NON-POINT SOURCE POLLUTION IN THE LITTLE CHAZY RIVER OF NEW YORK

ROBERT D. FULLER AND DAVID A. FRANZI
Center for Earth and Environmental Science, State University of New York, Plattsburgh, NY 12901

STEVEN KRAMER AND ERIC YOUNG
Miner Agricultural Research Institute, Chazy, NY 12921

INTRODUCTION

The Little Chazy River watershed (Fig. 1) drains into Lake Champlain, which is an oligotrophic to mesotrophic water body with low to moderate levels of phosphorus and nitrogen, the primary nutrients for primary productivity and principal determinants for associated water quality issues. Major sources of nutrients in Lake Champlain include point sources such as municipal sewage treatment plants and non-point sources including urban runoff and agricultural inputs. Extensive dairy operations in the Lake Champlain basin produce large quantities of manure, which is applied back to soils and can potentially become a major source of nutrients to nearby surface waters (Fig. 2). Consequently, reduction of nutrient inputs to Lake Champlain, which promotes healthy and diverse aquatic ecosystems and provides for sustainable human use and enjoyment of the lake, is a priority.

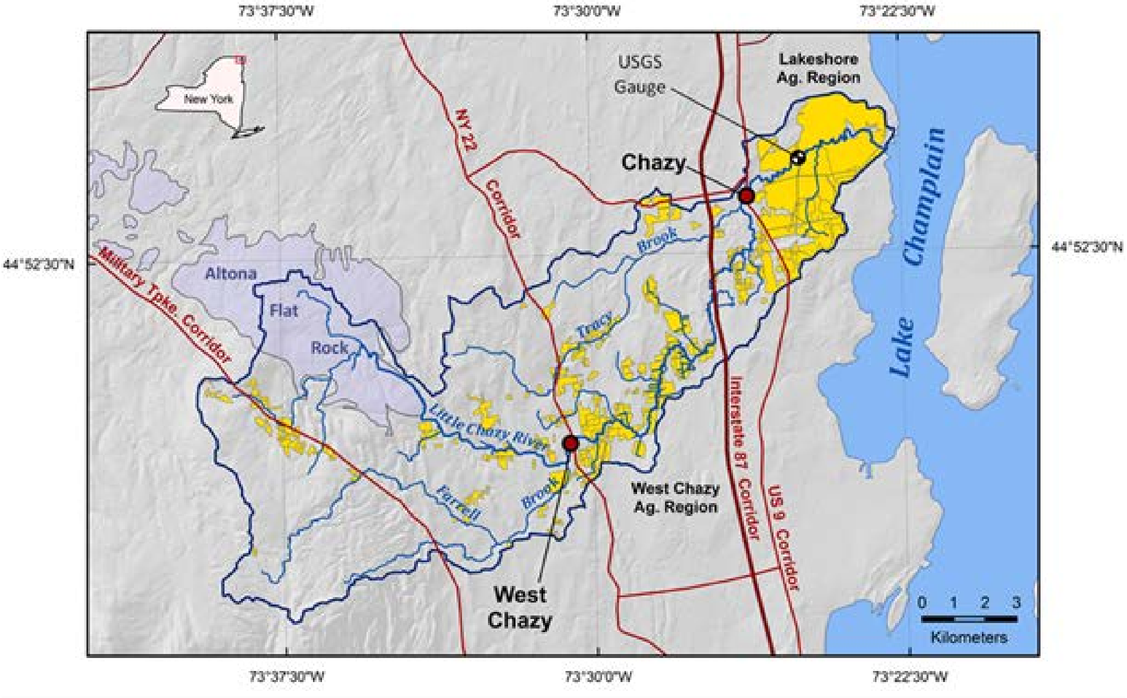

Figure 1. Map of northeastern New York, showing the distributions of agricultural land (yellow shading) and sandstone pavements or “Flat Rocks” (purple shading) in the Little Chazy River watershed. The Flat Rocks extent is from maps by Denny (1974). The figure is from Oetjen et al. (2012).

SUNY Plattsburgh and the William H. Miner Agricultural Research Institute (Miner Institute) used a high-resolution monthly synoptic water-sampling strategy to examine the spatial and downstream distribution of nutrient concentrations (i.e. nitrate-N, total phosphorus and soluble reactive phosphorus) in the Little Chazy River and its principal tributaries for five full years between January 2008 and December 2012 (Fig. 1). The Little Chazy River watershed is typical of medium-sized (basin area = 145 km^2), rural watersheds in the region, possessing a broad range of watershed issues and concerns reflected throughout the Champlain lowlands. Agriculture accounts for approximately 17% of land cover in the watershed, compared to approximately 24% of land cover county-wide, most of which is concentrated near the lake shore east of Chazy village. The watershed was identified on the 1996 Lake Champlain Basin Waterbody Inventory/Priority Waterbodies List Report as a class C river with possible impaired fish survival (NYSDEC, 2001). Karim (1997) cited on-site septic problems, particularly in Chazy and West Chazy, and high levels of livestock and crop agriculture as water pollution concerns in the watershed. The Little Chazy River has the highest median nutrient concentrations and median unit nutrient load (nutrient load per unit area of watershed) of any New York tributary to Lake Champlain that is monitored as part of the Lake Champlain Long-term Water Quality and Biological Monitoring Program (Vermont DEC and New York DEC, 2002).

Figure 2. Agricultural tributary entering the Little Chazy River 23 km from the mouth at Lake Champlain. Many of these tributaries receive inputs from tile-drained fields supporting dairy operations with attendant applications of manure solids and liquids.

Geological Setting: The Little Chazy River originates in upland forests in the northeastern foothills of the Adirondack Mountains and flows eastward through the Champlain lowland to its mouth at Lake Champlain. It has two principal tributaries, Farrell Brook (basin area = 27 km^2)

and Tracy Brook (basin area = 25 km^2). The headwater region is a predominantly forested area of moderate relief (<400 m) that is underlain by thin glacial soils (generally <3m thick), Cambrian clastic sedimentary rocks and high-grade Mesoproterozoic metamorphic rocks. This region (Fig. 1) includes a large area of exposed sandstone bedrock, or sandstone pavement, known locally as Altona Flat Rock (Franzi and Adams, 1993). Mainstream gradient in the headwater region commonly exceeds 10 m/km (Fig. 3).

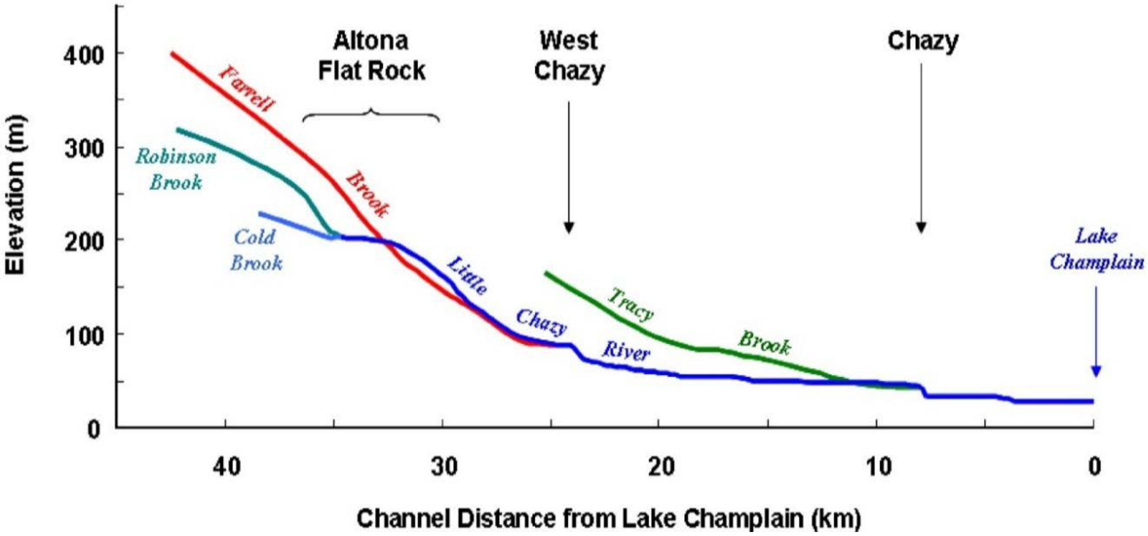

Figure 3. Stream profiles for the Little Chazy River and its principal tributaries.

The river descends steeply through dense headwater woodlands to the Champlain lowland and flows through a patchwork of forested and agricultural lands before emptying into Lake Champlain. The Champlain lowland is underlain by thick glacial, glacial-lacustrine, and glacial-marine sediments, and lower Paleozoic sedimentary rocks. Local relief in the lowland is generally less than 100 m and the mainstream channel gradient averages approximately 1 m/km. Prominent knickpoints (locations where stream gradient increases abruptly) on the Little Chazy River occur in the lowland portion of the watershed at the villages of Chazy and West Chazy (Fig. 2), where the river flows across bedrock obstructions. Dams at Route 9 and the Fiske Road in the village of Chazy create consecutive narrow, nearly sediment-filled impoundments that extend roughly 6 km upstream from Route 9. Other flow-control structures in the watershed include a series of small dams or weirs that extend downstream from Lake Alice on Tracy Brook to the Village of Chazy and abandoned dams, either flood damaged or otherwise compromised, on the Little Chazy River at West Chazy and two large dams at Altona Flat Rock. Most of the flow-control structures in the watershed date to the early 20th century when William H. Miner constructed several hydroelectric projects in the region (Dawson et al., 1981; Landing et al., 2007).

ANALYTICAL METHODS

Stream Hydrology: SUNY Plattsburgh and Miner Institute monitored river height, water temperature and logger temperature at 13 stream gaging stations (Fig. 4); four stations on Tracy Brook (TROSS, LKALI, LKALO and TB87), one station at the mouth of Farrell Brook (DENO) and eight stations on the main channel of the Little Chazy River below Miner Dam (MDAM, NEPH, GUEST, LANG, CHALIZ, WOOD, LC87 and CHAZY). All SUNY/Miner stations were equipped with Tru-Trac WT-HR water height (stage) dataloggers. Stream discharge records for the U.S. Geological Survey (USGS) gauging station near the river mouth east of Chazy (USGS) were obtained from the USGS website (http://waterdata.usgs.gov/ny/nwis/uv/?site_no=04271815). The USGS stream gage operated through the winter season and records are available from Water Year 1990 to November 2014.

Water Quality Sampling: Synoptic sampling involves the collection of closely spaced water samples in a short time period (generally less than four hours) to provide a snapshot of nutrient concentrations (nitrate-N, total phosphorus and soluble reactive phosphorus) and loadings throughout the watershed (Fig. 4). Sample spacing along the mainstream, tributaries and other inflows varied with accessibility and land use. Channel distance between samples varied from more than 5 km in forested upland regions to a few hundred meters in villages or agricultural lands where anthropogenic inputs such as ditches and drains are more common.

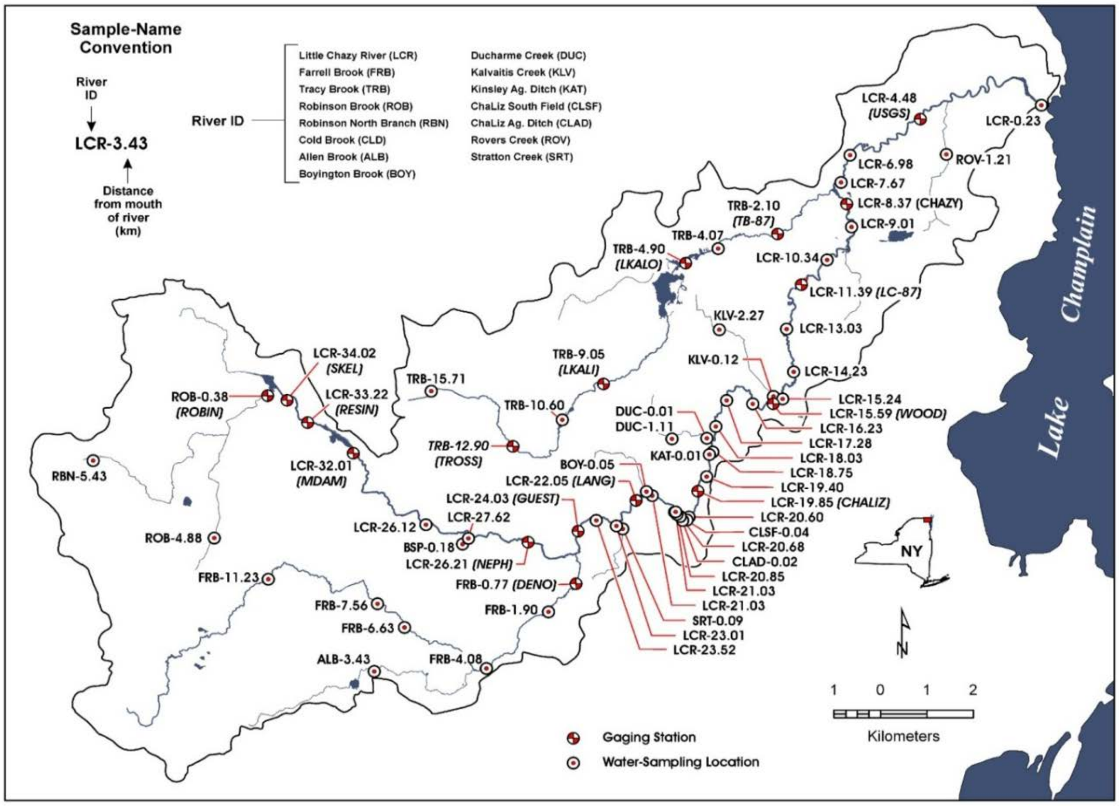

Figure 4. Locations for stream gaging stations and water-quality sampling stations used in this study.

Water Quality Analysis: Water samples were collected in acid-washed, 500 ml polyethylene bottles within a period of approximately four hours to minimize temporal variations in nutrient concentrations. At the end of the collection period, samples were transported to the lab in coolers within a period of one hour and immediately split into two fractions; one which was filtered through a 0.47μ membrane filter to remove particulates and the other left unfiltered. Filtered subsamples were analyzed for nitrate using a Dionex Ion Chromatograph with conductimetric detection and colorimetrically for soluble-reactive phosphorus (primarily phosphate) using a UV-Vis spectrophotometer with the ascorbic acid method (APHA, 1998). For total phosphorus, unfiltered water samples were digested using potassium persulfate in sulfuric acid on a block digester (APHA, 1998), followed by analysis for soluble-reactive phosphorus.

High-Resolution Temporal Sampling: A high-resolution temporal sampling strategy was used to evaluate the temporal distribution of nutrient concentrations at the USGS gaging station (Fig. 4) through three sequential runoff events in October 2010. Sampling interval varied from 3-4 hours during the initial phases of the rainfall events to >24 hours during periods of prolonged baseflow. In order to relate flow to instantaneous nutrient loading for each event, a system was developed to make each parameter (time, flow and load) dimensionless relative to its maximum value.

Dimensionless time = $t/t_{\text{peak flow}}$

Dimensionless discharge = Q/Q_{peak}

Dimensionless load = L/L_{peak}

Where t = time, Q = discharge in m^3/sec and L = Load in Kg/day.

RESULTS and DISCUSSION

Spatial Variability in Water Quality

Mainstream Nitrate, Total Phosphorus and Soluble Reactive Phosphorus concentrations in headwater forests were typically low (< 1 mg/L NO_3-N,< 10 µg/L P) and increased substantially upon entering lowland agricultural regions (Figs. 5A and 5B). Occasional abrupt increases in nitrate concentrations (Fig. 5A) within the agricultural areas may be attributed to high concentrations in inputs from agricultural ditches or tiles, but this trend was not consistent due to the low discharges measured in many of these tributaries. Nitrate-N concentrations generally leveled off at 0.4-0.5 mg/L in the agricultural area between West Chazy (Lang) and Chazy and actually decreased in two small, narrow impoundments in the village of Chazy. Decreases in nitrate concentration in the impoundment is most likely due to dilution, conversion to more chemically reduced forms, or sequestration in algae, aquatic macrophytes and sediments, particularly during the growing season. Nutrient concentrations increased substantially in the 7 km-long reach between the village of Chazy and Lake Champlain, where the river traverses a low-relief, intensively managed agricultural area developed on relatively deep glacial-marine soils. The Chazy wastewater treatment facility is also located in this reach, however little change was found in nutrient concentrations above and below its discharge.

Phosphorus (total phosphorus and soluble-reactive phosphorus) (Fig. 5B) concentrations also increased downstream, but with a pattern different from nitrate. Concentrations increased only slowly through the central portion of the watershed, with the largest increases occurring in the bottom reach, as with nitrate. Phosphorus concentrations also exhibited substantially more temporal variability; an effect of variable manure applications, overland transport during storm events or possibly measurement errors associated with relatively low phosphorus concentrations (10-100 µg/L).

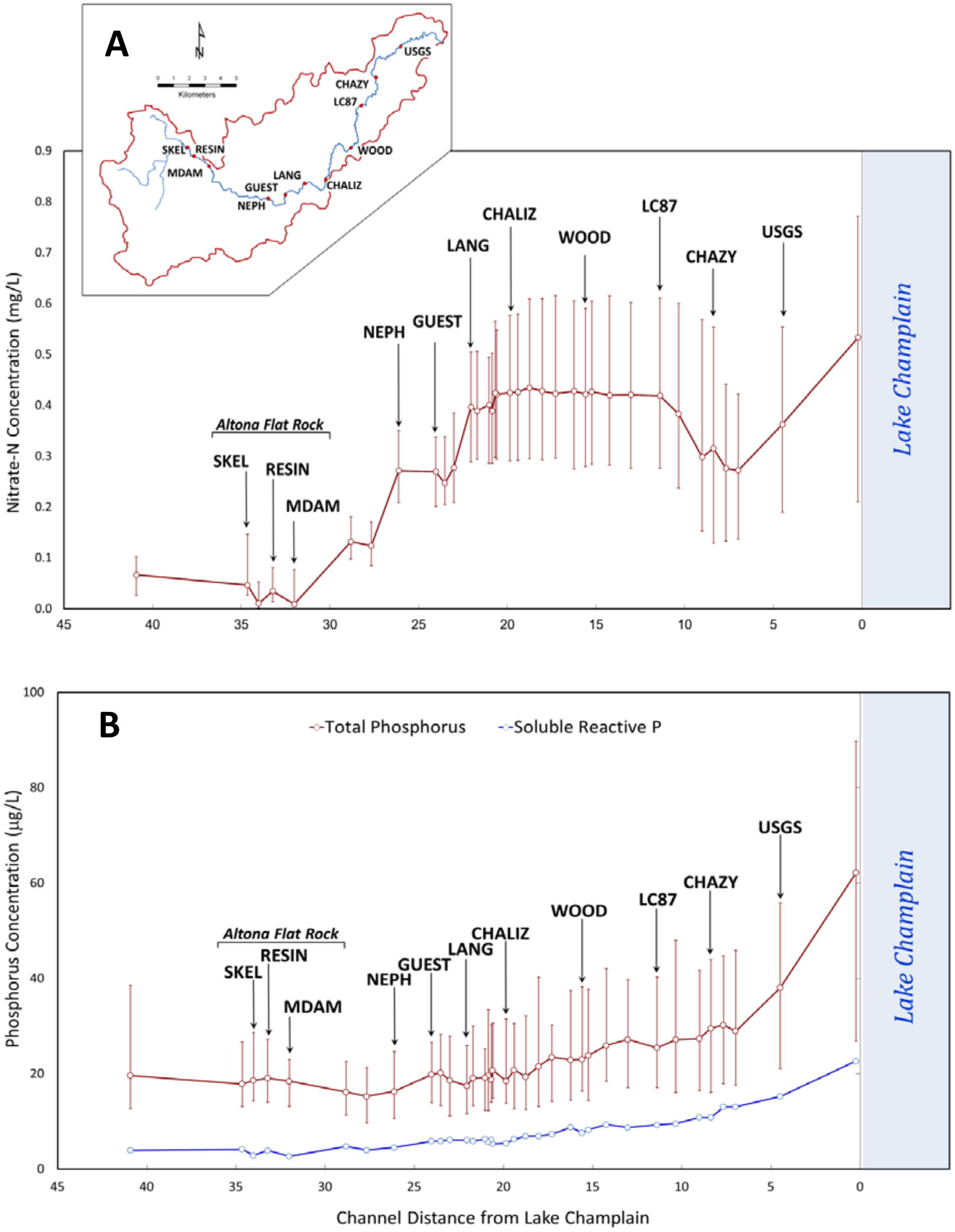

Figure 5. Box plots showing the longitudinal variability of median monthly nitrate-N (A), total P (B) and Soluble Reactive P (B) along the main channel of the Little Chazy River (error bars for nitrate-N and total phosphorus show 25th to 75th percentile range; n=62 for each point, except Altona Flat Rock headwater samples with sporadic flow).

Soluble Reactive P (largely free phosphate) comprised on average 31.4 +/- 6.9% (mean +/- S.D.) of Total Phosphorus concentrations, but increased from roughly 20% in the headwaters, to as high as 45% in the lower reaches (Fig. 6). Indeed, the increases in total P concentrations downstream are largely driven by increases in soluble reactive P, the form most available to aquatic biota. Large increases in nutrient concentrations in the lowermost reaches of the Little Chazy River, especially phosphorus (Fig. 5B), may be related to not only the large areal extent of agriculture in the lower reaches of the watershed (Fig. 1) but also to large areas of surface-drained agricultural fields near the lake that potentially contribute to overland flow from manured fields.

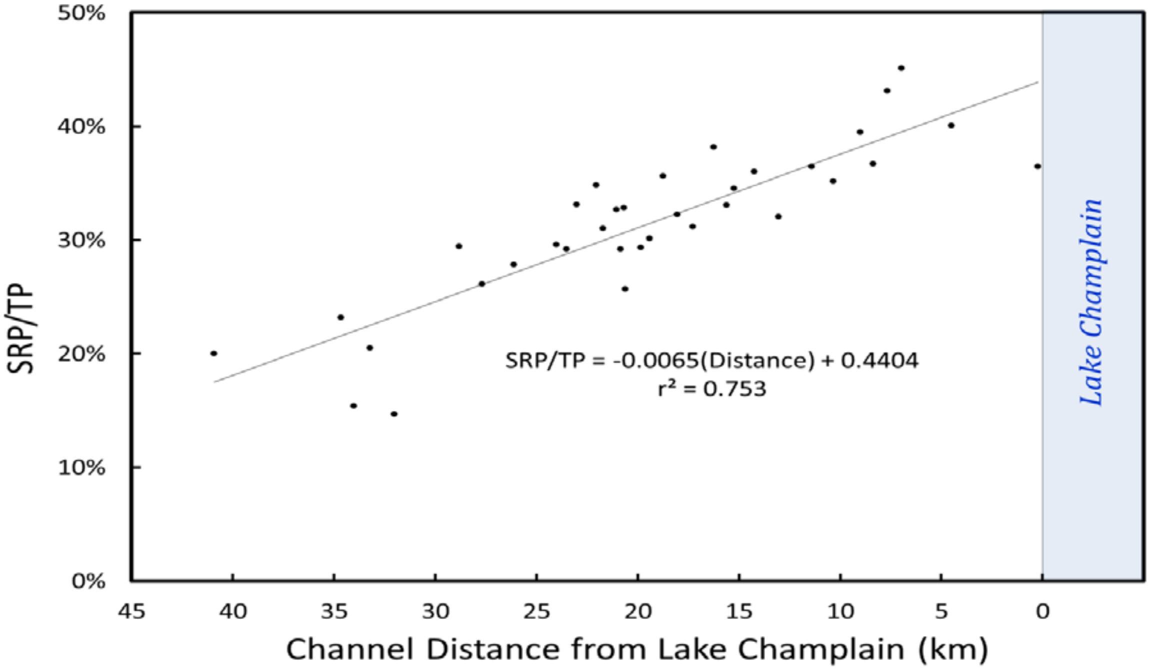

Figure 6. The ratio of soluble reactive P (SRP) to total P (TP) as a function of channel distance from Lake Champlain.

Temporal Variability – Seasonal Scale

Seasonal effects on stream nitrate concentrations (Fig. 7) were pronounced, with winter concentrations (Nov-Apr) being consistently higher than summer concentrations (May–Oct) throughout the watershed. There are many possible explanations for this relationship, but the most likely include extensive plant uptake of nitrogen in the summer growing season, as well as a lack of manure application to fields during much of the growing season, except on hay fields. Extremely low concentrations of nitrate were observed throughout the Altona Flat Rock pine barrens (Fig. 7). This oligotrophic ecosystem occurs on extremely thin soils (< 5cm) overlaying sandstone pavement, and it is possible that its unique vegetation actively scavenges nitrate from soil solutions and surface waters. As streams exit the Pine Barrens they enter a forested zone over deeper glacial tills and nitrate concentrations rise to levels (0.1 – 0.2 mg/L NO_3-N) more generally representative of forested sites. Increases throughout the stretch beginning at station NEPH (Fig. 7) are most likely influenced by the effects of agriculture.

Also apparent is a pronounced decrease in nitrate-N concentrations beginning at the Ratta site (Fig. 7) in the summer months. This site is the beginning of a small river-wide impoundment that is held by a small dam in the village of Chazy. In the summer months, during active transpiration and low flow, the residence time of water in this impoundment increases, and nitrate is lost. The mechanism for this loss is unclear, but may include biological uptake or conversion to more reduced forms.

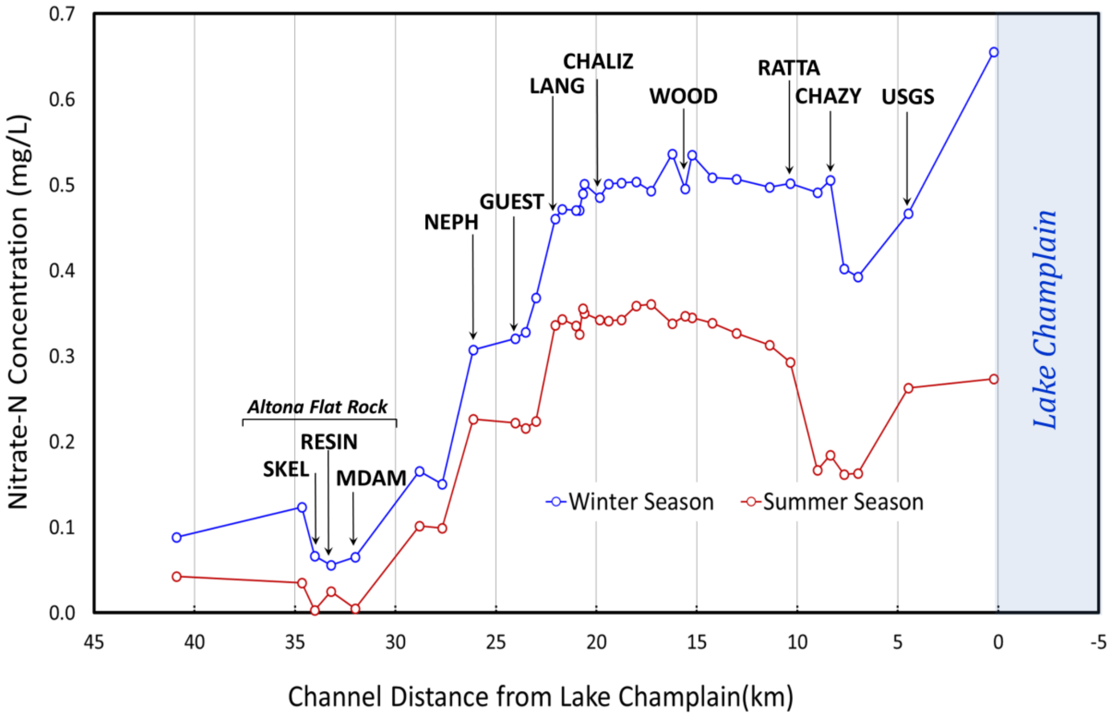

Figure 7. Nitrate-N concentrations as a function of channel distance from Lake Champlain and seasonality. Winter months are an average of November through April while summer months include May through October.

Temporal Variability – Event Scale

Three significant precipitation events occurred in October 2010 (Fig. 8A); 63.0mm (30 Sept. to 2 Oct.), 25.4mm (6-8 Oct.) and 48.8mm (14-17 Oct.). The resulting stormflow volumes were 1.34 hm^3, 1.01 hm^3 and 2.37 hm^3, respectively. Nutrient concentrations rose sharply during the initial rising limb of each major runoff hydrograph but returned to near background level concentrations by the time of peak discharge (Fig. 8A and 8B). Highest concentrations for all analytes corresponded to periods of active rainfall. Nitrate-N concentration for the third rainfall event dropped well below pre-storm background levels after peaking around 2 mg/L. Nitrate-N peak concentrations consistently lagged those for the SRP and total phosphorus peak by 4-11 hours for all three events. Moreover, the highest peak concentrations for total phosphorus and SRP occurred during the third (14-17 Oct.), and largest, runoff event while Nitrate-N reached its highest peak concentration during the first (30 Sep–2 Oct.) runoff event.

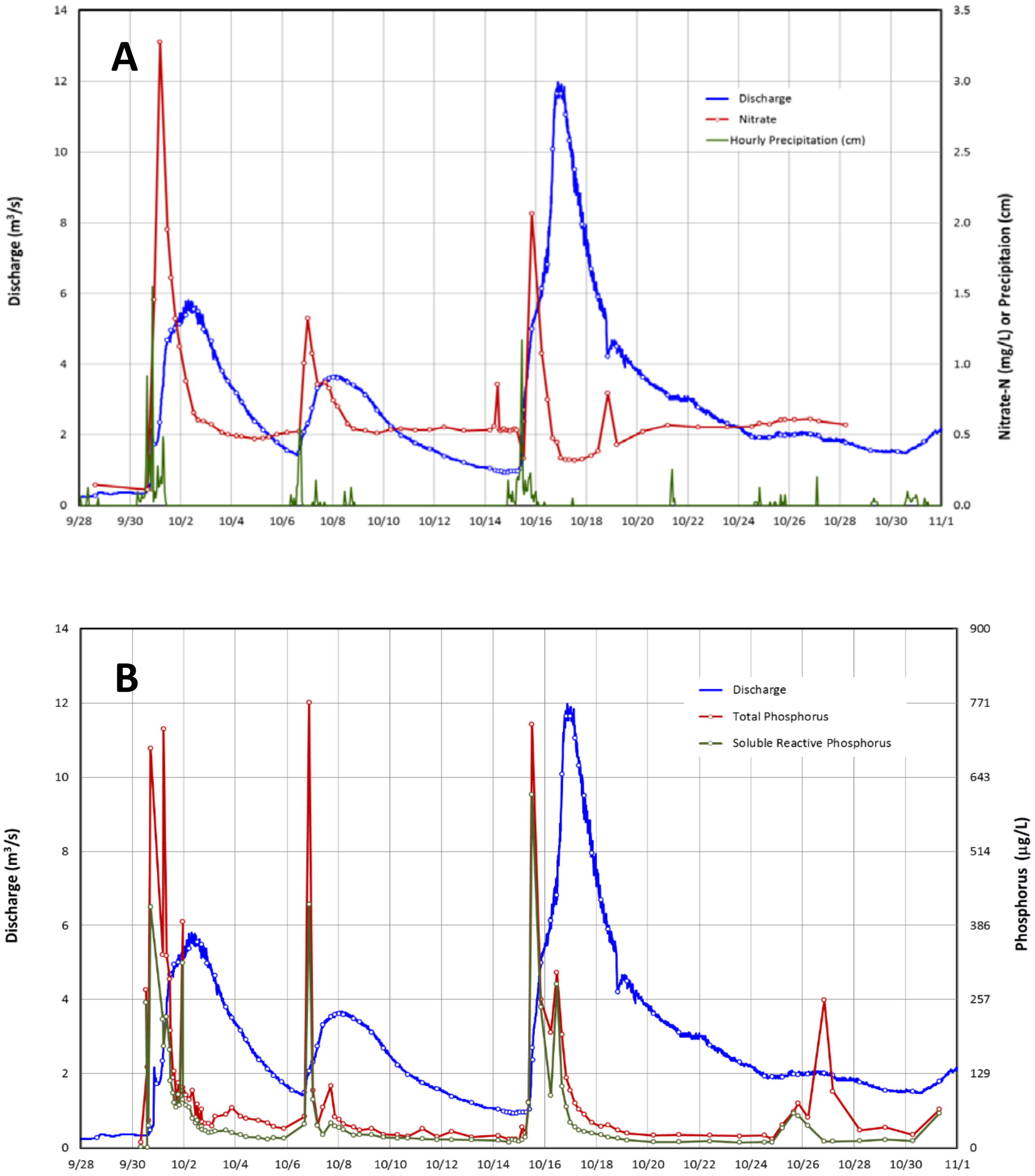

Figure 8. Temporal variability of solute chemistry for the Little Chazy River at the USGS gaging station for three runoff events in October 2010. A) Precipitation, discharge, and nitrate-N concentration. Provisional discharge data are from the USGS. B) Soluble reactive phosphorus, total phosphorus and stream discharge.

Concentrations of nitrate-N, SRP, total P, and TSS peaked on the rising limb of the runoff hydrograph during intense rainfall (Fig. 8). These high concentrations were most likely due to initial surface water runoff (overland flow) during active rainfall, which removed large quantities of particulate and soluble nutrients that had been accumulated or stored on the soil surface between runoff-producing rainfall events. Reapplication of manure to accessible fields was observed near the USGS gage site between events 1 and 2 but no reapplication was observed prior to the third event, perhaps in part due to the saturated soil conditions. Nutrients present in the soil due to nitrification and mineralization may also have been flushed through shallow subsurface runoff pathways at the beginning of rainfall events.

Nitrate-N concentrations typically fell to background levels between 0.4–0.6 mg/L shortly after the crest of the stream hydrograph, reflecting the concentration of soluble nitrate-N in runoff that followed subsurface pathways during the later portion of the event and between events.

The relatively low nitrate-N peak concentration and the subsequent drop below the background concentrations during event 3 (Fig. 8A) may be explained by depletion of land surface sources between events 2 and 3. Consequently, the initial runoff from this event was relatively depleted in nitrate-N by the cumulative flushing effect of surface nitrate-N by the two preceding events and the initial runoff from the third event. This may also be influenced by the relative high mobility of nitrate, which is not influenced by adsorption and subsequent desorption. Nitrate-N concentrations return to background levels only after stormflow recedes and subsurface runoff pathways dominate the chemical signature.

We observed that for all three events, SRP and Total P peak concentrations precede the nitrate-N peak by several hours (Fig. 8B). We hypothesize that differences in runoff pathways and nutrient mobility may explain this observation. Overland runoff pathways should contain both soluble and particulate nutrients, thus nutrient concentrations generally rise as the first overland flow reaches the stream channel. Preceding events, organic N and P are transformed to nitrate and phosphate by mineralization and/or nitrification at the land surface and shallow subsurface environments. Nitrate is mobile and travels through the soil with percolating ground water. SRP will also leach into the soil but tends to be adsorbed onto soil particulates, particularly oxides. Thus SRP and nitrate concentrations rise together during the initial overland flow segment, but mobile nitrate continues to rise as subsurface flow paths become more prominent later in the event, while SRP concentrations decline during this phase due to adsorption. Additional evidence for this hypothesis can be seen as SRP concentrations toward the middle of the event decline more slowly as desorption replenishes some of the SRP lost to runoff.

The observed dependence of nitrate-N concentration on time- and rainfall-dependent runoff pathways during storm events is shown in the hysteresis of dimensionless nitrate-N load and dimensionless discharge during the three October 2010 runoff events (Figs. 9A and 9B). High loadings were consistently observed in the initial stages of the event, during active precipitation and overland flow due a combination of high concentration combined with moderate flows. Loadings continued at high levels as concentrations declined, but flows increased on the rising limb. As peak flows were reached, loadings declined as concentrations fell precipitously. This hysteresis effect suggests that stream discharge may be a poor surrogate for predicting nutrient loadings in this area.

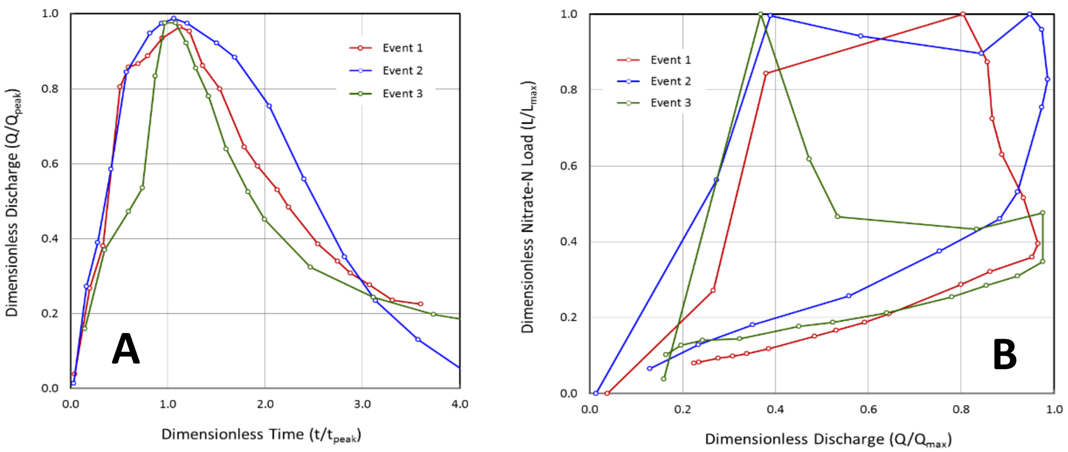

Figure 9. A) Dimensionless hydrographs for three runoff events in October, 2010. B) Plot of Dimensionless nitrate-N Load and Dimensionless Discharge, showing a discharge-dependent hysteresis effect on nitrate-N load.

CONCLUSIONS

The Little Chazy River headwaters rise in typical Northern Hardwood/Mixed forest communities on relatively deep glacial till and outwash soils, as well as unique, oligotrophic Pine Barren ecosystems growing on extremely thin organic soils shallow to bedrock. These headwaters have minimal agricultural influence. Surface water nutrient concentrations, particularly nitrate, tend to be relatively low in these reaches due to a lack of anthropogenic inputs, and biological uptake in these nutrient deficient soils.

Nitrate concentrations rise abruptly as the river leaves the upland forests and enters lowland areas dominated by agriculture with soils developed in till and glacial lacustrine and marine deposits. The more mobile nitrate anion arising from agricultural inputs is soluble and moves through these soils readily. In contrast, phosphorus concentrations do not rise notably in lowland reaches, possibly due to phosphate adsorption to hydrous oxides common in these soils.

Farther downstream (e.g. stations LANG to LC87 in Fig. 5), where the Little Chazy River enters areas dominated by fine-grained lacustrine and marine parent materials, nitrate concentrations remain relatively constant, whereas median total P gradually increases by as much as 45%. Moderate intensity agriculture, in which many fields drain through tile drain systems, may contribute to this increase in total P levels by surface erosion during precipitation events or direct flow through macropores to subsurface tiles. These runoff pathways may allow runoff to bypass sites of potential phosphate adsorption to hydrous oxide clays in subsurface soil horizons.

Small impoundments in the main channel, beginning at the RATTA site (Fig. 7), coincide with a rapid decrease in nitrate concentrations, particularly in the summer months. This reduction in nitrate concentration may be due to uptake of nitrate by biota or conversion to more chemically reduced forms. Nitrate concentration is further reduced by dilution at the lower end of the impoundment where Tracy Brook, which drains predominantly forested/wetland areas, enters the main channel.

In the lowest reaches of the watershed, both nitrate and phosphorus fractions increase markedly. This reach has the most extensive agriculture in the watershed with large dairy farms and their attendant manure applications. These fields are typically underlain by fine-textured glacial-marine soils, some of which are not tile-drained resulting in a greater proportion of overland flow during snowmelt and precipitation events and contributing to direct washout of surface applied manure. Lack of subsurface drain systems may also promote flooding of these soils during wet periods, and subsequently changes in redox status causing desorption and release of previously adsorbed P to surface waters (Young and Ross, 2001).

Event level sampling during three large events demonstrated that maximal loading of nitrate and P fractions occurred early in the event on the rising limb with low to moderate discharge but high concentrations, during periods of active precipitation and possibly overland flow. Loadings continued at high levels through peak flow, due to a combination of lower concentrations but with high discharge. The relationship between flow and discharge exhibited pronounced hysteresis.

In summary, concentrations of P fractions and nitrate exhibited pronounced changes in concentration and loadings throughout the Little Chazy River watershed on different spatial and temporal scales. Much of this variability can be explained by flow through different ecosystems, effects of land-use practices, differences in soils and their management, as well as in-stream processes. Many of the complex interactions of these processes must be sorted out at edge of field studies.

ACKNOWLEDGEMENTS

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FIELD GUIDE AND ROAD LOG

Meeting Point: Southeastern parking lot of Hudson Hall on the SUNY Plattsburgh campus. The lot is located at the corner of Beekman and Broad streets.

Persons using this log in the future should be aware that the field trip stops are located on private property that is owned and patrolled by the William H. Miner Agricultural Institute. A permit must be obtained from the Miner Institute to access this property.

Meeting Point Coordinates: 44.691°N, 73.467°W

Meeting Time: 9:00 AM

Distance in miles (km)

Cumulative	Point to Point	Route Description
0.0 (0.0)	0.0 (0.0)	Assemble in the southeastern parking lot of Hudson Hall. Leave parking lot, turn left at the entrance onto Beekman Street and proceed north.
0.9 (1.4)	0.9 (1.4)	Junction of Beekman and Tom Miller Rd., turn left at the traffic light and proceed west.
1.5 (2.4)	0.6(1.0)	Junction of Tom Miller Rd. and Quarry Rd., turn right and proceed north. Proceed straight through next traffic light, as Quarry Rd. becomes State route 22.
6.7 (10.8)	5.2 (8.4)	Junction of route 22 and O'Neill rd., turn left and proceed west. Follow O'Neill Rd. as it curves to the right and continue northward.
10.8 (17.4)	4.1 (6.6)	Intersection of O'Neill rd. and W. Church St., turn left and proceed west.
11.6 (18.7)	0.8 (1.3)	Intersection of W. Church St. and Barnaby Rd., turn right onto Barnaby Rd. and proceed north. Continue on Barnaby Rd. as it becomes a gravel surface and continue proceeding north on Miner Agricultural Research Institute property.
13.8 (21.2)	2.2 (3.5)	Left turn through locked gate, continue west on dirt road for 0.3 miles.
14.1 (21.2)	0.3 (0.5)	Stop at log cabin adjacent to the headwaters of the Little Chazy River immediately below Miner Dam.

STOP 1: Miner Dam, Town of Chazy, NY

Location Coordinates: (44.837°N, 73.571°W)

The Miner Dam was constructed near the headwaters of the Little Chazy River circa 1913 and was abandoned shortly thereafter due to excessive leakage. These headwaters traverse the Altona Flat Rock Pine Barrens, consisting largely of jack pine, pitch pine and lichens growing on a thin mantle of organic soil over sandstone bedrock. The area was scoured by a catastrophic breakout flood at the end of the last ice age, approximately 13,000 years ago. Lacking a substantial mineral soil, these ecosystems are oligotrophic, with extremely low nitrate-N concentrations (Fig. 4A), particularly during the summer growing season (Fig. 6). Nitrate is probably removed by biological uptake, both in the soil and in the impoundments above the dam. Phosphorus concentrations are also low (Fig 4B), and are largely in an organic or particulate bound form (Fig. 5).

Distance in miles (km)		
Cumu-lative	Point to Point	Route Description
13.2 (21.2)	0.0 (0.0)	Return to the vehicles and proceed eastward on dirt road 0.3 mi to gate
13.5 (21.7)	0.3 (0.5)	At gate, turn right and proceed southward on dirt road. Continue on Barnaby Rd. as it becomes paved to junction of Barnaby Rd. and W. Church St.
15.7 (25.3)	2.2 (3.5)	Turn left at junction of Barnaby Rd. and W. Church St. and proceed eastward on W. Church St., through the flashing light as it becomes E. Church St.
17.7 (28.5)	2.0 (3.2)	Park on south side of road next to agricultural tributary.

STOP 2: Agricultural Tributary Sample site, Town of Chazy, NY

Location Coordinates: (44.822°N, 73.498°W)

This site (StratAgTrib) illustrates the importance of agricultural inputs and their influence on nutrient concentrations in the Little Chazy River (Fig. 2). Immediately upstream from this site, nitrate concentrations rose as the River traversed dairy agricultural operations on well-drained, sandy glacial till and outwash parent materials. Numerous agricultural tributaries and ditches in the Little Chazy River receive inputs from tile-drained fields which receive manure applications, typically 2-3 times per year (Fig. 2). Nutrient concentrations in these tributaries are typically high, but low flows typically cause only minor increases in nutrient concentrations in the Little Chazy River. However, their effects are cumulative.

Distance in miles (km)		
Cumu-lative	Point to Point	Route Description
17.7 (28.5)	0.0 (0.0)	Return to the vehicles and proceed eastward on E. Church St.
18.0 (29.0)	0.3 (0.5)	At junction of E. Church St. and Fiske Rd., turn left and proceed northward.
19.6 (31.5)	1.6 (2.6)	At junction of Fiske Rd. and Slosson Rd., turn right and proceed eastward.
20.9 (33.6)	1.3 (2.1)	Park near wooden bridge over the Little Chazy River.

STOP 3: Wood Sample site along the Little Chazy River, Town of Chazy, NY

Location Coordinates: (44.846°N, 73.456°W)

The Wood sample site is more typical of the lowland reach of the drainage basin, with soil parent materials composed of fine-textured glacial lacustrine sediments. River gradients are typically low, and many of the agricultural fields have subsurface drainage. Evidence of river meanders is common, and during high flows extensive streambank erosion can occur. Throughout this reach, total phosphorus concentrations increase slowly, driven largely by the soluble reactive phosphorus fraction. Nitrate concentrations, however, remain relatively constant throughout this reach, suggesting that the magnitude of different flow paths may vary for the two nutrients. Downstream from this site, the River enters some small impoundments in which nitrate concentrations decline, particularly during low flow, suggesting either conversion to other forms and subsequent loss or biological sequestration.

Distance in miles (km)		
Cumu-lative	Point to Point	Route Description
20.9 (33.6)	0.0 (0.0)	Return to the vehicles and proceed westward on Slosson Rd. Go straight through the intersection with Ashley Rd.
22.2 (35.7)	1.3 (2.1)	At the junction of Slosson Rd. and Fiske Rd. (Old Route 348), turn right.
26.1 (42.0)	3.9 (6.3)	Proceed on Fiske Rd. northeastward, going over the interstate into the village of Chazy. At the junction of Fiske Rd. and Route 9, turn left.
26.2 (42.2)	0.1 (0.2)	At the junction of Route 9 and Old Route 191(Miner Farm Rd.), turn right.
27.2 (43.8)	1.0 (1.6)	At the junction of Miner Farm Rd. and Stetson Rd., turn left and proceed northward.
28.4 (45.7)	1.2 (1.9)	Proceed 1.2 miles on Stetson Rd. to the USGS sample site immediately before the bridge over the Little Chazy River.

STOP 4: USGS Sample site along the Little Chazy River, Town of Chazy, NY

Location Coordinates: (44.902°N, 73.415°W)

The U.S. Geological Survey maintains a discharge monitoring gauge at the USGS sample site, providing continuous flow data. Episodic sampling sampling was conducted at this site during three successive storm events in the fall of 2010. During each of these events, maximum concentrations of both nitrate, total P and soluble reactive P were observed on the rising limb of the hydrograph, while precipitation was still falling. By the time the maximum flow was observed, concentrations had declined to baseline levels. Loadings were near maximum levels at moderate flows on the rising limb due to high concentrations, and during the peak of the event due to high flows. The relationship between discharge and load shows a marked hysteresis.

Immediately upstream from this site is the outflow from the publicly owned treatment works for the village of Chazy. Sampling immediately upstream and downstream of this site showed only slight increases in concentration of either N or P fractions, suggesting that this source is small relative to other sources, such as those arising from agricultural practices. Immediately downstream, both nitrate and P fractions increase rapidly, as the lower stretch of the drainage basin has extensive agriculture, almost all with subsurface drainage.

Distance in miles (km) Cumulative	Point to Point	Route Description
28.4 (45.7)	0.0 (0.0)	Return to the vehicles and proceed southward on Stetson Rd. to the first stop sign.
28.8 (46.3)	0.4 (0.6)	At the junction of Stetson Rd. and N. Farm Rd., turn left and proceed westward into the village of Chazy to the stop sign.
30.0 (48.3)	1.2 (1.9)	At the junction of N. Farm Rd. and Route 9, turn right and proceed northward.
30.4 (48.9)	0.4 (0.6)	At the junction of Route 9 and Route 191 (Miner Farm Rd.), turn left.
32.0 (51.5)	1.6 (2.6)	Proceed westward on route 191, over the interstate, to the junction of Ridge Rd. and turn right (northward).
32.7 (52.6)	0.7 (1.1)	Continue on Ridge Rd. for 0.7 miles and park near the dirt road leading into the field on the right.

STOP 5: R15 Agricultural Field at Miner Institute, Town of Chazy, NY

Location Coordinates: (44.899°N, 73.467°W)

The R15 agricultural field is operated by the William H. Miner Agricultural Research Institute, a fully functional research dairy farm. Miner Institute conducts research on dairy operations as well as their impacts on the environment. The R15 field has been tile-drained since 1975, and includes extensive shallow groundwater sampling devices, a deep groundwater monitoring well, and a meteorological station. At this site, we will conduct a demonstration of “smoking” a tile line. This demonstrates the connectivity of subsurface tiles (approximately 1 m deep) to the surface through soil macropores which include worm tunnels as well as structural cracks. This provides a potential route for direct and rapid transit of pollutants applied on the surface, such as those through manure application, to tiles and surface waters.

Distance in miles (km) Cumulative	Point to Point	Route Description
32.7 (52.6)	0.0 (0.0)	Return to the vehicles and proceed northward on Ridge Rd. to the first stop sign.
33.8 (54.4)	1.1 (1.8)	At the junction of Ridge Rd. and McBride Rd., turn right to stay on Ridge Rd. and proceed eastward.
35.3 (56.8)	1.5 (2.4)	At the intersection of Ridge Rd. and Lavalley Rd., turn right and proceed eastward.

36.5 (58.7)	1.2 (1.9)	Pass over the Interstate and continue eastward to the junction with Route 9.
37.0 (59.5)	0.5 (0.8)	Turn left and proceed northward and park next to Edge of Field site.

End of Trip

STOP 6: Edge of Field Study Site, Town of Chazy, NY

Location Coordinates: (44.940°N, 73.440°W)

The USDA-NRCS edge-of-field (EoF) monitoring program is designed to quantify impacts of various nutrient management practices on runoff water quality. Data collection and analysis for EoF projects utilize a small paired watershed approach. Typically, one best management practice is evaluated in comparison to a reference condition. The objective of our project is to quantify water quality impacts associated with the practice of controlled subsurface tile drainage (CD) as compared to the standard practice of freely-drained subsurface tile drainage (FD). The practice of CD uses inline water control structures (AgriDrain, Adair, IA) to artificially raise the drainage outlet elevation during the non-growing season. Studies show that CD can reduce annual drainage flow volumes by as much as 80 % compared to FD. The two crop production fields were selected due to their close proximity, similar soil types, and for their ability to be instrumented properly to capture both surface and subsurface runoff water. The fields are currently in 2nd year production of corn for silage. Subsurface drainage tile (slotted plastic drain tile, 10-cm i.d.) was installed via a tile-plow at an average depth of 1.2 m below the soil surface during November 2014 (10.7 m spacing between tile lines within each field). Subsurface drainage water from each field's lateral lines flows to a main outlet pipe (schedule 40 PVC, 20-cm i.d.) that drains to individual concrete manholes (1.2-m i.d. and 2.4 m deep) where flow is gauged and sampled. Drainage water flows are measured by routing water through a plastic barrel equipped with a v-notch weir and stilling well that houses a pressure transducer-data logger to capture water elevation changes related to flow differences. Drainage flows are gauged by rating curves developed between measured flows and water height inside the barrels. Variation in nutrient and sediment concentrations will be quantified by taking multiple samples over an event using flow-programmable autosamplers. Overland flow is measured from each field by routing surface water to a fiberglass flume (Plasti-Fab, Tualatin, Oregon) using a combination of natural swales, field contouring and an earthen, clay berms. Event-based and seasonal mass loads of total N, nitrate-N, ammonium-N, total P, dissolved (<0.45µm) reactive P (orthophosphate), unreactive P (particulate-organic P), and total suspended solids will be calculated. Baseline monitoring will occur for two years after which CD treatment will be implemented and monitored over four years. Differences in mass nutrient loads between FD and CD will be evaluated using analysis of covariance. Agronomic data is also being tracked (i.e., yields, fertilizer and manure inputs and nutrient uptake) and will be utilized to calculate N and P mass balances each year of the study. A field-scale water quality model (APEX) will also be parameterized and calibrated as part of the project. Results will help quantify tradeoffs between drainage intensity, surface/subsurface hydrology, and nutrient loss dynamics at the field scale.

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