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Greg Van Riel/Next Level Stormwater Management

ROOFTOP STORMWATER MANAGEMENT TECHNOLOGIES

for Climate Change Adaptations and Resilience

By Sasha Aguilera, GRP and Karen Liu, PhD

Global warming increases the intensity and frequency of extreme weather events such as heatwaves, rainstorms and hurricanes. Last summer, China, India, Germany, Belgium and the United States have seen unprecedented rains and catastrophic floods that resulted in loss of life and widespread damage. More recently in Canada, a state of emergency was declared on both coasts due to record rains and floods.

In November 2021, a month's worth of rain (up to 250 mm [9.8 in.]) fell in two days in British Columbia, causing landslides and floods that washed out roads, destroyed farms and livestock, and forced evacuation of thousands. In Cape Breton, Nova Scotia and southwestern Newfoundland, up to 266 mm (10.5 in.) of rain fell over two days. Torrential rains flooded homes, washed out roads, forced closures of schools and shut down businesses.

New flood maps show "100-year" floods will happen every one to 30 years[1]. According to Western University's flood maps[2], about four million Canadians live in floodplains that may be at risk in coming years or decades. These include major cities like Vancouver and Montreal. While floods are common in many parts of the world, climate change and rapid urbanization have exacerbated the problem.

Green infrastructure builds climate resilience

The Government of Canada recognizes urgent climate actions are needed. In 2021, it announced $3.79 billion in new investments related to climate change adaptation and resilience in support of the National Adaptation Strategy.[3] It also launched five Advisory Tables that recognize the importance of resilient natural and built infrastructure and its relationship to a strong and resilient economy.

Green infrastructure mimics a site's natural hydrological cycle to manage runoff close to its source. As land is expensive real estate, designers are turning to the many rooftops, which make up 20 to 25 per cent of the land area in major North American cities. There are growing interests in using green roofs, blue roofs and blue-green roofs to manage stormwater in urban centres such as Toronto and Vancouver.

Sustainable roof colours – blue or green?

Rooftop stormwater management solutions are classified as source control tools – they capture rainfall right where it lands before it runs off into the storm sewer network. They are the first line of defence when working in combination with other at or below grade options onsite, such as bioswales or underground storage tanks. They manage stormwater through two distinct mechanisms: retention and detention (See sidebar on page 7).

FIGURE 1 - A example of a green roof. Photo by Greg Van Riel/NLSM

Green roofs

Green roofs are specialized roofing systems that support vegetation growth on rooftops (*see Figure 1*). The vegetation and growing medium capture rainfall, reduce runoff and delay peak flow. The rainwater is retained in the growing medium, which is either taken up by the vegetation or returned to the atmosphere through evapotranspiration, completing the natural hydrological cycle.

Green roofs reduce runoff volume, thus lessening the burden on storm sewers and wastewater treatment plants, particularly those located in areas where storm and sanitary sewers are combined. They work well most of the time except during back-to-back rainstorms because fully saturated green roofs cannot retain more water until they are dried out or "recharged" before the next rain event.

Green roofs are multi-taskers. They offer multiple benefits to buildings and the environment. They create amenity space, extend roof membrane longevity, reduce a building's energy demand, improve air quality and enhance biodiversity in the urban areas. Currently, more than 30 municipalities across North America have some form of policies or programs that encourage green roof adoption.

Blue roofs

Blue roofs pond rainwater on the roof and slowly release it over time. Runoff is controlled at the roof drains through a flow restrictor or a mechanical valve that opens and closes using smart technology. Water is detained on the roof and released slowly to prevent overwhelming the storm sewers during heavy rainstorms to avoid flash floods. All water must drain off the roof within 24 hours as per *National Building Codes of Canada*.

Blue roofs are often the most economical rooftop stormwater management tool. While effective, this technology has some inherent disadvantages that prevent it from gaining popularity in North America. First, dirt picked up by the runoff and wind-blow debris tend to collect at the control flow drains. Clogging affects the operation and effectiveness of blue roofs.

Also, blue roofs require zero per cent slope to maximize water storage as even a one to two per cent slope can prevent the surfaces further from the drain to be fully utilized. However, the *National Building Code of Canada* requires a minimum slope of two per cent to promote positive flow to drain, which can greatly impact the storage efficiency of blue roofs (*see Figure 2*).

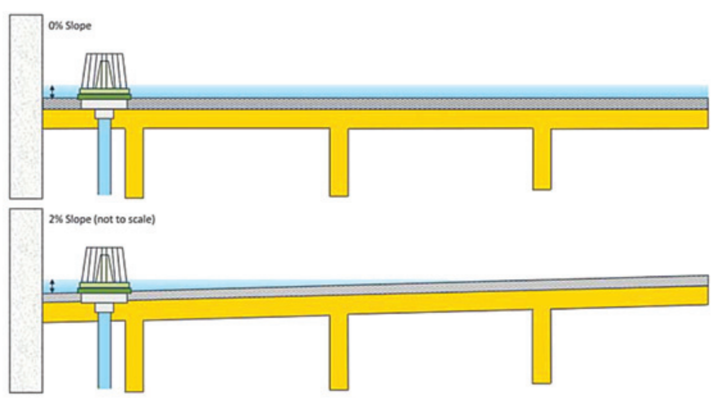


FIGURE 2 - Maximize water storage on a blue roof at 0 degree slope as even a two per cent slope can prevent the surfaces away from the drain to be fully utilized, thus reducing water storage efficiency.

In addition, ponding water exerts hydrostatic pressure, which can force water to leak through small defects in the waterproofing. Consequently, special attention must be paid on the membrane type, installation method and workmanship to ensure the roofing system warranties are valid. Lastly, standing water may pose risk of disease and safety issues to maintenance personnel.

Advanced rooftop stormwater management options

With increasing interests in using rooftops for stormwater management, green roofs and blue roofs have evolved to combine enhanced retention and advanced detention to provide greater stormwater management capabilities. We have summarized the advantages and limitations of a few options below. Selection will depend on the design intents and site constraints of the specific projects.

Enhanced retention green roofs

An enhanced retention green roof consists of highly absorbent materials to increase water storage capacity while reducing system weight. Water retention fleeces and horticultural mineral wool are lightweight and highly absorbent materials that can retain seven to 14 times their own weights in water. They have long history in the hydroponic industry and are increasingly being incorporated in green roofs.

Water retention layers can boost the water storage capacity while keeping the weight low for green roof systems (e.g. a 25-mm [0.98-in.] thick mineral wool mat retains about 24 l/m^2 [0.59 gal/sf] of water compared to 12 to 15 l/m^2 [0.29 to 0.37 gal/sf] for a typical green roof growing medium of the same thickness).

Water retention fleece and horticultural mineral wool are designed under the growing medium in a green roof system (*see Figure 3 (a)*). The additional water retention lowers irrigation needs, increases resilience of the plants and reduces annual runoff. Enhanced retention green roofs are particularly attractive on buildings where structural capacity is limited such as retrofits.

Although these systems have significantly higher water storage capacity than regular green roofs, like any retention-based systems, the enhanced retention layer will become saturated eventually and cannot retain more water. It still needs to dry out before it can retain more water, so it is not effective in managing back-to-back rainfall events or large intense storms.

Blue-green roofs

A blue-green roof consists of a green roof installed on top of a blue roof basin – a reservoir formed by a geo-cellular unit (*see Figure 3 (b)*). The upper vegetated portion filters and retains the rainwater and provides all the benefits of a green roof. Excess water infiltrates through the green roof and ponds in the blue roof underneath, which is detained and slowly released through control flow drains.

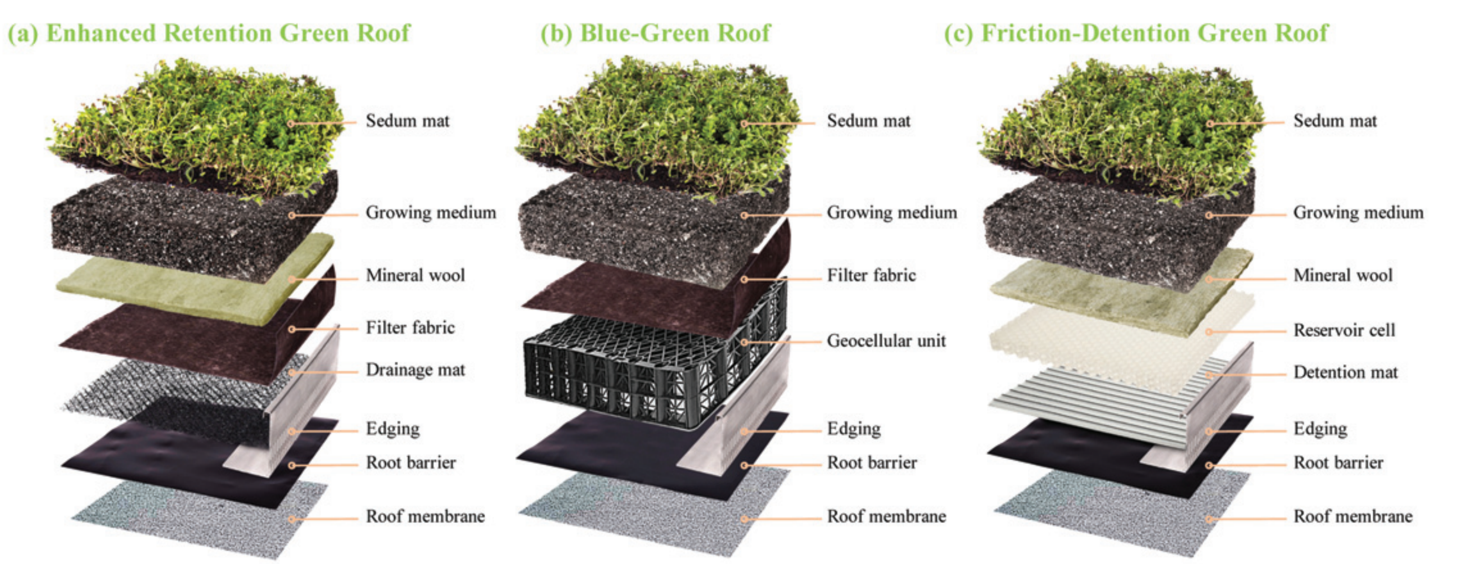


FIGURE 3 - System buildup of three rooftop stormwater management solutions (a) enhanced retention green roof (b) blue-green roof (c) friction-detention green roof.

This lower portion enables the blue-green roof to manage back-to-back rainfall events and large intense storms regardless of the antecedent weather conditions (i.e. even when the upper green roof is fully saturated). Water is released slowly, so the blue roof basin is emptied or "recharged" for the next storm. Blue-green roofs offer reliable controlled release of runoff like traditional detention-based systems.

At first glance, blue-green roofs offer the best of both worlds, combining retention and detention to maximize stormwater management potentials. Unfortunately, as detention is achieved through control flow drains, it also inherits many of the blue roof's weaknesses such as the dependence on zero-degree slope for water storage efficiency and clogging at the drains can affect the operation and effectiveness. As a result, blue-green roofs work best on dead flat roofs, preferably on large regular shaped roofs to minimize the number of flow restrictors required for best economics.

Friction-Detention Green Roof

A friction-detention green roof consists of an enhanced retention green roof on top of a friction detention mat (*see Figure 3 (c)*). The retention of the upper green roof is enhanced by a mineral wool and an optional reservoir cell. The detention mat consists of thousands of fine vertical fibres sandwiched between two geotextiles. These fibres create friction to slow down runoff traveling to the drain to achieve detention. Water is backed up, filling up the reservoir layer and saturating the retention layer and growing medium. The friction-detention mat allows small amounts of runoff to flow through unimpeded but slows down large volumes of runoff. As a result, runoff comes out at a slower rate over a longer time, which prevents overloading the storm sewers. The detention mat enables the system to manage back-to-back rainfall events and large intense storms regardless of antecedent weather conditions (i.e. even when the green roof is fully saturated). The water is released slowly within 24 hours and the system is "recharged" for the next storm.

It is important to note that because detention happens at the drainage level across the *entire* green roof, this avoids clogging issues associated with single-flow restrictors such as control flow drains. It also enables the system to be implemented on low-sloped roofs without losing efficiency and sloped roofs effectively. Lastly, the friction detention system is particularly economical on irregular shaped roofs where numerous roofs drains would require flow restrictors.

A successful friction-detention green roof design requires collaboration between several disciplines–architects, landscape architects, civil, and mechanical engineers–to provide project-specific details such as size, location, design storm, maximum allowable outflow rate...etc. Using these input data, a proprietary detention modeling program accurately predicts performance and calculates the appropriate green roof profile to meet detention and retention requirements of the project.

Guild Inn Estate gazebo green roof, Toronto. Photo: Greg Van Riel/NLSM

A short explanatory video can be viewed by scanning this QR code.

Vegetated systems from left to right: "traditional" using simple drainage cups to expedite fast drainage, "enhanced retention" with a high performing water retention layer, and "friction-detention" with both retention and friction-detention layers.

Preferential flow paths start to form immediately as the water moves through the systems. The traditional system begins generating runoff first and reaches a breaking point in which rainfall and runoff rates occur at the same rate. The retention-based, and friction-detention systems are still filling up and are not generating any runoff

All three systems are generating runoff but at different rates. The enhanced retention system reaches a breaking point where rainfall and runoff rates are equal. In contrast, the friction detention system has a lower runoff rate because it's macropores are still filling up.

The macropores in the friction-detention system reach full capacity thanks to the detention layer. The detention layer causes friction and restricts the maximum flow rate causing a calculated backup within the system. As a result, runoff flows at a much lower rate than rainfall. The friction-detention system slowly drains, thereby delaying and reducing the peak flow making it a reliable stormwater management tool, ready to face second day and extra-large storms.

FIGURE 4 - Performance comparison of three rooftop stormwater management solutions.

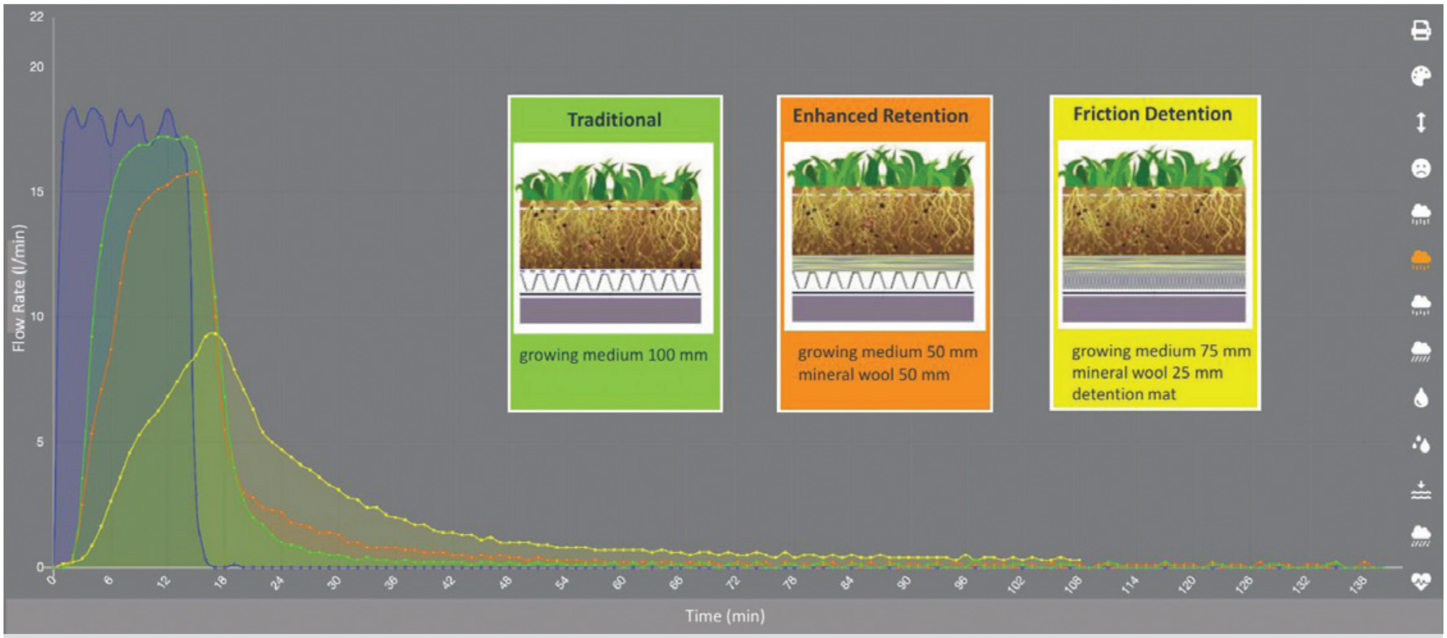


FIGURE 5 - Performance comparison of three rooftop stormwater management solutions – hydrographs.

The research behind friction-detention technology

Figure 4 (page 5) compares the water retention and detention performance of three distinct green roof systems. Water fills and exits differently given a "traditional" system using simple drainage cups to expedite fast drainage, an "enhanced retention" system with a high performing water retention layer, and a "friction-detention" green roof with both retention and friction-detention layers.

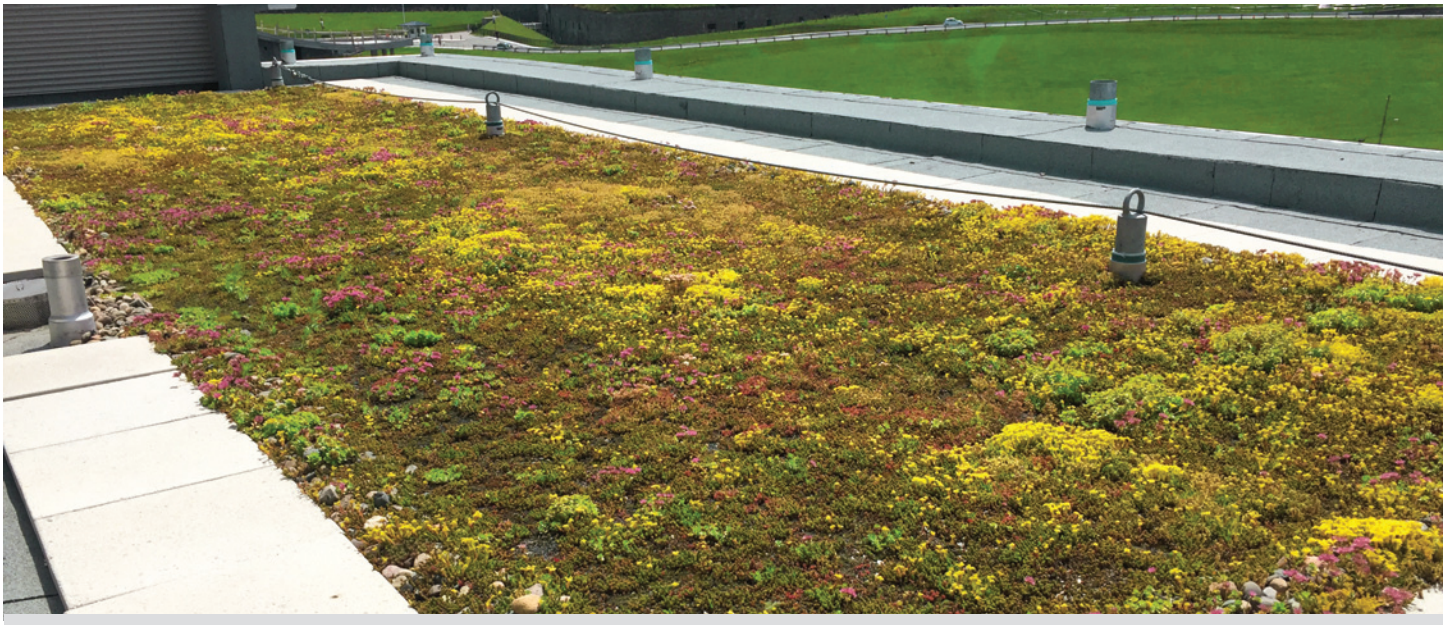
Figure 5 illustrates the effectiveness of the friction-detention green roof by comparing hydrographs from the same three systems in an actual rain test.

Conclusion

While green roofs and blue roofs are effective low impact development tools, enhancing retention capacity and adding detention elements can take their stormwater management potentials to the next level. Enhanced retention green roofs not only reduce runoff, but they also lower irrigation needs and increase resilience to heat and drought.

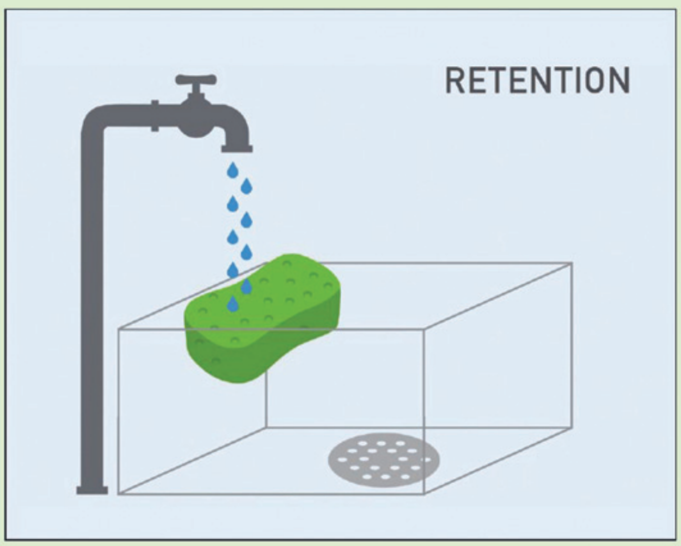
Blue-green roofs and friction-detention green roofs incorporate detention to reliably manage back-to-back rainfall events and large intense storms regardless of antecedent weather conditions. While blue-green roofs work best on large dead flat roofs, friction-detention green roofs also work well on low-slope and sloped roofs, as well as irregular shaped roofs with many roof drains.

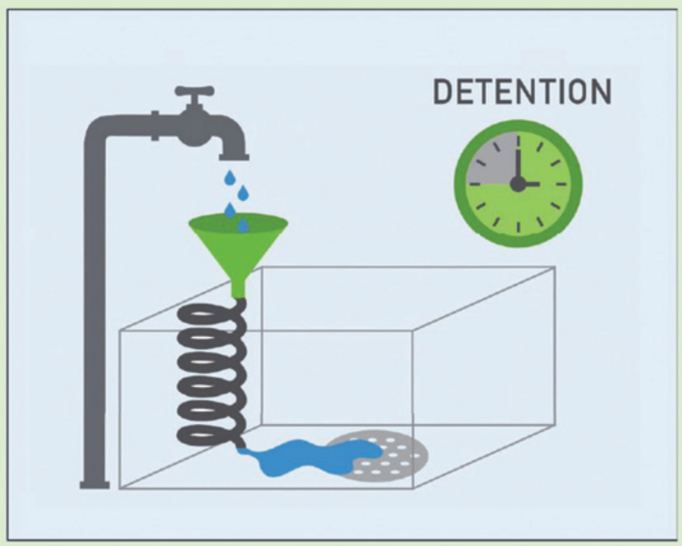
These advanced systems store a large amount of rainwater to be evaporated back to the atmosphere and delay runoff reliably during heavy downpour to minimize flood risks. Adding detention to retention on green roofs better manages stormwater and increases climate resilience in our cities.



Green roof on Nova Scotia's Citadel Halifax Hotel. Photo: Rhyno's Landscaping

Untangling Green Roof Retention & Detention





Retention

Retention is defined as keeping something or continuing to have something. As an analogy, retained water stays in the sponge and never reaches the drain. On a green roof, plants will eventually absorb and transpire retained water. The retained water also evaporates directly from the media back to the atmosphere. Retention is important for plant survival and annual runoff reduction. When the sponge is saturated, one must wring it out before it can soak up water again. Similarly, a saturated green roof needs to dry out and recharge. Retention is not effective in managing back-to-back storms.

Detention

Detention is defined as keeping something from proceeding temporarily or delaying something. As an analogy, detained water does reach the drain, only much later and at a slower rate. On a green roof, detained water is held up on the roof and slowly allowed to come out via control flow drains or friction detention layers. During a heavy storm, detention delays and reduces peak flow, which help prevent overloading the storm sewers and flash floods. Detention is reliable and facilitates back-to-back storms.

Sasha Aguilera, B.Arch, GRP, is Design Ambassador for Next Level Stormwater Management. With nearly 15 years of green roof experience, Sasha is recognized as a leading green roof design consultant. Sasha has considerable experience working on vegetated roofs of various complexities – from retrofits to new construction – across the country. She was honoured with the F. Ross Browne Award in 2017. Aguilera can be reached via e-mail at sasha@nlsm.ca.

Karen Liu, PhD, is Green Roof Specialist at Next Level Stormwater Management. Before joining the private sector, Liu was a lead researcher of the green roof programs at the National Research Council Canada (NRC) and the British Columbia Institute of Technology. In recent years, Liu was a key participant in the research consortium that developed the first national wind testing standard for vegetated roofing, the Canadian Standards Association (CSA) A123.24-15, Standard Test Method for Wind Resistance of Modular Vegetated Roof Assembly. Additionally, she has vast practical experience having worked on hundreds of green roof projects across North America, Europe, and Asia. At NLSM, Karen works on special projects and wind and stormwater calculations. She can be reached at karen@nlsm.ca.

NOTES

[1] Read *'100-year' floods will happen every 1 to 30 years, according to new flood maps*, Princeton university, phys.org/news/2019-08-year-years.

[2] Find Western Univeristy's Flood Map Viewer, by Slobodan P. Simonovic, Mohit Mohanty, and Andrew Schardong, at floodmapviewer.com/maps.

[3] Consult *Adapting to the impacts of Climate Change in Canada: An Update on the National Adapatation Strategy*, Government of Canada, canada.ca/en/services/environment/weather/climatechange-plan/national-adaptation-strategy/report-1.html.

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