2020 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance

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Introduction

Iowa State University monitors selected wetlands in Iowa as part of an ongoing monitoring effort associated with the Iowa Conservation Reserve Enhancement Program (CREP). The Iowa CREP is a targeted, performance-based strategy operated by the Iowa Department of Agriculture and Land Stewardship (IDALS) for nitrate reduction in tile-drained agricultural landscapes. The monitored wetlands are selected to span a wide range in wetland-to-watershed area ratio and inflow nitrate concentrations in order to ensure a broad range in hydraulic and nitrate loading rates. This allows the characterization of wetland performance across a wide range of conditions which provides information necessary to properly target new wetland locations and sizing wetlands to maximize nitrate loss.

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 threefold range in average inflow 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, ongoing monitoring and research programs will allow continued refinement of modeling and analytical tools used in site selection, design, and management of CREP wetlands. This report is part of a series of reports documenting the annual performance of selected Iowa CREP wetlands and summarizes results for the 2020 monitoring program.

Summary of 2020 Monitoring

Fourteen wetlands were monitored in 2020 (Figure 1), including 13 Iowa CREP wetlands and one mitigation wetland (DD15-N).

Wetland monitoring included measurements of wetland inflows, outflows, pool elevations and water temperature, and collection of weekly to biweekly water quality grab samples and daily samples. Daily samples were collected using automated samplers programmed to collect samples at wetland inflows and outflows when above freezing conditions allowed the equipment to function properly. After August 2020 inflow and outflow at all wetlands monitored declined to zero or near zero. When outflow stops, water quality samples are collected from the wetland pool near the outflow structure. Due to occasional equipment failure, some daily values may be missing.

During 2020 a beaver dam was observed at the KS wetland inflow, on the KS wetland outflow structure, and on the DD65 outflow structure causing elevated water depth at these wetlands. These beaver dams were periodically removed by the field crew (and by the landowner at the KS wetland) but were generally rebuilt within days.

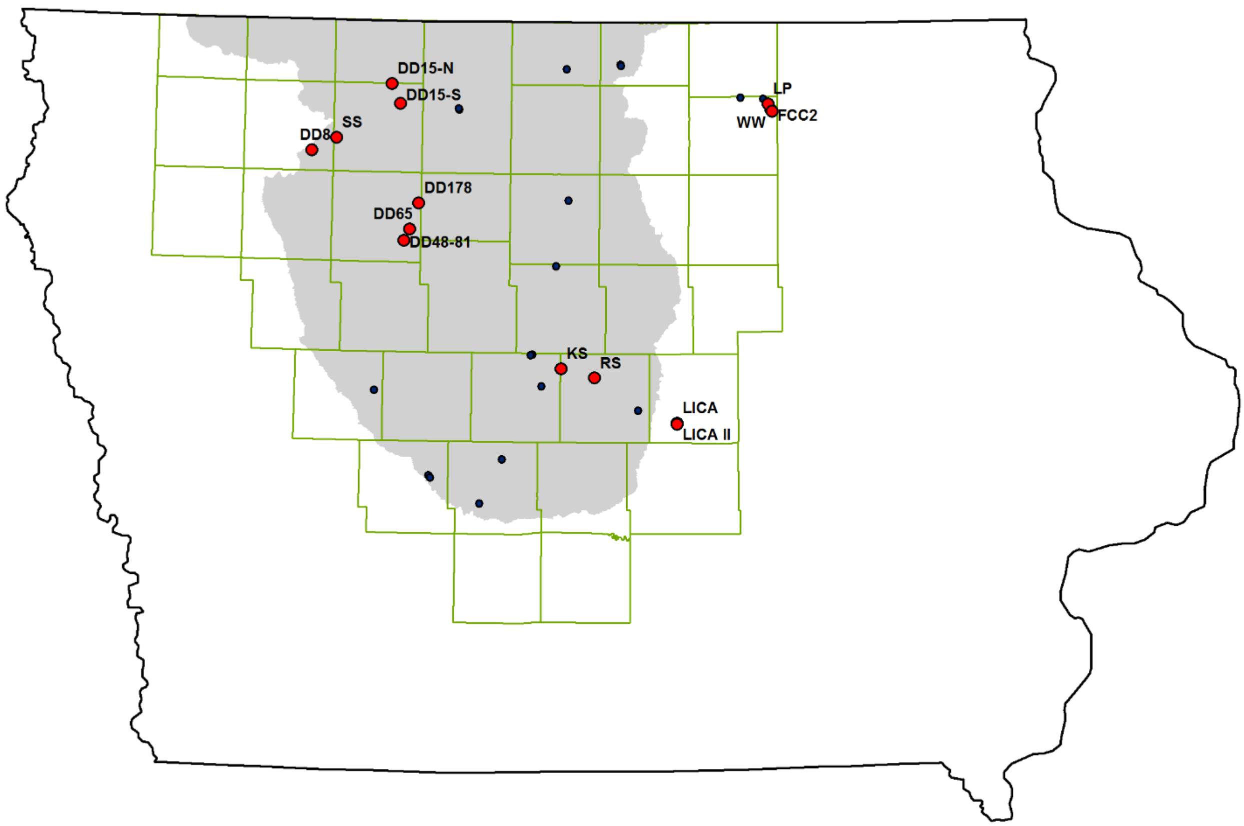

Figure 1. Wetlands monitored in 2020 (labeled red circles) and additional wetlands monitored in prior years (blue dots). The gray shaded area represents the Des Moines Lobe in Iowa and counties approved for CREP wetlands are shown with green outline.

Wetland inflow and/or outflow channels were instrumented with submerged area velocity (SAV) Doppler flow meters and stage recorders for close-interval (every five minutes) measurement of flow velocity and stream depth, respectively. 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. Water depth upstream of weir structures was monitored and discharge was calculated using calibrated weir equations. Wetland pool water levels were monitored at five minute intervals using stage recorders in order to calculate pool volume, pool area, and discharge at outflow structures. The discharge equations and SAV based discharge measurements are calibrated using manual velocity-area based discharge measurements collected during 2020 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 was 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 60% of the depth from the surface is taken as the mean velocity for the interval. The product of velocity and area summed over intervals gives the total discharge. Flow during winter periods having temperatures below which the monitoring instruments can function is estimated using water yields from nearby United States Geological Survey river gage station data scaled to the individual wetland watershed areas.

Patterns in Nitrate Concentrations and Loads

Despite significant variation with respect to nitrate concentration and loading rates, the wetlands display similar seasonal patterns and general relationships to discharge (Figure 2). Historically, inflow nitrate concentrations are variable during the winter. However, because winter flows are typically low, the winter nitrate loading is also low during most years. Snow-melt often results in increased flow during late February or March but nitrate concentrations in the melt water and associated runoff are typically low. Spring flow is usually high and shows the highest nitrate concentrations. Nitrate concentrations generally decline through July and August during dry periods, but may remain elevated as long as there is sufficient flow. Nitrate concentrations during large summer flow events often decline abruptly with peak flows but generally rebound within a few days of these high flow events - this is thought to be associated with surface runoff having low nitrate concentrations. In contrast to this, smaller summer flow events lacking significant surface runoff are often accompanied by an increase in nitrate concentration likely associated with a flushing of nitrate from the soil profile. 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.

Wetland Performance (Nitrate mass loss and removal efficiency)

Wetland performance is a function of hydraulic loading rate, hydraulic efficiency, nitrate concentration, temperature, and wetland condition. Of these, hydraulic loading rate (HLR, the total volume of water received per area of wetland surface per unit of time) and nitrate concentration are especially important for CREP wetlands. The range in HLR 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 large annual variation in both precipitation and water yield. The combined effect of these factors results in annual loading rates to CREP wetlands that 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, respectively, for each monitored wetland. All of the wetlands had been drained and cropped or pastured prior to restoration, and were predominately characterized by poorly to very poorly drained hydric soils. With the exception of LICA II, wetland restorations utilized the natural topography at each site with limited earthwork other than that required to create low earthen dikes with integrated overflow structures, and in a few cases submerged berms to reduce potential short circuiting. Wetland bathymetry was determined from as-built construction plans or bathymetric surveys. The construction plans for the LICA II wetland show extensive excavation to broaden the upper shallow portion of the wetland and to create a deep pond near the wetland outflow, along with a deep channel extending into approximately the upper two-thirds of the wetland resulting in significant potential for short circuiting of water flowing through that wetland. Wetland bathymetry data were used to characterize wetland volume and area as functions of wetland water depth. These bathymetric relationships were used in both numeric modeling of water budgets and nitrate mass balances to calculate nitrate loss, hydraulic loading, and hydraulic residence time.

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} $year^{-1}$). However, the LICA II wetland showed lower nitrate loss than expected on the basis of the wetland area, possibly due in part to potentially poor hydraulic efficiency of that wetland (see Figure 3). Variability in wetland performance is in part due to differences in wetland characteristics and condition and partly due to differences in loading rates and temporal patterns. At a given annual HLR, differences in wetland condition and in timing of loading can result in significant differences in performance (Figure 3).

Mass balance analysis and modeling has been 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. The results of the mass balance calculations for the 2020 and prior monitoring years (2004 through 2019) is illustrated in Figure 3. The results demonstrate that hydraulic loading rate is clearly a major determinant of wetland nitrate removal performance.

In addition to calculating the measured percent nitrate removal, the nitrate mass removal is also calculated. The expected average nitrate mass removal for CREP wetlands can be estimated based inflow flow-weighted average (FWA) nitrate concentration, hydraulic loading rate, and the percent loss function shown in Figure 3. Inflow FWA nitrate concentrations observed for 2004 through 2020 CREP wetlands not having another wetland upstream of them average 14.2 mg N L^{-1} and range from 6.2 to 30 mg N L^{-1}. The observed average nitrate mass removed for these same wetlands is 1770 kg N ha^{-1} yr^{-1} (1580 lb N $acre^{-1}$ yr^{-1}). While the percent nitrate loss is high at low HLR, those cases tend to occur during drier years having low nitrate loads, and hence, low total nitrate mass loss. Because of the non-linearity of the percent loss function (see Figure 3), long term nitrate mass loss is dominated by wetter years having high nitrate loads and high HLRs, even though wetter years tend to have lower percent removal.

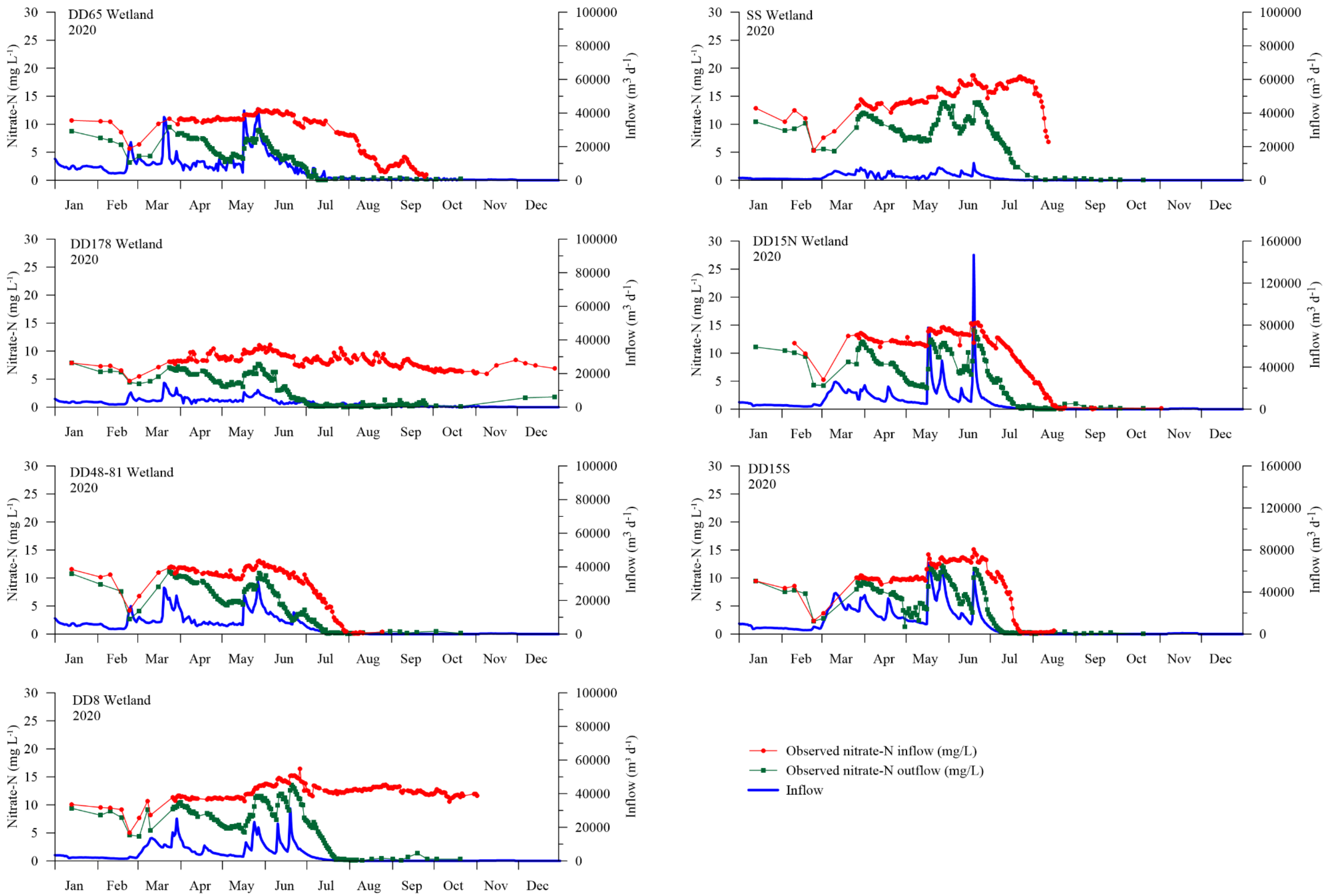

Figure 2. Measured nitrate concentrations and flows for northwest Iowa wetlands monitored during 2020.

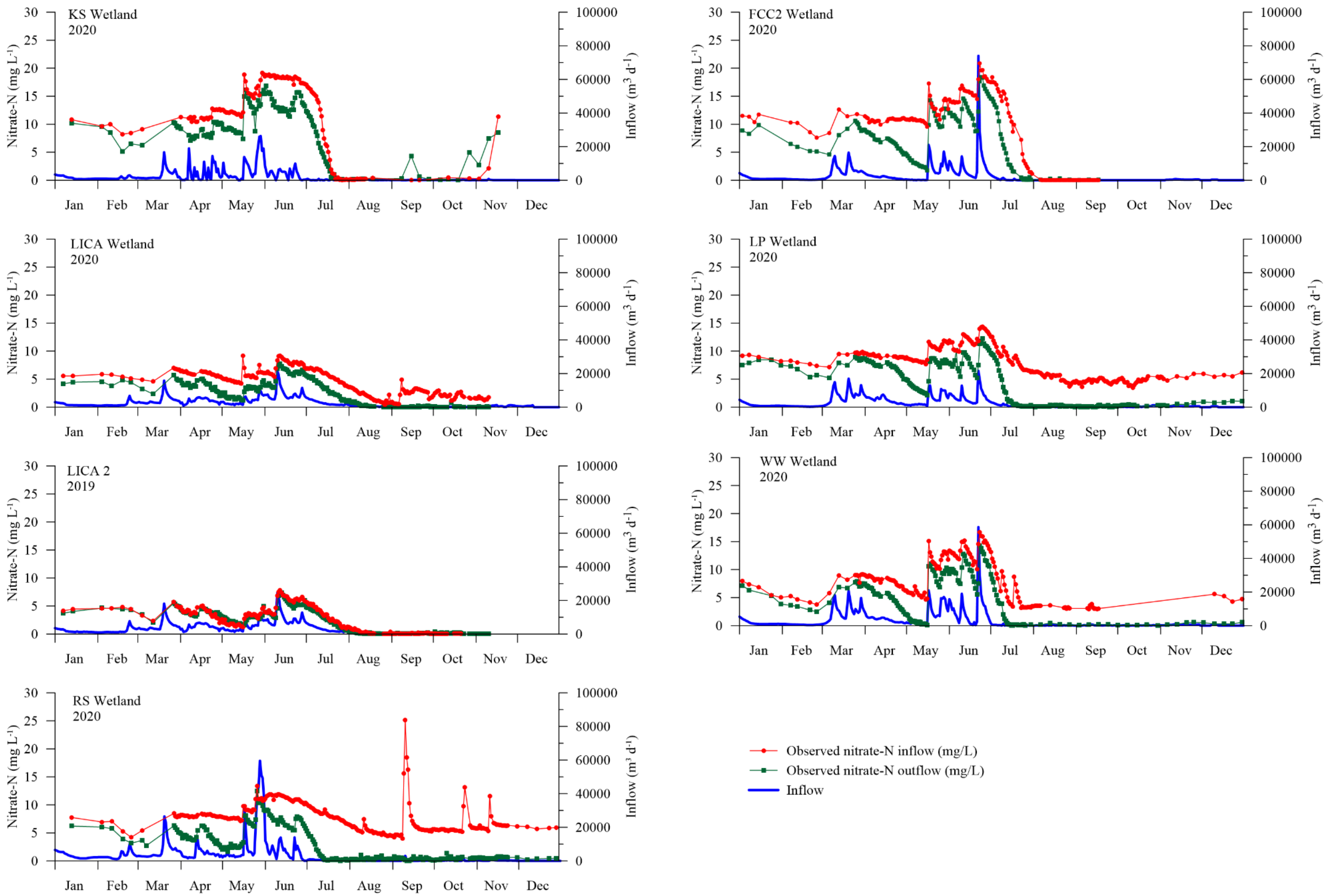

Figure 2. (Continued) Measured nitrate concentrations and flows for central and northeast Iowa wetlands monitored during 2020.

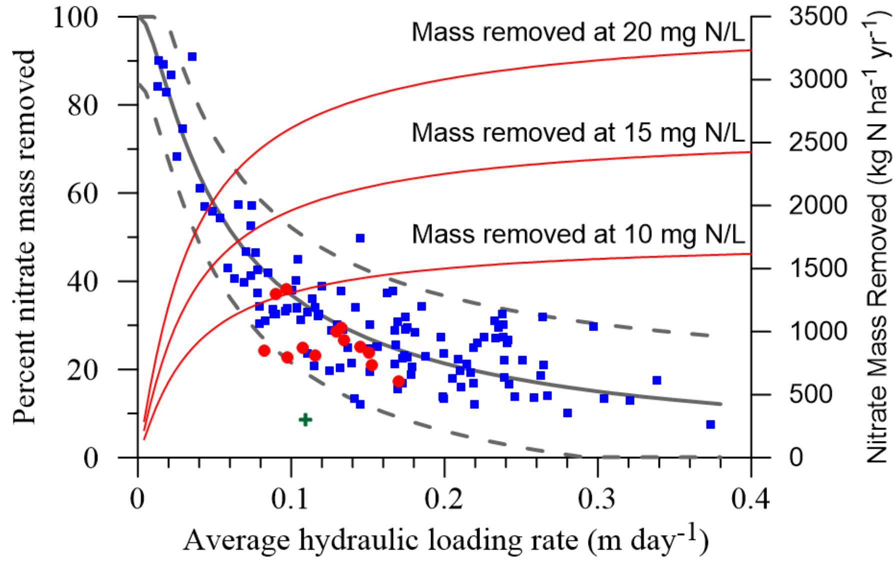

Figure 3. Percent nitrate removal performance for 2020 (red circles; the green plus sign shows the lower than expected performance for the LICA II wetland) and wetlands monitored during prior years (2004-2019, blue squares). The solid black line is the expected percent loss and the dashed gray lines indicate the range expected to contain 95% of similar wetlands in Iowa on the basis of the 2004 to 2015 monitored wetlands. The solid red lines (right y-axis) show the expected nitrate mass removal per ha of wetland for FWA concentrations of 10, 15, and 20 mg N L^{-1}. The low 2020 point having a HLR of 1.1 and percent nitrate removal of 9% is LICA II.