Annual Report

2005 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance

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January 1, 2005 – December 31, 2005

Submitted to
Iowa Department of Agriculture and Land Stewardship

Submitted by
Department of Ecology, Evolution and Organismal Biology
Iowa State University, Ames

Wetlands Monitoring and Evaluation

A unique aspect of the Iowa CREP is that nitrate reduction will not simply be assumed based on wetland acres enrolled, but will be calculated based on the measured performance of CREP wetlands. As an integral part of the Iowa CREP, a representative subset of wetlands will be monitored and mass balance analyses will be performed to document nitrate reduction. This will allow further refinement of modeling and analysis tools used to site and design CREP wetlands.

During all or part of the 2003 through 2005 crop seasons, eight different wetlands have been monitored for the Iowa CREP. These include RF Wetland, DH Wetland, AL Wetland, lower ML Wetland, upper ML Wetland, KS Wetland, TI Wetland, and VH Wetland. For close interval monitoring of nitrate-nitrogen concentrations, wetlands were instrumented with automated samplers that collected daily composite water samples at wetland inflows and outflows. Grab samples were collected at an approximately weekly interval at the inflow and outflow, and from within the wetland near the outflow location when there was no outflow. For these wetlands, the automated sampler also measured water depth and flow velocity during part of the season. A cross-section profile was measured at the autosampler depth and velocity probe deployment location and a depth versus cross-sectional area relationship was developed. This was used with the water depth and velocity measurements to generate a daily discharge. To estimate flow at sites or during periods for which autosampler depth and velocity data were not collected, flow rates were obtained from flow data of nearby USGS river gauging stations adjusted to represent the drainage area of the wetland.

By design, the wetlands selected for monitoring span the wetland/watershed area ratio range of 0.5% - 2.0% approved for Iowa CREP wetlands. The wetlands also span a range of average nitrate nitrogen concentrations from approximately 8 to 30 mg/l. 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 highest during high flow periods in spring and early summer, and decline with declining flow in late summer and 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

Over the 2003-2005 monitoring periods, the wetlands have performed predictably with respect to nitrate removal efficiency (expressed as percent removal) and mass nitrate removal. Wetland performance is a function of hydraulic loading rate, nitrate concentration, temperature, and wetland condition. Of these, hydraulic loading rate and nitrate concentration are the most important. Hydraulic loading rate is in part determined by wetland/watershed area ratio and the 0.05 to 2 percent wetland/watershed area ratio range approved for Iowa CREP wetlands can be expected to result in a four-fold range in hydraulic loading rate. However, the actual range in hydraulic loading rates is significantly greater due to spatial and temporal patterns in precipitation. In addition to spatial variation in precipitation (average precipitation declines from southeast to northwest across Iowa), there is tremendous year to year variation in precipitation. This can contribute an additional 3-5 fold variation in hydraulic loading rate over a typical 10 year period. Hydraulic loading rates to CREP wetlands can be expected to vary by an order of magnitude, and will to a large extent determine nitrate loss rates for individual wetlands.

Mass balance modeling was used to examine the long term performance expected for 7 operating wetlands and wetlands that will be constructed in 2006. For existing wetlands, close interval monitoring in 2003, 2004, and 2005 provided estimates of flow weighted nitrate concentrations at wetland inflows. For wetlands to be constructed in 2006, grab samples during spring high flow periods were used to estimate flow weighted nitrate concentrations at wetland inflows. Mass balance modeling was used to hindcast annual nitrate loads and nitrate removal for each of these wetlands over the 10 year period from 1996 through 2005. Recognizing that none of the CREP wetlands have been in place for more than a few years, this analysis is intended only to illustrate the expected performance over a representative 10 year period, if the wetlands had been constructed prior to the beginning of that period. Figure 2 illustrates the 10 year average mass loading and loss for individual wetlands at specific locations within the CREP service area.

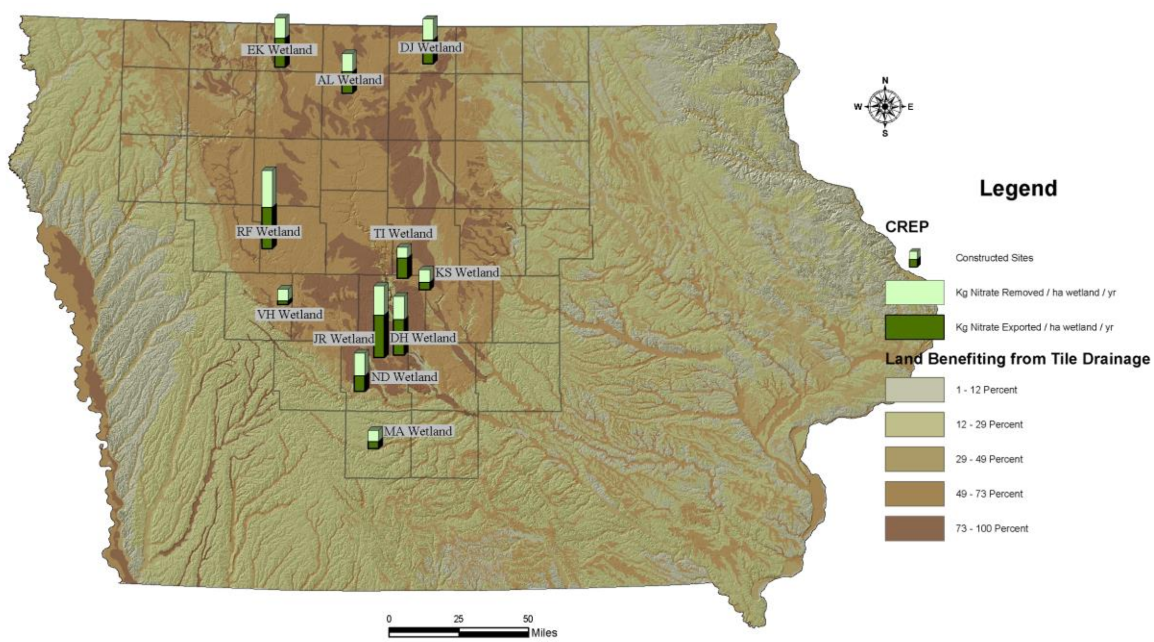

Figure 2. Predicted ten year average nitrate-N loading and loss rates (normalized to wetland area) for selected wetlands in the Iowa CREP service area for 1996 to 2005 input conditions.

Figure 3 illustrates the results predicted for six of the existing wetlands including flow rates entering each wetland, annual mass nitrate loading to each wetland, annual mass nitrate removal by each wetland, and annual % nitrate removal by each wetland. Widely varying annual loading and loss rates can be expected for any given wetland driven largely by yearly differences in precipitation and flow volumes. The wetlands can simply be expected to receive and remove much greater masses of nitrate in wet years than in dry year

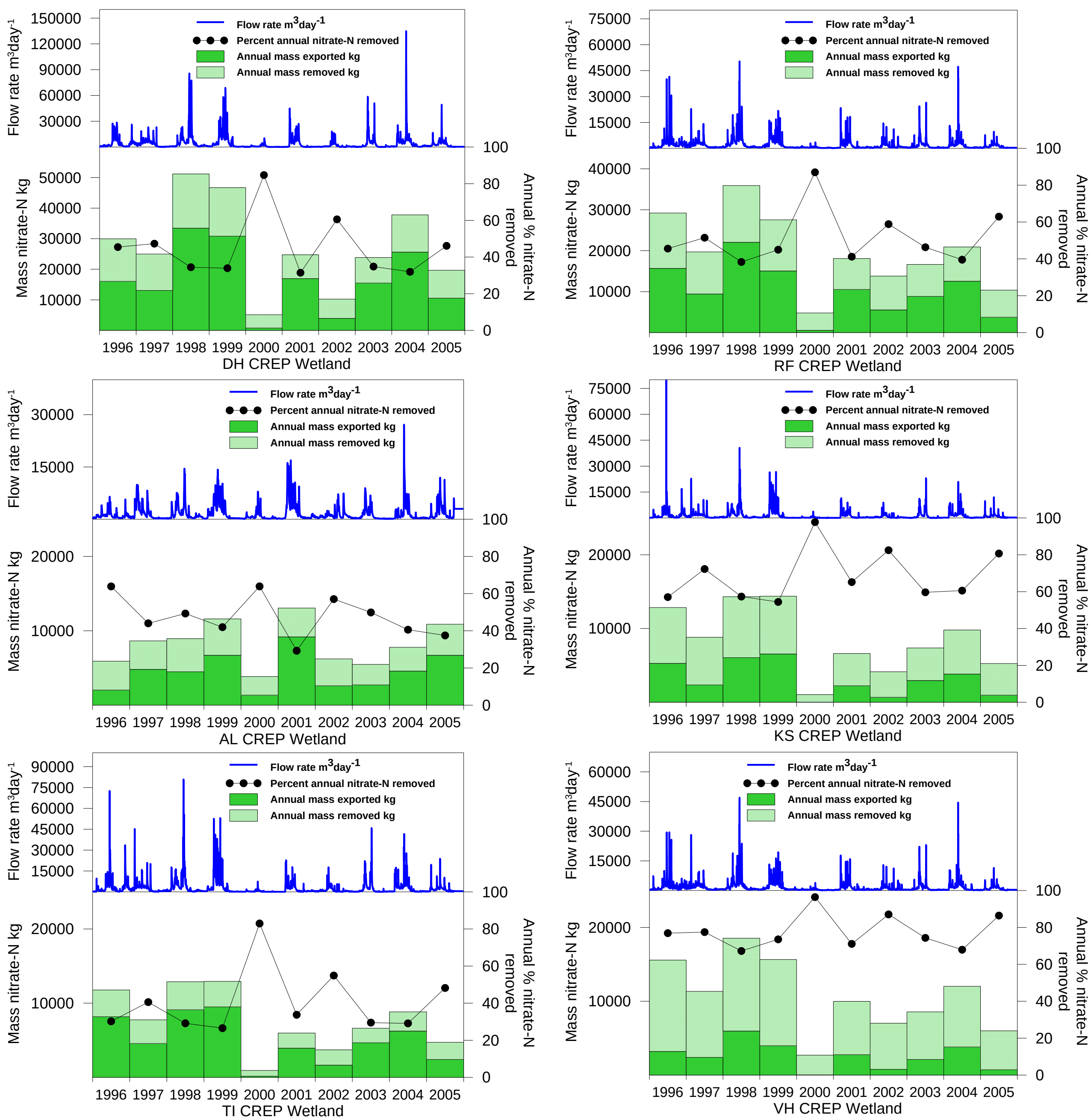

Figure 3. Predicted annual nitrate-N loading and loss rates for selected wetlands in the Iowa CREP service area for 1996 to 2005 input conditions.

Figure 4 illustrates the percent nitrate removal expected for the wetlands over the 10 year hindcast period. For comparison, percent nitrate removals measured for VH Wetland and RF Wetland in 2004 are also presented in Figure 4, and illustrate reasonably good correspondence between observed and modeled performance of the wetlands. As could be expected, the predicted percent nitrate removal is clearly a function of hydraulic loading rate.

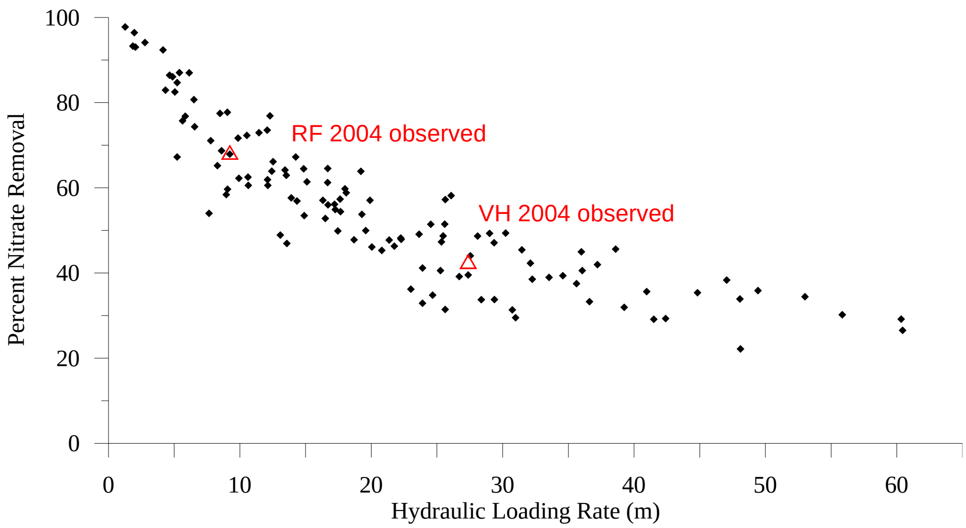

Figure 4. Modeled percent nitrate removal for 1996 to 2005 input conditions.

In contrast to percent removal, mass removal is not determined primarily by hydraulic loading rate. Although mass removal is constrained at lower hydraulic loading rates, mass removal rates vary widely at higher hydraulic loading rates (Figure 5). By itself, hydraulic loading rate explains relatively little of the pattern in nitrate mass removal rates. The observed mass removal rates are predictable using dynamic mass balance models integrating hydraulic loading rates, nitrate concentration, and temperature.

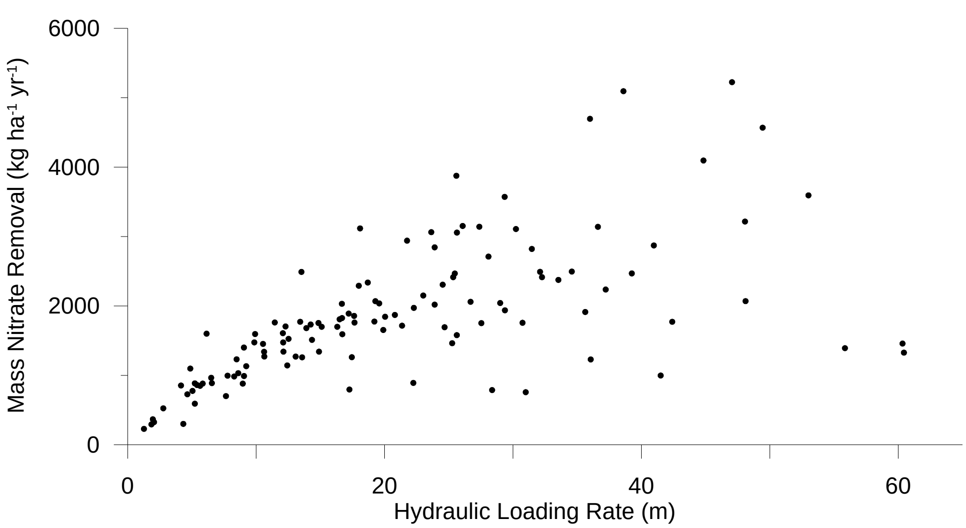

Figure 5. Modeled mass nitrate removal for 1996 to 2005 input conditions.

Nitrate in Tile Drained Watersheds: Synoptic Sampling Program

As discussed above, hydraulic loading rates are expected to vary significantly as a result of wetland/watershed ratios and precipitation patterns even for identical watersheds. However, nitrate concentrations are thought to be primarily determined by agricultural practices and drainage patterns, and are expected to be similar for tile drained watersheds in the same geographic area and with similar agricultural practices. However, monitoring of CREP wetland inflows demonstrated a greater than three-fold range in average nitrate concentrations, with no clear relationship to agricultural practices or drainage patterns. It is possible that differences in nitrate concentration are related to underlying landscape characteristics and that if these could be identified and understood, CREP wetlands could be targeted even more effectively.

Over the past two field seasons, we have implemented a broader monitoring program in an effort to better understand and predict the variation in nitrate concentration from tile drained watersheds in the CREP service area. During the 2004 and 2005 growing seasons, samples were collected from tile drained watersheds at approximately weekly intervals and analyzed for nitrate. In 2004, 46 sites were sampled in four Iowa counties. In 2005, sampling was continued at 23 sites in Cerro Gordo and Franklin Counties chosen to cover the range of concentrations found in the original 46 sites.

Water flow was estimated from nearby USGS gauging station discharge data adjusted to the estimated watershed area for each tile to allow a matching of temporal variation of nitrate concentrations with flow events and to allow estimation of flow-weighted average (FWA) nitrate concentrations. Because the actual flow is not known, field notes describing flow at the time of sampling were useful in interpreting low nitrate values that were occasionally observed when the flow was either zero or very low, even though the nearby gauging station indicated flow might be occurring. Nitrate concentrations in 2004 were generally similar to or somewhat greater than the 2005 values and nitrate concentrations at each location remained relatively consistent between years. The flow-weighted average nitrate concentrations show an approximate three-fold range at these sites (Figure 6).

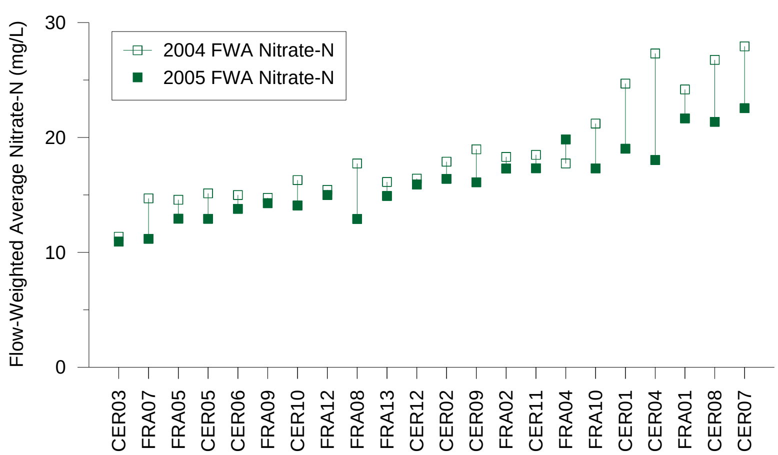

Figure 6. FWA nitrate-N for 2004 and 2005 at synoptic tile sampling sites.

We are currently exploring relationships between nitrate concentration and underlying landscape characteristics in an effort to understand and eventually predict variability in nitrate concentrations in tile drained watersheds with similar agricultural practices. The nitrate concentrations for each site were compared with watershed characteristic summarized from available soil survey attributes, surface slope, and Landsat land-use classification. Watershed boundaries were delineated using the USGS 30m Digital Elevation Model (DEM) and a simple D8 flow direction algorithm. Watershed characteristics were average values from a 30m grid generated for a specific attribute. Soil survey attribute grids were derived from ISPAID datasets which had compiled county soil survey information to a GIS database form. The county by county basis of this information produces some variability of a soils attribute between counties. However, the values reported do represent a relative scale of attribute values. All attributes in the ISPAID database that could reasonably have an effect on water flow or nitrate concentration were evaluated for statistical significance. Surface slope was derived from the DEM. The Landsat land-use was only analyzed for the 5 major land-use classifications found in the study area. It is generally known that nitrate concentrations are positively correlated with %RC. However, by design, the range of %RC across these study sites is low (about 84 to 98%) and thus explains very little of the variability in nitrate concentration. We have yet to identify any strong relationships between nitrate concentration and the landscape characteristics examined. If these can be identified and understood, it might be possible to develop siting criteria such that CREP wetlands could be targeted even more effectively.