

1. Title: **Phosphorus availability from the soils along two streams of the Lake Champlain Basin: mapping, characterization and seasonal mobility**

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3. Focus Categories: Nutrients, Nonpoint pollution, water quality

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10. Abstract

Nonpoint source phosphorus (P) inputs into lakes and streams can be a major source of nutrient loading. A critical need is a better understanding of the relative importance of various P sources (e.g. sediment from streambank erosion, runoff from agricultural fields, or release from aquatic sediments). The ability to predict P input from erosion is limited by a lack of soils data and outdated soils mapping. We will perform an extensive remapping, soil sampling and P analysis of the floodplain areas of two Vermont streams in the Lake Champlain Basin—Lewis Creek and Rugg Brook. Results will include a new digital soils map of the stream corridors and a data layer that includes total P content and a range of availability indices. We will also determine the transferability of results and the effort needed to provide updated map layers for other stream reaches in Vermont. Intensive, site specific soil studies will be carried out on an area along each stream where restoration projects are planned or underway. These studies will provide more detailed soils mapping and characterize the spatial variability of soil P. Results from these sites will be used to both inform the project managers and to determine the adequate scale necessary for soil P data layers. Field and laboratory studies will also determine P release potential of sediments and soils under reducing conditions on samples from critical source areas including eroded sediments, stream sediments and frequently flooded riparian zones. Results from these experiments will determine the likelihood of additional P release from sediments under oxygen-limiting environments. Geomorphic data from Lewis Creek will be used, along with the new soils map layers, to develop a conceptual model of P transport and storage in the watershed. Our research will develop and refine relationships between soil P fractions and produce simple predictive models of total and potentially mobile P. This will be a collaborative effort between University researchers, NRCS soil specialists and practitioners. Results will enhance our ability to quantify the effects of stream restoration and other best management practices on the control of P transport.

13. Title: Phosphorus availability in alluvial soils from the Lake Champlain Basin: Mapping, characterization and seasonal mobility.

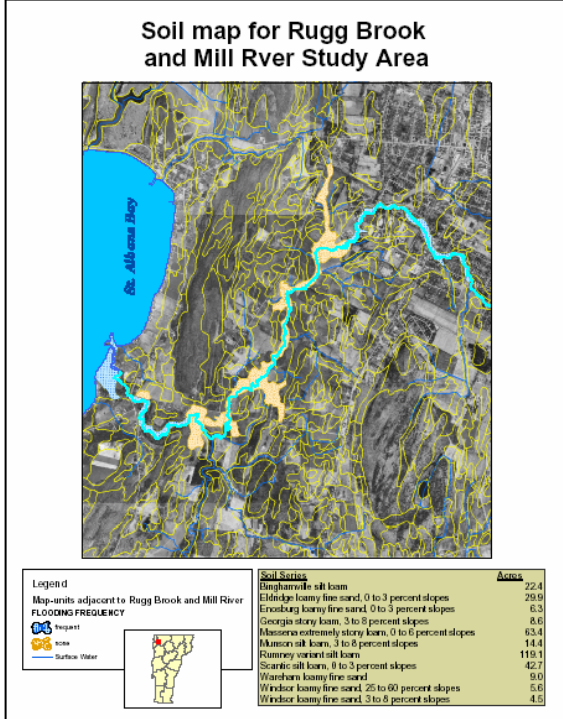
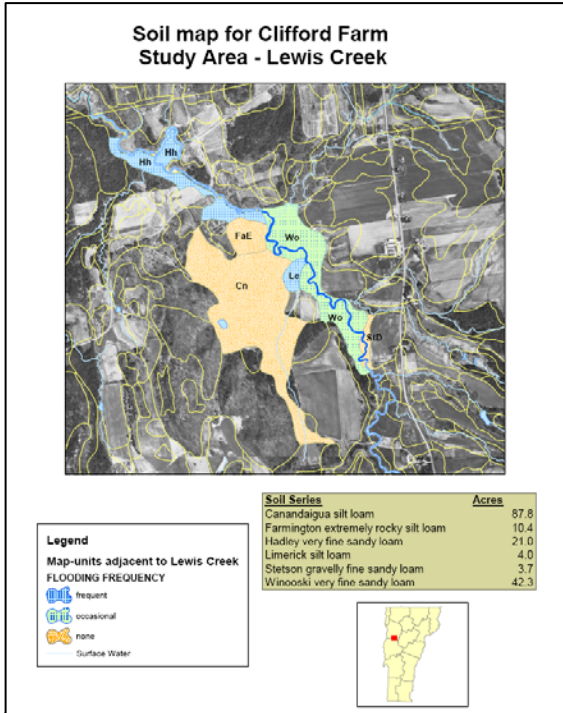
14. Statement of regional or State water problem: The Lake Champlain watershed includes areas of northwestern Vermont, northeastern New York and southern Quebec. Phosphorus has been identified as the nutrient limiting algal blooms. There is a clear need for a better understanding of the factors controlling phosphorus movement from the soils into the streams of the Lake Champlain watershed. Besides the erodibility of stream banks, it is important to know the P content of the eroding soil, both surface and subsurface, and the likelihood of this P becoming mobilized from aquatic sediments. It is also important to gain a better understanding of the relative importance of various P sources. Will erosion of subsoil sediments, either as part of natural stream processes or because of an altered landscape, contribute significant quantities of potentially mobile P? Are other sources, such as frequently flooded riparian soils important? This project will seek to answer some of these questions, focusing on refining the soil mapping along two streams, Lewis Creek in Addison and Chittenden Counties and Rugg Brook in Franklin County. In addition, we will intensively study areas on each stream where restoration projects are underway. Results will be used by the Vermont Agency of Natural Resources, the USDA Natural Resource Conservation Service, and the University of Vermont Extension.

15. Statement of results or benefits: Results will include a new digital soils map of the stream corridors. We will also provide a data layer that includes P content, both total and a range of available indices. After performing this research on two streams, we will also determine the transferability of results to other stream reaches (and how much effort will be needed to provide updated map layers). Additionally, our research will develop and refine relationships between soil P fractions and produce simple predictive models of total and potentially mobile P. The intensive, site specific, studies will result in a more detailed soils map and an explicit characterization of the range and spatial variation of soil P availability. Lastly, results from laboratory experiments will be compared with *in situ* measurements of solution P to determine the feasibility of using soil P fractions to predict P release from soils and aquatic sediments (stream and riparian sediments). Results will be published in peer reviewed journals. The work with restoration projects will be designed to provide useable and pertinent data to the project managers. All data will be made available to University, State and federal personnel.

16. Nature, scope and objective of the project, including a timeline of activities:

The project will be roughly divided into three components: i) an extensive remapping, soil sampling and P analysis of the floodplain areas of Lewis Creek and Rugg Brook; ii) intensive soil studies on an area in each stream where restoration projects are planned or underway; and iii) intensive studies on an area along each stream where changes in oxidation/reduction status may alter P mobility (e.g. stream sediments and frequently submerged riparian sediments/soils).

Soil surveys of Vermont counties have been published over the past 35 years. The mapping of Addison County occurred between 1941-1964 and was published in 1971. Chittenden County mapping occurred between 1940-1967 and was published 1974. Franklin County mapping occurred after these two counties, between 1968-1975, and was published in 1979. The soil surveys for Chittenden and Addison counties are considered out-of-date. Changes in technology and expansion of users of soils data beyond agricultural applications have affected the methodologies and level of detail used in producing soil surveys. There is a need for updated mapping and revision of the data for these counties. Beyond this, the information provided by soil surveys has limitations related to the scale at which the mapping was done. In Vermont, the most commonly used mapping scale is 1:20,000, with a minimum size mapping unit of 3 acres.



Flood-plain soils are often too small to be delineated at this scale. The maps shown to the left were derived from the existing database. Intensive (site specific) mapping that provides greater detail than the original mapping, will help determine if the soil series as they are currently mapped capture the true variation in soil patterns (in terms of P concentrations) found within stream and river corridors.

Soil series are the finest level of soil classification. The delineations shown on soil survey maps represent individual map-units of 1 to 3 soil series of major extent and several soil series of minor extent, commonly known as map unit inclusions, which occur in predictable patterns. The spatial extent of various map-units shown on a map provides useful information, however, connecting to the accompanying database is crucial to understand the behavior and attributes of specific soil series and to make predictions of soil behavior within individual map units. Soil Survey Geographic Database (SSURGO) Certified soils data is available for Addison and Franklin Counties. SSURGO Certified soils data for Chittenden County will be available some time in 2006. However, the database is not fully populated at this juncture in the soil survey program for Vermont. There is very limited phosphorus data for soil series. Chemical properties data are typically listed by horizon and provide both a high and low value to define a range. Additionally, a single representative value is derived for use in modeling applications. Within Vermont, there is minimal laboratory characterization data for individual sampling points and only for certain soil series. There has not been enough sampling to develop a robust understanding of the range of P values that exist throughout the full geographic extent of a soil series. Nor, is there enough data to understand

how P concentrations vary within soil profiles with increasing depth. To extrapolate data for regional assessment of soil properties, numerous measurements need to be obtained and analyzed. There is a critical need to perform this sampling work.

The soil survey provides a unique opportunity to estimate P loading potential to Lake Champlain. Little data exists, but it is expected that subsoils of series with similar parent material will contain similar concentrations of both total and readily available P. Surface soil P

concentrations may also be predictable but it is more likely that parent material is overshadowed by the influence of present and past land-use history. This project will test these hypotheses and generate useable, transferable data for the soils along both Lewis Creek and Rugg Brook. In addition, soil series should separate by other soil characteristics that can be used in modeling erosion potential. We will provide a suite of soil laboratory data for this purpose.

Total P concentrations have been used to estimate P loading to the lake. This test is unambiguous in that it measures the total amount of P that could conceivably mobilize out of the sediments. However, not all soil P is potentially mobile and we should strive to better understand soil P fractions within the context of soil series. Fractions range from readily soluble P of surface applied manure and fertilizer to P occluded in crystalline soil minerals. While land use will greatly affect the fractions in surface soils, P does not readily move downward through the soil profile. We hypothesize that subsoil P fractions should be consistent within soil series and probably across series of similar parent material. Numerous tests for the various P fractions have been developed, as have numerous procedures to estimate soil P uptake and release. We will employ a variety of methods, including both simple widely-used extractants and more labor intensive equilibrations. Phosphorus solubility will be evaluated using routine soil extractions as well as under conditions that mimic a low oxygen environment. Such characterization will provide insight on the magnitude of potential P release from sediments under low redox conditions. These areas include frequently flooded riparian zones, recently eroded and submerged sediments, and aquatic sediments (e.g. streams, wetlands and lakes).

The Vermont Phosphorus Index is used for nutrient management plans in Vermont to generate a relative ranking of the potential for runoff P losses from individual fields (Jokela, 2001). Phosphorus source (soil test P, fertilizer/manure P inputs) and transport factors (estimated annual erosion with RUSLE, soil hydrologic group, and riparian buffer width) are combined to produce an estimate of risk of P loss to the nearest water body. Flooding frequency was part of this equation but recently dropped because of uncertainties in assigning values. Our intensive study sites will provide needed data to help determine how flooding frequency can be accurately reincorporated into the index. We will also evaluate the ability of the P Index to predict long-term soil P movement from agricultural fields to riparian areas.

In addition to the need to better understand site-level processes and mechanisms for P mobilization in river corridors, there is a practical need to estimate P loading on a reach-scale and watershed scale in Vermont surface water basins. Phosphorus loading from many Lake Champlain tributary watersheds (including Lewis Creek) continues to exceed target levels outlined in the Lake Champlain P TMDL (VTDEC, 2005; Medalie & Smeltzer, 2004). Phosphorus levels are increasing in many segments of the Lake (including St. Albans Bay into which Rugg Brook watershed drains) (LCBP, 2004). More than 90% of the P contributions to the Lake are estimated to be from nonpoint sources including agricultural land uses and streambank erosion (LCBP, 2004).

Enhanced understanding of P mobilization at the site scale can contribute to: (1) greater understanding of the effectiveness of Best Management Practices and restoration designs applied in our stream channels and watershed landscapes; (2) improved reach-level and watershed-level estimates of nonpoint source load allocations from streambank erosion and overland processes. We will integrate the refined stream-corridor soil maps and updated P indices with existing geomorphic data for the Lewis Creek corridor. The goal will be to inform selection and prioritization of stream restoration and conservation projects in the watershed with the objectives of reducing phosphorus and sediment loading to receiving waters.

Objective 1. Using existing soil survey data, update the series identification and verify the mapping unit boundaries in the floodplain soils of each stream.

Obj. 2. Sample soils from profiles of all mapped series by soil horizon and depth increments to a depth of 2 m. Determine the variability of soil P fractions within and across series. Determine if subsoil concentrations are related to soil type and if surface concentrations can be related to land use.

Obj. 3. Develop a GIS layer containing revised soil mapping and P data. Determine the effort needed for similar remapping of other stream floodplains and the transferability of the data we have generated.

Obj. 4. Determine relationships between P soil fractions and potentially mobile P.

Obj. 5. Perform site specific mapping, soil sampling and analyses at two stream restoration sites.

Obj. 6. Perform field and laboratory studies of P release from stream and riparian sediments that experience redox fluctuations due to submergence or frequent flooding.

Obj. 7. Develop a simple GIS methodology for integrating refined stream corridor soil mapping results for the Lewis Creek Clifford site with geomorphic data to enhance understanding of lateral and longitudinal transport and storage of phosphorus within a stream segment.

17. Methods, procedures and facilities, Objective 1: Evaluation of the existing soils mapping along the entire floodplain of both streams will be done primarily by remote sensing using GIS and 3DMapper or equivalent after identifying the appropriate corridor width and mapping scale. Map unit delineation slopes and boundaries will be evaluated and adjusted as appropriate. The classification of all soil series will be evaluated, revised and updated. Field work will be conducted to resolve problem areas identified by remote sensing and to collect data needed to fill in data gaps. The final product will be a digital Order 2 soil survey of the watersheds.

Objective 2: We will sample within and among soil series, and distribute the sampling effort along the stream reaches to characterize and quantify spatial variation of soil P. Soils will be sampled by horizon with deeper horizons divided into 20-cm increments. Field characteristics will be recorded to verify soil series. In a subset of samples from each series, bulk density and textural analyses will be performed. Soil P variation within and among series and by depth will be assessed with the General Linear Model in SAS, version 8. Soil P chemical characteristics and spatial coordinates for each sampling-point*series combination will be used in the digital soils map under Objective 3.

Objective 3: The data gathered from sampling points will be recorded using GPS. Maps of the location and distribution of each sample site will ensure all included soil series are adequately sampled at the same intensity. Once laboratory analysis has been completed, interpretive maps showing changes in P concentrations (by a variety of tests) within stream corridors will be created. The GS+ geostatistical analysis package (Roberts, 2000) will be used to test for spatial data structure, and if appropriate, generate a continuous surface of soil P estimates across the landscape. Each horizon will have a separate map. Comparing the interpolated point data with the soils series delineations will help determine if the variability is captured by the soil series model, or if more intensive mapping is needed. Additionally, 3D maps showing the variation of P levels within sample profiles will be provided and allow comparison between sampling sites. The representative soil series found in the two study watersheds will be compared to those currently mapped in the major sediment-contributing stream corridors of Vermont's Champlain basin (e.g. Missisquoi and Otter Creek) to determine potential transferability of results. In year two, we will perform sampling outside of our study watersheds to i) obtain data for any dominant

soil series not found in our two stream reaches and ii) determine if our results for individual soil series will transfer to similar series located in other areas of the basin.

Objective 4: Field moist soil samples will be passed through a 2-mm sieve, dried, and analyzed for phosphorus, % carbon and nitrogen, and exchangeable cations using standard procedures of the UVM Agricultural and Environmental Testing Laboratory. Soil samples will be extracted with the following extractants: (i) 1.25 M NH₄OAc at pH 4.8, (ii) 1.25 M NH₄OAc and 0.03 M NH₄F at pH 4.8, (iii) 0.01 M CaCl₂, (Magdoff et al., 1999), and (iv) distilled water (1:1) (Torrent and Delgado, 2001). The first two extractants have been used by UVM for fertility recommendations and are thought to represent slowly available P, while the latter two are commonly used to measure the soluble and immediately available P fractions. A subset of soils will be tested field-moist with the weaker extractants (iii and iv) to determine the effect of drying on the solubility of P. In addition to determining molybdate reactive P on these two extracts, we will use phosphatase enzymes to determine soluble organic P (Turner et al., 2002). Total soluble P will be determined by in-line persulfate digestion on a flow injection autoanalyzer. Total soil P concentrations will be determined by microwave-assisted acid digestion (Kuo, 1996). Relationships among different P fractions will be analyzed by correlation and regression procedures.

Objective 5: Site specific mapping (Order 1) and soil sampling will occur at two ongoing stream restoration sites. We have permission to work at both the Clifford Farm site in Starksboro on Lewis Creek and the Rugg Brook restoration site on the Lapierre property in St. Albans. The sites both have significant stream bank erosion but somewhat different proposed management plans. At the Lewis Creek site, restoration activities (cattle exclusion, enhancement of forested riparian buffers, cedar revetments, willow waddles) have been undertaken with the main objectives of stabilizing streambanks and reducing nutrients and sediment loading, while the Rugg Brook site hopes to reestablish riparian wetlands to buffer high flows and lower stream incision. Our efforts at these sites will be to provide spatially detailed soils mapping that will include a full database of soil characteristics, measured as described above. The sampling plan will be developed in consultation with the agency involved in the restoration with the goal of providing data to model, either conceptually or explicitly, how changes in stream morphology will affect P transport into the stream. At both sites, we will establish sampling transects that will allow longer term (i.e. longer than this project's duration) assessment of changes in soil and sediment P. The sampling design at Rugg Brook will be coordinated with the Lake Champlain Committee's proposed geomorphic monitoring plan in order to enhance both efforts. In addition to the soil P tests detailed in Objective 4, we will determine the Phosphorus Adsorption Index (PAI) developed by Bache and Williams (1971) and the Degree of Phosphorus Saturation (DPS) as adapted by Sallade and Sims (1997). Both the PAI and the DPS provide a single metric for a soil that is intended to predict whether P will be released or sorbed. If not already in place, simple field instrumentation will be installed to monitor and collect water and sediment. These will include runoff collection pans in the field edge and zero-tension lysimeters in the surface of riparian zones. Samples will be collected on an event basis and analyzed for particulate, colloidal, and dissolved inorganic and organic P.

Objective 6: Sediment and soils along stream reaches at each site will be collected from the stream, streambanks, and frequently flooded riparian areas (focusing on areas of recently deposited sediment). All sediment/soil samples will be analyzed for the chemical characteristics in Objective 4. In addition, shallow core samples will be taken from the streams, recently submerged sediments, and frequently flooded riparian zones using custom-made centrifuge

extraction tubes (Giesler and Lundstrom, 1993). Soil solution will be extracted back in the lab by low-speed centrifugation and analyzed for P fractions, including total and reactive dissolved (<0.45 μm) P. Solution samples will also be assayed for redox-sensitive P by treating unfiltered samples with bicarbonate-dithionate to determine the potential P release upon reduction (Uusitalo and Turtola, 2003). These data will evaluate the usefulness of laboratory-based measures of P release as predictors of solution P concentrations as measured in the field. An effort will also be made to periodically sample saturated excess overland flows and frequently flooded riparian areas that are observed to contribute overland flow to streams during runoff events. This information is critical because it will provide P concentrations for overland flows that directly contribute to P loads.

Using the sediment P chemistry data generated from Objectives 4 and 6, a subset will be selected that encompasses a range of P availability, physical properties and soil drainage. Sediment microcosms will be created by submerging 500 mL of sediment or soil with deionized, distilled water in 1L polyethylene beakers (Young and Ross, 2001). Particulate, dissolved, and total dissolved P in porewater (soil solution) and floodwater will be monitored over time. Porewater will also be monitored for Fe^{2+} concentration (Muss and Mellen, 1942) as a proxy for redox status. A subset of solution microcosm samples will also be assayed for redox-sensitive P (Uusitalo and Turtola, 2003) to determine its relationship with sediment porewater P concentration upon reduction of Fe-P compounds. Phosphorus release data from the sediment microcosms will be compared to solution P concentrations measured in the field (where each sample was collected) and correlated with to their respective chemical characteristics determined under Objective 4.

Objective 7: Objectives 1 through 6 will yield a better understanding of P transformation and transport processes in riparian areas, and the physical and chemical (sediment type) controls on the potential “sink” or “source” functions of sediments in (i) the submerged and frequently flooded bankfull channel, (ii) the streambank profile, and (iii) the near-bank areas. Phosphorus sinks may include areas of floodplain accretion and locally aggrading channel sections. Phosphorus sources may include erosion sites where streambank sediments or channel bars are remobilized through channel migration, or active widening, or local scour of the channel bed. The potential sink or source role played by riparian area sediments, and the duration of that role, will vary over time with changing vegetation conditions and hydrology, and as a result of lateral and vertical adjustments of channel dimensions, planform, and profile. Objective 7 will overlap refined soil mapping data and P indices with existing field-based geomorphic assessment results for a 1000-foot length of Lewis Creek channel at the Clifford site. A channel and near-bank survey will be completed to identify and document the streambank and channel bed sediment sampling locations in Objectives 5 and 6 relative to geomorphic features. This survey, along with USGS gage data and pebble count data, will relate sediment sampling locations (and analytical results relative to P transformation and transport) to elements of flow regime, including flow stage (the degree, frequency, periodicity of sediment submergence) and flow velocity (the potential for sediment entrainment and transport from the various locations sampled in Objectives 5 & 6). The channel survey completed under Objective 7 will be tied to survey locations completed in 2004 under a separate study, thereby enabling quantification of lateral and vertical channel adjustments of channel dimensions, planform, and profile.

A conceptual model will be developed for the Clifford site that will predict how P sink or source functioning of riparian sediments may vary over time with varying hydrology (up to the magnitude of the annual effective discharge, unless a higher magnitude event is experienced

during the study duration), varying vegetative treatments (buffer types and extents along streambanks and nearbank areas), and changing channel dimensions, profile, and planform. The conceptual model will identify (in qualitative terms) how riparian sediments are distributed and transported laterally and longitudinally within the reach (streambank erosion at the toe of the slope and through bank collapse; overbank, channel bar, point bar, and flood chute deposits; beaver dam impoundments), and how P transformation and transportation processes will vary as sediments are transported.

Findings will speak to the effectiveness, compatibility and sustainability of Best Management Practices (cedar revetments, willow waddles, cattle exclusion) employed at the Clifford site, given the hydrologic and geomorphic setting:

- how well these practices have managed / will manage for the significant P transport pathways and transformation processes identified in Objectives 1 through 6;
- how the selected BMPs are affecting (and are being affected by) the geomorphic balance and internal P cycling within the site and reach.

18. Related research: Sediment and P are the largest contributors to surface water quality impairments in VT (VTDEC, 2002), and influx of sediment-bound P in tributaries also contributes to the eutrophication of Lake Champlain. There is a clear need to understand the sources and cycling of P in order to predict its transport across the landscape. There have been some studies in VT watersheds that have suggested stream bank erosion can be a significant P load for some streams, whereas others have characterized sediment-P in streams and impoundments with the goal of trying to hypothesize P transport processes.

DeWolfe et al. (2004) studied sediment and P contributions from stream bank erosion along ten reaches in the Lake Champlain Basin. Little variation in eroded sediment total P concentration was found, while variation in erosion rates among sites were high. They found an average total P of 613 mg/kg in samples from 10 reaches, including three from Lewis Creek. We have preliminary data from 14 samples taken from one reach on Lewis Creek (west of Route 7). Our average total P was 604 mg/kg (range 415-868 mg/kg). DeWolfe et al. (2004) concluded that streambank erosion can be a significant source of sediment-P, and showed it could be the largest sediment-P source for some stream reaches. They stressed a need to understand physical and chemical processes in sediments that regulate P bioavailability. McDowell et al. (2002) characterized sediment P properties in streams and impoundments from 41 sites in the Winnoski River basin. They found that finer sediments (<63 μm) predominated in impoundments and reservoirs, and that river sediments adjacent to agricultural areas had higher algal-available P compared to forested areas. Though few meaningful correlations among sediment P fractions and characteristics were noted, finer sediments had higher total P content and sorption capacity relative to river sediments. It was suggested that these sediments were acting as temporary sinks for P, although the authors stated that the sediments, like soils, may release P upon microbial reduction of Fe and S compounds.

A substantial research effort has been underway in the Northeast and across the US to quantify relationships between soil test P measures (based on crop response) of availability, P release to soil-water extracts, P release to simulated runoff, and various measures of P solubility (Sims and Pierzynski, 2005; Magdoff et al., 1999). Though much progress has been made in establishing relationships among batch-type extractions of P availability and simulated runoff, little research has tested the fitness of using such measures for predicting P mobility, or how they vary across the landscape (McDowell et al., 2004). In addition, much of the work has focused on

agricultural soils, while P mobility in recently eroded sediments, streambank/riparian soils, and aquatic sediments has received less attention.

It is well established that strongly-bound Fe(III)-P compounds in sediments can become soluble upon reduction of Fe(III) (Sallade and Sims, 1997). The potential for P release from sediments or flooded soils is strongly related to P content, soil redox status, and the oxygen concentration in the overlying water. If oxidizing conditions prevail in floodwater, solubilized Fe^{2+} and P may reprecipitate or be adsorbed on the aerobic side of the interface by oxidized Fe or polymerized hydroxy-Al (Bartlett and Ross, 2005). Three critical factors that could increase P release to overlying water would be the depletion of floodwater oxygen, disturbance at the soil-water redox interface, or a high soil P concentration, which could overwhelm the reprecipitation / adsorption capacity of the soil. Young and Ross (2001) studied soluble P release from seasonally flooded Champlain Valley soils in laboratory microcosms and showed large increases (2-27 fold) in porewater soluble P over a 60 day inundation. Significant release to floodwater only occurred for soils with high P content, and was attributed to the existence and maintenance of redox interfaces. Thus, understanding P release in the context of soil-water redox is required in order to generate hypotheses of P transport mechanisms among different storage compartments along stream corridors.

Another critical component of studying P fate and transport in the landscape is characterization of different P forms (Pierzynski et al., 2005). Research has shown that P can be lost in surface and subsurface runoff in the particulate, organic, inorganic, and/or colloidal P forms. Routine filtration can remove large amounts of particulate reactive P ($>0.45 \mu\text{m}$) that may otherwise remain in solution. Some research has shown that significant (50%) amounts of this particulate P is bioavailable (Uusitalo et al., 2001). Studies of P losses in surface runoff have provided mixed results relative to the contribution of dissolved versus particulate P. For example Haygarth et al. (1997) showed 78% of reactive P in runoff was in the particulate form, whereas Turner et al. (2004) found 50% of reactive P in runoff was associated with colloids $<1 \mu\text{m}$ in size. Shand et al. (2000) found 75% of reactive P in soil water from northeast Scotland was associated with particles $>0.45 \mu\text{m}$, while Turner and Haygarth (2000) showed 21 to 46% of reactive P from grassland leachate was in the particulate form. Colloidal P forms can be composed of primary and secondary minerals, sorbed and/or occluded complexes with clay-metal-humic moieties, and/or bacterial cells (Kretzschmar et al., 1999). These P forms have less affinity for soil sorption sites, and are thought to be more mobile in solution relative to phosphate (Turner and Haygarth, 2000). Gschwend and Reynolds (1987) found mobile ferrous phosphate colloids in anoxic ground water plumes, while Ryan and Gschwend showed (1990) anoxic ground water mobilized iron hydroxide-P species associated with clay particles attached to soil walls. Clearly, particulate and colloidal P forms can strongly influence surface and subsurface water quality.

The contribution of organic P to plant-available P and the likelihood for loss of dissolved or particulate organic P to leaching or runoff is not fully known, and can be difficult to quantify (Sims and Pierzynski, 2005). However, dissolved organic P forms are important sources of P losses from manured soils (Chardon et al., 1997). Research has shown that dissolved organic P (unreactive P) can comprise a significant (29-38%) portion of total P losses from subsurface drainage (Turner and Haygarth, 2000). Beauchemin et al. (1998) showed that subsurface P losses were dominated by particulate P forms, while dissolved organic represented less than 30%, and concluded that clay soils of moderate P status were particularly at risk for exceeding water quality standards because of mobile particulate-P associations. In seasonally flooded soils and

wetlands, inorganic P forms may be transformed to organic forms, and thus function as P transformers, rather than P sinks.

19. Training potential: This project will train a post-doctoral scholar in the management and collaboration required to carry out the proposed research. D. S. Ross will closely mentor the individual in this position. In addition, this project will provide valuable training to 3-5 undergraduate students, most likely majors in either Plant & Soil Science or Environmental Science. Students will assist in both field and lab studies during the summer months and the school year. Training will be provided in soil sampling, soil profile description, soil chemistry and laboratory procedures. There will also be the possibility of student internships associated with the NRCS and other agencies, both with soil mapping via GIS and with stream restoration projects. Currently, students from PSS 269, Soil and Water Pollution and Bioremediation, are conducting projects on soils from the floodplain of both of the proposed study streams, examining P fractions at various depths and distances from the stream bank. Such class projects will likely increase in number and intensity during the course of this project.

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