 2004 to 2011 Iowa CREP wetlands and exclude wetlands smaller than the 2.5 acre minimum size required by Iowa CREP criteria.

References

Crumpton, W.G., G.A Stenback, B.A. Miller, and M.J. Helmers. 2006. Potential benefits of wetland filters for tile drainage systems: Impact on nitrate loads to Mississippi River subbasins. US Department of Agriculture, CSREES project completion report. Washington, D.C. USDA CSREES.