Annual Report

2009 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance

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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. 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 2009 Monitoring

During 2009, six wetlands were monitored for the Iowa CREP (Figure 1). These include AL, DJ, DS, HS (north wetland), KS, and VH wetlands. Flow measurements, wetland pool elevation, and both weekly grab and autosampler composited daily samples were collected at these wetlands during 2009. For close interval monitoring of nitrate-nitrogen concentrations, wetlands were instrumented with automated samplers that collected daily composite water samples composed of four six-hour subsamples collected at wetland inflows and outflows. Grab samples were collected during approximately weekly site visits at inflow and outflow locations and from the wetland near the outflow location if there was no outflow.

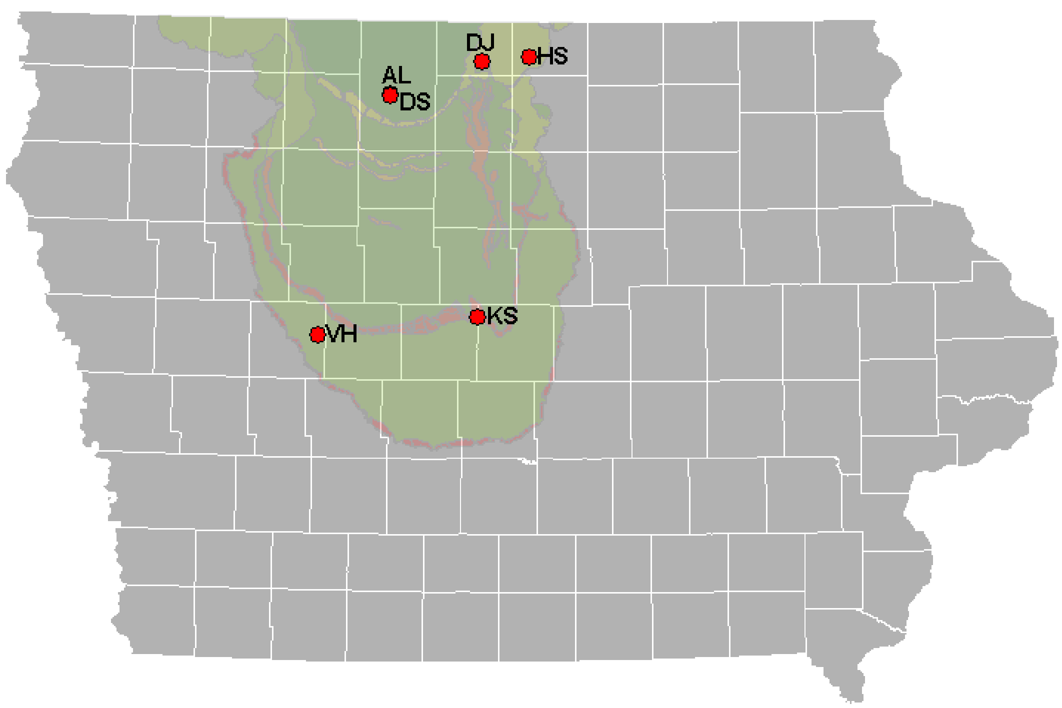

Figure 1. Wetlands monitored during 2009.

Wetland inflows and/or outflows were instrumented with Doppler flow meters for continuous measurement of average flow velocity. These measurements were combined with channel profiles and stream depth to calculate discharge. Wetland water levels were monitored continuously using stage recorders in order to calculate pool volume and discharge at outflow structures. Wetland bathymetry was digitized allowing development of mathematical equations to model pool area and volume as functions of wetland depth at six wetlands during 2007. While only two of these (DJ and KS) were monitored during 2009, the bathymetry calculations showed similar relationships between wetlands allowing approximate wetland volume and surface area relationships to be developed as functions of measured wetland depth for all monitored wetlands. These relationships are used in modeling water budgets and nitrate loss for each wetland during 2009. Wetland water temperatures were recorded continuously for numerical modeling of nitrate loss rates.

By design, the wetlands selected for monitoring span the 0.5% - 2.0% wetland/watershed area ratio range approved for Iowa CREP wetlands. The wetlands also span a 2-3 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. Despite significant variation with respect to average nitrate concentrations and loading rates, the wetlands display similar seasonal patterns. Nitrate concentrations and mass loads are typically somewhat depressed during the late winter, increase to their highest levels during high flow periods in spring and early summer, decline with declining flow in mid to late summer, and may increase again if there is increased flow during late summer or fall. 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 the 2009 monitored wetlands are illustrated in Figure 2. In addition, Figure 2 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling with 2009 water budget, temperature, and nitrate concentration inputs and forcing functions. Observed wetland inflow patterns indicate that nitrate concentrations range from low to high during the winter months, dip with peak flow events during February and March probably due to dilution from snow melt, are generally high during spring and summer with dips during peak flow events, decline during late summer and fall as flow declines, and increase as flow increases in late fall (Figure 2).

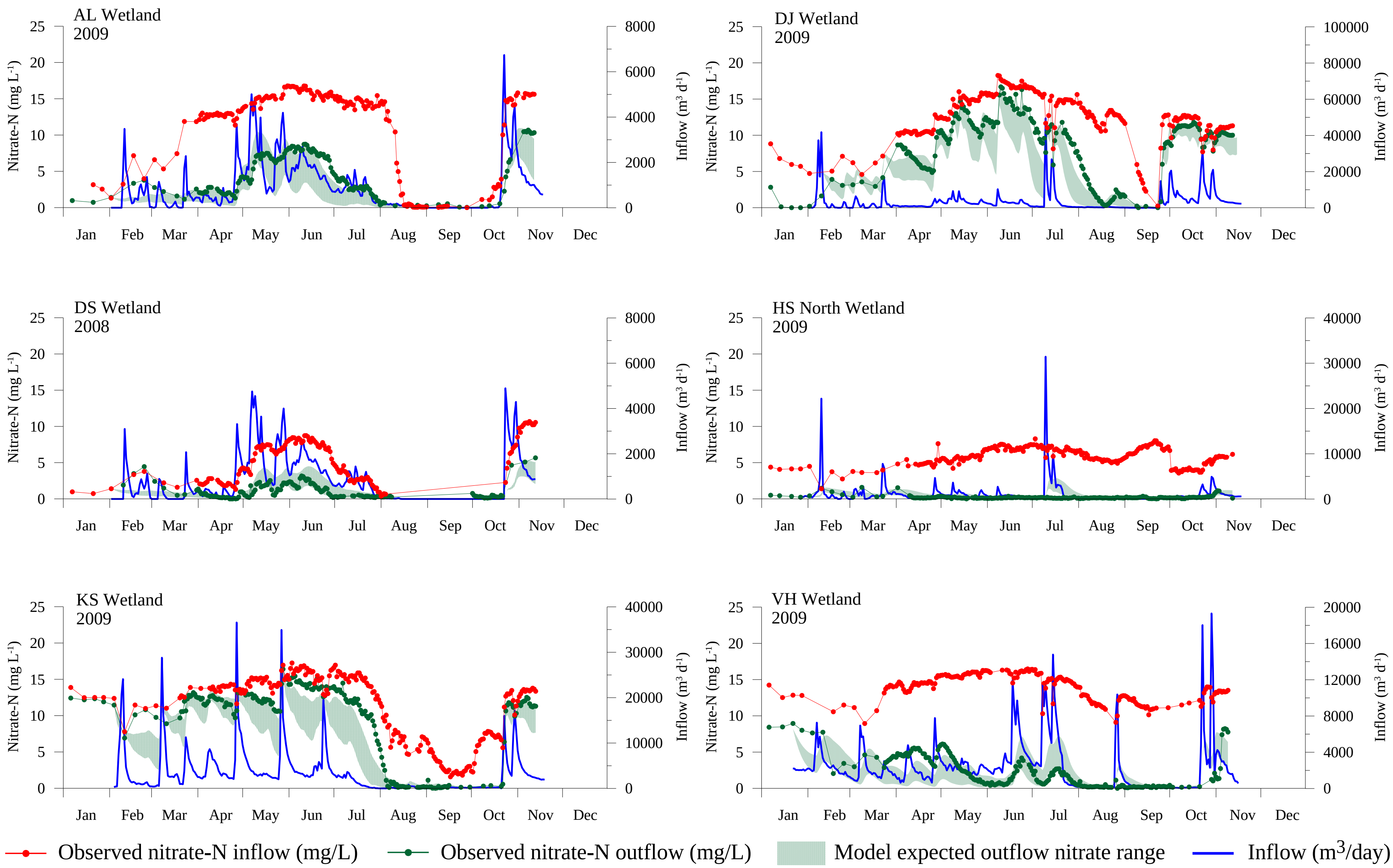

Figure 2. Measured and modeled nitrate concentrations and flows for selected wetlands monitored during 2009.

The monitored wetlands performed as expected with respect to nitrate removal efficiency (expressed as 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 10 year period from 1996 through 2005 (Figure 3). For comparison, percent nitrate removal measured for wetlands monitored during 2004 to 2009 is also presented and illustrates reasonably good correspondence between observed and modeled performance. Percent nitrate removal is clearly a function of hydraulic loading rate (Figure 3).

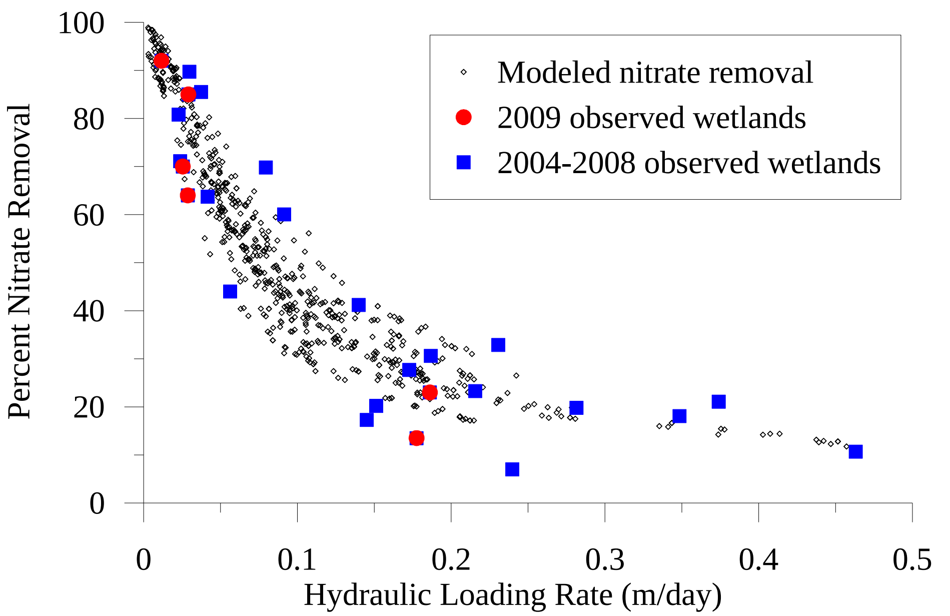

Figure 3. Modeled nitrate removal efficiencies for CREP wetlands based on 1980 to 2005 input conditions and measured nitrate removal efficiencies for CREP wetlands during 2004 to 2009.

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 2009 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.