Sediment Phosphorus Stability in Little Hatchet Creek

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For

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Glossary

Acronym	Description
cfs	Cubic feet per second
COE	US Army Corp of Engineers
EPA	US Environmental Protection Agency
GPS	Global Positioning System
MDL	Method Detection Limit
NELAC	Standards adopted by the National Environmental Laboratory Accreditation Conference
SE	Standard Error of the mean is the standard deviation of the sampling distribution of the mean
SJRWMD	Saint Johns River Water Management District
Analyte or chemical compounds measured in samples	
Alkalinity	The capability of water to neutralize acid. This is really an expression of buffering capacity. A buffer is a solution to which an acid can be added without changing the concentration of available H+ ions (without changing the pH) appreciably.
Ca	Calcium is a chemical element, naturally present in water which has dissolved it from rocks such as limestone.
Cl^-	Chloride is a monovalent anion consisting at one atom of chlorine.
DI	Deionized water has been mechanically filtered or processed to remove all ions.
DO	Dissolved oxygen is the amount of gaseous oxygen (O_2) dissolved in the water
DOP	Dissolved organic phosphorus
HCl	Hydrochloric Acid is a corrosive, strong mineral acid.
Hardness	The amount of dissolved calcium and magnesium in the water. Hard water is high in dissolved minerals, both calcium and magnesium.
K	Potassium is an elemental reactive alkali metal found as a major cation in water
F^-	Fluoride is an inorganic anion of fluorine. Fluoride is present in apatite rock which consists of calcium phosphate, the primary source of P in the Hawthorne Group materials.
Fe	Iron is a major cation found in surface waters.
Mg	Magnesium is a chemical element, naturally present in water which has dissolved it from rocks such as limestone.
N	Nitrogen is an elemental gas found dissolved in water or bound to organic and inorganic molecules.
Na	Sodium is a cation found in surface waters.
NaOH	Sodium Hydroxide also known as lye and caustic soda, is an inorganic, white solid ionic compound consisting of sodium cations Na^+ and hydroxide anions $OH^−$
NH_4Cl	Ammonium Chloride is an inorganic, white crystalline salt that is highly soluble in water. Solutions of ammonium chloride are mildly acidic.
NOx	Nitrate and Nitrite are naturally occurring ions that are part of the nitrogen cycle and an available nutrient for aquatic plants.
P	Phosphorus usually occurs in nature as phosphate $PO4^{-3}$. Phosphate that is bound to plant or animal tissue is known as organic phosphate. Phosphate that is not associated with organic material is known as inorganic phosphate. Both forms are present in aquatic systems and may be either dissolved in water or suspended (attached to particles in the water column).
pH	A measure of how acidic or basic water is, with a range of 0 - 14, with 7 being neutral and a pH value less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base.
PP	Particulate Phosphorus is the fraction of phosphorus removed from the water column using a 0.45 µm filter.

SO_4	Sulfate is a naturally occurring ion found in combination with metals in the form of salts. Sulfate salts with lower molecular weight metals such as sodium, potassium and magnesium are highly soluble and often found in natural waters.
SRP	Soluble Reactive Phosphorus is the dissolved portion of inorganic phosphate readily available to plants and algae.
TKN	Total Kjeldahl Nitrogen refers to the organic nitrogen and ammonia measured together.
TN	Total Nitrogen is the sum of all forms of N (Nitrate, Nitrite, Ammonia and Organic Nitrogen)
TOC	Total Organic Carbon is the measure of the level of organic molecules in water.
TP	Total Phosphorus is the sum of all forms of P found in a sample.
TSP	Total Soluble Phosphorus is the fraction of P that is dissolved or passes through a 0.45 µm filter
WSP	Water Soluble Phosphorus is the fraction of P that is dissolved
Phosphorus Fractions	
DIW Pi	Inorganic phosphorus extracted by de-ionized water, and measured as SRP
HCl-Pi	Inorganic phosphorus extracted by a strong acid, 0.5 M HCl, and measured as SRP
NH_4Cl-Pi	Inorganic phosphorus extracted by a weak salt, 1 M NH4Cl, and measured as SRP
NaOH-Pi	Inorganic phosphorus extracted by an alkali solution, 0.5 M NaOH, and measured as SRP
NaOH-Po	Organic phosphorus extracted by an alkali solution, 0.5 M NaOH and measured as the difference between TP and SRP
Units of Measure	
cm	Centimeter
cm^3	Cubic centimeter
m	Meters
km	Kilometer
µg/L	Micrograms per liter, or parts per billion
M	Molar concentration is the number of moles of a solute per liter of solution
mg/L	Milligrams per liter
mg/cm^3	Milligrams per cubic centimeter
g/cm^3	Grams per cubic centimeter
mg/kg	milligrams per kilogram (dry weight), or parts per million

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1. INTRODUCTION

Newnans Lake is a eutrophic water body in Alachua County, FL (Figure 1), where nutrient levels in the surface water exceed state water quality criteria (Gao and Gilbert 2003). Excessive phosphorus (P) loads from the surrounding watershed contribute to impairment of the lake. Naturally-occurring geologic formations within north-central Florida, such as the Hawthorn Group, are known to contain high amounts of phosphates (Pirkle 1956). This formation is often associated with clay soils that are frequently found along streams in this area. Where these formations are susceptible to erosion and weathering, they may contribute substantially to the P loads to the lake.

A recent study of the lake's watershed indicated that this geologic phosphate could be a dominant source of P to the lake, and that the middle-reach areas along Hatchet Creek, and especially along Little Hatchet Creek, have elevated P concentrations as compared to headwater areas, terminal wetland areas, or other tributaries (Cohen et al., 2008). A follow-on assessment was therefore conducted in Little Hatchet Creek to examine P contents of the stream bank sediments in areas with high erosion potential. Areas upstream and downstream of the erosion areas were sampled to examine whether the stream bed sediments were enriched in phosphorus. Finally, P contents of sediments and surface waters from the Little Hatchet Creek stream channel were compared to samples from Gum Root Swamp, located along the northern edge of Newnans Lake. The primary objective of this work, therefore, was to characterize the phosphorus storage and stability within stream bed and swamp sediments in the Little Hatchet Creek watershed, upstream of Newnans Lake.

2. METHODS

2.1. Sampling Approach

The present investigation into sediment P storage and stability was conducted in three phases. In the first phase (September 2014), a survey of the stream bank identified areas where clay materials were exposed. In the second phase, stream bed sediments were collected on two occasions (August 2015 and January 2016) along the middle reach of Little Hatchet Creek, in depositional areas with high potential for contributing P to the surface water in transit to Newnans Lake. In the third phase, sediments were sampled from Gum Root Swamp, as well as within tributaries to the swamp and outflow from the swamp, in April and May 2016.

Photos were taken at each location, station coordinates were verified by GPS and entered into the field notebook. A record was made of the vegetation observed within the sampling area. While our primary focus was on sediment collection, over the course of this project there was increasing interest in determining changes in surface water chemistry along the study reach, and our sediment collection events provided an opportunity to collect synoptic water quality data. Therefore, water sampling was incorporated into the field effort, initially to determine total phosphorus (TP) concentrations (Phase 2), and then expanded to include a more robust suite of surface water parameters during Phase 3. Water depth, pH, temperature, dissolved oxygen (DO), and conductivity were measured in the field at the time of sediment and water sample collections, yet declining water levels prohibited water sampling at every location.

A follow-on sampling of surface waters took place in June 2016, shortly after Tropical Storm Colin passed over the area. The rainfall from that storm, together with an additional subsequent rainfall event, sharply increased the stage in Little Hatchet Creek (Figure 2), rehydrated Gum Root Swamp and temporarily increased the flow of water leaving the swamp, providing a chance to determine P export from the swamp after rehydration. Thus, the June sampling concluded the third and final phase of field sampling for this project.

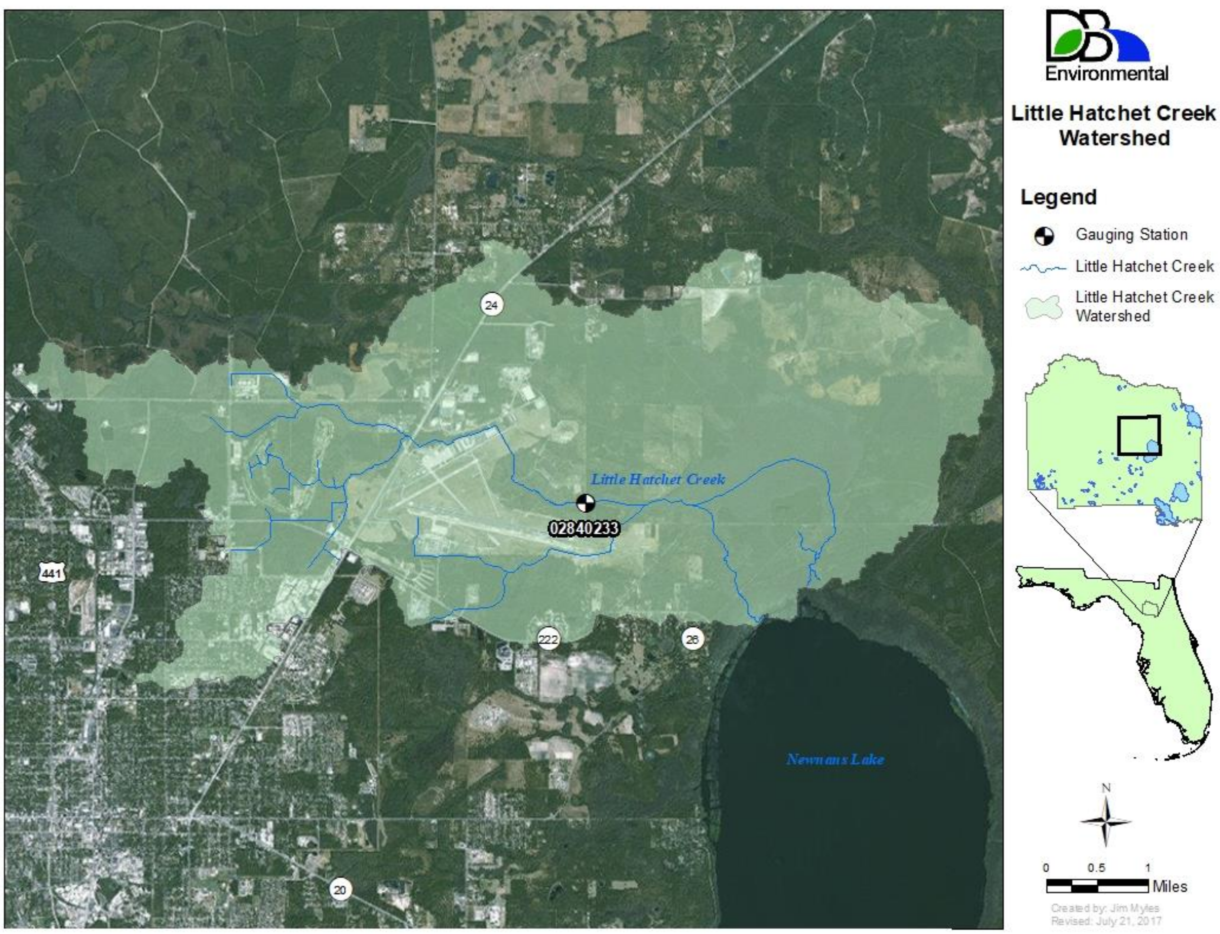

Figure 1. The Little Hatchet Creek watershed in Alachua County, FL and the SJRWMD gauging station 02840233 on North Branch Little Hatchet Creek.

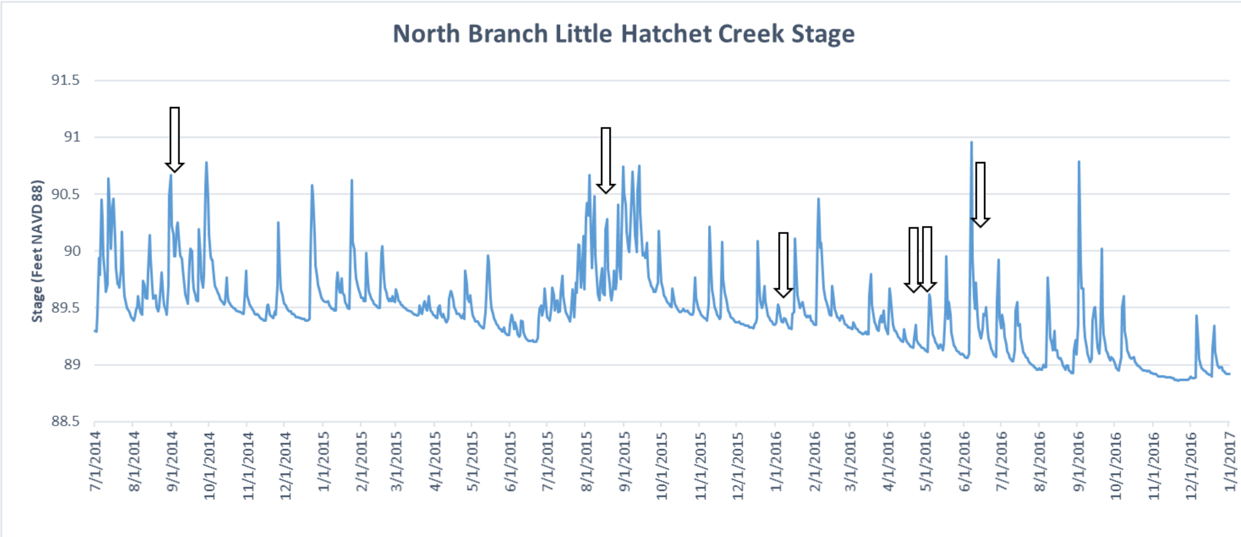

Figure 2. Stage at SJRWMD gauging station 02840233 North Branch Little Hatchet Creek during the study period. Arrows denote the survey periods.

2.2. Sampling Summary

2.2.1. Phase 1

The September 3, 2014 survey extended from the road crossing at SR 24 (Waldo Road) downstream ~1200 m to the east and ENE (Figure 3). The surveyed reach was upstream of where Little Hatchet Creek turns to the southeast and crosses the runway of the Gainesville Regional Airport. A total of 16 samples of the soil and stream bank materials were collected from 8 locations, with clustered sampling at locations where erosion was apparent and clays were exposed (Appendix A).

2.2.2. Phase 2

On August 18, 2015, stream sediments along Little Hatchet Creek were collected between the airport and the Saint Johns River Water Management District (SJRWMD) gauging station 02840233 (North Branch Little Hatchet Creek) (Figure 1). A total of 15 samples of the sediment material were collected from 10 locations (Appendix B), with clustered sampling at locations where deposition of gravel and clay nodules within the sand matrix was apparent. Water levels were high (89.63′ at the gauging station) and prevented access to much of the creek channel due to flooding outside the channel, especially downstream of the gauging station where the channel becomes braided within a broad flood plain. Water samples were collected for total phosphorus (TP) from the upstream and downstream endpoints of the study reach.

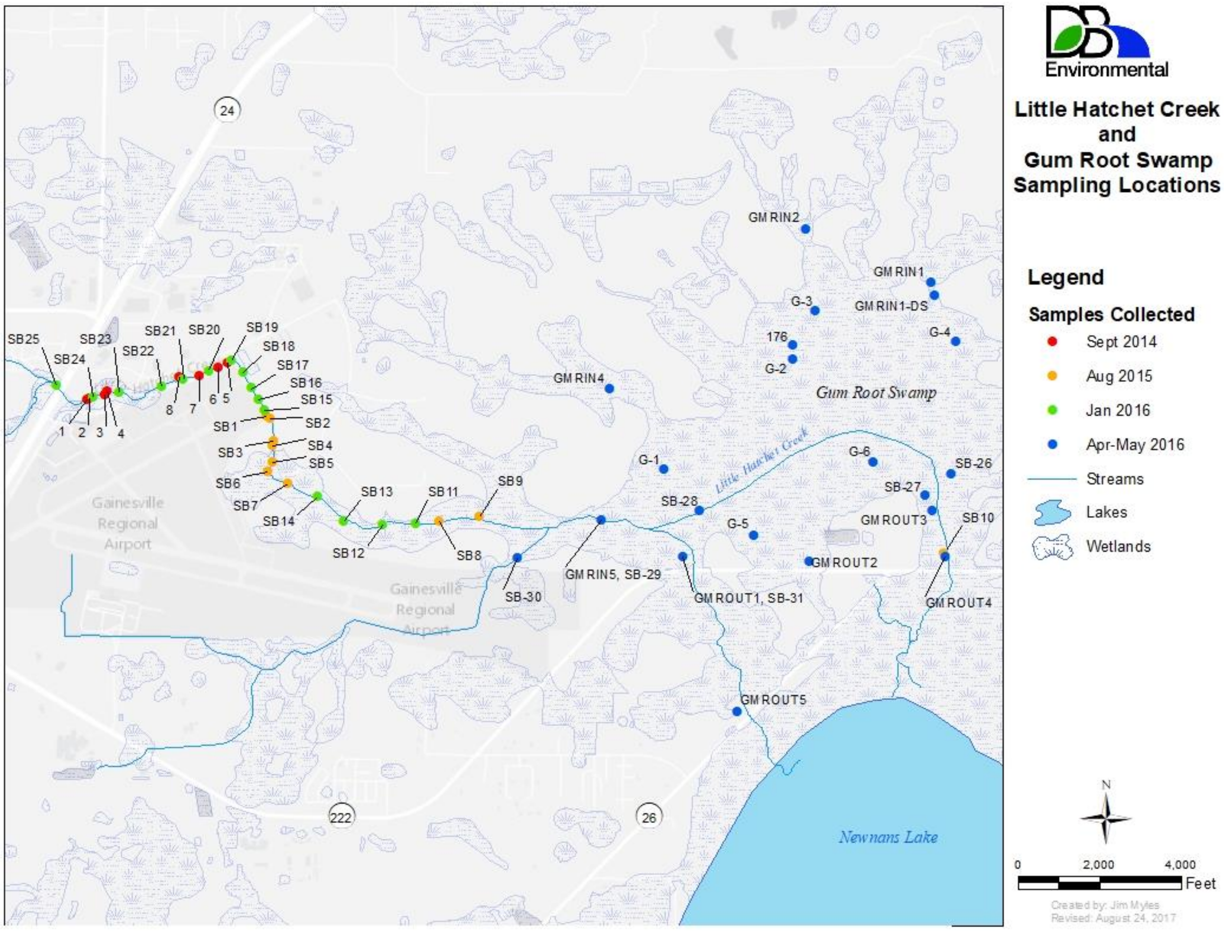

Figure 3. Location of stream bank and stream bed sediment sampling along Little Hatchet Creek and in Gum Root Swamp, for four surveys conducted between 2014 and 2016.

On January 6, 2016, stream bed sediments were sampled from an additional 15 locations (Appendix B) along Little Hatchet Creek above and below the sampling locations from August, extending the surveyed reach from Waldo Road to the recently-mitigated landfill site on the north bank of the creek. Surface water sampling was conducted at 10 stations spanning the study reach, and included analysis of both phosphorus and fluoride concentrations.

2.2.3. Phase 3

On April 19, 2016, the tributary inflows and outflows of Gum Root Swamp were sampled to determine surface water nutrient concentrations and sediment P contents. The following day, two excursions into the swamp were made from the south. On May 2, 2016, two additional excursions were made into the swamp from the northern side. A total of seven locations were selected for sediment sampling, and surface waters were collected where present. Station descriptions from April and May 2016 sampling events are provided in Appendix C. On June 15, 2016, Little Hatchet

Creek surface waters were collected from upstream and downstream of the project reach, and at the SJRWMD gauging station (Figure 13).

2.3. Sediment Collection

Stream bed sediments were collected from Little Hatchet Creek using a clean stainless steel spoon, targeting the upper ~5 cm of sediment from sand bar locations just above the water line (i.e., wet but not submerged sediments). In some locations, the stream bed sediments were more uniform within the stream channel (no sand bar formation above the water line, no sinuosity to the channel thalweg, sand smothered condition). In these locations, a submerged sediment sample was obtained and the water depth noted. However, sampling with the spoon into the sampling container (Ziploc® bag) was performed to eliminate excess overlying water from being incorporated into the sample.

Large leaves, leaf fragments, coarse woody debris and large (>1 cm) rocks were avoided or removed from the sampling area prior to collection. Macroinvertebrates, fishes, plants and algae were also avoided during sampling or removed from the sample (to the extent possible) before transport to the lab. Sediment samples were double-bagged using re-sealable plastic (Ziploc®) bags, and stored on ice for transport to the laboratory. An attempt was made to coarsely homogenize the sample by hand prior to subsampling for chemical extraction and bulk density determination. A more thorough homogenization procedure was performed on a dried subsample prior to analysis for nutrient and metal contents.

2.4. Sample Analysis

Sediment and water samples were stored on ice for transport to the laboratory (DB Environmental, Rockledge, FL, NELAC #E83330). At the lab, all sediment samples were analyzed for TP and bulk density according to the methods described in Appendix D. A portion of each homogenized sediment sample was packed into a known volume, then dried to a constant weight to obtain a bulk density (Blake and Hartge, 1986). The dried material was further ground to pass through a #60 mesh (<0.25 mm). Phosphorus analyses were completed by first digesting 50 mg of ground sample in concentrated nitric acid, followed by perchloric acid digestion at incrementally higher temperatures up to 210°C (Digestion Method COE 3-227, Plumb 1981). The digestates were then analyzed for total phosphorus (method EPA 365.2, EPA 1979). Bulk density and TP content were then used to calculate the mass of phosphorus per unit volume of sediment material.

The surveys of streambed sediments included further chemical characterization to better understand the stability of sediment-bound P downstream of the suspected source area. Calcium (Ca) and iron (Fe) analyses began with digestions according to EPA method SW 3050B (EPA 1979), followed by Fe (method EPA/SW 7380) and Ca (method EPA/SW 7140) determinations on the digestates. Nitrogen was analyzed by combusting finely ground samples in a carbon-nitrogen elemental analyzer (Costech ECS 4010).

Methods of water sample analysis are provided in Appendix D. Phosphorus analysis included soluble reactive phosphorus (SRP), a measurement of the filtrate through a 0.45 µm-pore sized membrane filter that is often equated to bioavailable P in the surface water, or inorganic phosphorus forms in soil extracts. Total soluble phosphorus (TSP) is a measure of phosphorus in the 0.45 µm filtrate after acid digestion and thus includes both SRP forms and non-reactive dissolved forms. By operational definition, the dissolved organic phosphorus (DOP) pool within a water sample is determined as DOP = TSP – SRP. Similarly, the particulate phosphorus (PP) form in surface waters is defined here as that fraction of P in a water sample that is > 0.45 µm, and is determined as PP = TP - TSP.

2.5. Sediment Phosphorus Fractionation

Not all forms of P are easily mobilized from the sediment to overlying surface waters. Therefore, a sequential chemical extraction procedure (Hieltjes and Lijklema 1980) was used to assess the stability of P within the stream bed sediments of Little Hatchet Creek. This method differentiates labile P (phosphorus adsorbed onto sediment surfaces, or iron-bound phosphorus that may become mobilized to the surface water) from more recalcitrant P forms (such as humic and fulvic-acid bound organic phosphorus, or Ca-bound phosphate minerals).

A portion of the wet sediment (0.4 g dry weight equivalent) was extracted at a 1:1,00 ratio with the following extractants in series: 1M NH_4Cl (2 consecutive 2 hr extractions, followed by SRP analysis), 0.1M NaOH (17 hr extraction, followed by SRP and TP analysis), and 0.5M HCl (24 hr extraction, followed by SRP analysis). After each extraction period, the sample was centrifuged and the supernatant was decanted and reserved for analysis, before the next extractant was added. The respective P pools are shown in Table 1. Note that TP content is determined on a separate subsample from the sequential extraction procedure. In addition, a portion of the total P content of the sediment may be highly recalcitrant and may not be extracted by any of the extractants in this method. Therefore, the sum of P fractions will not always equal the total P content of the sediment as determined through nitric acid-perchloric acid digestion. For samples collected during January-May 2016, the NH_4Cl extraction was preceded by a deionized (DI) water extraction step to assess the most labile P pool. The results of this DI extraction were considered the water soluble phosphorus (WSP) fraction, and was combined with the subsequent NH_4Cl-extractable P pool as the "Labile P" pool in comparisons to the August 2015.

Table 1. Sequential chemical extraction procedure used to assign sediment phosphorus compounds into increasingly stable fractions (based on Hieltjes and Lijklema 1980).

Extractants in Sequence	Duration	Phosphorus Fraction	Analysis	Interpretation
DI-water	1 hr. extraction	Water Soluble P (WSP)	SRP	Most labile
1 M NH_4Cl	2 consecutive 2 hr. extractions	NH_4Cl-Pi	SRP	Readily exchangeable
0.1 M NaOH	17 hr. extraction	NaOH-Pi	SRP	Fe-bound and Al-bound
		NaOH-Po	TP-SRP	Humic acid and fulvic acid-bound
0.5 M HCl	24 hr. extraction	HCl-Pi	SRP	Ca-bound and Mg-bound

3. RESULTS AND DISCUSSION

3.1. Stream Bank Soil Phosphorus

During our initial 2014 survey, soil P ranged from 50 mg/kg to 99,000 mg/kg across all samples, with a smaller range in bulk density values (0.6 – 1.7 g/cm^3). The highest P contents were at stations #5 and #6, to the eastern portion of the surveyed stream reach (Figure 4 and Table 2). These areas contained between 4.3 and 9.9% P by weight, and were located within actively eroding features along the southern stream bank (See station descriptions in Appendix A). At the lower end of the range of P concentrations were samples from a sand bar within the stream (Station #3, TP = 50 mg/kg) and from a sandy bank at an area of deep stream incision on the north side of the stream (Station #8, TP = 68-93 mg/kg). Despite being 20-25' above the water, the steep slope (essentially vertical) and loose, un-vegetated sands within this bluff indicated high potential for bank erosion to contribute material to the stream. These materials (Stations 3 and 8) represent a "background" level of P content for sandy soils (i.e., without enrichment by the Hawthorn Group materials).

Using the product of bulk density values and total P contents, a volumetric P storage was estimated for each sample. The stream bank materials sampled range from < 0.1 to 143 mg P/cm^3 of soil (Table 2). The upper end of this range represents a potentially substantial P load to the stream and to Newnans Lake if this material is destabilized by stream erosion and bank failure processes.

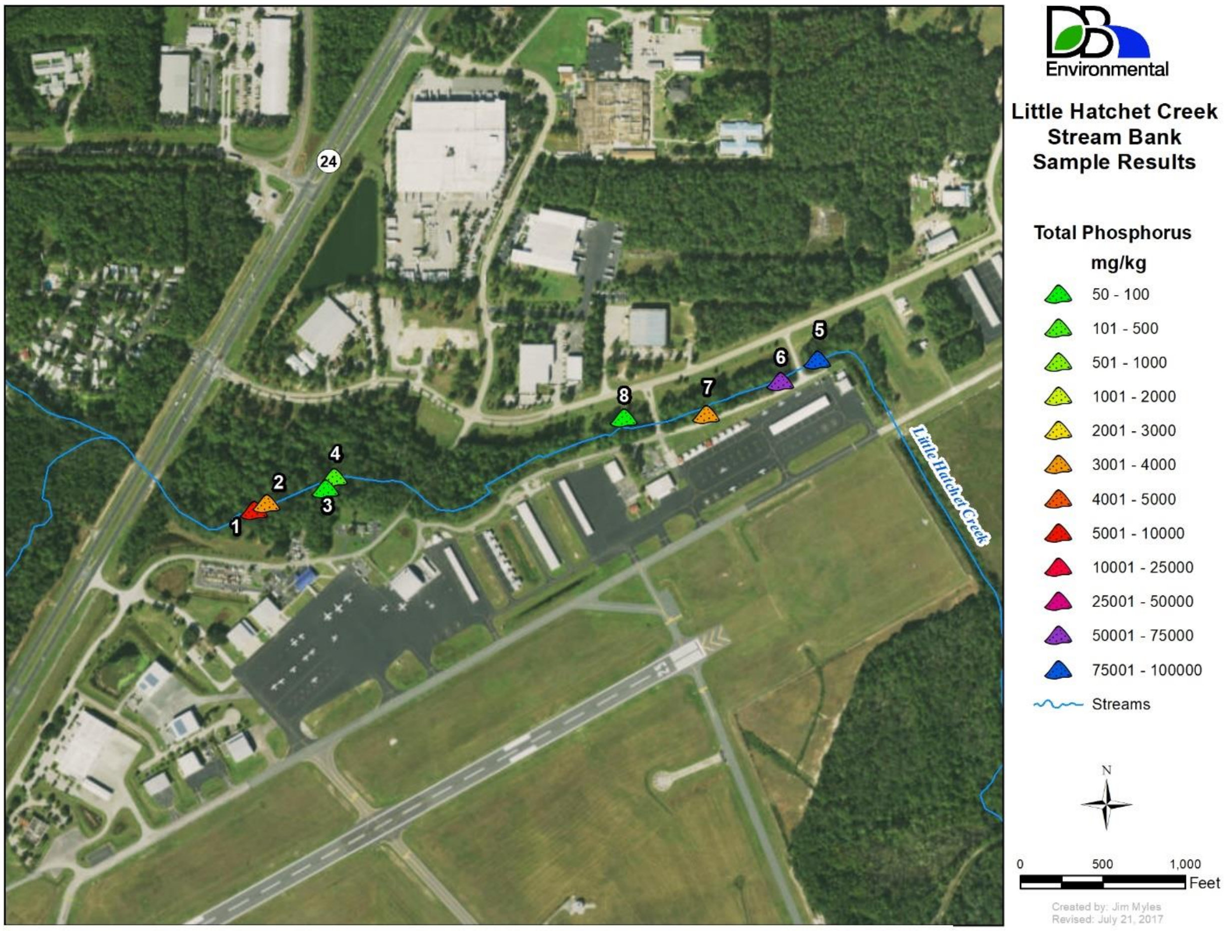

Figure 4. Total sediment P content of stream bank materials collected on September 3, 2014.

3.2. Stream Bed Sediment

3.2.1. Total Phosphorus

The stream bed sediment P contents for each station along the studied reach are provided in Table 3 and depicted in Figure 5. Upstream of Waldo Road, the sand sediments within the creek had among the lowest P contents of any sample in the study (45 mg/kg). A TP concentration of 50 mg/kg was measured at station SB-10, the station furthest downstream and closest to Newnans Lake (Table 3). Like the low P contents observed at some stations during our earlier survey (stations #3 and #8), these might be considered "background" levels of P in sandy sediments that have not been enriched with P.

By contrast to this background level of P, the sandy stream bed sediments collected between 1.44 and 4.15 km downstream of Waldo Road contained elevated P contents, ranging from 576 to 3,250 mg/kg. Sediment P-enrichment increased with distance below the outcrop of phosphatic clays identified in the 2014 stream bank survey. Between stations SB-20, upstream of the outcrop, and SB-19, downstream of the outcrop, stream bed sediment TP increased from 280 mg/kg to 969 mg/kg. The highest sediment TP levels among the 25 stream bed sediment samples were not located adjacent to or directly downstream of this feature, however. Instead, TP contents > 3,000 mg/kg were observed at distances of 2.83 km (SB-14) and 3.41 km (SB-12) downstream of Waldo Road, or about 1.5-2 km downstream of the clay outcrop. This suggests that either the identified "hotspots" at stream bank stations #5 and #6 may not be the only sources of concentrated P to the stream, or the conditions are more favorable for P deposition further downstream.

Table 2. Total phosphorus contents and bulk density of stream bank soils along Little Hatchet Creek, Alachua County, FL, on September 3, 2014.

Station	**Sample ID**	**Sample Description**	**Bulk Density (g/cm^3)**	**TP (mg/kg)**	**P Storage (mg P/cm^3)**
1	#1	Clay outcrop at water	1.6	6,590	10.5
2	#2	Clay from top of bank	1.1	8,050	8.9
	#3	Clay from streambed	1.0	3,850	3.9
3	#4	Sand Bar	1.5	50	0.1
4	#5	Sandy clay with gravel in stream bank (3 reps)	1.7	360	0.6
	#6		1.7	360	0.6
	#7		1.6	136	0.2
5	#8	Clay embankment (3 reps)	1.5	82,000	123.0
	#9		1.4	99,000	138.6
	#10		1.5	95,300	143.0
6	#11	Sandy clay 18" above water	1.2	43,400	52.1
	#12	Clay 2" above water	1.4	64,800	90.7
7	#13	Bluegreen clay lense	0.6	3,730	2.1
	#14	Surrounding sand	1.2	158	0.2
8	#15	Sandstone bluff	1.2	93	0.1
	#16		1.2	68	0.1

Table 3. Phosphorus storage per unit volume of sand sediments in Little Hatchet Creek, along with concentrations of P, Ca, Fe, and bulk density values, as a function of distance below (downstream of) Waldo Road. SE = standard error around the average of all samples.

Sample ID	Stream Distance below Waldo Road (km)	TP (mg/kg)	Ca (mg/kg)	Fe (mg/kg)	Bulk Density (g/cm³)	P Storage (mg P/cm³)
SB-25	-0.06	45	<500	425	1.50	0.07
SB-24	0.30	104	650	420	1.55	0.16
SB-23	0.50	210	1,100	350	1.54	0.32
SB-22	0.88	420	1,100	320	1.54	0.65
SB-21	1.06	173	550	380	1.54	0.27
SB-20	1.26	280	1,100	280	1.58	0.44
SB-19	1.44	969	3,600	< 250	1.52	1.48
SB-18	1.58	1,170	4,200	470	1.53	1.79
SB-17	1.71	1,610	4,700	460	1.53	2.47
SB-16	1.81	1,300	3,900	340	1.53	1.98
SB-15	1.90	1,250	3,600	420	1.54	1.93
SB-1	1.95	1,130	2,700	840	1.57	1.77
SB-2	1.99	576	1,900	< 250	1.53	0.88
SB-3	2.15	1,250	4,300	680	1.53	1.92
SB-4	2.19	1,310	3,000	500	1.49	1.95
SB-5	2.32	1,340	3,900	1,100	1.47	1.96
SB-6	2.40	1,710	4,900	520	1.55	2.66
SB-7	2.58	1,580	7,400	370	1.53	2.41
SB-14	2.83	3,230	9,200	690	1.61	5.20
SB-13	3.10	2,420	6,000	400	1.58	3.81
SB-12	3.41	3,250	7,300	480	1.51	4.92
SB-11	3.67	2,530	6,600	560	1.43	3.62
SB-8	3.85	1,530	3,700	440	1.54	2.36
SB-9	4.15	1,380	3,200	280	1.57	2.17
SB-10	8.51	50	< 500	< 250	1.29	0.06
Average		**1,233**	**3,852**	**488**	**1.52**	**1.89**
SE		183	482	41	0.01	0.28

Several stations within the study reach were located adjacent to, or upstream and downstream of an old landfill (recently mitigated). The chemical composition of sediments from these locations were examined to determine whether there may have been further contribution of P or P-binding metals such as Fe or Ca from this site. The highest P levels found in our Phase 2 stream bed surveys were located adjacent to the landfill site. Total P concentrations in sand sediments from two stations (SB-8 and SB-9) downstream of the landfill were higher than average for all sands, but within the range observed upstream of the landfill (Table 3 and Figure 6). Overall, the average (± SE) P content for all 25 stream bed sediment samples was 1,233 ± 183 mg/kg. Incorporating TP and bulk density of the sediments together, the average phosphorus stored in sand sediments within the study reach was 1.89 ± 0.28 mg P/cm^3, with a range from 0.06 to 5.20 mg P/cm^3 for sandy stream sediments (Table 3).

In addition to sand bar sampling along Little Hatchet Creek, several additional samples were collected opportunistically during our August 2015 survey. These included stream bed materials that were incorporated within a sandy matrix, but were composed of larger aggregates "nodules" or gravel-sized stones and clay deposits. The P content of these materials ranged from 2,360 to 101,000 mg/kg (Table 4). The P storage in the gravel-sized aggregates at SB-7 was 113.5 mg P/cm^3, nearly as high as the native material within the clay outcrop at station #5 (Table 2).

Table 4. Chemical characterization of aggregates in the sand sediments at three locations along Little Hatchet Creek, on August 18, 2015.

Sample ID	Bulk Density (g/cm^3)	TP (mg/kg)	P Storage (mg P/cm^3)	TN (mg/kg)	Ca (mg/kg)	Fe (mg/kg)
SB-1 Nodules	1.46	2,530	3.7	<850	5,700	1,900
SB-2 Nodules	0.72	55,900	40.5	<850	128,000	10,000
SB-2 Clay	0.64	10,200	6.5	1,470	21,000	6,600
SB-7 Clay	0.77	2,360	1.8	<850	7,500	22,000
SB-7 Gravel	1.12	101,000	113.5	<850	279,000	4,000

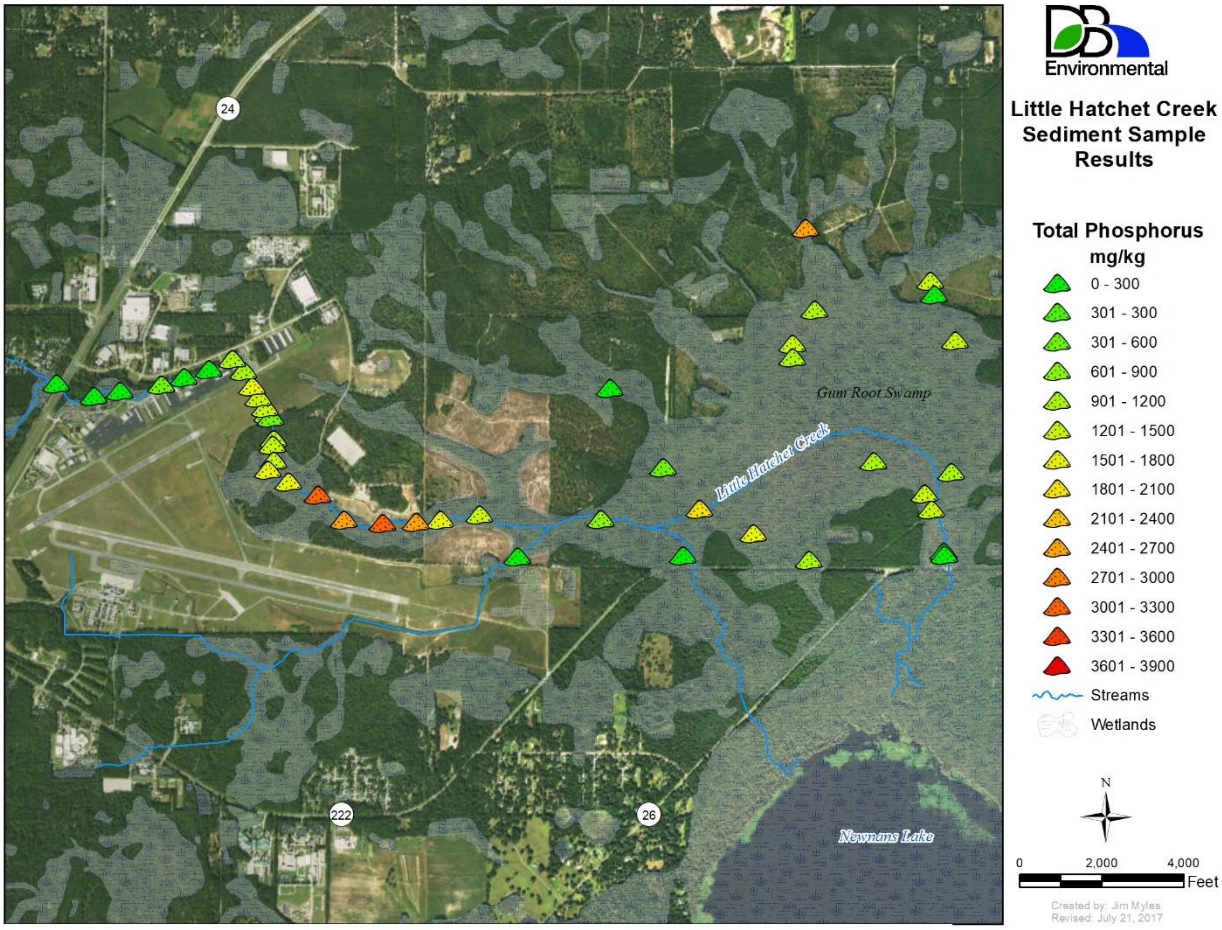

Figure 5. Sampling locations and relative total phosphorus (TP) contents for sediments along Little Hatchet Creek and within Gum Root Swamp, during the study period (September 2014 – May 2016).

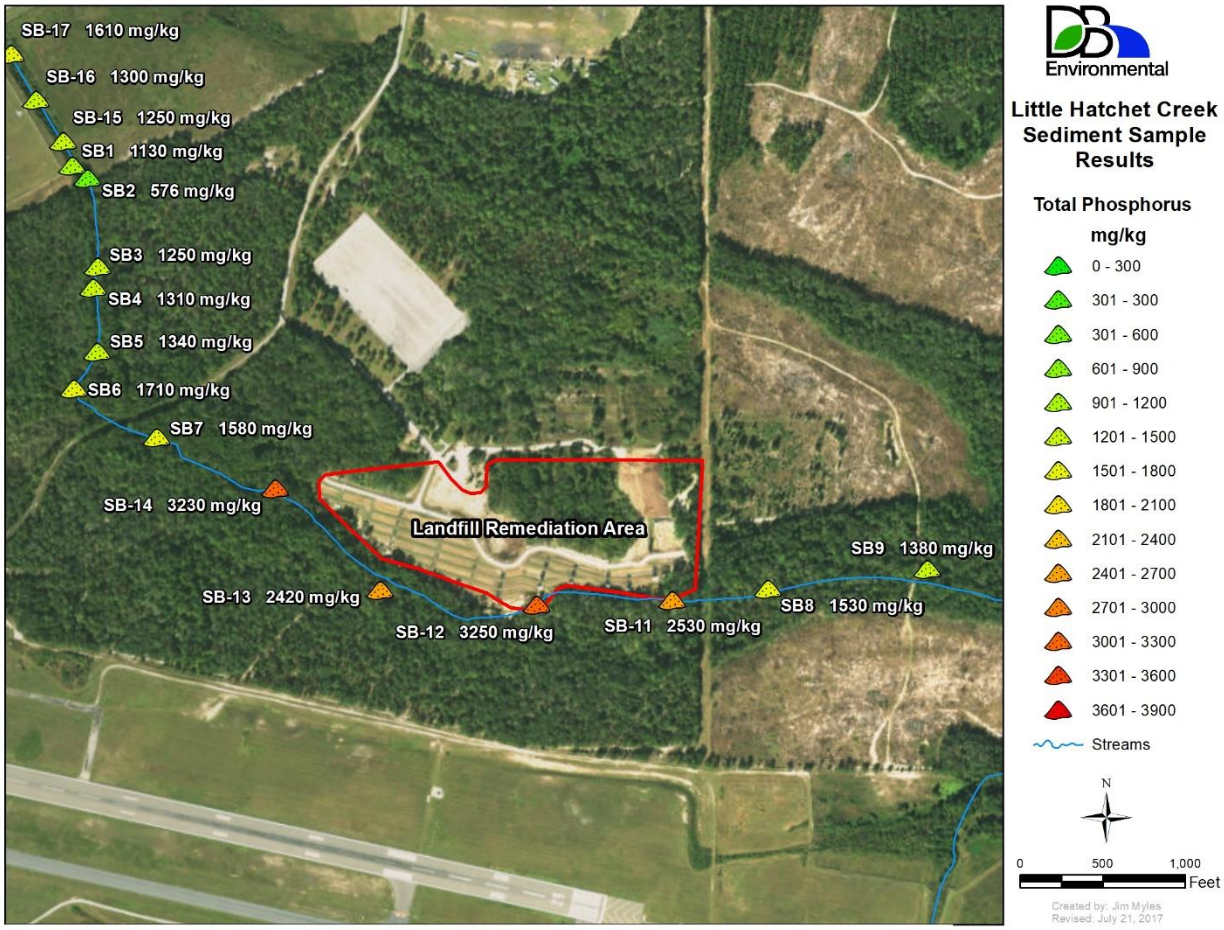

Figure 6. TP concentrations of sand sediment samples collected upstream and downstream of the closed landfill.

3.2.2. Other Chemical Constituents of Stream Bed Sediments

Nitrogen, calcium and iron contents were determined to characterize the composition of the depositional materials. Nitrogen contents were below detectable levels (<850 mg/kg) in all stream bed samples, which is not uncommon for highly-mineral sandy soils with low organic contents. Only the clay sample collected at station SB-2 contained measurable nitrogen contents (1,470 mg/kg), a very low level that likely resulted from slight enrichment with organic matter (Table 4). Calcium content varied from <500 to 9,200 mg/kg in the sand sediments, but was as high as 279,000 mg/kg (27.9%) in the gravel found at SB-7 (Table 3 and Table 4). Iron contents measured in the sand sediments ranged from < 250 to 1,100 mg/kg, and as high as 22,000 mg/kg (2.2%) in the clay at SB-7. Thus, the calcium and total phosphorus contents of gravel at this location were highly-enriched with respect to the remaining samples, whereas iron was lower. These elemental differences were reflected in the P fractionation results (described in Section 3.2.3, below), with high levels of Ca-bound P measured in the gravel at SB-7 (85,800 mg/kg).

The mineral phase of calcium phosphate present in both the gravel material from SB-7 and the clay outcrop at station #6 was determined to be apatite, using x-ray diffraction analysis at University of Florida (Dr. W. G. Harris, personal communication). Apatite is a form of calcium phosphate rock that is highly stable, but through weathering processes the P can become bioavailable over time. Calcium phosphate rock was historically mined throughout the north Florida region (Prinkle 1956), and likely constitutes a naturally-occurring source of phosphorus to surface waters when streams erode through this material. It should be noted that while the mineral occurs naturally, processes affecting exposure of this material (channel maintenance) or the rate of erosion (such as an increase in runoff from impervious surfaces in the watershed) will contribute to accelerated transport of the nutrient into downstream water bodies.

Among the sediments collected from in-channel sand bars throughout the study reach, Ca and P contents were well correlated (Figure 7). This was not the case for sediments collected in Gum Root Swamp as will be described in a later section of this report.

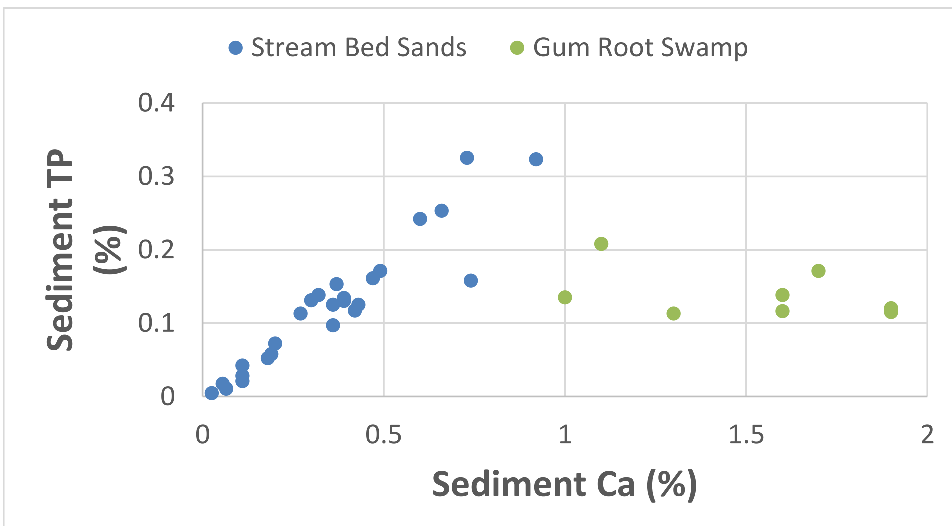

Figure 7. Relationship between calcium and phosphorus in sandy stream bed sediments collected in August 2015 and January 2016, and Gum Root Swamp samples collected in April and May 2016.

3.2.3. Sediment Phosphorus Forms and Fractions

The most labile and easily mobilized pool of sediment P was measured as the NH_4Cl-extractable inorganic P (NH_4Cl-Pi), and ranged from 1.0 to 11.6 mg/kg in the sand sediments (Table 5). The distribution of exchangeable P along the surveyed stream reach indicated higher levels close the airport, and lower values with distance downstream. This may reflect a diminishing effect of the source area determined within the incised channel north of the airport (Station #5 from our 2014 survey, see Figure 4).

Another relatively labile pool of sediment P is the NaOH- extractable inorganic P (NaOH-Pi), which is associated with P bound to iron and aluminum hydroxides. The inorganic P extracted by NaOH was greater than the organic P fraction (P associated with humic and fulvic acids) in all sand sediments except the furthest downstream (SB-10). Although the surface waters in Little Hatchet Creek can be enriched in these dissolved organic compounds as a result of a largely forested watershed, this pool of P in sediments was small relative to the inorganic NaOH-extractable P pool (Table 5 and Table 6). Fe-bound P and Al-bound P were not measurably greater below the landfill parcel, as compared to stations located further upstream. Stations SB-3 through SB-5 had the highest concentrations of NaOH-Pi, indicating significant amounts of P are potentially available for mobilization to the surface waters through this reach (Table 5). This fraction was higher in the aggregates co-located with the sands in depositional areas along Little Hatchet Creek, especially in the clay from SB-2 (1780 mg/kg NaOH- Pi) in the upstream portion of the surveyed reach (Table 6).

Table 5. Sediment total phosphorus (TP) content and fractions in sand sediments collected from Little Hatchet Creek, on August 18, 2015 and January 6, 2016, as a function of distance below (downstream of) Waldo Road. SE = standard error around the average of all samples.

Sample ID	Stream Distance below Waldo Road (km)	NH_4Cl-Pi (mg/kg)	NaOH-Pi (mg/kg)	NaOH-Po (mg/kg)	HCl-Pi (mg/kg)	TP (mg/kg)
SB-25	-0.06	1.5	13	4.7	6.5	45
SB-24	0.30	8.3	21	5.8	217	104
SB-23	0.50	4.2	16	4.3	463	210
SB-22	0.88	3.0	21	2.0	127	420
SB-21	1.06	5.5	196	62	162	173
SB-20	1.26	7.1	35	4.4	581	280
SB-19	1.44	11.6	88	8.7	2,180	969
SB-18	1.58	6.5	55	5.4	1,510	1,170
SB-17	1.71	9.0	60	6.9	2,600	1,610
SB-16	1.81	7.0	36	13	1,050	1,300
SB-15	1.90	6.6	61	6.1	1,650	1,250
SB-1	1.95	5.9	119	26	955	1,130
SB-2	1.99	4.0	33	5.4	1,330	576
SB-3	2.15	3.2	195	4.0	749	1,250
SB-4	2.19	4.8	144	21	1,400	1,310
SB-5	2.32	4.7	215	18	1,220	1,340
SB-6	2.40	3.5	85	1.9	930	1,710
SB-7	2.58	2.9	55	14	1,940	1,580
SB-14	2.83	10.8	107	11	2,460	3,230
SB-13	3.10	5.5	80	5.4	2,900	2,420
SB-12	3.41	5.8	99	6.6	2,030	3,250
SB-11	3.67	8.3	94	10.2	3,730	2,530
SB-8	3.85	2.7	101	13	1,776	1,530
SB-9	4.15	1.3	45	10.3	1,450	1,380
SB-10	8.51	1.0	11	23.8	1	50
Average		**5.4**	**79**	**12**	**1,337**	**1,233**
SE		0.6	12	2	194	183

Table 6. Phosphorus content and fractions of total P in aggregates found within the sand sediments at selected sites in Little Hatchet Creek, on August 18, 2015. All values in mg/kg.

		Fractions of Total P			
		Exchangeable-P_i	Fe and Al-bound P_i	Humic and Fulvic Acid-bound P_o	Ca and Mg-bound P_i
Sample ID	**TP**	**NH_4Cl-Pi**	**NaOH-Pi**	**NaOH-Po**	**HCl-Pi**
SB-1 Nodules	2,530	9.3	209	70	601
SB-2 Nodules	55,900	134	865	51	47,700
SB-2 Clay	10,200	4.0	1,780	1,240	5,340
SB-7 Clay	2,360	2.3	773	257	102
SB-7 Gravel	101,000	14	27	52	85,800

3.3. Gum Root Swamp Sediments

3.3.1. Interior Sediments

During the forays into Gum Root Swamp on April 19 and 20, and May 2, 2016, water levels had receded enough to permit access into the swamp interior (Figure 2). The many fallen trees and other dispersed areas of high ground (black gum roots, cypress knees and tussocks) were used as a path whenever possible. That did not make foot travel easy, however, and many areas with soft muck 0.6-0.9 m in depth were routinely encountered. Ten stations were sampled from within the swamp interior. These stations were primarily muck and peat soils with dark color and characterized by high organic matter content (% volatile solids) and low bulk density (Table 7). Several stations initially planned as stream channel samples (SB-26, SB-27, SB-28) were clearly like the other interior stations, and were located within Gum Root Swamp in areas without a well-defined stream channel. Two additional stations (GMRIN1 and Waypoint #176) were sampled opportunistically and included as interior stations, based on high organic matter contents (i.e., volatile solids) and total nitrogen, and low bulk density values (Table 7).

Average TP contents for the interior stations was 1,386 ± 96 mg/kg, which is comparable to the contents of Little Hatchet Creek stream bed sand sediments (1,233 ± 183 mg/kg). However, due to low bulk density values in the interior sediments, the mass P storage in the interior (N=10; average (± SE) = 0.18 ± 0.07 mg P/cm^3) is 10-fold less than in the stream bed sediments (N=25, average (± SE) = 1.89 ± 0.28 mg P/cm^3) on a volume basis. This is important when evaluating potential remediation alternatives, such as removal of P-rich materials from the stream channel. The sediments from the interior of Gum Root Swamp were only slightly enriched with P, on a volumetric basis, when compared to "background" sand sediments (e.g., SB-10 and SB-25), where only 0.06 – 0.07 mg P/cm^3 was stored.

Table 7. Chemical composition of the sediments collected from stations in the Interior of Gum Root Swamp.

Sample ID	Date Sampled	Bulk Density (g/cm3)	TP (mg/kg)	P Storage (mg/cm3)	TN (mg/kg)	Ca (mg/kg)	Fe (mg/kg)	Volatile Solids (%)
G-2	5/2/2016	0.081	1,150	0.09	23,700	19,000	3,100	88
G-3	5/2/2016	0.083	1,130	0.09	21,200	13,000	2,200	89
G-4	5/2/2016	0.048	1,350	0.06	26,700	10,000	2,100	91
G-5	4/20/2016	0.120	1,710	0.21	20,500	17,000	5,200	75
G-6	4/20/2016	0.081	1,180	0.10	19,750	17,500	4,450	85
GMRIN1	4/19/2016	0.085	1,210	0.10	19,000	9,900	2,800	85
SB-26	4/20/2016	0.057	1,200	0.07	23,700	10,000	2,100	93
SB-27	4/20/2016	0.090	1,470	0.13	20,400	15,000	6,400	87
SB-28	4/20/2016	0.390	2,080	0.81	9,020	11,000	4,000	35
Waypoint #176	5/2/2016	0.067	1,380	0.09	24,800	16,000	3,000	87
Average		**0.110**	**1,386**	**0.18**	**20,877**	**13,840**	**3,535**	**81**
SE		0.032	96	0.07	1,531	1,105	459	5

3.3.2. Tributaries

Six stations were sampled to characterize sediments and water quality associated with the tributary inflows to Gum Root Swamp (Table 8). One of these stations (G-1) was planned as an interior station, but the primary stream channel of Little Hatchet Creek was found to have migrated to this location under the low-water conditions present during our April 2016 survey. By contrast, a station initially planned as a stream bed station (SB-28) was located in an area without a channel nearby. This reflects the fact that stream lines based on the available information prior to these field surveys may not reflect the current path through the swamp, where the channel is braided and primary flow channels are likely to migrate over time. Another station (GMRIN1DS) was located downstream of a road crossing and culvert from the originally planned sampling location. The downstream location had a more well-defined stream channel, whereas the upstream location was in an area of stagnant water, held back by the road. For purposes of comparing the characteristics of "typical" swamp *Interior* locations to *Tributary Inflow* sediments and Little Hatchet Creek sediments, the station GMRIN1DS (Downstream) was therefore included with the *Tributary Inflow* station cluster, and GMRIN1 was added to the *Interior* station set.

Total P contents of the *Tributary Inflow* stations (N=6) averaged 643 ± 384 mg/kg, with 0.96 ± 0.58 mg P/cm^3 stored in the surficial sediments (Table 8). Organic matter contents were low, with volatile solids and TN below detectable levels for all samples. Where P concentration was highest (e.g., GMRIN2, TP = 2,470 mg/kg), calcium contents were also enriched (6,500 mg/kg), indicating that this tributary may also interact with the phosphatic clay deposits of the Hawthorn Group. Indeed, the sampling location was immediately downstream of a confluence of two stream channels, and the eastward channel was highly turbid at the time of sampling (See Appendix C). Identifying the cause and nature of this turbidity was beyond the scope of the present investigation, but may reflect either inorganic particulate matter (clay-sized minerals in suspension) within the stream channel, or a biological response (phytoplankton) to the high P contents of the sediments in that stream reach.

Two other inflow stations exhibited the lowest P contents of samples in the study. GMRIN1DS (Downstream) contained only 19 mg/kg, while SB-30 contained 31 mg/kg (Table 8). These levels were even lower than the "background" concentrations discussed earlier for un-enriched sandy sediments along the Little Hatchet Creek stream channel. Sediments from all stations classified as *Tributary Inflows* were sandy, with high bulk density values similar to the Little Hatchet Creek stream bed sediments, but much higher than the *Interior* stations from Gum Root Swamp. Despite the uniform bulk density in these inflow sediments, the variable P contents apparently reflected the degree to which the sediments have been enriched with calcium phosphate.

Table 8. Chemical composition of the sediments collected from stations along Tributaries flowing into Gum Root Swamp.

Sample ID	Date Sampled	Bulk Density (g/cm^3)	TP (mg/kg)	P Storage (mg/cm^3)	TN (mg/kg)	Ca (mg/kg)	Fe (mg/kg)	Volatile Solids (%)
G-1	4/20/2016	1.40	521	0.73	< 850	1,800	850	<1.35
GMRIN1 DS	4/19/2016	1.50	19	0.03	< 850	<500	<250	<1.35
GMRIN2	4/19/2016	1.50	2470	3.71	< 850	6,500	760	<1.35
GMRIN4	4/19/2016	1.60	91	0.15	< 850	<500	<250	<1.35
GMRIN5/ SB-29	4/20/2016	1.50	723	1.08	< 850	2000	320	<1.35
SB-30	4/20/2016	1.60	31	0.05	< 850	<500	<250	<1.35
Average		**1.52**	**643**	**0.96**				
SE		0.03	384	0.58				

3.3.3. Outflows from Gum Root Swamp to Newnans Lake

Five stations characterized the sediments within outflows of Gum Root Swamp (Table 9). These were located upstream of the culverts at SR 222 (GMROUT1 and GMROUT2) and SR 26 (GMROUT3 through GMROUT5). The main flow channel was sampled at GMROUT4, with discharge measured using a SonTeK FlowTracker to be 0.8 cubic feet per second (cfs) at the time of sampling on April 19, 2016. GMROUT3 was located ~0.4 km upstream, and a measured a flow of 1.3 cfs, while other Outflow stations lacked any flow.

Total P contents were highly variable across the five outflow region sampling locations, with a range of nearly two orders of magnitude (19 to 2,470 mg/kg). This variability was also reflected in the organic matter and TN contents of sediments, which indicated that some outflow locations were sandy-bottomed, high-energy areas (GMROUT1, GMROUT4, GMROUT5) and others were characteristic of depositional environments, with higher organics and TN values (GMROUT2, GMROUT3). These depositional stations also had elevated Ca and Fe contents in the organic soil, whereas the sandy sediments of the high-energy locations had undetectable levels of N, Ca, Fe, and organic matter (volatile solids). Phosphorus contents were elevated only in the locations typified low-energy, depositional conditions (GMROUT2 and GMROUT3).

Table 9. Chemical composition of the sediments collected from stations in the Outflows from Gum Root Swamp.

Sample ID	**Date Sampled**	**Bulk Density (g/cm^3)**	**TP (mg/kg)**	**P Storage (mg/cm^3)**	**TN (mg/kg)**	**Ca (mg/kg)**	**Fe (mg/kg)**	**Volatile Solids (%)**
GMROUT1 /SB-31	4/19/2016	1.6	117	0.19	< 850	<500	<250	<1.35
GMROUT2	4/19/2016	0.064	1,010	0.06	23,200	9,700	1,700	92
GMROUT3	4/19/2016	0.11	1,360	0.15	21,100	15,000	5,000	83
GMROUT4	4/19/2016	1.5	22	0.03	< 850	<500	<250	<1.35
GMROUT5	4/19/2016	1.4	163	0.23	< 850	<500	<250	<1.35
Average		**0.93**	**534**	**0.13**				
SE		0.35	272	0.04				

A comparison of sediments from these three regions of Gum Root Swamp (*Tributary Inflows*, *Interior*, and *Outflows*) to the Little Hatchet Creek stream bed sediments showed that the Interior stations had similar average P contents to Little Hatchet Creek, and was higher in P content than either the Tributaries or Outflow sediments (Figure 8). However, when considered on a volumetric basis (i.e., P Storage), the dense sand sediments along Little Hatchet Creek and at *Tributary Inflow* locations contained far more sediment P than Gum Root Swamp *Interior* stations or *Outflow* stations (Figure 9). A closer examination of the forms and stability of phosphorus stored in these sediments is described in the following section.

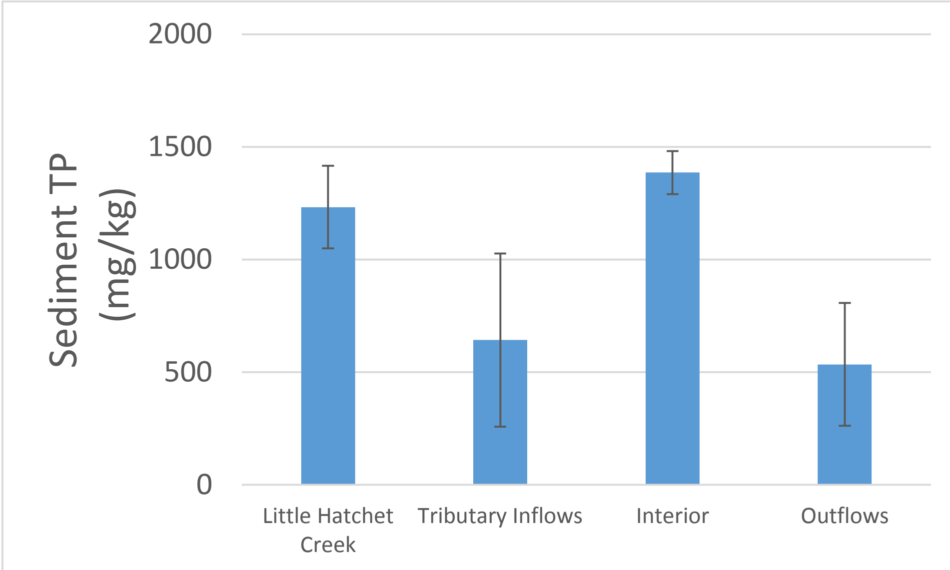

Figure 8. Average (± SE) sediment TP concentrations for four regions in the study area.

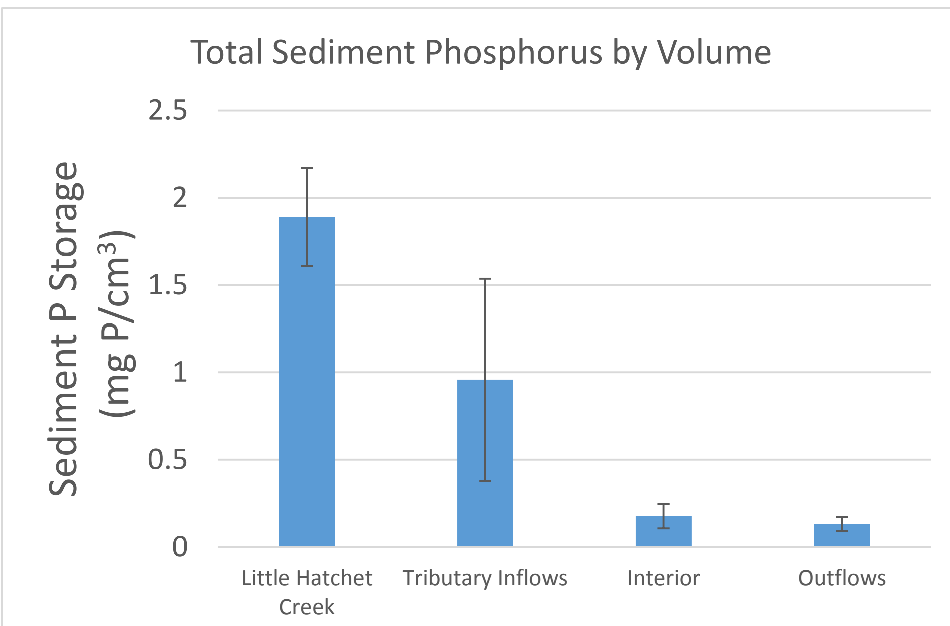

Figure 9. Volumetric phosphorus storage in the surficial sediments of four regions within the Little Hatchet Creek/Gum Root Swamp system.

3.4. Sediment Phosphorus Forms and Fractions

The sequential extraction procedure was used on sediments from the interior of Gum Root Swamp, from inflow tributaries and from outflow channels to divide sediment P into various fractions (Table 1). The distribution of P fractions in these sediments was then compared to the distribution found in stream bed sediments from Little Hatchet Creek, upstream of the swamp.

As a percentage of the total P pool, HCl-Pi was clearly dominant in stream bed sediments from both the main channel (North branch) of Little Hatchet Creek and other *Tributary Inflows* (Figure 10). That was not the case in the *Interior* region or *Outflow* channel sediments, where there was a larger percentage of NaOH-Po, a fraction that is associated with P bound to or within organic matter (Table 10, Table 11, and Table 12). This finding is in agreement with high organic matter content (as indicated by % volatile solids) of sediments from the *Interior*. In *Tributary Inflow* sediments, the NaOH-Pi fraction was larger than the NaOH-Po fraction, indicating that the Fe-bound and Al-bound P pools were greater than organic P in these sediments.

By comparison, in the *Interior* and *Outflow* regions, the reverse was true (NaOH-Po > NaOH-Pi), indicating that within the depositional swamp environment, P was predominantly bound in organic forms with a moderate degree of stability. In these regions, stable HCl-Pi forms were < 25% of the total extractable P (Figure 10). The most labile forms of sediment P (Labile P = DIW-Pi + NH_4Cl-Pi) were highest in the *Interior* (6.5 mg/kg) and the *Tributaries* (7.8 mg/kg), lower in the main channel of Little Hatchet Creek and lowest in sediments from the swamp Outflows (Figure 10 and Figure 11).

Despite higher calcium levels in the sediments from the Interior region, than inflow tributaries or Little Hatchet Creek itself, Ca-bound P forms were no longer dominant. The stagnant conditions of the swamp likely favor settling of Ca-rich particulate matter, but do not apparently favor the stability or formation of Ca-bound P compounds. Instead, NaOH Po forms are predominant.

Sediment P levels observed in stream bed sediments were comparable to areas in Florida that have been "highly-impacted" by dairy operations (Graetz and Nair 1995). That study found average TP contents of 34 mg/kg in sandy soils not impacted by dairy operations, and ~1680 mg/kg in "highly-impacted" areas. The highly-impacted soils in that study contained 69 mg/kg in WSP, and 400 mg/kg in the NH_4Cl-Pi fraction, a far greater pool of readily available P than the stream bed sediments in this study, which contained a maximum of 11.6 mg/kg in the NH_4Cl-Pi pool, and even greater than the aggregates of nearly pure apatite (gravel at SB-7), which contained 101,000 mg/kg TP but only 14 mg/kg in the NH_4Cl-Pi pool (Table 6). These results clearly demonstrate that the geologic phosphate materials that are P-rich and native to the Little Hatchet Creek watershed are relatively stable, compared to other potential P sources. For example, in Graetz and Nair's 1995 study, dairy manure contained 6500 mg/kg P, 42% of which was water-extractable. The present study encountered TP levels well above these previously documented examples of P enrichment, but we also observed background levels consistent with the sandy soils in that earlier study. The stability of sediment P in lakes has also been investigated using these P fractionation techniques (e.g., Olila et al., 1995), and this would be an appropriate next step in assessing the internal nutrient loading and potential for remediation of Newnans Lake, downstream of Little Hatchet Creek and Gum Root Swamp.

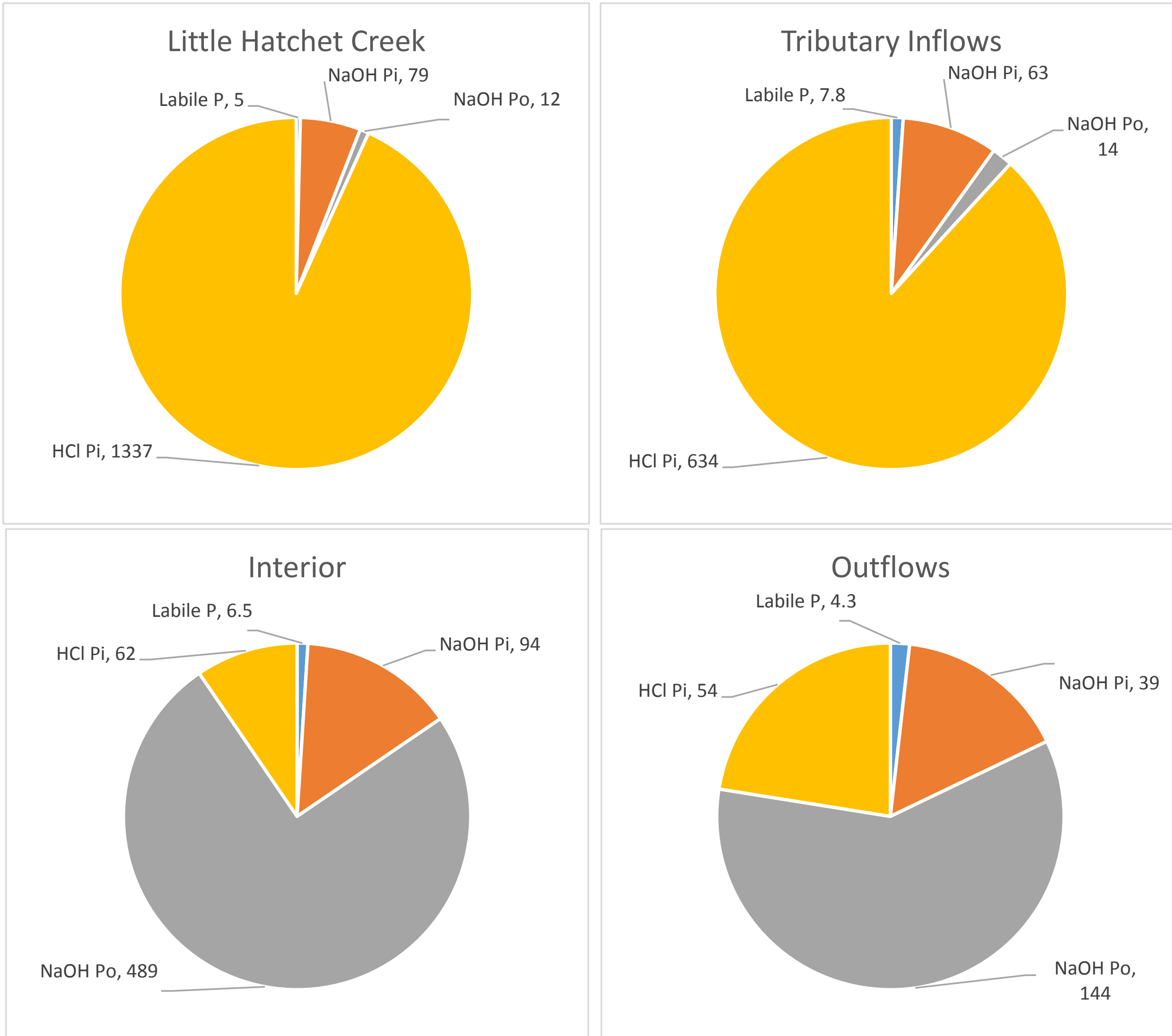

Figure 10. Fractions of extractable P in sediments from four regions within the study area. Values denote the average P content (mg/kg) in fractions defined in Table 1.

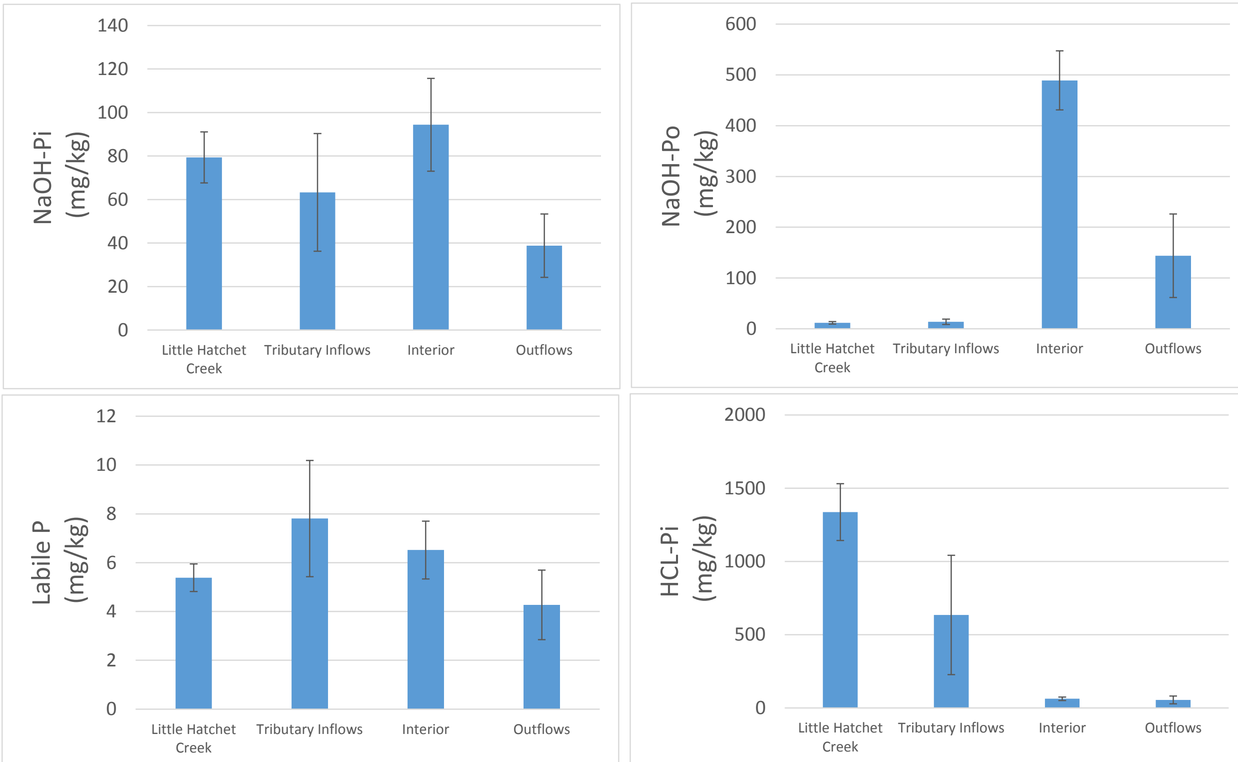

Figure 11. Comparison of the phosphorus fractions in sediments from four regions within the study area. Values denote the average ± SE of 5-25 stations within each region.

Table 10. Fractions of sediment phosphorus as determined by a sequential extraction procedure performed on sediments collected from stations in the Interior of Gum Root Swamp.

Sample ID	Date Sampled	DIW-Pi (mg/kg)	NH_4Cl-Pi (mg/kg)	NaOH-Pi (mg/kg)	NaOH-Po (mg/kg)	HCl-Pi (mg/kg)	TP (mg/kg)
G-2	5/2/2016	0.98	1.9	63	410	46	1,150
G-3	5/2/2016	1.8	4.2	58	379	38	1,130
G-4	5/2/2016	3.5	5.1	34	527	10	1,350
G-5	4/20/2016	1.3	2.6	117	505	118	1,710
G-6	4/20/2016	0.91	1.9	70	311	65	1,180
GMRIN1	4/19/2016	5.9	2.8	63	478	31	1,210
SB-26	4/20/2016	4.6	9.9	59	351	46	1,200
SB-27	4/20/2016	1.1	1.4	120	449	106	1,470
SB-28	4/20/2016	5.2	2.6	270	970	116	2,080
Waypoint #176	5/2/2016	2.2	5.3	89	513	46	1,380
Average		**2.7**	**3.8**	**94**	**489**	**62**	**1,386**
SE		0.6	0.8	21	58	12	96

Table 11. Fractions of sediment phosphorus as determined by a sequential extraction procedure performed on sediments collected from stations in the Inflowing Tributaries of Gum Root Swamp.

Sample ID	Date Sampled	DIW-Pi (mg/kg)	NH_4Cl-Pi (mg/kg)	NaOH-Pi (mg/kg)	NaOH-Po (mg/kg)	HCl-Pi (mg/kg)	TP (mg/kg)
G-1	4/20/2016	6.8	5.2	146	32	491	521
GMRIN1DS	4/19/2016	0.97	<0.40	2.3	5	0.67	19
GMRIN2	4/19/2016	10.2	6.1	142	29	2,570	2,470
GMRIN4	4/19/2016	4	1.6	11.9	3	0.58	91
SB-29/GMRIN5	4/20/2016	4	2.3	64.7	8	741	723
SB-30	4/20/2016	1.8	0.7	12.8	6	0.82	31
Average		4.6	3.2	63	14	634	643
SE		1.4	1.0	27	5	408	384

Table 12. Fractions of sediment phosphorus as determined by a sequential extraction procedure performed on sediments collected from stations in the Outflows of Gum Root Swamp.

Sample ID	Date Sampled	DIW Pi (mg/kg)	NH_4Cl-Pi (mg/kg)	NaOH-Pi (mg/kg)	NaOH-Po (mg/kg)	HCl-Pi (mg/kg)	TP (mg/kg)
SB-31/ GMROUT1	4/19/2016	1.4	<0.4	35	51	2	117
GMROUT2	4/19/2016	5.6	3.9	30	337	47	1,010
GMROUT3	4/19/2016	1.3	1.5	94	473	73	1,360
GMROUT4	4/19/2016	1.9	1.0	7	17	1	22
GMROUT5	4/19/2016	2.3	0.7	29	34	149	163
Average		2.5	1.8	39	182	54	534
SE		0.8	0.7	15	82	27	272

3.5. Surface Water

3.5.1. Phosphorus

On the day of our first stream bed sediment sampling event (August 18, 2015), surface water TP concentrations in Little Hatchet Creek were 126 µg/L at the upstream end of the project area (SB1) and increased to 261 µg/L where the stream passes below SR 26. This 2-fold increase in P concentration within the surface water indicated additional sources of P were located within the project reach. On January 6, 2016, TP concentrations were also lower at the upstream end of the study reach (41 µg/L at Waldo Road), then increased to as high as 225 µg/L TP at station SB-12, and with few exceptions showed a gradual increase in concentration with distance through the study reach (Figure 12).

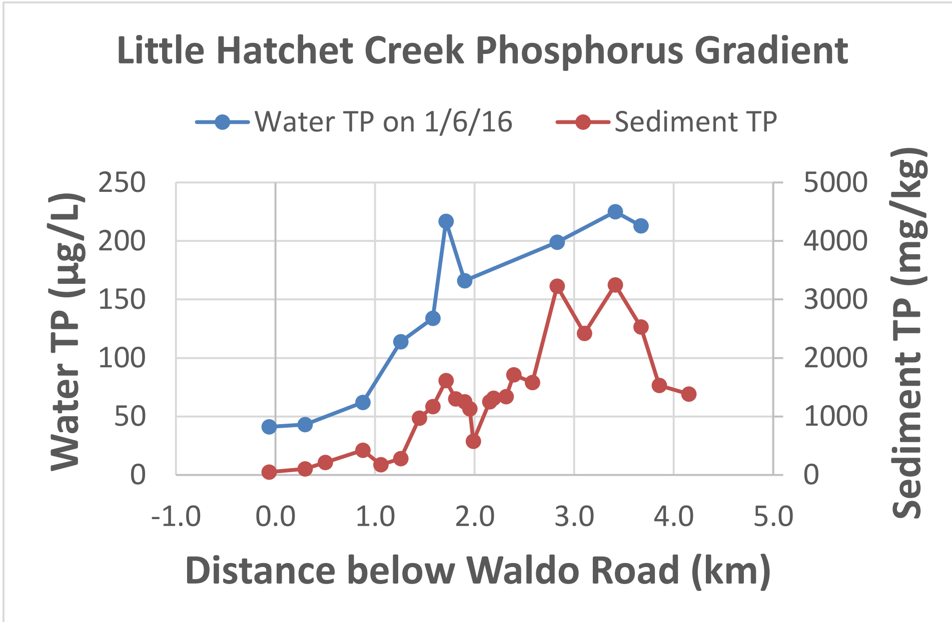

Figure 12. Phosphorus gradients along Little Hatchet Creek in surface water (January 6, 2016) and sediment (August 18, 2015 and January 6, 2016).

During the January 6, 2016, sampling event, determinations of the fractions of water phosphorus indicated that SRP was the dominant form of water P in Little Hatchet Creek surface waters, with 53-80% of the water TP concentration in this soluble, bioavailable form. The highest SRP concentrations (180 µg/L) also occurred at Station SB-12. Concentrations of DOP and PP were low upstream, and generally increased with distance downstream. The peak PP concentration was observed at SB-17, which was located just downstream of a culvert under the Gainesville Regional Airport north runway. However, those fractions remained less than SRP. This is contrary to the nutrient spiraling paradigm where nutrients and other constituents weathered from the watershed become diminished with distance along a flowing stream continuum (Newbold et al., 1981). Instead, Little Hatchet Creek is accumulating bioavailable nutrients in the surface water as it traverses that portion of the watershed that includes the airport and Gum Root Swamp.

During our April-May 2016 surveys, the highest surface water TP was recorded at GMRIN4, with 0.740 mg/L (Table 13). The SRP concentration at that location was also high (0.666 mg/L), indicating that P in the surface water remained in a bioavailable form. In fact, that was the general case across water samples from all dates and locations collected during this project, that SRP constituted the dominant form of P in the water column. The SRP fraction was 70-90% of TP across all samples except SB-30, located on the south side of the Little Hatchet Creek main channel, collected from a tributary that drains much of the airport property (Figure 3). This location (SB-30) also had very low TP concentration (0.020 mg/L) at the time of sampling on April

20, 2016, with 0.011 mg/L SRP (55% of the TP concentration). The fact that SRP was the dominant form throughout the Little Hatchet Creek watershed is likely a function of the high degree of canopy shading of the creek and swamp system, which limits the potential for instream plant and algal growth and concomitant nutrient uptake.

The flashy hydrograph in Figure 2 is characteristic of a developed watershed with low water retention and many impervious surfaces that rapidly deliver water into the creek. Under drying conditions, sediment P can become mobilized through mineralization of the organic P forms found in the swamp soils. Then, upon rehydration, anoxia develops in the soils, destabilizing Fe-bound P forms. Tropical Storm Colin passed over the area on June 6, 2016 and dropped several inches of rain on the Little Hatchet Creek watershed, causing stream flows to increase dramatically and Gum Root Swamp to rehydrate.

The surface waters flowing into and out of Gum Root Swamp were sampled June 15, 2016, to assess P transport and transformations under these rehydrating, high-flow conditions (Figure 13). The calculated discharge from the gauging station (02840233) was 2.04 cfs on June 15, 2016 and was as high as 56 cfs on June 7, 2016 as the storm passed through the region. Surface water TP concentrations at Waldo Road were 75 µg/L, but increased to 217 µg/L at the gauging station (02840233) and 351 µg/L at LHT26E, where the main channel flows out of Gum Root Swamp and passes beneath SR 26 (Table 14 and Figure 14). On that date, SRP was again the dominant form of P in the surface water at all stations; it increased from 65% of TP upstream at Waldo Rd, to 85% at LHT26E. This accumulation of bioavailable P in the surface water with distance downstream reflects the fact that the sediments are a source of P to the overlying water, in excess of in-stream P removal capacity, and delivery of bioavailable P to downstream Newnans Lake is a continuous process.

Table 13. Chemical composition of surface waters collected in April and May 2016, from Interior stations within Gum Root Swamp, from stations designated as Inflow tributaries to the swamp as well as from stations associated with Outflows from the swamp. All values in mg/L.

Region	Sample ID	Date	TP	PP	DOP	SRP	F^-	TN	Org-N	NH_4-N	NO_x
Interior	**G-2**	4/20/2016	No water sample								
	G-3	5/2/2016	0.570	0.041	0.037	0.492	0.63	2.22	1.48	0.718	0.016
	G-4	5/2/2016	0.331	0.011	0.052	0.268	0.50	2.12	1.83	0.272	0.017
	G-5	4/20/2016	0.246	0.026	0.029	0.191	0.19	0.86	0.65	0.185	0.032
	G-6	4/20/2016	0.219	0.021	0.022	0.176	0.255	0.91	0.75	0.126	0.026
	GMRIN1	4/19/2016	0.221	0.010	0.027	0.184	n.d.	1.31	1.26	0.028	0.021
	SB-26	4/20/2016	0.377	0.001	0.059	0.317	0.43	2.04	1.88	0.117	0.037
	SB-27	4/20/2016	0.232	0.019	0.025	0.188	0.18	1.24	1.09	0.108	0.044
	SB-28	4/20/2016	No water sample								
	Waypoint 176	5/2/2016	No water sample								
Inflows	**G-1**	4/20/2016	0.273	0.031	0.021	0.221	0.24	0.89	0.47	0.034	0.390
	LHATNBWMD	4/19/2016	0.392	0.092	0.024	0.275	n.d.	0.79	0.40	0.259	0.134
	GMRIN1DS	4/19/2016	No water sample								
	GMRIN2	4/19/2016	0.397	0.066	0.033	0.299	n.d.	0.34	0.33	0.008	0.007
	GMRIN4	4/19/2016	0.740	0.051	0.023	0.666	n.d.	0.47	0.44	0.012	0.024
	GMRIN5/SB-29	4/19/2016	0.276	0.035	0.019	0.222	n.d.	0.82	0.48	0.037	0.302
	SB-30	4/20/2016	0.020	0.004	0.005	0.011	0.13	0.38	0.35	<0.020	0.031
Outflows	**GMROUT1/SB-31**	4/19/2016	No water sample								
	GMROUT2	4/19/2016	No water sample								
	GMROUT3	4/19/2016	0.236	0.015	0.027	0.194	n.d.	1.11	0.97	0.089	0.050
	GMROUT4	4/19/2016	0.230	0.012	0.037	0.181	n.d.	1.13	0.98	0.061	0.091
	GMR OUT5	4/19/2016	No water sample								

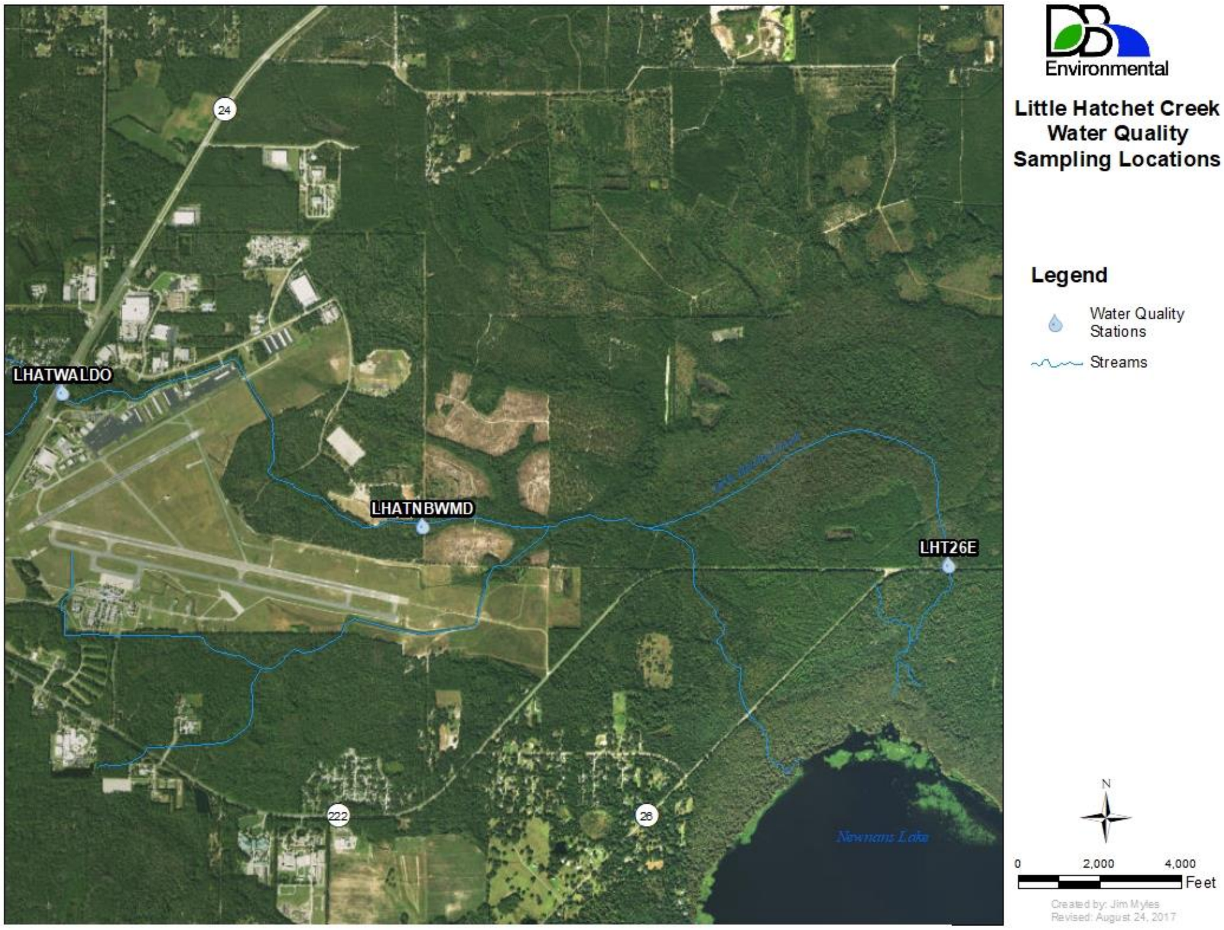

Figure 13. Established water quality monitoring locations along Little Hatchet Creek

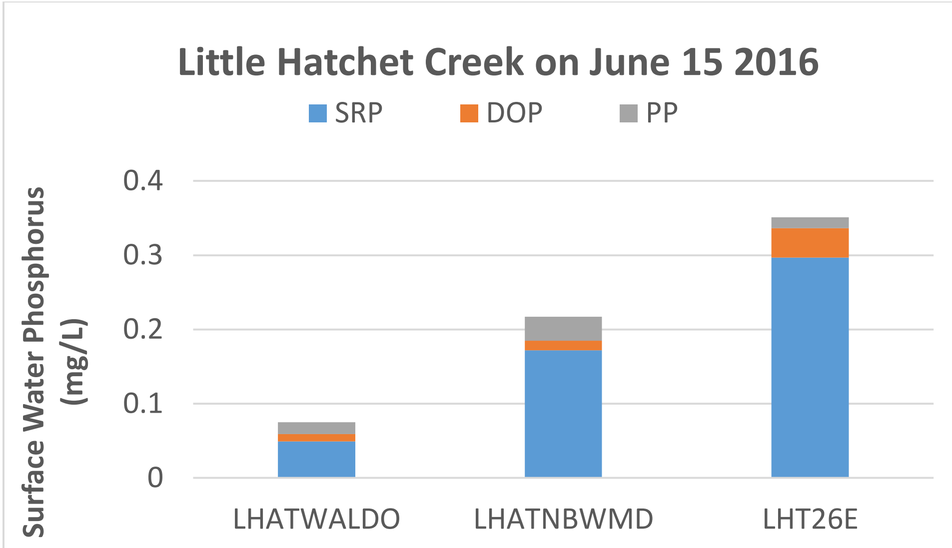

Figure 14. Phosphorus concentrations in the surface water of Little Hatchet Creek on June 15, 2016, shortly after rain associated with Tropical Storm Colin rehydrated Gum Root Swamp, leading to flow out of the swamp at LHT26E.

Table 14. Phosphorus forms in the surface water at three locations along Little Hatchet Creek, including LHATWALDO (upstream of a previously-identified P "hotspot" location), LHATNBWMD (near the long-term stage and WQ monitoring location between the hotspot) and LHT26E (just upstream of SR 26). All values are in mg/L.

Parameter	LHATWALDO	LHATNBWMD	LHT26E
TP	0.075	0.217	0.351
TSP	0.059	0.185	0.337
SRP	0.049	0.172	0.297
DOP	0.010	0.013	0.040
PP	0.016	0.032	0.015

3.5.2. Other water constituents

On January 6, 2016, fluoride (F^-) concentrations ranged from 0.26 to 0.35 mg/L throughout most of the study reach, with one station exhibiting higher F^- levels (0.75 mg/L). This higher level appeared to be an outlier, when fluoride data from this date and several follow-on surface water sampling events are compared to TP concentrations (Figure 15). During the interior sampling of the swamp in April and May 2016, F^- concentrations ranged from 0.18 – 0.63 mg/L, while two tributary inflows sampled in April 2017 contained low F^- concentrations (0.13 and 0.25 mg/L) (Table 13). In June 15, 2016, F^- concentrations in the stream increased slightly between 0.26 mg/L at Waldo Road and 0.33 mg/L at SR 26 (Table 15). For comparison, a statewide summary of "background" groundwater F^- concentrations in 194 wells in the intermediate aquifer in north central Florida contained a maximum concentration of 2.8 mg/L, and a median level of 0.29 mg/L (FDEP online report, accessed July 25, 2017, at http://fldeploc.dep.state.fl.us/ambient/triennial/default.htm).

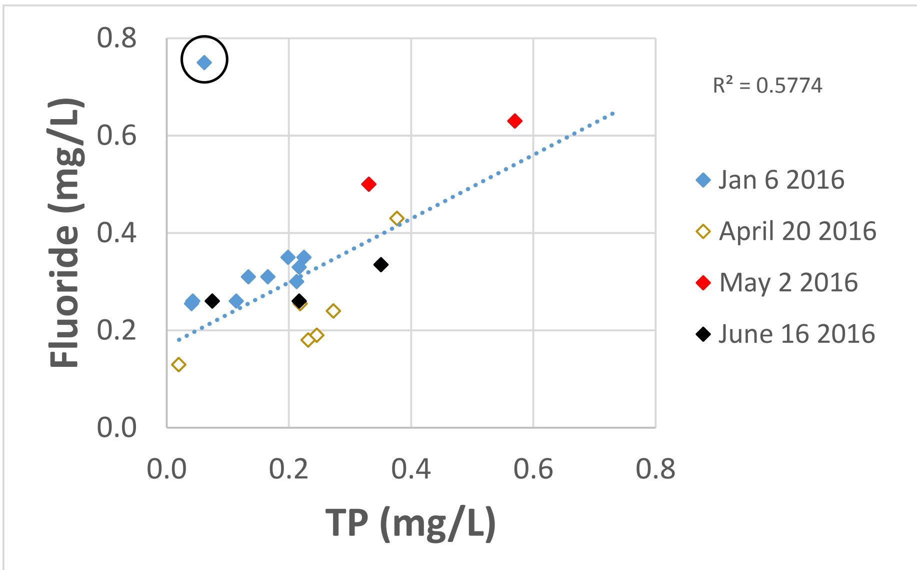

Figure 15. A comparison of fluoride and total phosphorus (TP) concentrations in the surface water of Gum Root Swamp and its inflow tributaries, inlcuding Little Hatchet Creek, on several sampling dates. The correlation coefficient and linear regression line shown represent all data points except for SB-22, sampled on January 6, 2016, where F- and TP concentrations were 0.75 and 0.062 mg/L, respectively (data point is circled in the above figure).

Water flowing into Gum Root Swamp on June 15, 2016 was elevated in most cations (Ca, Mg, Cl^-, K, Na, SO_4) and NOx, alkalinity, and hardness, compared to water flowing out of the swamp at LHT26E. By contrast, water leaving the swamp had become enriched in total suspended solids, P (as described above), TKN, and especially TOC (Table 15). Total nitrogen and ammonia-N values in the interior of Gum Root Swamp were also higher than inflows during our dry-season sampling in April-May 2016, while NO_x values were high in several inflows to the swamp, relative to the swamp interior or outflow locations (Table 13). A summary report of water quality for several creeks in the Gainesville, FL area, including Little Hatchet Creek, also found elevated levels of NOx and SRP at the North Branch location (LHATNBWMD in the present study), as compared to areas further downstream (ACEPD 2007).

Table 15. Chemical constituents in the surface water of Little Hatchet Creek on June 15, 2016, at two stations upstream and one station downstream of Gum Root Swamp, shortly after rehydration. All concentrations are in mg/L.

Parameter	LHATWALDO	LHATNBWMD	LHT26E
Alkalinity	82	84	35.5
Hardness	99	100	65
Calcium	31	32.8	17.9
Magnesium	7.76	6.88	4.665
Chloride	11	10	8.55
Fluoride	0.26	0.26	0.335
Potassium	1.330	1.310	0.874
Sodium	8.270	7.670	6.685
Sulfate	13	11	1.35
Iron	0.824	0.783	0.789
Ammonia-N	<0.020	0.085	0.051
NOx	0.11	0.14	0.057
TKN	0.71	0.7	1.65
Total Dissolved Solids	170	170	175
Total Organic Carbon	13	12	35.5
Total Suspended Solids	2.7	2.5	7.9

4. SYNTHESIS AND RECOMMENDATIONS

- High-P stream bank materials in the incised channel were also found within the stream bed, though most sand deposits were much lower in P.
- Stream bed sands contained mostly stable Ca-P compounds, with little increase in the labile P pool.
- Increases in sediment P were found where scour pools have deposited gravel-sized materials that are high in P.
- These high sediment P areas were located adjacent to an old landfill parcel that was recently mitigated to contain the solid waste and prevent further erosion and sediment transport into the stream. However, based on our chemical fractionation of sediment P, it does not appear that Fe-bound P enrichment has occurred near the landfill property. Instead Ca-bound P is the most abundant P form, suggesting geologic phosphate as a source and the change in depositional environment (lower stream channel energy and slope) as the reason for P accumulation along that reach.
- Gum Root Swamp organic soils are elevated in P contents (weight-basis) compared to tributary inflows, but only slightly higher than Little Hatchet Creek sands.

- Higher bulk density of sands in the Little Hatchet Creek stream channel and other tributary inflows to the swamp resulted in higher P mass per unit volume at those locations, as compared to Gum Root Swamp soils.
- Some deeper muck deposits within Gum Root Swamp may contain large pools of P. The material is bound in organic P forms that are likely unstable during dry out and reflooding.

4.1. Recommendations for reducing P in Little Hatchet Creek include the following:

- Mitigation strategies for reducing P loading into Little Hatchet Creek surface waters should address both actively-eroding areas along the stream bank, as well as depositional areas where eroded calcium phosphate minerals may have resettled. Continued release of P from the existing stream bed sediments into the overlying water should be expected until erosion is controlled, and existing bed materials are either removed or covered by newly deposited sediment.
- A P flux assessment of soils from within Gum Root Swamp should be conducted to determine whether these soils are a source or sink of P to the overlying water column. Such an investigation should include an assessment of the effect of sediment dry-out on P release or retention by these soils.
- An assessment of the sediments in Newnans Lake, close to the inflow of Little Hatchet Creek, would determine if weathered, naturally-occurring Ca-P minerals such as apatite have been transported into the lake and contribute directly to the long-term P enrichment of the lake.
- Exposed Hawthorn Group sediments along the west branch channel of Little Hatchet Creek downstream of NW39th Avenue and upstream of SR26, and/or in-stream locations along the east and west branches of Little Hatchet Creek downstream of SR26, could be sampled to provide a more complete evaluation of potential source areas to Newnans Lake.
- Routine monitoring of surface water phosphorus concentrations in the east and west branches of Little Hatchet Creek, both above and below the identified area of P-enrichment, will be important to evaluating any mitigation effort.

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Appendices

A. Field Notes from Stream Bank Sampling
B. Field Notes from Stream Bed Sampling
C. Field Notes from Sampling Gum Root Swamp, its Tributaries and Outflows
D. Quality Control of Laboratory Analyses

Appendix A

Survey of Stream Bank Soils - September 3, 2014

Samples collected from the stream banks on September 3, 2014. The latitude and longitude are in the WGS84 datum and decimal degrees.

Station	Sample ID	Sample Description	Latitude	Longitude
1	#1	Clay outcrop at water	29.697831	-82.278374
2	#2	Clay from top of bank	29.697924	-82.278172
	#3	Clay from streambed		
3	#4	Sand Bar	29.698139	-82.277187
4	#5	Sandy clay with gravel in stream bank (3 reps)	29.698300	-82.277052
	#6			
	#7			
5	#8	Clay embankment (3 reps)	29.699996	-82.269027
	#9			
	#10			
6	#11	Sandy clay 18" above water	29.699689	-82.269644
	#12	Clay 2" above water		
7	#13	Bluegreen clay lense	29.699209	-82.270872
	#14	Surrounding sand		
8	#15	Sandstone bluff	29.699159	-82.272242
	#16			

Station 1

Station Description

The first station represents the first clay outcropping within the stream channel of Little Hatchet Creek east of Waldo Road. Left bank, ~20 ft downstream of small fall, at clay outcropping near the water line. Some fossils present. Composite sample (#1) taken (GPS 001). Phosphorus content was high 6590 mg/kg.

Station 1	
Lat.	29.697831
Long.	-82.278374

Station 2

Station Description

Samples #2 and #3 were collected as clay rocks on stream bank and from the stream bed, respectively, at Station 2. Orange color was present on rock surfaces. Fossil imprints were observed, indicating geologically older sedimentary rock. Total P contents were 3850 mg/kg in the stream bed, and 8050 mg/kg in the rocks found on the stream bank.

Samples #2 and #3 collected as clay rocks on stream bank and from stream bed, respectively, at Station 2.

View upstream from Station 2.

Station 2	
Lat.	29.697924
Long.	-82.278172

Station 3

Station Description

Station 3 was a sand bar formed within in the stream at the confluence of a small tributary draining nearby parking area. Total phosphorus content was 50 mg/kg, the lowest among all 16 samples collected during this preliminary survey.

Sand bar at Station 3 sampled as depositional material, at confluence of tributary entering from the south (lower right in picture). Composite of multiple locations within this small sand bar.

Tributary (looking upstream) was stagnant at time of sampling. Water was noticeably clearer than main channel.

Station 3	
Lat.	29.698139
Long.	-82.277187

Main channel looking upstream of sand bar at Station 3, was flowing during sampling.

Station 4

Station Description

Station 4 was selected due to the presence of gravel imbedded in a sandy clay outcropping. Orange mottling indicated possible presence of iron and Fe-phosphate minerals. However, this station had moderate to low P contents (136 – 360 mg/kg).

Left bank at Station #4, sandy clay with embedded gravel, was eroding 2-3′ above the water. Grab samples #5 (above), 6, and 7 (next two photos) were collected above, below and above the water line, respectively. Sample #6 was of a large piece of the clay embankment that appeared to have recently fallen into the stream.

Sample #6 at Station 4. Clay rock fragment had fallen into the water, and was sampled.

Sample #7 at Station 4

Station 4	
Lat.	29.698300
Long.	-82.277052

Culvert at first road crossing.

Stream corridor looking back upstream from Station 5, to the culvert at the 3rd road crossing to the East of Waldo Road.

Station 5

Station Description

Station 5 was downstream of the third road crossing east of Waldo Road. The right bank was a clay embankment that was undercut, indicating active erosion into the bank material. This station had the highest P concentrations of any sampled during this preliminary sampling (8.2 – 9.9% P, or 82000 – 99000 mg/kg).

View of undercut right bank at Station 5. Samples #8, #9, and #10 collected from just above the water line.

Station 5	
Lat.	29.699996
Long.	-82.269027

Looking downstream at Station 5 over small riffles, with undercut bank to the right.

The moccasin was the downstream turn around point.

Between Stations 5 and 6.

Station 6

Station Description

Station 6 had elevated P concentrations in both the sandy clay soils ~18″ above the water line (4.3% P) and the clays 2″ above the water (6.5% P).

Upstream of 3rd road crossing, on Right Bank at Station 6. Sample of sandy clay was collected ~18″ above the waterline as #11, and clay material from 2″ above the water line as #12.

Station 6	
Lat.	29.699689
Long.	-82.269644

Rising bank heights on one side, between Stations 6 and 7.

View looking upstream (top photo) and downstream (bottom photo) between Stations 6 and 7. Sinuosity developing and one bank is noticeably lower than the other.

Station 7

Station Description

Station #7 was selected for sampling because of the visible erosion into the right bank, and an exposed blue-green clay deposit found ~2-3′ above the toe of the slope. This clay material was moderate in total P content (3730 mg/kg), but the lowest sample in bulk density (0.6 g/cm^3) of the survey. The sand soils which surrounded the clay deposit was also collected as sample #14.

Blue-green clay deposit found at ~2-3′ above the toe of the slope at Station #7. Sand which surrounded the clay deposit was also collected as sample #14.

Station #7	
Lat.	29.699209
Long.	-82.270872

Close-up view of blue-green clay deposit at Station #7

Pipe outflow falls short of stream and creates a small pool isolated from the main channel. Located between Stations 7 and 8.

Station #8

Station Description

Station 8 was a "sandstone" bluff on the north side of the stream. Despite being 20-25′ above the water, the steep slope (essentially vertical) and loose, un-vegetated sands within this bluff indicated high potential for bank erosion to contribute material to the stream. Total P contents were among the lowest of any samples in the study (68-93 mg/kg).

View from top of bluff at Station 8, looking down 20-25′ to the main channel.

Station 8	
Lat.	29.699159
Long.	-82.272242

Exposed sand layer at the bluff at Station 8.

Fine sand and clayey sandstone were sampled from an eroding bluff ~15-20′ above the water level at Station 8, located between the first and second road crossings east of Waldo Road.

Appendix B

Surveys of Stream Bed Sediments - August 18, 2015 and January 16, 2016

Samples collected along stream bed (SB1-SB10) on August 18, 2015, and (SB11 – SB25) on January 16, 2016. The latitude and longitude are in the WGS84 datum and decimal degrees.

Station ID	Approximate Stream Distance (m) Below Waldo Road	Latitude	Longitude	Sampling Date
SB-25	-64	29.698692	-82.280453	1/16/2016
SB-24	296	29.697978	-82.277940	1/16/2016
SB-23	500	29.698274	-82.276208	1/16/2016
SB-22	878	29.698636	-82.273428	1/16/2016
SB-21	1057	29.699041	-82.271934	1/16/2016
SB-20	1259	29.699501	-82.270243	1/16/2016
SB-19	1444	29.700096	-82.268698	1/16/2016
SB-18	1582	29.699420	-82.267951	1/16/2016
SB-17	1713	29.698519	-82.267370	1/16/2016
SB-16	1810	29.697852	-82.266955	1/16/2016
SB-15	1902	29.697257	-82.266509	1/16/2016
SB-1	1950	29.696909	-82.266354	8/18/2015
SB-2	1987	29.696727	-82.266104	8/18/2015
SB-3	2151	29.695452	-82.265933	8/18/2015
SB-4	2191	29.695146	-82.266012	8/18/2015
SB-5	2316	29.694224	-82.265944	8/18/2015
SB-6	2395	29.693696	-82.266325	8/18/2015
SB-7	2581	29.692989	-82.264955	8/18/2015
SB-14	2828	29.692249	-82.262992	1/16/2016
SB-13	3102	29.690793	-82.261249	1/16/2016
SB-12	3413	29.690577	-82.258653	1/16/2016
SB-11	3672	29.690642	-82.256401	1/16/2016
SB-8	3855	29.690803	-82.254808	8/18/2015
SB-9	4154	29.691091	-82.252165	8/18/2015
SB-10	8505	29.688925	-82.221138	8/18/2015

SB-25

Station Description

Soft shifting sand and organics with lots of fine particles of eroded Hawthorn Group sediments.

SB-25	
Lat.	29.698692
Long.	-82.280453

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.50	g/cm^3
TP	45	mg/kg
TN	<850	mg/kg
Ca	250	mg/kg
Fe	425	mg/kg
DIW Pi	1.1	mg/kg
NH_4Cl Pi	0.4	mg/kg
NaOH Pi	13.3	mg/kg
NaOH TP	18	mg/kg
HCl Pi	6.5	mg/kg

SB-24

Station Description

Sand and organics with lots of gravel and eroded Hawthorn Group sediments.

SB-24	
Lat	29.697978
Long	-82.277940

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.55	g/cm^3
TP	104	mg/kg
TN	<850	mg/kg
Ca	650	mg/kg
Fe	420	mg/kg
DIW Pi	3.3	mg/kg
NH_4Cl Pi	5.0	mg/kg
NaOH Pi	20.7	mg/kg
NaOH TP	26.5	mg/kg
HCl Pi	217	mg/kg

SB-23

Station Description

Soft shifting sand and organics with accumulated detritus and leaf litter.

SB-23	
Lat	29.698274
Long	-82.276208

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.54	g/cm^3
TP	210	mg/kg
TN	<850	mg/kg
Ca	1100	mg/kg
Fe	350	mg/kg
DIW Pi	2.5	mg/kg
NH_4Cl Pi	1.7	mg/kg
NaOH Pi	15.9	mg/kg
NaOH TP	20.2	mg/kg
HCl Pi	463	mg/kg

SB-22

Station Description

Soft shifting sand with some organics and small pebbles.

SB-22	
Lat	29.698636
Long	-82.273428

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.54	g/cm^3
TP	420	mg/kg
TN	<850	mg/kg
Ca	1100	mg/kg
Fe	320	mg/kg
DIW Pi	2.2	mg/kg
NH_4Cl Pi	0.8	mg/kg
NaOH Pi	21	mg/kg
NaOH TP	23	mg/kg
HCl Pi	127	mg/kg

SB-21

Station Description

Soft shifting sand with some organics and small pebbles.

SB-21	
Lat	29.699041
Long	-82.271934

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.54	g/cm^3
TP	173	mg/kg
TN	<850	mg/kg
Ca	550	mg/kg
Fe	380	mg/kg
DIW Pi	3.1	mg/kg
NH_4Cl Pi	2.4	mg/kg
NaOH Pi	196	mg/kg
NaOH TP	258	mg/kg
HCl Pi	162	mg/kg

SB-20

Station Description

Soft shifting sand with some organics.

SB-20	
Lat	29.699501
Long	-82.270243

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.58	g/cm^3
TP	280	mg/kg
TN	<850	mg/kg
Ca	1,100	mg/kg
Fe	280	mg/kg
DIW Pi	4.4	mg/kg
NH_4Cl Pi	2.7	mg/kg
NaOH Pi	34.5	mg/kg
NaOH TP	38.9	mg/kg
HCl Pi	581	mg/kg

SB-19

Station Description

Sand with some organics and a gravel bar on the right bank along with exposed Hawthorn Group sediments.

SB-19	
Lat	29.700096
Long	-82.268698

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.52	g/cm^3
TP	969	mg/kg
TN	<850	mg/kg
Ca	3600	mg/kg
Fe	125	mg/kg
DIW Pi	5.7	mg/kg
NH_4Cl Pi	5.9	mg/kg
NaOH Pi	87.9	mg/kg
NaOH TP	96.6	mg/kg
HCl Pi	2180	mg/kg

SB-18

Station Description

Sand with some organics and gravel in the stream bed.

SB-18	
Lat	29.699420
Long	-82.267951

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.53	g/cm^3
TP	1170	mg/kg
TN	<850	mg/kg
Ca	4200	mg/kg
Fe	470	mg/kg
DIW Pi	3.8	mg/kg
NH_4Cl Pi	2.7	mg/kg
NaOH Pi	54.8	mg/kg
NaOH TP	60.2	mg/kg
HCl Pi	1510	mg/kg

SB-17

Station Description

Sand with some organics exposed Hawthorn Group sediments in the banks along this stream segment.

SB-17	
Lat	29.698519
Long	-82.267370

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.53	g/cm^3
TP	1610	mg/kg
TN	<850	mg/kg
Ca	4700	mg/kg
Fe	460	mg/kg
DIW Pi	5.7	mg/kg
NH_4Cl Pi	3.3	mg/kg
NaOH Pi	60	mg/kg
NaOH TP	66.9	mg/kg
HCl Pi	2600	mg/kg

SB-16

Station Description

Soft shifting sand with some organics and exposed Hawthorn Group sediments in the banks along this stream segment.

SB-16	
Lat	29.697852
Long	-82.266955

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.53	g/cm^3
TP	1,300	mg/kg
TN	<850	mg/kg
Ca	3,900	mg/kg
Fe	340	mg/kg
DIW Pi	4.7	mg/kg
NH_4Cl Pi	2.3	mg/kg
NaOH Pi	36.1	mg/kg
NaOH TP	49	mg/kg
HCl Pi	1050	mg/kg

SB-15

<u>Station Description</u>

Soft shifting sand with some organics.

SB-15	
Lat	29.697257
Long	-82.266509

Surficial sediment sampled 1/6/2016.

Parameter	Result	
Bulk Density	1.54	g/cm^3
TP	1,250	mg/kg
TN	<850	mg/kg
Ca	3,600	mg/kg
Fe	420	mg/kg
DIW Pi	4.2	mg/kg
NH_4Cl Pi	2.4	mg/kg
NaOH Pi	60.7	mg/kg
NaOH TP	66.8	mg/kg
HCl Pi	1,650	mg/kg

SB-1

Station Description

Sand bar on the left bank of Little Hatchett Creek, downstream of the outfall at the Gainesville Regional Airport. Some nodules of Hawthorn material were present. Water quality samples were also collected.

SB-1	
Lat.	29.696909
Long.	-82.266354

Surficial sediment sampled 8/18/2015.

Parameter	Sand	Nodules	Units
Bulk Density	1.57	1.46	g/cm^3
TP	1,130	2,530	mg/kg
TN	<850	<850	mg/kg
Ca	2,700	5,700	mg/kg
Fe	840	1,900	mg/kg
NH_4Cl Pi	5.9	9.3	mg/kg
NaOH Pi	119	241	mg/kg
NaOH TP	145	285	mg/kg
HCl Pi	955	601	mg/kg

SB-2

Station Description

Depositional area on the right bank. Samples of the sand, nodules and clay were collected.

SB-2	
Lat.	29.696727
Long.	-82.266104

Sediments sampled 8/18/2015.

Parameter	Sand	Nodules	Clay	Units
Bulk Density	1.53	0.72	0.64	g/cm^3
TP	576	55,900	10,200	mg/kg
TN	<850	<850	1470	mg/kg
Ca	1,900	131,000	21,000	mg/kg
Fe	125	10,000	6,600	mg/kg
NH_4Cl Pi	4	134	4	mg/kg
NaOH Pi	32.6	865	1780	mg/kg
NaOH TP	38	916	3020	mg/kg
HCl Pi	1,330	47,700	5,340	mg/kg

SB-3

Station Description

Sand bar on left bank. A few nodules of Hawthorn material were present. Steep slope on right back is likely to contribute additional material to the stream over time.

SB-15	
Lat.	29.695452
Long.	-82.265933

Sediments sampled 8/18/2015.

Parameter	Result	
Bulk Density	1.53	g/cm^3
TP	1,250	mg/kg
TN	<850	mg/kg
Ca	4,300	mg/kg
Fe	680	mg/kg
NH_4Cl Pi	3.2	mg/kg
NaOH Pi	195	mg/kg
NaOH TP	199	mg/kg
HCl Pi	749	mg/kg

SB-4

Station Description

Sand bar downstream of a submerged log. A few nodules of Hawthorn material were present and the sand did contain some organic material. The stream channel is not as steeply incised and a fluvial terrace has formed within the much broader dredged channel.

SB-4	
Lat.	29.695146
Long.	-82.266012

Sediments sampled 8/18/2015.

Parameter	Result	
Bulk Density	1.49	g/cm^3
TP	1,310	mg/kg
TN	<850	mg/kg
Ca	3,000	mg/kg
Fe	500	mg/kg
NH_4Cl Pi	4.8	mg/kg
NaOH Pi	144	mg/kg
NaOH TP	165	mg/kg
HCl Pi	1,400	mg/kg

SB-5

Station Description

Sand bar downstream of a bend with trees on a small island. There was about 1 meter of sand deposited above a much harder substrate.

SB-5	
Lat.	29.694224
Long.	-82.265944

Sediments sampled 8/18/2015.

Parameter	Result	
Bulk Density	1.47	g/cm^3
TP	1,340	mg/kg
TN	<850	mg/kg
Ca	3,900	mg/kg
Fe	1,100	mg/kg
NH_4Cl Pi	4.7	mg/kg
NaOH Pi	215	mg/kg
NaOH TP	233	mg/kg
HCl Pi	1,220	mg/kg

SB-6

Station Description

Sand bar on left bank of a sharp bend.

SB-6	
Lat.	29.693696
Long.	-82.266325

Sediments sampled 8/18/2015.

Parameter	Result	
Bulk Density	1.55	g/cm^3
TP	1,710	mg/kg
TN	<850	mg/kg
Ca	4,900	mg/kg
Fe	520	mg/kg
NH_4Cl Pi	3.5	mg/kg
NaOH Pi	84.8	mg/kg
NaOH TP	86.7	mg/kg
HCl Pi	930	mg/kg

SB-7

Station Description

Sand bar with gravel deposits on the left bank just downstream of the culverts at ACEPD sampling station LHATNB (top photo). Samples of the sand, gravel and blue colored clay nodules were collected. Floodplain has a lot of gravel in it (bottom photo shows the gravel analyzed by sequential extraction from this station).

SB-7	
Lat.	29.692989
Long.	-82.264955

Sediments sampled 8/18/2015.

Parameter	Sand	Gravel	Clay	Units
Bulk Density	1.53	1.12	0.77	g/cm^3
TP	1,580	101,000	2,360	mg/kg
TN	<850	<850	<850	mg/kg
Ca	7,400	279,000	7,500	mg/kg
Fe	370	4,000	22,000	mg/kg
NH_4Cl Pi	2.9	14.3	2.3	mg/kg
NaOH Pi	55	26.7	773	mg/kg
NaOH TP	68.8	78.3	1,030	mg/kg
HCl Pi	1,940	85,800	102	mg/kg

SB-14

Station Description

Sand bar with some organics, downstream of a scoured pool. Stream bed contains lots of fossils and gravel.

SB-14	
Lat.	29.692249
Long.	-82.262992

Sediments sampled 1/16/2016.

Parameter	Result	
Bulk Density	1.61	g/cm^3
TP	3,230	mg/kg
TN	<850	mg/kg
Ca	9,200	mg/kg
Fe	690	mg/kg
DIW Pi	5.2	mg/kg
NH_4Cl Pi	5.6	mg/kg
NaOH Pi	107	mg/kg
NaOH TP	118	mg/kg
HCl Pi	2,460	mg/kg

SB-13

Station Description

Sand with some organic material was collected from a bar near the center of the stream channel. Gravel is abundant in this reach of the stream.

SB-13	
Lat.	29.690793
Long.	-82.261249

Sediments sampled 1/16/2016.

Parameter	Result	
Bulk Density	1.58	g/cm^3
TP	2,420	mg/kg
TN	<850	mg/kg
Ca	6,000	mg/kg
Fe	400	mg/kg
DIW Pi	3.1	mg/kg
NH_4Cl Pi	2.4	mg/kg
NaOH Pi	80.2	mg/kg
NaOH TP	85.6	mg/kg
HCl Pi	2,900	mg/kg

SB-12

Station Description

Collected sand with little organics from a bar on the right bank. Water samples were also collected from this location.

SB-12	
Lat.	29.690577
Long.	-82.258653

Sediments sampled 1/16/2016.

Parameter	Result	
Bulk Density	1.51	g/cm^3
TP	3,250	mg/kg
TN	<850	mg/kg
Ca	7,300	mg/kg
Fe	480	mg/kg
DIW Pi	3.4	mg/kg
NH_4Cl Pi	2.4	mg/kg
NaOH Pi	99.4	mg/kg
NaOH TP	106	mg/kg
HCl Pi	2,030	mg/kg

SB-11

Station Description

Sampled a submerged sand bar near center of channel. Primarily sand with a minor amount of organic matter.

SB-11	
Lat.	29.690642
Long.	-82.256401

Sediments sampled 1/16/2016.

Parameter	Result	
Bulk Density	1.43	g/cm^3
TP	2530	mg/kg
TN	<850	mg/kg
Ca	6600	mg/kg
Fe	560	mg/kg
DIW Pi	4.6	mg/kg
NH_4Cl Pi	3.7	mg/kg
NaOH Pi	93.8	mg/kg
NaOH TP	104	mg/kg
HCl Pi	3730	mg/kg

SB-8

<u>Station Description</u>

Sand bar in middle of stream. This station is just downstream of the SJRWMD gauging station 02840233 (North Branch Little Hatchet Creek). The channel is well defined and the stream was flowing at bank full. The sandy sediments which contained some organics were collected.

SB-8	
Lat.	29.690803
Long.	-82.254808

Sediments sampled 8/18/2015.

Parameter	Result	
Bulk Density	1.54	g/cm^3
TP	1,530	mg/kg
TN	<850	mg/kg
Ca	3,700	mg/kg
Fe	440	mg/kg
NH_4Cl Pi	2.65	mg/kg
NaOH Pi	100.5	mg/kg
NaOH TP	113.5	mg/kg
HCl Pi	1,776	mg/kg

SB-9

Station Description

Sand bar on right bank just downstream of a road crossing with two culverts. The sandy sediments contained a slight amount of organic material, without gravel. There were signs of recent over bank flows and sand deposition in the floodplain.

SB-9	
Lat.	29.691091
Long.	-82.252165

Sediments sampled 8/18/2015.

Parameter	Result	
Bulk Density	1.57	g/cm^3
TP	1,380	mg/kg
TN	<850	mg/kg
Ca	3,200	mg/kg
Fe	280	mg/kg
NH_4Cl Pi	1.3	mg/kg
NaOH Pi	45.3	mg/kg
NaOH TP	55.6	mg/kg
HCl Pi	1,450	mg/kg

SB-10

<u>Station Description</u>

Sampled the sand on the bottom of one of the many flooded channels just upstream of SR26. A water sample was also collected.

SB-10	
Lat.	29.688925
Long.	-82.221138

Sediments sampled 8/18/2015.

Parameter	Result	
Bulk Density	1.29	g/cm^3
TP	50	mg/kg
TN	< 850	mg/kg
Ca	<1000	mg/kg
Fe	<250	mg/kg
NH_4Cl Pi	1	mg/kg
NaOH Pi	10.7	mg/kg
NaOH Po	23.8	mg/kg
HCl Pi	0.8	mg/kg

Appendix C

Surveys of Gum Root Swamp April 19-20 and May 2, 2016

Inflow Stations Five stations were sampled to characterize sediments and water quality associated with the tributary inflows to Gum Root Swamp.			
Station ID	**Latitude**	**Longitude**	**Sampling Date**
GMRIN1	29.704646	-82.222050	4/19/2016
GMRIN1DS (Downstream)	29.703867	-82.221780	4/19/2016
GMRIN2	29.707688	-82.230392	4/19/2016
GMRIN4	29.698437	-82.243465	4/19/2016
GMRIN5 / SB 29	29.690835	-82.244067	4/20/2016
SB-30	29.688654	-82.249621	4/20/2016
Outflow Stations Five stations that were sampled to characterize the outflows of Gum Root Swamp. These were located upstream of culverts at SR 26.			
GMROUT1	29.688721	-82.238555	4/19/2016
GMROUT2	29.688434	-82.230146	4/19/2016
GMROUT3	29.691389	-82.221959	4/19/2016
GMROUT4	29.688753	-82.221094	4/19/2016
GMROUT5	29.679722	-82.234954	4/19/2016
Interior Stations Six stations were considered interior to the Gum Root Swamp. These stations were primarily muck and peat soils with dark color and high organic matter content.			
G-1	29.693819	-82.239885	4/20/2016
SB-28	29.691424	-82.237472	4/20/2016
G-5	29.689989	-82.233884	4/20/2016
G-6	29.694191	-82.225860	4/20/2016
SB-27	29.692304	-82.222445	4/20/2016
SB-26	29.693541	-82.220669	4/20/2016

The latitude and longitude are in the WGS84 datum and decimal degrees.

GMRIN1

<u>Station Description</u>

Peat with root mat collected below leaf litter layer. The area represents a low spot between fields recently harvested for timber.

GMRIN1	
Lat.	29.688721
Long.	-82.238555

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	0.085	g/cm^3
TP	1,210	mg/kg
TN	19,000	mg/kg
Ca	9,900	mg/kg
Fe	2,800	mg/kg
Volatile Solids	84.8	%
DIW Pi	5.9	mg/kg
NH_4Cl Pi	2.8	mg/kg
NaOH Pi	63.4	mg/kg
NaOH Po	478	mg/kg
HCl Pi	31.3	mg/kg

Surface water field parameters on 4/19/2016 at station GMRIN1.

Parameter	Result	
Water Temp.	17	°C
Dissolved Oxygen (DO)	12.1	%
	1.18	mg/L
Conductivity	104	µS/cm
pH	6.06	
Turbidity	1.86	NTU
Discharge	~0*	cfs

*too low to measure

GMRIN1DS (Downstream)

Station Description

Downstream of the road crossing, south of GMRIN1. The sediment at this site was more like a sand sample collected from a depositional area within the Little Hatchet stream channel, rather than the muck soils found upstream of the road crossing at GMRIN1.

GMRIN1DS	
Lat.	29.703867
Long.	-82.22178

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	1.5	g/cm^3
TP	19	mg/kg
TN	<850	mg/kg
Ca	<500	mg/kg
Fe	<250	mg/kg
Volatile Solids	<1.35	%
DIW Pi	0.97	mg/kg
NH_4Cl Pi	<0.4	mg/kg
NaOH Pi	2.3	mg/kg
NaOH Po	4.7	mg/kg
HCl Pi	0.67	mg/kg

Surface water field parameters were not measured on 4/19/2016 at station GMRIN1DS.

GMRIN2

Station Description

Sediment was sampled below the confluence of two channelized tributaries.

GMRIN2	
Lat.	29.707688
Long.	-82.230392

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	1.5	g/cm^3
TP	2,470	mg/kg
TN	<850	mg/kg
Ca	6,500	mg/kg
Fe	760	mg/kg
Volatile Solids	<1.35	%
DIW Pi	10.2	mg/kg
NH_4Cl Pi	6.1	mg/kg
NaOH Pi	142	mg/kg
NaOH Po	29	mg/kg
HCl Pi	2,570	mg/kg

Surface water field parameters on 4/19/2016 at station GMRIN2.

Parameter	Result	
Water Temp.	19.3	°C
Dissolved Oxygen (DO)	61.8	%
	5.67	mg/L
Conductivity	137	µS/cm
pH	7.05	
Turbidity	4.39	NTU
Discharge	NM*	cfs

*Not Measured

GMR IN 4

Station Description

Sand bar with very little organics. Water flowing from east to west and few leaves, some pollen on sand surface.

GMRIN4	
Lat.	29.698437
Long.	-82.243465

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	1.6	g/cm^3
TP	91	mg/kg
TN	<850	mg/kg
Ca	<500	mg/kg
Fe	<250	mg/kg
Volatile Solids	<1.35	%
DIW Pi	4	mg/kg
NH_4Cl Pi	1.6	mg/kg
NaOH Pi	11.9	mg/kg
NaOH Po	2.8	mg/kg
HCl Pi	0.58	mg/kg

Surface water field parameters on 4/19/2016 at station GMRIN4.

Parameter	Result	
Water Temp.	20.5	°C
Dissolved Oxygen (DO)	90.8	%
	8.17	mg/L
Conductivity	52	µS/cm
pH	6.67	
Turbidity	14.6	NTU
Discharge	NM*	cfs

*Not Measured

GMRIN5 / SB-29

Station Description

SB-29, sandbar with organics and leaves on surface.

GMRIN5/SB-29	
Lat.	29.690835
Long.	-82.244067

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	1.5	g/cm^3
TP	723	mg/kg
TN	<850	mg/kg
Ca	2,000	mg/kg
Fe	320	mg/kg
Volatile Solids	<1.35	%
DIW Pi	4	mg/kg
NH_4Cl Pi	2.3	mg/kg
NaOH Pi	64.7	mg/kg
NaOH Po	73	mg/kg
HCl Pi	741	mg/kg

Surface water field parameters on 4/19/2016 at station GMRIN5.

Parameter	Result	
Water Temp.	17.2	°C
Dissolved Oxygen (DO)	86.6	%
	8.34	mg/L
Conductivity	228	µS/cm
pH	7.6	
Turbidity	4.44	NTU
Discharge	1.139	cfs

SB-30

Station Description

SB-30, Sand point bar with very little organic matter. Slight green color to the top ~ 1 cm of sand, no gravel present, and very few leaves. Channel was 2 m wide and 5 cm deep.

SB-30	
Lat.	29.688654
Long.	-82.249621

Surficial sediment sampled 4/20/2016.

Parameter	Result	
Bulk Density	1.6	g/cm^3
TP	31	mg/kg
TN	<850	mg/kg
Ca	<500	mg/kg
Fe	<250	mg/kg
Volatile Solids	<1.35	%
DIW Pi	1.8	mg/kg
NH_4Cl Pi	0.70	mg/kg
NaOH Pi	12.8	mg/kg
NaOH Po	6	mg/kg
HCl Pi	0.82	mg/kg

Surface water characteristics on 4/20/2016 at station SB-30.

Parameter	Result	
Water Temp.	17.9	°C
Dissolved Oxygen (DO)	83.3	%
	7.89	mg/L
Conductivity	172	µS/cm
pH	7.12	
Turbidity	1.64	NTU
Discharge	0.108	cfs

GMROUT1

Station Description

Sediment sampled from point bar of medium and fine-grained sands within a braided channel of the floodplain forest.

GMROUT1	
Lat	29.688721
Long	-82.238555

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	1.6	g/cm^3
TP	117	mg/kg
TN	<850	mg/kg
Ca	<500	mg/kg
Fe	<250	mg/kg
Volatile Solids	<1.35	%
DIW Pi	1.4	mg/kg
NH_4Cl Pi	50.8	mg/kg
NaOH Pi	34.6	mg/kg
NaOH Po	50.8	mg/kg
HCl Pi	1.6	mg/kg

Surface water measurements were not taken on 4/19/2016 at station GMROUT1, no flow and water level was too low (< 10 cm).

GMROUT2

Station Description

Sediment sampled in apparent flow way. Deep muck (~2 ft above harder sand as determined by tile probe) was found upstream of the right-of-way for State Road 26.

GMROUT2	
Lat	29.688434
Long	-82.230146

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	0.064	g/cm^3
TP	1,010	mg/kg
TN	23,200	mg/kg
Ca	9,700	mg/kg
Fe	1,700	mg/kg
Volatile Solids	91.8	%
DIW Pi	5.6	mg/kg
NH_4Cl Pi	3.9	mg/kg
NaOH Pi	29.7	mg/kg
NaOH Po	337	mg/kg
HCl Pi	46.9	mg/kg

Surface water measurements were not taken on 4/19/2016 at station GMROUT2, no flow and water level was too low (< 10 cm).

GMROUT3

Station Description

Point bar (pictured) downstream of a large black gum tree. Fine organic silt and muck collected from ~2 cm above the water line.

GMROUT3	
Lat	29.691389
Long	-82.221959

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	0.11	g/cm^3
TP	1,360	mg/kg
TN	21,100	mg/kg
Ca	15,000	mg/kg
Fe	5,000	mg/kg
Volatile Solids	83	%
DIW Pi	1.3	mg/kg
NH_4Cl Pi	1.5	mg/kg
NaOH Pi	93.8	mg/kg
NaOH Po	473	mg/kg
HCl Pi	73.2	mg/kg

Surface water characteristics on 4/19/2016 at station GMROUT3.

Parameter	Result	
Water Temp.	17.3	°C
Dissolved Oxygen (DO)	36	%
	3.48	mg/L
Conductivity	146	µS/cm
pH	6.6	
Turbidity	1.58	NTU
Discharge	1.32	cfs

GMROUT4

Station Description

Main channel. Sand bottom without large sand bars.

GMROUT4	
Lat.	29.688753
Long.	-82.221094

Surficial sediment sampled 4/19/2016.

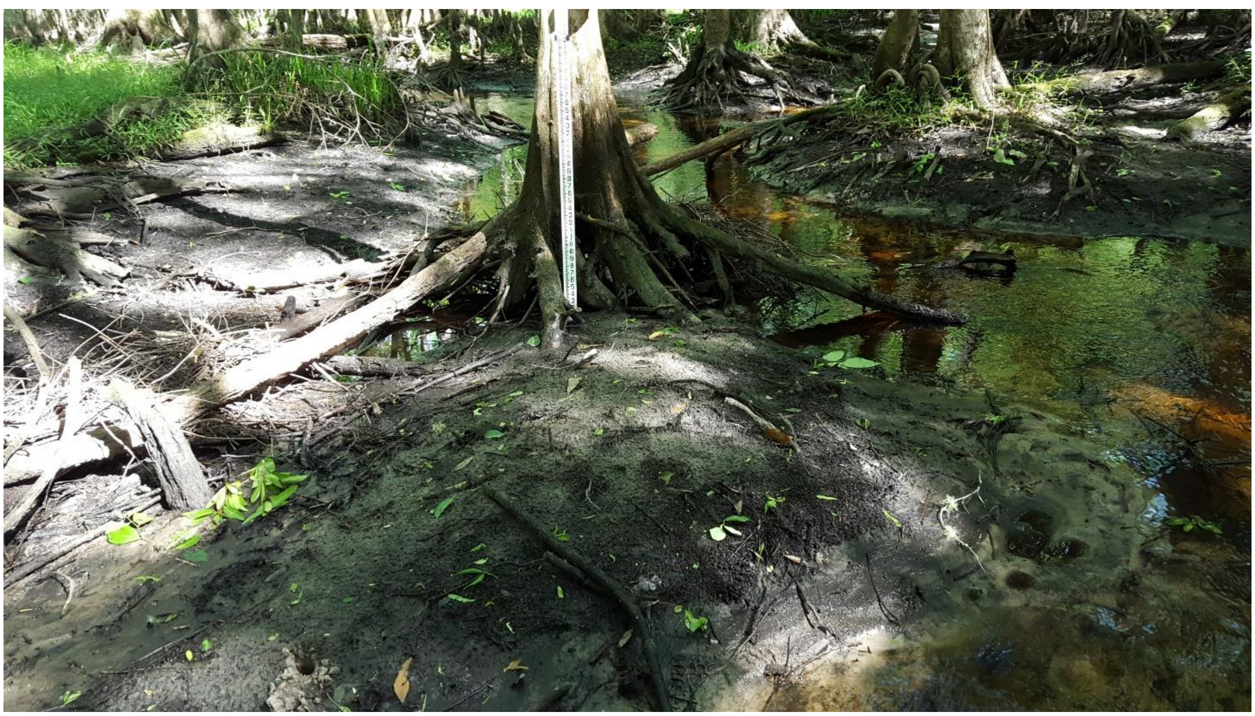
Parameter	Result	
Bulk Density	1.5	g/cm^3
TP	22	mg/kg
TN	<850	mg/kg
Ca	<500	mg/kg
Fe	<250	mg/kg
Volatile Solids	<1.35	%
DIW Pi	1.9	mg/kg
NH_4Cl Pi	1	mg/kg
NaOH Pi	7.2	mg/kg
NaOH Po	17.1	mg/kg
HCl Pi	0.5	mg/kg

Surface water characteristics on 6/15/2016 at station GMROUT4.

Parameter	Result	
Water Temp.	16	°C
Dissolved Oxygen (DO)	68.2	%
	6.74	mg/L
Conductivity	143	µS/cm
pH	6.86	
Turbidity	2.02	NTU
Discharge	0.81	cfs

Surface water quality on 6/15/2016 at station GMROUT4.

Parameter		Result		
		Rep 1	Rep 2	Avg.
TP	mg/L	0.347	0.355	**0.351**
TSP	mg/L	0.336	0.337	**0.3365**
SRP	mg/L	0.302	0.292	**0.297**
Alkalinity	mg/L	36	35	**35.5**
Calcium	µg/L	18,400	17,400	**17,900**
Magnesium	µg/L	4,870	4,460	**4,665**
Chloride	mg/L	8.5	8.6	**8.55**
Fluoride	mg/L	0.28	0.39	**0.335**
Potassium	µg/L	876	871	**873.5**
Sodium	µg/L	6,790	6,580	**6,685**
Hardness	mg/L	67	63	**65**
Sulfate	mg/L	1.2	1.5	**1.35**
Iron	µg/L	803	775	**789**
Ammonia-N	mg/L	0.054	0.048	**0.051**
NOx	mg/L	0.056	0.058	**0.057**
TKN	mg/L	1.7	1.6	**1.65**
TDS	mg/L	170	180	**175**
TOC	mg/L	35	36	**35.5**
TSS	mg/L	2.6	13.2	**7.9**



GMROUT5

Station Description

Large point sand bar. Little organics. Higher energy system than Out 1, 2 and District's #5. Channel is ~2 m wide at water line and 30 cm deep. Sweet gum and cypress along the channel transitions to oak-pine, palmetto uplands with less floodplain connectivity.

GMROUT5	
Lat.	29.679722
Long.	-82.234954

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	1.4	g/cm^3
TP	207	mg/kg
TN	<850	mg/kg
Ca	<500	mg/kg
Fe	<250	mg/kg
Volatile Solids	<1.35	%
DIW Pi	2.3	mg/kg
NH_4Cl Pi	0.7	mg/kg
NaOH Pi	28.6	mg/kg
NaOH Po	34.5	mg/kg
HCl Pi	141	mg/kg

Surface water field parameters were not measured on 4/19/2016 at station GMROUT5.

G-1

Station Description

G-1 was 600 m southeast of GMRIN4. There was a well-defined stream channel flowing to the northeast. Sample was collected from a sand bar in midstream, possibly the main channel of Little Hatchet Creek. Sample was sandy, with some organics and detritus mixed with leaf litter. Canopy was dominated by black gum, with maple, sweet gum, cypress, wax myrtle, ironwood and sweet bay also present. Ground cover included cinnamon fern and lizard's tail.

G-1	
Lat.	29.693819
Long.	-82.239885

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	1.4	g/cm^3
TP	521	mg/kg
TN	<850	mg/kg
Ca	1,800	mg/kg
Fe	850	mg/kg
Volatile Solids	<1.35	%
DIW Pi	6.8	mg/kg
NH_4Cl Pi	5.2	mg/kg
NaOH Pi	146	mg/kg
NaOH Po	178	mg/kg
HCl Pi	491	mg/kg

SB-28

Station Description

No channel nearby. Collected muck sediments from the upper ~5 cm, though muck soils were 2 ft thick in places. Vegetation at station is similar to surrounding area and along the path traversed from G-1.

SB-28	
Lat	29.691424
Long	-82.237472

Surficial sediment sampled 4/20/2016.

Parameter	Result	
Bulk Density	0.39	g/cm^3
TP	2,080	mg/kg
TN	9,020	mg/kg
Ca	11,000	mg/kg
Fe	4,000	mg/kg
Volatile Solids	34.7	%
DIW Pi	5.2	mg/kg
NH_4Cl Pi	2.6	mg/kg
NaOH Pi	270	mg/kg
NaOH Po	1,240	mg/kg
HCl Pi	116	mg/kg

Surface water field parameters were not measured on 4/19/2016 at station G-1 due to lack of water.

G-5

Station Description

G-5 was in a broad muck swamp dominated by black gum with some maples. No apparent stream channel nearby. The swamp stayed wet to the east and south, but toward the west an area of higher ground was planted in pine. State road 26 was ~250 m due south of G-5.

G-5	
Lat.	29.689989
Long.	-82.233884

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	0.12	g/cm^3
TP	1,710	mg/kg
TN	20,500	mg/kg
Ca	17,000	mg/kg
Fe	5,200	mg/kg
Volatile Solids	75.1	%
DIW Pi	1.3	mg/kg
NH_4Cl Pi	2.6	mg/kg
NaOH Pi	117	mg/kg
NaOH Po	622	mg/kg
HCl Pi	118	mg/kg

Surface water characteristics on 4/20/2016 at station G-5.

Parameter	Result	
Water Temp.	18.4	°C
Dissolved Oxygen (DO)	20.2	%
	1.9	mg/L
Conductivity	198	µS/cm
pH	6.87	
Turbidity	1.86	NTU
Discharge	0	cfs

G-6

Station Description

Flow is too low and swampy.

G-6	
Lat	29.694191
Long	-82.22586

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	0.088	g/cm^3
TP	1,200	mg/kg
TN	20,400	mg/kg
Ca	19,000	mg/kg
Fe	4,600	mg/kg
Volatile Solids	84.2	%
DIW Pi	1.1	mg/kg
NH_4Cl Pi	2.4	mg/kg
NaOH Pi	73.2	mg/kg
NaOH Po	388	mg/kg
HCl Pi	67.2	mg/kg

Surface water field parameters on 4/19/2016 at station G-6.

Parameter	Result	
Water Temp.	20.8	°C
Dissolved Oxygen (DO)	20.3	%
	1.85	mg/L
Conductivity	171	µS/cm
pH	7.02	
Turbidity	11.2	NTU
Discharge	0	cfs

SB-26

Station Description

Swampy, too low for flow measurements.

SB-26	
Lat	N 29.693541
Long	W -82.220669

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	0.057	g/cm^3
TP	1,200	mg/kg
TN	23,700	mg/kg
Ca	10,000	mg/kg
Fe	2,100	mg/kg
Volatile Solids	92.6	%
DIW Pi	4.6	mg/kg
NH_4Cl Pi	9.9	mg/kg
NaOH Pi	59.2	mg/kg
NaOH Po	410	mg/kg
HCl Pi	45.8	mg/kg

Surface water quality on 4/19/2016 at station SB-26.

Parameter	Result	
Water Temp.	19	°C
Dissolved Oxygen (DO)	12.2	%
	1.09	mg/L
Conductivity	127	µS/cm
pH	6.28	
Turbidity	2.38	NTU
Discharge	~0	cfs

SB-27

Station Description

Swampy area near bridge.

SB-27	
Lat	N 29.692304
Long	W -82.222445

Surficial sediment sampled 4/19/2016.

Parameter	Result	
Bulk Density	0.09	g/cm^3
TP	1,470	mg/kg
TN	20,400	mg/kg
Ca	15,000	mg/kg
Fe	6,400	mg/kg
Volatile Solids	86.9	%
DIW Pi	1.1	mg/kg
NH_4Cl Pi	1.4	mg/kg
NaOH Pi	120	mg/kg
NaOH Po	569	mg/kg
HCl Pi	106	mg/kg

Surface water quality on 4/19/2016 at station SB-27.

Parameter	Result	
Water Temp.	20.5	°C
Dissolved Oxygen (DO)	27.8	%
	2.48	mg/L
Conductivity	153	µS/cm
pH	6.92	
Turbidity	2.38	NTU

Appendix D

Analytical Methods and Detection Limits

Method detection limits for surface water parameters.

Parameter	Method	MDL	Units
Total Phosphorus	SM 4500-P F	0.003	mg/L
Total Soluble Phosphorus	SM 4500-P F	0.003	mg/L
Soluble Reactive Phosphorus	DBE SOP OPO4	0.002	mg/L
Fluoride*	EPA 300.0	0.02	mg/L
Ammonia-N	EPA 350.1	0.02	mg/L
NOx*	SM 4500NO3 H-2000	0.016	mg/L
TKN*	EPA 351.2	0.037	mg/L
Alkalinity*	EPA 310.2	1.9	mg/L
Calcium*	EPA 200.8	36	µg/L
Magnesium*	EPA 200.8	30	µg/L
Chloride*	EPA 300.0	0.29	mg/L
Potassium*	EPA 200.8	48	µg/L
Sodium*	EPA 200.8	32	µg/L
Hardness*	SM 2340C-1997	2	mg/L
Sulfate*	EPA 300.0	0.07	mg/L
Iron*	EPA 200.8	3.8	µg/L
Total Dissolved Solids*	SM 2540C-1997	10	mg/L
Total Organic Carbon	SM 5310 B	1	mg/L
Total Suspended Solids	EPA 160.2	0.5	mg/L

*Subcontract lab performed the analysis

Method detection limits for sediment parameters.

Parameter	Method	MDL	units
Bulk Density	ASA 13	0.001	g/cm³
Total Phosphorus	EPA 365.2/COE 3-227	10-50	mg/kg dry
Total Nitrogen	DBE SOP MVP	850	mg/kg dry
Calcium	EPA/SW 7140	500-1,000	mg/kg dry
Iron	EPA/SW 7380	250-1,300	mg/kg dry
Volatile Solids	EPA/COE 3-59	1.35	%
DIW Pi	DBE SOP OPO4	0.19-0.24	mg/kg dry
NH4Cl Pi	DBE SOP OPO4	0.37-0.44	mg/kg dry
NaOH Pi	DBE SOP OPO4	0.4-4.8	mg/kg dry
NaOH TP	EPA 365.2/COE 3-227	1.5-7.6	mg/kg dry
HCl Pi	DBE SOP OPO4	0.2-10	mg/kg dry

Field Duplicates

Replicate sampling of two locations within the stream bank sediments sampled in September 2014.

Station	Sample ID	Sample Description	Bulk Density (g/cm³)	TP (mg/kg)	TP (mg P/cm³)
4	#5	Sandy clay with gravel in stream bank (3 reps)	1.7	360	0.61
	#6		1.7	360	0.61
	#7		1.6	136	0.22
		Average	**1.7**	**285**	**0.48**
		SE	0.0	75	0.13

5	#8	Clay embankment (3 reps)	1.5	82,000	123
	#9		1.4	99,000	139
	#10		1.5	95,300	143
		Average	**1.5**	**92,100**	**135**
		SE	0.0	5,162	6

Summary of analysis of Field Duplicate sediment samples. All values in mg/kg.

Date	Sample ID	TP	DIW Pi	NH_4Cl-Pi	NaOH-Pi	NaOH-Po	HCl-Pi
8/18/2015	SB-8	1,390	NA*	2.6	100	12	2,560
	SB-8 Field Dup	1,670	NA*	2.7	101	14	991
	Average	**1,530**		**2.7**	**101**	**13**	**1,776**
	SE	140		0.1	1	1	785
1/6/2016	SB-25	54	1.2	<0.4	14.5	4.3	8
	SB-25 Field Dup	36	1.0	0.4	12.1	5.1	5
	Average	**45**	**1.1**		**13.3**	**4.7**	**7**
	SE	9	0.1		1.2	0.4	1
4/19/2016	GMROUT5	207	2.3	0.7	28.6	5.9	141
	GMROUT5 Field Dup	119	2.3	0.7	28.6	5.8	156
	Average	**163**	**2.3**	**0.7**	**28.6**	**5.9**	**149**
	SE	44	0.0	0.0	0.0	0.1	8
4/20/2016	G-6	1,200	1.1	2.4	73.2	388	67
	G-6 Field Dup	1,160	0.72	1.4	66.7	374	63
	Average	**1,180**	**0.9**	**1.9**	**70.0**	**381**	**65**
	SE	20	0	0.5	3.3	7	2

*Not Analyzed

Summary of chemical composition analysis of Field Duplicate sediment samples.

Date	Sample ID	Bulk Density (g/cm^3)	Ca (mg/kg)	Fe (mg/kg)	TN (mg/kg)	Volatile Solids (%)
8/18/2015	SB-8	1.55	3,400	400	< 850	NA*
	SB-8 Field Dup	1.53	4,000	480	< 850	NA*
	Average	**1.54**	**3,700**	**440**		
	SE	0.01	300	40		
1/6/2016	SB-25	1.50	<500	380	< 850	NA*
	SB-25 Field Dup	1.51	<500	470	< 850	NA*
	Average	**1.50**		**425**		
	SE	0.01		45		
4/19/2016	GMR OUT5	1.40	<500	<250	< 850	<1.35
	GMR OUT5 Field Dup	1.40	<500	<250	< 850	<1.35
	Average	**1.40**				
	SE	0.00				
4/20/2016	G-6	0.088	19,000	4,600	20,400	84
	G-6 Field Dup	0.074	16,000	4,300	19,100	86
	Average	**0.081**	**17,500**	**4,450**	**19,750**	**85**
	SE	0.007	1,500	150	650	1

*Not Analyzed