

**Twelfth Annual Brace Research Day  
April 5 2013, 10:00-14:00, Faculty Lounge, MS2-022,  
Macdonald Stewart Building  
Macdonald Campus / McGill University  
Abstracts**

**Modeling the Impacts of Spatial Heterogeneity in the Castor Watershed on Runoff, Sediment and Phosphorus Loss using SWAT: I. Impacts of Spatial Variability of Soil Properties**

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**ABSTRACT**

The spatial accuracy of hydrologic modeling inputs influences on the output from hydrologic models. A pertinent question is to know the optimal level of soil sampling or how many soil samples are needed for model input, in order to improve model predictions. In this study, measured soil properties were clustered into five different configurations as inputs to the Soil and Water Assessment Tool (SWAT) simulation of the Castor River watershed (11 km<sup>2</sup> area) in southern Quebec, Canada. SWAT is a process-based model that predicts the impacts of climate and land use management on water yield, sediment and nutrient fluxes. SWAT requires geographical information system (GIS) inputs such as the digital elevation model (DEM), as well as soil and land use maps. Mean values of soil properties are used in the soil polygons (soil series), thus the spatial variability of these properties is neglected. The aim of this research was to examine the effectiveness and impacts of considering soil variability on the prediction of runoff, sediment and total phosphorus (TP) loss using SWAT. The spatial clustering of the measured soil properties was undertaken using the Regionalized with Dynamically Constrained Agglomerative Clustering and Partitioning (REDCAP) method. Measured soil data were clustered into 5, 10, 15, 20 and 24 heterogeneous regions. Soils data from the Castor watershed which have been used in previous studies was also set up and termed "Reference". Overall, there was no significant difference in runoff simulation across the five configurations including the reference. This may be attributable to SWAT's use of the SCS Number method in flow simulation. Therefore having high spatial resolution inputs for soil data may not necessarily improve predictions when they are used in hydrologic modeling.

*Keywords:* heterogeneities, hydrology, model averaging, spatial variability, water quality.

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TITLE: Targeting payments for ecosystem services: A reductionist approach for socio-ecological sustainability

Abstract:

The protection and enhancement of watershed services in tandem with human development objectives is a priority for many governments. As a result of the failure of society in recognizing the role of land managers in protecting flows of critical ecological functions in a watershed setting and the suite of ecological services that derive from them, new environmental policy instruments such as 'payments for ecosystem services' (PES) have gained increased enthusiasm. PES is based on the premise that incentives can motivate land managers to engage in predefined actions to better ensure the delivery of critical ecosystem services, such as water quality improvement. Practitioners have increasingly sought to target payments to land parcels that can be compensated at lowest cost, are most responsible for water quality problems or vulnerable to future degradation, and are operated by the poorest households. In this manner, a 'triple-win' solution for environment and development can be achieved. While targeting payments reflect calls for improving the effectiveness while minimizing inefficiency of conservation investments, the reality of complex and dynamic ecological and social relationships are unlikely to exhibit market logic. Through an empirical case study of a proposed PES scheme for drinking water improvement for the city of Kathmandu, Nepal, this research highlights how assumptions underpinning the design of targeting PES to achieve 'triple-win' objectives dangerously simplify relationships between nature and society. This is due in part to community norms of resource management that transcend calculations of individual gain as well as ignorance towards dynamic economic drivers and socially constructed landscapes.

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Factors affecting the catch rate of American lobster, *Homarus americanus*, in the eastern Gulf of St. Lawrence

The effect of several environmental and fishing strategy variables on the catch rate of lobster was investigated during a spring fishery in the eastern Gulf of St. Lawrence. Five metrics of catch rate were recorded daily except on Sundays and days missed due to weather or mechanical trouble. The catch rate metrics (amount of lobster per trap day) were total weight of lobster, weight of markets, weight of canners, number of lobsters, and number of juvenile lobsters. The number of lobster per trap day was obtained from a systematic sample of 30 swings of lobster traps taken each day, stratified by six different regions of habitat. Explanatory variables measured were bottom water temperature at 9 and 18 m depth, accumulated fishing time, bait usage, and location. Bait usage did not have a significant effect on catch rates, but regression analysis showed that power transformations of temperature and time were significant predictors, with  $R^2$  (Adj.) between 0.481 and 0.680. Regression analysis looking at the different habitat regions separately revealed that time was still an active factor predicting catch rate at 5 of 6 sites, while temperature was only significant at 2 of 6. Further analysis of the number per trap data using Repeated Measures ANOVA determined that the day×location interaction was significant, with an  $R^2$  (Adj.) of 0.520. This may indicate that the effect of temperature is not as strong at a spatial scale smaller than the entire habitat, possibly due to a patchy or changing distribution of lobster within the habitat.

**12<sup>th</sup> Brace Day – April 5, 2013**  
**Dissertation Abstract**  
**Julie Anne Ames**  
**PhD Candidate, NRS**  
**Supervisor: Professor Peter Brown**

### **Program of Study – Property for the Anthropocene**

The objective of this dissertation is to re-conceptualize the institution of property, specifically as it relates to agriculture, in an ecological economics framework. My hypothesis is that the six principles of land-use management and property rights described by Trosper (2002) and relating to the approach taken by the Pacific Northwest coast First Nations (PNCFN) offer an exit from the decline in life's prospects. Ecological decline, I argue, has largely been related to the enclosure movement which turned resource-plentiful land into property (namely agricultural property) and has helped to instigate severe global environmental change. These six principles, as well as the overlaying theme of resilience of the ecosystem and reciprocity of the people with the land, can be reconceptualized within an ecological economic system in the Anthropocene.

My research can be broken into five exploratory streams: (1) western philosophy and its relations to the origins of the institution of property (both common law and civil law) in today's neoclassical economic (NCE) system; (2) land-use changes incurred in Canada from the Enlightenment era through to today, correlating with the institution of property and specifically with regards to land enclosed for agriculture (3) ecological economics and its current epistemological, ontological, methodological and ideological approaches to institutions (4) Aboriginal notions of property, specifically (but not limited to) the PNCFN and (5) a new framework for the institution of property for ecological economics, drawing on traditional Aboriginal approaches to property.

### **References**

Trosper, R. (2002). Northwest coast indigenous institutions that supported resilience and sustainability. In *Ecological Economics*, 41. Pp. 329-344.

## Minimizing Foodborne Outbreaks from Contaminated Irrigation Water

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### Abstract:

Food and water safety are of major international concern. Irrigation activities associated with agriculture and food production require special attention to reduce the epidemiological foodborne outbreaks, as observed more frequently during past years in many developed and developing countries. Food and water contamination could be due to many sources. Poor quality irrigation water can be one of the contamination sources. Microorganisms in irrigation water can lead to foodborne disease outbreaks. The mechanism by which pathogen enters into the fruits, vegetables crops requires in depth study as every pathogen has different mode of entry to crops. There are various irrigation water quality guidelines. For example, there is limit of 1000 fecal coliforms per 100 ml of water recommended by World Health Organization (WHO) for unrestricted irrigation, whereas Canadian Water Quality Guidelines for Irrigation (CWQGI) recommended more stringent guidelines as 100 fecal coliforms per 100 ml and 1000 total coliforms per 100 ml of irrigation water. Indicator organisms (*E.coli*, *Enterococci*, Fecal *Streptococci*) have been selected mainly to indicate the potentially occurring fecal contamination rather than presence or concentration level of any specific pathogen. This presentation will focus on pathogen identification in irrigation water using the Microbial Source Tracking (MST) approach. A coupling of the MST tools and various epidemiological models can be used to implement effective mitigation measures and practices to reduce food contamination outbreaks.

### Keywords:

Foodborne disease outbreaks, irrigation water, indicator organisms, water quality guidelines, and Microbial Source Tracking.

**Research Title:** An analysis of the drainage requirements and hydrology of a sugar cane field in Guyana.

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**Abstract:**

Sugarcane is one of Guyana's major agricultural crops accounting for 3.8% of the country's GDP (BoS, 2010). Located north of the equator between latitudes 1° and 9°, the country's climate is wet tropical with an annual average precipitation of 2300mm. According to Potter (1970) there is a short wet season (December-January) accounting for 22% of the annual average rainfall, short dry season (February-April), long wet season (May-July) accounting for almost 50% and a long dry season (August-November).

Sugarcane is planted and harvested on a narrow band of coastal lowland that relies on a system of canals and dykes for drainage. Water management with respect to drainage and irrigation on the sugar estates is critical to ensure the sustainable and effective use of the water resources available for agriculture. Emphasis on drainage is key since the nature of the soil type (heavy clays) imposes challenges to evacuate surplus water effectively and efficiently. To this end, a water balance study is proposed to analyze the performance of the drainage systems for a typical sugarcane plot on the coastland.

A 4.2 ha field at La Bonne Intention on the East Coast of Demerara, Region 4, is being instrumented to measure hydrometeorological and soil moisture data continuously. In addition to the field measurements, DRAINMOD, a computer drainage simulation model will be used to simulate the drainage and hydrology characteristics for long term historical climate trends. The simulations will also indicate if there is need to re-examine the drainage coefficient in light of climate change.

**References:**

BoS. 2010. *Guyana System of National Accounts*. Georgetown, Guyana: Bureau of Statics.

Potter, K. 1970. *An Appraisal of the Hydrology and Climate of Guyana*. Land Use Study Supplement Paper#1. Georgetown, Guyana: Hydrometeorological Services.

## **Inactivation Rates of Selected Gram-Positive and Gram-Negative Bacteria Attached to Metal Oxide Surfaces: Role of Solution and Surface Chemistry**

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### **Abstract**

Earlier studies have demonstrated that metal oxide coatings such as ferric or aluminum oxides can play an important role in the retention of bacteria in granular aquatic environments; however, their role in bacterial inactivation is not well understood. Herein, the inactivation rates of three bacterial strains when adhered to three different surfaces, silica, alumina, and iron oxide, were measured *in situ*, over a broad range of environmentally relevant solution ionic strengths (1 to 100 mM) of either monovalent or divalent salts (KCl and CaCl<sub>2</sub>). The nature of the chemical bonds between bacteria and the three surfaces was also examined using X-ray photoelectron spectroscopy (XPS). For all three surfaces, a consistent increase in inactivation rate was observed with the type of bacterium in the order: *Enterococcus faecalis* (a Gram-positive bacterium), *Escherichia coli* O157:H7, and *E. coli* D21f2 (two different Gram-negative bacteria). There was a high correlation between the amounts of C-metal or O-metal bonds and the corresponding bacterial inactivation rates for each surface. Increasing the solution ionic strength from 1 to 100 mM increased the corresponding adhesion of cells on all surfaces. Our findings demonstrate that physicochemical conditions such as water chemistry and grain surface chemistry can play an important role in both bacterial retention and attached inactivation rates in granular aquatic environments.

# **Transport of Palladium-Doped Nanosized Zero Valent Iron (Pd-nZVI) Particles in a Model Ground Water Environment: Influence of Water Chemistry and Aquifer Grain Geochemistry**

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## **Abstract**

Palladium-doped nanosized zero valent iron (Pd-nZVI) particles can transform various subsurface ground water contaminants into innocuous products. For *in-situ* site remediation application, these nanoparticles need to be stable in water so that upon direct injection they can easily migrate to a targeted contaminated zone. However, the major challenge is rapid Pd-nZVI aggregation and hence very limited transport. Therefore, to reduce aggregation and improve transport, the surface of bare Pd-nZVI can be coated with various stabilizers. In this study, we used carboxymethyl cellulose, soy protein and other natural macromolecules as Pd-nZVI stabilizing agents. Nanoparticle electrophoretic mobility and hydrodynamic diameter were determined using laser Doppler velocimetry and dynamic light scattering (DLS), respectively. The nanoparticle transport potential was assessed by conducting well controlled laboratory column experiments in two types of porous matrices: i) quartz sand, and ii) loamy sand collected from a farm near Quebec City. In this presentation, we will show to what extent the changes in water chemistry and aquifer grain surface chemistry can influence Pd-nZVI transport behavior.

Mixing of a passive scalar emitted from a turbulent jet into a turbulent background.

Alejandro Perez-Alvarado<sup>1</sup>; Susan Gaskin<sup>2</sup>; and Laurent Mydlarski<sup>3</sup>

The release of harmful materials into the atmosphere and oceans frequently occurs in the form of a jet discharging into turbulent surroundings. The reduction of the detrimental effects of such discharges is achieved by the dilution of the contaminants in the ambient fluid. Dilution in turbulent jets occurs as the result of entrainment (the process of incorporation of ambient fluid into the jet flow) and mixing. However, the details of entrainment and mixing of the jet and ambient fluids are still not well understood. Furthermore, the vast majority of studies of turbulent jets considered quiescent backgrounds, and thus the effect of external turbulence on turbulent jets is not fully described. The main objective of the present research is to accomplish the first systematic study of the concentration field of a turbulent jet in the presence of ambient turbulence by means of Laser Induced Fluorescence (LIF). To this end, punctual concentration measurements and planar visualizations of the jet will be performed as the external turbulence levels are increased. An approximately homogeneous, isotropic and almost zero-mean-flow turbulent background is generated by a Random Jet Array (RJA). The expected contributions of the present work include increasing our understanding of the dilution process in turbulent jets, as well as the possible application of the results to industrial processes (e.g. combustion, where entrainment and mixing of fuel and oxidizer occurs).

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# THE EFFECTS OF SULFIDE AND SULFATE IONS ON DEGRADATION KINETICS OF TRICHLOROETHYLENE BY NANOSCALE ZERO VALENT IRON

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Trichloroethylene (TCE) is a widely used industrial solvent and accidental spills and past improper disposal practices have led to widespread groundwater contamination. Successful remediation of chlorinated solvent sites will protect critical and renewable resources of land and water, and human health. A promising technology for the clean-up of such sites is the sub-surface injection of nanoparticles of zero valent iron (NZVI) into the TCE-contaminated zones to enable rapid, *in situ* destruction of chlorinated compounds. NZVI is a strong reductant that can effectively transform TCE and other chlorinated solvents to non-toxic end products such as ethene, acetylene, and ethane via surface mediated electron transfer and hydrogenation reactions. However, iron oxide shells form readily on the surface of the NZVI which may reduce its reactivity over time. Although several studies have examined the reactivity of NZVI to chlorination aliphatic pollutants, there is limited knowledge on the effects of natural groundwater ions on the surface chemistry and reactivity of NZVI to target pollutants. In this study we show that sulfide and sulfate ions, which are ubiquitous in groundwater environments, may significantly alter the reactivity of NZVI.

Sulfide and sulfate ions readily react with NZVI in solution to form FeS precipitates on the NZVI surface. The FeS-coated NZVI enhances the ability of the NZVI to degrade TCE by surface mediated electron transfer. Our studies show that the reactivity of the NZVI-FeS was distinct from the reactivity of pure FeS. Batch experiments containing TCE and NZVI with varying sulfide doses were conducted under strict anaerobic environments. Rapid dechlorination of TCE was observed particularly at low concentrations of sulfide (around 2 mM). The first order TCE degradation rate constant increased from 0.0075 hr<sup>-1</sup> for NZVI only to 0.0697 hr<sup>-1</sup> NZVI reacted with sulfide. The surface morphology and chemistry of NZVI reacted with sulfide and sulfate were studied using TEM-EDX and X-ray photoelectron spectroscopy (XPS) to better understand the relation between reactivity and the spatial distribution and state of S on the surface of NZVI. The characterisation from TEM-EDX and XPS indicate iron sulfide (FeS) formation at the surface. Particle size measurements by nanoparticle tracking analysis showed no observable change in the average hydrodynamic diameter of bare NZVI and NZVI reacted with sulfide and sulfate. Thus increases in reactive surface area cannot be attributed to the increase in reactivity. The experimental data suggests that FeS or sulfide deposited on the NZVI created a conductive outer layer for efficient transfer of electrons from the electron rich core of the zero valent iron nanoparticles as shown in a schematic in Figure 1.

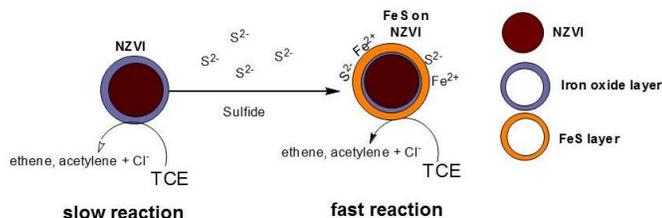


Figure 1: Schematic of TCE degradation by sulfide amended NZVI systems

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**EROSION AND STREAM SEDIMENTATION DUE TO PIPELINE CONSTRUCTION IN LATERITE SOILS  
- MADAGASCAR**

*Madagascar - Ambatovy region, AMBATOVY Project - Sherritt International.*

*The Ambatovy Project, a mine for nickel and cobalt ore located in the centre of the country, required the construction of a slurry pipeline to transport the ore 220 km to be processed on the east coast. The pipeline and its maintenance road traverses primary forests, the sensitive Torotorofotsy Wetlands and includes 172 stream crossings in sensitive laterite soils. The restoration and rehabilitation of the cut and fill geotechnical works and stream crossings are important technical works within the environmental portfolio and for project cost reductions.*

*The surface water erosion of the soil and the associated stream sedimentation are studied. These processes are classified based on the characteristics of the vegetation/land use, the slopes and the type of laterite soil. Three representative sites are chosen for a detailed study using field observations, field measurement (TSS in streams) and empirical models to calculate soil loss and sediment transport and sedimentation in the streams. These results will be compared to numerical modeling results using RUSLE for surface erosion and GeoWEPP, a USGS –LESAM model which conducts continuous and process-based simulations of small watersheds, for soil erosion and sedimentation.*

*At the three selected sites, possible mitigation measures using geotechnical engineering methods combined with revegetation can then be investigated and compared. The results of these studies will be used to mitigate environmental impacts associated with the pipeline construction for the Ambatovy Project.*

**Pilot scale study of bioremediation of petroleum hydrocarbon contaminated  
fine-textured soils from a sub-arctic site**

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Pore size characteristics of soil particles and aggregates of different soils can significantly affect the bioavailability of pollutants, nutrients, and oxygen to microorganisms. For cold regions, bioremediation studies on contaminated soils have focussed on coarse-textured sandy soils while bioremediation of fine-textured petroleum contaminated soils has not been studied systematically. This study investigates the extent of biodegradation of non-volatile petroleum hydrocarbons (C<sub>16</sub>–C<sub>34</sub>) and the associated microbial activity in a pilot-scale biopile experiment conducted at 15°C, with a clayey soil, from a crude oil-impacted site in northern Canada. The results indicate 20 to 40% biodegradation of non-volatile petroleum hydrocarbon fraction in un-amended, low level nutrient amended (95 mg-N/kg) and moisture amended (70% of WHC) biopiles; whereas in high level nutrient amended (1340 mg-N/kg) biopile, only 2% reduction was observed. Terminal Restriction Fragment Length Polymorphism (T-RFLP) of *alkB* and *16S rRNA* genes revealed that stimulated biological activity in terms of biodegradation of hydrocarbons was associated with shift in structure and increased diversity of microbial community. To delineate the role of the fine texture of soil on biodegradation pattern, the *in-situ* soil aggregate microstructure was characterized using micro-CT scanning. The results indicate that the fraction of pores wide enough to accommodate the bacteria was significantly higher in case of larger aggregates (macro-aggregates,  $d_p > 2$  mm) compared to meso-aggregates ( $d_p = 0.25-2$  mm) which can explain the higher biodegradation extent for macro-aggregates. Overall, our findings suggest that the biological activity of endogenous microbial community is stimulated during biopile treatment; however, the extent of biodegradation is mainly controlled by the aggregate microstructure in terms of pore size distribution.

## **Phosphorus in runoff and leaching potentially mitigated by biochar application in agricultural fields**

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Dissolved and particulate phosphorus (P) leaching and runoff from agricultural soil poses an environmental risk to nearby watercourses. Biochar, a carbon-rich soil amendment made from pyrolysed biomass, may reduce P leaching and runoff rates by altering the physical and chemical soil properties. Two experiments were conducted in biochar-amended soils to assess the dissolved and particulate P concentrations in (1) simulated runoff (in-field experiment) and (2) leachate from repacked soil columns (laboratory experiment). Soils were collected from an on-farm experiment in Ste-François-Xavier-de-Brompton, Quebec (Canada). Two years earlier, agronomic plots were amended with three types of biochar at 0, 5, and 10 Mg/ha in a randomized complete block design, with 3 replicates. Two 30-minute rainfall simulations were done using the Cornell Sprinkle Infiltrometer. The runoff was collected 5 times (every 6 minutes) and analyzed for ortho-P, dissolved P, and particulate P. A column leaching experiment was conducted by collecting coarsely sieved soil (<6 mm mesh) and packing PVC columns (10.1 cm dia., 30 cm tall) to field bulk density (1.1 g cm<sup>-3</sup>). Each column was leached with 8 pore volumes of water and the leachate is analyzed for ortho-P, dissolved P, and particulate P. Runoff from the rainfall simulation contained significantly less particulate P concentration ( $p = 0.012$ ,  $0.024$ , and  $0.047$ ) in 3 of the 6 biochar-amended plots but there were no significant differences in P concentrations in the column leaching leachate. These results indicate that biochar could potentially reduce the P concentration in agricultural runoff but not in water leaching through the soil matrix.

# Modeling and Analysis of Non-stationary Flood Records in Quebec

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**Abstract** Recently, it has been recognized that society as a whole has become more vulnerable to extreme weather and flood events. This paper investigates therefore the variability of flood peaks in Quebec based on a detailed statistical analysis of the historical annual maximum flow (AMF) records. Firstly, temporal trends in the mean of flood peaks were examined. Then, a new method is proposed to parametrically model the AMF to account for temporal trends in the moments of the time series. In this study, two probability distributions (GEV & Gumbel) are used to model four different types of time varying moments of the studied time series, comprising eight competed models. The eight models are applied for every watershed and compared in order to select the optimal model for its time series. The comparison methodology involves two phases: (1) a descriptive ability which is based on likelihood-based optimality criteria; and (2) a predictive ability which is based on the residual bootstrap. It was found that a quarter of the analyzed stations show significant trends in the AMF. Particularly, all of the significant trends are negative, indicating decreasing flood magnitudes in Quebec. It is shown that the new method could be a flexible and accurate approach for estimating parameters in the context of nonstationarity. The results reveal the importance of taking into consideration the nonstationary behaviour of the flood series in order to improve the quality of flood estimations.