Review of the Science and Practice of Stormwater Infiltration in Cold Climates





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Review of the Science and Practice of Stormwater Infiltration in Cold Climates

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PUBLICATION INFORMATION

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SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The Sustainable Technologies Evaluation Program (STEP) is a multi-agency program, led by the Toronto and Region Conservation Authority (TRCA). The program was developed to provide the data and analytical tools necessary to support broader implementation of sustainable technologies and practices within a Canadian context. The main program objectives are to:

- monitor and evaluate clean water, air and energy technologies
- assess barriers and opportunities for implementing technologies
- develop tools, guidelines and policies
- promote broader use of effective technologies through research, education and advocacy.

Technologies evaluated under STEP are not limited to physical structures; they may also include preventative measures, alternative urban site designs, and other innovative practices that help create more sustainable and liveable communities.

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EXECUTIVE SUMMARY

As the practice of stormwater management evolves to better address such issues as channel erosion and aquatic ecosystem protection, there is increasing interest in decentralized micro-controls at or near the source of drainage networks that supplement traditional detention facilities. Alternatively referred to as 'Low Impact Development', 'Sustainable Urban Drainage Systems', 'Water Sensitive Urban Design', or 'Stormwater Source Controls', these approaches attempt to reproduce the pre-development hydrologic regime through site planning and engineering techniques aimed at infiltrating, filtering, evaporating and detaining runoff, as well as preventing pollution.

Stormwater infiltration practices that direct runoff to pervious areas or engineered structures for storage and eventual infiltration are central to these approaches because the infiltration component of the water balance is substantially reduced under most urban development scenarios. These practices can provide multiple benefits where conditions are suitable. They reduce runoff volume and thereby minimize flood risk and prevent alterations to the natural channel and stream flow regime. They help to maintain groundwater levels and sustain stream flows during dry periods. They also reduce pollutant loading to receiving watercourses from runoff by retaining contaminants in the engineered structures and underlying soil.

This review provides an updated summary of the body of knowledge on infiltration based stormwater management. Particular emphasis is placed on peer reviewed journal articles and published reports from jurisdictions with climate and soil conditions similar to Ontario, including the northeastern United States, United Kingdom, France, Norway, Sweden, Denmark, Germany, Austria, Switzerland and Japan. The review begins with a comparison of guidelines regarding the suitability and siting of stormwater infiltration practices from selected cold climate jurisdictions, followed by descriptions of general types of infiltration practices, their typical application, and pretreatment requirements. Stormwater management issues specific to cold climates are then briefly summarized and overviews are provided of typical urban runoff contaminants and the physical, chemical and biological processes by which these may be treated as water percolates through soil. This more theoretical discussion is followed by a review of literature addressing the risk of soil and groundwater pollution from application of stormwater infiltration practices and associated management recommendations. Available information on the performance of each type of infiltration practice is summarized with regard to runoff reduction (*i.e*., hydrologic benefits), surface water quality (*i.e.,* effects on water quality in overflow or underdrain flows), groundwater quality (*i.e*., potential for groundwater contamination) and soil quality (*i.e*., accumulation of contaminants). The final section outlines typical inspection and maintenance requirements for each type of infiltration practice.

Comparison of guidelines on the suitability and siting of stormwater infiltration practices from selected cold climate jurisdictions reveals that while consistent direction is provided regarding the factors that should be considered, specific criteria vary considerably among jurisdictions. Of particular note are differences in direction regarding types of land uses considered to have potential to generate highly contaminated runoff (*i.e*., stormwater hot spots or pollution hot spots) and that are, as a result, unsuitable for application of stormwater infiltration practices. Current stormwater planning and design guidelines in Ontario can be interpreted as blanket restrictions on infiltration practices installed within any industrial or

commercial land use, which leaves little flexibility for exceptions. Improving direction in this regard in the updated guideline would reduce a significant barrier to the application of infiltration practices in Ontario.

There are numerous studies documenting the performance of stormwater infiltration practices in cold climate regions. The vast majority of literature reports favorable performance for most parameters examined, suggesting that greater integration of infiltration practices into stormwater management system designs in cold climates could further reduce impacts of urbanization on receiving waters and their aquatic ecosystems. Few studies have examined the performance of bioretention and infiltration chambers after several years of operation. There is also insufficient information regarding the effects on receiving water quality of infiltrating deicing salt laden runoff in small areas distributed across the catchment versus discharging runoff to centralized end-of-pipe facilities. These are topics requiring further research.

A number of common concerns about the performance of stormwater infiltration practices have been addressed in the literature cited in this paper. Concern about the potential for clogging through the accumulation of fine sediments has been addressed through improvements to design, installation and maintenance, as indicated by recent performance monitoring studies. While longer term performance studies are needed, the research to date indicates that stormwater infiltration practices are effective at preserving the predevelopment hydrologic function of a site and removing pollutants from runoff.

Concerns about the effectiveness of infiltration practices in cold climates and on fine-textured soils have been topics addressed in several recent studies on stormwater infiltration technologies. Permeable pavement and bioretention facilities have been observed to function well in cold climates during winter months, even with frost in the ground, albeit at lower efficiencies than during warm weather. While guidelines in some jurisdictions discourage the application of infiltration practices on sites with fine-textured soils containing greater than 20% clay, recent studies have shown that substantial volumes of stormwater can be infiltrated in tight soils beneath permeable pavement installations.

The ability of infiltration practices to remove typical contaminants from urban stormwater is becoming well established, with a few exceptions. High reductions in the concentration (and loads) of suspended solids, metals, polycyclic aromatic hydrocarbons (PAH), and other organic compounds have been consistently observed in performance studies. Observations of effects on nutrient (dissolved nitrogen and phosphorus) concentrations and loads have been more variable. Adapting designs to utilize media with lower or slow-release phosphorus content, combined with pretreatment practices that help to retain nitrates and dissolved phosphorus (*e.g.*, vegetated filter strips, grassed swales), could improve net load reductions for these constituents.

Risk of groundwater contamination from stormwater infiltration practices is the most common concern due to the presence of a wide variety of pollutants in urban runoff. Most pollutants are well retained by infiltration technologies and soils and therefore, have a low to moderate potential for groundwater contamination. The most notable exceptions are de-icing salt constituents (typically sodium and chloride), which are not well attenuated in soil and can easily travel to shallow groundwater. Infiltration of de-icing salt constituents is also known to increase the mobility of certain heavy metals in soil (*e.g.*, lead, copper and cadmium), thereby raising the potential for elevated concentrations in underlying groundwater. However, very few studies that have sampled groundwater below infiltration facilities or roadside ditches receiving de-icing salt laden runoff have found concentrations of heavy metals that exceed drinking water standards. The few instances where this has been observed have received runoff from high traffic areas (*i.e*., large highways) with elevated levels of metals. Some jurisdictions (*e.g*., Maine and Minnesota) consider high traffic areas where large amounts of de-icing salt are used to be unsuitable for the application of stormwater infiltration practices.

With the exception of infiltration basins, most infiltration practices are well distributed across the landscape, rather than centralized in a small area. With a distributed approach there is less potential for runoff to accumulate large masses of pollutants and therefore, the occurrence of elevated, potentially toxic concentrations of pollutants in the soil and groundwater is less likely. Collecting and treating stormwater from high traffic areas and pollution hot spots in centralized detention facilities, while using infiltration practices to treat runoff from roofs and low traffic areas may provide a good margin of safety where groundwater contamination is a concern. While it is prudent to restrict infiltration practices in designated pollution hot spots, broader guidance regarding the suitability and siting of these practices should be provided through detailed technical studies at the watershed, subwatershed and local scales.

Landowners and municipalities have been concerned about soil quality below infiltration facilities and the potential need for future remediation and disposal. Available evidence indicates that small distributed infiltration controls such as permeable pavements do not contaminate underlying soils, even after more than 10 years of operation. Based on limited results it can be concluded that for large centralized infiltration facilities, removal and landfilling of at least the upper 5 centimetres of soil may be required when the facilities are decommissioned.

Based on comparison of stormwater management design guidelines from selected jurisdictions, and consideration of recent research on the performance of infiltration practices in cold climate regions, some recommendations can be made regarding on-going work to update the Ontario guidelines:

- Serious consideration should be given to providing revised criteria for evaluating site suitability for stormwater infiltration practices. This guidance should be provided in an up-front, easy to locate section.
- Evidence that significant runoff reduction can be achieved by infiltration practices on fine-textured soils and that such practices continue to function during much of the winter, suggests that minimum percolation rate of the native soil should not be used as a screening criterion, or that a much lower rate than the current 15 mm/hr should be used. Alternatively, different criteria could be recommended for facilities designed for partial infiltration (with an underdrain) than those designed for full infiltration (no underdrain).
- Consideration should be given to requiring underdrains with adjustable flow restrictors to be installed in facilities located on fine-textured soils with percolation rates less than 15 mm/hr in order to ensure complete drainage of water between rain events and reduce the potential for freezing during winter.
- Acknowledging that infiltration rates of newly built facilities will gradually decrease as they age and accumulate fine sediments, it is recommended that updated guidelines require that such reductions be factored into facility design.
- Clarification regarding the criterion for maximum drawdown time is needed, as the current Ontario guideline is vague in this regard. Such a criterion should consider the typical length of time between storm events in a given geographic location from long-term climate records, and the maximum

acceptable amount of time that standing open water should be allowed to occur in an urban area to prevent mosquito-borne illnesses.

- As previously noted, improved guidance is needed regarding what conditions constitute areas where infiltration practices should not be applied due to risk of groundwater contamination. While blanket restrictions may be appropriate in certain circumstances, broader application decisions should be based on a thorough understanding of present and future groundwater uses, contaminant types and loads and the attenuation capacity of native soils. Guidance regarding the suitability of infiltration practices in communities where water supply is derived from groundwater will also need to consider Ontario drinking water source protection requirements that may prohibit certain types of land use or human activities or require contaminant management plans be put in place within wellhead protection zones.
- Current guidance in the Ontario Stormwater Management Planning and Design Manual indicates that implementation of lot level and conveyance controls can only be used to reduce the active storage volume component of end-of-pipe facilities (*i.e.*, not the permanent pool volume). This criterion should be reviewed in light of the significant runoff volume and contaminant load reductions made feasible through the use of distributed micro controls upstream of the stormwater pond or wetland.

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