

Appendix 1

Pre-European Settlement Streams and Wetlands, and the Timing of Legacy Sediment Deposition

The Pre-European Settlement Landscape

Wet organic-rich mud provided the perfect environment—little oxygen and no disturbance—to protect this landscape for several hundred years. We find pristine pollen and flora, including tree stumps (often logged), fallen trees, woody debris, seeds, roots, leaf mats, and fields of sedges. We also find buried corduroy roads made of rows of logs, early native American tools and Colonial ceramics, and the foundations of old buildings.

The pre-settlement horizon generally appears as a thin (<0.5 m), dark greyish brown to black, organic-rich (roughly 20-25 weight %C) silty clay above a basal gravel and forms a resistant horizon. The large amount of disseminated organic matter, combined with the abundance of fresh wood, leaves, seeds, and other organic detritus, gives the pre-settlement material a dark gray to black color. We have observed this horizon at nearly every site we have studied to date ($n \approx 90$). We interpret this nutrient-rich stratum as the pre-settlement histic epipedon of marsh, swampy meadow (Prosser, Chappell et al. 1994), or poorly drained hydric soils that were wetted frequently by overbank flooding. Frequent wetting resulted in the accumulation of substantial amounts of organic carbon, nitrogen, phosphorous, and trace metals in wetland sediments (discussed below).

Our examination of the pre-settlement landscape in dozens of trenches and stream bank exposures, combined with geochemical and palynological analysis of the pre-settlement material, indicates that valley bottoms were broad riparian wetlands, with small (possibly anabranching and chain-of-pool) streams and low vegetated islands within the flood zone, possibly impacted by beaver ponds (Butler and Malanson, 2005). Pre-settlement channel forms are small and rarely observed, despite excellent exposure of pre-settlement floodplains. Channel depths of 0.25-0.5 m are constrained by the distance between planar bedrock valley floors and pre-settlement

floodplain surfaces. *In sum, pre-settlement stream channels were small and shallow, carried little sediment, and frequently flowed overbank onto a broad mosaic of wetland types.*

Timing of Legacy Sediment Accumulation

The timing of legacy sediment accumulation is important to modern efforts to understand and restore impaired streams. For example, if sediment in valley bottoms was deposited quite recently and is associated with modern stream processes, then the cause of sedimentation might be modern land use practices. If, on the other hand, the sediment has been in storage for more than one hundred or so years with no recent significant deposition, then deposition occurred by processes that no longer exist. It logically follows then, that the cause of that deposition no longer exists as well, or at least is much less common. If processes have switched from sustained deposition to net erosion of sediment, then the cause of that change should be determined before attempting restoration.

To constrain the timing of legacy sediment accumulation, we use several approaches to date both the onset of sedimentation and the more recent cessation of deposition. The organic-rich pre-settlement floodplain/wetland sediments provide a *maximum age for the timing of legacy sediment deposition*. In other words, the pre-settlement material must be older than the legacy sediment. The uppermost legacy sediment layers provide a *maximum age for the timing of cessation of deposition*. The fill surface represents a threshold that marks the timing of complete reservoir filling, and must pre-date incision into that fill.

Forty-nine radiocarbon ages from the dark organic-rich sediment sampled from the base of stream bank exposures and trenches throughout Pennsylvania and Maryland range from 11,500 to 300 yr BP (Figure 9). Twenty-nine of these radiocarbon dates were provided to us by Dr. Fred Kinsey, retired archaeologist and former director of the North Museum in Lancaster. Radiocarbon measurements were conducted by Beta Analytic, Inc., using standard AMS (accelerator mass spectrometry) and conventional (alpha counting) techniques and calibrations.

The age range spanned by these deposits indicates that pre-settlement floodplains and/or marshes were stable throughout the warm interglacial Holocene Epoch. Over a period of ~10,000 years, sedimentation rates were <0.03 cm/yr.

We used historical documents and isotope geochronology to constrain the timing of both the onset and cessation of millpond sedimentation at two sites in the Conestoga watershed (1200 km² area), southeastern Pennsylvania: (1) Denlinger's Mill is a 5-m high sediment stack adjacent to a breached, 5-m high milldam; and (2) Big Spring Run is a 1.3-m high sediment stack 1.8 km upstream of a breached, 3-m high milldam. Unpublished historic records gleaned from the Lancaster County Historical Society indicate that the milldams at Denlinger's Mill and Big Spring Run were built in ca. 1730, which represents the maximum age for the onset of post-settlement sedimentation in these reservoirs. In addition, several of the radiocarbon dates for the pre-settlement material shown in Figure 9 are from these sites, and are consistent with the time of dam building. At Denlingers Mill, radiocarbon dates from the basal organic layer, and a leaf mat between the organic layer and the overlying silts and clays, yield ages of 1620 +/- 60 AD (330 yr BP) and 1720 +/- 60 AD (230 yr BP), respectively, which indicate deposition during the late pre-settlement to early post-settlement period (Figure 10). Radiocarbon analyses of two wood fragments from the dark, organic-rich layer at Big Spring Run yield ages of 1,580 +/- 60 yr BP and 700 +/- 40 yr BP (Figure 11).

The age of the top of the millpond sediment stack at Denlingers Mill and Big Spring Run was determined by gamma spectroscopy of ²¹⁰Pb and ¹³⁷Cs from methods outlined by Matisoff et al³⁰. (Note: Here we focus on the ²¹⁰Pb analysis; the ¹³⁷Cs provides similar information. For the ²¹⁰Pb analysis, each sample was counted for a period of 23 to 48 h. Samples and standards used the same geometry to minimize counting errors, and corrections were made for low energy ²¹⁰Pb photon emission (46.52 keV) for sediment self-attenuation.) A radioactive isotope, ²¹⁰Pb (half life = 22.3 yr) reaches secular equilibrium with the activity of its ²³⁸U parent decay chain in roughly 155 yr (7 half lives). Analysis of the activity of ²¹⁰Pb in a millpond sediment profile -- from its upper surface to some depth -- provides evidence of where in the profile the activity of ²¹⁰Pb reaches equilibrium. That depth in the profile represents a time of ~155 yr or greater for deposition of that stratum.

Based on the ^{210}Pb analysis, about 97% of the 5-m-thick post-settlement alluvium in the mill pond reservoir at Denlinger's Mill was deposited between 1730 and 1850. At Big Spring Run, roughly 80% of the 0.9-m-thick alluvium overlying the organic stratum was deposited between 1730 and 1850. Our analysis of the upper 50 cm of sediments at both sites, in 2.5 cm increments, indicates that secular equilibrium is reached at a depth of 15-20 cm below the surface, which suggests that sediments at this depth were deposited in the year 1850 or earlier (as some of the upper surface might have been eroded), and indicates that these reservoirs reached their sediment storage capacity by at least 1850.

Although we don't have the same level of analytical detail for other sites, we conclude from historic documents and maps that many mill ponds had reached capacity by the late 1900s. This conclusion is consistent with our examination of time series of historic maps, which illustrate ponds that are smaller and, eventually, gone on later versions of maps.

Appendix 2

Field and Laboratory Methods

I. Sediment Sampling Methods

A. Trenching

1. Excavate trenches with backhoe, adjacent to the stream and perpendicular to stream flow, through the floodplain terrace sediments down to bedrock.¹
2. The ideal trench, or series of trenches, extends from valley wall to channel edge, which gives a comprehensive, cross-sectional view of the sediment stack, which is useful to determine paleo-geomorphic changes in the fluvial system.
3. Measure stratigraphic sections, delineate sedimentary units, describe sediments, and collect samples for geochemical and geophysical studies, including nutrient and trace metal contents, radiocarbon dating and magnetic susceptibility.
4. Sampling Methodology -- Beginning at the upper (topmost) surface, cut a vertical channel or mini-trench with a trowel in approximately 15 cm long (along the face of the cutbank), by 10 cm wide (perpendicular to face) by 5 cm deep increments. If the sediment is moist and consolidated, the sediment can be extracted in oriented bricks (which has some advantages in subsequent analyses), but for most cases simply scoop the material into a zip-lock bag one trowel tip at a time until a representative sampling of each increment has been achieved (ca. 300 – 500 g). Continue sampling down section in 5x10x15 cm increments until bedrock or groundwater table is reached
5. Although trenches are the best way to get full stratigraphic exposures, trenches must be pumped as bedrock is below the local water table.
6. In the lab, open ziplock bags and allow samples to air dry (usually 2-3 weeks).
7. During the first week, magnetic susceptibility measurements are made using a probe through the ziplock bag pressing against the surface of the sample. We routinely do three measurements to check reproducibility and homogeneity of sample.²

¹ Archaeological and historical research, regarding pre- and post-settlement land used histories, is useful for helping to reconstruct historical changes in stream functions and sediment dynamics.

² Magnetic susceptibility is a measure of how readily a material is magnetized. We have discovered that this technique is useful for distinguishing between pre-settlement sediments (very low susceptibility levels) and post-settlement sediments (moderate to high susceptibility levels).

8. For the remaining geochemical analyses, disaggregate the air dried samples in a large ceramic mortar and pestle using a pounding motion to pulverize the sample and break up material along grain boundaries. Disaggregated material is passed through a 2 mm mesh sieve and split with a geochemical splitter into enough fractions for subsequent studies.
9. Texture and color estimates, and grain size and density measurements can be made on one of these fractions.
10. Geochemical methods used [“F&M” denotes in-house analytical capabilities]:
 - a. ICP-OES (using the EPA 3051 method for detection of environmentally available trace metals and phosphorus) [F&M]
 - b. ^{137}Cs and ^{210}Pb analyses for age controls covering the last 250 years.
 - c. ^{14}C (radiocarbon) dating, for age controls covering ca. 300 year BP to pre-Holocene timescales.
 - d. Injection flow analysis for the analyses of various species of phosphorus and nitrogen [F&M].
 - e. Combustion Analyzer for total nitrogen and total carbon measurements [F&M].
 - f. Less frequently used analyses include: pollen, x-ray fluorescence [F&M], x-ray diffraction [F&M], electron and optical microscopy [F&M].
11. Data are plotted on binary diagrams, plotted against depth from surface.
12. Note: Digital photographs, GPS coordinates and detailed notes are recorded for each sediment profile.

Stream Bank Sampling

1. Cut face back 10 to 20 cm to assure a clean, uncontaminated surface (using a pick, hoe, shovel or trowel).
2. Measure stratigraphic sections, delineate sedimentary units, describe sediments, and collect samples for geochemical and geophysical studies, including nutrient and trace metal contents, radiocarbon dating and magnetic susceptibility.
3. Sampling Methodology -- Beginning at the upper (topmost) surface, cut a vertical channel or mini-trench with a trowel in approximately 15 cm long (along the face of the cutbank), by 10 cm wide (perpendicular to face) and 5 cm deep increments. If the sediment is moist and consolidated, the sediment can be extracted in oriented 5x10x15 cm bricks (which has some advantages in subsequent analyses), but for most cases simply scoop the material into a zip-lock bag one trowel tip at a time until a representative sampling for each 5x10x15 cm increment has been achieved (ca. 300 – 500 g).
4. Typically, the stream surface is intersected before bedrock is reached, so this will be an incomplete stratigraphy unless it is possible to reach below the water line and extract sediment samples by hand.
5. In the lab, open ziplock bags and allow samples to air dry (usually 2-3 weeks).

6. During the first week, magnetic susceptibility measurements are made using a probe through the ziplock bag on the surface of the sample. We routinely do three measurements to check reproducibility and homogeneity of sample.³
7. For the remaining geochemical analyses, disaggregate the air dried samples in a large ceramic mortar and pestle using a pounding motion to pulverize the sample and break up material along grain boundaries. Disaggregated material is passed through a 2 mm mesh sieve and split with a geochemical splitter into enough fractions for subsequent geochemical studies.
8. Texture and color estimates, and grain size and density measurements can be made on one of these fractions.
9. Geochemical methods used:
 - a. ICP-OES (using the EPA 3051 method for detection of environmentally available trace metals and phosphorus)
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 - d. Injection flow analysis for the analyses of various species of phosphorus and nitrogen.
 - e. Combustion Analyzer for total nitrogen and total carbon analyses.
 - f. Less frequently used analyses include: pollen analyses, x-ray fluorescence, x-ray diffraction, electron microscopy and optical microscopy.
10. Data are plotted on binary diagrams, plotted with respect to depth from surface.
11. Notes: Digital photographs, GPS coordinates and detailed notes are recorded for each sediment profile.

GeoProbe Cores

1. GeoProbe cores are pneumatic cores that are pushed through soft sediments via a rig mounted on the back of a pick-up truck or mounted on an ATV. The sediment is extracted in a ca. 1-m-long clear plastic sleeve.
2. Magnetic susceptibility measurements can be made using an O-ring analyzer, drawing the core through the ring in 3 – 5 cm increments.
3. The plastic casing can be slit on each side with a box cutter and the core extracted and analyzed using the methods described above.

³ Magnetic susceptibility is a measure of how readily a material is magnetized. We have discovered that this technique is useful for distinguishing between pre-settlement sediments (very low susceptibility levels) and post-settlement sediments (moderate to high susceptibility levels).

4. Note 1: Sediments cores typically are compressed by 30-50% of their in situ volumes.
5. Note 2: This is an excellent tool for determining depth to bedrock across the floodplain when trenching is not an option.

II. Sample Preparation and the EPA 3051 Microwave Digestion Method

Abstract The EPA Method 3051 is used to partially digest 0.2500 +/- 0.0002 g of crushed soil samples in 10 mL of concentrated nitric acid heated to 175°C for (insert time) in a CEM MARSXpress microwave unit. The resulting digestion solution is filtered and diluted to 50 mL, resulting in a 20% HNO₃ solution. Finally, the amounts of 14 trace elements (Al, Ba, Be, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, P, Pb, and Zn) in these solutions are measured by ICP-OES.

Materials and Methods

Solids Ratios Measurement Approximately 1 gram of precisely weighed sample is placed in a tin cup in a Precision brand Economy oven for 16 to 24 hours at approximately 104°C. The sample is precisely reweighed after cooling in a desiccator and calculations are completed to determine the solids ratios.

Digestion Solution Preparation: Materials Sixteen soil samples are digested in each batch. The samples are digested in clean and dry fluorocarbon (PFA Teflon®(?)) (look up volume) vessels with Fisher Scientific Trace Metal Grade concentrated Nitric Acid. A Fisherbrand 2-10 mL Finnipipette with a Finntip 10 mL tip is used to measure the 10 mL of nitric acid used in the digestion. A CEM MARSXpress heats the nitric acid and sample mixture. Rinsed Whatman #4 Qualitative 125mm diameter circle filter papers are used to filter the material through Pyrex 60° glass funnels into 50mL Pyrex glass volumetric flasks. Approximately 6 MegaOhm resistance distilled water is used throughout the procedure. Three standards are used: NIST Standard Reference Material 2711 Montana Soil (Moderately Elevated Trace Element Concentrations), Environmental Resource Associates D050-542 (further crushed to <80 mesh size in alumina shatterbox), and an internal standard, BS-1 #13a 60-65cm.

Digestion Solution Preparation: Methods Initial preparations minimize the potential for contamination of the digested sample solutions. These include:

1. Thorough soaking of the digestion vessels in a 1:1 nitric acid (Pharmco ACS Reagent Grade) solution followed by rinsing in distilled water.
2. Drying the digestion vessels prior to use
3. cleaning the 50 mL volumetric flasks and glass funnels in multiple rinses of 1:1 nitric acid (Pharmco ACS Reagent Grade) and distilled water
4. Rinsing the filter papers in distilled water and drying them in the oven (sometimes)
5. Cleaning the inside of the microwave with distilled water and Kimwipes after each use.

An ANALYTICAL *Plus* balance is used to weigh out 0.2500 +/- 0.0002 g of soil sample onto Fisherbrand 4"x 4" weighing paper. This sample is then poured into a numbered digestion vessel. The Fisherbrand 2-10mL Finnipipette is used to add 10 mL of concentrated nitric acid to the digestion vessels containing the soil samples. The vessels are then weighed on a Sartorius balance before placing them in the microwave carousel which is in turn placed in the CEM MARSXpress microwave unit. The samples are rotated to ensure homogenous distribution of heat in the microwave using a pre-programmed heating and cooling cycle. After removal from the microwave, the samples are reweighed on the Sartorius balance to check that no significant weight change has occurred during heating, which would indicate the loss of material by venting of vapors from the digestion vessels.

The next step in the procedure is the filtering of the nitric acid and soil sample solution. Because this procedure only partially digests the soil samples, there still remains much solid material after heating which must be separated from the nitric acid containing digested ions in solution. The glass funnels containing the conically folded filter papers are placed on a stand with their outlets running into the 50 mL glass volumetric flasks. The inner caps of the digestion vessels are covered in droplets of condensed vapor from the heating and so are rinsed into the funnel with distilled water. The contents of the digestion vessel are then poured into the filter with distilled water (used to keep the filter paper from tearing). The liquid portion of the vessel's contents filters through the paper and drips into the volumetric flask and the solid portion remains in the filter. The digestion vessel is rinsed twice with distilled water, which is then poured into the filter.

Once all of the digestion solution has been filtered, the filter paper is removed from the funnel and placed aside to dry. The glass funnel is rinsed into the volumetric flask with distilled water. Subsequently, the digestion solution is diluted to 50 mL with distilled water. Occasionally the samples must be diluted to 100 mL due to tearing of the filter paper during initial pouring or to overfilling of the 50 mL volumetric flasks.

III. ICP-OES (Inductive Coupled Plasma – Optical Emission Spectroscopy)

ICP-OES Methods The ICP spectrometer is calibrated with five calibration standards (Table 1) and a blank (20% HNO₃) each time it is used to measure the trace elements present in the digested soil samples. The standards are made from the initial solutions found in Table A2. The standards are made in Pyrex glass volumetric flasks of various sizes using ~6 MegaOhm distilled water. Volumes are measured using Fisherbrand Finnipipettes of 2-10mL, 1-5mL, and 100-1000µL sizes and Finntip 10mL and 5 mL and Fisherbrand 101-1000 µL pipette tips. Standards are stored in Nalgene bottles and used within 10 days of preparation. The samples are analyzed by

ICP-OES on a Spectro Ciros CCD machine connected to a Hewlett Packard computer running Smart Analyzer Ciros CCD software. This ICP spectrometer runs using Argon plasma.

Table A1. A summary of the trace elemental concentrations for all of the SOILS standards used to calibrate the ICP-OES prior to processing each batch. All of the solutions contain 20% Nitric Acid.

	SOILS Blank	SOILS Std. 1	SOILS Std. 2	SOILS Std. 3	SOILS Std. 4	SOILS Std. 5
Element	conc. (ppm)	conc. (ppm)	conc. (ppm)	conc. (ppm)	conc. (ppm)	conc. (ppm)
Al	0	50	100	30	0	150
Ba	0	3	6	2	10	0
Be	0	0.1	0.05	0.02	0	0.25
Cd	0	0.1	0.05	0.02	0	0.25
Co	0	0.1	0.05	0.02	0	0.25
Cr	0	0.2	0.1	0.5	0.4	0
Cu	0	0.2	0.1	0.5	0.4	0
Fe	0	150	50	100	200	0
Mn	0	10	20	6	30	0
Mo	0	0.1	0.05	0.02	0	0.25
Ni	0	0.2	0.1	0.5	0.4	0
P	0	3	6	2	10	0
Pb	0	0.6	1	0.4	0	2
Zn	0	3	1	1.5	0	5

Table A2. A summary of the solutions used to prepare the SOILS calibration standards for the ICP spectrometer.

Element	Conc. (ug/mL)	Acid solution	Brand
Al	1000 +/- 3	2 % HNO ₃	High Purity Standards
Ba	1000	5 % HNO ₃	Specpure
Be	1000	5 % HNO ₃	Specpure
Cd	1000	5 % HNO ₃	Specpure
Co	1000	5 % HNO ₃	Specpure
Cr	1005	1-4 % HCl	Aldrich
Cu	1000 +/- 3	2 % HNO ₃	Environmental Express
Fe	1000	5 % HNO ₃	Specpure
Mn	1000	5 % HNO ₃	Specpure
Mo	1000		Spex CertiPrep
Ni	1000	5 % HNO ₃	Specpure
P	1000	5 % HNO ₃	Specpure
Pb	1000	5 % HNO ₃	Specpure
Zn	999	1.1 % HNO ₃	Aldrich

ICP-OES Analyses After initializing the ICP spectrometer and a 30 minute warm-up period, the machine is calibrated with the five SOILS standards and the blank. The calibration curves are checked and updated. After the calibration, the machine is ready to process samples. During the measurement procedure, standards are measured at the beginning, middle, and end (or at appropriate intervals for large batches) to check the consistency of the measurements. If there appears to be significant change in the measured values of the standards' trace elements, the instrument is recalibrated. The trace elemental compositions of each digested soil solution are measured three times by the spectrometer and an average and standard deviation are calculated, printed, and stored in a data file on the computer. The data are retrieved after the measurements have been completed and they are further reduced in an Excel spreadsheet.

IV. Flow Injection Analysis (FIA)

Flow Injection Analysis: Flow injection analysis, or FIA, is a continuous flow method for rapidly processing samples. A peristaltic pump draws sample from the sampler into the injection valve. Simultaneously, reagents are continuously pumped through the system. The sample is loaded into the sample loop of one or more injection valves. The injection valve is then switched to connect the sample loop in line with the carrier stream. This sweeps the sample out of the sample loop and onto the manifold. The sample and reagents then merge in the manifold (reaction module) where the sample can be diluted, dialyzed, extracted, incubated and derivatized. Mixing occurs in the narrow bore tubing under laminar flow conditions. For each method, the operating parameters are optimized to address high sample throughput, high precision and high accuracy. The samples are passed over a spectrophotometer that is set to specific wavelengths for reading N or P.

Quickchem 8500 Total Phosphorous Method:

- 1) Use samples that have been digested using the EPA 3051 for microwave digestion.
- 2) Make calibration standards using a 20% nitric acid solution. Then standards range in concentration from 10 mg P/L to 0 mg P/L. Made form a stock solution of 1000 mg P/L. Weigh 4.396 g of dry Potassium phosphate and add to 1 liter volumetric flask. Dissolve in water. Use this to make a liter of 10 mg P/L solution. This second solution is then used to make a series of diluted standards. (10, 4, 2, 1, 0.4, 0.2, 0.1, 0).
- 3) Load calibration standards and samples into test tubes to put in sample holder for the auto sampler. Use the placement chart to keep track of sample location. A total sixty tubes may be run at one time (7 calibration standards and 53 unknowns).
- 4) Run 3 samples for each digestion in duplicate. These are labeled on the results sheet with an R.
- 5) Turn on the computer, the quickchem 8500, the autosampler, the pump and the heater. Start running distilled water through the system at set speed 35. Set the heater temperature to 125° C. Liquid must be running through the tubes when the temperature is above 80° C (the tubes will melt if there is no liquid).
- 6) Once the temperature has reached 125, put the tubes in the proper reagent bottles. The reagents are as follow: Digestion reagent 1 (a dilute sulfuric acid solution), Digestion reagent 2 (a potassium persulfate solution), an ascorbic acid solution, the carrier (distilled water for this method) and the molybdate color reagent. Run all these solutions through the lines for at least 15 minutes to guarantee that the solutions are completely through and there is no extra water remaining in the tubes.
- 7) Open the Omnion program on the computer. Open the file Total P starting point2.omn. Use this file as the template for your samples. Type in the calibration standards and samples that you have written on the placement chart.

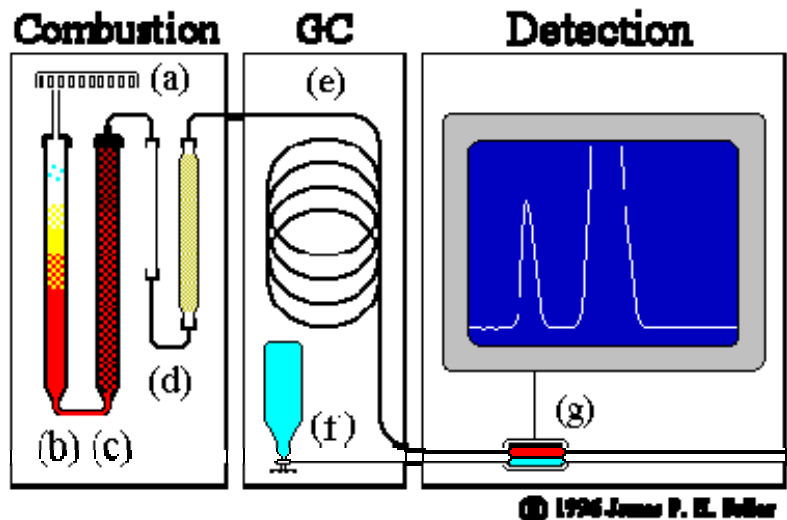
- 8) Check to make sure that the reagents have run through all the lines, by using the preview button when the file is open. The baseline for all the reagents should be between .6 and .75. If it is higher than this, the lines need to be cleaned. Use a sodium hydroxide solution to clean the lines. Run the cleaner solution for at least 20 minutes through the lines. Then rinse the lines in distilled water and start the reagent solutions again. Run the cleaner solution as many times as it takes to get the baseline low enough.
- 9) Once you have ascertained that the baseline is low enough, start the omnion application by pressing the green arrow button.
- 10) The autosampler will start automatically and draw the first calibration standard. It will take about 3 minutes for a peak to appear on the computer. Verify that a peak does appear. Once you have made sure that the peaks have appeared and that your calibration coefficient is above .996, you may let the application run by itself and do other things around the lab. About two hours later (depending on the number of samples) the application will be finished.
- 11) Once you check the data to make sure that you have everything you need, save this run under a new name (usually Total P followed by the date.omn). Then print the data, using the report function. Use the ten per page format found under the tools/report heading.
- 12) Once you have the data, enter it into the excel spreadsheet that contains all the ICP data that has been collected. The spreadsheet will make the necessary calculations to turn the data from mg/L to ppm.
- 13) Run distilled water through the lines to clean them and lower the temperature on the heater. Run the water for at least 15 minutes or until the temperature drops below 80°C, depending on which one is longer.
- 14) Once the heater is cool enough, run air through the lines to keep them dry. Once air is through the lines, turn off all of the machines.
- 15) Repeat as necessary.

V. Elemental Combustion Analysis (ECA)

Overview of technique For total nitrogen and total carbon analysis, sample materials in solid or liquid states must be converted into N_2 and CO_2 gases.

For N, the Kjeldahl-Rittenberg procedure (e.g. Hauck 1982) has a long history and a large following. In this wet-chemistry method an acid digestion is used to produce an ammonium salt, which is then oxidized to N_2 gas using hypobromite. This procedure is slow and laborious and involves certain hazards such as hot acid fumes. It also requires care to avoid loss of N during transfer between steps.

The alternative, elemental combustion analysis for total carbon and total nitrogen in solid-phase samples (plant tissue, soils, sediments, etc.) is based on transformation to gas phase by extremely rapid and complete flash combustion of the sample material, and measurement of concentrations via gas chromatography (GC).



In the apparatus shown above, a rotating autosample changer: (a) delivers one tin-encapsulated sample at a time into the top of a quartz combustion tube (b). This tube contains granulated chromium III oxide combustion catalyst and is held at 1000 degrees C. A pulse of pure O₂ is admitted with each sample, which is enclosed in an ultra-pure tin combustion capsule. Thermal energy from the combustion of the tin and the sample material can generate an instantaneous temperature of as much as 1700 degrees C at the moment of flash combustion. All combustible materials in the sample are burned and the resulting gas-phase combustion products are swept out the bottom of the furnace by a constant stream of non-reactive helium carrier gas.

All carbon in the sample is converted CO₂ during flash combustion. Nitrogen-bearing combustion products include N₂ and various oxides of nitrogen NO_x; these pass through a reduction column filled with chopped Cu wire (600 degrees C) in which the nitrogen oxides give up their oxygen to the copper and emerge as N₂.

Water vapor from the sample is removed by a gas trap (d) containing magnesium perchlorate. If the samples are being analyzed for nitrogen only, CO₂ is removed by a second gas trap containing a CO₂ scrubber (sodium hydroxide on silicate carrier granules).

The clean sample gases now pass through a gas chromatograph column (E) to separate the N₂ and CO₂. N₂ elutes from the GC column first, then CO₂.

The sample gas pulses and a separate reference stream of helium (f) pass through a detector (g); differences in thermal conductivity between the two streams are displayed as visible peaks and recorded as numerically integrated areas.

Linear regression applied to combustion of known standard materials yields a regression line by means of which peak areas from unknowns are converted into total element values for each sample.

Calibration and reference materials The Elemental Combustion Analyzer at F&M is a Costech ECS 4010 CHNS-O system. It is calibrated by including five solid-phase reference materials in the tin capsule stage at the beginning of each run, and at fixed intervals thereafter (usually one reference standard per ten unknowns.)

Ultra-high purity acetanilide (four samples in ca. 0.25, 0.50, 0.70 and 1.00 micrograms increments) and atropine (at ca. 0.1 micrograms) were used to generate the calibration curve; total C and total N contents of these materials are calculated from their chemical formulae.

Empty tin-capsule blanks are included every tenth sample, and any detectable N or C in these blanks was subtracted from the sample and standard values to give a true zero baseline. Blanks allow correction for traces of C originating from the tin capsules and for the small amount of N₂ gas introduced as an impurity in the oxygen pulse.

Analytical Procedures

- 1) Soil were oven-dried (80 degrees C, 24 hours).
- 2) Dried samples are ground to talcum powder consistency (250 um or less) using a ball mill (e.g. Spex Industries 8000) before being sealed into 5 x 9 mm tin capsules. Thorough sample homogenization in the grinder stage is required, to make certain that the tiny subsample taken for analysis is representative of the total sample. Poor precision can often be traced to visible granules in the sample.
- 3) Roughly 25 micrograms of soil samples are weighed into pure tin capsules using an automated and computer controlled microbalance.
- 4) In addition to the calibration standards, a certified standard reference soil (ECA 542) and an internal soils standard (BS-1 13) were analyzed every ten unknowns.
- 5) All samples, standards and blanks we loaded in a 50-slot auto-changer carousel.
- 6) Automated analyses were controlled by Windows-based EAS Software with a multichannel 24 bit A/D interface connected to the electronic detection system in the ECA.
- 7) The ECS software compares the elemental peak to the calibration standard data, and generates a report for each element on a weight basis.

Bibliography

Costech Instruments, 2006, Elemental Combustion System CHNS-O, www.costechanalytical.com

Hauck, R. D. 1982. Nitrogen-Isotope Ratio Analysis, sec.36-3.2.2, Conversion of total nitrogen to ammonium-nitrogen. pp.744ff. In **Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties**. American Society of Agronomy, Madison, Wisconsin.

Kirsten, Wolfgang. 1983. **Organic Elemental Analysis: Ultramicro, Micro, and Trace Methods**. Academic Press/Harcourt Brace Jovanovich, New York.

University of Georgia Institute of Ecology, Elemental Analysis by Micro-Dumas Combustion. www.uga.edu/~sisbl/

Appendix 3 Analytical Results for Standards

**Certified Standard MONT.
2711**

(Note: Certified values for complete digestion)

Element	Certified Values Range (Median)	Meas. for 0.5g	S.D.	Meas. for 0.25g	S.D.	Meas.	S.D.	Meas.	S.D.	Meas.	S.D.	Meas.	S.D.
Ba	170-260 (200)	179	2	178	2	181.6	1.4	168.6		169.2	3.5	169.2	
Cd	32-46 (40)	36.6	0.7	35	0.7	29.0	0.7	39.0		39.9	0.3	38.5	
Cr	15-25 (20)	17.2	0.2	16.8	0.4	14.5	0.5	15.8		15.3	1.3	15.7	
Co	7-12 (8.2)	4.14	0.08	N/A	N/A	3.9	0.1	7.8		7.9	0.3	7.8	
Cu	91-110 (100)	125	2	122	2	101.2	3.0	103.2		84.5	0.5	96.4	
Mn	400-620 (490)	468	6	477	15	433.9	10.7	475.0		467.2	6.1	457.1	
Mo	N/A	N/A	N/A	N/A	N/A	22.8	0.1	N/A					
P	N/A	N/A	N/A	N/A	N/A	492.9	31.3	698.7		512.6	1.4	513.1	
Pb	930-1500 (1100)	N/A	N/A	N/A	N/A	922.7	N/A	1058.1		1099.7	13.0	1050.7	
Ni	14-20 (16)	19.5	0.4	18.5	0.2	18.4	0.2	16.6		16.3	0.5	17.2	
Zn	290-340 (310)	272	4	273	2	243.2	10.7	298.9		318.3	5.9	301.4	

Certified Standard STSD4

(Note: Certified values for complete digestion)

Element	Certified Values	Meas. for 0.5g	S.D.	Meas. for 0.25g	S.D.
Cd	0.6	2.46	0.0	0.7	0.2
Co	11	7.01	0.1	2.6	0.2
Cr	30	25.8	0.2	25	0.5
Cu	66	74.5	0.2	72	2
Mn	1200	1080	3.0	1092	38
Mo	2	1.2	0.3	N/A	N/A
Ni	23	27.7	0.3	25.6	0.2
Pb	13	26	2.0	15	2
Zn	82	68.6	0.5	75	3

Certified Standard EAR 540(Note: Certified values for EPA 3051 Method -- microwave partial digestion using HNO₃)

Element	Certified Values	Meas.	S.D.
Ba	124-184 (154)	154.2	14.0
Cd	197-283 (240)	169.6	7.6
Cr	45.6-69.2 (57.4)	52.1	3.2
Co	49.1-81.9 (65.5)	63.2	5.5
Cu	106-156 (131)	129.3	12.4
Mn	234-338 (286)	273.8	18.4
Mo	41.9-67.1 (54.5)	22.8	0.1
P	N/A	533.3	8.7
Pb	61.6-95.2 (78.4)	51.6	11.8
Ni	39.0-57.6 (48.3)	54.3	3.8
Zn	90.20136 (113)	97.4	3.1

Certified Standard EAR 542

Element	Certified Values	Meas.	S.D.	Meas.	S.D.	Meas.	S.D.	Meas.	S.D.
P	373-987 (680)	769		720	11	696.5	38.3	670	
N	652-1630 (1140)	1019	33	1378	102	1014	51	1084	24
C	4480-13200 (8850)	8480	221	10133	948	7970	144	8388	99

Internal Standard BS-1 #12

Element	PSU Lab	Meas.	S.D.	Meas.	S.D.
Cu	11.64	13	1	11.7	0.1
Cr	14.09	10.1	0.7	10.6	0.1
Ni	13.95	15	1	14.9	0.2
P	455.8	352	24	359	3
Pb	15.52	28	3	25	1
Zn	50.66	45	4	44.2	0.7

Internal Standard BS-1 #13

Element	PSU Lab	Meas.	S.D.	Meas.	S.D.	Meas.	S.D.
Cu	10.79	9.9	4.7	12.4	0.2	7.3	1.5

Cr	12	10.5	4.6	12.5	1.6	12.5	0.1
Ni	12.51	12.4	5.8	15.5	1.6	16.0	0.2
Pb	14.09	24.5	6.9	22.1	9.6	18.2	1.4
P	438.8	438	17	429	20	409	7
Zn	48.94	43.8	19.2	51.9	6.8	59.8	4.1

Appendix 4
Analytical Results for Big Spring Run

ECA Data Sample #	%N %	N (ppm) ppm	%C %	C (ppm) ppm	P (ppm) ppm ICP- 3051	Depth (cm)
Trench 3	ECA		ECA			
BS-1-1	0.19	1900	1.70	17000	607	2.5
BS-1-2	0.36	3600	2.95	29500	768	7.5
BS-1-3	0.24	2400	1.96	19600	666	12.5
BS-1-4	0.17	1700	1.34	13400	590	17.5
BS-1-5	0.12	1200	0.99	9900	476	22.5
BS-1-6	0.09	900	0.83	8300	434	27.5
BS-1-7	0.11	1100	0.94	9400	481	32.5
BS-1-8	0.10	1000	0.88	8800	482	37.5
BS-1-9	0.10	1000	0.84	8400	444	42.5
BS-1-10	0.11	1100	0.89	8900	417	47.5
BS-1-11	0.11	1100	0.90	9000	402	52.5
BS-1-12	0.11	1100	0.89	8900	456	57.5
BS-1-13	0.11	1100	0.90	9000	439	62.5
BS-1-14	0.13	1300	1.02	10200	495	67.5
BS-1-15	0.13	1300	1.08	10800	505	72.5
BS-1-16	0.15	1500	1.21	12100	544	77.5
BS-1-17	0.18	1800	1.44	14400	576	82.5
BS-1-18	0.24	2400	2.24	22400	664	87.5
BS-1-19	0.29	2900	2.88	28800	700	92.5
BS-1-20	0.17	1700	1.65	16500	525	97.5
BS-1-21	0.17	1700	1.62	16200	561	102.5
BS-1-22	0.19	1900	1.98	19800	627	107.5
BS-1-23	0.13	1300	1.52	15200		112.5
BS-1-24	0.14	1400	1.67	16700		117.5
BS-1-25	0.19	1900	2.62	26200		122.5

BS-1-26	0.28	2800	4.32	43200		127.5
	Average	1658		15869	539	65
	lbs/ton	3.3		31.7	1.1	
Trench 2						
BST2-62	0.32	3200	2.76	27600	703	2.5
BST2-61	0.23	2300	1.88	18800	587	7.5
BST2-60	0.18	1800	1.50	15000	548	12.5
BST2-59	0.13	1300	1.15	11500	502	17.5
BST2-58	0.11	1100	0.99	9900	481	22.5
BST2-57	0.12	1200	1.02	10200	452	27.5
BST2-56	0.10	1000	0.86	8600	413	32.5
BST2-55	0.10	1000	0.89	8900	417	37.5
BST2-54	0.11	1100	0.90	9000	421	42.5
BST2-53	0.10	1000	0.91	9100	430	47.5
BST2-52	0.10	1000	0.88	8800	402	52.5
BST2-51	0.11	1100	1.00	10000	492	57.5
BST2-50	0.11	1100	1.00	10000	467	62.5
BST2-49	0.12	1200	1.06	10600	471	67.5
BST2-48	0.13	1300	1.10	11000	473	72.5
BST2-47	0.12	1200	1.10	11000	502	77.5
BST2-46	0.16	1600	1.37	13700	521	82.5
BST2-45	0.17	1700	1.44	14400	491	87.5
BST2-44	0.16	1600	1.45	14500	475	92.5
BST2-43	0.15	1500	1.38	13800	416	97.5
BST2-42	0.07	700	0.72	7200	200	102.5
BST2-41	0.04	400	0.41	4100	151	107.5
BST2-40	0.04	400	0.42	4200	148	112.5
BST2-39	0.04	400	0.37	3700	140	117.5
BST2-38	0.05	500	0.45	4500	188	122.5
BST2-37	0.06	600	0.59	5900	368	127.5
BST2-36	0.05	500	0.51	5100	325	132.5
	Average	1178		10411	414	
	lbs/ton	2.4		20.8	0.8	

ICP Data

Sample #	Lab #	Depth (cm)	Cd ppm	Cu ppm	Cr ppm	Pb ppm	Ni ppm	Zn ppm	TP ppm
BS-1-1		2.5	<0.25	17.2	14.4	23.6	13.4	71.7	607
BS-1-2		7.5	<0.25	18.2	13.1	25.3	13.5	82.6	768
BS-1-3		12.5	<0.25	17.8	13.8	27.9	13.7	73.5	666
BS-1-4		17.5	<0.25	18.1	15.3	25.8	14.5	67.7	590
BS-1-5		22.5	<0.25	17.1	12.7	21.7	12.7	57.1	476
BS-1-6		27.5	<0.25	16.1	11.5	18.5	12.0	53.4	434
BS-1-7		32.5	<0.25	17.1	11.4	19.3	12.2	54.2	481
BS-1-8		37.5	<0.25	14.5	13.0	19.0	13.3	54.8	482
BS-1-9		42.5	<0.25	13.1	11.6	17.8	12.2	51.7	444
BS-1-10		47.5	<0.25	12.6	11.1	18.0	11.8	49.9	417
BS-1-11		52.5	<0.25	12.1	12.0	16.0	12.5	49.2	402
BS-1-12		57.5	<0.25	11.6	14.1	15.5	14.0	50.1	456
BS-1-13		62.5	<0.25	10.8	12.0	14.1	12.5	48.9	439
BS-1-14		67.5	<0.25	12.3	13.1	16.1	13.8	52.2	495
BS-1-15		72.5	<0.25	12.5	14.3	15.0	15.0	54.4	505
BS-1-16		77.5	<0.25	14.1	17.0	26.7	18.5	62.2	544
BS-1-17		82.5	<0.25	14.4	18.3	17.5	18.4	62.4	576
BS-1-18		87.5	<0.25	10.7	15.8	15.3	15.4	57.9	664
BS-1-19		92.5	<0.25	8.7	13.3	13.9	13.1	45.8	700
BS-1-20		97.5	<0.25	5.3	11.0	13.5	11.3	33.9	525
BS-1-21		102.5	<0.25	4.3	11.7	12.1	12.4	34.9	561
BS-1-22		107.5	<0.25	4.7	15.2	13.9	15.6	41.1	627
BS-1-23		112.5	<0.25	4.1	16.8	15.0	14.9	42.6	
BS-1-24		117.5	<0.25	4.2	16.0	13.7	12.4	38.0	
BS-1-25		122.5	<0.25	6.0	14.5	13.8	12.8	41.1	
BS-1-26		127.5	<0.25	9.3	20.2	11.2	11.6	38.7	
Sample #	Lab #	Depth	Cd	Cu	Cr	Pb	Ni	Zn	TP
BST2-62	1	2.5	<0.25	17.3	15.9	25.4	15.8	85.2	703

BST2-61	2	7.5	<0.25	17.2	15.0	28.8	15.0	74.0	587
BST2-60	3	12.5	<0.25	16.8	16.1	28.6	15.5	70.8	548
BST2-59	4	17.5	<0.25	15.3	14.5	22.4	14.5	62.6	502
BST2-58	5	22.5	<0.25	13.8	16.6	19.2	15.0	58.6	481
BST2-57	6	27.5	<0.25	13.6	14.2	18.1	13.9	55.2	452
BST2-56	7	32.5	<0.25	11.8	14.6	15.2	13.8	50.8	413
BST2-55	8	37.5	<0.25	11.3	16.9	14.1	13.4	48.9	417
BST2-54	9	42.5	<0.25	11.7	13.4	14.1	13.2	49.5	421
BST2-53	10	47.5	<0.25	11.5	13.2	15.9	17.2	51.3	430
BST2-52	11	52.5	<0.25	11.0	13.0	12.3	13.0	48.6	402
BST2-51	12	57.5	<0.25	12.8	13.7	13.7	14.2	52.3	492
BST2-50	13	62.5	<0.25	12.8	14.8	14.6	15.2	55.6	467
BST2-49	14	67.5	<0.25	13.7	16.0	15.2	16.1	58.0	471
BST2-48	15	72.5	<0.25	13.5	14.6	20.8	15.1	57.4	473
BST2-47	16	77.5	<0.25	14.5	18.0	16.0	17.7	62.2	502
BST2-46	17	82.5	<0.25	14.8	17.7	15.9	17.8	64.8	521
BST2-45	18	87.5	<0.25	14.2	16.7	16.0	17.3	63.2	491
BST2-44	19	92.5	<0.25	13.9	17.3	17.4	17.4	64.1	475
BST2-43	20	97.5	<0.25	11.2	17.4	15.4	15.8	61.6	416
BST2-42	21	102.5	<0.25	7.3	14.8	50.3	11.1	51.6	200
BST2-41	22	107.5	<0.25	6.2	15.4	13.6	11.4	50.4	151
BST2-40	23	112.5	<0.25	5.7	12.0	12.2	9.3	39.6	148
BST2-39	24	117.5	<0.25	7.6	15.0	13.9	12.3	45.8	140
BST2-38	25	122.5	<0.25	9.2	20.3	16.5	18.5	57.8	188
BST2-37	26	127.5	<0.25	9.2	19.6	18.1	18.1	58.8	368
BST2-36	27	132.5	<0.25	7.3	19.5	16.1	18.9	56.9	325

Appendix 5
Analytical Results for Denlinger's Mill on West Branch Little Conestoga Creek

ECA Data

Sample	Wt. g	N %	N (ppm) ECA	C %	C (ppm) ECA	N/C	Depth (cm)	P (ppm) ICP	P (ppm) FI
DM-1a-3 5cm	23.835	0.248	2480	2.259	22590	0.042	5	846	939
DM-1a-3 10cm	26.793	0.106	1060	0.934	9340	0.042	10	707	689
DM-1a-3 15cm	24.079	0.085	850	0.756	7560	0.042	15	628	653
DM-1a-3 20cm	30.416	0.077	770	0.714	7140	0.040	20	620	716
DM-1a-3 25cm	21.472	0.081	810	0.720	7200	0.042	25	698	768
DM-1a-3 30cm	23.652	0.084	840	0.747	7470	0.042	30	592	654
DM-1a-3 35cm	22.446	0.078	780	0.706	7060	0.041	35	607	645
DM-1a-3 40cm	21.223	0.074	740	0.699	6990	0.040	40	634	866
DM-1a-3 45cm	27.248	0.071	710	0.656	6560	0.040	45	568	614
DM-1a-3 50cm	26.236	0.082	820	0.704	7040	0.044	50	687	699
DM-1a-3 55cm	21.416	0.084	840	0.727	7270	0.044	55	650	725
DM-1a-3 60cm	20.569	0.092	920	0.831	8310	0.042	60		
DM-1a-3 65cm	22.567	0.093	930	0.793	7930	0.044	65	779	628
DM-1a-3 70cm	23.797	0.075	750	0.750	7500	0.037	70	631	474
DM-1a-3 75cm	29.186	0.088	880	0.769	7690	0.043	75	725	556
DM-1a-3 80cm	26.853	0.077	770	0.696	6960	0.041	80	729	566
DM-1a-3 85cm	24.125	0.100	1000	0.842	8420	0.045	85	905	698
DM-1a-3 90cm	25.041	0.103	1030	0.896	8960	0.043	90	919	714
DM-1a-3 100cm	33.161	0.078	780	0.675	6750	0.043	100		
DM-1a-3 120cm	28.716	0.098	980	0.798	7980	0.046	120		
DM-1a-3 140cm	22.162	0.095	950	0.788	7880	0.045	140	993	679
DM-1a-3 160cm	22.668	0.097	970	0.849	8490	0.043	160		
DM-1a-3 180cm	28.838	0.094	940	0.838	8380	0.042	180		
DM-1a-3 200cm	31.205	0.121	1210	1.075	10750	0.042	200		
DM-1a-3 220cm	30.893	0.115	1150	1.013	10130	0.043	220		
DM-1a-3 240cm	24.080	0.132	1320	1.217	12170	0.041	240		

DM-1a-3 260cm	31.719	0.125	1250	1.201	12010	0.039	260		
DM-1a-3 280cm	27.532	0.151	1510	1.583	15830	0.036	280		
DM-1a-3 300cm	23.644	0.162	1620	1.939	19390	0.031	300		
DM-1a-3 320cm	21.276	0.167	1670	1.821	18210	0.034	320		
DM-1a-3 340cm	24.862	0.135	1350	1.249	12490	0.040	340		
DM-1a-3 360cm	25.418	0.156	1560	1.805	18050	0.033	360		
DM-1a-3 380cm	26.822	0.148	1480	1.766	17660	0.032	380		
DM-1a-3 400cm	27.348	0.153	1530	1.490	14900	0.039	400		
DM-1a-3 420cm	30.091	0.162	1620	1.628	16280	0.038	420	1000	831
DM-1a-3 440cm	31.164	0.033	330	2.179	21790	0.006	440	618	468
Avg.		0.109	1089	1.086	10865			727	679
lbs/ton			2.2		21.7			1.5	1.4
Avg. 0-100			935		8355				
Avg. 100-200			1010		8696				
Avg. 200-300			1370		13906				
Avg. 300-400			1518		16262				
Avg. 400-440			975		19035				
Wt. Avg.			1162		13251				

Internal Check on Reproducibility

DM-1a-3 100cm	33.161	0.078		0.675		0.043			
DM-1a-3 100cm b	32.810	0.079		0.670		0.044			
DM-1a-3 100cm c	24.552	0.077		0.688		0.042			
Avg.		0.078		0.678		0.0430			
S.D.		0.001		0.009		0.0010			
DM-1a-3 300cm	23.644	0.162		1.939		0.031			
DM-1a-3 300cm b	24.609	0.159		1.929		0.031			
DM-1a-3 300cm c	27.266	0.162		1.942		0.032			
Avg.		0.161		1.937		0.0314			

	S.D.	0.002	0.007	0.0003
Certified Standard				
ERA-542-1	28.329	0.141	1.053	0.0504
ERA-542-2	20.873	0.146	1.146	0.0477
ERA-542-3	26.052	0.154	1.141	0.0504
ERA-542-4	29.612	0.134	0.977	0.0514
ERA-542-5	27.836	0.143	1.02	0.0526
ERA-542-6	34.088	0.133	0.946	0.0526
ERA-543-7	30.238	0.122	0.891	0.0515
ERA-542-8	25.753	0.129	0.932	0.052
	AVG	0.14	1.013	0.051
	STD	0.01	0.095	0.002

**ERA
Certified
Range** **0.11
.065 -
.163**

Internal Standards				
BS-1-13a 60-65cm a	28.847	0.112	0.966	0.0433
BS-1-13a 60-65cm b	25.392	0.115	0.986	0.0437
BS-1-13a 60-65cm c	33.012	0.114	0.972	0.0438
	AVG	0.114	0.975	0.0436
	STD	0.002	0.010	0.0003
	PSU Data	0.11	0.90	

ICP Data									
Sample	Be	Al	Cr	Mn	Fe (1)	Cu	Zn	Mo	Ba
DM-1A #2	0.8	15662.4	22.0	769.9	28224.4	20.4	81.7	0.0	96.4
DM-1A #5	0.8	16594.1	28.9	893.8	35604.6	27.1	87.3	0.0	88.5
DM-1A #7	0.8	17860.2	21.5	864.1	26199.1	19.8	75.0	0.2	111.1
DM-1A #9	0.9	18815.7	18.5	881.8	24044.2	17.6	72.1	0.2	125.1
DM-1A #11	1.0	20296.1	18.3	996.4	25278.1	16.8	80.4	0.0	130.8

DM-1A #13	0.9	18345.9	16.6	910.3	22304.5	15.7	68.2	0.0	126.1
DM-1A #15	0.9	18436.1	17.1	926.5	22660.4	16.1	67.5	0.2	131.8
DM-1A #17	1.0	15308.9	14.2	932.8	22767.7	12.7	60.1	0.0	112.5
DM-1A #19	0.9	16574.8	15.4	962.9	20683.7	14.6	58.9	0.0	119.1
DM-1A #21	1.0	18980.2	16.0	1037.7	23013.7	17.6	69.4	0.2	145.8
DM-1A #23	1.0	18847.0	17.5	1110.2	24176.5	17.6	71.4	0.0	137.8
DM-1a #27	1.3	20849.3	17.7	1046.5	26417.2	19.7	76.8	0.0	151.4
DM-1a #29	1.1	16416.9	15.4	739.5	22935.1	16.3	63.1	0.0	116.8
DM-1a #31	1.3	20931.8	17.6	2202.8	26291.6	18.9	74.8	0.5	183.7
DM-1a #33	1.2	18631.9	16.7	952.4	27139.5	17.0	69.0	0.5	121.2
DM-1a #35	1.6	27767.0	21.7	1144.5	31521.0	21.9	97.6	0.0	195.2
DM-1a #37	1.6	27560.5	21.4	778.1	30501.1	22.7	97.3	0.0	188.2
DM-1b #55	2.0	27328.2	22.0	1102.1	35258.2	21.8	97.5	1.0	185.2
DM-1d #167	1.5	26780.8	20.7	1418.3	30418.0	22.6	87.1	0.5	185.3
DM-1d #171	1.4	12853.1	17.3	572.2	22235.7	11.8	52.6	0.0	72.7
ERA-542	0.6	7418.4	15.5	227.9	15117.7	50.6	68.0	0.2	82.6
ERA-542	0.8	14528.3	14.6	235.3	14508.2	55.3	62.7	0.5	78.9
BS-1 #13A	0.6	7834.4	7.3	373.9	10632.2	6.6	30.2	0.3	43.7
BS-1 #13a	1.1	15793.7	13.6	761.1	19137.8	12.5	56.7	0.5	91.5
MONT-2711	1.1	15748.6	17.8	490.0	19081.5	105.3	321.4	0.4	180.9
MONT-2711	0.0	14740.1	15.8	475.0	17390.4	103.2	298.9	0.6	168.6

Sample	Pb	Cd	Fe (2)	P (ICP)	P (Lachat)
DM-1A #2	48.1	3.6	32732.4	846.4	939.0
DM-1A #5	48.3	5.3	43115.6	706.7	688.5
DM-1A #7	41.5	3.8	30890.6	628.4	652.8
DM-1A #9	39.1	2.9	28535.0	620.4	716.2
DM-1A #11	48.1	2.6	28615.7	697.7	768.2
DM-1A #13	38.6	2.6	25565.6	591.7	654.0
DM-1A #15	35.2	2.7	26319.3	606.9	645.4
DM-1A #17	46.1	0.7	25337.0	633.6	865.6
DM-1A #19	34.2	2.4	23815.7	568.1	614.0

DM-1A #21	40.3	3.1	27021.6	686.7	699.5
DM-1A #23	34.2	2.6	25873.1	650.1	724.7
DM-1a #27	41.0	3.4	29201.2	778.7	627.9
DM-1a #29	31.9	3.5	24999.9	631.4	473.7
DM-1a #31	38.9	3.5	29133.9	725.4	556.3
DM-1a #33	34.3	3.5	30413.3	729.3	565.8
DM-1a #35	46.6	4.1	35172.9	905.2	697.7
DM-1a #37	50.1	4.1	34394.8	918.9	713.9
DM-1b #55	56.9	3.5	38552.3	993.5	679.1
DM-1d #167	36.3	4.3	35538.4	999.9	831.1
DM-1d #171	35.0	1.7	24172.7	617.8	468.1

ERA-542	33.0	1.4	15736.4	0.0	933.1
ERA-542	22.7	1.5	16015.3	798.6	667.1
BS-1 #13A	19.6	0.3	11088.7	320.9	397.5
BS-1 #13a	28.9	2.1	21112.0	602.9	443.2
MONT-2711	1079.8	39.6	19802.6	729.2	845.9
MONT-2711	1058.1	39.0	18899.1	698.7	591.2

ICP (PSU Lab) Sample #	Cd ppm	Cu ppm	Cr ppm	Pb ppm	Ni ppm	Zn ppm	TP ppm
DM-1a-2	<0.25	15.25	18.37	19.29	18.21	67.45	517
DM-1a-3	<0.25	18.25	23.23	22.98	24.82	71.80	673
DM-1a-4	<0.25	16.92	26.01	24.39	23.94	75.29	637
DM-1a-5	<0.25	21.38	25.19	22.20	23.60	74.34	597
DM-1a-7	<0.25	15.64	17.55	18.56	19.59	65.06	512
DM-1a-9	<0.25	14.77	15.12	18.96	16.93	63.79	507

Appendix 6
Analytical Results for Levan's Mill on Little Conestoga Creek

ECA Data

	N% AVG	N% SD	C% AVG	C% SD	Depth	C/N				
LM4	0.137	0.003	1.302	0.020	10	9.478				
LM5	0.114	0.002	1.025	0.017	30	9.018				
LM6	0.101	0.001	0.970	0.001	50	9.652				
LM7	0.119	0.008	1.254	0.003	70	10.582				
LM8	0.103	0.001	1.344	0.006	90	13.044				
LM9	0.125	0.002	1.431	0.004	110	11.494				
LM10	0.120	0.001	1.415	0.002	130	11.788				
LM11	0.151	0.008	1.902	0.020	150	12.638				
LM12	0.133	0.006	1.748	0.045	170	13.139				
LM13	0.124	0.001	1.366	0.008	190	11.061				
LM14	0.139	0.000	1.486	0.011	210	10.691				
LM15	0.209	0.001	2.855	0.021	230	13.691				
LM16	0.202	0.001	2.840	0.011	250	14.057				
LM1	0.069	0.017	6.623	0.258	270	95.986				
LM2	0.182	0.013	7.890	0.498	280	43.271				
LM3	0.163	0.033	9.103	0.439	300	55.845				
	N ppm	S.D.	C ppm	S.D.	Depth	C/N	n	% err N	% err C	P ppm
LM4	1373	32	13017	198	10	9.478	3	2.3	1.5	511
LM5	1137	21	10250	173	30	9.018	3	1.8	1.7	550
LM6	1005	7	9700	14	50	9.652	2	0.7	0.1	508
LM7	1185	78	12540	28	70	10.582	2	6.6	0.2	623
LM8	1030	14	13435	64	90	13.044	2	1.4	0.5	480
LM9	1245	21	14310	42	110	11.494	2	1.7	0.3	613
LM10	1200	14	14145	21	130	11.788	2	1.2	0.1	641
LM11	1505	78	19020	198	150	12.638	2	5.2	1.0	649

LM12	1330	57	17475	445	170	13.139	2	4.3	2.5	706
LM13	1235	7	13660	85	190	11.061	2	0.6	0.6	764
LM14	1390	0	14860	113	210	10.691	2	0.0	0.8	813
LM15	2085	7	28545	205	230	13.691	2	0.3	0.7	661
LM16	2020	14	28395	106	250	14.057	2	0.7	0.4	801
LM1	690	168	66230	2584	270	95.986	3	24.4	3.9	254
LM2	1823	127	78897	4983	280	43.271	3	7.0	6.3	326
LM3	1630	334	91027	4390	300	55.845	3	20.5	4.8	187
Avg.	1368		27844		150					568
lbs/ton	2.7		55.7							1.1

(LM4-16) **1365** **16104**
2.7 **32.2**

Sample	%N	N (ppm)	%C	C (ppm)	N/C Area
ERA542a	0.1	1000	0.864	8640	0.0413
ERA542b	0.107	1070	0.854	8540	0.0439
ERA542c	0.099	990	0.829	8290	0.0425
ERA542d	0.097	970	0.812	8120	0.0415
ERA542e	0.105	1050	0.874	8740	0.0427
ERA542f	0.104	1040	0.848	8480	0.0436
ERA542g	0.102	1020	0.832	8320	0.0443
	Avg.	1020		8447	
	S.D.	36		216	

ICP Data
Sample

#	Depth	Be (ppm)	SD	Cr (ppm)	SD	Mn (ppm)	SD	Co (ppm)	SD
LM4	10	1.7	0.0	17.2	0.6	857	7	6.8	0.1
LM5	30	X	X	18.2	0.7	1508	105	9.7	0.2
LM6	50	X	X	15.2	0.7	1133	12	8.2	0.5
LM7	70	0.7	0.0	19.5	0.9	1032	48	9.9	0.3

LM8	90	X	X	16.8	0.5	574	21	7.3	0.4
LM9	110	1.6	0.1	18.3	0.4	750	61	11.8	0.5
LM10	130	1.6	0.0	19.0	0.5	703	16	12.4	0.3
LM11	150	1.5	0.1	20.4	1.1	636	109	11.7	0.7
LM12	170	1.6	0.0	22.1	0.1	622	4	11.5	0.2
LM13	190	0.9	0.0	22.0	1.2	387	2	12.2	0.4
LM14	210	0.9	0.0	19.8	1.5	331	17	11.5	0.5
LM15	230	0.9	0.0	21.3	1.4	690	35	13.4	0.9
LM16	250	1.0	0.0	22.2	0.2	989	15	13.7	0.2
LM1	270	1.5	0.6	12.2	0.1	93.5	0.4	9.0	N/A
LM2	280	1.7	0.6	12.9	0.2	93.8	0.1	8.5	N/A
LM3	300	0.1	0.0	11.4	0.5	128	4	8.0	0.0

		Ni		Cu		Zn		Mo	
		(ppm)	SD	(ppm)	SD	(ppm)	SD	(ppm)	SD
LM4	10	22.7	0.3	15.0	0.2	81	2	N/A	N/A
LM5	30	21.4	0.9	19.8	0.5	85	5	N/A	N/A
LM6	50	18.6	1.0	16.6	0.6	67	3	N/A	N/A
LM7	70	23.0	1.1	19.4	0.6	95	2		
LM8	90	17.9	0.3	14.4	0.4	90	3		
LM9	110	22.1	0.6	18.7	0.2	167	1	4.0	0.1
LM10	130	21.4	0.7	17.1	0.1	98	5	3.4	0.1
LM11	150	21.4	0.9	17.3	0.8	108.5	0.4	4.1	0.1
LM12	170	22.6	0.3	18.2	0.4	112.4	0.0	4.2	0.5
LM13	190	23.5	0.9	20.6	0.7	110	4	N/A	N/A
LM14	210	21.7	1.9	19.0	0.9	99	7	N/A	N/A
LM15	230	22.0	1.1	19.0	1.0	116	11	N/A	N/A
LM16	250	23.7	0.1	20.2	0.3	106.7	0.2	N/A	N/A
LM1	270	8.0	0.1	12.0	N/A	67	8	N/A	N/A
LM2	280	11.1	0.0	11.0	N/A	106	45	N/A	N/A
LM3	300	8.9	0.2	10.0	N/A	61	2	23.7	0.2

Ba

Pb

Cd

P

		(ppm)	SD	(ppm)	SD	(ppm)	SD	(ppm)	SD
LM4	10	146	1	25.2	0.2	3.8	0.1	511	6
LM5	30	152	0	28.9	2.0	6.9	0.1	550	1
LM6	50	120	3	21.8	1.6	5.8	0.3	508	15
LM7	70	152	5	32.1	1.1	6.8	0.2	623	12
LM8	90	105	4	21.5	0.2	5.0	0.1	480	19
LM9	110	136	9	74.7	1.6	9.3	0.3	613	31
LM10	130	130	1	66.3	0.3	8.7	0.1	641	7
LM11	150	116	8	66.9	2.0	8.7	0.3	649	20
LM12	170	126	0	159.6	122.4	8.9	0.0	706	4
LM13	190	142	2	65.0	N/A	10.3	0.3	764	23
LM14	210	143	9	50.0	N/A	11.0	0.3	813	38
LM15	230	124	7	25.0	N/A	9.3	0.5	661	48
LM16	250	150	1	20.0	N/A	10.3	0.1	801	11
LM1	270	59	4	13.8	7.1	7.0	N/A	254	15
LM2	280	56	4	7.0	N/A	6.0	N/A	326	18
LM3	300	45	1	5.0	N/A	5.0	0.1	187	9

Appendix 7
Analytical Results for Hammer Creek

ECA Data											
Sample	Wt. (mg)	%N	N (ppm) ECA	%C	C (ppm) ECA	N/C	Depth	Locality	Type	P (ppm) ICP	P (ppm) FI
HC-1-17	21.107	0.221	2210	3.135	31350	0.0251		Hammer Cr.	Aggregate	993	974
HC-18	24.416	0.134	1340	2.248	22480	0.0209		Hammer Cr.	Aggregate	369	272
		Wtd. Avg	2162		30857					958	935
ERA 542-1	21.427	0.099	990	0.783	7830	0.0427			Std.	774.4	642.5
ERA 542-2	29.169	0.098	980	0.803	8030	0.0419			Std.	818.2	618.9
ERA 542-2	22.021	0.11	1100	0.804	8040	0.0464			Std.		
ERA 542-3	23.882	0.102	1020	0.781	7810	0.0445			Std.		
ERA 542-4	20.55	0.098	980	0.814	8140	0.0404			Std.		
		Avg.	1014	0.797	7970				Std.		
		S.D.	51	0.014	144						
BS-1 13-1	26.258	0.102	1020	0.959	9590	0.0363			Int. Std.	535.5	419.2
BS-1-13-2	35.029	0.102	1020	0.951	9510	0.0372			Int. Std.	553.8	401.2
BS-1 13-2	33.564	0.099	990	0.951	9510	0.036			Int. Std.		
BS-1 13-3	22.705	0.098	980	0.948	9480	0.0353			Int. Std.		
		Avg.	1003	0.952	9523				Int. Std.		
		S.D.	21	0.005	47						
ICP Data											
Sample	Be	Al	Cr	Mn	Fe (1)	Co	Ni	Cu	Zn		
HC-1	0.7	5184.4	8.81	327.1	9245.4	5.7	8.6	16.5	45.6		
HC-2	0.7	5497.7	9.7	268.0	9321.8	5.7	8.9	15.6	38.6		

HC-3	1.4	15735.0	22.7	635.8	28521.0	15.0	22.2	29.5	92.0
HC-4	1.4	14871.3	22.5	394.6	24484.2	15.3	21.3	28.4	91.1
HC-5	1.5	18361.9	26.2	384.2	23684.8	12.6	24.9	34.0	107.3
HC-6	1.2	11797.0	18.3	292.1	15756.6	11.2	17.8	27.7	81.5
HC 1-17	1.3	14394.7	21.1	431.2	20602.8	12.1	20.9	36.3	119.4
HC 1-17 (2)	1.3	15335.2	22.5	441.7	20990.4	12.6	21.7	36.0	97.5
HC 18	1.1	9613.8	14.5	240.0	12245.3	7.8	13.8	15.4	53.8
BS-1 #13a	1.0	13401.8	11.6	719.9	17553.4	9.5	14.9	14.4	51.4
BS-1 #13a	1.0	13588.6	11.8	715.5	18870.9	9.9	15.3	10.3	53.1

	Mo	Ba	Pb	Cd	Cd	Fe (2)	P (ICP)	P (FI)
HC-1	0.0	62.4	7.9	0.5	0.5	10033.3	406.1	325.3
HC-2	0.5	60.1	8.2	0.4	0.4	10207.1	390.7	297.1
HC-3	0.0	166.2	46.2	3.6	3.6	33429.2	1181.7	1018.8
HC-4	0.0	162.3	42.8	3.0	3.0	28140.4	1070.2	901.7
HC-5	0.6	176.4	45.8	3.1	3.1	26779.5	1246.1	1089.3
HC-6	0.0	114.9	32.6	1.6	1.6	17369.0	678.8	547.0
HC 1-17	1.5	144.2	46.5	0	2.3	21850.2	1003.1	1107.0
HC 1-17 (2)	1.5	146.5	47.8	0	2.5	22559.1	1011.1	1217.7
HC 18	1.5	112.3	29.3	0	1.0	13157.6	384.4	871.8
BS-1 #13a	0.5	83.2	17.6	0.0	1.7	19871.0	535.5	419.2
BS-1 #13a	1.5	83.7	19.3	0	1.9	19999.9	553.8	401.2

Appendix 8
Analytical Results for Conoy Creek

ECA Data											
Sample	Wt. (mg)	%N	N (ppm) ECA	%C	C (ppm) ECA	N/C	Depth	Locality	Type	P (ppm) ICP	P (ppm) FI
ETMV-8-3 (T1)	31.742	0.028	280	0.372	3720	0.0243		Conoy Cr.	Aggregate	214	847
ETMV-2-1 (T1)	34.089	0.082	820	1.14	11400	0.0251		Conoy Cr.	Aggregate	381	694
		Wtd. Avg.	415		5640					256	809
ETMV-10-17 (T2)	28.809	0.028	280	0.364	3640	0.024		Conoy Cr.	Aggregate	132	748
ETMV-18 (T2)	27.904	0.129	1290	1.633	16330	0.0276		Conoy Cr.	Aggregate	555	751
		Wtd. Avg.	533		6813					238	749
ERA 542-1	21.427	0.099	990	0.783	7830	0.0427			Std.	774.4	642.5
ERA 542-2	29.169	0.098	980	0.803	8030	0.0419			Std.	818.2	618.9
ERA 542-2	22.021	0.11	1100	0.804	8040	0.0464			Std.		
ERA 542-3	23.882	0.102	1020	0.781	7810	0.0445			Std.		
ERA 542-4	20.55	0.098	980	0.814	8140	0.0404			Std.		
		Avg.	1014	0.797	7970				Std.		
		S.D.	51	0.014	144						
BS-1 13-1	26.258	0.102	1020	0.959	9590	0.0363			Int. Std.	535.5	419.2
BS-1-13-2	35.029	0.102	1020	0.951	9510	0.0372			Int. Std.	553.8	401.2
BS-1 13-2	33.564	0.099	990	0.951	9510	0.036			Int. Std.		
BS-1 13-3	22.705	0.098	980	0.948	9480	0.0353			Int. Std.		
		Avg.	1003	0.952	9523				Int. Std.		
		S.D.	21	0.005	47						

ICP Data

Sample	Be	Al	Cr	Mn	Fe (1)	Co	Ni	Cu	Zn	Mo	Ba
ETMVT1 #08-03	0.9	9257.9	15.9	593.5	11131.3	7.0	9.8	2.2	28.3	1.5	87.4
ETMVT1 1-2	0.9	9293.8	14.3	462.1	12247.8	7.5	10.8	10.7	61.3	1.5	82.2
ETMVT2 10-17	1.0	9993.0	26.9	221.1	11692.2	6.4	10.1	2.9	34.1	1.5	79.4
ETMVT2 18	1.0	10544.5	17.7	488.6	13216.0	8.3	12.6	13.1	75.2	1.5	84.7
BS-1 #13a	1.0	13401.8	11.6	719.9	17553.4	9.5	14.9	14.4	51.4	0.5	83.2
BS-1 #13a	1.0	13588.6	11.8	715.5	18870.9	9.9	15.3	10.3	53.1	1.5	83.7
ERA-542	0.8	14777.7	13.1	224.1	13512.8	4.5	9.4	56.8	62.9	0.5	75.4
ERA-542	0.8	7899.1	14.2	233.1	15271.8	4.9	8.9	60.5	71.7	1.5	80.1
MONT-2711	0.0	15011.1	15.7	479.5	17111.8	7.8	16.6	109.7	302.9	0.6	167.4
MONT-2711	1.1	15171.4	16.1	464.4	18354.4	7.9	16.3	87.5	314.2	1.5	169.9
Sample	Pb	Cd	Cd	Fe (2)	P (ICP)	P (FI)					
ETMVT1 #08-03	9.2	N/A	0.7	11675.7	213.8	846.9					
ETMVT1 1-2	36.9	N/A	1.0	12954.0	380.8	694.1					
ETMVT2 10-17	12.5	N/A	0.7	12137.2	131.9	748.5					
ETMVT2 18	47.2	N/A	1.2	14066.0	555.0	750.9					
BS-1 #13a	17.6	0.0	1.7	19871.0	535.5	419.2					
BS-1 #13a	19.3	N/A	1.9	19999.9	553.8	401.2					
ERA-542	24.6	75.4	1.4	15159.2	774.4	642.5					
ERA-542	25.4	N/A	1.6	15814.3	818.2	618.9					
MONT-2711	1070.8	38.9	38.9	19253.4	709.6	589.4					
MONT-2711	1078.9	134.0	0.0	19181.2	712.3	312.1					

Appendix 9
Analytical Results for East Branch Codorus Creek

ECA Data										
Sample	Wt. (mg)	%N	N (ppm)	%C	C (ppm)	N/C	Depth	Locality	Type	P (ppm)
EBCC-1	28.066	0.174	1740	1.862	18620	0.0348	5	EB Codorus Cr.	Sequence	ICP
EBCC-2	26.382	0.119	1190	1.277	12770	0.0342	15	EB Codorus Cr.	Sequence	
EBCC-3	25.948	0.093	930	0.946	9460	0.0355	25	EB Codorus Cr.	Sequence	
EBCC-4	19.867	0.087	870	0.873	8730	0.0356	35	EB Codorus Cr.	Sequence	
EBCC-5	21.283	0.068	680	0.78	7800	0.0307	45	EB Codorus Cr.	Sequence	
EBCC-6	24.072	0.08	800	0.888	8880	0.0321	55	EB Codorus Cr.	Sequence	
EBCC-7	20.276	0.089	890	0.937	9370	0.0338	65	EB Codorus Cr.	Sequence	
EBCC-8	26.721	0.075	750	0.903	9030	0.03	75	EB Codorus Cr.	Sequence	
EBCC-9	26.429	0.065	650	0.853	8530	0.027	85	EB Codorus Cr.	Sequence	
EBCC-10	25.604	0.046	460	0.628	6280	0.0257	95	EB Codorus Cr.	Sequence	
EBCC-11	23.774	0.036	360	0.436	4360	0.028	105	EB Codorus Cr.	Sequence	
EBCC-12	26.092	0.034	340	0.411	4110	0.0285	115	EB Codorus Cr.	Sequence	
EBCC-13	32.595	0.034	340	0.482	4820	0.0248	125	EB Codorus Cr.	Sequence	
EBCC-14	24.639	0.036	360	0.521	5210	0.0235	135	EB Codorus Cr.	Sequence	
EBCC-15	33.063	0.033	330	0.5	5000	0.0231	145	EB Codorus Cr.	Sequence	

EBCC-16	19.259	0.137	1370	2.848	28480	0.0177	155	EB Codorus Cr.	Sequence	
EBCC-17	21.236	0.137	1370	2.773	27730	0.0182	165	EB Codorus Cr.	Sequence	
		Avg.	790		10540		85			
		lbs/ton	1.6		21.1					
EBCC 1-15		0.0713	713	0.8198	8198				Average	
EBCC 16-17		0.137	1370	2.8105	28105				Average	
		Wtd.								
		Avg.	790		10540					
EBCC 1-15	23.061	0.043	430	0.598	5980	0.0248	75	EB Codorus Cr.	Aggragate	260.8
EBCC 16-17	19.504	0.148	1480	2.902	29020	0.0189	160	EB Codorus Cr.	Aggragate	225.6
		Wrt.								
		Avg.	554		8691					257
ERA 541-1	23.719	0.111	1110	0.829	8290	0.0481		Std.	Std.	774.4
ERA 542-2	29.44	0.107	1070	0.833	8330	0.0465		Std.	Std.	818.2
ERA 542-3	26.984	0.11	1100	0.834	8340	0.0476		Std.	Std.	
EAR 542-4	31.659	0.105	1050	0.845	8450	0.045		Std.	Std.	
ERA 542-5	30.704	0.109	1090	0.853	8530	0.0465		Std.	Std.	
		Avg.	1084		8388					796
		S.D.	24		99					31
BS-1 13-1	20.642	0.105	1050	0.963	9630	0.039		Int. Std.	Int. Std.	535.5
BS-1 13-2	21.519	0.107	1070	0.959	9590	0.0401		Int. Std.	Int. Std.	553.8

BS-1 13-3	24.23	0.108	1080	0.973	9730	0.0403		Int. Std.	Int. Std.	
BS-1 13-4	21.051	0.101	1010	0.959	9590	0.0378		Int. Std.	Int. Std.	
		Avg.	1053		9635					545
		S.D.	31		66					13
ICP Data										
Sample	Depth	Be	Al	Cr	Mn	Fe (1)	Co	Ni	Cu	Zn
EBCC 1-15	0-150	0.7	15498.3	21.8	281.6	36924.8	13.3	19.0	3.4	71.1
EBCC 16-17	150-170	0.8	14435.0	23.3	190.8	13724.4	11.4	22.0	6.1	73.2
		Mo	Ba	Pb	Cd	Fe (2)	P (ICP)	P (FI)		
EBCC 1-15	1.5	34.9	21.7	N/A	4.7	41699.7	260.8	847.8		
EBCC 16-17	1.5	39.2	19.2	N/A	0.0	14577.1	225.6	416.2		

Appendix 10
Analytical Results for East Branch Penns Creek

ECA Data

Sample	%N ECA	N (ppm) ECA	%C ECA	C (ppm) ECA	N/C ECA	Depth	Locality	Type	P (ppm) ICP	P (ppm) FI
PC-1	0.295	2950	3.11	31100	0.034	5	Penns Cr.	Sequence	726	506
PC-2	0.252	2520	2.445	24450	0.0368	15	Penns Cr.	Sequence	691	504
PC-3	0.193	1930	1.834	18340	0.0373	25	Penns Cr.	Sequence	678	459
PC-4	0.182	1820	1.807	18070	0.0355	35	Penns Cr.	Sequence	527	382
PC-5	0.177	1770	1.815	18150	0.0345	45	Penns Cr.	Sequence	524	370
PC-6	0.154	1540	1.525	15250	0.0352	55	Penns Cr.	Sequence	469	336
PC-7	0.097	970	0.939	9390	0.0352	65	Penns Cr.	Sequence	362	262
PC-8	0.089	890	0.785	7850	0.0388	75	Penns Cr.	Sequence	319	255
PC-9	0.099	990	0.832	8320	0.0404	85	Penns Cr.	Sequence	329	244
PC-10	0.085	850	0.561	5610	0.0505	95	Penns Cr.	Sequence	294	217
PC-11	0.063	630	0.369	3690	0.0564	105	Penns Cr.	Sequence	234	182
PC-12	0.072	720	0.443	4430	0.0538	115	Penns Cr.	Sequence	296	224
PC-13	0.087	870	0.719	7190	0.0413	125	Penns Cr.	Sequence	337	238
PC-14	0.077	770	0.568	5680	0.0463	135	Penns Cr.	Sequence	358	326
PC-15	0.073	730	0.495	4950	0.0496	145	Penns Cr.	Sequence	389	296
PC-16	0.062	620	0.366	3660	0.0556	175	Penns Cr.	Sequence	1376	1242
PC-17	0.062	620	0.482	4820	0.0427	185	Penns Cr.	Sequence	866	727
PC-18	0.163	1630	4.243	42430	0.0142	200	Penns Cr.	Sequence	156	128
PC-19	0.105	1050	2.118	21180	0.0171	205	Penns Cr.	Sequence	183	156
	Avg. lbs/ton	1256 2.5		13398 26.8		102.5		Avg.	480 0.96	
PC-1-17	31.021	0.114	1.11	11100	0.0357	87.5	Penns Cr.	Aggregate	526	394
PC-18-19	31.569	0.116 Wtd. Avg.	2.869	28690	0.0146	202.5	Penns Cr.	Aggregate	179	142
ERA 542-1	21.427		0.783	7830	0.0427			Std.	774.4	642.5

ERA 542-2	29.169	0.099	0.803	8030	0.0419	Std.	818.2	618.9
ERA 542-2	22.021	0.098	0.804	8040	0.0464	Std.		
ERA 542-3	23.882	0.11	0.781	7810	0.0445	Std.		
ERA 542-4	20.55	0.102	0.814	8140	0.0404	Std.		
	Avg.	0.098	0.797	7970			796	631
	S.D.	0.1014	0.014	144			31	17
		0.0051						
BS-1 13-1	26.258		0.959	9590	0.0363	Int. Std.	535.5	419.2
BS-1-13-2	35.029	0.102	0.951	9510	0.0372	Int. Std.	553.8	401.2
BS-1 13-2	33.564	0.102	0.951	9510	0.036	Int. Std.		
BS-1 13-3	22.705	0.099	0.948	9480	0.0353	Int. Std.		
	Avg.	0.098	0.952	9523			545	410
	S.D.	0.100	0.005	47			13	13
		0.002						

ICP Data

Sample	Depth	Be	Al	Cr	Mn	Fe (1)	Co	Ni	Cu	Zn
PC-1	0-10	1.3	12826.6	14.3	772.3	19916.0	11.2	23.6	19.5	N/A
PC-2	10-20	1.4	13498.5	14.5	810.3	20444.2	11.7	24.1	19.2	N/A
PC-3	20-30	1.9	17411.5	18.5	936.6	23549.2	13.2	25.7	16.1	N/A
PC-4	30-40	1.4	17548.8	17.7	834.5	20535.8	12.0	24.7	16.9	N/A
PC-5	40-50	1.4	17389.9	17.8	870.1	21261.8	12.4	25.9	16.6	N/A
PC-6	50-60	1.5	18378.5	18.9	933.2	21655.9	14.0	27.4	16.5	N/A
PC-7	60-70	1.6	19042.9	19.3	652.0	23908.5	14.1	25.7	20.9	N/A
PC-8	70-80	1.5	18061.6	19.2	512.8	24151.1	12.8	24.0	19.6	N/A
PC-9	80-90	1.5	19672.8	20.8	547.5	25346.9	13.2	25.8	22.2	N/A
PC-10	90-100	1.4	20550.9	22.1	401.7	25317.2	12.2	27.3	22.3	N/A
PC-11	100-110	1.1	16245.3	19.0	235.0	22694.1	8.6	21.0	17.1	N/A
PC-12	110-120	1.3	18636.4	21.6	219.1	24910.3	7.4	25.3	20.9	N/A
PC-13	120-130	1.6	18706.3	21.7	821.4	26664.3	17.7	26.7	27.4	N/A
PC-14	130-140	1.8	19607.4	22.6	930.0	28181.8	15.8	29.6	23.8	N/A

	140-									
PC-15	150	1.8	19564.8	22.0	1278.3	28311.9	17.9	31.6	36.3	N/A
PC-16	175	1.7	20450.3	22.9	632.7	67167.0	18.0	41.0	36.8	N/A
	180-									
PC-17	190	1.3	14949.2	17.6	158.3	35622.8	6.4	23.9	26.2	N/A
PC-18	200	1.0	7928.1	11.1	91.2	9525.7	13.1	28.5	29.8	N/A
PC-19	200	0.8	7848.8	10.8	115.0	10883.0	10.1	22.7	19.7	N/A
PC 1-17	0-190	1.3	17832.2	20.6	638.1	29320.8	12.1	28.5	21.2	70.0
PC 1-17	0-190	1.3	19299.3	22.0	716.4	30478.0	13.8	30.0	22.1	75.3
PC 1-17	0-190	1.8	18925.6	20.8	718.2	31652.9	14.2	28.1	5.6	80.0
PC 18-19	200	0.8	8524.3	10.6	94.9	10253.2	9.9	22.7	8.7	42.4
PC 18-19	200	0.8	8167.6	11.9	91.3	11282.3	11.1	26.1	18.2	43.0
PC 18-19	200	0.8	9342.6	13.5	102.3	12234.6	12.5	30.7	16.8	47.5
BS-1 #13a		1.0	13401.8	11.6	719.9	17553.4	9.5	14.9	14.4	51.4
BS-1 #13a		1.0	13588.6	11.8	715.5	18870.9	9.9	15.3	10.3	53.1
BS-1 #13a		1.0	14585.4	12.3	702.2	18700.8	9.7	15.8	8.0	63.3
BS-1 #13a		1.0	15089.8	12.5	704.1	18963.1	9.9	16.0	8.3	60.9
BS-1 #13a		0.987107	14826.8	12.6	727.4	19258.7	10.2	16.2	5.6	55.3
BS-1 #13a		1.148268	15793.7	13.6	761.1	19137.8	10.2	16.7	12.5	56.7
BS-1 #13a		0.987897	12943.5	11.4	707.1	17560.4	9.1	14.3	12.2	47.2
ERA-542		0.685346	6240.7	11.6	191.7	12396.7	3.9	8.7	42.3	76.3
ERA-542		0.745519	7487.4	13.7	222.4	14991.0	4.8	89.1	69.2	79.8
ERA-542		0.743197	10465.0	13.5	231.6	14663.1	4.9	10.9	48.6	70.2
ERA-542		0.763589	14528.3	14.6	235.3	14508.2	4.5	8.7	55.3	62.7
ERA-542		0.783683	6930.6	13.5	222.0	13603.9	4.3	27.0	79.1	70.4
MONT-2711		1.121076	13514.1	14.3	462.9	16877.3	7.7	15.9	84.2	314.1
MONT-2711		1.141459	15307.8	16.2	471.5	18548.7	8.1	16.6	84.9	322.5
MONT-2711		2.8E-05	14740.1	15.8	475.0	17390.4	7.8	16.6	103.2	298.9

Sample	Mo	Ba	Pb	Cd	Cd	Fe (2)	P (ICP)	P (FI)
PC-1	0.0	102.9	43.0	2.3	2.3	21739.6	726.0	506.1
PC-2	0.5	112.0	43.7	2.4	2.4	22201.3	690.8	504.4
PC-3	0.0	140.2	42.9	1.9	1.9	25411.6	677.9	459.4
PC-4	0.6	143.5	23.5	0	2.4	23025.0	527.3	381.7
PC-5	0.6	155.0	21.0	0	2.5	23726.7	524.2	369.8
PC-6	0.6	159.5	20.2	0	2.7	24725.9	469.4	336.0
PC-7	0.6	138.4	18.9	0	2.9	27243.1	362.4	262.2
PC-8	0.6	119.1	18.5	0	2.8	27050.9	318.8	254.8
PC-9	0.6	113.1	21.7	0	3.1	28432.4	329.5	244.4
PC-10	0.6	108.5	21.0	0	3.1	28515.4	294.4	216.7
PC-11	0.6	82.3	15.8	0	2.5	25056.0	234.1	181.6
PC-12	0.6	97.8	17.0	0	3.0	28715.7	295.8	224.2
PC-13	0.6	124.2	20.7	0	0.0	30777.6	336.7	237.7
PC-14	0.6	151.9	22.3	188.3	0.0	32789.3	357.6	326.4
PC-15	0.0	162.7	25.0	1.9	3.7	31967.0	388.5	295.8
PC-16	0.0	191.4	48.4	11.5	4.9	89305.8	1375.9	1242.4
PC-17	0.6	137.1	22.4	4.9	4.9	42479.7	866.5	726.9
PC-18	1.0	51.9	15.1	0.6	0.6	10630.5	155.9	128.0
PC-19	0.0	50.9	8.1	0.7	0.7	11965.2	183.4	156.0
PC 1-17	0.8	133.3	25.7	133.3	3.7	30829.2	496.7	359.5
PC 1-17	0.8	139.3	30.6	0	3.9	32317.0	511.0	378.1
PC 1-17	3.0	134.0	29.0	134.0	2.6	33636.4	569.4	1698.3
PC 18-19	1.5	47.0	9.5	0	0.6	10556.6	157.5	1448.4
PC 18-19	1.0	52.0	10.2	0	1.0	11195.0	171.5	137.2
PC 18-19	0.8	58.9	13.9	0	1.2	12193.2	187.3	146.2
BS-1 #13a	0.5	83.2	17.6	0.0	1.7	19871.0	535.5	419.2
BS-1 #13a	1.5	83.7	19.3	0	1.9	19999.9	553.8	401.2
BS-1 #13a	1.5	84.4	17.4	0	1.9	19891.1	586.6	413.6
BS-1 #13a	1.5	85.9	19.9	0	1.9	19971.8	581.2	413.6
BS-1 #13a	1.5	86.6	17.4	0.0	2.0	20487.5	571.7	400.9

BS-1 #13a	0.5	91.5	28.9	0.0	2.1	21112.0	602.9	443.2
BS-1 #13a	0.5	80.5	15.3	0	1.8	19495.9	533.5	415.3
ERA-542	1.5	67.7	18.4	0	0.0	13142.5	759.7	536.2
ERA-542	1.5	76.6	23.1	130.1	0.0	15716.4	833.6	616.6
ERA-542	1.5	81.1	22.1	81.1	1.4	15305.8	814.5	618.7
ERA-542	0.5	78.9	22.7	78.9	1.5	16015.3	798.6	667.1
ERA-542	0.5	75.3	19.0	0	1.3	15030.6	783.5	629.0
MONT- 2711	1.5	166.7	1090.5	0	39.7	17855.7	725.8	511.6
MONT- 2711	1.5	171.6	1108.8	0	40.2	19364.0	734.0	513.7
MONT- 2711	0.6	168.6	1058.1	39.0	39.0	18899.1	698.7	591.2

Appendix 11
Analytical Results for East Branch Emmas Creek

ECA Data

Sample	Depth (cm)	N (ppm) ECA	C (ppm) ECA	P (ppm) ICP	P (ppm) FI		Locality	Type
EC5B 1-17	0-170	1250	13210	374	293		Emmas Cr.	Aggregate
EC1 #1-9	0-90	1540	15490	438	338	388	Emmas Cr.	Aggregate
EC1 10-13	90-120	2250	41790	251	204	228	Emmas Cr.	Aggregate
	Wtd. Avg.	1758	23582	381	297	339		
MONT 2711				670	513			Std.
ERA 542		1084	8388	743	598			Std.
BS-1 #13A		1053	9635	512	379			Int. Std.

ICP Data

Sample	Depth (cm)	Soils Ratio	Be	Al	Cr	Mn	Fe (1)	Co
EC5B 1-17	0-170	0.98	1.16	14879.00	15.77	569.31	27417.26	14.29
EC1 #1-9	0-90	0.98	1.02	13063.26	14.59	855.76	25107.18	14.85
EC1 10-13	90-120	0.97	1.17	12304.36	14.39	137.47	14921.87	9.85
MONT 2711		0.98	0.98	14253.62	15.74	457.13	17593.03	7.76
BS-1 #13A		0.99	0.83	13021.61	12.05	692.60	18564.87	9.05
ERA 542		0.99	0.60	14097.31	13.63	215.69	14359.12	4.51
		Ni	Cu	Zn	Mo	Ba	Pb	Cd
EC5B 1-17	27.11	20.82	49.44	0.00	108.69	21.70	4.03	3.36
EC1 #1-9	25.31	21.57	48.53	0.00	106.61	23.48	3.01	1.57
EC1 10-13	25.02	17.48	35.82	0.78	91.39	21.27	1.59	1.59

MONT								
2711	17.19	96.37	301.36	0.77	169.21	1050.70	38.46	38.46
BS-1 #13A	15.58	11.85	54.38	0.77	80.81	13.53	0.00	2.02
ERA 542	10.94	57.80	65.83	0.77	78.62	20.78	78.62	1.63
	Fe (2)	P (ICP)	P (FI)					
EC5B 1-17	28801.35	373.71	293.10					
EC1 #1-9	26348.30	438.26	337.75					
EC1 10-13	15004.31	251.45	203.84					
MONT								
2711	18163.18	669.72	513.13					
BS-1 #13A	19169.59	511.79	378.96					
ERA 542	14399.40	742.53	598.13					

Appendix 12

Procedure for Analyzing Legacy Sediment in Stream Corridors with LiDAR (Prepared by Michael Rahnis)

MAKE THE TERRACE HORIZON

A. Outputs TerrPt

Create a point dataset that represents points on legacy sediment terraces, this should have at least one attribute other than OID for the conversion to raster to work.

B. OPTION 1 Requires 3D Analyst

1. Outputs TerrPtZ

Use 3D Analyst to convert TerrPt to a PointZ feature layer.

2. Outputs [horizon]

Use interpolation tools to create an interpolation surface from the [TerrPtZ] feature layer.

B. OPTION 2 Requires Spatial Analyst

1. Outputs [terrpt_tmp]

Convert terrace points from feature to raster [terrpt] (convert tool or command line)

2. Outputs [terrpt]

Reclassify the [terrpt] so that each point is 1 rather than 0.

3. Outputs [elevpt]

Get the elevations for the points [con tool, raster calculator, command line or map algebra]. In GRID the command would be:

```
[elevpt_fit] = con([terrpt], [elevation])
```

4. Outputs [elevpt_int]

Convert elevation point continuous raster to an integer raster (Euclidean Allocation tool accepts only integers).

We will scale the numbers in order to preserve precision.

```
[elevpt_int] = int([elevpt_fit] * 10000)
```

5. Outputs [horizon_int]

Perform the allocation in GRID

Eucallocation elevpt_int horizon_int 100

...where all cells within a distance of 100 cells from each point will be assigned an elevation based on its nearest neighbor elevation point. This assigns elevation to points in a neighborhood based on their nearest neighbor horizon point. Other methods for creating the horizon surface are possible such as IDW, Kriging or other interpolation method.

6. Outputs [horizon]

Convert the allocation surface back to float.

[horizon] = float([horizon_int]) / 10000

II. MAKE THE ERODED SURFACE

A. Outputs [eroded_con]

Get a conditional raster that represents areas where the elevations are below our horizon surface.

[eroded_con] = [elevation] < [horizon]

B. Outputs [filled]

Fill the DTM with a conditional statement to create a new filled surface.

[filled] = con([eroded_con], [horizon], [elevation])

C. Outputs [eroded]

Get the difference between the DTM and the filled DTM.

[eroded] = [filled] - [elevation]

III. MAKE THE TERRACE EXTENT SURFACE

A. Outputs [terrace]

Create a surface representing the approximate extent of the legacy sediment.

[terrace_extent] = ([elevation] <= [horizon]) | ([elevation] <= [horizon] + 0.75 & [slope] < 6)

...this returns a 0/1 raster where 1 represents the terrace or legacy sediment extent. It will have holes in it but the next step would be to vectorize it and remove any inner rings in the resulting polygon.

B. Outputs RasterToTerracePly

Use the From Raster To Vector tool on [terrace]. Make sure that 'Simplify' is deselected.

C. Outputs dissolved TerracePly

1. Start editing the shapefile.
2. Select the outermost polygon –the one that represents the limits of the interpolated data and delete it.
3. Stop editing, saving edits.
4. Dissolve the polygons with the 'Create Multipart' checkbox unchecked.

IV. MAKE THE HYDRO FLOW LINES

A. Remove the bridges from the DTM

1. make points upstream and downstream of each bridge at the lowest elevation you see, adding an ID that indicates to which pair of points each point belongs
2. connect the points
3. buffer the resulting line by 4m
4. convert to raster
5. set the raster values to 0
6. combine the bridge-cutting raster and the DTM to create cuts through the bridges

B. Use the hydrology tools to generate a hydro flow line dataset

1. Fill the modified DTM (stamping holes through the bridges should minimize the effects of filling)
2. Calculate flow direction
3. Calculate flow accumulation
4. Calculate stream raster [flow_acc] > 20000

C. Outputs a 3D point feature dataset with Z in the table.

1. Using a hydrology line dataset (could be from hydrology tools, ArcHydro or MIT Profiler) convert the vertices to points.
2. Use ArcHydro to add a HydroID to each segment
3. Use ArcHydro 'Create 3D Line' function
4. Use ArcHydro 'Create Smoothed 3D Line'.

V. MAKE THE WATER SURFACE HORIZON

A. Convert hydro flow line feature vertices to points.

B. Outputs an interpolated surface at the elevation of the level of the water surface.

Use IDW interpolation using the Z values of the 3D hydro line vertices (searched for 4 points within 200 meters).

VI. MAKE THE TERRACE HEIGHT SURFACE

A. Outputs the thickness of a hypothetical sediment wedge whose thickness is the bank height.
 $[\text{terrace_height_tmp}] = [\text{elevation}] - [\text{water_horizon}]$

B. Clip the `terrace_height` raster to the `terrace_extent`
Use the Extract by Mask tool to clip the `terrace_height_tmp` raster to the extents of the terrace.