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# Sediment Transport in Ice-Covered Rivers: A Prospect Research Project

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## EXTENDED ABSTRACT

The process of sediment transport in rivers can be linked to both open channel hydraulics and sediment supplies. Compared to its open channel version, a limited amount of research has been directed to sediment transport in ice-covered rivers. In northern regions, the presence of an ice cover modifies channel hydraulics and the availability of sediment during a significant portion of the year, thus adding to the complexity of this process and affecting the distribution of the carried sediments over a year cycle.

Few flume studies have investigated the effects of a modeled ice cover on channel hydraulics and sediment transport while a limited number of under-ice sediment transport measurements (mostly suspended) have been performed in the field. A general consensus however exists on a significant reduction of sediment transport capacity once the ice cover is present. An ideal free-floating ice cover increases channel roughness and water depth, thus directly affecting water velocities and sediment transport capacity. Meanwhile, sediment availability in winter conditions has mostly been addressed only qualitatively (Beltaos and Prowse, 2009; Ettema, 2002; Milburn and Prowse, 1996). Yet, it is believed that the reduction in sediment transport could be promoted by a decline in sediment supplies during winter.

Nevertheless, a number of known ice-related transient processes are likely to increase sediment transport. These ice cover processes are commonly observed in most ice affected rivers and could counter-balance the expected decrease in sediment transport rates in winter. Ice jams, during the freeze-up and break-up periods, are probably the most documented phenomena locally affecting sediment transport. However, limited hydraulic and sediment transport measurements have understandably been obtained during these events. Frazil, in the form of anchor ice or

hanging dams, has received less attention, but probably fewer efforts and hazards are implied in their monitoring in the field. Mid-winter discharge increases have almost been ignored as potential sediment transport generators. In fact, the ice cover behavior and the corresponding sediment transport response are not clearly defined during mid-winter hydrological events. Finally, ice runs during break-up are believed to affect sediment supplies (Beltaos and Prowse, 2009; Jasek, 2003), while the sediment transport capacity is generally significant when these processes occur. Most break-up events have been described only qualitatively and their contribution to the annual sediment transport budget has yet to be quantified.

This project aims at quantifying the volume of sediment transported by two tributaries of the Saint-Lawrence River during the winter period. Specific objectives are: (1) to identify the relative contribution of different ice-related processes to the annual sediment transport budget, (2) to understand the hydraulic conditions associated with complex ice-related phenomena such as winter discharge increases and (3) to estimate long-term morphological variations of river channels and river deltas associated with different climate change scenarios.

Since north and south-flowing rivers are distinctly affected by weather conditions and discharge variations throughout winter (Prowse and Carter, 2002; Prowse and Culp, 2003), a tributary was selected on both shores of the Saint-Lawrence: the Batiscan River on the north shore (south-flowing, 4,688 $km^2$ watershed) and the St-François River on the south shore (north-flowing, 10,230 $km^2$ watershed). The field investigation started in Fall 2008 with the bathymetric survey of 30 cross-sections on each river using a boat mounted Sonar coupled with a Global Positioning System (GPS). Comparable measurements were obtained just prior to break-up in 2009 using a Ground Penetrating Radar (GPR). A second Sonar survey will be completed once both rivers are no longer ice-affected in Spring 2009. The comparison of cross-sections will help to identify the most active river segments on which further field work will focus during the next 3 years.

During the winter of 2009, the accuracy of the GPR to measure ice thickness and water depth was explored. GPR data were compared to direct ice thickness and water depth measurements. GPR results presented an absolute average error of 0.035m (std. dev. of 0.041m) for ice thickness measurements and an absolute average error of 0.070m (std. dev. of 0.073m) for bathymetric measurements. The presence of dunes and ripples on the river channel bed probably amplified estimated errors. These results also show that the precision of the GPR measurements was independent of water depth and ice thickness.

During Summer 2009, instrumentation will be deployed in the river reaches to measure suspended and bedload sediment transport. Optical Backscatter Sensors (OBS) will be installed on bridge piers for suspended sediment data collection. Bedload represents a more challenging parameter to estimate in wide rivers. The presence of a small hydroelectric reservoir on the Batiscan River (23 km from the estuary, 1 km long), where important sedimentation has been reported, represents an appropriate site to measure sediment deposition rates year-round. The more active river cross-sections, in terms of lateral shifting and sediment erosion-deposition, will be monitored using the GPR and Sonar. Field measurements will be collected regularly, especially before and after significant hydrological and dynamic ice events.

Additional instrumentation will include an Acoustic Doppler Current Profiler (ADCP) for velocity profile measurements and possibly to estimate bedload transport rates (Rennie et al., 2002). Aquatic cameras will be used to describe the water-ice boundary as well as to confirm the presence of bedload transport activity. Scour chains and magnetic tracers will complete the instrumentation for estimating bedload transport. The presence of discharge measurement stations and weather stations close to each site will provide the data required for linking sediment transport activity to hydrological and meteorological conditions.

The data analysis will intend to correlate sediment transport rates to ice conditions, dynamic ice events, and hydrological pulses. This will allow documenting, not only sediment transport throughout the research period, but also to understand the potential winter sediment transport budget ratio, which is especially relevant in a changing climate perspective (Beltaos and Burrell, 2003; Beltaos and Prowse, 2009).

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