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# A Multi-Sensor Remote Sensing Approach for Railway Corridor Ground Hazard Management

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Characterizing and monitoring ground hazard processes is a difficult endeavor along mountainous transportation corridors. This is primarily due to the quantity of hazard sites, complex topography, limited and sometimes hazardous access to sites, and obstructed views. The current hazard assessment approach for Canadian railways partly relies on the ability of inspection employees to assess hazard from track level, which isn't practical in complex slope environments. Various remote sensing sensors, implemented on numerous platforms have the potential to be used in these environments. They are frequently found to be complementary in their use, however, an optimum combination of these approaches has not yet been found for an operational rail setting. In this study, we investigate various cases where remote sensing technologies have been used to characterize and monitor ground hazards along railway corridors across the Canadian network, in order to better understand failure mechanisms, identify hazard source zones and to provide early warning.

Since early 2012, a series of high resolution gigapixel images, Terrestrial Laser Scanning (TLS), Aerial laser scanning (ALS), ground based photogrammetry, oblique aerial photogrammetry (from helicopter and Unmanned Aerial Vehicle (UAV) platforms), have been collected at ground hazard sites throughout the Canadian rail network. On a network level scale, comparison of sequential ALS scanning data has been found to be an ideal methodology for observing large-scale change and prioritizing high hazard sites for more detailed monitoring with terrestrial methods. The combination of TLS and high resolution gigapixel imagery at various temporal scales has allowed for a detailed characterization of the hazard level posed by the slopes, the identification of the main failure modes, an analysis of hazard activity, and the observation failure precursors such as deformation, rockfall and tension crack opening. At sites not feasible for ground based approaches or requiring rapid deployment, aerial photogrammetry has been shown to be a reliable and accurate method to characterize and monitor hazard sites. A benefit of having ALS data for the entire project area is that photogrammetry data can be easily and accurately scaled and aligned without the use of targets and thus avoiding direct contact to the hazard sites. In a case example, the combined use of ALS, TLS and oblique helicopter photogrammetry was used to provide early warning to potential rockfall failure by monitoring the progression of pre-failure deformation, assessing risk from the identified rockfall source zones and providing a rapid means to assessing post failure volume and run out. The combined use of remote sensing approaches in this project area has allowed for improved management of ground hazards.