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Suspended sediment transport, storage and hysteresis characteristics in an Arctic catchment subject to recent permafrost disturbances

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Recent and projected climate change is expected to have significant effects on the stability of permafrost terrain in the Arctic. Increased summer active layer (thaw) depths due to warming and increased soil moisture from rainfall or ground ice melt are factors that can result in the failure of slopes and release large amounts of sediment into stream channels. Despite the potential impact on stream channel systems by permafrost disturbance, little research has been undertaken to determine how these catchment processes affect sediment transport and storage dynamics in channel systems.

This study reports results from an intensive field program to investigate these processes in a catchment subject to recent permafrost disturbance. The research was carried out at the Cape Bounty Arctic Watershed Observatory (CBAWO, 74°55'N, 109°30'W), located on Melville Island in the Canadian High Arctic. Exceptional summer temperatures and heavy rainfall in 2007 resulted in widespread permafrost slope disturbances termed active layer detachments that abruptly increased delivery of fine grained sediment to the stream channel. In 2010, we sought to investigate the spatial distribution of sediment transport in the channel by determining sediment budgets for five reaches of the main stream, as well as four disturbed tributaries. Hydrometric stations at nine locations provided discharge data, and frequent manual sampling for suspended sediment concentrations were undertaken to determine sediment fluxes in each channel reach. Results from 2010 were also compared to stream measurements obtained prior to any disturbance in 2004-6 to determine the impact on sediment loads and hysteresis patterns.

Results indicate substantial sediment storage in reaches downstream of disturbances and turbid inflows. Sediment storage was particularly pronounced during baseflow conditions in July, where >99% of the suspended sediment transported in the upper reaches was stored during a 23 day interval. Over a wide range of discharge and channel snow conditions, reaches downstream of major disturbances consistently showed net storage. These results suggest that even highly mobile suspended sediment is subject to storage and release phases that contribute to morphological changes in the channel system. These results also indicate that sediment dynamics in these first and second order channel networks have substantial storage and release components that buffer the effect of disturbance in terms of sediment transport. These results will be used to develop models to estimate the long term impact of permafrost disturbances on arctic fluvial and channel systems and to improve estimates of water quality impacts due to disturbance.