Water Parcel Tracking to Evaluate Conservation Practice Effectiveness in Agricultural Watersheds

Ryan Felton[1*], John Baker[1,2], Brent Dalzell[1,2], Kade Flynn[2], Joel Nelson[2]
[1]University of Minnesota, [2]USDA-ARS, *felto044@umn.edu

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Abstract

In agricultural landscapes, differences in management practices, soil characteristics, and topography can all interact to influence the delivery of nutrients from farm fields to receiving ditches and streams. While a wide variety of conservation practice options are available to landowners and conservation professionals, it can be difficult to know where they are most cost effective because of a disconnect in information between plot-scale studies and monitoring data collected at watershed outlets. To address this gap, we are employing a Lagrangian sampling technique to monitor a water parcel as it travels through an agricultural ditch network.

We use an ultralight (8 lb.) inflatable kayak capable of navigating narrow, shallow agricultural ditches. It contains a sensor platform consisting of an optical nitrate sensor and a multiparameter sonde coupled with a GPS receiver which allows us to generate spatial data sets through a ditch and stream network. Preliminary results have been helpful in identifying the influence of key micro-watershed tributaries as important sources of nitrate, and assessing the role of wetlands in mediating nitrate loads. Ongoing efforts are focused on combining frequent Lagrangian sampling with continuous Eulerian monitoring at selected sites in order to identify biogeochemically important hot-spots and hot-moments. Potential applications of this methodology include evaluation of the impact of specific practices such as saturated buffers and constructed wetlands on water quality as well as identifying areas of concern within small watersheds.

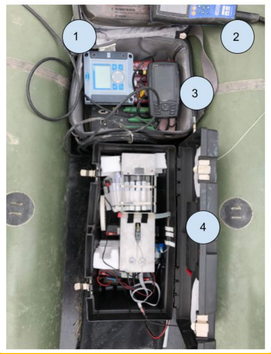
Methods

Streams and ditches in watersheds dominated by agriculture provide a unique set of challenges. The use of a rugged and lightweight raft allows for portages over log jams, low ditches, and other hazards. A human powered craft allows for sampling in a variety of flow conditions where streams can be as low as six inches deep. The ability to monitor wide ranges of flow conditions allows for insights into the effects of single precipitation events on nutrient loading and in stream nutrient dynamics.

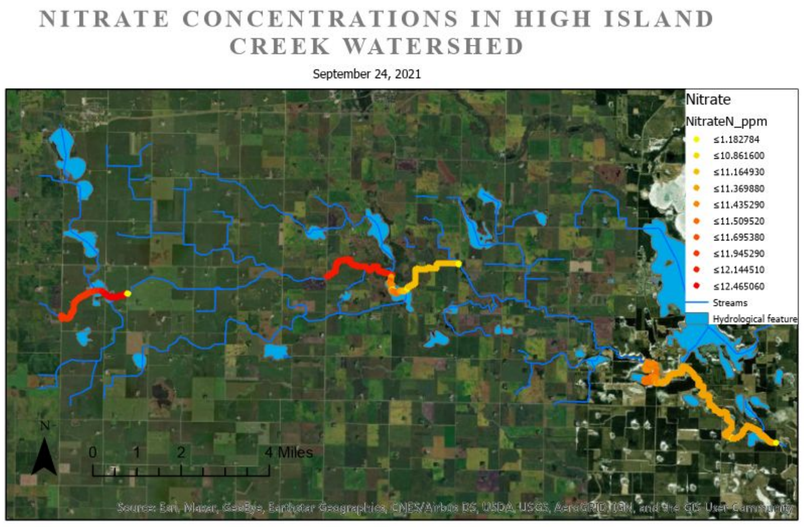
The sensor platform is designed to allow a researcher to be hands off with the instrumentation, allowing longer reaches of stream to be paddled in a single day. The method allows for researchers to enter and exit waterways legally from road easements and stay within a navigable channel throughout the sampling event.

The current sensor platform is shown to the right:

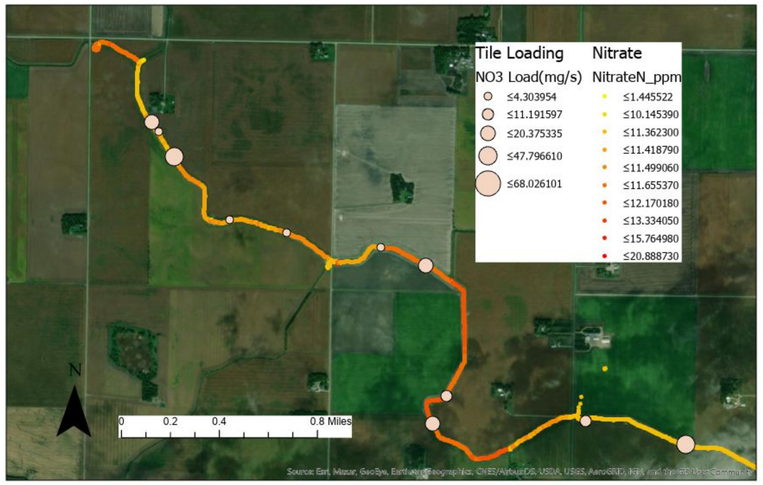
1. Hach Nitratax in situ optical Nitrate sensor.
2. YSI EXO2 multi-parameter sonde carrying sensors to measure DO, fDOM, pH/ORP, TSS, algae, optical nitrate, and conductivity.
3. Garmin GPS unit and sonic depth sensor and Campbell data logger which geo-references readings from the nitratax and other inputs.
4. Bandalero discrete sampling manifold. Can carry more than 100 exetainer vials for laboratory analysis that are geo-referenced with the Garmin unit.



Results



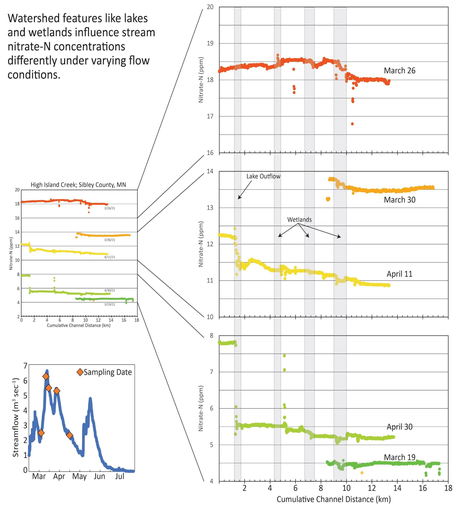
The above map shows three sections of High Island Creek sampled on 9/24/2021. High Island Creek is an agriculturally dominated watershed in the Minnesota River basin, approximately 65 miles southwest of Minneapolis. The figure shows a change from east to west across the watershed from low order judicial ditches to lake and wetland storage with more morphologically undisturbed channels. Nitrate concentrations decrease through wetland sections indicative of in-stream processing.



The figure above shows an expanded view of a section of western, (agriculturally dominated) High Island Creek from a sampling event on 8/30/2021.
Beige circles indicate incoming tile drains. The size of the circle relates to the nitrate load from that individual tile.

Discussion

These preliminary results show spatial and temporal variation in nitrate concentrations in High Island Creek.



In the figures on the left, a Jenk's natural breaks distribution is used to highlight change in concentration, while the figure on the right shows five sampling events during spring 2021. The variability of each run is retained through the use of standardizing runs by cumulative distance but the reference to the landscape is less clear. A combination of these display techniques can be useful to highlights the impact of watershed features as well as the variability of individual sampling events.

Future Plans

Instantaneous Flow Approximations to Distinguish in Stream Processes

A limitation of the current sensor platform is the challenge of approximating instantaneous flow rates from the position of a moving boat. With flow information, it would be possible to determine instantaneous loads an multiple locations in the watershed. This would provide greater insight into how nitrate budgets may change at different watershed locations and under varying seasonal and flow conditions.

Modeling and Conservation Planning using ACPF

These Lagrangian data may fit well into efforts aimed at identifying potential areas for the implementation of conservation practices. Existing spatial models such as SWAT (Soil and Water Assessment Tool) could be validated and improved through water parcel tracking. The ACPF model (Agricultural Conservation Planning Framework) also provides tools for distinguishing small, field scale, watersheds in tile drained areas that fits with the fine spatial resolution of water parcel tracking. Combining ACPF with water parcel tracking may help to implement conservation practices more effectively in agricultural landscapes.

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