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Biogeosciences Section Oral Presentation Abstracts:

Saturday, February 6, 9:00 – 16:00
University of Waterloo
EV1 132

Nutrient processing rates scale inversely with water residence times

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Nutrients such as nitrogen and phosphorus are prevalent pollutants in the world's water resources. Features in the waterscape such as lakes, reservoirs and wetlands are important bioreactors that naturally remove or retain nutrients through biogeochemical processes. We synthesized the effective first-order rate constants of water bodies to assess the removal of total nitrogen (TN), nitrate (NO_3^-), total phosphorus (TP) and phosphate (PO_4^{3-}). Our results show that the reaction rate constants scale inversely with the residence time of water in the system. The strong, linear relationships points to the primary influence of hydrological processes on nutrient cycling with other factors (such as temperature) acting as secondary controls. A parsimonious model was used to demonstrate the interplay of the system hydraulics and biogeochemistry as a function of system size. The results highlight the importance of small water bodies which have greater reactive surface areas on regional and global scale nutrient cycling.

Assessing biogeochemical characteristics of a reclaimed upland during the initial stages of succession in a constructed watershed

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The climate of the Western Boreal Plains (WBP) is characterized by greater evapotranspiration (ET) losses than input due to precipitation (P). Thus, this environment has adapted to prolonged periods of droughts followed by relatively intense wet cycles. In order for the WBP landscape to be resilient in the face of this climate, water storage capabilities are needed for the duration of the dry periods. Forested uplands have the ability to store water and redistribute water to the landscape during drought cycles and facilitate the transmission of large amounts of water through the landscape during wet periods. During the drought cycles, when storage from forested uplands has declined, wetlands will serve as sources of water for the vegetation of the upland forested areas. These two hydrological units are therefore co-dependent of one another. Currently, this landscape is being modified due to anthropogenic disturbances (i.e. open pit oil sands mining, in-situ oil sands extraction, conventional oil and gas, and forestry), which must be reclaimed. Industry is currently mandated to re-establish the initial functionality of this landscape and the individual landscape units (i.e. forests, wetlands and peatlands). Pilot fen projects are currently underway in an attempt to re-create self-sustaining peatlands. In order for this to be successful, entire watersheds including forested uplands are implemented in the landscape design. In this study, a biogeochemical assessment was made in an attempt to understand the surface flow interaction occurring between a newly formed upland and a constructed fen during the initial stages of succession in the Athabasca Oil Sands Region (AOSR). It is hypothesized that certain nutrients are being lost due to runoff during large storm events, which will have an ecohydrological impact on the upland and receiving fen. In order to test this hypothesis, soil physical properties were taken along a topographical gradient (High-slope, Mid-slope and Low-slope) throughout the upland. Plant Root simulators (PRS probes) were incubated along those same transects throughout the research season (Early, Middle and Late) to quantify if nutrients were gradually decreasing in concentration on the higher slope and increasing on the lower slope, indicating potential nutrient runoff. Runoff collectors were place at three locations on the "Lower" section of the slope to quantify Soluble Reactive Phosphorus (SRP) and Total Inorganic Nitrogen (TIN) losses during major storm events. The results from this study will not only indicate if the upland and fen are interacting with one another from surface flow, but also indicate the uplands potential towards becoming resilient and what management practices could be implemented to aid with the succession.

Effect of Fertilizer Application on Greenhouse Gas Emissions From Short-Rotation Willow Biomass Plantations

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Fast growing woody perennials used for biofuel production have the potential to replace our global reliance on fossil fuels. Willow (*Salix* spp.) short-rotation coppice systems established on marginal lands are an effective option to provide ecosystem services, including long-term carbon (C) sequestration. However, concerns have emerged regarding potential environmental disservices of willow biomass plantations. Although nitrogen (N) fertilizer application increases aboveground woody biomass production, it also affects C and N transformations, leading to greater soil-derived CO_2 and N_2O emissions. The objective of this study was to examine the effect of N fertilizer addition on greenhouse gas (GHG) emissions in short-rotation willow biomass plantations. Two willow clones [*S. miyabeana* (SX67), *S. dasyclados* (SV1)] were evaluated for CO_2-C and N_2O-N emissions, and soil chemical characteristics in a split-plot design with fertilized and unfertilized treatments in Guelph, Ontario. Soil temperature and moisture, and photosynthetic photon flux density were also quantified. Mean CO_2-C emissions from SV1 and SX67 ranged from 72 to 91 mg CO_2-C m^{-2} h^{-1} in fertilized treatments, and from 63 to 105 mg CO_2-C m^{-2} h^{-1} in unfertilized treatments, respectively. Carbon dioxide emitted from the SV1 clone was significantly lower ($p=0.0001$) than that from the SX67 clone. Carbon dioxide emissions were strongly affected by seasonal temperature and moisture variability and availability of C substrates. Nitrous oxide emissions, and NO_3^- and NH_4^+ soil concentrations increased immediately following fertilizer application. Mean N_2O-N emissions from SV1 and SX67 from fertilized treatments ranged from 22 to 26 µg N_2O-N m^{-2} h^{-1} and was significantly higher ($p=0.009$) than emissions from unfertilized treatments, which ranged from 16 to 17 µg N_2O-N m^{-2} h^{-1}. Elevated N_2O-N emissions from fertilized treatments persisted for approximately month. There was no significant difference between N_2O-N emissions from clones SV1 and SX67. Results indicated that N_2O emissions were more strongly affected by inorganic N fertilizer application than fluctuations in soil moisture and temperature associated with seasonal changes.

Comparing biogeochemical responses of a forest soil to biochar and phosphorus amendment

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Biochar, a carbon-rich solid product of biomass pyrolysis, has been proposed as a soil amendment to sequester carbon which has been demonstrated to increase the concentration of ionic plant nutrients in soil. However, biochar may also stimulate microbial activity, potentially accelerating soil organic matter (OM) decomposition and altering soil OM molecular composition. Here we compare changes in soil microbial activity and native soil OM composition three years after the amendment of biochar (0, 5, 10 and 20 t/ha) and phosphorus (P; 0 and 200 kg/ha) at the Haliburton Forest in southeastern Ontario, a P-limited forest ecosystem. Soil microbial activity and community structure were assessed using phospholipid fatty acid (PLFA) analysis, while soil OM composition was examined using biomarker extractions. PLFA results indicated that fungal activity was stimulated by biochar but not P amendment, whereas bacterial activity increased with all treatments. Concentrations of solvent-extractable acyclic and cyclic lipids, base-hydrolyzable components of cutin and suberin, as well as lignin-derived phenols increased with the biochar treatments and, to a lesser extent, with P fertilization. Biomarker ratios indicated that the soil OM composition shifted toward a greater proportion of cyclic vs. acyclic aliphatic lipids and lignin-derived phenol monomers vs. dimers with biochar amendment, but not with P fertilization. Since biochar addition elicited similar biogeochemical responses as P fertilization without increasing soil OM degradation, biochar could potentially be used as a replacement for P fertilizer in P-limited forest soils to improve soil fertility.

Soil oxygen dynamics: Implications for dynamic hydrological and climatic drivers

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Dynamic hydrological and climatic drivers influence the biogeochemistry, microbial activity, nutrient and carbon cycling in soils, and regulate subsurface oxygen (O2) availability, affecting greenhouse gas exchanges between soils and the atmosphere. The ability to monitor changes in O2 levels is fundamental to understand how changes in the frequency and amplitude of hydrological and climatic driver (e.g. water table fluctuations and freezethaw cycles) affect the soil's geochemical conditions and microbial activity. In this study, two independent soil column experiments were designed to accurately simulate water table fluctuations and freeze-thaw dynamics under controlled conditions. Molecular O2 levels throughout the soil columns were monitored using luminescence-based, Multi Fiber Optode (MuFO) microsensors. Image-processing techniques were used to convert sensor-emitted light intensity (captured by digital images) into O2 concentrations. Soil CO2 emissions were measured from headspace gas analysis during the experiment and exhibited periodic variations in the columns due to a combination of O2 diffusion dynamics and the onset of aerobic/anaerobic soil respiration. Pulsed CO2 emission to the headspace was observed at the onset of water table drawdown and thawing, however, the magnitude of the pulse decreased with subsequent water saturation-drainage and freeze-thaw cycles, indicating depletion of the accessible carbon pool. In the

freeze-thaw column, soil CO2 flux was due to a combination of the physical release of gases dissolved in pore water and entrapped below the frozen zone and changing microbial respiration in response to electron acceptor variability.

Subarctic peatland-pond interactions in a permafrost landscape: runoff quantity and quality depend on frost table development and antecedent moisture conditions

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In subarctic permafrost environments, ecological productivity is often nutrient-limited, both in terrestrial and aquatic vegetation. The subarctic is experiencing significant climatic change, including rapid warming and changing precipitation patterns, which may result in changes in nutrient dynamics within terrestrial and aquatic systems and hydrologic transport between them. It is unclear if changes in hydrologic connectivity throughout the ice-free season will also result in enhanced nutrient mobilization in the landscape, and/or if changes in seasonal dynamics will alter the speciation of those nutrients. The objective of this research was to characterize changes in runoff pathways, quantity and quality between peatlands and ponds over the snow-free summer season. Twenty-two ponds and five transects of piezometer nests along moisture gradients were instrumented to measure changes in hydrologic storage, frost table position, and water quality over three snow-free seasons in Churchill, Manitoba, within the Hudson Bay Lowlands. Differences in antecedent moisture conditions across landscape units, combined with frost table position (inhibiting infiltration and storage) produced non-linear, threshold responses in runoff generation. Greater inputs were required to exceed storage (‘fill and spill’) when a lower frost table permitted deeper infiltration. The snow-free (non-winter) hydrology of the site displayed three clear periods: (1) the post-melt wet period where runoff-generating threshold catchment storage was exceeded during rainfall events, and frost table development was rapid and consistent across space; (2) the mid-summer drying period in which ponds desiccated, threshold storage was not achieved in the catchment, resulting in hydrological disconnection between ponds and catchments. During this period, frost table development diverged within the catchment along a moisture gradient (most rapid development in wet soils and least on dry peat plateaus); (3) the autumnal wet-up period, where frost table development had slowed and/or progressed beneath the peat layer into underlying glacial till. During this wet-up, antecedent wetness and catchment storage returned to the threshold conditions at which runoff was generated and catchments began to interact hydrologically with ponds again. Seasonal variations in groundwater chemistry were reflective of different layers of peat and mineral soil accessed at different times throughout the season, governed by frost table and water table positions. Varying thaw rates across landscape units (controlled by moisture and vegetation) resulted in changing groundwater pathways throughout the season, and, changing groundwater pathways combined with precipitation events throughout the season produced temporally variable nutrient concentrations in runoff and ponds. Although the decay of permafrost may expose nutrient-rich peat, this may not be reflected in future runoff chemistry or surface water bodies due to low hydraulic conductivities at those depths. Instead, hydrochemical contributions to ponds may be more reflective of extended drying period in early- to mid-summer and extended autumnal seasons with increased frequency and intensity of storms during a period of lesser evaporative demand with flow primarily through highly-conductive upper peat layers. This work has implications for how nutrient dynamics and exchange between terrestrial and aquatic systems in cold regions may evolve under a changing climate.

Wastewater contaminant treatment in a nutrient limited ribbed fen: Potential for Methylmercury and Phosphate release

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Fen peatlands in sub-arctic Canada are used for tertiary wastewater treatment from remote communities and mining operations; however, there is a limited understanding of wastewater treatment in peatlands and their treatment efficiency. To better characterize wastewater treatment in fen peatlands, approximately 37 m^3 day^{-1} of simulated wastewater, a concentrated custom-blend fertilizer (NO_3^-, PO_3^{3-}, SO_4^{2-}, NH_4^+, K^+, and Na^+) and Cl^- diluted with water, was pumped into a small 0.5 ha sub-arctic ribbed fen continuously for 42 days (July 15th –August 31st 2014). Contaminant concentrations of 3 similar ribbed fens varied between 0.0-6.0 mg L^{-1} over the study period (May – September 2014). Diffusion into inactive pores retarded Cl^- transport by a factor of 1.2 (retardation factor, R) and adsorption increase Na^+ R to 2.1, while other contaminants were removed rapidly through biogeochemical processes (i.e., SO_4^{2-} R = 3.2). The elevated SO_4^{2-} concentrations and its subsequent reduction produced extremely high levels of MeHg (> 90 % of total Hg) and increased total Hg (~ 2 µg L^{-1} – 10 µg L^{-1}), potentially released from decomposing peat. Additionally, the added PO_3^{3-} was initially removed from the pore water but a decrease in treatment efficiency was observed over time leading to enhanced mobility of PO_3^{3-}. Northern ribbed fens have a large capacity to detain certain wastewater contaminants (NO_3^- and NH_4^+), yet allow rapid transport (SO_4^{2-} and Cl^-) or release (PO_3^{3-}, Hg, and MeHg) of other contaminants. Thus, these peatlands have the potential to significantly decrease wastewater contamination in northern aquatic environment by both biogeochemical and physical processes but careful management of the hydrology is required to prevent the release of mobile contaminants.

A High Precision Passive Air Sampler for Gaseous Mercury

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Passive air samplers provide an opportunity to improve the spatial range and resolution of gaseous mercury (Hg) measurements. Here, we propose a sampler design that combines a sulphur-impregnated activated carbon sorbent, a Radiello® diffusive barrier, and a protective shield for outdoor deployments. The amount of gaseous Hg taken up by the sampler increased linearly with time for both an 11-week indoor (r^2=0.990) and 12-month outdoor deployment (r^2=0.996), yielding sampling rates of 0.158±0.008 $m^3 \cdot day^{-1}$ indoors and 0.121±0.005 $m^3 \cdot day^{-1}$ outdoors. These sampling rates were close to modelled estimates of 0.166 $m^3 \cdot day^{-1}$ indoors and 0.129 $m^3 \cdot day^{-1}$ outdoors. Replicate precision was lower than for all previous PASs for gaseous Hg, especially during outdoor deployments (2±1.3%). Such low precision is essential for discriminating the relatively small concentration variations occurring at background sites. Deployment times for obtaining reliable time-averaged atmospheric gaseous Hg concentrations range from a week to at least one year.

Paleoecological history and contemporary controls of mercury accumulation in Kluane Lake, Yukon

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Canada's North is a sparsely populated region, with limited industrial development and few local sources of contamination. Nonetheless, many areas of the North have become contaminated with pollutants arriving via long-range atmospheric transport from temperate regions. One of these contaminants, mercury (when methylated), is a bioaccumulative environmental contaminant. It has been found in aquatic organisms across the North, often at high concentrations, putting both the organisms and the humans that eat them at risk of neurological impairment. However, mercury concentrations are highly variable across the northern landscape, resulting in significant differences in mercury dynamics between lakes, even within the same region. We lack understanding of the exact nature of the environmental influences on the bioaccumulation rates of mercury, which may include species-specific growth rates, nutrient concentrations and the pH of lake waters. Climate change is expected to affect many of these environmental influences, making investigations of climate-induced effects on mercury bioaccumulation key in protecting the future of northern species and communities. Kluane Lake, located within the Kluane First Nation traditional territory, is the largest lake in the Yukon Territory: it is large, deep, and fed mainly by glacial meltwater from the Kluane Icefields. Despite the recreational and cultural importance of Kluane Lake, this system has received very little scientific study. We seek to provide understanding of how specific influences, such as species, growth rate, and feeding ecology can impact mercury accumulation in fish species in several trophic positions: lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), round whitefish (*Prosopium cylindraceum*), and longnose sucker (*Catostomus catostomus*). This understanding will address concerns of the Kluane First Nation regarding the safety of their traditional food, and develop an understanding of mercury in the Kluane Lake food web. We will assess the trophic ecology and age structure of fish species using stable isotopes and otolith (fish ear bone) aging methods. We will also provide baseline information on the history of human impacts on the paleoecology of the lake. We will explore 1200 years of ecological history in Kluane Lake using decade-specific metal concentrations and preserved algal remains in sediment cores from the lake, which can be used as proxies for environmental conditions. This time period included The Little Ice Age (approx. 300 to 800 years ago), which we can use to gain understanding of how the ecosystem of Kluane Lake has responded to climate change in the recent past. Understanding the lake's past and present will support more accurate predictions of the lake in the future in light of climate change (particularly higher glacial inflow) and resource development (e.g., mining), allowing for sustainable and appropriate resource management in the years to come.

Soil CO_2 efflux in a temperate deciduous forest ecosystem

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The production and emission of carbon dioxide (CO_2) from soils, referred to as soil respiration (Rs), has a significant influence on the global carbon balance. Carbon is acquired by vegetation from the atmosphere through photosynthesis and stored on the surface and in soils as organic matter. This stored organic matter is returned to the atmosphere as CO_2 through belowground decomposition of organic matter by microbial communities (heterotrophic respiration) and metabolic activity of roots and mycorrhizae (autotrophic respiration). In this study, we explore temporal and spatial dynamics of

Rs in a temperate deciduous forest located in Southern Ontario and how it is influenced by climatic controls over a two year period (2014/2015). The research site is a 90-year-old managed hardwood forest (Carolinian species) and part of the Turkey Point Flux Station and global Fluxnet network. An automated soil CO_2 efflux system (LI-8100A) was utilized for continuous monitoring of Rs since July 2014 at our site. To better capture the spatial variability of Rs, a portable soil CO_2 efflux system (LI-6400) was also used along two 50-m transects. Comparing the two chamber systems, they both measured within one standard deviation of each other indicating that the long-term automatic chamber site is representative of the surrounding area. Monthly mean Rs varied from a maximum of 14.76 $\mu mol/m^2/s$ in June 2015 to a low of 1.22 $\mu mol/m^2/s$ in December 2014. Rs showed a soil temperature-driven seasonal trend. Spatial variability in the soil water content had little effect on Rs values. This study will allow us to have a better understanding of the dynamics of Rs and how it responds to its main controlling variables, soil moisture and temperature. It will also help us to determine the impact of climate change and extreme weather events on Rs in temperate deciduous forests and help in developing vegetation ecosystem models.

Enhanced carbon release under future climate conditions in a peatland mesocosm experiment: The role of phenolic compounds

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Future climate conditions (warmer, wetter) are expected to change aboveground plant communities with linked belowground alterations (e.g. porewater chemistry) that can influence carbon dynamics. Accordingly, the aims of this study were 1) to determine if porewater phenolic compound concentrations reflect the changing aboveground plant community and 2) to elucidate if changes in phenolic compounds alter belowground carbon release. We monitored the changes in vegetation biomass, porewater phenolic compound concentrations, respired CO_2 and phenol oxidase enzyme activity in 84 intact peatland mesocosms exposed to elevated atmospheric CO_2, elevated temperature, and decreased water table conditions in a full factorial design. We found phenolic compound concentrations were indicative of the vascular plant expansion that occurred under warmer and anaerobic conditions, suggesting that phenolic compounds could be a simple indicator of northern plant community dynamics. Ecosystem CO_2 respiration increased with rising phenolic compound concentrations, suggesting that phenolic compounds can decrease microbial carbon use efficiency in northern peatlands. By using an aboveground-belowground framework we present a previously unrecognized mechanism influencing northern carbon dynamics; wherein, climate change conditions can restructure the plant community composition in turn increasing porewater phenolic concentrations, which results in decreased microbial carbon use efficiency and enhanced carbon release.

Non-Invasive geophysical monitoring of subsurface biogeochemical processes under redox oscillating conditions

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The general lack of data and knowledge on the biogeochemical functioning of the subsurface, under redox oscillating conditions (e.g. water table fluctuations), severely limits our ability to predict the impacts of anthropogenic pressures on soil and groundwater resources. The application of non-invasive geophysical methods can aid to map and monitor these processes at a greater spatial and temporal scale. To determine the effects of water table dynamics on subsurface biogeochemistry, we are carrying out state-of-the-art automated soil column experiments with fully integrated monitoring of hydro-bio-geophysical process variables under both constant and oscillating water table conditions. An artificial, homogeneous mixture consisting of minerals and organic matter is used to provide a well-defined starting material. In the currently ongoing experiment, three replicate columns are incubated while keeping the water table constant at middepth, while another three columns alternate between drained and saturated conditions. Periodic spectral induced polarization (SIP) and self-potential (SP) measurements are performed in order to track the development of the soil's geophysical response and relate this to the observed changes in biogeochemical properties. In addition, continuous redox potential (Eh) and oxygen levels are monitored at depth, as well as, pore-water pH, EC, DIC/DOC and ion/cation compositions and solid phase microbial analyses. These measurements allow us to track the changes in pore water geochemistry and relate them to differences in nutrient cycling between the contrasting water table regimes and asses the effectiveness of SIP and SP as proxy techniques for subsurface biogeochemical monitoring. The experiment is in progress with an expected total duration of 6 months.

Characterization of Protected Organic Matter in Grassland, Agricultural, and Forest Soils

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Soil organic matter (SOM) plays important roles in soil fertility and biogeochemical cycling of elements. Therefore, it is imperative to characterize SOM at the molecular-level to better understand and predict the fate and role of SOM in the environment. Chemical extraction is commonly used to analyze specific components in SOM. However, recent research has showed that some of the organic matter may form organo-mineral complexes with clay minerals, which are also abundant in soil, and become non-extractable. As such, it is important to test the role of minerals in stabilizing SOM as well as protecting SOM from analytical measurement. It is hypothesized that demineralization using hydrofluoric acid (HF) prior to the chemical extractions may release a significant portion of the mineral-protected organic matter. To test this, base hydrolysis was performed to study suberin- and cutin-derived compounds, which are believed to be environmentally persistent components of SOM, in four Canadian soils (grassland, agricultural, and forest soils) before and after demineralization. Results show that 81-98% of the suberin- and cutin-derived compounds were protected by clay minerals. The % of protected compounds is largely related to the clay mineralogy of the soils. However, the preferential protection of specific compounds indicates that the compounds were not protected by clay minerals alone, but possibly also by mineral-associated SOM constituents. Therefore, clay mineral and SOM-SOM interactions likely play important roles in the long-term stabilization of suberin and cutin in soil. Further research is needed to elucidate the stabilization mechanisms of these hypothesized recalcitrant compounds.

Methane emission dynamics with an emphasis on vegetation effects from a constructed fen including comparison to reference sites in the Athabasca Oil Sands, Alberta

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Fen construction in a post-mined landscape in the Athabasca Oil Sands near Fort McMurray, Alberta has recently been attempted with an aim to return a disturbed landscape to an ecosystem that may retain water and sequester carbon. Ongoing monitoring necessary to understand the fen design and success should include a consideration of carbon dynamics, as well as the use of reference sites to compare these artificial systems to naturally functioning ecosystems. Methane (CH_4) flux was monitored over the 2015 growing season at a constructed fen as well as saline and poor fen reference sites near Fort McMurray to determine differences in CH_4 dynamics. As vegetation is known to influence CH_4 flux to the atmosphere, this study focused on the influence of two graminoid species, *Carex aquatilis* and *Juncus balticus*, and moss on CH_4 emissions within the constructed fen site as well as between the constructed fen and reference sites. Controls on CH_4 flux at these sites, including water table depth, soil temperature, geochemistry, and vegetation productivity and biomass, were further evaluated. Methane flux between treatments (*Carex, Juncus,* moss, mixed graminoid and moss, and bare) within the constructed fen did not differ significantly (p=0.0586) averaging 3.95 mg/m^2/day (±0.31 standard error) across all treatments over the season. Comparing seasonal CH_4 emissions from all treatments at the saline fen (*Juncus,* and bare) and poor fen (mixed *Carex* and moss, and moss) to the constructed fen revealed that the poor fen had significantly higher flux (p<0.001) averaging 23.90 mg/m^2/day (±3.94) compared to the other sites. Seasonal methane release from the saline fen was significantly similar to the constructed fen (4.40 mg/m^2/day ± 0.81). Considering the controls on CH_4 flux across all three sites geochemistry was especially important, with high sulfur, which was measured at the constructed fen, corresponding to low CH_4 flux in linear regression (R^2=0.34).

Carbon, water, and energy dynamics of a pine forest during the first decade since afforestation on former cropland

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To our knowledge, no decadal-scale CO_2 flux studies have been reported for afforested stands. This study presents the energy, carbon (C), and water exchange dynamics of a recently afforested temperate white pine (*Pinus strobus* L.) forest, established on former agricultural land in 2002, in southern Ontario during the initial eleven years (2003-2013) following planting. Initially, the forest was a small source of C in 2003, with a net ecosystem productivity (NEP) of -17 g C m^{-2}. It became a consistent sink of after only 4 years of its establishment, with a NEP of 1261 g C m^{-2} from 2006 to 2013, owing to sandy soils and low residual soil organic matter from previous agricultural activities. This region frequently experiences low precipitation and soil moisture limitations in late summer, causing a reduction in NEP. Seasonal and annual dynamics of NEP showed reduced C uptake during years with drought events such as in 2007 and 2012. The impact of seasonal drought was much more exacerbated if it was combined with heat events. In 2005, an early growing season drought that coincided with a heatwave caused the young forest to become a net C source with a NEP of -126 g C m^{-2}. In contrast, evapotranspiration (ET) had low inter-annual variability. Mean ET was 370 mm year^{-1} over the 2003-2013 period. Water use efficiency (WUE) consistently increased over the study period with a mean value of 3.00 g C uptake per kg of water loss from 2003-2013. Quantum yield, α (0.01 to

0.04) and maximum photosynthetic capacity, A_{max} (4.0 to 27.4 μmol $m^{-2}s^{-1}$) increased steadily as the size and density of the canopy increased over the stand age. Energy fluxes were influenced by canopy development as net radiation (Rn), latent heat (LE), and sensible heat (H) flux increased, while ground heat flux (G) peaked in 2007 and gradually became negative. Our analysis showed that C fluxes during the growing season are climate driven, as 86%, 90%, and 57% of the variability in gross ecosystem productivity (GEP), ecosystem respiration (RE), and NEP were explained by meteorological variables. Annual C fluxes were determined by stand structure as the continually increasing leaf area index (LAI), explained 94%, 95%, and 37% of variability in annual GEP, RE, and NEP respectively. This study is a significant contribution to our understanding of the energy, C, and water dynamics of young afforested stands and controls on their growth. It also adds to our understanding of how young forests may respond to extreme weather events. Our findings demonstrate the potential of utilizing white pine as a means to sequester C in southern Ontario, in regions with similar site characteristics, through future climate variability (e.g. drought).

Hydrologic Controls on Trembling Aspen (*Populus tremuloides*) Regeneration and Succession Post-Fire

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The Western Boreal Plains (WBP) is characterized by a sub-humid climate where evapotranspiration often exceeds precipitation, resulting in moisture deficits in most years. This highlights the importance of peatlands that hydrologically feed uplands. An additional process that connects peatlands to forests is hydraulic redistribution (HR). While this has been previously studied in the WBP, it is uncertain if this process continues post-fire disturbance, and if so, if it will facilitate upland regeneration. The purpose of this study was to monitor trembling aspen (*Populus tremuloides* Michx.) regeneration across a burned hillslope in north central Alberta during the summers of 2013 and 2014, two and three years post-fire. This study also aimed to understand the controls that have allowed *P. tremuloides*, a dominant upland species, to regenerate in peatlands and if they contribute to forest recovery. To determine aspen stress along a burned forest-peatland gradient, plot transpiration (E_{plot}) was taken during both growing seasons where midslope (0.42 mm hr^{-1}) > hilltops (0.29 mm hr^{-1}) > riparian (0.23 mm hr^{-1}) > peatlands (0.095 mm hr^{-1}). Leaf area and stem height followed similar trends. While soil moisture was limited in forests where volumetric water content (VWC) was <0.25 m^3m^{-3}, aspen roots present in peatlands and peatland margins likely participated in hydraulic redistribution. Evidence for this was observed in oxygen and hydrogen isotopes ($\delta^{18}O$, $\delta^{2}H$) where upland xylem and peat core signatures were -10.0, -117.8 and -9.2, -114.0, respectively. This study demonstrated that while aspen seedling germination was dependent on soil substrates and moisture, peatlands were unsuitable for the continued growth of *P. tremuloides*. Instead, the amount of water that was hydraulically redistributed to moisture-limited uplands was sufficient for aspen regeneration post-fire. These findings also highlight the role of roots that aid in hydrologically connecting land units.

Groundwater supply controls nutrient silicon limitation in the Grand River watershed

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Nutrient silicon (Si) limited systems tend to promote more harmful algal blooms, compared with phosphorus (P) or nitrogen (N) limited systems. In this project, we studied the biogeochemical sources and sinks of Si in the Grand River watershed (GRW), a 7000 km^2 basin located in the largely agricultural region of southwestern Ontario, Canada. The river, its major tributaries, and eastern Lake Erie, into which the GRW drains, have historically been considered P limited. We collected groundwater and surface water samples at 11 locations in the lower half of the GRW at monthly to weekly intervals for one year. Samples were analyzed for dissolved and reactive particulate Si (DSi and PRSi), total dissolved P, soluble reactive P, and a suite of other macro and micronutrients including nitrate, nitrite, sulfur and iron. Results indicate that groundwater discharge to surface water provides a year-round source of DSi to surface water, with concentrations roughly equal to winter surface water concentrations. For the majority of the year, this groundwater DSi flux results in Si excess in the GRW. However, during extreme high flow events such as the spring snowmelt and long-term heavy rain events, P is flushed in high concentrations into the river, while DSi concentrations, which experience seasonal drawdown due to biological uptake, are diluted. These dynamics can lead to periods of Si limitation, which persists throughout the river and into Lake Erie.

Hydrological Sciences Section Oral Presentation Abstracts:

Saturday, February 6, 9:00 – 16:00
University of Waterloo
EV3 1408

Multi-year impacts of physical disturbance and thermal perturbation on High Arctic stream chemistry

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Warming of the Arctic has been linked to the formation of physical disturbances and thermal perturbation of the permafrost, which has been shown to alter the chemistry of surface waters. However multi-year impacts, impact trajectories, and recovery times are not well understood. We measured major ion concentrations, TDS concentrations, seasonal TDS fluxes, and stable isotope ratios in waters collected between 2006 and 2014 from a disturbed and undisturbed catchment. Extensive physical disturbance in the form of slope failures occurred in 2007. 2007 and 2012 were exceptionally warm which represent instances of thermal perturbation in both catchments. Results indicate that the key control over hydrochemical impacts following physical disturbance is the exposure of soluble ions in near surface soils, and not driven by evaporation or the contribution from an additional runoff source (such as thawed ground ice). Increased TDS concentrations and seasonal fluxes, and changes to the relative composition of individual ions persisted for seven year after disturbance. Thermal perturbation increased solute yield for two years as ions released from deep ground thaw appear to be available for enhanced flushing in subsequent summers. The combination of both physical disturbance and thermal perturbation appears to intensify the impact on water chemistry and complicate the recovery process. The occurrence of major rainfall events has also contributed substantially to solute transport and may further complicate chemical recovery. This study distinguishes the hydrochemical

impact of different types of permafrost change and provide a means to improve model predictions of watershed impacts to projected climate change.

Economic valuation of five water-related ecosystem services in the Grand River watershed, Ontario

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Valuation of ecosystem services can inform watershed management by analyzing the financial implications of land use changes. Here, we estimate the economic value of five water-related ecosystem services in the Grand River Watershed, Ontario, Canada. The watershed covers about 7000 km2 of which about 80% is under agriculture. The watershed is undergoing rapid urbanization, with 81% of a population of 960,000 currently living in cities. The five services included in our analysis are water purification, water supply, water regulation, nutrient cycling and carbon sequestration. They are valuated using a methodology based on unit values of the services and land cover in the watershed. Four land use scenarios are considered that correspond to (1) pre European settlement, (2) the year 1900, (3) the year 2014 and (4) a future land use target based on the recommendations of Environment Canada. The scenarios illustrate the impact of agricultural intensification and urbanization on the ecosystem services within the watershed. The estimated monetary value of the ecosystem services dropped sharply by $178 million from pre European settlement to the year 1900 due to deforestation and clearing of lands for cultivation. However, conservation and restoration practices have since then caused the value of the ecosystem services to rise again by $123 million.

Streamflow Prediction of Highly Managed Watershed in Madawaska River Watershed using Statistical Modelling

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The Madawaska River watershed, located just southeast of Algonquin Provincial Park, is a watershed with a drainage area of 8500 square kilometres and a long history of water management. There are 41 dams within the watershed, operated primarily by Ministry of Natural Resources (MNR) and Ontario Power Generation (OPG). Recent projects to develop hydrological models of the watershed have created a need for reliable streamflow predictions from the upstream portion of the watershed, which is controlled by MNR flood management dams. However, a hydrological modelling approach is problematic due to (1) reservoir operations dominating hydrological responses, (2) an unclear set of operating procedures for upstream dam operations, and (3) treating multiple dams in series. This prompts the use of statistical models, which can be useful in capturing complex behaviour when the physical processes are not well understood. This study will explore the use of various autoregressive-moving average models, transfer function noise models, and neural network models to create reliable streamflow predictions using a limited amount of available data.

Changing runoff pathways due to permafrost thaw in discontinuous permafrost terrains

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In the wetland-dominated basins that characterise the southern margin of permafrost, permafrost thaw and disappearance and resulting land-cover change, is occurring at an unprecedented rate. Permafrost thaw has the potential to fundamentally alter the processes giving rise to streamflow in this region by altering the physical structure, type and relative proportions of biophysical terrains. Field studies were conducted at the Scotty Creek Research Basin, a 152 km^2 watershed, located about 50 km south of Fort Simpson, Northwest Territories, Canada. Scotty Creek is typical of other basins in the region and is underlain by discontinuous permafrost. There are three major land-cover types in the basin, each exhibiting a distinct hydrological function. Channel fens convey water to the basin outlet, flat bogs can either store water or transmit water to the fen via ephemeral channels, and permafrost plateaus are runoff generators. As permafrost in this region thaws, the wetlands (*i.e.* fens and bogs) grow at the expense of the plateaus and are increasing both hydrological connectivity and runoff contributing area. At the study site, the annual ground heat flux is positive, indicating a net loss of permafrost and allowing for the development of taliks. The formation of a talik serves two purposes: 1) it allows for the year-round lateral transmission of water and energy between wetlands on either side of a plateau; and 2) it creates unstable thermal conditions for the underlying permafrost, as the temperature of the talik is always above 0°C. Extensive frost table mapping was conducted in 2011 and 2015 to determine the depth to the frost table and the date when the active layer thawed through to a talik. 10 transects were completed across peat plateau-wetland interfaces to map both lateral and vertical changes in permafrost extent. Meteorological stations were installed in both wetland and plateau environments to determine differences in total energy input between the years. It was found that lateral thaw was most prevalent along the interface of peat plateaus and channel fens, where energy is advected due to flowing water. The depth of the permafrost table below the ground surface increased from 66.5 cm in 2011 to 86.2 cm in 2015 (n: 153). In 2015, frost was no longer detectable (using a 2m probe) at 18 points and a new talik had developed at 9 points. We hypothesize that increased ground thaw resulting in the formation of taliks is increasing the subsurface hydrologic connectivity between wetlands. The increased presence of taliks provides new routes for the transmission of moisture from bogs to fens; this moisture would have been previously unavailable to the fen network and retained as storage in the bog. This study will work towards incorporating the lateral transmission of subsurface water through taliks in conceptual and numerical models to create an improved understanding of the storage and flux of water in this region.

Permafrost Thaw Rate and Hillslope Runoff Generation in the Permafrost Transition Zone

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A preliminary simplified computational model of permafrost thaw is developed based on a water balance relation developed by Wright et. al. (2008) and a heat conduction model developed by Hayashi et. al. (2007). This new model requires only air temperature and precipitation data to predict frost table depth, water storage in the soil column and basal runoff on a peat plateau in the region of discontinuous permafrost of the Northwest Territories, Canada. The model is very sensitive to the bulk thermal conductivity of the system, which is determined by the soil moisture and also shows strong dependence on air temperature. The model is compared to frost table depth measurements. Though the model is successful in the prediction of frost table depth under moss and lichen ground cover, the model is unable to reliably predict basal runoff, and there is some uncertainty in the prediction of soil moisture. Further work implementing a more strongly coupled compartmentalized model, and validation of the system against a base model, is needed.

Exploring the hydrological function of a heterogeneous, low-relief moderate-rich fen watershed in the Western Boreal Plain, northern Alberta, Canada.

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In the sub-humid Athabasca oil sands region (AOSR) of the Western Boreal Plain (WBP) ecozone, peatlands, primarily in the form of moderate-rich fens, comprise roughly 65% of the landscape. In this region, peatland systems are typically located in watersheds characterized by gentle topographic relief. To date, no studies have provided a comprehensive overview of the hydrogeology of these systems at the watershed scale. As a result, little is known about the groundwater-surface water interactions of moderate-rich fens in the AOSR. The specific objectives of this research are to: 1) explore the role of topographic position and surficial geology on the hydrological and geochemical function of the various land types in a low-relief moderate-rich fen watershed in the AOSR, 2) to characterize the interconnected nature of these land types along with their degree of connection to groundwater flow systems, and 3) to identify how these connections change throughout the growing season, and between 'wet' and 'dry' years. The study site (Poplar fen) is a ~2.5 km^2 watershed located ~30 km north of Fort McMurray. The site is characterized by a large moderate-rich fen (~0.6 km^2), with gentle sloping uplands (relief: 5-8 m; slope: ~1%), and occasional mineral-poor peatlands. To conduct a comprehensive groundwater study, the watershed was instrumented extensively over the 2015 growing season. Preliminary data identify that water tables in all major landscape types respond frequently to rainfall events. In contrast to uplands in more elevated regions of the WBP, water tables in the gentle-sloping uplands of Poplar fen respond to most rain events (>5 mm) with flow reversals between upland and fen occurring frequently throughout the growing season. Results also suggest that the relative importance of uplands and underlying mineral in supplying groundwater to the moderate-rich fen will vary throughout a growing season in response to changing hydrometeorological conditions. Conversely, mineral-poor peatland systems are located in elevated upland regions of the watershed. These small systems form between mineral uplands over discontinuous fine-grained sediment, which limits drainage and promotes long-term peat accumulation. These low pH/EC systems are virtually disconnected from groundwater sources and are fed almost exclusively from rainfall. These results suggest that subtle changes in topographic position and surficial geology result in markedly different land types at Poplar fen. Additional 2016 fieldwork will include hydrological monitoring from onset of snowmelt until the fall, along with additional water sampling and ecological gradient analyses to properly characterize the hydrogeology and ecohydrology of the watershed.

Snowmelt Energy Balance at Scotty Creek, NWT

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At high latitudes, snow has a significant influence on hydrological and atmospheric processes. Portions of these regions are dominated by evergreen coniferous forests which affect energy and mass exchanges between the atmosphere and the land surface. Beneath a forest canopy, energy budget dynamics are strongly influenced by the large spatial variability of radiative and turbulent fluxes. The spatial variation of shortwave irradiance to snow is important to quantify as it can affect the depletion of snow covered area and areal melt rates. Currently, the magnitude of this variation has been sparsely quantified by field measurements during melt and hence, limits the physical basis with which spatial distributions of melt can be estimated. This study was conducted in the high-Boreal zone of discontinuous permafrost at Scotty Creek, NWT for the purpose of addressing these discrepancies. The specific objectives were to 1) compute the snowmelt energy balance in a high-latitude forested environment; and 2) determine the relative importance of the energy balance terms with respect to controlling the spatial distribution of melt energy and partitioning of radiative and turbulent fluxes. Point measurements of snowmelt were used in combination with aerial remote sensing, including high-resolution LiDAR, to examine the spatial distribution of snowmelt rates. Analysis suggests that under most circumstances, incoming shortwave radiation provides the majority of melt energy below the tree canopy.

The transport of sodium from a contaminated tailing sands upland to a constructed fen peatland: two years post-construction

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Current reclamation efforts within the Athabasca Oil Sands Region (AOSR) includes the complete reconstruction of the post-mined landscape, in which the concept of fen peatland construction is first being attempted. In constructed fen peatlands, tailing sands and other mine waste materials are typically used to construct important landforms such an upland aquifer which will act to store and supply water to the fen peatland. However, tailing sands are heavily contaminated with sodium, which is a primary concern when establishing fen vegetation. Thus the design and geometry must account for the management of sodium transport. This study will assess the transport and movement of sodium from a constructed upland tailing sands aquifer to an adjacent constructed fen peatland, which is hydrologically connected through a high permeable petroleum coke underdrain. 2013 and 2014 results have shown that the initial sodium distribution was characterized by high concentrations (~390mg/L) within the tailing sands upland and relatively low concentrations within a petroleum coke underdrain (~150mg/L) and peat profile (<100mg/L). As expected, sodium concentrations quickly increased within the petroleum coke undrain and peat layers immediately above the underdrain (240mg/L and 150mg/L, respectively), indicating the migration of sodium from the upland tailing sands to the fen peatland. Slight increases in sodium concentrations within the near surface peat layer indicates overland flow transport.

High resolution spatial variability of snow depth and water equivalent across a patchy tundra, forest and shrub landscape.

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In high-latitude regions, where snow is the primary type of precipitation and there is a lack of tall vegetation, blowing snow is a key player in the water budget as it controls sublimation rates over the winter and is the dominant process controlling end of winter snow cover distribution. At a watershed scale, deep snow drifts contribute a large percentage of total snow retained on the arctic

tundra for the small percentage of area they occupy. With drifts storing a great amount of snow per area throughout the winter and spring, the impacts on streamflow and ground temperature are significant and their magnitudes are hard to measure. The purpose of this study is to use a combination of field observations of snow accumulation using traditional snow surveys, cosmic ray snow sensors and other instruments to calculate the percentage of total snow water equivalent stored in drifts on lee slopes, along stream valleys and lake edges and in shrub and tree patches. Knowledge of shrub properties, patch size, slope and aspect are critical in order to understand the quantity of end of winter snow water equivalent that can accumulate in these drifts and the impact on the timing and volume of streamflow.

Using Remote Sensing Data to Assess Trends in Lake Ice within Ontario and Manitoba between 2001-2014

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Lakes cover a large portion of the land surface in northern latitudes and play an essential role in the natural system that exists. Investigating lake ice processes is an important part of modelling these natural systems and understanding the changes that occur. However, there has been a decline in the collection of in situ data on ice formation and decay dates over the past thirty years. Remote sensing can be used to address this gap in data collection. This study focuses on investigating the trends in the last 14 years of lake ice on/off dates for lakes with a surface area greater than 0.1 km^2 in the provinces of Ontario and Manitoba. This was done using a pre-classified snow and ice product with a 500 metre resolution (MOD10A1) based on images from the Moderate Resolution Imaging Spectroradiometer (MODIS). Trends and spatial clustering were identified in the ice formation and decay dates over the 14 years, with ice-off dates primarily shifting later while ice-on dates displayed a mixture of both earlier and later trends. These trends were compared to the ERA-Interim reanalysis dataset in order to investigate connections between changes in lake ice phenology and 2m air temperature. Initial investigation shows some links between ice-off and air temperature in the spring months, however the links between fall temperatures and ice-on are tenuous. Results were validated using data collected by the IceWatch network and the Environment Canada Adjusted and Homogenized Temperature data.

Developing a hydrological monitoring program for the Peace-Athabasca Delta (Alberta, Canada) using water isotope tracers

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The Peace-Athabasca Delta (PAD), protected mainly within Wood Buffalo National Park and located in northern Alberta, is a designated Ramsar Wetland of International Importance, a UNESCO World Heritage Site and the world’s largest inland boreal freshwater delta. Concerns over the supply of freshwater in the delta persist because of hydroelectric regulation (W.A.C. Bennett dam [since 1968] and the recently approved Site C dam), water withdrawal by upstream oilsands development and climate-driven decline of river discharge. Despite widespread concern and international attention, there is presently no long-term hydrological monitoring program,.The objective of this project is to develop a water isotope hydrological monitoring program for lakes in the PAD, an essential aspect of detecting periods of low water and flood events, hydrological trends over time, and determining their causes. Four times during the 2015 ice-free season, we sampled 62 lakes and 9 river sites that span the hydrologic gradient of the PAD. Using water isotopes tracers, we document a large range of hydrologic conditions among lakes due to varying relative importance of river flooding, rainfall and snowmelt input, and evaporation to the lake water balances. Isotope-mass balance modelling, combined with 7 prior years of water isotope data spanning 2000-2006, were used to generate hydrological metrics for detecting status and trends useful to our agency partners including Parks Canada. Our results highlight the ability of water isotope tracers to detect spatial and temporal variability in lake water-balances and the applicability for efficient long-term monitoring in northern remote, hydrologically-dynamic, deltaic landscapes.

Silicon cycling through Hamilton Harbour Area of Concern

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In eutrophic environments, silicon may play an important role in influencing the composition of phytoplankton communities through nutrient limitation. If the growth of diatoms, a siliceous algae, becomes constrained by the bioavailability of silicon, the nutrients phosphorus and nitrogen are available in greater supply to fuel harmful algal blooms later in the season. A mass balance modelling of silicon through the Hamilton Harbour Area of Concern has been undertaken to determine if the harbour is a net source or sink for silicon. A water budget for the harbour has been developed, and monthly water sampling and analysis for both dissolved and particulate silicon is underway. Early results show that wastewater treatment plant effluents contribute a considerable flux of silicon to the harbour, which was previously unknown . This research could determine if stoichiometric silicon limitation occurs in Hamilton Harbour and if this could be a causal component for seasonal harmful algal blooms in the area. This research could identify processes to help guide future restoration efforts and contribute to long-term novel nutrient management remediation strategies.

Evaluating prospective hydrological model improvements with consideration of Data and model uncertainty

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The complex and nonlinear nature of hydrological models makes it difficult to assess a single modelling decision independently. Making meaningful modelling decisions is further complicated by data and model uncertainty obscuring the true results of any comparisons. In this work the hydrological modelling framework Raven was used to expose individual modelling decisions to testing by generating distributions of performance indicators (e.g. Nash Sutcliffe) which can then be compared using basic statistical methods. Two methods of generating the distributions have been tested. The first method is to recalibrate the model to flows sampled from a prescribed uncertainty model. This test is designed to ensure that model improvements aren't the result of observation errors balancing model errors by random chance. The second method is to split a long period of observed data into many calibration and validation periods. This test prevents perceived model improvements being caused by a more favorable calibration or validation period. Preliminary testing was done on the Alouette basin in coastal British Columbia and has focused mainly on competing infiltration algorithms and subsurface representations. The results show that sometimes modelling decisions are indistinguishable even when a single performance indicator shows improvement. This suggests that more robust testing is needed than what is typically reported in literature proposing model enhancements.

Evaluating Effectiveness of Mechanical Compression to Change the Hydraulic Properties of *Sphagnum* Moss.

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Ten years post-restoration were implemented at the Bois-des-Bel peatland (BdB) there was limited hydrological connectivity between the regenerated *Sphagnum* moss and the remnant cutover peat due to the formation of a capillary barrier. This resulted in lower soil water content and decreased productivity of the regenerated *Sphagnum* moss compared to a natural analogue. This study evaluates the effectiveness of mechanical compression of the regenerated *Sphagnum* moss to ameliorate the capillary barrier effect. Hydraulic conductivity-soil water content relationships were determined for non-compressed and compressed cores of regenerated *Sphagnum* moss (n=5 cores of 4 depths). The resulting data was used to parameterize a Hydrus-1D model to further elucidate the effect of compression on the hydraulic properties of the regenerated *Sphagnum* moss. Samples were compressed by an average of 1.3 cm which resulted in an increase in bulk density by 49% across all samples and an increase in average unsaturated hydraulic conductivity at each pressure step by 88% to 413%. An average increase of θ by 0·10, 0·09, and 0·08 at ψ = -5 cm, -15, and -25, respectively, while at ψ = -10 cm θ decreased by -0·04. Preliminary results indicate that compression will likely increase hydrological connectivity to the surface and decrease hydrological stress on the moss, warranting field level investigation of compression as a restoration technique (preformed Jan 2016).

Confounding Complexity or Emerging Simplicity? Biogeochemical Regimes in Intensively Managed Catchments

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Watersheds demonstrate a range of both chemostatic and chemodynamic responses to changes in discharge based on land use, solute species, and hydrologic regime as well as the presence or absence of large solute mass stores within the watershed. The dynamics of solute export, as captured by concentration-discharge patterns, can be described mathematically based on a power-law concentration-discharge relationship of the form $C = aQ^b$, where a purely chemostatic system is characterized by a b value equal to 0. It is our hypothesis that different solute export regimes are created primarily as a function of solute mass stores in different compartments of the landscape, e.g. the vadose zone or groundwater, and that these regimes may vary temporally based on the triggering of these compartments as a function of stochastic forcing within and between years. In the present work, we synthesize both high and low temporal resolution concentration data for a range of solutes to better our understanding of the variations in concentration-discharge relationships as a function of land use, climate and solute type. We then develop a modeling framework allowing us to address the following questions: (1) How do C-Q relationships vary across climate and land-use gradients? (2) Is there any seasonality to C-Q patterns? (3) Can C-Q patterns be explained as a function of the activation of fast and slow hydrologic pathways in response to stochastic, hydro-climatic forcing? (4) How do these interactions lead to the development of hot spots and hot moments in catchment biogeochemical processing?

Investigating multiyear suspended sediment flux after a 500-year runoff event in Catskills, NY, USA

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Extreme rainfall events can have lasting impacts on rivers by introducing sediment through slope failure, incision, and surface and channel-bank erosion. Sediment load may be greater following large events due to new sediment sources. The Schoharie Watershed, 2300 km^2, drains the north slope of the Catskill Mountains, New York State. Tropical Storms Irene (28-29 August, 2011) and Lee (6-9 September, 2011) generated extreme runoff events in this watershed, maximum runoff on August 29 was estimated at over 3600 m^3/s. Greater sediment loads were observed during these events and through the subsequent winter. This study used the multiyear suspended sediment loads following Tropical Storms Irene and Lee to investigate longer-term impacts of large-magnitude runoff events. Runoff and suspended load data were evaluated through the 2013-15 water years. Discharge – suspended load correlation strength was calculated. The suspended sediment response to discharge was evaluated over 69 runoff events, finding no trends related to the event magnitude, duration, or timing within the year. For example, the suspended sediment load associated with the spring runoff in each year was proportionate to the runoff, indicating a lack of sediment exhaustion. In June 2013, an intense rainfall event generated nearly 50% of the total suspended sediment load of that water year. Events following June 2013 showed no evidence of sediment exhaustion. Extreme events and opportunities to research their impacts on sediment cascades in temperate watersheds are rare. Preliminary results suggest the suspended sediment supply remains relatively unchanged following Hurricane Irene and Tropical Storm Lee despite initial observations indicating otherwise (e.g., sustained high suspended sediment concentrations).

Determining the wetting preference of peat with respect to water and non-aqueous-phase liquids

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The threat of non aqueous phase liquids (NAPL) spill is increasing in Canada, because of the expanding oil industry. The problem threatens the health of plants, surface water, and underground water resources. One type of lands that are in risk of oil spill damages is peatland. There is no general agreement on the methodology to deal with NAPL contamination. Besides, the methodology is dependent to the physical properties of contaminated area. However, to deal with the hydrocarbon contamination, and to understand its behaviour underground and specially in the vadose zone, three phase flow characteristics of the medium is determined. Several researches investigated the flow NAPL contaminants in soil and rock. However, no study has been done on peat. Considering that peat is composed of organic material its physical and chemical properties in presence of hydrocarbons can be different from properties of soil or rock. Therefore, an investigation of three phase flow characteristics of peat seems necessary. As the primary step of every multiphase flow study, the wettability measurements were done on peat samples and the contact angle as a measure of oil-wetness or water-wetness of the peat samples were determined. In next step, capillary pressure-saturation curves for oil-air and water-oil systems were measured and the results successfully validated the measured contact angles. The obtained contact angles and the capillary pressure design will be helpful in studies

of three-phase flow in peat and will help determining the vertical distribution of water, NAPL and air in the vadose zone of peat layers.

Biogeosciences Section Poster Abstracts:

Saturday, February 6, 14:15 – 15:15
University of Waterloo
EV3 Atrium

Vegetation controls on DOC production on a reclaimed fen in the Athabasca Oil Sands Region, Alberta

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In the Western Boreal Plain (WBP) fens comprise up to 65% of the landscape, however much of this area has been disturbed due to bitumen extraction in the Athabasca Oil Sands Region. Since there is a legal requirement to return equivalent land capability, the Nikanotee Fen was constructed. Within the fen, peat is the dominant sediment type, which is primarily colonized by planted sedge species (*Juncus balticus, Carex aquatilis*) and spontaneously occurring vegetation (*Typha*). It is likely that as the system develops DOC will no longer be sourced solely from the peat, but additionally from seasonal inputs of vegetation. Yet, there is limited information on DOC dynamics in constructed peatlands, with none focusing on site-specific vegetation controls. We report on the impacts these vegetation covers (in addition to moss and bare treatments) have on DOC production in the Nikanotee fen compared to a poor and saline fen within this region. Preliminary results indicate that DOC concentrations are significantly greater near the surface of the Nikanotee fen, however there are no distinct differences within the rooting zone between vegetation covers. This is in contrast to natural sites, which show greater DOC concentrations below the rooting zone compared to the near-surface. Therefore, while vegetation growth is now contributing significantly to the DOC budget of the constructed fen, differences between cover type and DOC production are not evident in a field setting. It is possible that rapid lateral redistribution of water homogenizes DOC concentrations within this layer, or that there are no significant differences in DOC production between vegetation types.

Overwinter habitat of endangered minnows in small Southwestern Ontario Streams

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Highly variable hydrologic and hydraulic conditions in winter present challenges for fish living in small channels. Reduced suitable habitat, and flow dynamics beneath ice cover creates stress for fish, especially minnow species. Our understanding of overwinter habitat is limited to large, economically valuable fish species such as salmonids and there is little information about smaller fish species. Land use changes are altering hydrological processes by modifying the amount and timing of runoff in adjacent river systems. These alterations degrade stream ecosystems and negatively impact biodiversity. Stream restoration is used to restore stream ecosystems by improving habitat quality and

quantity of target species. The aim of this study was to survey and evaluate the physical processes and microhabitat features that provide overwinter habitat for endangered minnow species in Southern Ontario. A total of nine sites around the Greater Toronto Area were selected with three in the Don River watershed, one in the Humber River watershed and five in the Credit River watershed. During each site visit, depth, velocity and water quality were also measured. Relative fish abundance was evaluated with MaxN index using fish counts from 30-second frames from video footage taken during each site visit. Creek chub (*Semotilus atromaculatus*) was the most common fish observed at all sites. West Humber was the only site to have redside dace consistently observed during the winter. Silver Creek had redside dace (*Clinostomus elongatus*) present in autumn and spring. No redside dace were observed at Spring Brook Creek and Patterson Creek during the field season. There was no significant relationship between physical habitat variables and fish density during the winter unlike other seasons (e.g., water depth, water temperature). Instead, the difficult to quantify quality of refugia within the channel (areas that provide protection from high velocities and predators) were observed to be the most important characteristics for overwintering habitat. Examples of refuge habitat that occur at the study sites include: woody debris, instream vegetation, and large cobbles and boulders. During the winter fish sought shelter in available refuge. Other physical processes that impact fish distribution and abundance during other seasons become less important during the winter. This work suggests that stream restoration designs need to consider refuge features to increase the quality of overwinter habitat for minnow species. Qualitatively, instream vegetation refuge features were the most effective at providing overwintering habitat.

Evaluation of clay mineral and suberin and cutin protection of lignin in soil

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Soil organic matter (SOM) plays a major role in carbon sequestration but the fundamental factors governing SOM stabilization remain unclear. Organo-mineral associations contribute greatly to OM stabilization mechanisms. Recent studies have demonstrated that OM may be protected from degradation through clay mineral interactions but such associations are rarely examined at the molecular-level. Previous research has proposed that lignin may protect cutin and suberin from degradation in spruce litter, which triggered our investigation into the preservation patterns of cutin and suberin in soils. Hydrofluoric acid (HF) demineralization was used to evaluate the extent of clay mineral protection of lignin-derived phenols. Base hydrolysis was used to isolate suberin and cutin monomers in grassland, agricultural and forest soils before and after demineralization. Gas chromatography-mass spectrometry was used to analyze lignin-derived phenols released from soil using CuO oxidation before and after cutin and suberin extraction and demineralization. The percentage of mineral-protected lignin monomers ranged from 3-100%, where greater protection was observed in the grassland soils which contain montmorillonite. The agricultural soil exhibited a lower degree of mineral protection but more suberin and cutin protection of lignin. This may be due to the relatively lower clay content and lack of high surface area smectite minerals in this sample. These results suggest that mineral protection is a major protection mechanism of lignin, while suberin and cutin protection plays a secondary role and depends upon soil properties. The preservation patterns of cutin, suberin and lignin should be further examined to understand their contributions to OM stabilization processes.

Effects of changing rainfall frequency on CO_2 exchange among different vegetation communities in a Southern Ontario poor fen

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Climate change projections for the Northern Hemisphere show an increase in the intensity of rainfall events, but at a lower frequency that may lead to lower water tables and drier surface conditions. These changes could potentially threaten Sphagnum moss-dominated peatlands, which depend on moist surface conditions to continue to function as carbon sinks. Recent research has linked lower water tables to increased carbon dioxide emissions (CO_2), but minimal attention has been paid to the influence of the temporal distribution of rainfall on water table position. Thus, the objective for this project was to investigate the effects of varying rainfall frequencies on CO_2 exchange in a poor fen located in Southern Ontario. In a growth chamber setting, we manipulated rainfall over nine mesocosms of 3 groups of different plant community types: (1) Sphagnum-moss only, (2) Sphagnum moss with ericaceous shrubs, and (3) Sphagnum moss with sedges. Simulated rainfall treatments over each of the plant community types varied in frequency but the total amount of water applied to all treatments remained the same. Over a 4-month period, net ecosystem exchange (NEE), ecosystem respiration (R_{tot}), and gross ecosystem photosynthesis (GEP) were monitored using the static chamber method. Our results show that as the water table drops, larger but less frequent events resulted in less CO_2 uptake in all three vegetation communities. Furthermore, while the presence of sedges increased water table decline relative to other vegetation types, increasing CO_2 release, the frequent small rainfall treatment minimized this response. These results, linked to changes in hydrology including soil moisture, water table position, evapotranspiration (ET), and soil water tension will be discussed in the context of climate-change induced changes to rainfall regimes and peatland CO_2 balance.

Carbon exchange in a restored peatland: evaluating the role of three graminoid species

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Close to 30,000 ha of Canadian peatland have been disturbed by extraction for horticulture; this affects their ecosystem function, including their ability to act as a sink for atmospheric carbon. Following peat extraction, recovery of ecosystem function is slow without active restoration. The site for this study, situated in central Alberta, is a restored peatland colonized mostly by graminoids. Although graminoid species are often group as one plant functional type, the greenhouse gas exchange of individual species in restored ecosystems is not well quantified. We focused on three species of graminoids: *Eriophorum vaginatum (E.vag)*, *Calamagrostis canadensis (C.can)* and *Carex canescens (Cx.can)*. In order to quantify each species' impact on fluxes of carbon dioxide, measurements were made with static chambers using plots established in both wetter area (data from May to September) and drier sections of the site (data from August and September). Results indicate that the Gross Ecosystem Photosynthesis (GEP) was greater for every species under wet conditions, with *E.vag* having the greatest GEP. Considering the net exchange of CO_2, results show that the three species act as a carbon sink when photon flux density of photosynthetically active radiation (PAR) exceeds 300 µmol m^{-2} s^{-1} under wetter conditions. Under drier conditions, *E.vag* sequesters carbon less than wetter sites, *C.can* acts as a net sink when PAR exceeds 500 µmol m^{-2} s^{-1}, and *Cx.can* acts as a carbon source under

all measured PAR levels. In conclusion, the three species of graminoids have similar responses under wet conditions, but show distinct responses under dry conditions. More research will be undertaken during the upcoming growing season in order to establish if these species demonstrate enough disparity to be considered individually in process-based models of carbon exchange in restored peatlands.

Greenhouse Gas Flux on an Inverted Well Pad Peatland Restoration in Peace River, Alberta

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The oil industry in Canada is one of the highest sources of anthropogenic carbon emission in the world. Canada also has 25% of the earth's peatlands which have the potential to sequester as well as emit globally significant amounts of carbon, yet little research has been done on the restoration of peatlands previously used as oil well pads. In this experiment, three different inversion types involving the mixing of peat and clay were implemented on an abandoned clay well pad in Peace River, Alberta in 2009. Each inversion type: mixed, clay and peat, was split into three experimental blocks. One experimental block was revegetated with Sphagnum, one with Brown moss, and the final was a control block that was covered in straw. Greenhouse Gas (GHG) flux measurements were taken in each of the blocks in 2014 and 2015 using the closed chamber technique. Water table depth was found to be lowest in the mixed inversion and highest in the clay inversion consistently. The mixed inversion also had the highest Net Ecosystem Exchange (NEE) and Gross Ecosystem Production (GEP) in 2015 on Brown Moss blocks. The 2015 NEE was lower than those measured in 2014 in all but 2 out of 23 blocks. This suggests that CO2 sequestration increased in the second year of measurements. CH4 emissions however, also increased overall in the second year.

Hydrological Sciences Section Poster Abstracts:

Saturday, February 6, 9:00 – 16:00
University of Waterloo
EV3 Atrium

Modeling permafrost degradation under linear disturbance in the regions of discontinuous permafrost

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Thin and warm permafrost of the peatlands in subarctic regions is highly sensitive to surface disturbance. Seismic lines are one of the most common types of linear disturbance, yet their impact is poorly understood. Based on temperature and water level observations that were carried out over the 2012-2014 period and results of geophysical surveys that were conducted in March 2013, we modeled permafrost thaw from the moment the seismic line was cut. The modeled results show that permafrost thaw under linear disturbance is an irreversible process and that complete permafrost disappearance may occur in the nearest 250 years. However, the proposed model is not taking into account heat transfer by advection, which can accelerate the process of permafrost degradation. We also found out that as soon as the permafrost table descends below the water table, the linear disturbance creates a link between previously disconnected fens and bogs, slowly conveying water along the line. The water flow takes place all year round through talik. At the same time, due to the ice loss within the permafrost water may seep through the frozen core of peat plateau. Redistribution of water flow consequentially affects the total runoff from the basin

Numerical modelling of sodium transport at a constructed fen in the Athabasca Oil Sands Region, Alberta.

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In response to the legal obligation to investigate peatland reclamation, an engineered fen was constructed on the Suncor Energy Inc. lease using oil sands process-affected materials (containing residual sodium contamination) and peat from a donor fen on the mine lease. These materials were layered and distributed according to the ideal geometry specified in a conceptual design developed by Price et al. (2010). Of particular concern is whether the residual sodium (Na^+) will be flushed from the system, or will accumulate in the rooting zone. The transport and fate of contaminants in the system and the response of the system to projected climate change are unknown. Furthermore, the implications of the design choices on water and contaminant distributions are not fully understood. Therefore, a predictive hydrochemical numerical model will be developed to assess the current and potential trajectories of the constructed fen. The objectives of the study are as follows: (1) Determine accumulation rates of Na^+ in the shallow subsurface, (2) evaluate flow and transport under stable climatic conditions, as well as under four distinct climate trajectories developed by the IPCC, (3) investigate how modifications to the system geometry could favourably control water and contaminant redistribution, and (4) assess the long-term viability of using constructed fens as a technique to reclaim the post-oil sands landscape and suggest recommendations to improve the performance of these constructed systems. A numerical model will be developed in HYDRUS, coupled with the geochemical reactions package PHREEQC. The model will be parameterized using field data and laboratory experiments to measure unsaturated hydraulic conductivity. Spatially variable hydraulic properties observed within the peat will be represented as statistically derived homogeneous macroscopic equivalents. Sensitivity analyses will be conducted to evaluate model robustness, assess uncertainty, and quantify the influence that altered climate, and suboptimal geometry has on solute transport and water redistribution. Representing changes to geometry will be accomplished by varying the thickness of the stratigraphic layers individually and in combination, and varying the dimensions of system components relative to each other. Accumulation rates of Na^+ will determine the fate of the constructed fen, and provide insight on the utility of using oil sands process-affected materials for wetland reclamation. Understanding the sensitivity of the system to changing climatic conditions will allow the design criteria for constructed peatlands to be refined. This has broad implications, not only for improving oil sands reclamation, but also for managing contamination and enhancing resilience to climatic stressors in all constructed wetlands. Finally, simulating deviations from the ideal system geometry will directly inform industry and wetland reclamation specialists on the suitability of implementing landscape-scale reclamation using constructed fens in different geomorphic settings.

The influence of water table fluctuation on nutrient dynamics in sand from a freshwater beach environment.

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Water table fluctuations between groundwater and surface water significantly affect the biological and geochemical functioning of soils. The pulse of oxygen introduced or removed by cyclic draining and rewetting results in significant oxidation and reduction of redox sensitive chemical species. My approach to unravel the biogeochemical implications of water table fluctuations is to conduct laboratory experiments with soil column in which the position of the water table can be manipulated. In this project, I use a novel automated soil column system where the time course of the water level is imposed via a programmable multichannel pump. An undisturbed sand core, 40 cm in length was collected from the Burlington beach site and was introduced into a column in the lab. The soil column has ports that are used to install ceramic pore water samplers to characterize the evolution of pore water chemistry (pH, major anions/cations, nutrients, DOC and DIC) in soil column during water table fluctuations. At the end of experiment, the soil will be extruded via the top of the column using a lifting jack and will be sliced every 2 cm for further solid phase geochemical characterizations. The goal of this study is to better delineate the role of water table oscillations on nutrient fate and distribution in sand from a freshwater beach environment.

Geospatial Estimates of Road Salt Usage Across a Gradient of Urbanizing Watersheds in Southern Ontario

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Chloride (Cl) salts, while an effective de-icing agent, have significant environmental consequences to local aquatic ecosystems. Chloride has been recognized as a pollutant of concern in Canada by the Canadian Council of Ministers of the Environment, especially in urban areas. In many waterways, Cl concentrations have been increasing since the early 1990s, often exceeding national water quality guidelines, resulting in negative ecological effects for many aquatic organisms. Determining accumulated Cl levels in urban and urbanizing watersheds requires accurate estimates of road salt application. Complex jurisdictional control over salt applications requires a geospatial approach for calculating Cl inputs. Our study site will be 12 subwatersheds with salt accumulation issues across a gradient of urbanization: 7 in the Lake Simcoe area (considered first), 3 in Toronto, and 2 in Hamilton Harbour. The goal of this study is to develop a geospatial protocol for combining information on road salt applications and road network areas to improve the accuracy of watershed-scale Cl storage estimates. First, geospatial shapefiles will be used to calculate “lane-lengths” for each subwatershed as managed by each governmental jurisdiction predominantly in ArcGIS. Second, road salt application data from various sources was reviewed and refined due to inconsistencies in order to determine quantities and rates of application. Third, this “cleaned” data is evenly allocated for each layer to these lane-lengths, then refined based on managerial/operational inputs, and summed to the impacted subwatershed of concern. Lastly, statistical analysis of the relationships between salts/solids distributed and various predictive factors in order to compare intra- and inter-watershed spatiotemporal patterns as they relate to climatic patterns (i.e. weather based around nearby Environment Canada stations and urbanization measures based on ENVI classification). A specific subwatershed (Lovers Creek) is used as a sample subwatershed in preliminary statistical analysis; scatterplots and regression results relating weather data as predictors of salt application data are included. Next steps include using more location-specific weather data (Road Weather Information Systems), refining jurisdictional boundaries, and reviewing operator inputs. Results will become the input for mass balance equations that calculate how salt allocation contributes to chloride accumulations across the various areas.

Exploring the Effects of Turbulent Sheltering within Wetlands in the Western Boreal Forest, Alberta, Canada

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The landscape of the Western Boreal Plains (WBP) of Alberta have experienced significant levels of destruction over the past century which is primarily due to the expansion of the oil and gas industry. Development in this region is destroying the natural upland and wetland mosaic of the landscape, whereby the reclamation of these areas is required following resource extraction. However, this is a complex task impart due to the constant water deficit condition, which has the potential to inhibit the primary function of these landscape and transforming them into a carbon sink, making evapotranspiration (ET) management critical. One of the dominant drivers of ET is wind and its ability to control the boundary layer, which has the potential to reduce wind turbulence within a wetland. Previous research has been conducted on the formation of the boundary layer around a block (frontward facing step (FFS) followed by a backward facing step (BFS) sequence). However, there has been minimal consideration directed at how the boundary layer will react to the space between a BFS and FFS sequence, which is theoretically representative of a wetland in the WBP. Moreover, no research has been conducted assessing the impact of vegetation (surface roughness) and thermal stratification's impact on boundary layer around a step sequence. The complex mosaic of the WBP has the potential to change how the boundary layer interacts with the wetlands; surrounding wetlands have the potential to modify the initial boundary layer conditions assumed in previous step sequence research. Results from simulations ran in the Regional Atmospheric Forest Large Eddy Simulation (RAFLES) will give insight into the small scale interactions within the space between a BSF and FFS sequence and the impact of surface roughness and thermal stratification on boundary layer separation around these features. Additionally, at the landscape scale, interactions between surrounding wetlands and the upland forest will be assessed to determine if the boundary layers within wetlands are influenced by surrounding wetlands.

Detecting spatial patterns in hydrology and carbon export across the drainage network of a vast lake-rich permafrost landscape (Old Crow Flats, Yukon, Canada)

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Lake-rich permafrost landscapes are widespread across northern regions and provide refuge for abundant wildlife and resources for local communities. Evidence suggests that these landscapes are highly sensitive to climate change. Old Crow Flats (OCF), YK is a vast 5600-km^2 lake-rich landscape that is internationally recognized for its ecological and cultural integrity. Pronounced changes in lake and river water levels, and land cover compositions have been observed during recent decades by local community members and in recent studies. Research presented here focuses on identifying spatial patterns in hydrology and carbon export in OCF and the associated influence of changing landscape features. Water samples were collected from 12 lakes and 22 river sites spanning the OCF drainage network during July 2015 and have been analyzed for a suite of water chemistry and isotopic parameters including dissolved inorganic carbon and dissolved organic carbon (DIC/DOC) concentrations, water isotope compositions ($d^{18}O$, $d^{2}H$, and DIC and DOC $d^{13}C$) and total suspended sediments (TSS). Multivariate and spatial analysis results show broad systematic variation across the landscape. DIC concentration decreased downstream along the 350-kilometer stretch of the Old Crow River and its main tributaries, whereas DOC and TSS concentrations increased along the same reaches. It is likely that DOC increases are due to higher proportions of lake water contribution to flow further downstream. Water sampled at these locations was also marked by elevated $d^{18}O$ and $d^{2}H$ compositions, which is an indicator of exported lake water that has undergone greater evaporation. Lake to river hydrological connectivity is evidently greater in the southern OCF. Fluvial geomorphic processes including erosion of channel shorelines are also likely contributing to increases in TSS and DOC. Samples will be collected from the same locations during 2016 to assess the roll of variation of inter-annual meteorological conditions. The focus of the next phase of research will include evaluating spatial correspondence among lake-river hydrological connectivity and changing landscape conditions including slumping river shorelines and shrub proliferation. Findings from this work will enhance our understanding of the influence of changing landscape features on hydrology and carbon export in northern lake-rich landscapes.

Pitfalls in Model Calibration using Streamflow at the Watershed Outlet: Getting the Right Answers for the Wrong Reasons

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Most watershed models are calibrated solely using stream flow at the watershed outlet, ignoring the possibility of equifinality and non-uniqueness issues where multiple combinations of spatially distributed parameters can lead to similar integrated responses. Lack of availability of spatially distributed data is identified as the primary cause of such an approach. In agricultural watersheds, there exists spatially distributed data on crop yields that is most often not used for model calibration, despite the fact that crop growth alters the evapo-transpiration flux and thus the water balance within the soil profile which could greatly affect the stream flow. We hypothesize that crops can act as distributed sensors within the watershed that can be used to constrain the streamflow flux and lead to a more correct description of the watersheds' internal processing. To demonstrate this, we have used the Soil Water Assessment Tool (SWAT) model at a 33,000 km2 agricultural watershed in the mid-western U.S. Our objective was to attempt multi objective calibration through two scenarios, (i) calibrate only streamflow at eight locations within the watershed and (ii) add crop yield as calibration target. The first case led to a good Nash Sutcliffe Efficiency for streamflow, but did so at the expense of poor crop yields. Inclusion of crop yields as a calibration target improved both the stream flow statistics significantly, as well led to a more realistic representation of the flow partitioning within the watershed.

The Impacts of Wildfires on Seasonal and Permafrost Thaw on a Peat Plateau at Scotty Creek, Northwest Territories, Canada

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Permafrost marks the vital ecological structure of northern ecosystems. Permafrost thaw is consistently increasing due to human induced climate change, particularly with increasing rates of forest fires. Studying this relationship may be key to understanding the changing northern ecology and hydrology as our northern Canadian landscape is being drastically altered. In the lower Liard River valley, south of Fort Simpson, NWT, the area occupied by permafrost has decreased from approximately 70% to 40% (Quinton & Baltzer, 2013). In recent years the frequency and severity of forest fires has also increased. Following a wildfire in July 2014, a burned peat plateau as well as an adjacent unburned peat plateau were instrumented to measure differences in meteorological and ground temperature variables. A field campaign from March to August 2015 allowed for the measurement of snowpack, snowmelt and ground thaw variables. The objective was to compare and quantify the variation between a burned and unburned peat plateau in order to investigate the impact of a wildfire on the patterns of snow accumulation, snowmelt, and ground thaw. Preliminary results demonstrate the net solar radiation at the surface from April to June was 23% higher on the unburned plateau than the burned one, whilst the cumulative incoming shortwave radiation was 11% lower on the unburned plateau. Prior to snowmelt the unburned plateau had a snowpack which was 10% shallower and 27% less dense. The unburned snowpack began showing snow free patches four days earlier than the burned plateau, yet the burned snowpack disappeared seven days earlier. At the end of August the frost table depth on the burned plateau is 30% deeper than the unburned plateau.

Canadian Flood Quantile Estimation

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Extreme hydrological events, such as floods, can have a profound effect on human health, safety, infrastructure and the environment. The frequency of occurrence of a flood event of a given magnitude is of great importance in designing river engineering works, designing hydraulic structures, and also required for effective development and management of water resources. It is hence essential to accurately estimate the probability of exceedance of these extreme events. Flood frequency analysis relates the magnitude of extreme events to their frequency of occurrence. However, extreme events are by definition rare and the available data record is often short. In such situations, regional flood frequency can be employed to augment the short data record. Regional flood frequency analysis uses several records from a region with similar flood behavior, rather than only single site information. In the past decades, there has been advancement in different regional flood frequency analysis methods and some classical approaches have been identified. In Canada, there is no up to date national standard for flood frequency analysis. This research will explore ways to better estimate the probability of occurrence of flood events based on a regionalization approach in Canada. The study will deliver a unified procedure for flood frequency analysis and will provide updated estimates of extreme events for selected locations across Canada.

Recent Variation of Daily Precipitation and Temperature Extremes at Fort Simpson, NWT

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Since the mid-90s, discharge from streams and rivers draining the discontinuous permafrost zone of the southern Northwest Territories has increased and these rates have accelerated in recent years. Work done by Connon and others suggested two hypotheses; one is related to meteorology and other to landscape changes and feedbacks caused by the permafrost thaw. This research will investigate meteorological hypothesis. The impacts of extreme climate and weather across the globe have shifted the focus of the climate research community towards changes in weather and climate extremes, as any change in climate may have an impact on ecosystems through vegetation or hydrology. This aspect of extreme weather patterns is not fully understood and a challenge resides in the ability to scale this global information down to regional and local impacts. In this work, we will focus on quantitative analysis of extreme events using historical and reanalysis data for Fort Simpson, NWT. Preliminary results show significant warming trends for minimum and maximum temperature as well as for cold and warm days and nights throughout the study area, whereas warm extremes and night-time based temperature indices show increasing trends. Precipitation extremes are occurring more frequently and intense precipitation events have increased during winter and summer months at Fort Simpson since 1898.

Classification of hydrological response units for modelling source water dynamics in a High Arctic Watershed

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High Arctic watersheds fluxes of water, sediment, and nutrients are traditionally dominated by snowmelt. Projected climate changes are anticipated to impact winter snowpack and melt season conditions, which in turn will affect water quality and quantity. The water within these watersheds is both a key source of freshwater for northern communities, as well as a crucial component for local ecosystems. Understanding the current watershed dynamics and potential future trajectories are crucial to protecting source water. The objective of this research is to identify the watersheds surrounding Pond Inlet and to derive topographic indices to aid in the identification of hydrological response units and spatial parameters. The resultant hydrologic response units will be used with spatial parameters for modeling current and projected hydrologic processes in the watershed using the Cold Regions Hydrological Model. These results will provide preliminary findings that can be used to assess the potential of the Cold Regions Hydrological model to model hydrologic processes under current and future climate scenarios. The results will provide a framework for determining potential source water catchment areas and for developing source water protection plans.

Developing a hydroecological monitoring program for ponds in Wapusk National Park, northern Manitoba

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Wapusk National Park (WNP), located on the southwest coast of Hudson Bay, contains over 10,000 shallow lakes which provide key habitat for many wildlife and waterfowl, but their hydroecological integrity is threatened by climate change and rapidly increasing Lesser Snow Goose (LSG) population. For example, lake desiccation has recently been observed and has been attributed to low snowmelt runoff (Bouchard et al. 2013; *Geophysical Research Letters*). Additionally, studies have shown that ponds in catchments disturbed by LSG grubbing and vegetation loss experience changes in carbon cycling (MacDonald et al. 2014; *Arctic, Antarctic, and Alpine Research*), and increased nitrogen availability and aquatic productivity (MacDonald et al. 2015; *Ecology and Evolution*). To track the ongoing consequences of these stressors, we are developing the foundation of a hydroecological monitoring program for ponds in WNP in collaboration with Parks Canada. The monitoring program includes use of water isotope composition ($d^{18}O$, $d^{2}H$) measured at sixteen ponds located in the three main ecozones of WNP (coastal fen, interior peat plateau-palsa bog, and boreal spruce forest) during 2010-2015, which provide data to assess changes in pond hydrological conditions and capture the diverse hydrological conditions throughout the park. Isotopic modelling has been utilized to evaluate the relative roles of hydrological processes on pond water balances. Results show strong seasonal and spatial variability in the isotope composition of lake-specific input water (d_I) and evaporation to inflow ratios (E/I) related to meteorological and catchment conditions. To refine measures to assess the aquatic consequences of LSG disturbance, sampling targeted five severely-disturbed ponds, five moderately-disturbed ponds, and five undisturbed ponds in 2014 and 2015. Ponds were visited in mid-June after ice-off, late-July and mid-September before ice-on and sampled for water chemistry, water isotope composition and the upper 1 cm of sediment (2014 only). Analysis of pond surface sediments indicates that there are geochemical and biological differences associated with the degree of LSG disturbance. For example, severely disturbed ponds possess the lowest C/N ratios, reflecting high nitrogen availability, and the diatom assemblage reflects hypersaline conditions. Moderately disturbed ponds have high percentage of the diatom *Denticula kuetzingii* reflecting benthic mat habitat. Non-disturbed ponds are characterized by high C/N ratios and the nitrogen-fixing pigment aphanizophyll, results consistent with low nitrogen availability. Overall, the monitoring approaches will generate key metrics to assess aquatic ecosystem status and trends in response to ongoing changes in climate and LSG population.

Sustainability Trajectories in a Water Stressed Environment: A Systems Approach

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Groundwater plays an important role in improving the resilience of agriculture practices by mitigating the risk associated with unreliable and seasonal rainfalls. This has been an important driver in satisfying the food demand for an ever increasing population across the world. However, the inability to manage this large but limited freshwater reserve has resulted in a sharp decline in water table levels, with India being at the forefront of this problem. This study looks at the temporal trajectory of groundwater extraction in India over a 40 year time span during which well irrigation has evolved to become a central component of agriculture there. Using a systems approach, we identify the regional hot-spots of unsustainable groundwater extraction and then analyze its relationship with the environmental, economic and social components of the region. Early results indicate that the state of Punjab has been overexploiting its groundwater resources since the early 1980?s with a 22% jump in groundwater extraction after the introduction of a free electricity policy, with a concomitant reduction in the number of marginal farmers by 36%. This is in contrast with the state of Tamil Nadu, in which groundwater extraction is less severe, but the number of marginal farmers has increased."

Using paleolimnology to establish baseline metal concentrations and to reconstruct hydroecological conditions within a community monitoring program, Marian River Watershed, NWT.

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Tłı̨chǫ Lands occupy approximately 39000 km^2 in the Northwest Territories between Great Slave and Great Bear lakes. Established in 2013, the Marian Watershed Stewardship Program (MWSP) is designed to assess and monitor areas within the Marian River watershed important to traditional livelihoods. The program aims to assess ecosystem health through monitoring and sampling of water, sediment, and fish. Of particular concern is the proposed NICO mine and the potential for cumulative effects of development, land disturbance, and climate change in the Marian River watershed. Working with the MWSP, this research uses paleolimnological approaches to establish baseline sediment metal concentrations in lakes and to reconstruct past hydroecological conditions using lake sediment cores obtained in late summer 2015. Sediment cores are being analyzed for radiometric (^{210}Pb, ^{137}Cs), physical (loss-on-ignition), geochemical (organic carbon and nitrogen elemental and isotope composition, cellulose oxygen isotope composition), and biological parameters (diatoms, pigments), and metal concentrations. Hydroecological reconstructions will place recent low water conditions into a longer temporal context needed to assess potential causes, and provide knowledge to interpret stratigraphic trends in natural metal concentration prior to the Nico mine development.

Exploring Nitrogen Legacies and Time Lags: A 200-Year Longitudinal Study of the Mississippi and Susquehanna Watersheds

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Global flows of reactive nitrogen (N) have increased significantly over the last century in response to land-use change, agricultural intensification and elevated levels of atmospheric N. Despite widespread implementation of a range of conservation measures, N concentrations in surface waters are in many cases remaining steady or continuing to increase. Such time lags to the recovery of surface water quality are increasingly being attributed to the presence of legacy N stores in subsurface reservoirs. It has remained unclear, however, what the magnitudes of such stores might be, and how they are partitioned between soil and groundwater reservoirs. In the present work, we have developed a comprehensive, 200-year dataset of N inputs to the land surface of the continental United States. We have concurrently developed a parsimonious, process-based model utilizing this N input trajectory to simulate biogeochemical transformations of N along subsurface pathways. Model results allow us predict the magnitudes of legacy N in soil and groundwater pools and to predict long-term N-loading trajectories over the last century and into the future. We have applied this modeling approach to two major U.S. watersheds, the Mississippi River and Susquehanna River Basins, which are the sources of significant nutrient contamination to the Gulf of Mexico and Chesapeake Bay, respectively. Using the model, we estimate spatiotemporal patterns of N accumulation in both groundwater and soil organic matter in response to increases in N inputs to agricultural soil as well as changes in N residence times across the terrestrial system.

Changing climate and snowmelt regimes in northern tundra environments, NWT

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Warming trends have been well documented across Canada's western Arctic over the past few decades where observed increases in average surface temperatures have risen approximately 2.5 degrees Celsius since 1970 (Burn and Kokelj 2009). Global Climate Models (GCMs) have demonstrated that the air temperatures across the western Arctic are only expected to further increase over the next couple of decades. Associated with trends of increasing air temperature in the North are multiple changes in the natural environment and hydrological cycle of these regions. Using an extensive record of surface air temperature for a remote tundra site located in the Northwest Territories this study aims to analyze changes in air temperature across the western Arctic and study the effects on the regions annual snowfall and spring snowmelt characteristics. A year-by-year analysis of the spring (April, May, June) melt period has shown that warming trends have a direct influence on the overall snowmelt period resulting in earlier snowmelt initiation dates and shorter spring melt periods, and increased the seasonal variability.

The Effects of a Changing Snowpack on the Bathurst Caribou Herd, Northwest Territories

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The Bathurst caribou herd has experienced a significant decline over the last two decades. Many northern barren-ground caribou herds around the circumpolar region have experienced similar declines. Natural population cycles do occur with this ungulate species, yet the population numbers for the Bathurst herd are the lowest on record. The cause of this population decline is not completely understood. Some hypotheses of the cause of the rapid decline include the change in food availability, habitat transformation resulting from increased frequency and severity of wildfires, increased predation, however each of these potential causes are at least partially mediated by snowpack characteristics during the winter months. The amount of seasonal snow can affect both the caribou's access to food in the winter and can increase the risk of predation. In this paper we explore changing patterns in amount of seasonal snow water equivalent in relation to caribou winter ranges. Using remotely sensed snow water equivalent data and collared caribou data, relationships between caribou and snowpack were investigated at the individual and population levels. Results have shown a northern shift in caribou habitat. This shift is critical due to the change in environment and change in habitat type. This change may affect the way the Bathurst caribou forage for food and travel. Also, a northern shift in habitat exposes caribou to new environments and differing snowpack characteristics. This analysis provides preliminary results to a complex relationship between the winter environment, change in snowpack characteristics and the Bathurst caribou herd.