Annual Report

2013 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance

William Crumpton
Professor

Greg Stenback
Associate Scientist

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Iowa State University, Ames

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.

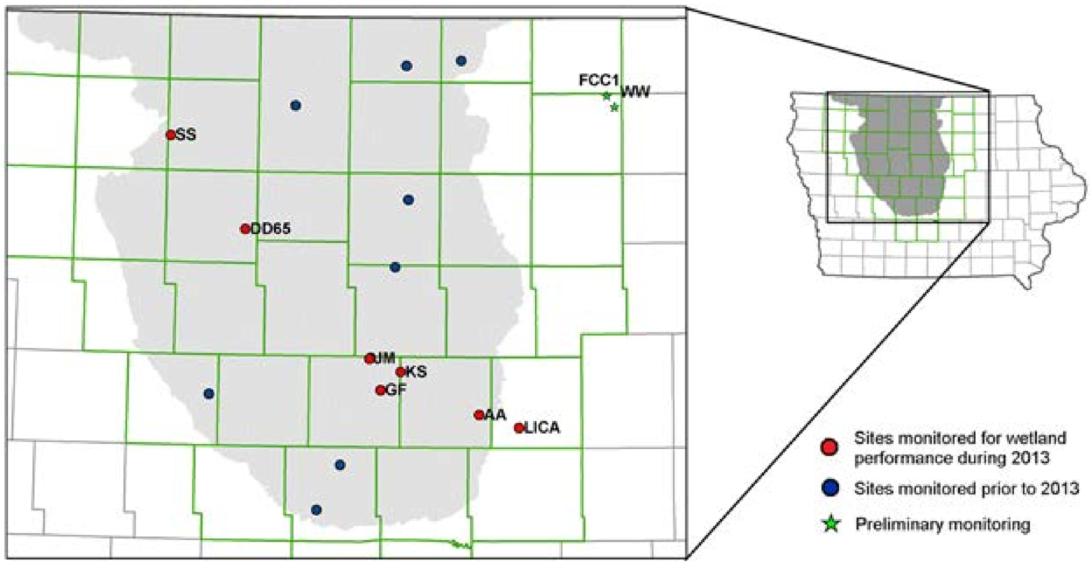

Figure 1. Wetlands monitored during 2013 and wetlands monitored during prior years and utilized for performance evaluation (see Figures 3 and 4). The shaded area represents the Des Moines Lobe in Iowa.

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.

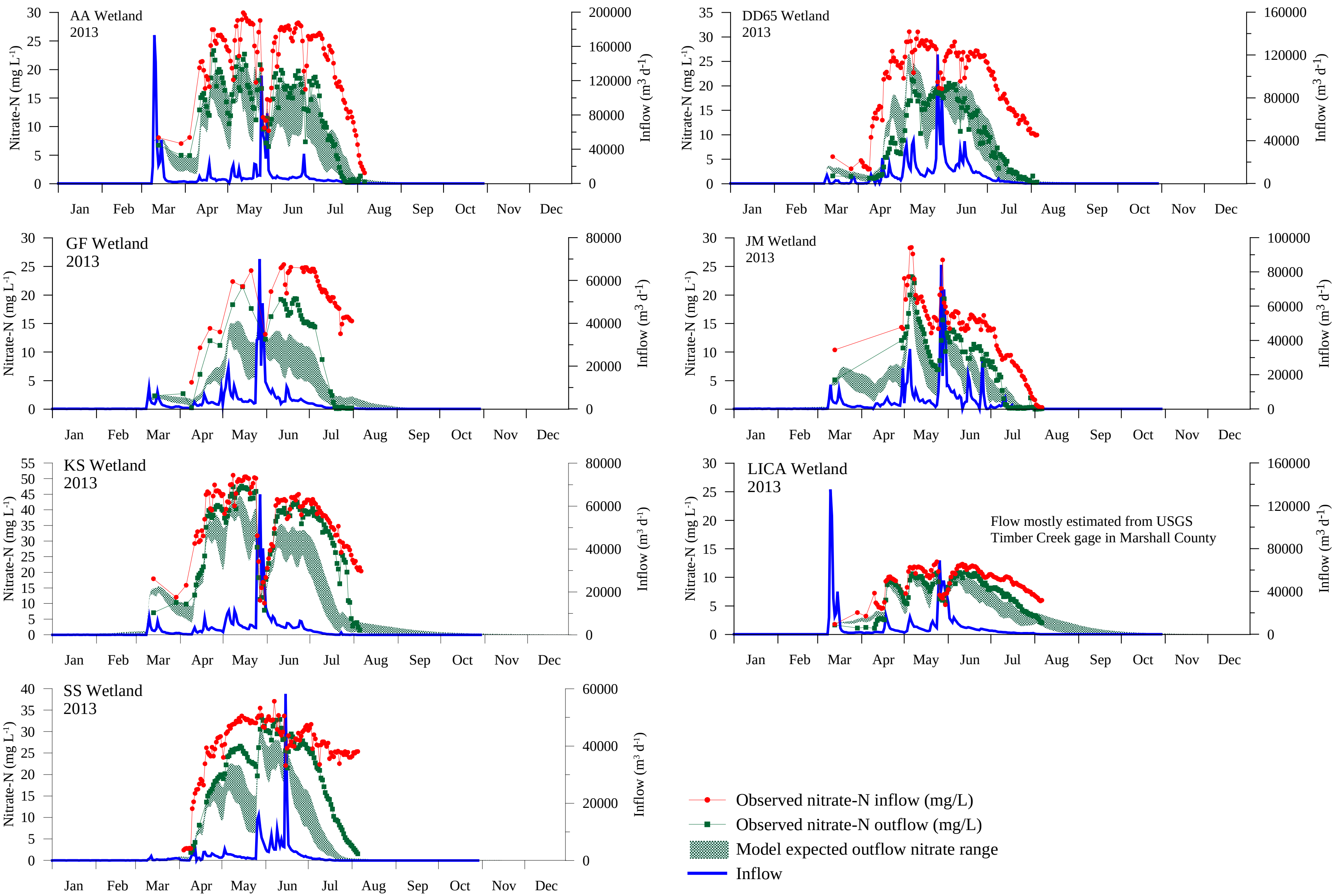

Figure 2. Measured and modeled nitrate concentrations and flows for wetlands monitored during 2013.

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).

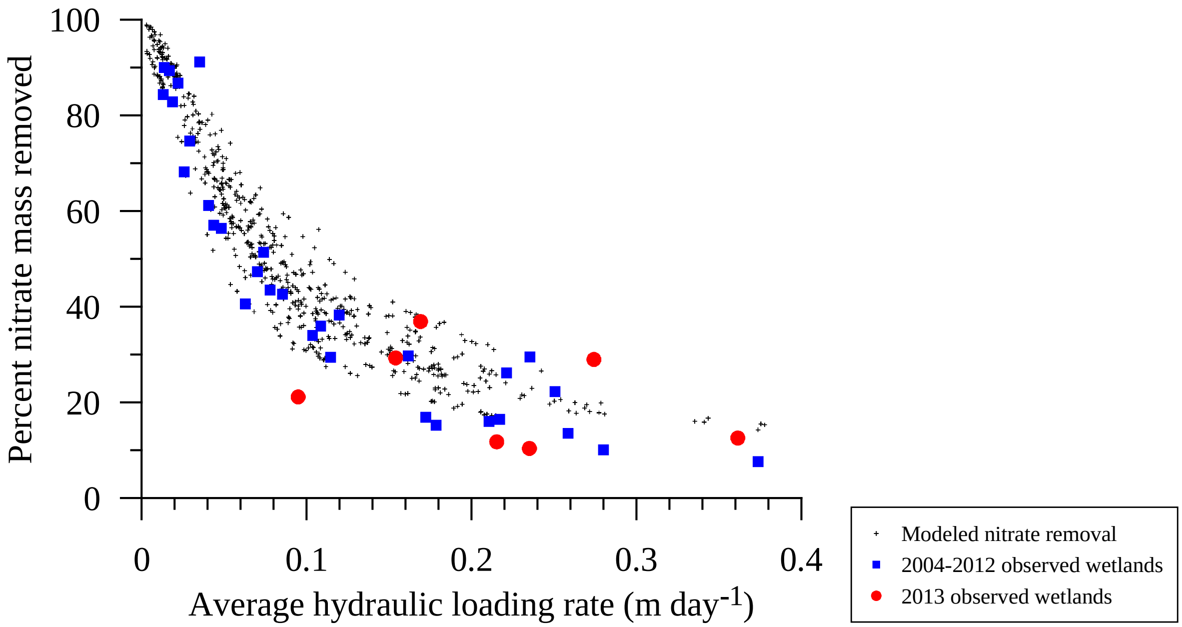

Figure 3. Modeled nitrate removal efficiencies for CREP wetlands based on 1980 to 2005 input conditions and measured nitrate removal efficiencies for CREP wetlands during 2004 to 2013. (*The visible outlier having 21 percent removal and HLR near 0.95 m day*$^{-1}$ *is the GF wetland which was drawn down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

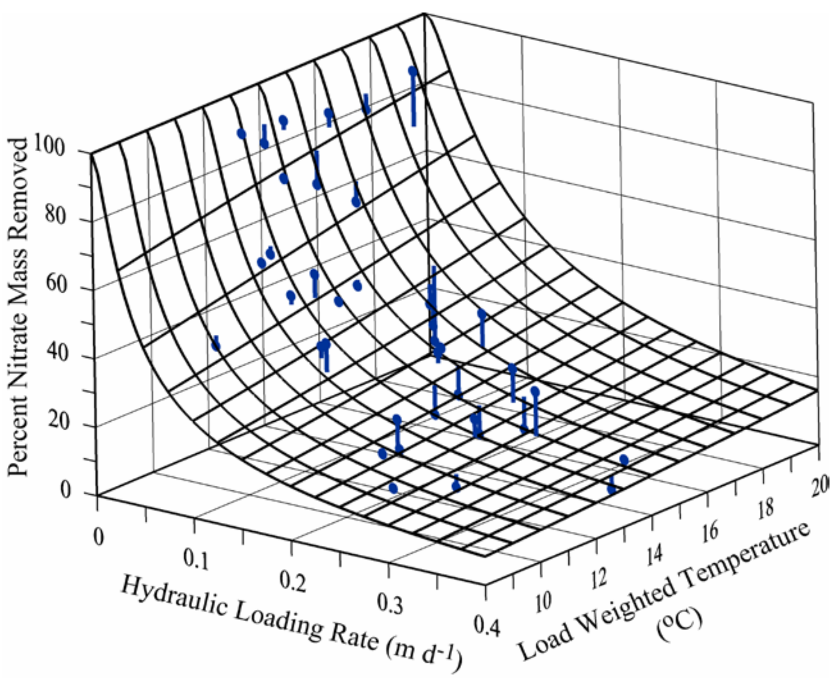

Figure 4. Percent nitrate mass loss versus hydraulic load rate and temperature (R^2 = 0.947).

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.