Growing Greener Roofs with Less Potable Water

A Close Look at Green Roof Water Use in Vancouver's West End

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ABSTRACT Green roofs are well known for their environmental, economic, and aesthetic contributions to cities as sustainable infrastructure. Their potential benefits, however, can sometimes be overshadowed by daunting resource requirements. This paper looks at a specific case study to generalize the irrigation requirements of intensive at-grade green roofs in downtown Vancouver in order to recognize potential issues related to landscape water use and inform future design decisions.

INTRODUCTION

Green, or living roofs, are becoming more popular in building design, adding aesthetic improvement and new amenity space above below-grade structures such as parking garages (Metro Vancouver 2009); however, studies are beginning to question the ecological sustainability of different green roof benefits in particular contexts. The general consensus by prominent green roof researchers is that the success of green roof benefits is linked closely to location, public perception, and climate (Connelly 2012; Fassman 2012; Hemstock 2012; Kong 2012; Roehr 2012; Schreier 2012). These considerations are used in design to determine the most appropriate functions for a particular green roof.

Depending on a green roof 's location, the success of certain attributes can vary. For example, a green roof that extends over a large body of water is not needed to delay water runoff for the purpose of mitigating the effects of a storm event on a city's sewer system. The runoff can be diverted straight into the water. In fact, a green roof in this location can have negative impacts on water quality as runoff from the roof is likely to transfer water with higher levels of nutrients from the soil into the waterbody (Glass 2007; Teemusk and Mander 2007). Similarly, a green roof located next to a large nature park may not offer any additional biodiversity benefit that the park does not already provide (Vaughan 2012).

The public perception (or misperception) of green roofs is also important in determining its function. In Vancouver, ground level green roofs are almost always intensive green roofs (heavily manicured for human use). Metro Vancouver (2009) suggests that this may be because extensive green roofs "look messy and are not 'green'" (p3-20), whereas intensive green roofs appear to be more cared for and intentional.

While public perception may not seem to be of obvious importance in the implementation of green roofs in Vancouver, perception does influence the choice of green roof attributes throughout the design process. Extensive green roofs are usually more ecologically sustainable than intensive green roofs (Roehr 2012), but they are often pushed aside for their aesthetically-pleasing counterpart. We have to ask ourselves if the implementation of these types of green roofs is appropriate in Vancouver. And if not, what are the alternatives?

GREEN ROOFS AND VANCOUVER'S CLIMATE

The most significant green roof benefit for Vancouver is thought to be stormwater management (MetroVancouver 2009; Roehr and Kong 2010). When it rains on a pervious or natural landscape (figure 3), most of the precipitation infiltrates into the groundwater or is evapotranspirated by plants back into the atmosphere. Less than 15% of the precipitation becomes runoff that is eventually infiltrated into the ground or ends up in waterbodies. As population density in cities increases, the amount of impervious surface such as traditional roofs and asphalt increases. When it rains (figure 4) the water has nowhere to infiltrate into the groundwater. There is typically less vegetation to evapotranspirate water back into the atmosphere, and the majority of the precipitation, approximately 80%, turns into stormwater runoff. This leads to an increase in stormwater velocity, a risk of flooding and erosion, and increases requirements for infrastructure to manage the runoff (Roehr 2012).

In Vancouver, the runoff is often directed into a combined storm sewer system--one pipe for both human effluent and water runoff. When there is a storm event the infrastructure may become overloaded, and to avoid risk of flooding, the untreated effluent and water is sent through outfalls into Vancouver's surrounding waterbodies (Schreier 2012). Green roofs can help mitigate the need to upgrade costly infrastructure and can help manage stormwater in a passive way. In Vancouver, green roofs can be used to reduce runoff by up to 58% (figure 5) (Roehr and Kong 2010).

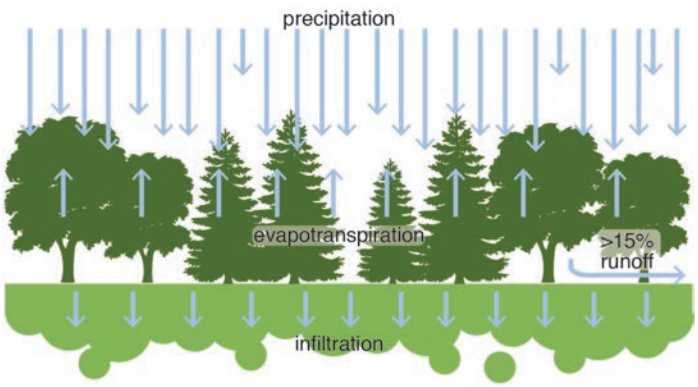

Figure 3. The natural hydrological cycle (adapted from Roehr 2012)

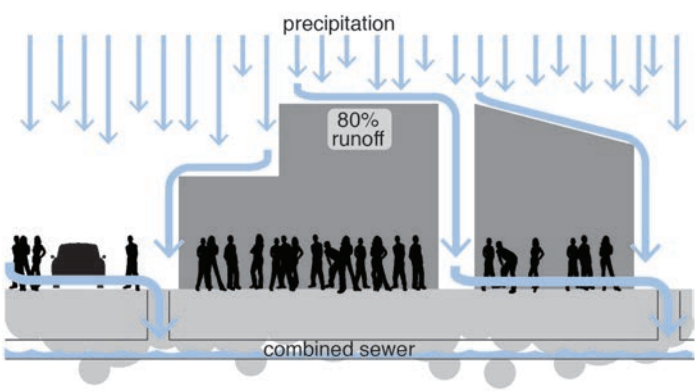

Figure 4. City hydrological cycle (adapted from Roehr 2012)

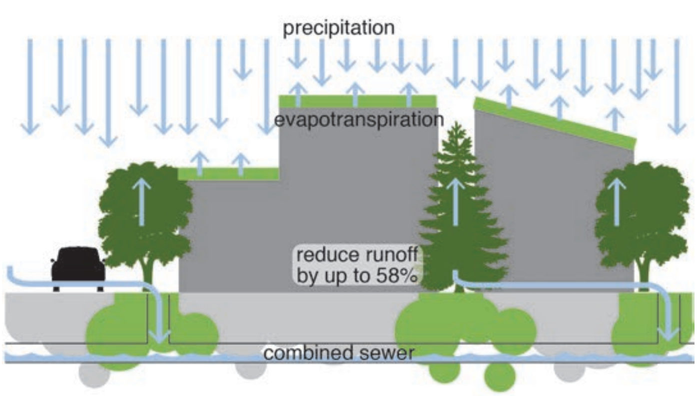

Figure 5. Green roof hydrological cycle (adapted from Roehr 2012)

Like other vegetation systems, a healthy green roof requires specific conditions, including adequate amounts of water. Vancouver experiences wet winters and dry summers. When plant evapotranspiration is greater than the available precipitation, there is not enough water to sustain plant life. This occurs annually in Vancouver between May and September when precipitation is at its lowest and temperatures are at their highest. The plant material on Vancouver green roofs therefore requires irrigation in order to survive the summer. While irrigation requirements in Vancouver are not ideal, what is problematic is not so much that they require irrigation as it is *how* we are irrigating them.

SITE STUDY: BAYSHORE GARDENS

The study site for this investigation was chosen for numerous reasons, including design intent, location, land use, and landscape materials. Bayshore Gardens is located on the north side of Vancouver's downtown near Stanley Park, and is bounded by Denman, Cardero, and West Georgia Streets, and Coal Harbour (figures 7 and 8). The site is a master planned development that comprises the Westin Bayshore Hotel, a collection of predominantly residential towers with some mixed-use development at ground level, a boat marina, and park land.

The project was a collaborative effort between developers, City of Vancouver staff, and well-known architects and landscape architects such as Arthur Erickson and Don Vaughan. The overall concept was "to create a pedestrian-oriented environment in a rich garden setting" (City of Vancouver 2003, p34).

The resulting design was an intensively landscaped strategy which layered building and gardens on top of below-grade parking garages. With the exception of the Westin Bayshore Hotel, marina, and road right-of-ways, the entire site was built on concrete slab or green roof (figure 9) (Vaughan 2012) with little, or no opportunity for groundwater infiltration. The development won countless awards including five gold Georgie Awards, silver awards by the Canadian Home Builder's Association in British Columbia, and an Excellence on the Waterfront Award. The landscape architecture component of the Bayshore Lands also received a Canadian Society of Landscape Architects (CSLA) Merit Award in 2001.

Bayshore Gardens was chosen as a study site because it represents countless other developments in Vancouver though the use of ground level intensive green roof landscapes for aesthetic and recreational benefit (Vaughan 2012). A green roof located on the edge of Coal Harbour isn't as beneficial for stormwater management because precipitation and runoff can drain directly into the harbour. Biodiversity benefits are insignificant as the site is almost directly adjacent to Stanley Park. The green roof insulates a parking garage, and so doesn't provide much benefit in the way of energy efficiency. There is also a range of landscape ownership, from inaccessible and accessible private landscapes, to the entirely accessible publicly owned landscape of Marina Square.

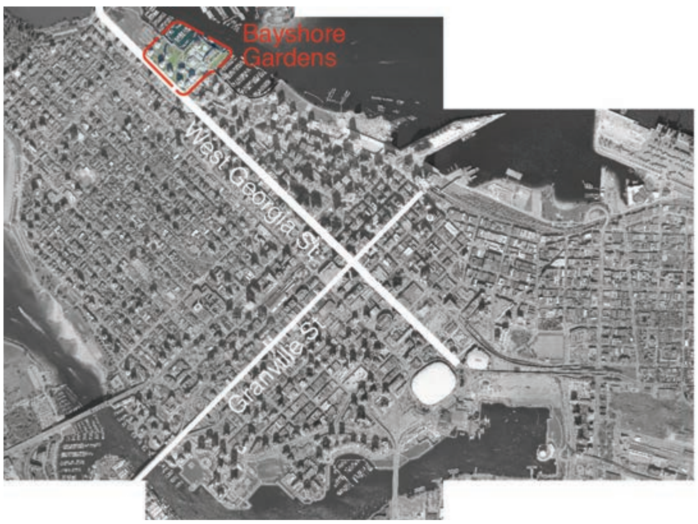

Figure 7. Bayshore Gardens downtown Vancouver context map

Figure 8. Bayshore Gardens site context aerial map

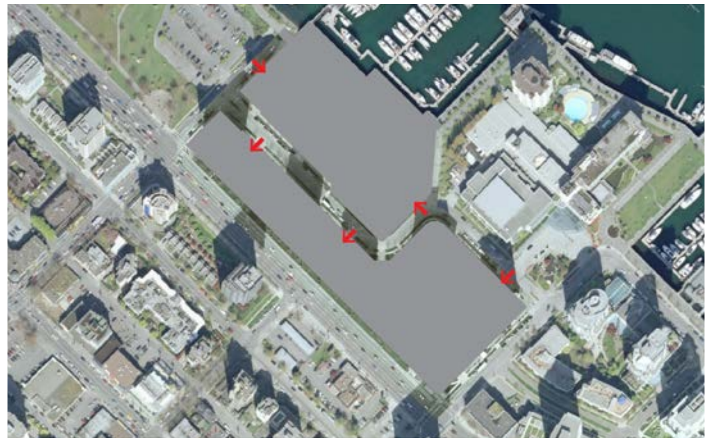

Figure 9. Bayshore Gardens green roof and below-grade parking lot entrances

WATER NEEDS: BAYSHORE GARDENS

The range of surface materials at Bayshore Gardens allowed for an in-depth exploration into the feasibility of different landscape types with regards to outdoor water requirements in the Vancouver climate.

Bayshore Gardens can be divided into five general surface types (figures 11 and 12):

- 25% (approximately 8,700 square meters) of the site is grey roof or traditional impervious roof
- 28% (9,700 square meters) is other impervious surface such as impervious concrete paving and asphalt
- 10% (3,500 square meters) is open water features
- 26% (9,300 square meters) is intensively planted gardens
- 11% (3,900 square meters) is mown lawn for recreational use

The majority of the lawn is located on parkland where the recreational value is highest (figure 13). The impervious surface is predominantly used for pathways, with some private and semi-private patios (figure 14). The water features were designed to visually connect West Georgia Street with Coal Harbour and, in conjunction with the garden areas, aim to limit public access to the site (Vaughan 2012). The two largest water features are adjacent to the highest volume pedestrian routes. The largest follows the sidewalk along West Georgia Street (figure 15), and holds approximately 473,400 litres of water. The other major water feature cascades down between two residential towers to the seawall (figure 16), and has a volume of approximately 407,700 liters.

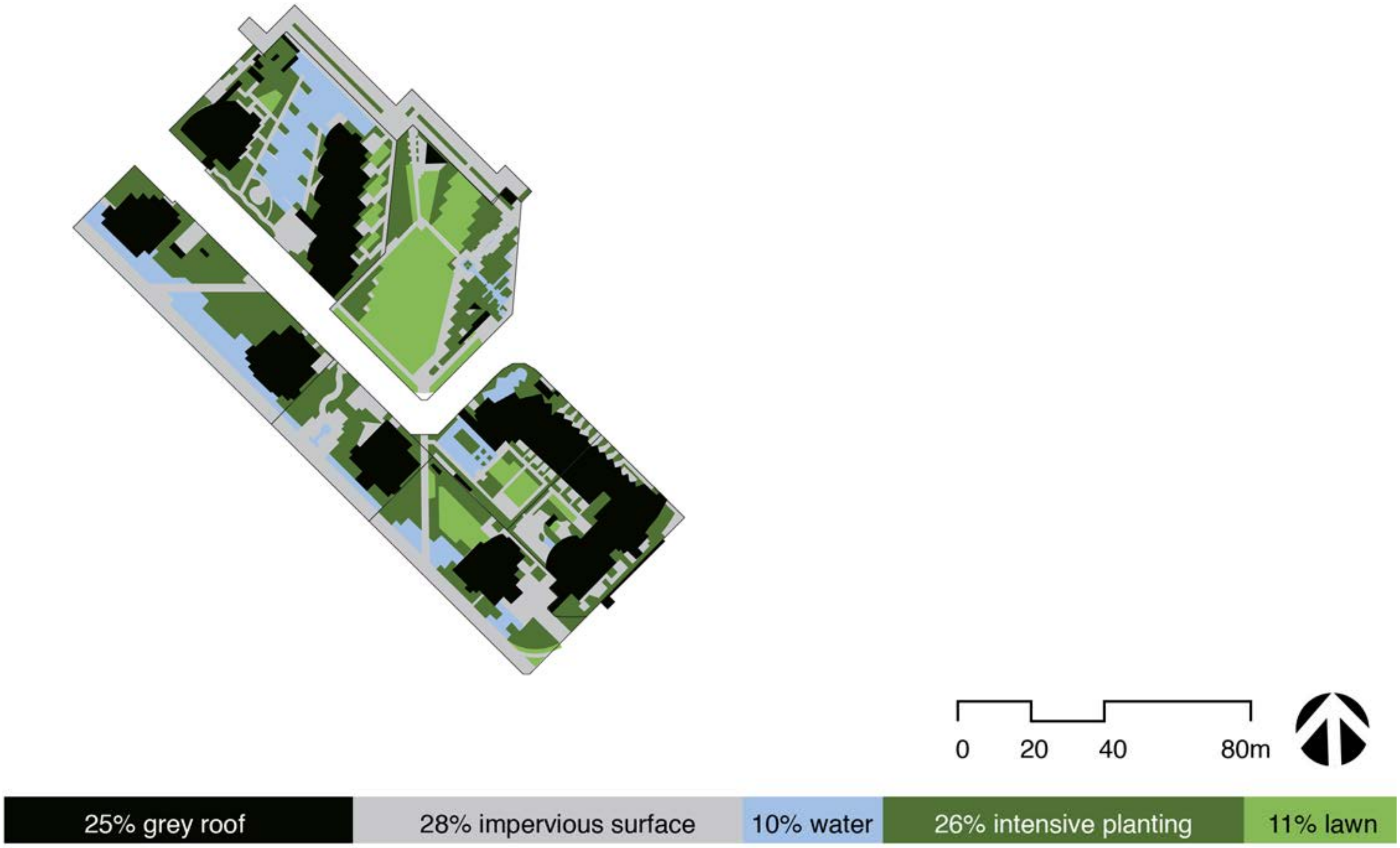

Figure 11. Surface areas and types

Figure 12. Site model showing surface areas and types

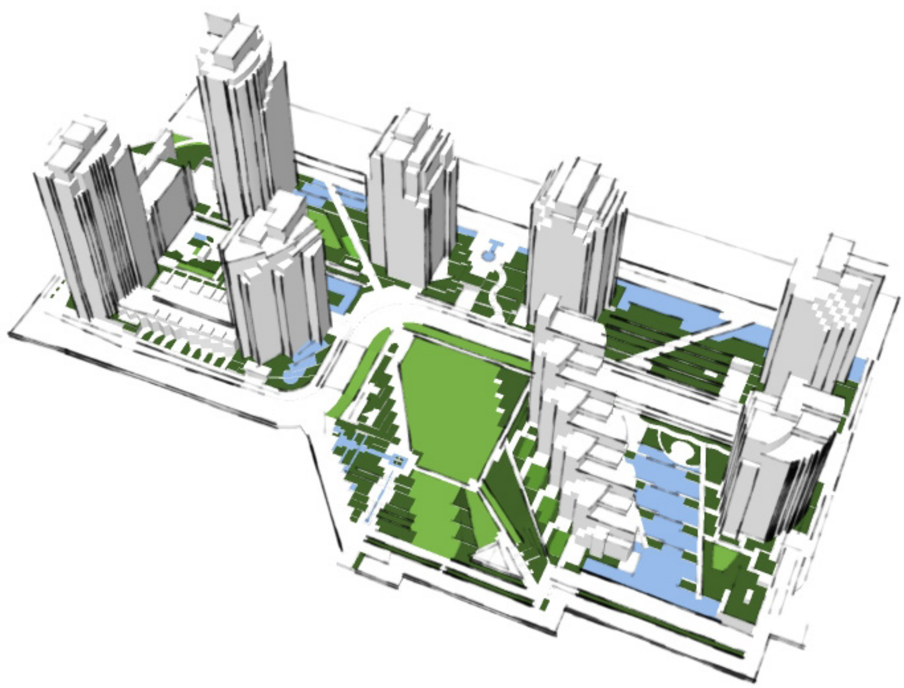

Figure 13. View south across the Marina Square lawn (photo taken April 2012)

Figure 14. View north down the pedestrian path connecting West Georgia Street with Bayshore Drive (photo taken April 2012)

Figure 15. View east from the public art fountains along Georgia Street's sidewalk (photo taken April 2012)

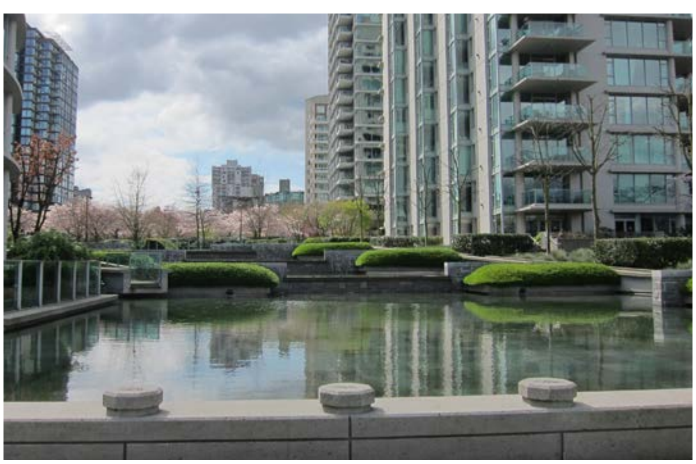

Figure 16. View south from the seawall up the second largest water feature (photo taken April 2012)

Based on rough area calculations and the monthly water and irrigation requirements of each landscape type in Vancouver, I was able to approximately measure the amount of water required to sustain the Bayshore Gardens landscape over the course of a year. Approximately 2,390,300 litres of water are required in an average year to maintain the green roof landscape. Of this, 29% is needed to irrigate lawns, 16% is needed to irrigate intensively planted areas, and 55% is needed to maintain the level of the water features (figure 18).

Data collected from informal conversations and emails to Bayshore Gardens property managers, site maintenance personnel, and relevant City staff showed that the landscape water use was not limited to the amount indicated by the original calculations. Yearly maintenance and cleaning is conducted on the water features, which requires them to be completely or partially drained. If the water features have an average ideal depth of 30 centimetres, a maximum of 1,064,400 litres of water would be required annually to re-fill them. An estimated total amount of 3,454,700 litres of water would be required every year to irrigate the vegetation and maintain the water features on site (figures 18 and 19).

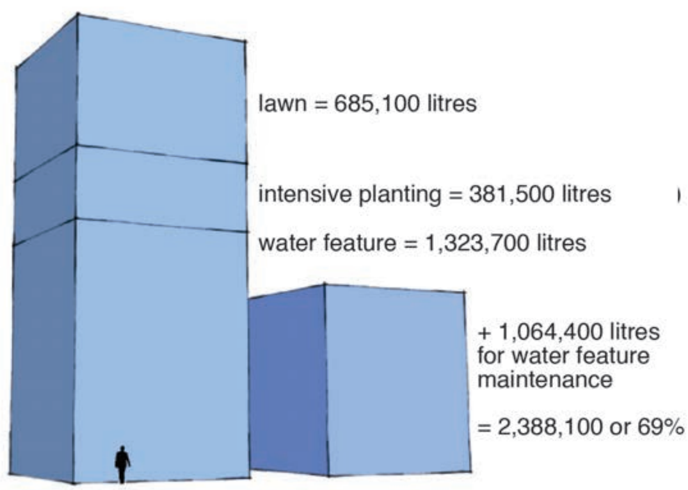

Figure 18. Total yearly amount of water required to maintain the landscape on the Bayshore Gardens green roof

USING POTABLE WATER FOR IRRIGATION

The high water requirement of intensive ground level green roofs in Vancouver is only part of the problem. The real issue hindering the environmental sustainability of green roofs is the demand on natural resources including potable water which is most often used for irrigation and maintenance.

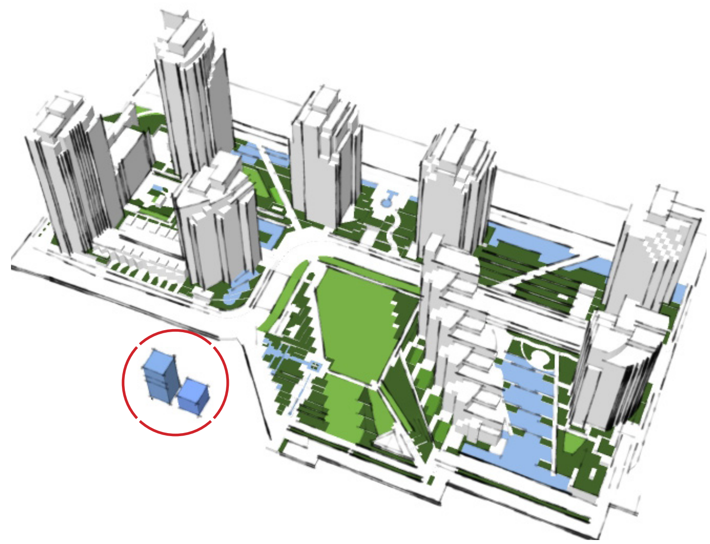

Figure 19. Scale of required irrigation cistern in relation to the case study site

The data collected from this study indicated that the Bayshore Gardens green roof uses potable, or treated drinking water for landscape maintenance (City of Vancouver 2012; Paunovski 2012). Automatic sprinklers are used during the summer months to irrigate the lawn and intensively landscaped areas, with water feature level top-ups occurring, on average, twice over the season. 3,454,700 litres is a large amount of treated water, just under the volume held by 1.4 Olympic sized swimming pools. At 80 cents per litre (Metro Vancouver Tap Water Campaign 2011) this amount of drinking water costs tax payers almost $2,800.00 a year.

While Vancouver doesn't experience extreme drought conditions, there are indicators that we need to start managing our drinking water better. About 90% of the precipitation received during the winter overflows the reservoirs and cannot be stored for later use (Metro Vancouver Conservation and Reservoir Levels 2011). In the summer, when seasonal precipitation is at its lowest, water use almost doubles due to outdoor use (figure 20). Metro Vancouver is currently implementing Stage 1 of the Water Shortage Response Plan (2011) to try and reduce the demand for water in the summer by restricting the use of potable (tap) water for irrigation. The restrictions help ensure that demand does not exceed what the existing system can deliver throughout the region. Metro Vancouver's lawn sprinkling advertising campaign notes that "1 hour is all you really need for a healthy lawn", yet at the same time, in an hour, one lawn sprinkler uses as much water as 25 toilet flushes, 5 loads of laundry, and 5 dishwasher loads combined (Metro Vancouver Conservation and Reservoir Levels 2011).

The combination of population growth and predicted changes in climate will put more stress on the water supply system in future years (Metro Vancouver Drinking Water Management Plan 2011). Roughly 1 billion litres of potable water are used everyday in the Greater Vancouver Regional District. At the current rate, we have sufficient reservoir supply capacity to see us through until about the year 2050. If capacity is exceeded, upgrades to existing infrastructure can help reduce stress on the water system in the short-term; however, these are not long-term sustainable solutions (Metro Vancouver Conservation and Reservoir Levels 2011).

DESIGN IMPLICATIONS AND OPTIONS

In order to decrease landscape water use on ground level green roofs in Vancouver, design solutions need to consider water use both before construction of new projects and as retrofits to old projects. Probably the most common design solution is rainwater harvesting. The amount of rainwater runoff from the grey roofs at Bayshore Gardens (figure 22) is greater than the irrigation requirements of the landscaped areas. All properties, except for Marina Square and the seawall, would be able to collect enough water to supply their own irrigation requirements over the summer.

There is enough runoff from the grey roofs adjacent to the park land that water could be shared with the park to minimize potable water use. The rainwater could be collected from the grey roofs and stored in closed cisterns in the underground parking lots. The cisterns could be strategically located within the parking garages to minimize their size and reduce the amount of energy that would be needed to pump the water back to the surface for use. The infrastructure for this self-sustaining option would be very expensive, particularly when retrofitting an existing development (Roehr 2012).

Another solution would be to minimize the use of water features in Vancouver. Water features have high aesthetic value but are one of the most expensive types of landscapes to design, construct, and maintain (Vaughan 2012). Water feature levels could be allowed to fluctuate with the seasons. By not trying to keep the water at a consistent level and by reducing the schedule for cleaning and maintenance, Bayshore Gardens could decrease landscape water use by as much as 69%.

In theory, water features can be used as open cisterns to minimize the need for additional rainwater harvesting infrastructure; however, open cisterns are problematic under Vancouver's health and safety bylaws. Should these loosen in the future, water features on this site acting as cisterns could reduce the landscape potable water consumption by as much as 99%.

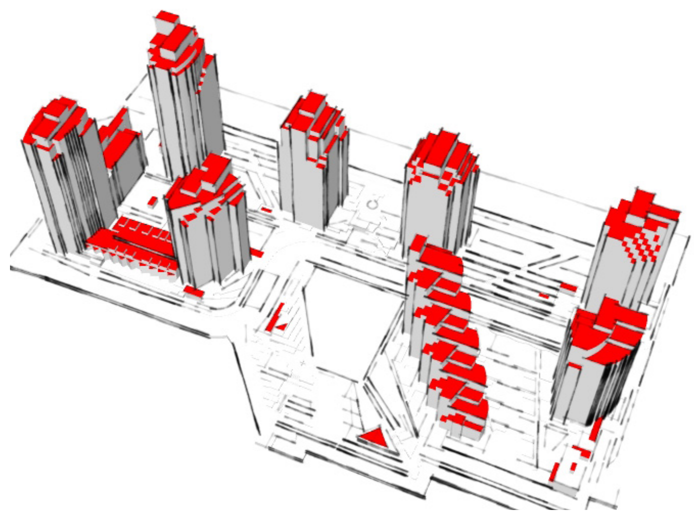

Figure 22. Grey roofs can be used to harvest rainwater, which can then be stored in cisterns and used for future landscape irrigation

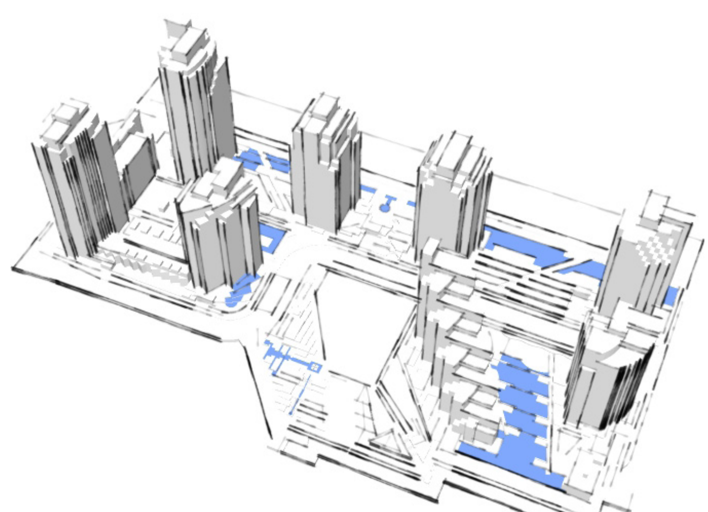

Figure 23. Water features could be used as open cisterns to store rainwater for landscape use

RETROFITTING FOR SMARTER WATER USE

Some concerns for the use of water features as open cisterns could relate to water quality and public safety. The water features at Bayshore Gardens are publicly accessible. By planting a vegetative buffer in front of the water features, physical access could be prevented without compromising sight lines to the water (figure 25). Increasing separation between people and water features might also reduce the risk of water contamination, perhaps making an open cistern concept more feasible.

Existing water features could also be drained and planted with low water-use plants (figure 26). In Vancouver, the calculation showed that low water-use plants would only need irrigation in the months of July and August. At 3,900 litres of additional water for irrigation each year, such plants would still reduce landscape water consumption by as much as 69%. The largest challenge associated with using low water-use plants in a highly visible location might be in the visual acceptance of a naturalistic landscape. Investigations indicate a potential level of acceptance of naturalistic vegetation as long as there are obvious 'cues to care' in both design and management (Nassauer 1995). In design, 'cues to care' could involve an ornamental or patterned planting scheme of low water use plants (figure 26), and/or the integration of colour by using wildflowers (Dunnet 2006). In maintenance, 'cues to care' might involve ensuring a high standard of visual upkeep like what is currently seen at Bayshore Gardens.

The Bayshore Gardens development uses retaining walls to address topography changes. The retaining walls form planters that extend above-grade to contain plant and growing material. A good example of this is the planted strip that divides the bike path and pedestrian path along the seawall (figure 28). If the edges of the planters were lowered to be at-grade with the surrounding impervious surface, they would be able to collect and use the stormwater runoff (figure 29). To decrease the chance of plants drowning during the wet winter months, the planters could be turned into rainwater gardens with plants that are very tolerant of extreme weather. Not only would this reduce the need for the current automatic sprinkler system, but could also improve water quality by not directing the runoff and the potential harmful contaminants, directly into Coal Harbour.

Figure 25. Edge of water feature planted to limit physical public access without impeding sight lines

Figure 26. Artful placement of low water-use plants in a Bayshore Gardens water feature

Figure 28. Existing planter that separates the bike and walking path along the seawall

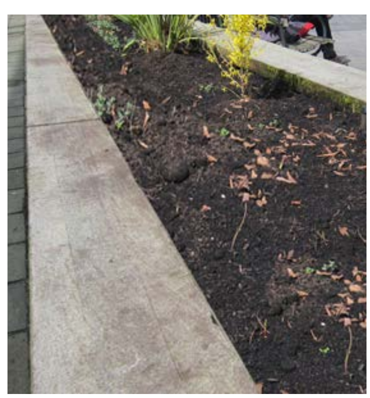

Figure 29. Removing the planter edge so that it is flush with surrounding impervious surfaces allows stormwater runoff to irrigate the garden

CONCLUSION

Green roofs should be self-sustaining in order to deliver any type of environmental benefit. The chosen green roof benefits should be decided based off of location, public perception, and climate requirements. In Vancouver this means that green roofs should take into account water requirements. When designing, implementing, and maintaining green roofs in Vancouver it may not be that any one solution is best. A combination of solutions can minimize cost and reduce the disturbance to intended green roof benefits. While using green roofs for purely aesthetic benefit isn't environmentally ideal in any climate, the case study and resulting discussion shows that the impact on water resources can be minimal if the green roof is designed, implemented, and maintained carefully.

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