Advancing Nature-based Solutions and Green Infrastructure: The Case of Metropolitan Vancouver

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Abstract

There is a gap in understanding how regional governmental authorities like Metro Vancouver understand the terms nature-based solutions (NbS) and green infrastructure (GI). Without a more fulsome and consistent understanding of how these terms are being applied, decision makers throughout the region lack an understanding of the perceived barriers to and opportunities for advancing NbS and GI uptake and are unable to shift policy.

This research was conducted as a continuation of ongoing ACT research into the value of establishing a regional green infrastructure network in Metro Vancouver. Conducted over three months, this project contains the results of over 100 qualitative surveys with Metro Vancouver regional advisory committees.

Findings indicate that NbS and GI are distinctly defined, that costs, knowledge gaps, and uncertainty are key barriers, and that framing NbS and GI as climate change strategies is a key opportunity to advance NbS and GI uptake.

Keywords: Nature-based solutions; green infrastructure; regional network; climate change; land use planning; low carbon resilience

Dedication

To Mom and Dad.

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List of Acronyms

GHG	Greenhouse Gases
SLR	Sea Level Rise
CO_2	Carbon Dioxide
NbS	Nature-based Solutions
GI	Green Infrastructure
MV	Metro Vancouver
LGA	Local Government Act
OCP	Official Community Plan
EV	Electric Vehicle
FCM	Federation of Canadian Municipalities
RGS	Regional Growth Strategy
RCS	Regional Context Statement

Chapter 1. Introduction

1.1. The Case for Innovative and Integrated Climate Action

Climate change has been named the number one global risk in terms of impact, and the number two global risk in terms of likelihood by the World Economic Forum (World Economic Forum, 2020). It has been identified as the biggest global health threat of the 21st century, and detrimental impacts such as heat waves, flooding, and extreme weather events are already affecting populations across the globe (WHO, 2020). Climate change threatens the most integral and essential elements of human life –access to clean water, nourishing food, and the biodiverse species and ecosystems necessary for the survival and prosperity of the human population –especially as populations in concentrated urban areas continue to grow and expand their boundaries (Danish, 2019). If global societies continue to emit GHGs at the same alarming, unfettered rate, it is likely that global temperatures will surpass the 2ºC limit imposed by the 2016 Paris Agreement, with significant consequences (Schreurs, 2016). For instance, under Representative Concentration Pathway 8.5, a high greenhouses gases (GHG) concentration scenario, it is projected that around half of total species may lose nearly all of their suitable climate and habitats by 2100 (Dash, Praskasho Sahooo, & Chandra Samal, 2020).

The increased concentration of GHGs (e.g., CO_2, CH_4, O_3, and N_2O) in the atmosphere is currently at 412 ppm, up from 370 ppm at the beginning of the century (Buis, 2019). As this concentration continues to rise, shifts in local, regional, and global long-term weather patterns continue to emerge (Chao & Feng, 2018). The impacts of these shifts in weather patterns manifest differently across the globe and across land-uses, but generally include more extreme changes in temperature and precipitation (International Panel on Climate Change, 2001). These changes can lead to more severe and frequent flooding, droughts, heatwaves, wildfires, glacier loss, permafrost melt, and sea level rise (SLR) (Council of Canadian Academies, 2019). Extrapolated climate change impacts include shifts in produce availability and agriculture, shifting global supply chains, massive displacement and immigration, an increased incidence of infectious diseases and respiratory disorders, losses in tourism and recreation revenue, and exacerbated inequities and justice issues (Council of Canadian Academies, 2019) (MacKinnon, 2019).

Canada is especially vulnerable to the impacts of climate change, as national temperature increases are twice that of the global average (Council of Canadian Academies, 2019). Due to the inertia and persistence of certain GHGs, the aforementioned impacts of climate change are at this point, largely locked in (Council of Canadian Academies, 2019). Although different GHGs do stabilize at different speeds, CO_2 has significant inertia and will continue to impact human populations after different root causes of emissions have been addressed and reduced in conjunction with carbon sequestration technology (International Panel on Climate Change, 2001). Thus, it is exceedingly important to implement strategic policy and planning tools across sectors and departments of government and adopt strategic timelines, goals, and targets to reduce GHG emissions and avoid irreversible damage. To accelerate these practices, local and regional governments specifically must be leaders in integrated climate change planning. Although cities only cover roughly one percent of the earth's surface, they are responsible for producing 80% of gross world product, consuming 78% of the world's energy and producing more than 60% of all CO_2 emissions (Estrada, Wouter Botzen, & Tol, 2017). These figures indicate the importance of local government leadership for pursuing unified development strategies that allow for adaptation to the impacts of climate change without further increasing emissions and associated rises in temperature, reducing the risks of maladaptation (Harford & Raftis, 2018).

Considering these factors and the profound impacts of climate change not only reveals the urgency and severity of climate change and its multiple, compounding impacts, but the urgency to reciprocate with strategies that can respond to meet not one, but many of the widespread impacts of climate change. Nature-based Solutions (NbS) and Green Infrastructure (GI) are increasingly prevalent climate change and land-use planning strategies that enhance or work within nature's boundaries to provide high levels of service while reducing the impacts of climate change to improve overall resilience (Kesstra, et al., 2018) (Bush & Doyon, 2019). Nature-based solutions and GI strategies are gaining popularity and are being considered over conventional grey infrastructure systems because of their ability to jointly reduce risks (adaptation) and emissions (mitigation), to reconnect humans with nature, and to provide additional community co-benefits, like habitat provision, water filtration, and improved air quality (Kabisch, et al., 2016) (Randrup, Bujis, Konijnendirk, & Wild, 2020).

Nature-based solutions and GI are entry points for integrated climate change planning because they simultaneously reduce vulnerabilities and emissions, and advance co-benefits. For instance, a green infrastructure intervention like a rain garden can absorb and filter excess overland water to reduce flood risk, can reduce extreme urban temperatures and can sequester carbon and reduce the emissions associated with maintenance and construction of grey infrastructure (Zungia-Teran, et al., 2020). Rain gardens also offer co-benefits; ancillary benefits beyond the intended purpose, such as habitat provision, improved biodiversity, water filtration, and surface-level pollutant capture (Puppim de Oliveria & Doll, 2017). To receive the full benefit of NbS and GI interventions, these strategies should be layered from small-medium scale GI interventions to larger NbS interventions and then applied at scale –regional networks such as the Metro Vancouver (MV) region are optimal (see Fig.1) (Metro Vancouver, 2018). Additionally, a growing body of literature discusses the extent of NbS and GI across disciplines, from planning to engineering to public works, and examines the need for

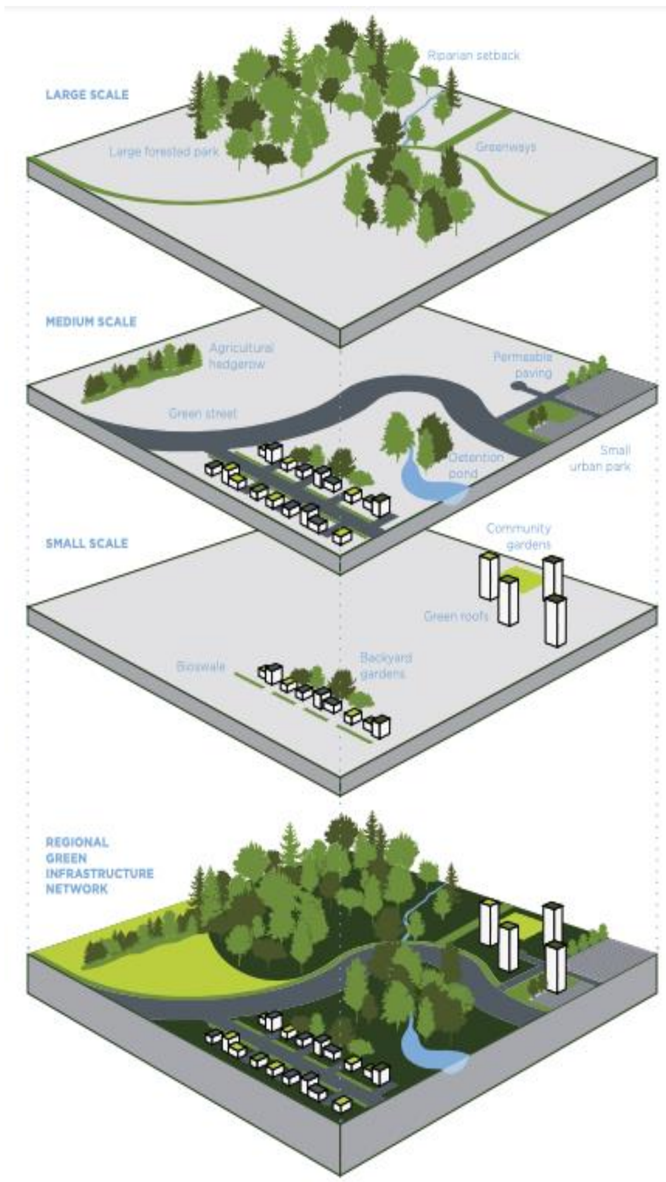

Figure 1. A layered approach to NbS and GI is comprised of small, medium, and large-scale interventions for network connectivity and regional benefits. (Metro Vancouver, 2018)

interdepartmental coordination to facilitate knowledge sharing and trust to advance best practice knowledge sharing amongst local governments across regions (Kabisch, et al., 2016) (Dhakal & Chevalier, 2017) (Johns, 2019).

NbS and GI strategies flourish when adopted using a layered approach, ideally at the regional scale, and when advanced under the supervision of collaborating departments to hone synergies and perpetuate the interests of multiple stakeholders. For these reasons, it is important to understand how and if different sectors and departments of MV regional governments are considering and using these terms in their climate action response to determine where opportunities lie to advance these strategies.

1.2. A Changing Landscape

When compounded with unforeseen but increasingly likely global events like the COVID-19 pandemic, the increasing frequency and severity of climate change impacts will continue to exacerbate embedded societal vulnerabilities and inequities and will change how and what urban land is utilized for. For example, density in urban space has long been touted as best practice for benefits such as improved access to essential services, lowered carbon footprints, and enhanced transportation networks (Lehmann, 2019). However, if habitat loss and temperature increases are to become the norm, then exposure to novel viruses might become a consistent side-effect and may lead to a reimagining of the benefits of density, or at least a reimagining of how to temper the urban landscape with natural spaces (Lehmann, 2019) (Hamidi, Sabouri, & Ewing, 2020). These and other types of compounded, intertwined impacts will require innovation in policy and planning responses throughout urban areas, where the majority of Canadian citizens currently do, and will continue to reside.

It is estimated that by 2030, five billion people globally will live in cities; in Canada, the equivalent of 81% of the population, and that global land cover is expected to increase by 200% between 2000-2030 (Green, 2016). From an inventory of current stock, it is estimated that 60% of all urban infrastructure existing in 2030 will have been built during this 30-year period to accommodate growing urban populations (Green, 2016). As a response to these development demands and the economic losses prompted by COVID-19, massive infrastructure investments and stimulus packages are further triggering significant transformations in urban ecosystems and landscapes (Green, 2016). In the final ten years (2020-2030) of this momentous urban transformation, when many municipalities throughout the MV region and globally have declared Climate Emergencies to signify their organizational commitment to combatting the risks of climate change, the responsibility and role of local government to develop and optimize policies that manage the climate crisis, while contributing to the local economy and other pressures like biodiversity, has increased. For instance, it is crucial that COVID-19 stimulus packages are aligned with climate policy to systemically embed decarbonization practices and promote resilience building (Castagnino, 2020), respond to expanding socio-economic inequities, and reduce the impacts of climate change on urban populations locally and globally. This sentiment was articulated in Canadian Prime Minister Justin Trudeau's 2020 Throne Speech, in which Canadians were promised increased conservation measures and the use of NbS to fight climate change (World Wildlife Foundation, 2020).

Urban growth is also driving a global biodiversity crisis by fragmenting and converting urban land, and it is estimated that locally, species are going extinct at rates 100-1000 times the global average (IPBES, 2019) (Satzewich, 2019). The current biodiversity crisis, also referred to as 'the sixth mass extinction' is primarily driven by human influences that cause habitat loss as well as climate change, introduce invasive species, lead to overharvesting, the release of pathogens, and shifting ecosystem boundaries that challenge the conditions species rely on to survive, requiring them to navigate new obstacles, such as urban spaces (Lees, Attwood, Barlow, & Phalan, 2020). To both mitigate and adapt to climate change, manage the biodiversity crisis and improve the diverse factors that contribute to the health and well-being of global populations requires solutions that can meet these diverse needs, solutions that have long been right in front of us, yet slowly exiled from urban landscape (Seddon, 2019). Nature-based Solutions and GI are strategies to respond to these needs, however, they necessitate a shift in thinking about how our cities operate and a reintroduction of naturalized spaces and systems into the urban landscape at a large scale to incorporate the natural infrastructure and ecosystem services that are provided by NbS and GI largely for free (Dhakal & Chevalier, 2017) (ACT, 2020).

Although the adoption of NbS and GI strategies is growing (Kesstra, et al., 2018) (Randrup, Bujis, Konijnendirk, & Wild, 2020), there is a lack of consistent definitions and the two terms are frequently conflated. Consequently, there is a need for more consistent terminology and an improved conceptual understanding of NbS and GI to advance consistent, regional uptake of NbS and GI (Conway, Khan, & Esak, 2020). Additionally, there is a gap in understanding how regional governmental authorities like MV understand and consider NbS and GI in planning, policy, and decision making. Without a more fulsome and consistent understanding of these terms and how they are and are not being applied, decision makers in the region lack an understanding of the perceived barriers to and opportunities for improved NbS and GI uptake and are unable to shift policy surrounding NbS and GI.

This research project was conducted as a continuation of ongoing ACT (Adaptation to Climate Change Team) at Simon Fraser University research into the value of establishing a regional green infrastructure network in MV. This project was conducted over three months and is comprised of six presentations and over 100 surveys with MV regional advisory committees. The MV regional advisory committees are broken into sectors and comprised of available senior representatives from MV's 21 municipalities, one electoral area, and one treaty First Nation. This research was conducted to further understanding of how NbS and GI are being articulated by these regional advisory committees and to advance uptake of NbS and GI as a strategic response to climate change by examining how these dual processes are being internalized, reiterated, and applied throughout MV regional planning processes. To this end, this research asks three questions: 1) How do MV regional advisory committees understand, reiterate, and apply NbS and GI, especially to manage the impacts of climate change? 2) What opportunities and barriers exist to advance consistent knowledge and understanding of NbS and GI? And 3) How can these processes be better communicated to advance regional networks of NbS and GI?

Chapter 2. Literature Review

2.1. The Role of Local Government in Climate Action

It is largely recognized through international frameworks like the Paris Agreement (2016) and national frameworks like the Canada Action Plan 2000 on Climate Change that climate change is an urgent global problem that requires innovation, international action, and new approaches to governance (Schreurs, 2016) (Broto, 2017). Local governments especially have a crucial role in advancing climate action and must coordinate a wide range of actors and interests coming together across disciplines to develop frameworks that steer communities and society towards low carbon resilient objectives (Broto, 2017). Given their vernacular position, local governments are uniquely poised to tackle and respond to climate change while being on the front lines of climate impact, adding urgency to their response (Dekker, 2020).

In Canada, different jurisdictional and regulatory powers influence climate change policy and corresponding action. Federal government responses to climate change, such as the Pan-Canadian Framework on Clean Growth and Climate Change (2016) emerged as a response to the Paris Agreement, and are signed on by Canadian provinces and territories with the goal of "growing our economy while reducing emissions and building resilience to adapt to climate change" (Government of Canada, 2016, p. 6). The Province of B.C. then influences climate action by delegating functional responsibilities and access to sources of operating revenue to local governments (Guyadeen, Thistlethwaite, & Henstra, 2018), while also "imposing legal and financial obligations to local governments, who are then expected to serve as administrative agents in implementing provincial policy directives (Fowler and Siegel 2002)." (Guyadeen, Thistlethwaite, & Henstra, 2018, p. 123). For example, in B.C., regulatory requirements through the Local Government (Green Communities) Statutes Amendment Act (*Bill 27*, 2008) supports local governments in reducing emissions and creating more compact, sustainable communities (Legislative Assembly of BC, 2008) by requiring that under the Local Government Act (LGA) Bill 27, municipalities that decide to adopt an Official Community Plan (OCP) are required to include Community GHG Reduction Targets (Legislative Assembly of BC, 2008). Documents like the Vancouver Declaration on Clean Growth and Climate Change (2016) and local government plans like OCPs can thus have significant traction in regard to local climate change action. This lends support to the idea of a more collaborative and cooperative approach between different levels of governments to advance climate change action (City of Vancouver, 2016).

It is clear that alignment and collaboration across legislation, policy and plans, and levels of government is a necessary part of transformative climate change action (Burch, Shaw, Dale, & Robinson, 2014). Consider transportation planning in B.C. – although funded by the provincial government, transportation is regionally planned and fundamentally influenced by municipal government land use plans and OCPs that determine a myriad of factors, including density, community connectivity, and other unique municipal priorities (Burch, Shaw, Dale, & Robinson, 2014). Adopting a more holistic approach to regional land use planning using NbS and GI strategies requires interactions and relationships amongst different levels of government, not only to ensure the proper management and maintenance of assets, but to allow benefits to be shared across the board. Further, a holistic approach to NbS and GI planning can create synergies in adaptation and mitigation planning and can be embedded throughout municipal strategic plans to reduce unexpected damages over time and avoid introducing new vulnerabilities; for example, ensuring that electric vehicle (EV) infrastructure is not built on hazard areas, like flood plains.

2.1.1. Adaptation and Mitigation Planning in British Columbia

Systemic, integrated climate action must consider two interacting parts: adaptation, those actions taken to adjust to the actual or expected climatic changes and the resulting local impacts, and mitigation, those actions to minimize and prevent the release of GHG concentrations into the atmosphere, and (Klein, Schipper, & Dessai, 2005). If climate action planning is done in a coordinated manner that considers the moving parts of adaptation and mitigation, it can produce co-benefits; additional benefits beyond the intended goal that can be tailored for municipal contexts (Puppim de Oliveria & Doll, 2017). Traditionally, adaptation and mitigation have been researched and planned separately for three key reasons. Firstly, because of the spatial disparity, mitigation is considered to have a global benefit, whereas adaptation has localized benefits (Klein, Schipper, & Dessai, 2005). Secondly, the costs and the benefits are quantified differently, making it hard to align the advantages of the two (Klein, Schipper, & Dessai, 2005). Thirdly, there are different actors and policies involved in implementation; mitigation has traditionally had an energy, infrastructure, and transportation focus whereas adaptation might represent urban and social planning, coastal management, emergency management, or human health (Klein, Schipper, & Dessai, 2005). Research and policy have begun to move past this siloed approach, largely because the benefits of a streamlined approach outweigh siloed approaches and reduce the incidence of maladaptation. Benefits of a streamlined approach include greater internal communication and coordination amongst departments, increased planning and financial synergies, the advancement of additional community priorities, or co-benefits, and time and resources saved by opting for one, rather than many planning processes (Harford & Raftis, 2018).

To date, climate action in the Province of B.C. has been mitigation-intensive, measured by GHG emissions reductions from 2007 baseline levels. This is in line with traditional climate policy which is largely synonymous with energy policy as the logical entry point for mitigation, as energy supply has largely been dominated by fossil fuels (Klein, Schipper, & Dessai, 2005). In 2018, the major sectors responsible for emissions in Canada were oil and gas, transportation, and buildings (Environment and Climate Change Canada, 2020) and emissions reductions in the associated areas were achieved by introducing numerous tools, from financial levers (e.g., B.C.'s Carbon Tax), to developing and adopting standards and targets (e.g., Clean Fuel Standard), to investing in technology (e.g., EV infrastructure). As it stands, all climate action legislation (~11) currently enacted by the B.C. Government is oriented towards emissions reductions and controls and energy efficiency, indicating a gap in legislation to enforce Canada's adaptation response and a lack of legislation for solutions that can be applied to meet both mitigation and adaptation targets. This is a significant gap, especially from an equity standpoint, as the increased frequency and severity of climate events threatens to influence communities disproportionately across Canada, and uncoincidentally, the distribution of naturalized green areas in Canada is also disproportionate (Council of Canadian Academies, 2019) (Luo, 2020).

Funding opportunities and tools for mitigation are evident in policy and planning and have been for over a decade. Adaptation, however, has not had the same legal consequence as mitigation, for example, the B.C. Provincial Government only just updated its Hazard Risk and Vulnerability Assessment (HRVA) to mandate the inclusion of climate projections in the Spring of 2020 (Province of BC, 2020). Yet, the adaptation impacts of climate change such as “energy shortages, damages to infrastructure, loss to industry, heat-related mortality and illness, [and] scarcity of food and water” (Gasper, 2011), along with SLR, flooding, wildfire, and extreme heat will occur more frequently and are increasingly likely to have significant financial, societal, and environmental impacts that will disrupt daily routines in Canada (Council of Canadian Academies, 2019). Economic losses due to climate change can exacerbate social issues and impact industry, transportation, and the availability of goods and services (Gasper, 2011). For instance, in 2018, the cost for *insured* damage due to severe weather events such as storms and floods, ice storms, windstorms, summer storms and tornadoes reached $1.9 billion (Insurance Bureau of Canada, 2019). Frighteningly, much of the large public infrastructure that Canadians rely on and that will be affected by severe weather, such as bridges, roads, railways, and riverbeds goes uninsured (Munich RE, n.d.). Taken together, this underemphasis on adaptation planning in Canada underpins Guyadeen et al.’s notion that focusing on mitigation enhances the likelihood of a reduced focus on adaptation (2018), the consequence of which is the development and integration of maladaptive practices, and the perpetuation of policy and planning that does may not fully consider climate projections. To move forward with systemic climate action, it is critical to adopt approaches like NbS and GI that consider both adaptation and mitigation for streamlined climate action and co-benefit production. Failing to do so increases like likelihood of maladaptation and damages into the future.

2.1.2. Maladaptation

Siloed adaptation and mitigation responses to climate change may result in maladaptive actions, those that are “taken to ostensibly avoid or reduce vulnerability to climate change” but inadvertently adversely increase the vulnerability of other systems, sectors, or social groups (Barnett & O'Neill, 2010, p. 211) namely through increasing GHG emissions. For instance, the increased use of air conditioning during heat waves increases energy use and emissions, compounding future vulnerabilities (Barnett & O'Neill, 2010).

Maladaptive planning (Figure 2, top left and bottom right quadrants) may emerge for a number of reasons: a lack of communication and collaboration between departments and levels of government; a separation of funding pathways that encourage siloed planning (e.g. Federation of Canadian Municipalities (FCM) Local Government

Adaptation Funding); disparities in scale and timeliness (e.g. adaptation happens locally, mitigation is global); the culture of climate planning in the municipality may favour or already be pursuing one approach (e.g. local governments with mitigation-centric infrastructure); or diverse policy objectives that are accentuated by contending priorities, limited resources, and competing urban space (Landauer, 2018). Alternatively, those strategies that coordinate and mainstream adaptation and mitigation actions while advancing co-benefits in municipal decision processes are being referred to as low carbon resilience strategies (Figure 2, upper right quadrant) (Harford & Raftis, 2018). Nature-based Solutions and GI are low carbon resilience strategies because they offer both adaptation and mitigation potential, for example reducing ecosystem degradation and enhancing carbon sequestration and because they advance co-benefits like improved air quality (Seddon, 2019).

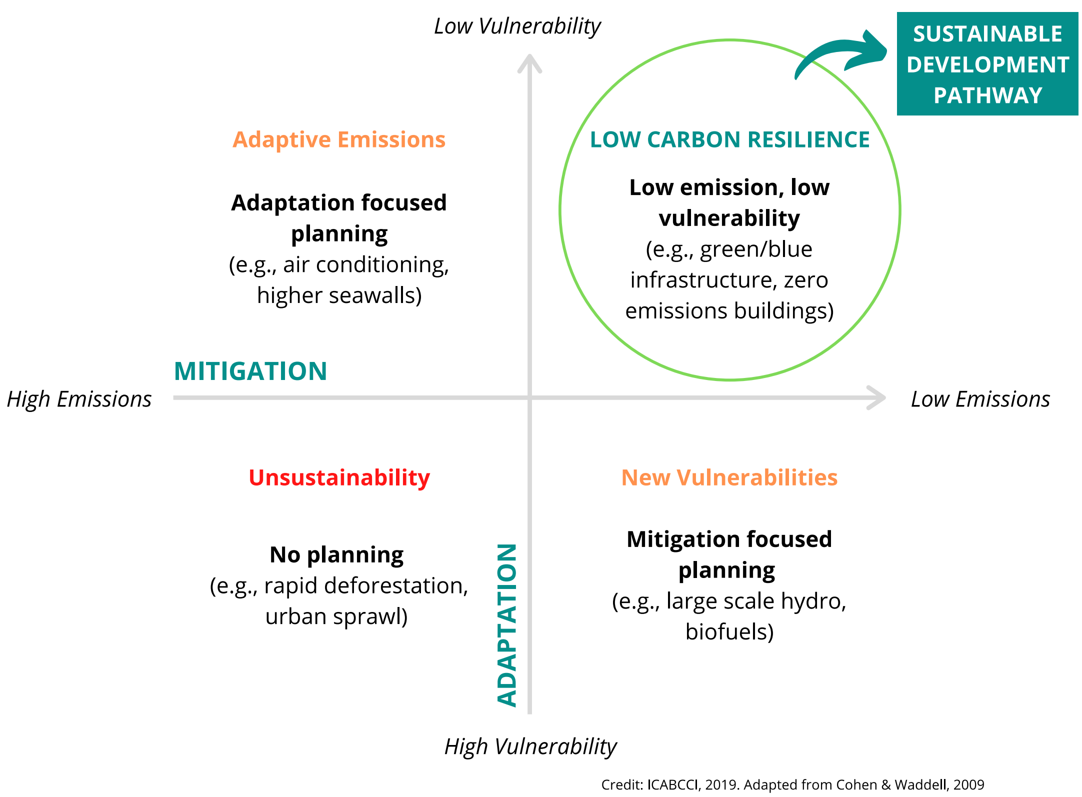

Figure 2. Adopting NbS and GI approaches allows decision makers to co-evaluate adaptation and mitigation strategies in policy and planning to prevent contradiction, advance co-benefit opportunities, and transition towards sustainable development. (ACT, 2020).

2.2. Nature-based Solutions and Green Infrastructure in Climate Change Planning

Nature-based solutions are those strategies or actions that support or enhance nature to help address societal challenges and build resilience (University of Oxford, 2020). These types of “solutions bring more diverse natural features into cities, landscapes, and seascape through locally adapted, resource-efficient and systemic interventions” (Randrup, Bujis, Konijnendirk, & Wild, 2020, p. 920). At their core, NbS are broad, wide-ranging strategies and actions to incorporate the ecosystem services provided by natural systems into the urban environment, from protecting and managing natural to semi-natural ecosystems to applying more targeted blue and green infrastructure (Seddon, 2019). Green infrastructure interventions exist under the umbrella of NbS and refer to the integration of strategically planned networks of natural and semi-natural components in land-use planning, engineering, urban design, and climate policy to advance ecosystem services and achieve various local governmental goals that improve resilience (Metro Vancouver, 2018) (Johns, 2019) (Zungia-Teran, et al., 2020). When adopted with a network or systems approach, NbS and GI can offer holistic benefits for local governments and residents (Metro Vancouver, 2018).

Nature-based solutions and GI are being applied by local governments to improve their resilience across the board; from improving public health and well-being, to flood management, to recreation revenue, and for the economic value they hold (Zungia-Teran, et al., 2020). For instance, one county in Pennsylvania discovered that the Return on Environment they receive from avoided costs (i.e., costs the county would otherwise need to pay for, like natural system services and air pollution removal), outdoor recreation revenue, and reduced impacts on property value was in the realm of $800 million annually (Rogers & Poole, 2018). The value of NbS and GI is leading increasing numbers of local governments to adopt NbS and GI into policy, for example, the City of Toronto’s Green Roof Bylaw (2009), the City of Surrey’s Biodiversity Conservation Strategy (2014), the City of Victoria’s Rainwater Management Standards (2015), the City of Vancouver’s Urban Forest Strategy (2018 update), and VanPlay, the City of Vancouver’s Equitable Parks and Recreation Framework (2020). Policies to advance NbS and GI are being perpetuated through the adoption of new development standards and development permit areas, by new plans specifically for NbS, GI, and biodiversity, through bylaws and rezoning, and by enhancing and restoring community connections to nature throughout the urban landscape (Jato-Espino, Sanudo-Fontanenda, & Andreas-Valeri, 2018). Although beneficial, a multitude of diverse plans can be conduits for NbS and GI to be uniquely defined or lost in translation when many actors, for example Surrey and Vancouver, are working in the same region.

Nature-based solutions and GI are used in climate change planning for their potential to reduce emissions and vulnerabilities in a coordinated manner, while advancing co-benefits that improve community livability and can be tailored to meet a myriad of unique community goals (Harford & Raftis, 2018) (Seddon, 2019). These interventions can be applied as mitigation strategies because they can store and sequester carbon and because they can avoid or reduce the embodied emissions associated with maintaining, building, and operating grey adaptation infrastructure, like sewers and pipes. For instance, Seattle's urban forest is estimated to store two million tons of CO_2 representing $10.9 million (USD) annually in carbon storage and $768,000 (USD) in annual carbon sequestration (Tenneson, Ciecko, Dilley, & Wolf, 2012). Green infrastructure interventions such as rain gardens manage and slow the flow of stormwater runoff, supplementing and reducing the burden on stormwater systems while only emitting a fraction of the CO_2 (<5%) of combined sewer systems (De Sousa, Montalta, & Spatari, 2012). Concurrently, NbS and GI can be used as adaptation strategies to absorb and slow overland floodwaters, improve hydrological connectivity, store water, provide thermal regulation, and reduce urban heat islands (UHI) (Derkzen, van Teefelen, & Verburg, 2017). For instance, NbS like the naturally occurring wetlands in southern Ontario reduce flood damage costs to buildings by $3.5 million (or 29%) at a rural pilot site and by $51.1 million (or 38%) at an urban pilot site (Moudrak, Feltmate, Venema, & Osman, 2018). Green infrastructure interventions like green roofs absorb and cool through shading and evapotranspiration, with a potential reduction of ambient air by 1.5°C (Arabi, Shahidan, Kamal, Jaafar, & Rakhshandehroo, 2015). Conserving, preserving, and maintaining healthy ecosystems through networks of layered NbS and GI maintains and/or improves levels of service and can reduce shocks to human socio-ecological systems (Green, 2016).

2.2.1. Valuing Nature-based Solutions and Green Infrastructure

A significant percentage of grey infrastructure in Canada is in poor or very poor condition, according to a yearly report card that grades Canadian infrastructure (Federation of Canadian Municipalities, 2019). The report estimates that nearly 40% of roads and bridges, 30-35% of recreational and cultural facilities, and 30% of water infrastructure is in poor or very poor condition, with many assets over 20 years old, representing an immediate need for action to maintain levels of service (Federation of Canadian Municipalities, 2019). Even with the $2 billion provided to 3,600 municipalities for infrastructure renewal by the Federal Gas Tax Fund, the scale of renewal is immense and a major challenge for municipalities (Federation of Canadian Municipalities, 2019). To supplement gray infrastructure, NbS and GI can be retained to “effectively act as decentralized, distributed systems of infrastructure service delivery, which are usually inherently more resilient that large, centralized grey infrastructure (Depiertri & McPhearson, 2017)” (Bush & Doyon, 2019, p. 3). Coupled with economic constraints across the country due to the COVID-19 pandemic and the increased pressures of climate change, municipalities are motivated to find options to maintain levels of service in a cost-effective manner. The services provided by NbS and GI are often undervalued or go unvalued entirely and local governments are overwhelmingly receiving these services for little to no cost. Whereas grey infrastructure assets are costly to repair, degrade over time, and use virgin, carbon emitting materials, NbS are regenerative, more cost-effective over time, can absorb and sequester carbon, reduce the impact of natural hazards, and with provide invaluable ecosystem services such as soil formation (Seddon, 2019).

For municipalities, the suite of benefits associated with NbS and GI offer a glimpse into the significant costs that can be avoided and the savings to be gained. For instance, SLR and storm surges in Canada are expected to cause damages over $50 billion in present value costs by 2050, representing between 0.39 and 0.80% of Canadian GDP—and a majority of the cost will occur in B.C. (Withey, Lantz, & Ochuodho, 2016) (Council of Canadian Academies, 2019). On the other hand, the protection of coastal wetlands and habitats can provide immense protection and benefits; in the United States, coastal wetlands provide $23.2 billion (USD) in storm protection services annually (Bassi, Pallaske, Wuennenberg, Graces, & Silber, 2019), and the services provided by eelgrass habitats like habitat provision and sediment accretion in the Salish Sea have an annual value of $80,929/ha (Molnar, Kocian, & Batker, 2012). Ascribing value to the services provided by natural systems is important and necessary to “advance planning and operation about how to protect, expand, reward, and prioritize short- and long-term services” (ACT, 2020, p. 6).

Although there are significant economic benefits of adopting NbS and GI approaches, there are direct costs related to the development of NbS and GI rooted in the procurement of land through purchasing or covenants and the restoration of sites in urban environments (Metro Vancouver, 2018). In regions like MV, where the cost of land is especially high, these costs can be a significant barrier and deterrent to conserving space for NbS, especially when the alternative option of development, benefits municipal income streams. Additional concerns include apprehension about NbS and GI strategies, with engineers and planners being worried about their own liability and wary that these strategies will not be as effective as traditional infrastructure, which will lead to additional investments down the line (Marchal, et al., 2019). Further, higher upfront costs of pursuing NbS and GI strategies can dissuade decision makers, even though the occurrence of benefits and co-benefits increases and the costs of maintenance and monitoring are generally lower for NbS and GI than grey infrastructure over time (Metro Vancouver, 2018) (Marchal, et al., 2019).

2.2.2. Co-benefits of Nature-based Solutions and Green Infrastructure

Nature-based solutions and GI interventions offer numerous co-benefits which can advance multiple municipal priorities. The co-benefits approach is rooted in “win-win” climate policy and is an opportunity for local governments to engage in climate action without forgoing development or other priorities while receiving supplementary benefits (Puppim de Oliveira & Doll, 2017). Regardless of the intervention, from conserved wetland, to trail network, to rain garden, the intervention is likely to result in extra social, economic, and environmental benefits that extend beyond the intended outcome (Puppim de Oliveira & Doll, 2017). For instance, a rain garden implemented on a street corner may be purposefully implemented to absorb and slow stormwater, but the rain garden can also be part of a habitat network, improve water quality through pollutant breakdown, reduce urban heat temperatures through shading and evapotranspiration, and provide a sense of community (Zungia-Teran, et al., 2020). When applied at a regional scale, these benefits begin to have significant impact due to their impact and connectivity. Approaches that consider co-benefits can maximize community benefits by streamlining needs and avoiding counter-productive efforts (Puppim de Oliveria & Doll, 2017), expanding unique funding opportunities that may not otherwise be accessible, operating as an accessible communication tool for government and the public to explain the multiple benefits of NbS and/or GI projects, and magnifying how the project may be relevant to unique stakeholder interests. Integrating criteria for co-benefits can become part of the overall planning prioritization process and help frame adaptation and mitigation strategies and actions that are more well-rounded and consider tradeoffs (Thornton & Comberti, 2013).

2.3. Barriers to Nature-based Solutions and Green Infrastructure Projects

The literature indicates that although plans and policies that advance NbS and GI approaches are growing (Lindholm, 2017) (Randrup, Bujis, Konijnendirk, & Wild, 2020), there are still significant challenges that limit NbS and GI uptake. Reoccurring barriers cited are inadequate financial resources, a lack of strong leadership and siloed governance, path dependency and implementation concerns (Johns, 2019).

Financial resources and specific funding opportunities to advance NbS and GI may be limited, especially in a post-COVID-19 future, and the upfront cost of NbS and GI interventions can be prohibitive. However, when faced with the challenge of aging infrastructure compounded by climate impacts and other social planning matters, like equitable access to green spaces, investing in NbS and GI approaches emerge as integral tools to open up diverse funding pathways and opportunities. For instance, the total economic value of investing in a GI project in Brampton, Ontario is likely to generate a net present value of $225,777 over 60 years (Moudrak, Feltmate, Venema, & Osman, 2018). It was estimated that the social, financial, and environmental benefits of the project were ten times higher than the additional financial investment required to support the marginally higher operating costs of GI features, and that without adopting and analyzing the GI approach, these benefits would not normally be captured (Moudrak, Feltmate, Venema, & Osman, 2018).

Nature-based solutions and GI projects can also be advanced and perpetuated through user fees; for example, in the City of Victoria, B.C., stormwater utilities are partially determined by the amount of impervious area on the property, incentivizing owners to increase green space on their property, while generating revenue for the municipality (City of Victoria, 2020). This revenue could be put towards NbS and/or GI funds to manage the upfront costs of other NbS or GI projects. For instance, although permeable pavements may be more expensive to install than traditional pavement, less de-icing salt is needed on permeable pavements, leading to lower operations and maintenance costs and to fewer chlorides in stormwater runoff (Environmental Finance Center, 2014). Part of the NbS and GI transition is in shifting the mindset to how NbS and GI are used to manage *resources*, like stormwater, instead of nuisances, like stormwater (Dhakal & Chevalier, 2017). When stormwater is classified as a resource, it can be afforded a marketable value, and subsequently it can be conserved, preserved, or stored as a resource. Thus, landowners can see either returns by using their land to store resources like stormwater in the City of Victoria, or can be charged, based on their inability to store resources. When other options become available, citizens may shift their mindset and be less inclined to alter or develop their land as the only method to maximize economic benefit (Dhakal & Chevalier, 2017).

As mentioned above, the upfront costs of pursuing NbS and GI might be higher than grey infrastructure. However, the cost of inaction may be significantly higher, as both the transition to low-carbon markets and the potential cost-savings over time are incentives for governments to act now in green industry to save money, and likely lives, down the road. For instance, a report for the National Resource Defense Council estimates that in the U.S., the cost of climate inaction will be $1.6 trillion by 2100, more than 1.5% of U.S. output (Ackerman, Stanton, Alberth, Fisher, & Biewald, 2008). In Canada, it is estimated that every dollar invested in mitigation can save between three to five dollars in recovery costs (Federation of Canadian Municipalities, 2019). Further, being on the low-carbon side of business can be beneficial to Canadians (Insurance Bureau of Canada; Federation of Canadian Municipalities, 2018). It is estimated that as global mitigation opportunities increase, the low carbon goods and services industry will expand; in Canada, it is estimated that these markets could grow between $36-$60 billion by 2050, up $7.9 billion from 2010 (Dalby, Scott, Dasilva, & Suen, 2017). Alternatively, new infrastructure developments such as pipelines that are highly contested given their GHG contributions, land fragmentation and destruction, and path-dependency contributions to high-carbon industries are no longer generating the jobs and revenue they once did. Employment in Canada's oil and gas sector has fallen by eight percent in 2020, roughly 25,600 jobs, due to low oil prices and the economic impact of COVID-19 (Seskus, 2020). Other indicators of decline include the TransCanada Corporations decision to cease their proposed $15.7 billion Energy East Pipeline, taking a $1 billion loss in the deal (Dalby, Scott, Dasilva, & Suen, 2017). Based on these estimations, it is likely that although upfront costs of NbS and GI may be higher, there are valid economic incentives to consider these as viable adaptation and mitigation infrastructure options.

Siloed governance and a lack of strong leadership are significant barriers to NbS and GI implementation, as notably, "effective climate action requires serious engagement and commitment by senior leadership from within government and corporate organizations" (Okereke, Wittneben, & Bowen, 2012, p. 25). Siloed governance can lead to siloed action and planning, the results of which may not only be maladaptive, but may also reduce opportunities to streamline planning time and costs, saving municipalities time and money. Further sectoral language and knowledge is likely to be trapped in siloes, therefore knowledge may be unlikely to cross departments, inducing knowledge gaps and hesitations from one department to another (Kabisch, et al., 2016). When siloed, people have defined responsibilities, and public bodies or stakeholders with which they have accountability to, and may adopt actions that only serve one interest, rather than pursuing those actions which may serve multiple interest groups and provide more than one benefit (Okereke, Wittneben, & Bowen, 2012). Another danger of this siloization is the potential lack of proper ongoing operations and maintenance for NbS and GI projects as departments and governments change over time, posing a risk to the continuity of desired socioeconomic and environmental benefits into the long term. This can lead to a disconnect between political and public receptivity and a reduced readiness to apply ecological and biological results and concepts.

Additionally, a lack of strong governmental leadership can be detrimental to advancing NbS and GI. This lack of leadership may be induced by a lack of knowledge about the process of NbS and GI application and a fear of the unknown. The results of this uncertainty of can be: a preference and increased trust in technical engineering knowledge over ecological and biological knowledge in conjunction with technical knowledge; administrative fragmentation and fluctuating political cycles and agendas that can hinder long-term maintenance and thus project success (Johns, 2019); and a reluctance to support new approaches and unknowns, for example one resource cites, "because of their nature they [NbS and GI] must be handled differently and require new protocols for implementation and maintenance, which is perceived as the operational unknown" (Kabisch, et al., 2016, p. 6). The combination of these hesitancies and the reluctance to advocate for new projects at a senior level can be demonstrative of a lack of vision and intent to act on climate change, especially as senior local government influence is uniquely important for affecting societal change (Rickards, Wiseman, & Kashima, 2014).

Path dependency represents an additional challenge to the adoption of NbS and GI. Path dependency refers to organizational decision making that is confined to memories of past experience and conditions, rather than opting for innovation and new pathways (Sarabi, Han, Romme, Vries, & Wendling, 2019). Path dependency fosters a mindset that can lead to resistance to change and a lack of trust and buy-in towards new approaches (Sarabi, Han, Romme, Vries, & Wendling, 2019). Path dependency is largely generated by actions and policies with significant supporting institutions and the political authority to generate returns over time to specific key instructions and players (Johns, 2019). Policies that benefit the interested of those institutions and players are therefore reinforced and sustained (Johns, 2019). Johns explores the process of 'layering', a way to amend rules and structures slowly, while maintaining core practices and institutions (2019). In this way, NbS and GI practices that are in sync with normative, social, and political environments can be introduced as amendments or alterations to traditional engineering approaches, slowly transforming existing processes (Johns, 2019). In green infrastructure, for example, the exploration and communication of co-benefits as an additional benefit to the project can be a way to sync with broad normative ideals, like health, breathable air, and clean water. Through the accumulation of small changes and by layering in new policies and planning tools, bigger changes can be advanced overtime. In a group with diverse departmental members such as the MV regional advisory committees, the potential to layer in strategies in different sectors is profound and could lead to innovative change.

Two final commonly cited barriers to implementing NbS and GI concern: 1) how to effectively implement NbS and GI in unique community contexts; and 2) how to manage concerns of neighbouring jurisdictions. First, NbS and GI are novel strategies in many communities and are unlikely to be completely replicable from one community to the next, making them difficult for communities to apply in terms of capacity, technical knowledge and understanding, and trust and buy-in. Further, a dearth of relevant best practices and case studies can hinder uptake and spark concern. Unique and contextual community factors like location, health of asset and ecosystem, climate, scale, and size can make it difficult to determine what type of NbS or GI intervention to apply, as well as how to monitor it, what services it can provide, and what indicators to use for success (Kabisch, et al., 2016). For example, large natural forests with minimal human interaction generally house trees with longer lifespans as they have more space to root, which can lead to higher carbon stores than that of urban forests (Fares, Paoletti, Calfapietra, & Mikkelsen, 2017). However, urban forests may bring more acute benefits to human populations, like reduced UHI and mental benefits like reduced stress (Seddon, 2019) (Chang, et al., 2020).

Varying levels of maintenance required for NbS and GI may also produce varying levels of service. A lack of capacity and technical knowledge is a considerable implementation issue, as without it, NbS and GI interventions may not serve their intended purpose and can increase perceived risks and lack of trust in communities. For example, planting monocultures is unlikely to improve biodiversity and may falsely contribute to the resilience of natural areas, lead to negligible levels of service, and contribute to reduced buy-in for NbS and GI (Lepczyk, et al., 2017). Thus, it is important to engage with professionals from a wide range of sectors, from biodiversity to engineering to ensure that various contextual elements and local conditions and climate projections have been factored in to ensure that the conditions for NbS and GI strategies to thrive are met (Lepczyk, et al., 2017).

Second, jurisdictional concerns regarding NbS and GI exist at the regional level in regard to authority over resources, damages, and service provision. Nature-based solutions may "extend beyond the boundaries of a single jurisdiction and may require collaboration between municipal departments, private property owners, adjacent property municipalities, and other orders of government", (Municipal Nature Assets Initative, 2017, p. 11) creating issues about how to manage assets and how to ensure that services are maintained. For example, Still Creek flows through Vancouver and Burnaby before draining into the Fraser River. The Creek falls into federal, provincial, regional, and municipal legislation and provides services to both Vancouver and Burnaby, which could be cut off if either municipality shifted their management plan (Municipal Nature Assets Initative, 2017). Thus, in an innovative manner, an Integrated Stormwater Management Plan was jointly developed and collaborated upon by relevant stakeholders in 2007 to manage the watershed (Municipal Nature Assets Initative, 2017).

Chapter 3. Case Context and Methods

3.1. Metro Vancouver

Metro Vancouver is a federation of 21 municipalities, one Electoral Area, and one Treaty First Nation that work together to collaboratively plan for and develop regional scale policy (Metro Vancouver, 2020). As a regional governmental authority, Metro Vancouver is responsible for developing influential regional plans like the Regional Growth Strategy (RGS) (Metro Vancouver, 2020). Regional growth strategies guide policy and influence land use throughout region, because they are developed to consider how much growth a region can expect, and how the growth will be distributed. The RGS is accepted by all municipalities throughout the region and influences policy uptake via municipal OCPs and other strategic documents.

Although municipalities are neither required to have an OCP, nor integrate natural approaches into one, they are bound to abide by the policy they develop into the OCP and align it with the RGS. Municipalities prepare and adopt Regional Context Statements (RCS) which detail how the local aspirations expressed in their OCP support and align with the greater vision of the RGS. These RCSs are then accepted by the MV Regional District Board. Because of the influential nature of the RGS, it is integral to determine how NbS and GI are articulated within the RGS to better understand how NbS and GI may become manifested across the region.

The most current iteration of the RGS is *Metro Vancouver 2040 Shaping Our Future*, adopted in 2011 and is being updated by council starting in 2019. Goal three of the five goal plan is to “Protect the Environment and Respond to Climate Change Impacts” and refers to the significance of the ecosystem services provided by natural along with the importance of connectivity (Metro Vancouver, 2011). The most significant contribution of the RGS is to manage climate change mitigation through a continued focus on the urban containment boundary and land use patterns that support sustainable transportation. Although there is no mention specifically of NbS and GI, these strategies are both conduits to help achieve the aforementioned goal and meet various other municipal priorities.

3.1.1. Climate Projections for Metro Vancouver

Metro Vancouver's climate is characterized as Pacific Maritime; known for mild winters and cool summers. As a result, significant heat temperatures have not been integrated into planning or consideration of regional urban form and infrastructure (Stewart, et al., 2017). Overall temperatures in the MV region are expected to increase by 3°C by 2050 (Metro Vancouver, 2016). Climate change in MV will result in increases in temperature and precipitation. Temperature increases will result in longer summer dry spells, a decrease in snowpack and changing seasonal melt periods. Increases in precipitation in fall, winter and spring months are likely to be unevenly distributed and coupled with more intense extreme weather events, which can lead to flash flooding, and impact sewage and drainage systems, as well as water supply (Metro Vancouver, 2016). The results of these changes in temperature and precipitation will have significant impacts on the MV region, from changes in food availability and agricultural practices and production, to fluctuations in highly tourist dependent sectors, to the implications of SLR, increases in extreme weather events, longer wildfire seasons, and changes in ecosystems health and productivity.

3.2. Methodology

This research project was conducted as a continuation of ACT research into the value of establishing a regional green infrastructure network in MV. As phase three of three of ongoing ACT work to advance transboundary municipal ecosystem governance and biodiversity-led green infrastructure, this project focuses on building an understanding of the needs of different sectors and departments of MV regional advisory committees to facilitate knowledge sharing across siloes and advance a GI community of practice across Southwestern B.C.. ACT is a university-based think tank based out of Simon Fraser University in Burnaby, B.C. that advances climate change adaptation research, amongst other impact areas (ACT, 2021).

Qualitative research like surveys allows researchers to examine the meaning and values attached to specific terms; (Taylor, Bogdan, & DeVault, 2016) in this case, to the terms "nature-based solutions" and "green infrastructure". To understand how these two terms are being utilized by MV regional advisory committees and then advanced through strategic planning documents required surveying respondents to examine how these terms were being internally interpreted and reflected within the advisory committee's own frames of references and how they interact with these terms (Taylor, Bogdan, & DeVault, 2016). These findings will help advance understanding of how different disciplines are thinking about and considering the terms NbS and GI. Ideally, this work can be used to advance future resources that can be tailored to each discipline's baseline understanding.

Inductive research was an important approach for this research, to discern what themes and explanations would emerge organically. Inductive research has previously been considered to have little theoretical basis, however, the absence of bottom-up, inductive research limits the questions that can be asked, and the data received (Woo, 2017). Further, an inductive approach allows for results coded via patterns in the data, to find relationships that can then be generalized to provide information for broader populations of interest (Woo, 2017). Adopting open-ended questions for this research allowed respondents to respond in their own words rather than having the researcher 'fix' their words for them, signaling how the terms NbS and GI were represented in the respondent's minds (Family Health International, 2005). In this way, the responses given are likely to hold meaning for the participants, unanticipated by the researcher, and are truly exploratory by nature (Family Health International, 2005). For these reasons, an inductive approach to data analysis was necessary to determine how these terms are being understood and applied in respondent's real-world scenarios.

The questions in the ACT survey (Appendix 1) used a variety of multiple choice, open-ended, ranking questions, check box (i.e., "check all that apply"), and sliding scale questions. This research asked broad questions within three core sections: communication, to determine how respondents think about GI and NbS; barriers, to identify obstacles to GI and NbS uptake; and opportunities, to identify paths forward for GI and NbS. To determine similarities and differences about how these terms are being used, it was important to survey different departments, for instance between planning and engineering departments. To do this, presentations and surveys were conducted via online Zoom presentations and SurveyMonkey surveys with Metro Vancouver regional advisory committees. Each presentation began with a brief overview of low carbon resilience, natural asset valuation, discussed Phases one and two of this work, and explained our goals of the research –to determine what NbS and GI meant to respondents, why they might be adopting these methods, and to determine where the knowledge gaps lie.

There are several advantages of an online survey format: 1) online surveys are accessible to a wide range of people and can be finished on the respondents own time, 2) online surveys can cover an broad range of topics in a short period of time, 3) online surveys can reach geographically dispersed populations, or in this case, given the external circumstances of COVID-19 can be adapted for individuals working from home, 4) online surveys can give a voice to those people who might traditionally abstain from face-to-face research, or may hold back answering questions in person, 5) online surveys are an indirect format that can increase participant safety (Braun, 2020), and 6) online surveys may allow participants to be more open and honest in their responses. Rather than discussing in a roundtable of peers, participants have the option to be candid and frank about their opinions given the anonymity of the online survey format. This final advantage was especially important in this research, as unknown social and political factors would likely influence responses in groups of this size and nature.

From January – March 2020, ACT conducted a literature review and preparatory research, and from April – June of 2020, ACT organized meetings with six different regional advisory committees:

1) April 17th, the Regional Planning Advisory Committee
2) May 1st, the Regional Engineering Advisory Committee
3) May 7th, the Stormwater Interagency Liaison Group
4) May 14th, the Regional Engineering Advisory Committee – Climate Protection Subcommittee
5) May 21st, the Regional Planning Advisory Committee – Environmental Subcommittee
6) June 11th, the Regional Finance Advisory Committee

The survey was shared before and during the presentations with MV regional advisory committees, allowing members time to consider their responses. In the first committee presentation on April 17, 2020 respondents were asked to complete the survey after the presentation, which resulted in very few responses. Following this, the team changed the presentation style in the remaining workshops, guiding respondents through the survey during the second half of the presentation, by reading each question aloud and giving them the appropriate time to answer. This gave the participants time to complete the survey in our presentation and resulted in a much higher response rate. However, as the process was altered after the first presentation, all responses were sorted on Survey Monkey by Q1: In which general department or sector do you work in? not the date by which the survey was completed. For example, if a respondent selected ‘engineering’ as the department they worked in, then all those who selected engineering were filtered, and the responses sorted accordingly. The number of respondents from each department were: Engineers ($n = 36$), Finance ($n = 22$), Climate ($n = 14$), Planning ($n = 9$), Other (Environment Management and Administration) ($n = 6$), Parks, ($n = 5$), Ecology/Biology ($n = 5$), Stormwater Management ($n = 3$), and Health ($n = 2$). Two of the advisory committees are subcommittees of the regional committees (*the Regional Engineering Advisory Committee – Climate Protection Subcommittee and the Regional Planning Advisory Committee – Environmental Subcommittee),* and because this research was sorted by self-identified committee, it is unclear if those that identified as working in climate, were also planners, for example.

Following completion of the meetings with the MV regional advisory committees, all responses (*n.101)* were collated and organized into an Excel spreadsheet. The questions were first organized by questions on different tabs, then organized by department/sector representation within each question tab. This was done by sorting the Survey Monkey responses by sector depending on what the respondent selected in question one. For example, if a respondent selected ‘engineering’ as the department they worked in, then all those who selected engineering were filtered, and the responses sorted by question accordingly. These responses were counted and checked to ensure that no responses were left out. Once all the responses were organized into a spreadsheet, inductive coding was undertaken for those responses that were open ended (Q2, Q3, Q5, Q11, Q12, Q13, Q15), to derive key themes that emerged from each question. Themes were then grouped together and interpreted into areas of impact. Certain questions asked respondents to identify, for example, ‘the top 3 barriers’, resulting in numerous responses with a multitude of answers. In these cases, when respondents gave multiple answers, the answers were broken down into relevant ‘mentions’ and coded accordingly. Once the responses were coded, they were sorted into similar code responses, then each group of codes was divided by the total number of mentions to discern impact areas. The other questions, which were a combination of check box, ranking, or sliding questions were organized on Survey Monkey to discern distributions.

3.3. Limitations

Changing the presentation style and survey delivery hindered the ability to accurately sort responses according to presentation/survey date and known regional advisory committee, alternatively, responses were sorted by self-identified department. Only certain questions and answers have departments with a reliable sample size, which may not have been the case if the data had been sorted by regional advisory committees. Additionally, it is likely that the style of presenting before asking advisory committee members to participate in a survey could sway or at least frame the results.

While COVID-19 was an initial limitation to the in-person format of these presentations and surveys, the online format and anonymity of the surveys allowed respondents to speak freely without concern of internal politics and was accessible to those who might normally refrain from answering questions in person.

Chapter 4. Results

The following survey results are broken down into three overarching sections: communications, barriers and risks, and opportunities, and then further broken down by question. The top responses received were from respondents who identified that they worked in engineering (35.3%), finance (21.6%), and climate (13.7%). Given the breakdown of participants in the various regional advisory committee meetings, respondents that self-identified working in 'climate' may overlap with other departments such as planning or engineering. The total number of survey respondents was 101.

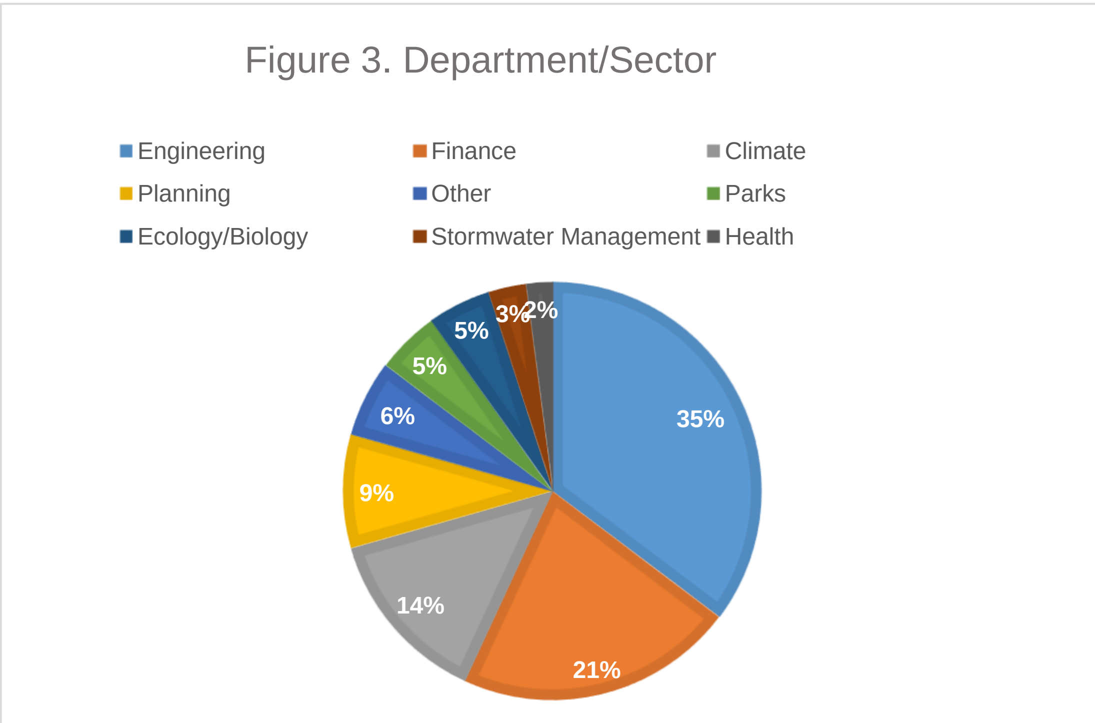

Figure 3. The top three departments/sectors represented in this research are engineers, finance, and those working in climate. Other includes government administration and environmental management. No. respondents = 101.

4.1. Communication About GI and NbS

4.1.1. Communications Question One

What does the term Nature-based Solutions (NbS) and the term Green Infrastructure (GI) mean to you?

Respondents identified a diverse range of responses indicating the various ways that NbS and GI are being considered and discussed throughout the region. Despite the lack of consistent definitions for NbS and GI, key themes emerged. NbS were referred to as "complete, intact systems" such as wetlands that sustain *existing* natural features. NbS was frequently discussed using conservation and goal-oriented language, for example, *"use of natural processes to replace or support engineering solutions"* or *"natural elements such as ditches or wetlands that can replace or augment physical infrastructure".* GI was primarily identified as "constructed green interventions" such as rain gardens, with a focus on the services provided and/or functionality, such as water filtration and/or stormwater management. One respondent identified GI as *"infrastructure which is integrated with ecosystem function (e.g., ecosystem services, biomimicry etc.)."* Both GI and NbS were referred to as having the ability to support or replace grey infrastructure by using or mimicking natural systems. These finding are consistent with the literature in that NbS are commonly attributed to systems and land management (Kesstra, et al., 2018), and GI referred to the interventions that provide services, like the gears in the NbS clock.

When asked "What does the term nature-based solutions mean to you?" respondents identified the following themes:

- NbS sustains or conserves *existing* natural features
- NbS has an aspect of biomimicry
- NbS replaces or supports grey infrastructure
- NbS language is goal-oriented

When asked "What does the term green infrastructure mean to you?" respondents identified the following themes:

- GI supports or replaces engineered infrastructure with nature.

- GI has a mimicking quality.
- GI is sustainable and environmentally friendly, with multiple benefits.
- GI is related to climate change/climate action.
- GI is often related to stormwater/stormwater management.
- GI is often conflated with nature-based solutions.

4.1.2. Communications Question Two

Does language use differ depending on who you are discussing NbS and/or GI with?

NbS language was seen as generally more solutions-focused, but it was noted that the language itself was taken less seriously. Green infrastructure was the preferred term of use, because respondents believe that it was more easily understood. However, most respondents identified that they unsure how and if language use differed depending on who they were discussing NbS and GI with.

- A majority of respondents (49%) were unsure how and if language use differed depending on who they were discussing NbS and GI with. *"Clear definitions are required."*
- Twenty-one percent of respondents stated that there was no difference between the terms, and they were used interchangeably. *"Used in the same manner. Synonyms."*
- Seventeen percent of respondents stated that GI was the term that they used more, because they believe that GI is more broadly understood. *"We try to stick with the GI terminology as most others won't understand the nuanced difference between the term."*
- Eight percent of respondents stated that different terms were used depending on who they were talking to. *"Yes, NbS doesn't seem to be taken as seriously in some crowds (i.e., engineers), but is often better understood by public, mayor, council."*
- Five percent of respondents identified that they use NbS and GI differently depending on what type of intervention they are talking about, rather than who they are talking to. *"Yes, GI often includes construction using non-natural materials while NbS would be considered a more 100% natural solution."*

4.1.3. Communication Question Three

How do you receive and relay information about NbS and/or GI?

In terms of how information about NbS and GI is both received and relayed by municipalities, materials that could be quickly digested or interactive were identified as the most useful for communicating to busy government staff.

Respondents primarily receive information from:

- Conferences/workshops
- Relevant, trusted organizations
- Academic sources

The most useful communications tools to relay information:

- Visual representations, figures, posters, and infographics
- Talks and public events
- Data and statistics

4.2. Barriers and Risks to GI and NbS Uptake

4.2.1. Barriers and Risks Question One

What are the top three barriers to NbS and GI uptake?

The upfront cost and lack of financial resources was identified as the top barrier to advancing NbS and GI uptake. The second barrier identified by respondents was uncertainty about the effectiveness of these approaches, largely because of self-identified knowledge gaps and the lack of understanding how these approaches were climate strategies. The third top barrier identified was a lack of trust and buy-in, with many respondents stating their reluctance to try something new.

- Funding (21%) refers to the upfront costs and lack of financial resources to advance NbS and GI approaches. *"Cost (e.g., raingardens are expensive to implement)."*
- Knowledge gaps and uncertainty (21%) refers to the doubt respondents had about their ability to develop NbS and GI and provide services in an effective manner. *"Knowledge and understanding of the importance of integration of NB."*
- Trust and buy-in (16%) refers to respondent's reluctance to adopt new approaches and adjust to new practices. *"Lack of trust in the concept and stuck in BAU way thereby needing the doubling up with a grey infrastructure underneath."*
- Competing priorities (10%) refers to the various interests that respondents have to consider and appropriately manage. *"Competing demands for development/urbanization."*
- Policy, standards, and regulation (9%) refers to a lack of policy frameworks and guidelines and aligned regional regulations and standards. *"Clear policy or regulatory framework with requirements."*
- Capacity (7%) refers to the lack of staff ability to find the time and resources to advance NbS and GI. *"Capacity to implement, monitor, and maintain."*
- Maintenance (7%) refers to concerns about adequately being able to continuously support NbS and GI interventions.

- Coordination and collaboration (6%) refers to the lack of and need for streamlined inter-departmental collaboration to advance joint priorities. *"Coordination between functional departments."*
- Timeliness (3%) refers to the establishment period of new policies and standards and the long-term performance of the NbS and/or GI intervention. *"Takes time to update plans and standards."*

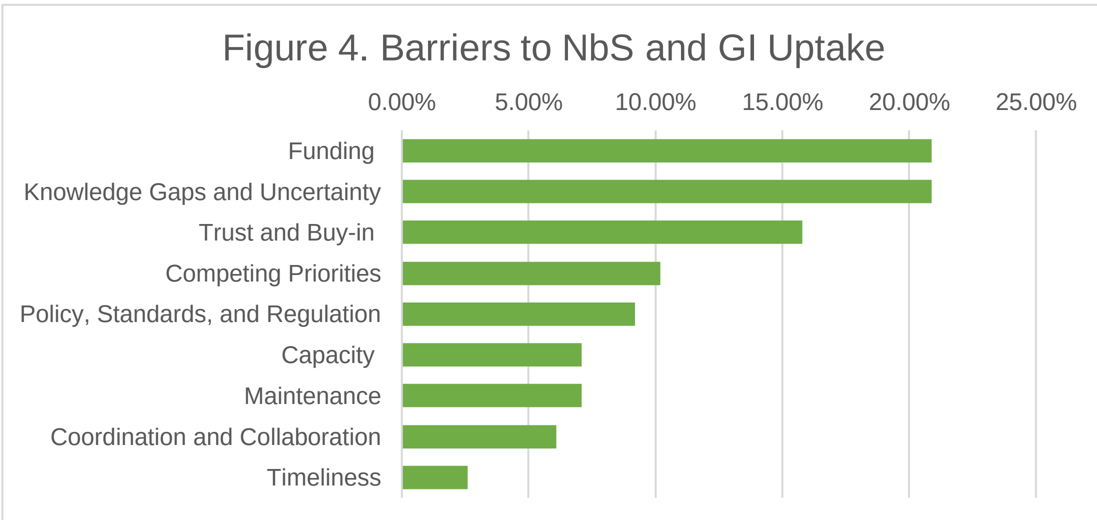

Figure 4. The top three barriers to the uptake of GI/NbS interventions identified by all respondents are funding concerns, uncertainty and knowledge gaps, and a lack of trust and buy-in. No. of mentions = 196.

Understanding the barriers to NbS and GI is an integral piece of this research. If the barriers to action can be identified, then strategies and resources can be developed to respond to barriers. As such, it was important to break down barriers by the top three sectors represented by this survey: engineering, finance, and those working in climate.

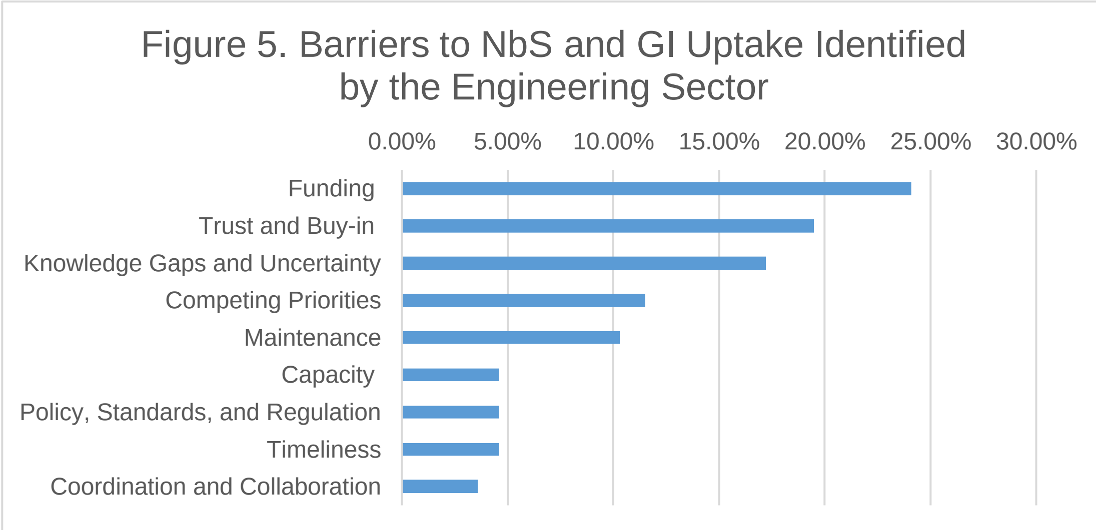

Figure 5. The top three barriers to GI/NbS uptake identified by respondents in the engineering sector include funding, trust and buy-in, and knowledge gaps and uncertainty. No. of mentions = 90.

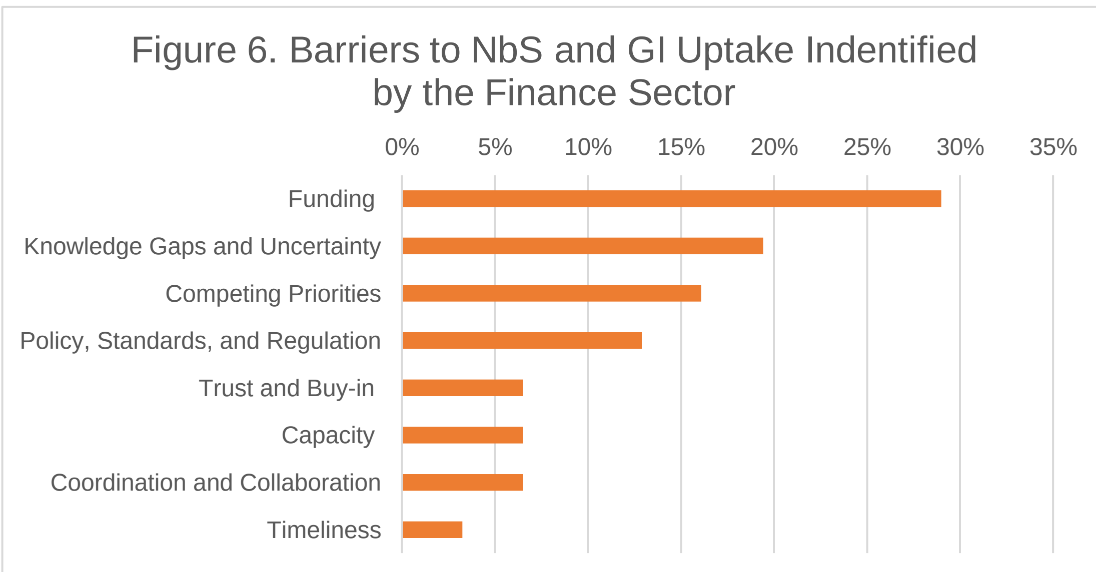

Figure 6. The top three barriers to NbS and GI uptake identified by respondents in the financial sector are funding, knowledge gaps and uncertainty, and competing priorities. Respondents in the financial sector did not indicate maintenance as a barrier. No of mentions = 33.

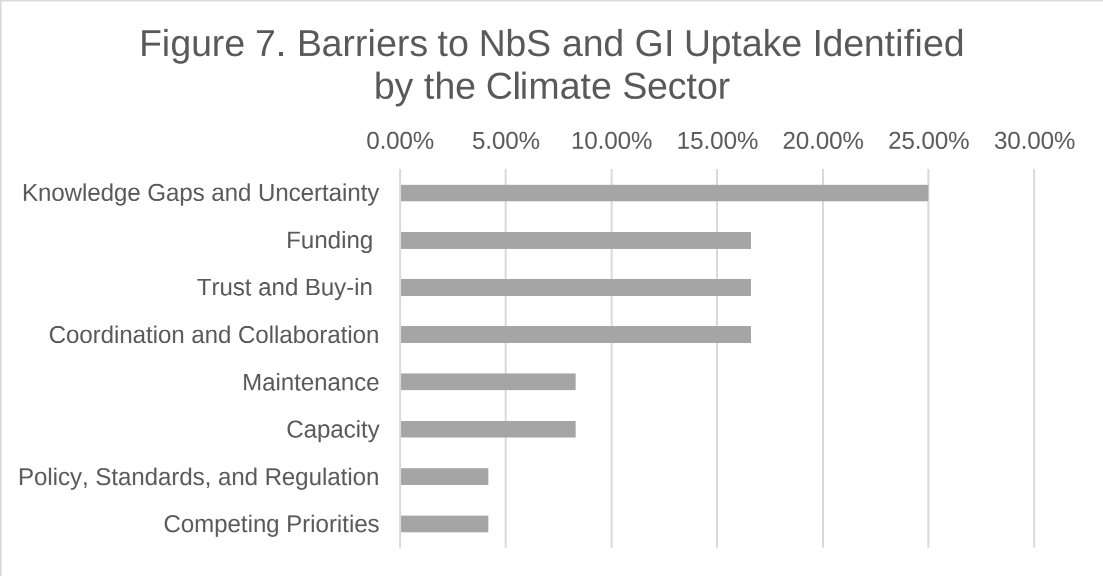

Figure 7. The top barrier to NbS and GI uptake identified by respondents in the climate sector is knowledge gaps and uncertainty. The following three barriers were tied: funding, trust and buy-in, and coordination and collaboration. Respondents in the climate sector did not indicate timeliness as a barrier. No of mentions = 24.

4.2.2. Barriers and Risks Question Two

Are there perceived risks of using GI and/or NbS?

The top perceived risks of using GI and/or NbS identified by respondents were failure, cost, and maintenance.

- Failure (34%) refers to the perceived risk that NbS and/or GI interventions will be ineffective, will not work, or will be less efficient that grey infrastructure. *"What if it doesn't work?", "It will fail faster than more traditional means (i.e., hard engineering solution)."*
- Cost (23%) refers to high initial cost and increased costs over time. *"Additional cost upfront, for something without a guarantee."*
- Maintenance (18%) refers to the costs to maintain the intervention, and the unknown maintenance requirements. "*Maintenance is unfamiliar and potentially unpredictable therefore harder to adopt without doing a bunch of pilots."*
- Uncertainty (11%) refers to the lack of knowledge about how to apply the intervention, along with how to monitor and maintain it to ensure effectiveness and success. *"Uncertainty of success and communicating success."*
- Lifespan (9%) refers to the long-term performance of the intervention. *"Questions*

about long-term lifespan."

- Public perception (5%) refers to public response and potential skepticism of all aspects of adopting GI and/or NbS solutions. *"Lack of public understanding and acceptance can make it a tough sell too. We need to be telling more truthful stories of our limited GI experience."*

The most critical risk that emerged from all respondents was the risk of failure, the effectiveness of NbS/GI and the concern that NbS/GI interventions could fail to provide the intended service. This, along with maintenance concerns particularly impacts the engineering respondent group, who have significant liability when designing infrastructure projects and responsibility to ensure long-term effectiveness via maintenance. Engineers perceived the key risks of adopting NbS and/or GI interventions to be:

- Failure (33%)
- Maintenance (23%)
- Cost (18%)
- Lifespan (10%)
- Public Perception (7.5%)
- Uncertainty (7.5%)

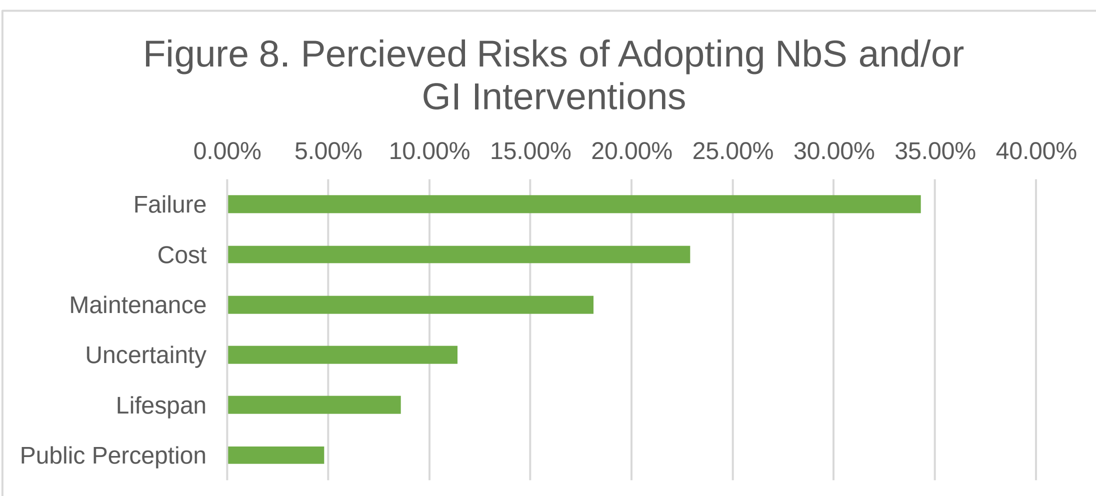

Figure 8. The top perceived risks to using NbS/GI interventions identified by all respondents are failure, cost, and maintenance. No. of mentions = 114.

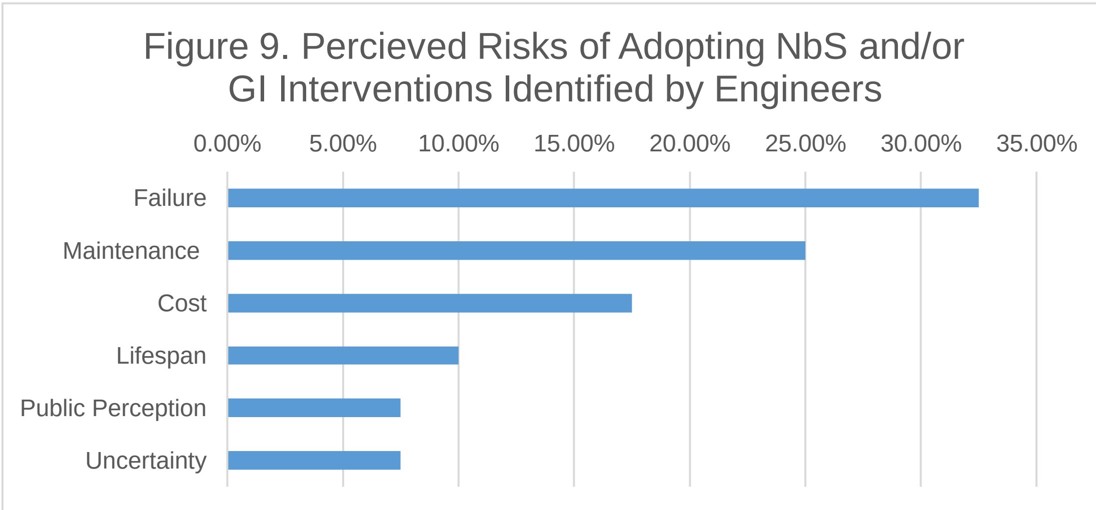

Figure 9. The perceived risks of using NbS/GI interventions identified by engineers are failure, maintenance, and cost. No. of mentions = 40.

4.2.3. Barriers and Risks Question Three

What are the most difficult barriers to overcome in the NbS and/or GI planning process?

Funding (22%) was ranked as the top barrier to the NbS and/or GI planning process or project stage, followed by capacity and time (19%), and a lack of familiarity and uncertainty of how to proceed with projects (15%). This was a "check all that apply" question and as such, there are a high percentage of answers.

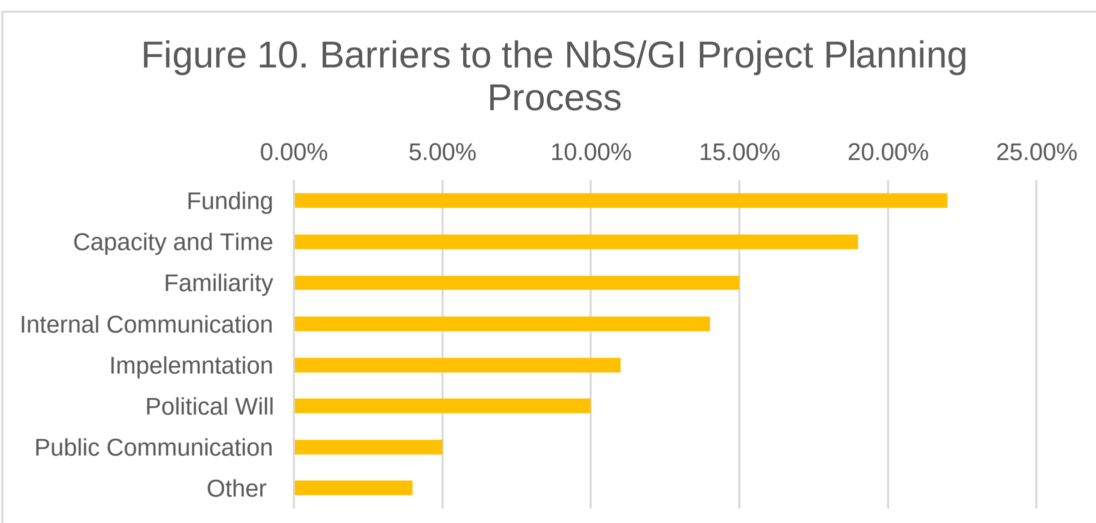

Figure 10. Perceived risks of using NbS/GI interventions identified by engineers. No. of responses = 254.*

**This question asked respondents to check all that apply, accounting for the large number of responses.*

4.3. Opportunities to Pursue NbS and GI

4.3.1. Opportunities Question One

What are the top reasons to pursue a NbS and/or GI approach?

Respondents identified three key reasons for pursuing a NbS and GI approach. The top reason was to reduce the impacts of extreme weather including flooding and extreme temperatures (19%), followed closely by enhancing biodiversity (18%), and using NbS and/or GI as an overall climate change response tool (18%).

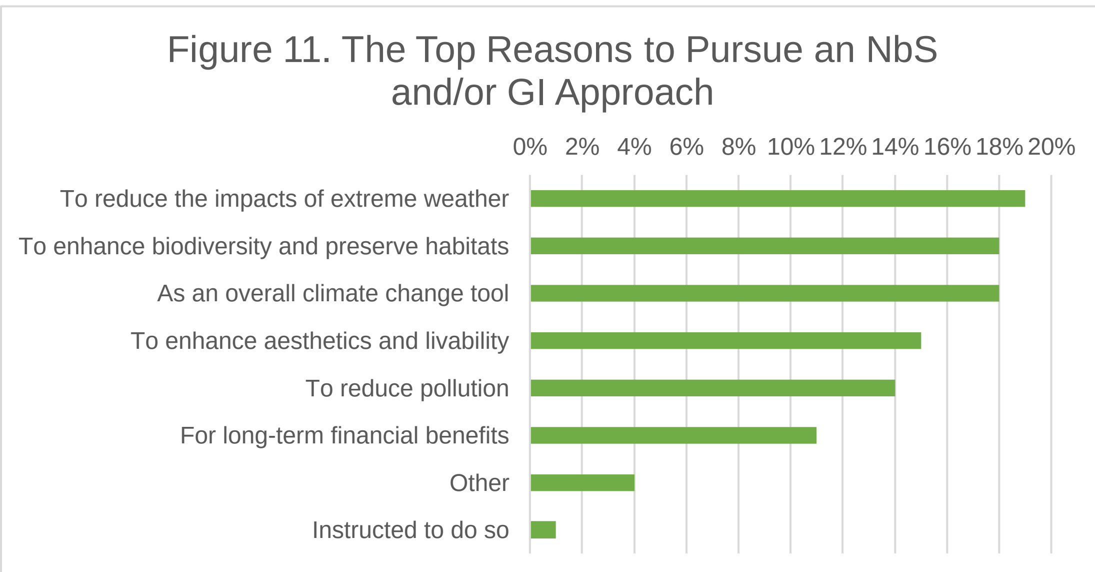

*Figure 11. The top reasons respondents identified to pursue a NbS and/or GI approach. No. responses = 356**

**This question asked respondents to check all that apply, accounting for the large number of responses.*

The top reasons identified to pursue a NbS and/or GI approach by department:

- **Finance:** As an overall climate change tool.
- **Engineering:** To reduce the impacts of extreme weather.
- **Climate:** As an overall climate change tool.
- **Parks:** To enhance biodiversity and preserve habitats.
- **Planning:** As an overall climate change tool.
- **Ecology/Biology:** To reduce the impacts of extreme weather.

4.3.2. Opportunities Question Two

Which departments/sectors do you see the need for coordination with the most to impact NbS/GI uptake?

Engineering (19%), planning (17%), and stormwater management (14%) were identified as the top two departments with which to coordinate on advancing NbS and GI uptake.

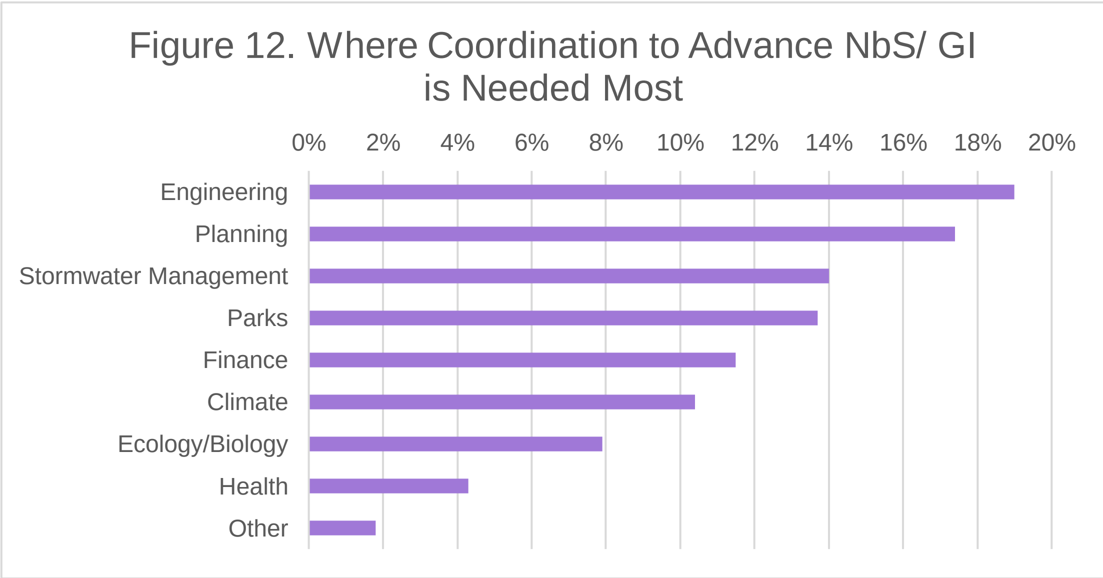

Figure 12. Coordination to advance GI/NbS is most needed between staff in engineering, planning, and stormwater management. No. of mentions = 356.*

**This question asked respondents to check all that apply, accounting for the large number of responses*

4.3.3. Opportunities Question Three

What factors associated with NbS and GI would municipal staff like to see accompany a regional growth strategy update?

The predominant need identified by respondents was for NbS and GI related bylaws, policies, standards, and guidelines (40%) to be integrated in Metro Vancouver's RGS update. This was followed by targets and objectives (14%) to allow policy makers to meet identified goals, along with coordination, collaboration (12%), including political buy-in.

Figure 13. The top benefits for municipalities in an RGS update include bylaws, policies, and guidelines, targets and objectives, and more coordination. No. of mentions = 57.

4.3.4. Opportunities Question Four

What key factors influence the choice to pursue grey or green infrastructure in a project?

Participants identified cost, capacity, and knowledge as the key factors to consider when pursuing grey or green infrastructure in a project.

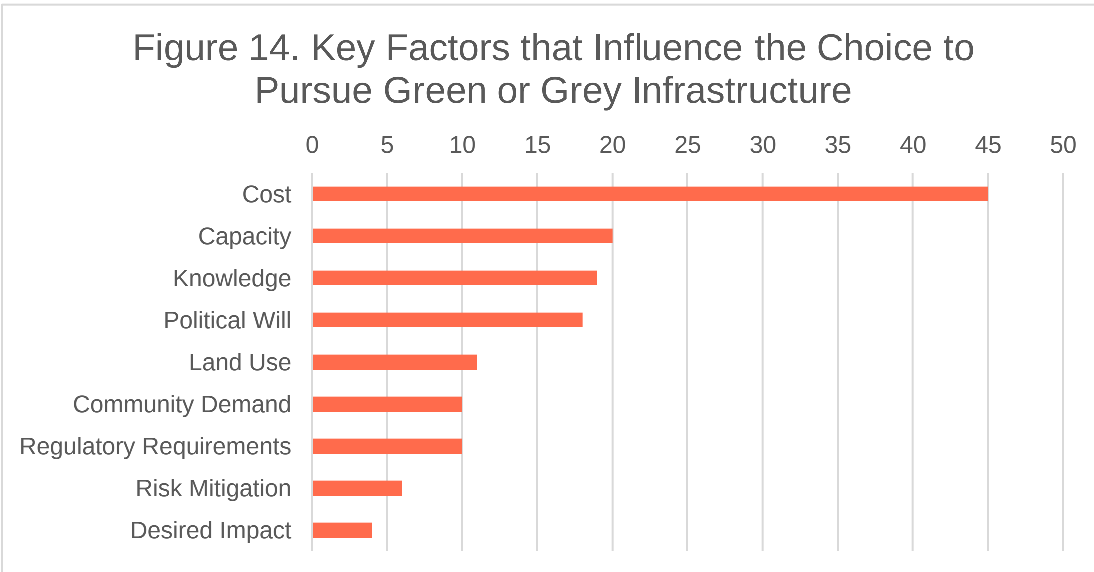

Figure 14. The factors that primarily influence the choice to pursue green or grey infrastructure include cost, capacity, and knowledge. No. of mentions = 141.

4.4. Conclusions from Survey Results

The results from the three core sections led to four key findings:

Communications

NbS were referred to as "complete, intact systems" such as wetlands that sustain existing natural features, while GI was primarily referred to as "constructed green interventions" such as rain gardens, with a focus on the services provided and/or functionality, such as water filtration and/or stormwater management.

Barriers

- The primary barrier to advance NbS and GI uptake are costs, both related to upfront costs and the lack of financial resources to advance, maintain, and monitor NbS and GI and the secondary barrier is knowledge gaps and uncertainty, related to the doubt respondents had about the ability of these interventions to provide services effectively. Following that, trust and buy-in emerged as a significant barrier, with respondents citing their *“reluctance to try something new”.* Notably, cost, knowledge, and capacity also emerged as key considerations when deciding whether to pursue green or grey infrastructure.

- The predominant risk to uptake identified were the failure of NbS and GI systems to provide intended levels of service.

Opportunities

The top reasons to pursue a NbS or GI approach was to reduce the impacts of extreme weather, to enhance biodiversity and preserve habitats, and as an overall climate change tool. To pursue NbS and/or GI approaches, respondents would like to see policies and guidelines, targets and objectives, and improved opportunities for coordination and collaboration in an RGS update.

Chapter 5. Discussion and Recommendations

5.1 Communications

The communications section correlates to the first and third question posed by this research; how does the MV regional government understand, reiterate, and apply NbS and GI strategies? And how can these processes be better communicated to advance regional networks of NbS and GI? One of the most profound findings of this research question is the diversity of ways that the MV regional advisory committees think about NbS and GI. The implication of this diversity of responses and the importance of this finding is the potential for discrepancies in how NbS and GI are communicated both internally and externally, and in how the two terms are reiterated in planning processes across the region. It is important to have consistent and relevant terminology to advance a cohesive NbS and GI network across the region. The large breadth of responses about what NbS and GI meant to respondents may imply that the terms are relatively novel and have diverse applications, or that the terms are being misused, misunderstand, and that their role in different planning documents across the region is misinterpreted. These discrepancies can lead to amplified uncertainties and increased jurisdictional barriers when advancing NbS and GI. Since there is already a high level of uncertainty and significant knowledge gaps surrounding NbS and GI it is imperative to determine the true meaning behind different responses and develop terminology that is reflective of this, ensuring that definitions are not too restrictive or rigid that they are bypassed by decision makers entirely.

In general, it was determined that NbS language was identified as more solutions-focused, but it was noted that the language itself was taken less seriously. One potential reason for this is because the term NbS is less common, more abstract, and more unclear and broader than the language of GI, which has consistently been gaining more use. Green infrastructure was more predominantly referred to as constructed green interventions like rain gardens and bioswales, implying the service provision and functionality component of GI. Both NbS and GI were referred to as having the ability to support or replace grey infrastructure by using or mimicking natural systems. These finding are consistent with the literature in that NbS are commonly attributed to systems and land management (Kesstra, et al., 2018), and GI referred to the interventions that provide services that help greater systems, such as the hydrological system, function.

5.1.1. Recommendations

The number of wide-spread and diverse responses indicate that a clear definition of both NbS and GI is needed in the RGS update to coordinate regional understanding of NbS and GI and streamline unified integration and dissemination at a regional scale to advance layered networks of NbS and GI. It is imperative that MV regional planners liaise with respondents from diverse departments to ensure that the definitions of NbS and GI are either all-encompassing for diverse groups, or that distinct definitions are developed that are tailored for unique sectors for example, engineering and planning, so that they may be relevant and useful. Developing a guidebook with case studies and business cases that can advance understanding about NbS and GI approaches is recommended to advance trust and buy-in. Further, it is recommended that tools that are developed to advance said understanding are visual in nature and include graphs, figures, and infographics to easily represent data and statistics while appealing to a wide range of stakeholders.

5.2 Barriers and Risks

This section corresponds with question two posed by this research: what barriers exist to advance consistent knowledge and understanding of NbS and GI? In accordance with the literature, one of the main barriers to advancing NbS and GI uptake identified by respondents was funding, including the potential of higher upfront costs for NbS and GI interventions and the lack of municipal financial resources in general. Largely, respondents were unsure how to pay for NbS and GI, especially because of the respondents concerns that NbS and GI could be ineffective and may require an additional investment in conventional infrastructure to compensate. Respondents were also unprepared to invest in NbS and GI because of the uncertainty of maintenance costs and the potential for increased costs over time. These funding concerns are significant hurdles, as they represent planners needs to accommodate diverse interests, manage public perception, manage their own liability and the uncertainties attributed to more novel forms of land use planning like NbS and GI.

Costs and issues of funding were identified as the main barrier articulated by respondents and were common throughout responses, but it is likely that this and other barriers are rooted in the second and third highest barriers identified by respondents: knowledge gaps and uncertainty and a lack of trust a buy-in, along with limited literature about this subject matter. Taken together, these two barriers indicate that decision makers are uncertain about how to apply NbS and/or GI strategies, are unsure of the effectiveness of NbS and/or GI interventions and are unsure of how these interventions should be maintained. These uncertainties are reflected in the tangible decisions that members of MV regional advisory committees would need to make regarding costs, maintenance, and competing priorities. These uncertainties also significantly influence perceptions about NbS and GI, including the feasibility of implementing NbS and GI interventions and moving beyond planning stages. Notably, the motif of knowledge gaps and uncertainty threaded throughout responses regarding costs and funding is indicative that the true value of the services provided by ecosystems and NbS and/or GI may not be clear.

Municipalities likely do not have a clear understanding of the services being provided by ecosystems within their jurisdiction. Conducting a natural asset inventory and a corresponding valuation of the services provided by ecosystems such as water filtration, food provision, and soil formation can allow municipalities to determine the level of service they are receiving and arms them with the knowledge of the cost savings/avoided costs of enhancing those services via preservation and restoration of natural areas and clarifies the true costs of fragmentating and destroying these services. For example, natural wetlands in southern Ontario reduce flood damage costs to building by $51.1 million (or 38%) at an urban pilot site (Moudrak, Feltmate, Venema, & Osman, 2018), but if that wetland was to be fragmented or altered, the affected locality would need to determine where money would come from to provide the same level of engineered flood mitigation services. It is arguable that the biggest barrier to municipalities is not costs, maintenance, or competing priorities as cited by respondents, but the lack of knowledge of the services the natural assets within their boundaries and performing. Without reducing these knowledge gaps, it is likely that the natural assets existing in municipal boundaries and their corresponding levels of service will decrease and will positively reinforce the top risks identified by respondents, such a lack of effectiveness and failure and maintenance. However, the fact that this knowledge gap is being articulated by respondents evidences their awareness. Additionally, one of the top needs mentioned by respondents to include in an RGS update is bylaws, policies, standards, and guidelines and targets and objectives, both of which can help guide respondents in planning for NbS and GI.

5.1.2. Recommendations

Notably, many of the barriers identified by respondents such as knowledge gaps and competing priorities compound each other and are likely to be exacerbated by each other, for instance by a lack of capacity. Knowledge gaps are likely to aggravate shortcomings in capacity, as familiarity and understanding of NbS and GI processes takes time and may require specialized personnel. It is recommended that knowledge-sharing events, infographics, and other interactive, quickly digestible information as identified in the Communication section of this document, are used to more rapidly alleviate knowledge gaps and to increase trust and buy-in. To further reduce knowledge gaps, it is recommended that MV integrate policy in the RGS that advises local governments to conduct natural asset inventories. This will allow municipalities to better understand the value of the services provided by their ecosystems, such as water filtration, and to understand the money they are saving on service provision, and the avoided damage costs provided by natural assets. Additionally, this approach can be used as an entry point to engage with ecologists and biologists, as well as professionals from the Finance department to determine the condition of assets and the value of their services. Even though respondents from the finance department and ecologists and biologists were not highly recommended to coordinate with on NbS and GI strategies, their expertise and perspective can add significant value. It is highly recommended that moving forward, planning, engineering and other departments working on advancing NbS and GI engage with professionals in these departments to better understand the condition and economic value of assets.

To manage capacity limitations while simultaneously reducing knowledge gaps, it is recommended that NbS and GI training for municipal staff is planned for and funded by the municipality. Concurrently, decision makers should undertake an analysis of available resources and programs to determine where training for NbS and/or GI projects is adequate or needs to be increased, determine how relevant training can be tailored to various departments, and evaluate opportunities for departments to educate each other, developing organizational connections and reducing a siloed approach. Additionally, types of NbS and/or GI certification can be incentivized and incorporated into professional training programs including the continuing education credits through the Planning Institute of B.C..

To manage the financial constraints identified by respondents it is recommended that established, low risk financing mechanisms for developing NbS and GI are adopted for unique contexts by: adopting standards for project financing and investments that mandate responsible environmental projects (European Commission, 2016); adopting risk management frameworks to prioritize, assess, and manage environmental risk in projects and/or mandate that projects over a certain value must integrate NbS and/or GI considerations; conducting natural capital inventories to establish the regional value of existing municipal natural assets; and exploring funding for the co-benefits of NbS and GI strategies. For example, active transportation networks that use permeable pavements and/or are buffered by natural vegetation are NbS/GI strategies but can be funded under active transportation grants.

Following the top barriers listed, respondents also identified key risks to NbS and GI uptake, noting concerns of failure and the notion that NbS and/or GI interventions were less effective than conventional grey infrastructure. Other risks identified were high costs and the unknowns of maintenance requirements. Ultimately, it is likely that these risks are also rooted in knowledge gaps. To mitigate the perceived risks of failure it is recommended that long term maintenance plans are developed at the outset of NbS and/or GI project planning that will supersede political cycles and incorporate a monitoring schedule into the maintenance plan. Additionally, it is recommended that monitoring standards are established for readily accessible data about how NbS and/or GI projects are performing to reduce uncertainty and iterate maintenance plans. For issues of capacity related to maintenance, municipalities might explore developing strategic partnerships with academic institutions, NGOs, community groups, and other organizations to advance data collection, management, and analysis.

5.3 Opportunities

This section corresponds with question two posed by this research: what opportunities exist to advance consistent knowledge and understanding of NbS and GI? Respondents indicate that NbS and GI strategies are pursued for their ability to address the projected impacts of climate change throughout Metro Vancouver, specifically for their value to reduce the impacts of extreme weather and to enhance biodiversity and preserving habitats. Interestingly, although enhancing biodiversity was one of the top reasons to pursue NbS and/or GI cited by participants, biologists were identified as the seventh most important department to coordinate with to advance NbS/GI approaches, indicating that departmental siloes are likely to play a significant role in the advancement of NbS and/or GI strategies. Additionally, this finding represents entry points for how to frame NbS and/or GI planning into the future. Taking into account that most respondents would pursue these strategies to manage climate change, framing and layering NbS and GI and corresponding strategies as climate change strategies is likely to be useful.

It is noteworthy that of the barriers identified by respondents, many align with, or can be framed as opportunities for further research. By honing in on the barriers identified by respondents, researchers, academic institutions, and regional and local governments can develop resources and communications that pinpoint these direct concerns.

5.1.3. Recommendations

This research has illustrated that one of the most salient opportunities to advance NbS and GI uptake is clear policy guidance. Local governments have limited jurisdictional authority when managing the environment, and thus using all available policy tools at their disposal is critical. Thus, in future RGS updates it is recommended that policy to advance NbS and GI is adopted so that it may trickle down into OCPs and other municipal plans.

Additionally, to advance more serious uptake of NbS and GI, it is recommended that these strategies are framed used climate change planning. One way to do this is through the concept of layering, mentioned above. By slowly slotting in strategies to changing existing structures over time, NbS and GI practices that are in sync with certain normative, social, and political environments can be introduced as alterations or mixed method approaches to traditional engineering and can slowly transform existing processes (Johns, 2019). The co-benefits of green infrastructure strategies, for example, can be a way to sync with broader ideals that many people would agree with, like healthy communities and clean water. Through the accumulation of small changes and by layering in new policies and planning tools, larger changes can be advanced over time.

Chapter 6. Conclusion

Climate change is a global phenomenon, yet local and regional governments exist on the frontlines of its impact. Far from being passive actors and recipients of negative consequences, local governments have significant capacity to advance localized action and influence regional planning to mitigate and adapt to climate change. Nature-based solutions and GI are land use planning strategies that can be applied to both reduce vulnerabilities and emissions and provide co-benefits to meet unique municipal contexts and streamline planning. Implemented at a regional level, networks of NbS and GI can reduce vulnerabilities by providing opportunities for flood absorption and heat regulation and can reduce emissions through carbon storage and sequestration. These approaches also provide co-benefits such as increased access to green space, improved human physical and mental health, and job creation, making NbS and GI strategies not only achievable, but desirable climate change and land use planning strategies.

Over the course of three months in Spring of 2020, members of six MV regional advisory committees made up of staff from available member jurisdictions spanning expertise in engineering, planning, finance, climate, and stormwater, gathered to explore how they understand and articulate the terms NbS and GI and to determine what barriers and opportunities exist to advance consistent knowledge and understanding of NbS and GI to support its implementation. Their responses indicate four key findings:

1) NbS are referred to as complete, intact systems like wetlands and GI is referred to as constructed green interventions, like rain gardens. There is a diversity of ways that the MV regional advisory committees think about and use the terms NbS and GI;
2) Costs, knowledge gaps, a lack of trust, and capacity issues were identified as key barriers to advancing NbS and GI;
3) Failure of NbS and GI systems was identified as the top risk; and
4) A key opportunity to advance NbS and GI strategies is to frame and apply them as climate change tools.

Identifying and responding to the barriers identified and building on the opportunities identified is a crucial step towards advancing NbS and GI throughout the region. By determining the factors that obstruct NbS and GI strategies like costs and knowledge gaps, decision makers can work to address and minimize these obstacles. By advancing consistent definitions, visuals, and clear and easily digestible information, data about NbS and GI can be advanced to reduce knowledge gaps and ultimately, advance climate change planning.

There are three key areas to expand on this research to continue exploring how to advance networks of NbS and GI.

1) Explore how private property research can advance NbS and GI goals. Regional governments like Metro Vancouver have opportunity to influence public lands, but private property makes up a significant proportion of land throughout the region. Backyard spaces and green alleys can help advance adaptation and mitigation goals, and also work as connective spokes for the transport and growth of animal and plant networks.

2) Expand on the connection between topics of equity, biodiversity, and NbS and GI planning. Advancing climate change must consider an equity lens, but the ways in which these interconnected concepts are being advanced and influence one another at the regional level are underexplored.

3) A final area of exploration is to discern how surrounding jurisdictions and other levels of government are exploring the concepts of NbS and GI, and to determine entry points for this work to expand beyond a regional scope.

This research was a crucial first step towards better understanding what regional governments are considering as they work to advancing planning and implementation of NbS and GI projects, especially as climate change strategies. More research could be conducted to test and develop NbS and GI terminology. What has emerged from this research is the notion that nature-based solutions and green infrastructure interventions are inherently wise, are crucial components of resilient regional urban landscapes, bring significant benefits, and can help respond and reduce the impacts of climate change. For these reasons, it is crucial that we bring nature back into the urban ecoscape.

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Appendix. Survey Questions

Survey Questions

Q1: In which general department or sector do you work in?

a) Engineering
b) Planning
c) Stormwater management
d) Parks
e) Finance
f) Climate
g) Ecology/Biology
h) Health

Other (please specify)

Q2: Please write a few brief words about what the phrase “green infrastructure” means to you.

Q3: Please write a few brief words about what the phrase “nature based solutions” means to you.

Q4: How do you view the relationship between GI and NbS?

Q5: Does language used regarding GI and NbS differ in your interactions with other staff members, interactions with the public, and if relevant, interactions with mayor and council?

Q6: Please rank the usefulness of the following communications tools to relay information from 1-6, where 6 is the most useful and 1 is the least useful.

a) Visual representations
b) Talks and other public events
c) Data and statistics
d) Reports
e) Business Cases
f) Case Studies

Q7: Which departments/sectors do you see the need for coordination with the most to impact green infrastructure and nature-based solutions uptake? Please check all that apply.

i) Engineering
j) Planning
k) Stormwater management
l) Parks
m) Finance
n) Climate
o) Ecology/Biology
p) Health
q) Other (please specify)

Q8: Where do you usually get your information about green infrastructure and nature-based solutions? Please check all that apply.

a) Conferences/workshops
b) Relevant organizations
c) Academic sources
d) Team members
e) Media Sources
f) Other (please specify)

Q9: Why are you pursuing GI and/or NbS? Please check all that apply.

a) To reduce the impact of extreme weather, including flooding and extreme temperatures.
b) To enhance biodiversity and preserve habitats
c) As an overall climate change tool
d) To enhance aesthetics and livability
e) To reduce pollution
f) Long-term financial benefits
g) I've been instructed to do so
h) Other (please specify)

Q10: If relevant, how much guidance regarding GI would you take from Metro Vancouver's Regional Growth Strategy?

Q11: If relevant, what would you like to see in the Regional Growth Strategy that would be of benefit to your municipality?

Q12: If relevant, are there areas of your Official Community Plan that align with GI and NbS?

Q13: Please list the top three barriers of green infrastructure and nature-based solutions uptake, including policy barriers, and knowledge gaps.

Q14: When working on GI and/or NbS planning/projects, what is the most difficult barrier to overcome Please check all that apply.

a) Funding
b) Capacity and time
c) Lack of familiarity, uncertainty how to proceed
d) Communication internally
e) Implementation
f) Political will
g) Communication with the public
h) Other (please specify)

Q15: Are there perceived risks of using GI or NbS? Please list.

Q16: What key factors influence the choice to pursue grey or green infrastructure in a project?