Gonzaga-in-Delft Program Final Report:
The Feasibility of Green Roofing and Walling as a Sustainability Action Measure for the City of Spokane

Antonio Roman Campos

CENG 440: Delft Sustainable Cities

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On the Cover: An aerial photograph of Riverfront Park, a well-designed greenspace at the heart of the City of Spokane.

Abstract

Based on research conducted on site in the Netherlands by Gonzaga University undergraduate civil engineering students, this report responds to the City of Spokane's "Sustainability Action Plan" by introducing specific recommendations for the city to lessen its environmental impacts and improve its civil engineering works to mirror certain European solutions. This report begins with an extensive discussion of the term "sustainability," including its technical definition, and its feasibility in a city like Spokane. The first chapter also examines how cities are well situated to embrace sustainability at local levels and how civil engineers are uniquely suited to support civic sustainability efforts. A second chapter focuses more intensively on the role of water resources civil engineers in improving sustainability measures, and direct attention is paid to the water resources goals of Spokane's "Sustainability Action Plan." Finally, green roofing and walling is discussed in the third chapter as a particular way to help meet Spokane's green goals using civil engineering, and a concluding chapter emphasizes how these measures could be specifically implemented within the physical context of Spokane's built environment.

Chapter 1: The Sustainable City

Sustainability is a term that requires a bit of unpacking. The City of Spokane's Sustainability Action Plan, created by a dedicated team of city councilmembers, planners, and experts, frequently equates *sustainability* with terms like *environmental responsibility*, *resilient planning,* and being *green*. Of course, all of these concepts are related; however, it is important to remember that sustainability also has a distinct definition of its own. Sustainability does not just mean urban improvement or waste reduction, but it actually describes a continuous regeneration of usable resources, such that they can be consumed at a given rate *forever* without a net depletion of available material or substance quality. Practically, the creation of truly sustainable systems is extremely challenging. This is both because human beings seek to use resources at rates faster than they are produced by natural processes, and because Americans often seek to maximize tangible economic gains, even when profitable practices are at odds with intangible environmental improvements.

In contrast to human models of extraction-consumption-disposal (linear systems and economies), most natural systems achieve sustainability and self-maintenance through cyclical actions (Nikolaou, et al., 2021). Cyclical systems and economies are not static or monodirectional, but instead they represent dynamic relationships between consumers and producers, and these relationships maintain a zero-sum net ecological impact. This is the case for predator-prey cycles, water and nutrient cycles, rock and mineral cycles, climactic cycles, and numerous other relationships seen in nature (Polking, 2018). Natural systems *are* sustainable, in contrast to human beings' patterns of rapid consumption (or overconsumption) of slowly-accruing resources, such as fossil fuels, minerals, and animal products. For these reasons, sustainability initiatives often focus on making linear human practices into cyclical ones that mirror nature and incorporate the ambient world. Moreover, sustainability initiatives, including improved land management, environmental preservation, and resource conservation, are not only good for natural systems and the needs of future generations, but they also help to improve people's lives in the present. Medical researchers have shown that environmental health leads to prolonged life expectancy, increased individual happiness, and more positive and healthy communities around the world (Beyene and Kotosz, 2021).

To ensure these benefits, national and international organizations help to establish base level standards for environmentally, socially, and economically sustainable development, notably

with the creation of treaties like the accords of Paris and Montreal; however, international organizations often struggle to achieve pinpointed local impacts, except in major metropolitan capitols. For example, the United Nations Sustainable Development Action Plan for Cities notes that "rapid urbanization is resulting in a growing number of slum dwellers, inadequate and overburdened infrastructure, and services (such as waste collection, water and sanitation systems, roads and transport), worsening air pollution and unplanned urban sprawl" (UN, 2015). However, the United Nations General Assembly has no executive arm to actually implement any solutions to these issues, beyond calling for increased charity and "care for poor and vulnerable populations" (UN, 2015). Indeed, while local government finds its strong suit in direct implementation, pinpointed solutions to pollution problems, and policing, national and international treaties struggle to find even political unanimity on the most fundamental changes.

In contrast, as local units of governance with high levels of autonomy, control, and interest in local issues and impacts, *cities* (such as Almere, Netherlands, pictured in Figure 1) are uniquely well situated to embrace sustainability solutions, and this can bring far-reaching benefits to the lives of municipal citizens and stakeholders. Indeed, the City of Spokane plays an integral role in determining community rules, regulations, and guidelines concerning sustainability, especially regarding infrastructure, zoning, consumption, waste, and pollution ordinances. The City of Spokane has the power to implement certain zoning requirements to support the construction of green buildings, and it can enforce future building preferences through fines and penalties, both of which tip economic scales in favor of sustainable designs. Likewise, the City of Spokane has control over municipal waste management systems, which can influence consumption levels of toxic or unsustainable materials by promoting the reuse, refurbishment, recycling, repurposing, or composting of numerous disposables (City of Spokane, 2021). Already, the City of Spokane prioritizes recycling as a sustainability measure, and citizens can be paid for properly disposing of materials like steel, aluminum, and copper at nearby plants, and this monetization of sustainable choices certainly motivates citizen involvement in environmental strategies. Finally, the City of Spokane has the ability to set pollution standards for both water and air at or above national and international standards, including pollution generated from homes, vehicles, and industrial facilities within city limits.

Figure 1. A photograph of a portion of the Floriade Exposition Park, a large sustainable engineering project established in the City of Almere, northeast of Amsterdam, Netherlands.

Thanks to their ability to regulate resource consumption, cities have the capacity to become not only greener, but completely sustainable. The City of Spokane is already taking steps in the right direction by seeking to limit unsustainable development and by defining developmental standards to maintain natural surroundings. Spokane can also continue to implement strict regulations on waste-producing systems to prevent ecological and environmental disasters, which tend to be "more prevalent and more severe [in] densely populated municipal centers" (UN, 2015). Finally, cities like Spokane must also work to become sustainable by retrofitting outdated systems in order to make sure they last for posterity, by finding ways to revamp old water and transportation systems before they decay and require total replacement, and by ensuring that environmental problems are addressed as quickly and directly as possible through specially appointed groups, like the Sustainable Action Subcommittee (City of Spokane, 2021).

This is great progress, but there is still more to be done. Since, as the United Nations points out, "the world is becoming increasingly urbanized… with more than half the world's population living in cities," (UN, 2015) it is imperative that cities like Spokane continue to implement long term sustainable retrofits to major civic infrastructure, including sewers, industrial works, transportation systems, and housing developments. Furthermore, since all these systems are essentially civil engineering creations, today's engineers must be relied upon to not only develop new sustainability standards for cities, but also physically implement them into the built environment through design, construction, and maintenance work. Indeed, there is a moral obligation for civil engineers to work with city officials, both creating and constructing the progressive local networks of the future, coevolving the built and natural environments to ensure sustainability, safety, and harmony in the most densely populated and intensively utilized districts on Earth—the cities. Only with the help of civil engineering can social, environmental, and economic sustainability be attained.

Following this introduction to sustainable cities, the remainder of this report focuses on the specific role of water resources engineers in the sustainability initiatives of the City of Spokane, drawing from the Spokane Sustainability Action Plan of 2021. This report begins by describing the importance of water resource engineering in sustainable urban development (Chapter 2), before investigating green roofing and walling elements, like those featured in Figure 2, a specific case study transported from research conducted in the Netherlands (Chapter 3). Lastly, a summary of how this study can be applied to the City of Spokane, with specific recommendations, will conclude this work (Chapter 4).

Figure 2. A portion of an extensive green roof and park continuous assembly from the Floriade innovation center in Almere, Netherlands. With a gentle slope, this garden transitions into a rooftop feature at the back of the image.

Chapter 2: Water Resources Engineering and Sustainability

According to the 2021 City of Spokane Sustainability Action Plan, the water of the Spokane River has always been *the* central feature of Spokane's natural environment. Indeed, the "lifeways of Spokane's original inhabitants revolved around the river: it was their main source of sustenance and their cultural touchstone" (City of Spokane, 2021). Likewise, later European settlers also chose to establish themselves "along the Spokane River to access all the benefits that a major river provides" (City of Spokane, 2021). Thus, the Spokane River—and its abundance of water resources—has always provided a central element to Spokane life, and this essential importance of water has transcended cultural, geographical, and political divides in a way of which few things are capable. Thus, it is difficult to overstate the role of urban water systems in Spokane, which are used not only for conveyance, recreation, and irrigation, but which are also crucial to ecosystem development and sustainably measures, like the goals outlined by the Spokane Sustainability Action Subcommittee and showcased in Table 1, below.

Table 1. Water Resources Goals Identified by the Spokane Sustainability Action Subcommittee (City of Spokane, 2021).

Water Resources	
GOAL 1. Protect the Spokane River and natural aquatic ecosystems (wetlands, shorelines, aquatic ecosystems biodiversity, streams, floodplains, aquifer recharge areas)	
WR 1	Protect water quality, fish, wildlife, ecosystem function, and no-impact recreational opportunities in the Spokane River through responsible, long-term watershed planning and management
WR 2	Build climate resilience in natural water systems through responsible watershed planning
WR 3	Actively manage pollution within Spokane River and SRVP Aquifer
WR 4	Support the protection, restoration, and reintroduction of native fish species and their habitats in the Spokane River Watershed
WR 5	Improve stormwater and wastewater management
GOAL 2. Ensure sustainable water supply	
WR 6	Work with regional partners to reduce pumping from the Spokane Valley Rathdrum Prairie (SVRP) Aquifer in the face of projected population growth and future climate
WR 7	Create clear process and policies for assessing and approving land use and development that will impact future aquifer pumping volumes
GOAL 3. Educate & engage community in water resources stewardship	
WR 8	Promote opportunities to engage the community
WR 9	Promote and fund City programs that align with the Water Conservation Master Plan
GOAL 4. Establish partnerships with regional organizations and agencies to leverage funding and invite community input	
WR 10	Partner with regional groups to provide City input for Spokane River Watershed/SVRP Aquifer management plans and projects
WR 11	Identify opportunities to acquire and restore critical areas, natural areas, and connect riparian corridors for protection and conservation

With the old Washington Water Power building located at the center of town, and with much of Spokane's urban heart situated among a series of dams, it is important to remember that the power of the Spokane River has been harnessed for human consumption for decades. Hydraulic power generated from dams is a major energy source in Washington State, and this power source can perennially be both plentiful and sustainable if managed appropriately by civil engineers in the water resources and energy sectors. "In 2020, hydroelectric power accounted for about 66% of Washington's total electricity net generation," (EIA, 2022) and this represents a major step towards Spokane's 100% renewable energy goal. However, inappropriate damming practices and complex environmental considerations have the potential to cause ecological detriment instead of environmental and fiscal benefit. Fish passage, a major issue in Washington, cannot be achieved without additional engineered solutions, like fish ladders, being added to existing dam and power structures. Additionally, dams must be continuously maintained to ensure proper working order of critical energy generation equipment; without routine inspections and timely corrections, dams will not only fail to produce energy quotas, but they could even pose dangers to large populations living downstream. Thus, even routine water resources engineering solutions are critical to broader hydroelectric functionalities (EIA, 2022).

The exposed and depleting Spokane Valley-Rathdrum Prairie Aquifer, the "sole source" of most Spokane drinking water, has also been cited as a primary concern of Spokane's Sustainability Action Subcommittee (City of Spokane, 2021), and recharging the aquifer must be a top priority for Spokane's future. Aquifer recharge, within the purview of water resources engineers, can be accomplished through a few key shifts in urban planning and land management, including the use of permeable or semipermeable pavements on roadways, the establishment of larger green spaces in urban zones, and a de-emphasis on concrete and asphalt hardscapes in urban environments, in favor of natural groundcovers capable of absorbing water. Developed by European companies like FieldFactors, new methods for the systematic pumping of water into the ground to recharge aquifers also offer mechanical solutions that help speed up natural processes to avoid future groundwater scarcities (FieldFactors, 2022).

Waterways and the ecosystems that surround them further offer tremendous biodiversity, with biomass that helps to stabilize and buffer anthropogenic environmental impacts. The preservation of habitat reaches along rivers and streams in the Spokane area can help to bolster riparian, wetlands, and freshwater ecosystems with myriad floral and faunal species necessary for

nutrient processing and natural preservation. Living within natural confines, rather than subverting natural spaces to developmental wills must be emphasized, and environmentally conscious water resource infrastructure can help to prevent the degradation of ecosystems and communities through a variety of methods. For example, the stabilization of soils is critical to environmental success, as is the broadening of river zones to allow room for natural flood patterns, rather than channelizing rivers to decrease their physical footprints (Zevenbergena, et al., 2013). Indeed, in urban areas like Spokane city center, engineers must find creative ways to make "room for rivers" to behave naturally, providing dividends in the form of improved sustainability as well as flood and water damage risk reduction (Zevenbergena, et al., 2013). This "room for rivers" concept is a quintessentially Dutch development, which encapsulates an engineering emphasis on "sustainability, flexibility, and solidarity" in infrastructure projects as articulated in the Dutch Delta Works core values, attempting to bring environmental and human needs into alignment to ensure that all viewpoints are seen, heard, and addressed (Marjan and Bloemen, 2014).

Finally, the Spokane River and other nearby surface water features provide important recreational opportunities for residents of Spokane, which in turn promote civic virtues and increased profits for the city. Indeed, acting sustainably and environmentally does not necessarily involve decreasing human interests and experiences, but actually heightening them. Through water resources engineering, outdoor spaces must be improved and managed so that they can be enjoyed by all. In keeping with the aforementioned key points of increasing water and food security, biodiversity, and recreational prospects, the remainder of this paper will hone in on engineered green roofs and walls—fairly simple features that can help with all of these topics. First, some international research on green building features will be discussed in Chapter 3, and then specific implementation approaches and recommendations for these features in Spokane will be described in Chapter 4.

Chapter 3: The Sustainable Benefits of Green Roofing and Walling

"Green" roofs and walls are structural design elements that incorporate living vegetation spaces into the exposed surfaces of buildings, including homes, office spaces, and campuses. While the concept of having green rooftop gardens or vine-clad walls may not seem particularly new or innovative, many of the most recent designs and interpretations of urban greenscapes, as envisioned by architects and executed by engineers, are actually quite unique and technologically driven. From earlier concepts of small green roof gardens, rooftop horticulture has expanded to include some of the largest feats of environmentally sustainable engineering, including the massive six acre living roof of the Vancouver Convention Center in British Columbia, which boasts more than 400,000 native Canadian plants in addition to beekeeping boxes and nature trails (Gardth and Evaus, 2016). The massive weight of rooftop soil spaces for gardens has also been reduced thanks to recent advancements in specially synthesized nutrient rich soil templates, now commonly used by European agriculturalists, which can support flourishing vegetation without adding large topsoil loads (Viviano, 2022). Finally, at the 2022 Floriade Exposition in Almere, Netherlands, a team of international engineers revealed what could become the next generation of architectural "greenscaping" as they displayed hanging wall gardens, complete with trees, bushes, and ground plants, that could literally grow on the exposed, vertical walls of buildings. An example of this innovation may be seen in Figure 3, with a detail in Figure 4.

Figure 3. A massive vertical garden installed on a retrofitted building at the Floriade Exposition in the Netherlands. Note the extensive six level scope of this project.

Green roofs and walls physically superimpose sustainable natural landscapes on top of essential existing buildings. The incorporation of these features into Spokane's built environment could be especially helpful for achieving multiple goals of the Spokane Sustainability Action Plan, including "improving stormwater and wastewater management," and "educating and engaging the community in water resources stewardship" (City of Spokane, 2021). Like any garden, rooftop and wall clinging gardens help to retain stormwater and prevent runoff as rain percolates into soil and is absorbed by root systems. This would reduce stormwater runoff in Spokane and also limit or eliminate the possibility of overflow in the city's combined storm/wastewater sewer system, thus promoting public health. Rooftop gardens on apartment complexes or office buildings also present a great way for community members to engage with sustainability and stewardship on their own terms as they help to decide which plants to cultivate, and grow fruit and vegetables for personal consumption. Not only do many gardeners take pride in their fruitful plants, but the aesthetic value of greenscapes can also make people more joyful in their living and working spaces

and, by extension, their city. Just like in Vancouver and Almere, rooftop gardens also provide a novel place to reintroduce threatened or endangered native species, replanting built surfaces with the very wildlife that they replaced. In some cases, entire ecosystems can be fostered on a single building, with incredible environmental results compared with traditional concrete and glass hardscapes.

Figure 4. A detail of the vertical garden installed at Floriade, showing how a variety of local plants have been secured into lightweight vertical planters on the building face, using a textured and slotted design.

Internationally, highly developed countries like Germany, Canada, Japan, Singapore, and Hong Kong have been the first to adopt largescale green roofs on the biggest buildings of universities, offices, health centers, and public agencies (GoodNet, 2021). However, the United States is also slowly adopting green roofing measures with buildings like the New City Hall of Chicago, which has a 38,800 square foot green roof installed since 2001 (GoodNet, 2021). Given their plethora of benefits and the possibility of retrofitting existing structures with green roofing, the City of Spokane should certainly consider adding these environmentally friendly features to several key buildings, as will be discussed in Chapter 4.

Chapter 4: Implementation of Green Roofing and Walling in Spokane

In Figure 5, a satellite view of downtown Spokane reveals large regions of grey hardscapes throughout the city, including several large and unused rooftops, such as those of apartment buildings, hotels, arenas, and convention centers (Google Earth, 2022). While visitors and residents of Spokane tend to notice the well planned green spaces of Riverfront Park, Gonzaga University campus, and several smaller open spaces, images like these reveal just how grey the city really is, and the potential that exists for rooftop and vertical gardens in town. Some of the largest roof spaces in town are already city and county possessions, like the Spokane Transit Campus, New Courthouse, and Public Defender Offices located in the upper left oval of the satellite image (just north of the historic courthouse geographically). With their flat, uninterrupted rooflines, all of these buildings could be great locations for green roof sustainable features provided that engineering analysis determines they can support the additional loadings associated. Certain private properties, like the Hilton Double Tree Hotel, and the Riverfront Convention Center, located in the lower oval, also have great potential for greenscape features, which could support the city's sustainability action goals. Tax incentives or zoning regulation updates could be ways to facilitate the conversion of these large buildings into green roof locations, and such incentives or regulations could be expanded to other city regions as well.

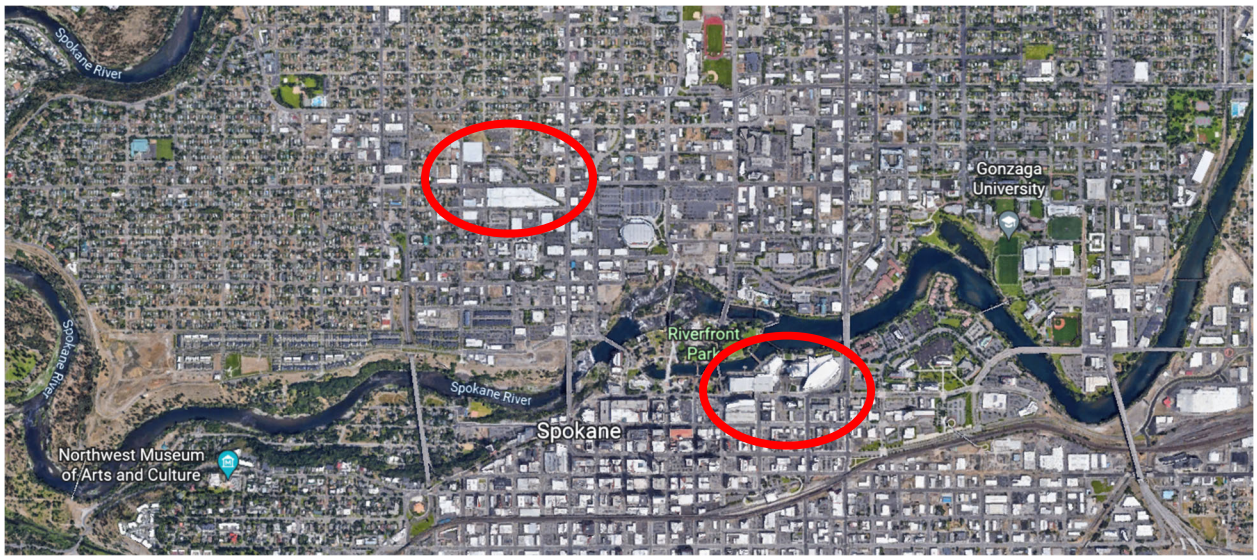

Figure 5. A satellite image of downtown Spokane, Washington, with two zones circled as described in text.

With goals established from its Sustainability Action Plan and demanding targets for energy and waste consumption reduction, it is clear that the City of Spokane is taking positive

steps towards a sustainable future. While individual citizens are capable of taking small steps to reduce personal consumption and increase household resiliency, the largest improvements to Spokane's environmental sustainability will still come down to engineered projects, especially including infrastructural retrofitting. Green rooftops and vertical gardens are two relatively low investment and high impact ways to promote the sustainability goals of the city by increasing public green space, water stewardship, and civic pride. Additionally, some specific locations for implementing green rooftop recommendations have been identified, and some tools for effecting these civic improvements have been addressed.

Now, it is up to all of us to ensure that environmental improvement plans, like these, are designed and implemented by civil engineers and dedicated citizens in the Spokane community.

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