

## Investigating the effects of urban stormwater run-off and de-icing salts on tree stress and soil environment in stormwater tree pit infrastructure

Effets du ruissèlement salin urbain sur le stress d'arbres et l'environnement du sol dans des fosses d'arbres drainantes.

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### RÉSUMÉ

Les fosses d'arbres pour eaux pluviales (STP) sont une solution naturelle pour gérer les risques d'inondation et de pollution des eaux urbaines, en redirigeant le ruissèlement vers le sol d'un arbre de rue. Cependant, le ruissèlement contient de nombreux polluants, en particulier des concentrations élevées de sel de dégivrage, le chlorure de sodium, dans les villes au climat froid. Les villes nordiques sont intéressées par l'impact de ce ruissèlement sur la croissance et la santé des arbres en STP. Nous présenterons ici les résultats préliminaires d'un projet pilote en cours dans la ville de Montréal, Québec visant à déterminer les conditions de croissance de 2 espèces d'arbres en STP et leur réaction à 3 niveaux de blocages d'accès à l'eau de la rue (18 STP). Nous mesurons l'effet du blocage sur le niveau des eaux souterraines, le sol (en particulier la salinité), la santé et la croissance des deux espèces. Nous avons constaté que, pendant et après de fortes précipitations, les hausses et les baisses du niveau d'eau étaient plus marquées dans les fosses ouvertes ou semi-ouvertes que dans les fosses fermées. Cela suggère que l'infiltration, la percolation et la transpiration y sont plus importantes que dans les fosses fermées. Les niveaux de conductivité (un indicateur de la salinité) atteignaient leur maximum au printemps, mais ils ne différaient pas de manière significative entre les traitements durant le période de croissance. Des analyses supplémentaires seront présentées sur la croissance des arbres, la chimie du sol, l'effet des traitements et des années.

### ABSTRACT

Stormwater tree pits (STP) are a nature-based solution for managing urban water flood risk and pollution. They reduce-road runoff, by re-directing it to infiltrate into the soil of a street tree. However, runoff has many pollutants, especially high concentrations of de-icing salt, sodium chloride in cold climate cities. Nordic cities are concerned with the impact of street runoff on trees in STP. We will present the preliminary results from the 3<sup>rd</sup> year of an ongoing pilot study in Montreal, Quebec aiming to determine growth conditions of street trees in STP, and how they are affected by the level of blockage of street runoffs access for different periods. We measure the effect of the blockage (3 levels) on ground water height, the soil chemical environment (especially salinity), and the health and growth of two common street tree species planted in STPs (total 18 stp). We found that during and after heavy rainfall, rises and falls in water levels were more pronounced in open or semi-open pits than in closed pits. This suggests that infiltration, percolation and transpiration are more significant there than in closed pits. We also determined that conductivity levels (a proxy for salinity) peaked during spring, but and that during the tree's growth period, conductivity did not differ significantly between treatments. Further analysis will be presented about tree growth, soil chemistry, conductivity between treatments and multi-year analysis.

### KEYWORDS

Infrastructures vertes, sels de dégivrage, arbres urbains, arbres de pluie, stress salins, projet pilote, ruissèlement routier, hydrologie urbaine, développement à faible impact

Green infrastructure, de-icing salts, urban trees, stormwater trees, salt stress, pilot project, stormwater run-off, urban hydrology, low impact design (LID)

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## INTRODUCTION

Cities often become more susceptible to flooding as impervious groundcover increases, and as climate systems become more irregular (Kuehler et al., 2017). More rainwater is converted to runoff, which fills limited drainage systems rather than infiltrating into the earth (Elliott et al., 2018). The stormwater tree pit (STP) is gaining popularity as a green infrastructure (GI) that infiltrates urban runoff into the soil where a street tree can grow (Grey et al., 2018b). STP designs vary, but they all have an inlet for street water and tend to have a pit that accumulates the water.

Trees in STP are directly exposed to runoff pollutants, in highest concentration (by 3 orders of magnitude), de-icing salt sodium chloride (NaCl) in Montreal's climate (Frosi et al., 2019). NaCl increases soil osmotic pressure which can alter root growth and decrease water acquisition (Zhang et al., 2021). Some tree species will also accumulate salt ions in leaves; effects differ by species (Dmuchowski et al., 2022). De-icing salts threatens tree health but their concentrations in STPs also peak before a tree growing season (Frosi et al., 2019). Another element that STP alters is increased water availability, which can have a positive effect on growth, if waterlogging can be avoided (Grey et al., 2018a). Water access is usually considered to be the primary limiting factor of urban trees, especially during the first couple years after planting in which they are more vulnerable (Bouliane, 2021; Wattenhofer & Johnson, 2021). Further, Wattenhofer & Johnson (2021) suggest that regular watering be the most important tactic for urban tree survival. However, if STP can naturally provide the right amount of water without long term waterlogging or pollutant concentrations that harm trees is unknown.

STP are gaining in popularity along with other GI, yet little research has been done **on performance of trees** in STP (e.g. Grey et al., 2018). Even, fewer have been done in cold climates and those that have been done cite the need for longer term research. (Frosi et al., 2019; Ordóñez-Barona et al., 2018). A four-year STP pilot project has been established in the city of Montréal to test the impact of street runoff on trees in locally designed STP before expanding their use. Previous years work on the project identified initial environmental changes in the drainage pits (Brown, 2025). **We will focus on a longer-term analysis of environmental conditions and tree conditions for two commonly planted tree species in STPs with an experimental blockage of street runoff (year-round, winter and spring melt season, no blockage).** After three years of trial and data, we are testing how street runoff affects a) the underground water height in the STP, b) the soil chemical conditions of STP, and c) the tree health and growth. In this abstract, we will present preliminary results from 2025.

## 1 METHODOLOGY

### 1.1 Site

The pilot study tests 18 stormwater tree pits (STP) in the city of Montreal's Belanger street, established in 2023 by the city of Montréal. They are planted half with *Gymnocladus dioicius* and half *Ulmus* 'Morton' all on the same side of the road. To test the effect of street runoff on STP soil environment and trees, three treatments were set up, by experimentally modifying the pits access to water with a barrier. Our design tests the difference between STPs with permanent barriers to block runoff year-round, STPs that are blocked only during the winter and the spring melt period (during salinity's peak), and STPs open year-round to runoff, each with six replicates: three of each species.

### 1.2 Soil, water and tree measurements

We measured soil conditions each month during the growing seasons (eg. conductivity and humidity) with a Time Domain Reflectometer (TDR) reader at 7 points in each tree pit, as well as doing a soil chemical analysis at the end of the season (eg. soil nutrients, pollutants, pH) near and far from the road and water entry point (see figure 1). We also collected bi-weekly water quality (eg. conductivity, pH, [Cl<sup>-</sup>]). Conductivity of soil and water is used as a proxy for salinity validated with a strong correlation with the concentration of chloride ions in our water samples. We

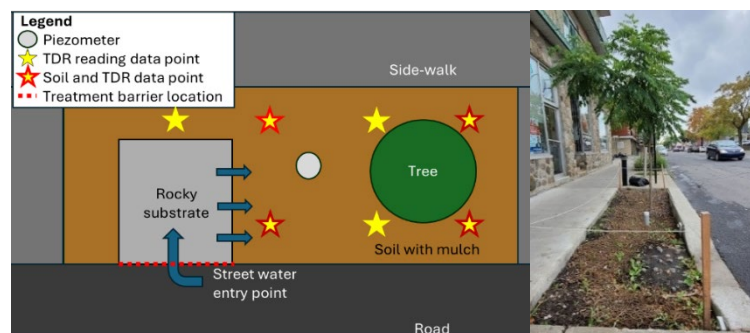


Figure 1: Stormwater tree pit design and data collection locations

measured water height, using a 1m depth piezometer in each pit, weekly throughout the season, and before and after large rainfalls (>10mm/hr or >15mm/day) and after a period of percolation. To test each tree’s condition, we measured tree growth (eg. tree height, crown diameter, foliar density, trunk diameter) and tree health (eg. stomatal conductance, leaf chemical analysis, visual leaf deficiencies and damages) according to the protocol followed by Brown (2025). Stomatal conductance (gsw) was measured using a handheld *LI-600 Porometer/Fluorometer*. It is the physiological measure of the degree of opening of a leaf’s stomata; a low gsw has been linked to salt stress (Rahnama et al., 2010). Chemical analysis of leaf content (Na+, Cl-, Ca+, N, and P) tests for accumulation of salts and changes in nutrient uptake and storage relevant to saline conditions (Dmuchowski et al., 2022). A visual analysis informs us on leaf condition.

Preliminary statistical analysis for water level, water conductivity, and stomatal conductance data from summer 2025 was done in R with library(nlme). We made a linear mixed model with random effect for tree-pit to account for repeated sampling. Water conductivity data was also analysed graphically.

## 2 PRELIMINARY RESULTS AND DISCUSSION

### 2.1 Water level during rain events during the growing season

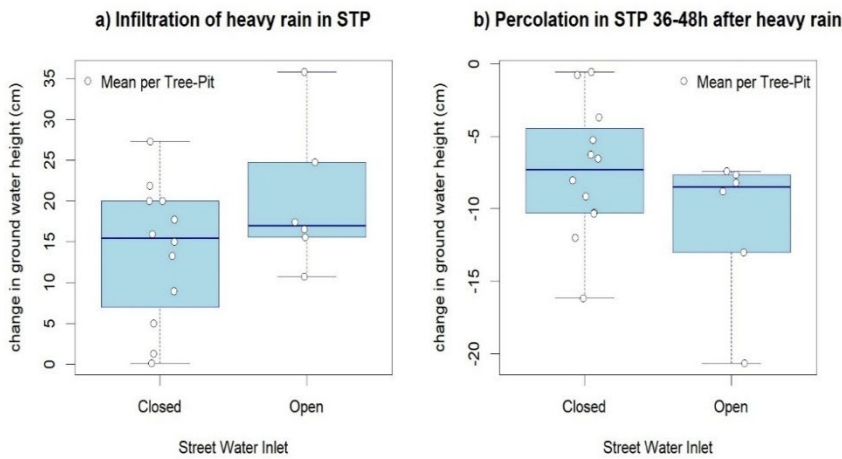


Figure 2: The difference in water level changes in closed and open STP from June-October 2025: a) before and after rain and b) after a period 36-48h period after rainfall

For STP with inlets open in the growing season (Open and partially open treatments) ground-water height increased more than that of closed pits over the course of heavy rainfall (p-value: 0.0081; figure 2a).

Also, open inlet STP ground-water height decreased more in the percolation period (<12h after the rain, to after 36-48h) as compared to closed STP (p-value of 0.0109; Figure 2b). This suggests that open STP are able to infiltrate, percolate and transpire more water, an asset in the urban environment.

### 2.2 Seasonal maximum for water conductivity

We witnessed confirmed that conductivity is at a maximum in the spring during the snow melt period, during plant dormancy (figure 3). During the growing season we found no significant difference in water conductivity between treatments: open, closed and partial. Further analysis on soil and soil water chemistry is planned to better characterize the growing environment of trees throughout the season.

### 2.3 Affect on trees

Stomatal conductance was not significantly different with the data collected in 2025, between the open, closed and partial treatments, for each species. More on tree growth and multi-year analysis will be presented at the conference.

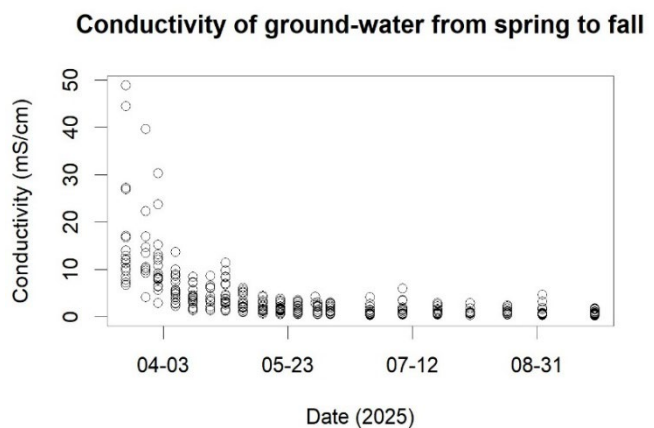


Figure 3: Conductivity of ground water of STP March-Oct 2025

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### 3 CONCLUSION

Preliminary results of this pilot study suggests that STP do help water percolation and transpiration in cities which can help mitigate flood risk. The major pollutant of de-icing salts is present but at a minimum during the growing season in all STP regardless of if the pit has access to street water. Further analysis on the soil chemistry, and its observed and predicted effect on tree health and growth will be presented at the time of the conference. STP are a promising infrastructure for flood mitigation, but region-specific conditions like climate, alters runoff quality and quantity which must be considered for successful STP design, promoting tree longevity.

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