

Opportunities for Building-Integrated Low Impact Development

Prepared by:
Toronto and Region Conservation Authority (TRCA)

March 2018

www.sustainabletechnologies.ca

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Under the

Sustainable Technologies Evaluation Program (STEP)

PUBLICATION INFORMATION

This document has been prepared by Toronto and Region Conservation Authority (TRCA), under the Sustainable Technologies Evaluation Program (STEP) for Sustainable Buildings Canada.

Citation: Toronto and Region Conservation Authority (TRCA) 2018. *Opportunities for Building-Integrated Low Impact Development*. Toronto and Region Conservation Authority (TRCA), Vaughan, Ontario.

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THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The water component of the Sustainable Technologies Evaluation Program is a partnership between Toronto and Region Conservation Authority, Credit Valley Conservation and Lake Simcoe Region Conservation Authority. STEP supports broader implementation of sustainable technologies and practices within a Canadian context by:

- Carrying out research, monitoring and evaluation of clean water and low carbon technologies;
- Assessing technology implementation barriers and opportunities;
- Developing supporting tools, guidelines and policies;
- Delivering education and training programs;
- Advocating for effective sustainable technologies; and
- Collaborating with academic and industry partners through our Living Labs and other initiatives.

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

ACKNOWLEDGEMENTS

Funding support for this document was generously provided by Sustainable Buildings Canada.

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REGULATORY CONTEXT

In Ontario, judicious use of rainwater is being driven by stormwater management targets rather than drought conditions. In 2016 the Ministry of the Environment and Climate Change (MOECC) published a review of stormwater volume control targets from other jurisdictions[1] and a report of geospatial statistics[2]. This second report established the 90th percentile rainfall volume control target for all regions across Ontario. At the time of writing, the Ministry is considering comments on a document which proposed what should be done with this volume of water. Alternatives include that every property owner completely retain the rainwater without discharging it to a sewer, or that each property owner should treat the water to remove contaminants and slow the flow to sewers, reducing the risk of flooding[3].

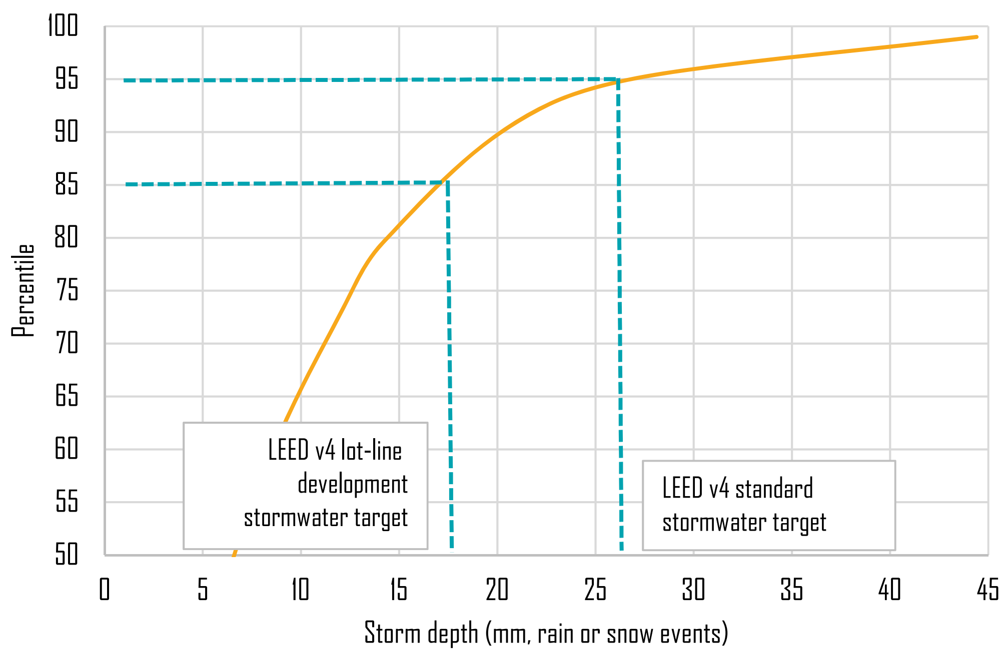

Figure 1 - In Toronto the 85th percentile event equates to 17 mm of water, the 90th percentile yields around 20 mm, and the 95th percentile event is a storm of 27 mm rainfall.

As shown in Figure 1, the 90th percentile event is a significant storm, with rainfall equal to, or greater than that experienced during 9 out of 10 rainstorms. In Toronto it represents around 20 mm of rain falling over 12 hours; collected over a 1,950 m^2 area and this would fill a standard shipping container. For comparison, in LEED v4 where there is no prerequisite to manage stormwater; a 2 point credit requires management of the 95th percentile or 85th for lot-line developments[4]. So if an MOECC target of 90th percentile is implemented in a regulatory jurisdiction, any lot-line projects achieving this would get a head start on LEED credits.

The Insurance Bureau of Canada reports that it is increasingly normal for annual insured losses from catastrophic events to be around $1B, and that the majority of these losses are due to water damage[5]. Rainwater management is also listed by Canada Green Building Council as Regional Priority Credit in the LEED v4 framework across the 7A area - Mixedwood Plains + Urban Population in Ontario. This is designed to incentivise developers to achieve this particular credit.

Regardless of credit schemes, or even the MOECC's final recommendations on stormwater management, regulation of site plans most often occurs at municipal or conservation authority level. Policies between the densest municipalities in Ontario vary according to the natural driver of local water resources, budget and internal resources. This can be easily seen by plotting the cost of drinking water in the fifteen most densely populated municipalities.

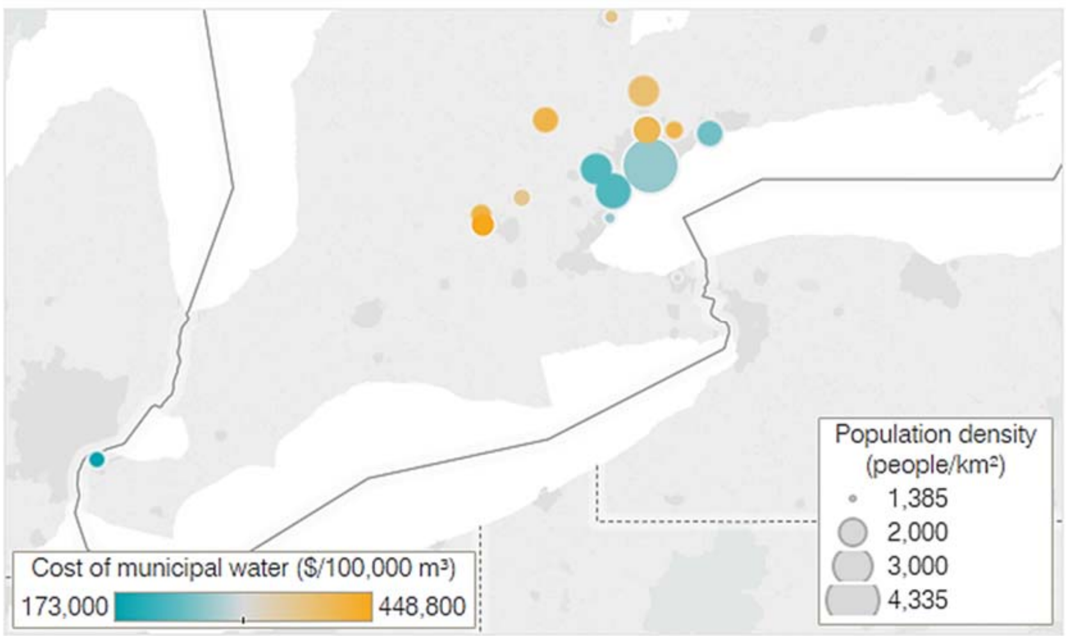

Figure 2 - The cost of water supply varies according to the source. Lake or river water is relatively cheap, whilst municipal supply is much more expensive in areas relying on groundwater supply[8].

As seen in Figure 2, water is more expensive away from the lakeshores, including Richmond Hill and Markham who rely upon supplies from neighbouring areas, and the towns and cities who rely fully or in part upon groundwater wells (full list in Appendix A). The difficulty of obtaining fresh water is also a key indicator for municipalities that have implemented some form of separate stormwater management fee structure. Exceptions in this dataset include Orangeville, which is reliant on costly groundwater and has no stormwater fee, and Mississauga, which has access to raw water from Lake Ontario, but also a fee and a detailed credits program.

Kitchener and Waterloo were amongst the earliest adopters of incentive schemes to encourage private landowners to adopt low impact development strategies by offering up to 45% rebate on a partitioned stormwater fee from 2011[9,10]. Mississauga, Guelph and Newmarket in Ontario have all implemented a fee structure to incentivise stormwater management in the last two years. Mississauga is on the shore of Lake Ontario and has placed an emphasis on peak flow reduction, which is associated with flood mitigation. Guelph relies upon groundwater for its drinking water source and encourages overall runoff reduction. Opportunities exist to get credit in Guelph for strategies that infiltrate excess stormwater into the ground, or capture the water for evapotranspiration by landscaping or other reuse.

"…It is often cost-prohibitive to attempt to return a site to natural hydrologic conditions, particularly in older urbanized areas with high imperviousness or where soils have been heavily compacted."

– City of Guelph[11]

Newmarket is also located on a groundwater source which is not only under threat from potential contamination, but there are also concerns about the volume of available groundwater. As such the municipality is strongly motivated to recharge the aquifer by infiltrating water into the ground. This is reflected in their credit program which is potentially the most generous of the three, but also the most onerous. In Newmarket, the 90% reduction in fees requires that private landowners manage peak flow and specifically infiltrate their stormwater. i.e. there are no incentives for any building integrated technologies.

	Mississauga[12]	Guelph[11]	Newmarket[13]
Peak flow reduction	40%	15%	90% for both peak control and infiltration
Runoff volume reduction	15%	40%	
Water quality	10%	15%	N/A
Operations	5%	15%	5%
	Sum ≤ 50 %	Sum ≤ 50 %	

Table 1 - Comparison between the maximum rebates available on three municipal stormwater fees for Markham, Guelph and Newmarket, ON.

In 2016, the Environmental Commissioner of Ontario surveyed 77 municipalities and found that 65 % of them were not recovering the full costs of managing their stormwater[14]. By then some municipalities such as Richmond Hill and Markham, had already increased awareness of stormwater management costs by listing a separate fee on resident's bills, without having implemented incentive schemes.

In the densest urban areas where land prices force parking lots underground and buildings too many storeys, municipalities may have more access to soil for infiltrating stormwater than property developers. This is reflected in the stormwater management opportunities available to each sector. Linear systems designed to divert excess stormwater underground, such as infiltration or exfiltration trenches, are becoming routine practice on road retrofits in Region of Peel and in the City of Kitchener. The City of Toronto is currently in the implementation phase of their Green Streets project[15]. This policy also refers to these trench technologies, but also advocates for living, biotic systems such as bioretention and soil cells for stormwater capture and improved growth of street trees.

In suburban settings these land-based technologies are also used by developers for fitting beneath and alongside parking lots and driveways. On lot-line developments, there are several alternatives.

Land-based	Building-Integrated	Operations
• Infiltration galleries	• Blue roofs	• Pollution prevention
• Permeable pavement	• Green roofs	• Salt management
• Enhanced vegetated swales	• Stormwater planters	
• Constructed wetlands	• Absorbent surfaces	
• Stormwater ponds	• Rainwater harvesting	
• Oil/grit separators		
• Street sweeping programs		
• Bioretention systems		

Table 2 - Low impact development strategies categorized by site location.

BUILDING INTEGRATED LOW IMPACT DEVELOPMENT

A common concern for all forms of low impact development, particularly building integrated systems, is the potential for future failure. For example, the Ontario Ministry of Transportation will not permit the most commons forms of rooftop detention or rainwater harvesting to be routine components of stormwater plans for rights-of-way[16]. All mechanical systems within a building require ongoing maintenance and inspection. But stormwater controls may be unique in that the impact of failure may be experienced far beyond site boundaries.

BLUE ROOFS

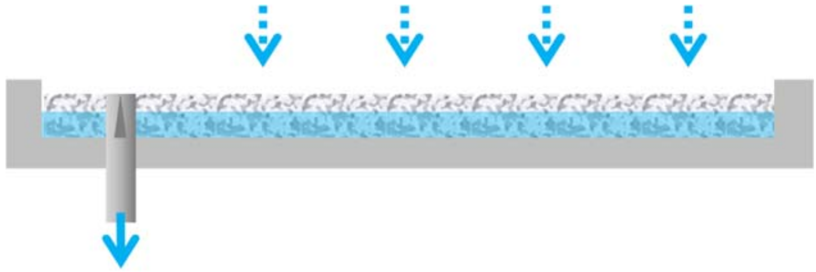

Figure 3 - Conceptual diagram of a blue roof where flow control is provided by a shaped weir on the roof leader (shown as triangular notch).

This term describes the temporary detention of excess rainfall on the roof, with a mechanical device to slow the release of water, as shown in Figure . Article 7.4.10.4 of the Ontario Building Code (OBC) requires that the maximum depth of retained water not exceed 150 mm and that roofs be fully drained of standing water within 24 hours[17]. Providing that no additional areas drain onto the roof, this should be sufficient capacity to accommodate a 100-year storm, even under climate change predictions through to the late 21st century[18].

On new buildings with sufficient structural capacity, modern waterproofing membranes are not the limiting factor for the duration of water storage. According to one roofing manufacturer, an inverted roof system has a technical limitation of 48 hours, due to the increased risk of the insulation becoming saturated after this time[19]. One limitation to storing open water on the roof is the lifecycle of naturalized mosquitoes, the prevalence of which may increase if a changing climate results in warmer weather throughout the year[20]. Typically, this limitation is around 72 hours to include a safety margin on the 6 to 7-day breeding cycle. Seventy two hours is also the average dry period between storms in part of Southern Ontario[21]. This is the time available for any storage system to drain and regenerate capacity for the next event.

As noted above there are sometimes concerns that the flow control devices will be removed at a later date if they are found clogged and their purpose is not understood. A potential solution, which could also work in retrofit scenarios, is a modular tray system to capture and retain the water. A study in New York found that this type of blue roof reduced peak flows and retained more water overall than the alternative flow control devices[22]. All blue roof modules and inverted roofs require ballast to protect them against wind damage. In southern Ontario the default aggregate is often limestone, although granite or concrete pavers are also readily available.

Due to their ease of modeling, blue roofs are amongst the most popular building integrated stormwater controls. Nine of eleven water resource professionals surveyed had implemented or planned to use this type of system.

EXTENSIVE GREEN ROOFS

Green roofs, as illustrated in Figure 4, are highly promoted and familiar to most professionals in building design and construction. Extensive green roofs are popular for being relatively lightweight and easy to install. They are the shallowest class of building integrated vegetation, with planting medium no greater than 150 mm in depth. When planning a stormwater strategy green roofs do not usually receive water flowing on from other surfaces. The storage capacity of green roofs varies according to the type of planting medium and the provision of irrigation; the choice of vegetation and the depth of the medium demonstrated relatively little impact on the long term water retention in Toronto climate[23]. The selection of commercially available media in Ontario remains strangely influenced by a set of fairly narrow German recommendations[24,25], even though project needs vary considerably. All typical green roof media comprise some coarse aggregate, supplemented with compost to provide water retention and a sustainable source of nutrition.

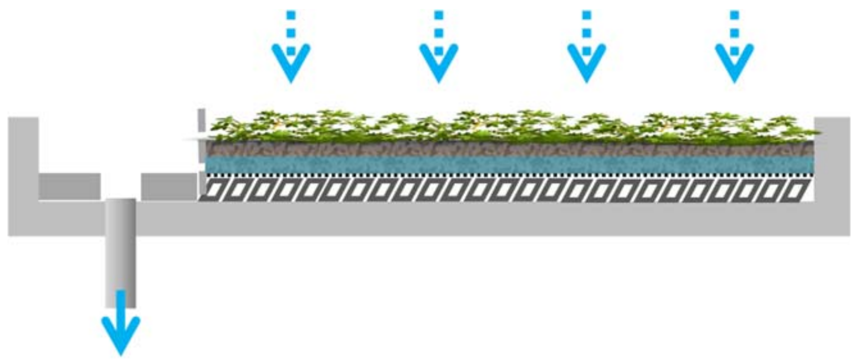

Figure 4 - Conceptual diagram of a green roof where flow control and water storage is primarily provided by the planting medium used to support the vegetation.

Green roofs have been strongly promoted by the City of Toronto since the implementation of their 2009 bylaw mandating the use of extensive green roofs in all new construction projects over 2,000 m^2 [26]. However, due to the variation in green roof performance, they currently apply a relatively conservative and universal estimate of 5 mm storage capacity.

A short survey of twenty water resources professionals found that 46 % had successfully incorporated an extensive green roof into a stormwater plan; there were two reports of regulatory hurdles having prevented this strategy. These figures may reflect the limited storage capacity of a green roof as a stand-alone system, as (63 %) of the respondents had successfully used a green roof as a means to empty a rainwater harvesting vault through irrigation. The gritlab at the University of Toronto has demonstrated no harm to extensive green roof plants after five years of daily summer-time irrigation to saturation [27].

FLOW-THROUGH STORMWATER PLANTERS

Conceptually, stormwater planters are a hybrid between a green roof and a bioretention cell or rain garden, see Figure 5. When integrated into a building site plan, they comprise a planter box connected to a roof leader and have a freely draining base. To date they have been considered to provide filtration only and no water retention or flow control benefits. However, some field studies and recent computer modeling have indicated that stormwater planters may retain 20% annual inflow volume, and provide significant mitigation of peak flow rates[28,29].

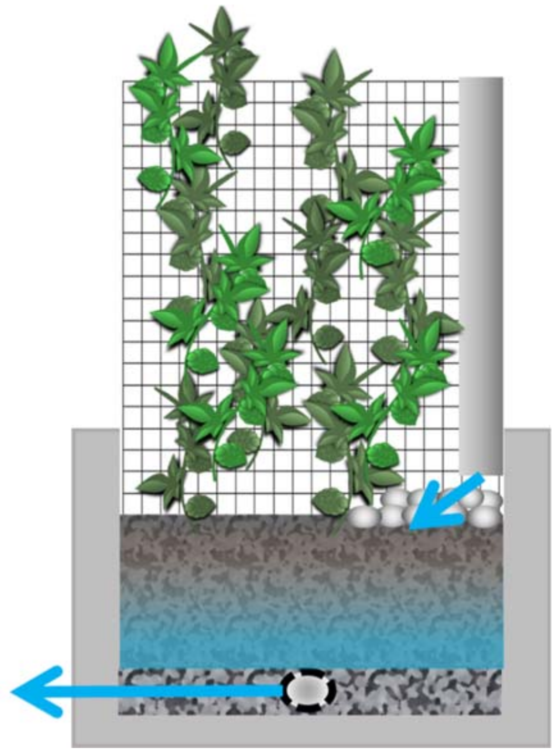

Figure 5 - Conceptual diagram of a stormwater planter. As with the green roof flow control and water storage are primarily provided by the planting medium used to support the vegetation.

As a stormwater control measure, it is desirable to maximize losses through evapotranspiration. One way to do this could be to plant vegetation that has the leaves well above the soil surface such as deciduous climbing plants and trees, both of which provide the co-benefits of shading to increase occupant's comfort and building efficiency. Mulching these stormwater planters with decorative aggregates will reduce the erosive power of the flowing water and the maintenance requirement for weeding, but will suppress evaporation from the planting medium directly. Planting media for this type of structure has varied between studies, although the components are usually some combination of topsoil, sand and compost. The Sustainable Technologies Evaluation Program (STEP) has ongoing research to develop design recommendations for stormwater planters, including the planting media.

ABSORBENT SURFACES

A relatively recent addition to the building integrated toolkit is the option of solid paving which has a sponge-like pore structure designed to retain a modest volume of rainwater until it is evaporated away. The local distributor reports that the pavers have the capacity to absorb 6 mm of rain[30].

RAINWATER HARVESTING

Most simply a rainwater harvesting system comprises a storage location for the rainwater to balance supply and demand, and a treatment system appropriate to the end use. The quality of the output water needs to minimize risk to humans in contact with the supply, and be appropriate for any mechanical processes. However, the amount of treatment required varies greatly according to where the water was collected. The quality requirements for reuse of harvested water are made through article 7.1.5.3 of the Ontario Building Code[17], and recommendations within the keenly anticipated B805 standard from ICC/CSA. Both distinguish between cleaner 'rainwater' and dirtier 'stormwater':

"…Stormwater: "…runoff from rain or snowmelt that flows over land and/or impervious surfaces (e.g. streets, parking lots, vegetative roofs, and roofs with public access."

–ICC/CSA draft B805[31]

The lowest degree of treatment might be applied by collecting water only from non-vegetated and inaccessible rooftops, filtering out particulate matter, and supplying a sub-surface irrigation system. This is a popular choice for reducing the use of municipal supply for a non-potable purpose, but only provides reliable stormwater control for around half the year.

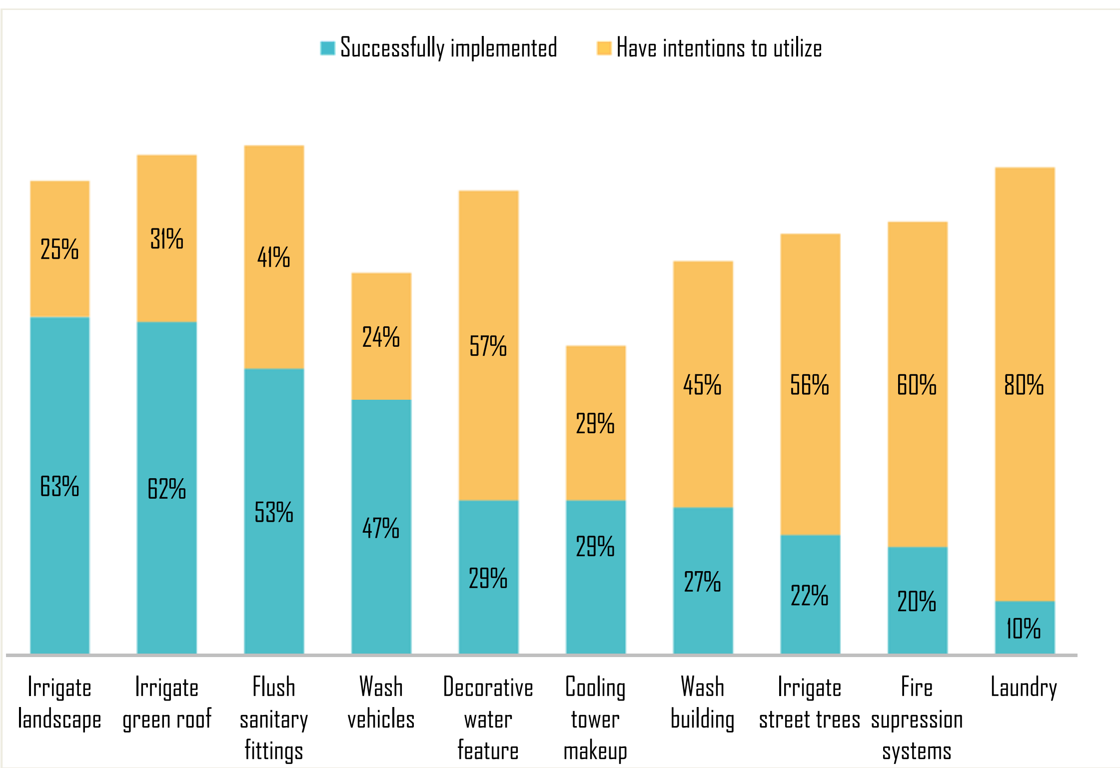

Figure 6 - Results from twenty water resources design professionals answering the question: Have you used this as destination for harvested rainwater?

Figure 6 summarizes the experiences of a number of stormwater management professionals employing rainwater harvesting systems in Ontario. After green roof and landscape irrigation, the most popular destination for harvested rainwater is for use in flushing sanitary fixture. As the risk to human health through exposure to the water is only moderate, the water receives some disinfection and may be treated to remove any yellow color. The additional costs for non-potable plumbing can be minimized where many sanitary fittings are located together in the building, making this is a popular choice for schools and colleges. Vehicle washing is increasing in popularity for transit providers including GO/Metrolinx[32] and Guelph Transit[33]. Laundry appear to be of increasing interest with only 2 engineers having already made an installation using harvested water for laundry, but the majority having an interest in pursuing this option. As with the vehicle washing, it is likely that this application will only appeal to specialized organizations, which own and operate a building and consistently wash a large volume of laundry.

Survey participants were also asked to report instances where they had made a proposal for a rainwater harvesting scheme which they believed to be technically feasible, but which had not received a permit; these are presented in Figure 7. The greatest number of or refusals were associated with using rainwater for cooling tower make up water.

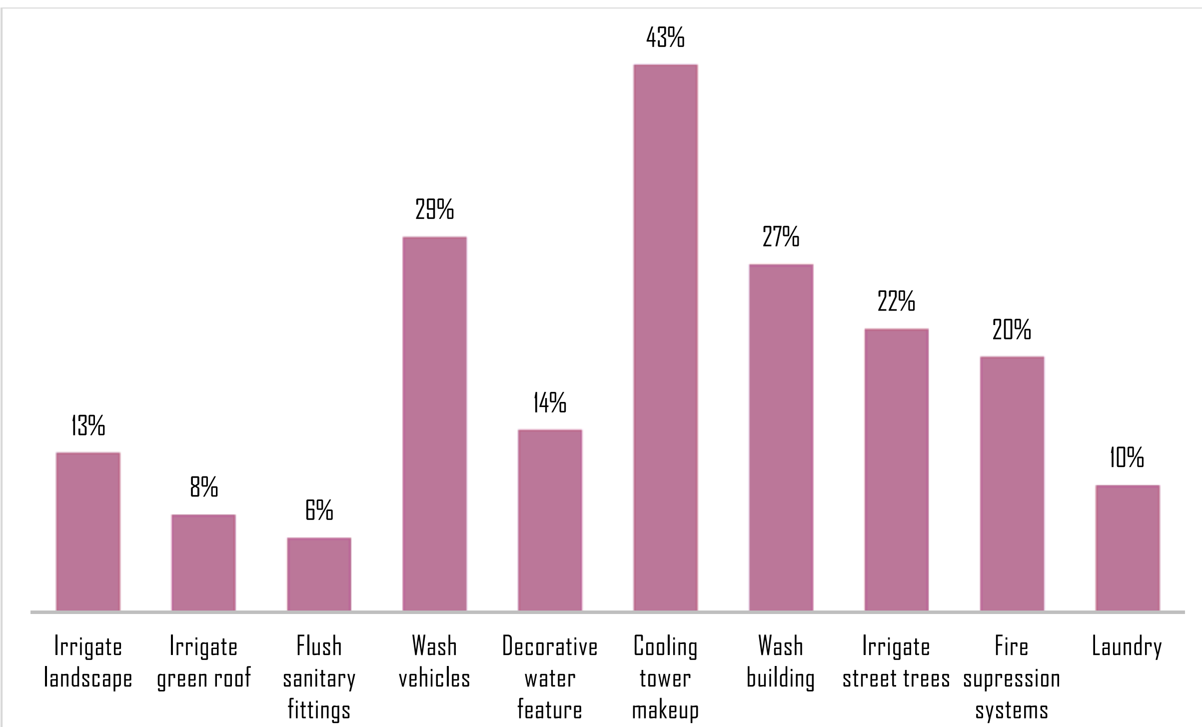

Figure 7 - Results from twenty water resources design professionals answering the question: Have you encountered regulatory hurdles that prevented this rainwater use option (which you believed to be technically feasible)?

This is a missed opportunity as rainwater is typically softer than both surface water and groundwater, making it an ideal source water for evaporative cooling towers in HVAC systems. Other limited applications included washing of vehicles or buildings, both of which may be associated with uncertainty about how often such an activity might reasonably be performed. The concern is that in some cases diverting stormwater into sanitary drains of sewer through a spurious use may actually add to water treatment burdens downstream rather than alleviate excess flow in the overall sewer system.

COMBINING SYSTEMS

For a variety of reasons, it may be desirable or necessary to use more than one building integrated LID system. A number of the options presented above have been considered in combination, and comments are presented in Appendix B.

Harvesting water for evaporative cooling towers is a three season use and a very reliable, efficient and sustainable option, but the design of the rooftop can optimize or jeopardize success. When rainwater falls it is very low in dissolved salts (i.e. it is soft), but it is also naturally, slightly acidic owing to dissolved carbon dioxide from the atmosphere (pH 5.6). When it encounters any sort of limestone on the roof, in aggregate, concrete, or planting medium, the water immediately picks up hardness which can scale in the cooling tower as in a tea kettle. Furthermore, any compost used in planting media adds more yellow color to the water, which can significantly impair the UV sterilization process.

So a roof with no ballast or only granite ballast is recommended to optimize the efficiency of a rainwater fed cooling tower.

A similarly clean rooftop would also be preferred when harvested rainwater is being used to flush sanitary fittings, although the potential for lime scaling is lower as the water isn't deliberately evaporated and concentrated. As an example, a green roof/rainwater flushed sanitary system has been operating for many years at the Earth Rangers centre in Vaughan. There the water is notably discoloured yellow, but the bathrooms themselves do not capitalize on the opportunity for public education as to the reason.

Rainwater harvesting for irrigation makes sense in combination with any other building integrated technology, so long as there is some vegetation to receive the water. The water quality requirements are low, so long as the likelihood of human contact is low. i.e. drip or capillary as opposed to spray. Spray irrigation is the better method of transforming excess stormwater into microclimatic evaporative cooling for the building though. Rainwater irrigation systems should also consider routing the water down the outside of the building to pass through and saturate stormwater planters prior to storing excess. Taken to an extreme, this could reduce energy costs for subsequent pumping and result in a building covered in vegetation with relatively little storage capacity in a cistern.

To meet both green roof and stormwater management requirements, at least two options are available locally which support a green roof system over a layer of free water[19,34]. These products are designed primarily to hold the vegetation free from the waterlogged conditions; control of the excess water is still performed via a restriction at the roof drain.

CONCLUSIONS

The aging infrastructure of our urban areas is not able to keep pace with the additional burden of our increasing population density, without even considering the potential impact to our sewers if rainfall patterns change in the future. Businesses and residents would like to pay taxes and make water resources management the municipality's problem. But even with significant capital investment the challenges may require significantly more collective action than simply replacing the main sewers.

A number of models are being applied to try and increase awareness and to share this almost insurmountable resource management problem. These include: regulatory constraints, highlighting the costs/fees required, and providing financial incentives for property owners. These instruments vary between areas owing to fundamental differences in the geography of the land we've settled and developed.

If a lot-line project has a stormwater target and no opportunity for infiltration, there are options for managing and even capitalizing on this free water resource. Some combinations of technology appear better suited than others.

Where a strong rainwater harvesting and reuse strategy is proposed to manage stormwater, which includes a long-term management plan. This should be considered holistically by permitting agencies to assess the whole water balance including any sewer discharges which would otherwise arise from used drinking water. Where the reuse would benefit from a clean catchment, all in-line building vegetation including green roofs is best avoided and ballast systems should be designed with water quality in mind.

Alternatively, proposals which incorporate a large quantity of planting media and vegetation to absorb and evapotranspire excess water need greater recognition and credit for stormwater management. In part this is due to remaining research questions about typical performance to help guide designers and regulators.

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APPENDIX A: WATER IN ONTARIO'S 15 DENSEST URBAN AREAS

Municipality	Population density[35]: People/km^2	Relative cost for 100,000 m^3 municipal supply /$k	% sewer fees	Raw water source	Separate stormwater fee	SW credit program established (ICI)[36]
Kitchener	1,705	449	54	Groundwater and Grand River	Yes[10]	2011
Waterloo	1,640	417	57	Groundwater and Grand River	Yes[9]	2011
Orangeville	1,851	417	46	Groundwater		
Markham	1,549	414	-	Lake Ontario (via Toronto Water)	Yes[37]	
Richmond Hill	1,929	410	-	Lake Ontario (via Toronto Water)	Yes[38]	
Newmarket	2,191	391	54	Groundwater and Lake Ontario	Yes[13]	2017
Guelph	1,511	369	52	Groundwater	Yes[11]	2017
Barrie	1,428	372	58	Groundwater and Lake Simcoe		
St. Catharines	1,385	320	52	Welland Canal		
Oakville	1,396	275	54	Lake Ontario		
Toronto	4,335	272	57	Lake Ontario		
Ajax	1,786	251	61	Lake Ontario		
Brampton	2,229	231	43	Lake Ontario		
Mississauga	2,468	231	43	Lake Ontario	Yes[12]	2016
Windsor	1,484	173	58	Detroit River		

APPENDIX B: OPPORTUNITIES AND CONSTRAINTS FROM COMBINING BUILDING INTEGRATED STORMWATER MANAGEMENT TECHNOLOGIES

	Rainwater harvesting for HVAC cooling tower	Rainwater harvesting for flushing sanitary	Rainwater harvesting for irrigation	Stormwater planters	Blue roof
Green roof	The compost components of planting media contribute organic matter into the water which impedes disinfection required for HVAC use. The mineral components of planting media can add hardness which reduces the efficiency of the cooling cycles.	Green roofs increase the yellow color of the harvested water. This can be removed with additional treatment, or can be opportunity for educational signage about water reuse inside the facility.	Where possible designers should consider increasing the water quality to permit spray irrigation (rather than drip or capillary). Spray provides a more even distribution onto the planting media, and maximizes evapotranspiration.	These could be an ideal pairing, where the planters are at a lower level than the green roof. Particularly where the green roof coverage is limited due to mechanical or other roof top systems.	A number of proprietary scaffolding type systems have been developed to keep green roof components out of ponded water. The primary concerns these address is the risk to the health of the vegetation.
Blue roof	This could be a very effective combination for buildings with extended cooling needs. Storing water on the roof permits passive evaporative cooling, and can help offset indoor cistern size requirements.	Where the building has daily flushing requirements, a system that retains the head of water on the roof long enough to flush it away could permit a significant reduction in the volume balancing cistern.	Permitting rainwater to remain on the rooftop until drawn down for irrigation could eliminate the requirement for a cistern and all energy costs associated with pumping. The receiving landscape must be designed to receive and absorb several consecutive days of saturation without runoff.	Retaining water on an upper level and slowly discharging it down into the planters over a longer period helps optimize stormwater retention by providing time for additional evapotranspiration and capitalizing on the wetting properties of the compost.	
Stormwater planters	The compost components of planting media contribute organic matter into the water which impedes sterilization for HVAC use. The mineral components of media can add hardness which reduces the efficiency of the cooling cycles.	This combination does not make best use of the water resources, but does provide a passive irrigation solution where decks or balconies have planted areas planned already. Again, the planting medium adds additional yellow color to the water.	The combination of storage cistern and planted landscapes is common practice. An optimized configuration would have rainwater pass through building integrated planters to fully saturate the planting media before the excess is stored. This would reduce the cistern sizing and extend the period before the irrigation is required again.		

	Rainwater harvesting for HVAC cooling tower	Rainwater harvesting for flushing sanitary	Rainwater harvesting for irrigation	Stormwater planters	Blue roof
Rainwater harvesting for irrigation	This combination competes for the limited water resource. Water quality requirement for irrigation is lower than for HVAC cooling.	This combination competes for the limited water resource. Water quality for sanitary reuse should be higher than for drip irrigation, but may be of lower quality than spray.			
Rainwater harvesting for flushing sanitary	Flushing sanitary is a year round use, and has lower water quality requirements. Supplying an HVAC system requires less plumbing.				

APPENDIX C: SURVEY

Survey of professional water resource managers, as forwarded directly to contacts and circulated through social media channels: LinkedIn, Twitter, and Facebook throughout January 2018.

I'm a Research Scientist at the Sustainable Technologies Evaluation Program (STEP, a collaborative project between several Conservation Authorities in Southern Ontario). https://sustainabletechnologies.ca/

This month, I'm exploring any regulatory hurdles that remain to implementing contemporary stormwater management systems. The purpose of this survey is to compile some overall metrics, so answers will remain anonymous. .
Please distribute this short survey to friends and colleagues.

Thanks for your time,
Jen
jenny.hill@trca.on.ca

1. **Ways to empty a stormwater vault or rainwater cistern**
Check all that apply.

	I have successfully implemented a SWM plan including this	I intend to use this in a future project, but have not yet applied for permits	I encountered regulatory hurdles that prevented this option (which I believed to be technically feasible)	This is outside of my usual scope of work.
To irrigate green roof	☐	☐	☐	☐
To irrigate turf and ornamental planting	☐	☐	☐	☐
To irrigate street trees in right of way	☐	☐	☐	☐
For decorative water feature	☐	☐	☐	☐
For cooling tower make-up water	☐	☐	☐	☐
To flush toilets	☐	☐	☐	☐
To wash vehicles	☐	☐	☐	☐
To wash some part of the building	☐	☐	☐	☐
For laundry	☐	☐	☐	☐
For fire suppression system	☐	☐	☐	☐
For ice rink	☐	☐	☐	☐

2. **Have you successfully obtained permits to use harvested rainwater for another purpose? Please describe.**

3. **Other systems**
Check all that apply.

	I have successfully implemented a SWM plan including this	I intend to use this in a future project, but have not yet applied for permits	I encountered regulatory hurdles that prevented this option (which I believed to be technically feasible)	This is outside of my usual scope of work
Underground infiltration of stormwater (e.g. trenches, soakaways, chambers etc.)	☐	☐	☐	☐
Surface infiltration (e.g. bioretention)	☐	☐	☐	☐
Landscaping for water quality treatment (e.g. biofiltration, stormwater planters etc.)	☐	☐	☐	☐
Proprietary tree pits (e.g. Silvacell, Filterra)	☐	☐	☐	☐
Permeable pavement (PICP block type)	☐	☐	☐	☐
Permeable pavement (pervious asphalt or concrete type)	☐	☐	☐	☐
Extensive green roof	☐	☐	☐	☐
Rooftop detention (aka blue roof)	☐	☐	☐	☐
Constructed wetland for stormwater	☐	☐	☐	☐
Constructed wetland for wastewater	☐	☐	☐	☐
Dry pond (detention basin)	☐	☐	☐	☐

4. **Do you have any other examples of LID, for which you have encountered regulatory hurdles on apparently technically feasible plans? Please describe?**

RAW DATA GATHER FROM SURVEY

RWH	Yes	Soon	Turned down
Irrigate landscape	10	4	2
Irrigate green roof	8	4	1
Flush sanitary fittings	9	7	1
Wash vehicles	8	4	5
Decorative water feature	2	4	1
Cooling tower makeup	4	4	6
Wash building	3	5	3
Irrigate street trees	2	5	2
Fire systems	2	6	2
Laundry	1	8	1
Ice rink	0	4	1
Total responses	49	55	25

Other LID	Yes	Soon	Turned down
Underground infiltration	16	0	1
Dry pond	12	1	1
Surface infiltration	11	3	1
Blue roof	7	2	2
Stormwater planters	7	4	1
PICP	6	3	2
Constructed wetland SW	5	4	1
Extensive green roof	6	5	2
Constructed wetland WW	2	1	2
Proprietary tree pits	3	7	1
Pervious surface	2	5	2
Total responses	77	35	16

"Laundry machines manageable but over regulated on requirements."

"Before we even get to regulatory hurdles, most large-scale developers don't see a strong need for rainwater systems on houses. If they can meet their requirements with simpler LID measures, they would rather not have to guarantee complicated systems. Most systems I see are for specialty cases…"

"The regulatory burdens I've experienced are from… … staff opposing permeable pavement proposal"

"Most common hurdle is costs to the client"

"Cooling tower was rejected… …on the grounds that they don't have precedent for a similar system being implemented. I believe cooling tower reuse is the most environmentally sustainable and effective reuse method and should be promoted, not obstructed by the city."

"There can be resistance at a lower tier level of regulation of implementation of non-traditional solutions."