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Ice Processes in Stormwater Retention Ponds

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1. Introduction

Storm water retention facilities have become a necessary component of urban drainage systems and are designed to manage both the quantity and quality of run-off water (City of Edmonton, 2014). The City of Edmonton has constructed more than 140 such facilities, all within the past 40 years (City of Edmonton, 2015). This includes many in residential communities where, despite prohibitive signage, they serve a secondary function as popular winter recreational sites. The safety of recreational users has become a particular concern due to the variable, and often dynamic, ice conditions on these facilities.

The spatial variability in ice cover thickness on natural lakes has been attributed to a number of factors, including the insulating effects of snow cover, exposure to solar radiation, and heat transport by currents (Bengtsson, 1986). This study focuses on characterizing the ice covers on storm water retention ponds and determining the dominant mechanisms influencing ice cover thickness on these urban lakes.

2. Methodology

Three 'wet facilities' and one constructed wetland in Edmonton, Alberta, were selected for study over the course of two winters. These included two shallow L-shaped ponds (one being the constructed wetland), a shallow triangular pond, and a deeper rectangular pond. Monitoring of the ice cover included time-lapse photography, direct measurement of the ice thickness, collection of ice cores, and ice thickness surveys using ground penetrating radar (GPR). Additional year-round monitoring included the installation of climate stations at each site, submerged instrumentation, and collection of water samples.

Multiple time-lapse cameras were installed at each pond for monitoring the formation and degradation of the ice covers, development of holes at inlets, flooding and erosion of ice covers by surface flows, and recreational use by local residents. Direct measurements of the ice thickness and visual estimates of snow ice thickness were made at augured holes. Ice cores were collected at several locations using a CRREL barrel for ice-crystal visualization using polarized filters.

Surveys of ice thickness were conducted 2-3 times per winter season at each pond. A SIR3000 GPR system and antenna from GSSI was secured to a plastic toboggan and towed across the ice cover. The location of the antenna was tracked with a Real Time Kinetic (RTK) GPS and the two datasets combined in post-processing. For the first winter, a 400 MHz antenna was used to try to capture both the ice-water interface as well as the water-soil interface. In the second winter, half of the surveys were conducted with a 900 MHz antenna with the intention of increasing the resolution of the data through the ice cover. Processing and analysis of the GPR survey data was completed using MATLAB and the freeware package MATGPR3 (Tzanis, 2006).

3. Results and Observations

Direct measurements of ice cover thickness confirmed that there was significant variability, particularly in the three shallower ponds. On average, 43% of the ice thickness was snow ice. The 2013-2014 winter season was colder than that of 2014-2015, with 1824 and 1219 cumulative freezing degree-days, respectively. As a result, ice thickness measurements were consistently smaller during the second year of monitoring. Mid-winter thaw events during both winters had significant impacts on the ice cover; however, it was only during the second year of observations that holes were observed over some of the inlets during mid-winter thaws.

While direct measurements of ice thickness confirmed variability, it was the GPR surveys that provided a comprehensive picture of the entire ice cover in each pond (Figure **1**). The influences of snow clearing for skating rinks, submerged inlets, and the pond bathymetry were all evident in the survey data. The interfaces between ice, water, and sediment were usually discernable in the data collected using the 400 MHz antenna; however, analyzing the 900 MHz data proved more challenging and required more filtering to isolate the ice-water interface.

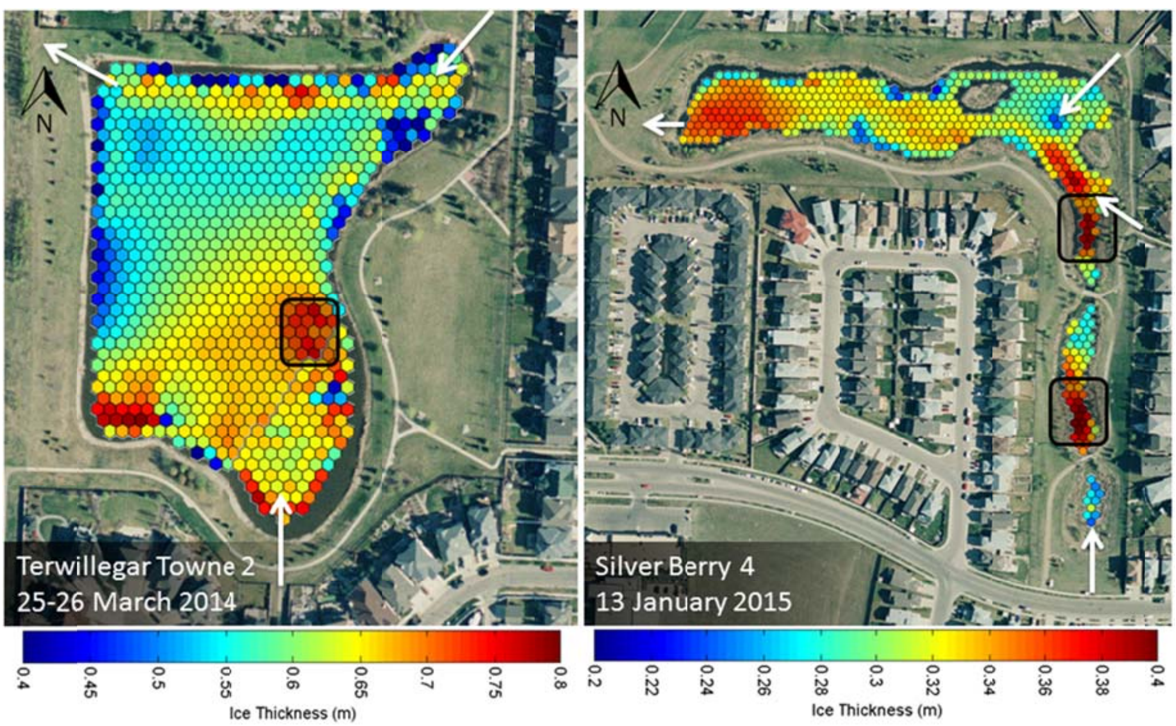

Figure 1. Processed GPR ice thickness surveys showing thinner ice at inlets and thicker ice near the outlets and rinks (inlets and outlets indicated by white arrows and rinks by black rectangles).

At several locations, submerged inlets are located within deeper forebays such that any outflow is forced across a shallower region before reaching the outlet. The ice covers over the inlet forebays were consistently found to be 20-30% thinner than ice over outlets and sections cleared for ice rinks. Increased exposure to solar radiation may be responsible for thinner ice in the northern half of the largest pond (Figure 1). Localised thinnning was also evident along flow paths through the shallow regions and, in some circumstances, across the surface itself.

Visual observations and photographs of the ice covers revealed the formation of longitudinal cracks at inlets during the spring, formation of aufeis at a surface inlet, deposition of debris by surface flows and a resulting localised degradation due to changes in albedo, and inclusion of bubbles in the ice cover. Some of these processes may have a significant influence on the integrity of the ice and should be considered in addition to ice thickness when evaluating whether the ice cover is safe for recreational use.

4. Conclusions

Monitoring of the ice covers confirmed that there was a significant variability at each pond, but also between ponds of different designs. Ground penetrating radar coupled with an RTK GPS was a very effective tool for mapping the spatial variability in ice thickness at the four storm water ponds. The 400 MHz antenna returned a stronger reflection at the ice-water and ice-soil interfaces, with sufficient resolution to capture spatial variations.

Bathymetry and the placements of submerged inlets were found to influence significantly both the distribution and range of ice thicknesses. Forebays with submerged inlets and with downstream shallow regions were found to have the thinnest and most variable ice covers and to present the most risk to the public.

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