Combining built and natural infrastructure to motivate flood resilient communities in Greater Montreal

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WAGENINGEN UNIVERSITY AND RESEARCH

EBB & FLOW:

Combining built and natural infrastructure to motivate flood resilient communities in Greater Montreal

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science in Landscape Architecture
Wageningen University

Louise Capelle-Burny

August 2019

Thank you

Pursuing a masters at Wageningen University would not have been possible without the love and support of my parents, my in-laws and my friends at home. This masters journey opened a new world and filled with all the layers of the landscape – I am grateful to have shared the experience with a close group my fellow students. I would like to thank Rudi for patiently listening to my thousands of thoughts, and for guiding me when I was overwhelmed by the process. Thank you to my neighbor Sara, and to Blauwdruk Publishers for sharing a beautiful Room for the River book with me. Thank you, Paul, for taking the time to look over my drawings with me and giving me direction during my design process. This thesis would not have been possible without the support of Stichting N. H. Bos, who enabled me to travel back and forth to Montreal to host a design feedback event. I can't imagine having gone through this thesis journey without Danïelle; thank you for being my constant motivation, my uiterwaarden buddy, and my personal timekeeper. Thank you, Devon, for being my rock throughout this master's experience, but especially while working on my thesis - I couldn't have done it without you. Finally, I would like to thank you, Rob, for your incredible adobe skills, your creative suggestions and your encouragement while completing my thesis.

Abstract

In 2017 and 2019, communities across southern Quebec and Ontario flooded to unprecedented levels. The spring floods were both 1-in-100-year floods, exacerbated by climate change and overly developed waterfronts. Montreal and Quebec's hierarchy of governing bodies seek solutions to alleviate the affects of future floods on waterfront communities whom taxpayers are inevitably supporting. Holistic, landscape interventions could help to reduce the impact of future floods. This master thesis explores the socio-cultural obstacles that challenge the integration of international flood-adaptive strategies in the vernacular landscape of Greater Montreal. A feedback event revealed a lack of empathy towards the flooded communities. A literature review determined that 'orderly frames' were needed to incorporate unfamiliar landscapes into North American environments. The author proposes a typology of landscape elements, consisting of built and natural infrastructure, derived from Green Infrastructure approaches and the Room-for-the-River programme. A case study approach tests the typologies in the floodplain municipalities of Sainte-Marthe-sur-le-Lac, Pointe-Calumet and Saint-Joseph-du-Lac. The results indicate that resilient landscapes could be incorporated in the vernacular landscape, if local cultural values are adhered to.

Keywords: *Greater Montreal Area; climate change; socio-cultural obstacles; Green Infrastructure; Room for the River; resilient landscapes; resilient communities*

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This research has been partly made possible through the support of Stichting NH BOS

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ter bevordering van de landschapsarchitecuur

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Preface

In my early years, as a child of parents who worked in the diplomatic corps, I had the incredible opportunity to travel the world and experience life in many cultures, traditions, and languages. During my formative years, however, I lived in Montreal, Canada where I pursued a bachelor's degree in urban planning at Concordia University during which my passion flourished. Little did I know it was only the beginning of my path as I spent hours panning around satellite images of the Greater Montreal Area (GMA), trying to interpret the patterns and the various flows - urban expansion, transportation networks, green networks, water networks and electrical networks - that connected each neighborhood. The final studio of my studies gave me a taste of landscape architecture. I instantly craved more green spaces, more trees, more vegetation. In February 2017, I moved to Wageningen.

Within months of arriving in the Netherlands, a disastrous spring flood event struck southeast Ontario and southern Quebec. Thousands of people were displaced, many of whom endured irreparable damage to their homes. It became clear to me that I wanted to focus my master's thesis on flood adaptation in Montreal, one of many North American cities that relies on insurance companies to 'save' their livelihoods. Over the next year-and-a-half, I would be immersed in the Dutch culture of managing water; in a country where one doesn't win the water-battle, they learn to flood safely and adapt.

One of the main challenges of my master's thesis is tackling the socio-cultural differences between my internationally inspired flood-adaptation design solutions and the local North American context of my design site. I look to the writings of Joan Iverson Nassauer, a well published Minnesotan Landscape Architect, who wrote about the socio-cultural challenges of landscape ecology in the United States. I hosted a two-day design feedback event in May 2019, to further explore the Montreal perspective of the spring flood events and the potential for flood-adaptation.

The goal of my master's thesis is to motivate flood-resilient communities along the waterfronts of Greater Montreal. My case study involves three municipalities on the north shore of the Lake of Two Mountains: Saint-Joseph-du-Lac, Pointe-Calumet and Sainte-Marthe-sur-le-Lac. Large portions of these communities found themselves under water during this year's April-May (2019) spring floods. The study sites are reimagined to incorporate internationally inspired built and nature-based flood adaptive solutions in a Canadian context.

Introduction

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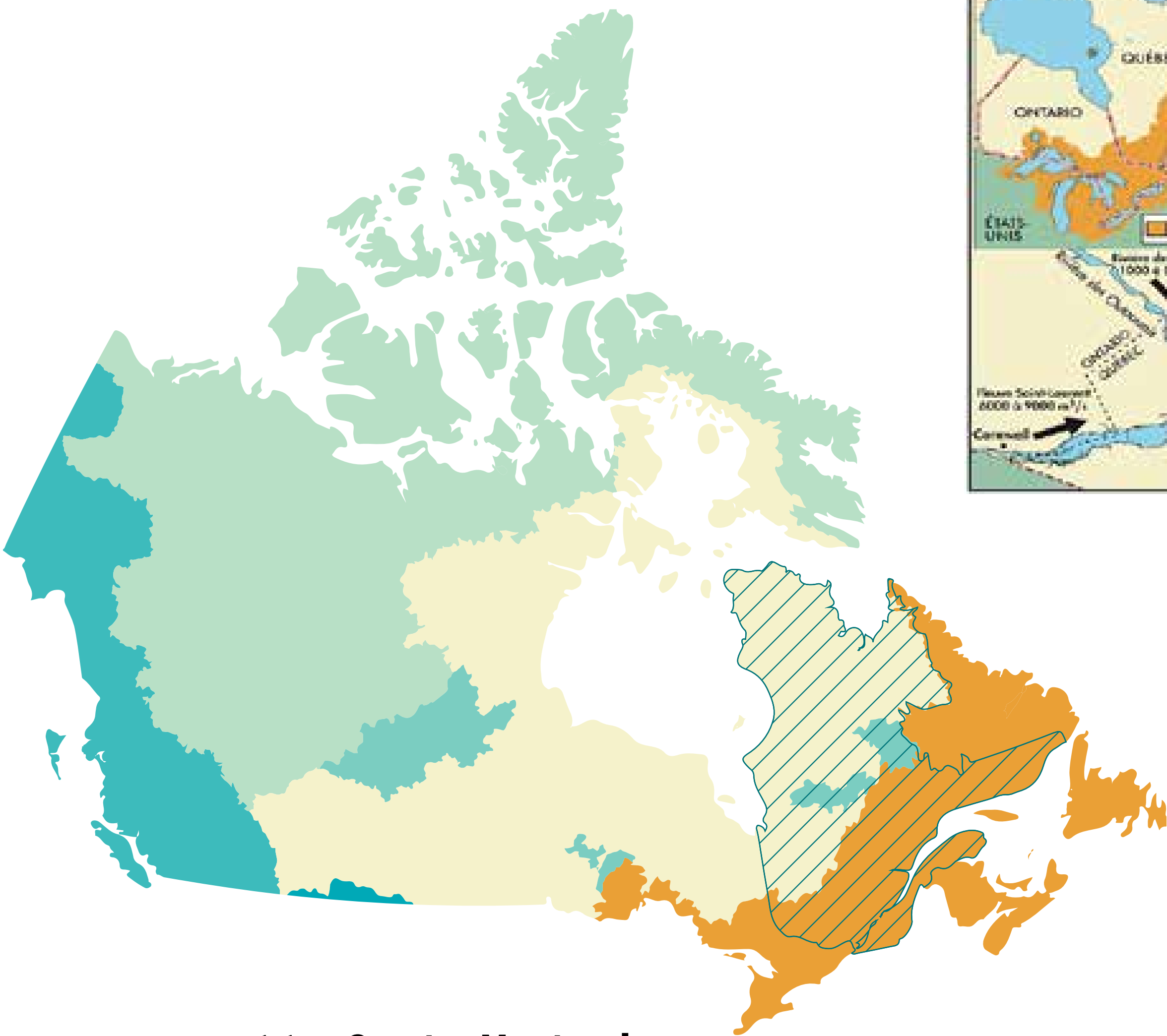
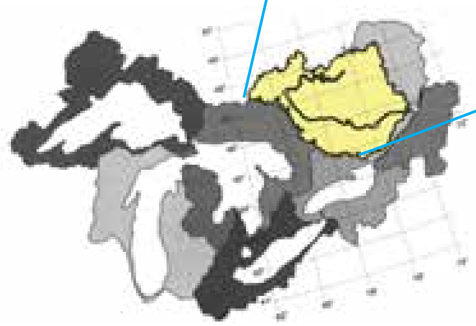


1.1. **Greater Montreal: Geographic Location**

The Ottawa River Drainage Basin encompasses an area of 150,000 square kilometres – an expanse larger than Hungary and Slovakia combined. Many of the northern tributaries are regulated through reservoirs and hydroelectric dams, as seen in the map below. The southern tributaries are free flowing, or uncontrolled, with water levels fluctuating in cohesion with seasonal weather patterns (Ottawa River Regulation Planning Board, n.d.). Carillon dam, the last dam managing the flow of the Ottawa River, is located 30-kilometers upriver from the Lake of Two Mountains (Google, n.d.-a).

The Ottawa River flows into the Lake of Two Mountains, at a maximum of 8000 m3/s, as it enters the Greater Montreal Area. From there, two tributaries flow northeast, encompassing the Island of Laval, and two flow southeast, into Lake Saint-Louis. The Saint Lawrence River, carrying up to 9000 m3/s from the Great Lakes, flows into Lake Saint-Louis from the west (Plans d'action Saint-Laurent 2011-2026, 2015). The fresh water (from the Lake of Two Mountains and Lake Saint-Louis) flows northeast, past Montreal, where it regroups and collectively becomes the Saint Lawrence River. The river continues to flow northeast and widens after it passes Quebec City. It continues its north-eastern journey for 800-kilometers where it opens out into the Gulf of Saint Lawrence, eventually joining the Atlantic Ocean (Google, n.d.-b).



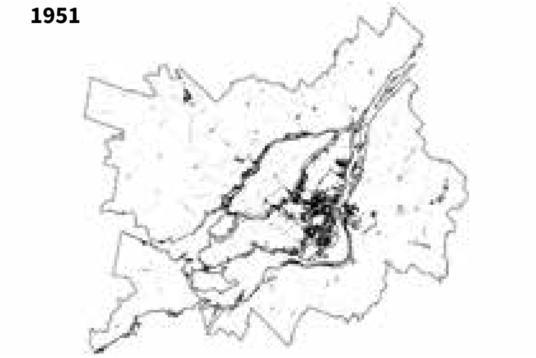
Top left: *Canada's five watersheds overlaid with the province of Quebec.*

Centre top: *The St. Lawrence watershed containing the Great Lakes and the water flow from the Saint-Lawrence and Ottawa Rivers as it enters Montreal (Plans d'action Saint Laurent 2011-2016, 2015).*

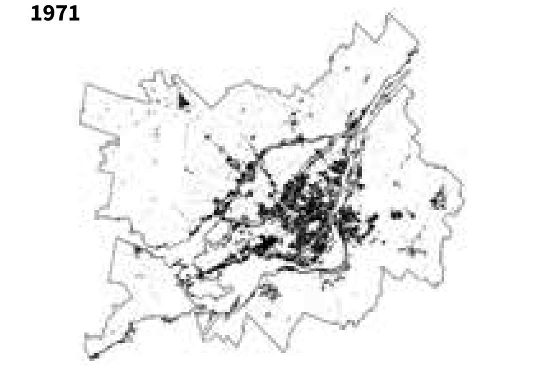
Top right: *The Ottawa River Drainage Basin with all of its tributaries, seen in context with the Great Lakes.*

Right: *The metropolitan area of Greater Montreal, encompassing the Island of Montreal.*

1951

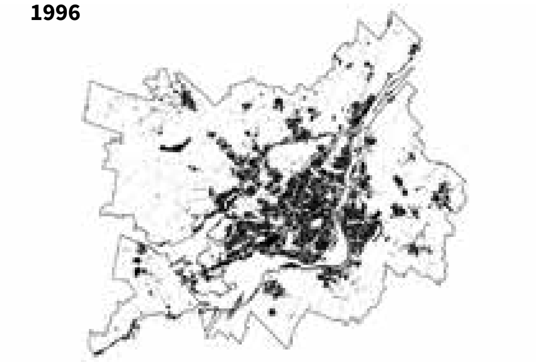


1971



1986

1996

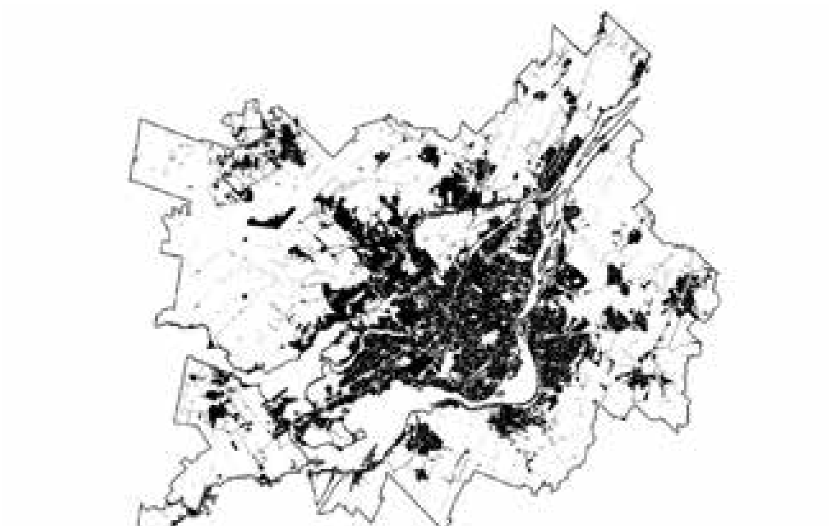


1.2. **Urban Growth Patterns**

A study that compared 96 North American cities, found that the least fragmented metropolitan areas were in Canada. In contrast, Montreal and Quebec City were the most municipally fragmented metropolitan areas in Canada – rendering them more comparable to American metropolitan areas than to their Canadian counterparts (Nazarnia, Shwick, & Jaeger, 2016).

The Montreal Census Metropolitan Area has been severely affected by urban sprawl, which increased 29-fold between 1951 and 2011. In the 1960's, Montrealers began settling the east and west of the island. At the turn of the century suburban sprawl was prevalent – a migration to Montreal's off-island suburbs was on the rise. Today, urban sprawl in Montreal continues at an exponential rate and appears to be out of control (Nazarnia, Shwick, & Jaeger, 2016).

Built-up areas in Montreal Census Metropolotan Area (2011)



(Nazarnia & Jaeger, 2014)

1.3. **Climate Change in Canada**

This past July, the Council of Canadian Academies published their report on Canada's Top Climate Change Risks (Expert Panel on Climate Change Risks and Adaptation Potential, 2019) for the Government of Canada. The report identified six top areas of climate change risks which could result in significant losses, damages or disruptions for Canada over the next twenty years. The three areas of risk addressed by this thesis are physical infrastructure, human health and wellness, and ecosystems; the unaddressed areas are coastal communities, northern communities and fisheries. The following are the Panel's (2019, p. ix) descriptions of the highlighted areas of risk:

Physical Infrastructure
"Risks to physical infrastructure in Canada from extreme weather events, such as damage to homes, buildings, and critical infrastructure from heavy precipitation events, high winds, and flooding; increased probability of power outages and grid failures; and an increasing risk of cascading infrastructure failures."

Human Health and Wellness
"Risks to human health and wellness in Canada, including adverse impacts on physical and mental health due to hazards accompanying extreme weather events, heatwaves, lower ambient air quality, and increasing ranges of vector-borne pathogens."

Ecosystems
"Risks to Canadian ecosystems and species, including threats to biodiversity, ecosystem resilience, and the ability of ecosystems to provide a range of benefits to people such as environmental regulation, provision of natural resources, habitat, and access to culturally important activities and resources".

"Since 1948, Canada's annual average temperature over land has increased by approximately 1.7 °C – roughly double the global average level of warming."

- Expert Panel on Climate Change Risks and Adaptation Potential, 2019, p.ix.

Climate change risks are complex and unpredictable, affecting natural and human systems alike. Their interconnections create a challenging environment for adaptation planning and implementation. Flooding poses risks to physical infrastructure, which impacts human health and wellness through the disruption of health and safety services along with an interruption of water treatment and distribution services. The degradation of ecosystem services can also exacerbate flood risks (Expert Panel, 2019).

According to the Panel, "climate change is advancing too fast for natural systems to keep pace" (2019, p. x). Conservation, restoration and management practices are needed to enhance ecosystem resilience. Adaptive measures must consider systemic interconnections across the six areas of risk, in addition to factoring in the socio-economic and technical feasibility of said measures when evaluating their potential (Expert Panel, 2019).

1.4. **History of fluvial flooding in Montreal**

Montreal has a history of flooding. Montrealers are affected by a myriad of problems ranging from flash floods to storm-water pipes backing up and flooding homes through toilets and drains to water mains bursting in the streets. Since 1886, nine major riverine floods have hit the Island of Montreal. The latest one was in May 2017 (CBC, 2017).

Climate change has been credited as one of the leading factors of the most recent flood event. Extreme rainfall events occur more frequently, as the global temperature rises it increases the humidity in our atmosphere (Greenway, 2018). Urbanization also has a hand in climate change. Buildings, roads, and parking lots reduce the permeability of the landscape, while increasing the local temperature. Urbanization not only encourages development up to the edge of the river, it also promotes covering wetlands, where rainwater accumulates seasonally. Wetlands typically reveal themselves during the winter melt and spring showers. Water temporarily accumulates before draining into adjacent streams and rivers, evaporating, getting absorbed by trees and vegetation, and penetrating the ground water table (Montgomery, 2017).

[1] geomatics: collecting, storing, processing and delivering geographic data (GISGeography, 2018).

(Rachiele, 2014)

(Chiasson, 2017)

Spring 2017

In April 2017, southern Ontario and Quebec endured an unseasonal temperature fluctuation. The temperature plummeted below freezing and then rose again rapidly, causing the accelerated melting of snow in the Ottawa river drainage basin. The Ottawa river jammed with the expanding and contracting surface ice. Forty-eight hours of non-stop rain flooded the drainage basin. The Carillon dam, the last resort for water retention along the Ottawa River, surpassed it's 100-year flood capacity (Ottawa River Regulation Planning Board, 2018).

Every spring an average of 5000 m3/s of water passes through the Carillon dam. During the 2017 flood event 8862 m3/s of water flowed through the Carillon dam, breaking historical records. Engineers set the dam to hold back 20% of the water flow, which translated to a reduction of 50-90cm of rising flood waters in the hardest hit riverine communities (Ottawa River Regulation Planning Board, 2018). Their efforts weakened the flood impact, but not enough to mitigate its devastating effects.

Between May 3rd and May 16th, the floods affected 261 municipalities across Quebec: 3 deaths took place, 5,371 residences were flooded, 4,066 people were evacuated, approximately 550 roads were damaged and 2,600 Canadian military personnel were engaged in mitigation and clean-up operations (Gignac & Legaré, 2017).

Spring 2019

Winter 2018-2019 brought about one of the harshest and longest winters experienced in the last couple decades. Snow began accumulating at the beginning of November and the last snowstorm occurred in the first 10-days of April. The heavy winter weather – more familiar to the 1980's & 1990's – was followed by two-weeks of warming weather and heavy rainfalls, swelling rivers and lakes to unprecedented levels. This resulted in a second "1-in-a-100-year" flood event for southern Ontario and Quebec.

As of April 24th, close to 2500 homes were flooded and almost 1500 Canadian armed force and reservists had been deployed to build sandbag walls and assist in evacuations (CBC, 2019a). Montreal Mayoress, Valerie Plante, declared a state of emergency on Friday, April 26th, fearing that the rising water levels would overwhelm the city's dikes (CBC, 2019b). The following evening a 20-meter wide channel breached the 41-year-old dike protecting the lakefront municipality of Sainte-Marthe-sur-le-Lac. Over 6000 residents were evacuated from 2500 homes in under 45-minutes (Bruemmer, 2019). The April 2019 spring floods affected 250 municipalities across Quebec; over 10,000 people were evacuated from their homes (CTV Montreal, 2019b).

Montreal Timeline *(CBC, 2017) (CTV Montreal, 2019b)**

Spring 1886	Montreal. Saint-Lawrence River. Caused by ice jam, built up 8m high. 3 deaths. 'Millions' in damages.
1965	Saint-Lawrence River. 20-people died. Caused by ice jam.
Spring 1971	Ottawa River Basin. Flooded Lake of Two Mountains & West Montreal to Lac St. Pierre along St. Lawrence River.
1974	300 municipalities affected. Province wide - spring snow melt. 1600 homes flooded. 10,000 people evacuated. $99.6-million cost incurred
Spring 1976	Quebec wide floods. Unusually wet spring, runoff from snowmelt. $79-million cost incurred.
Spring 1987	South Central Quebec. Heavy rain and melting snow. 300 evacuated.
Summer 1987	Montreal. 100mm of rain in 1-hr. 2 deaths. 40,000 homes flooded. Tornado & severe thunderstorm. $112.4-million cost incurred.
Winter 1996	Montreal. 150mm of rain in 36-hrs. 121-municipalities & 6000 residences affected. 1000 people evacuated. $125.6-million cost incurred.
Spring 2017	Southern Quebec. Saint Lawrence River valley. Multiple freeze-thaw days in a row. 155mm of rain in 2-days. $223-million in insured damage. Total cost unknown.
Spring 2019	Quebec-wide floods. Above average snowfall. Warm temperatures and heavy rainfall. Over 10,000 people evacuated – 6000 in Sainte-Marthe-sur-le-Lac following a dike breach. Cost incurred unknown.

1.5. Precautionary Measures

The Canadian Government does not have a flood protocol, per se. Floods are dealt with in a top down approach, as seen in figure X. The following sections describe the level of involvement of the federal, provincial and local government, along with the non-government organizations.

Canada

The federal government has no direct input on the methods used by cities or provinces to implement their flood mitigation strategies. Instead, they are invested in establishing a framework to facilitate a national approach for flood mitigation. The framework organizes national floodplain mapping requirements alongside the acquisition and management of geospatial data. On a communicative level, the federal government has also set up various forums to guide Canadian geomatics[1] and emergency services management, which involves coordinating policies and legislation across all levels of government (Natural Resources Canada, 2017).

[1] geomatics: collecting, storing, processing and delivering geographic data (GISGeography, 2018).

Quebec

In June 2017, the National Assembly of Quebec passed Bill 132. The Act proposed to modernize the legal framework to ensure the conservation of wetlands and bodies of water. The Act amended legislation pertaining to land use planning, integrated water management, environmental and natural heritage conservation. A few notable changes included implementing water master plans adapted for climate change and creating a program to restore and create wetlands and bodies of water (Bill 132, 2017).

In February 2018, the Ministry of Public Security put forth an action plan regarding civil security in relation to flood events. They lay out 24-measures, covering three main topics, with the intention of creating a Quebec society that is resilient in the face of natural disasters. The three topics consisted of: knowledge, preparation & prevention, coordination & management, and best practices for the future. In addition, they address citizen and municipal responsibilities (Sécurité publique, 2018).

In December 1987, the Quebec Government adopted the 'Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains', one of the 68 policies & regulations framing the Quebec Environment Quality Act. The Policy was updated in January 2019. What pertains to this thesis project are the Policy objectives that include: preserving plants and wildlife characteristic of floodplains, rehabilitating riparian zones using natural techniques, and ensuring the safety of people and the protection of property (Protection Policy, 2018).

On April 30th, 2019, the Premier of Quebec, Francois Legault, reiterated that there was a need to redraw Quebec's flood maps and ban new construction in the flood zones. At the same time, he put a cap on the compensation that flooded property owners would receive. The offer was a cumulative $100,000 per property (not per homeowner) or $200,000 to move (CTV Montreal, 2019a). At the end of June, the interactive Zone d'intervention spéciale (ZIS) 2019 maps were released to the public. In July, a Quebec-wide public consultation was held in 25 locations. Over 5,600 participants attended in frustration. The ZIS map impacts residential property values and insurance. The map delineates the flood zones where a moratorium has been placed on new construction and the rebuilding of flood-damaged buildings (CTV, 2019b).

Montreal

Following the May 2017 extreme weather event, the ‘Direction de la sécurité civile et de la résilience’ (DSCR - Civil Security and Resilience Division) published an incident and feedback report regarding the river floods. The document, titled “Making Montreal a Flood-Resilient Community”, recommended that the city improve their support, coordination and communication with government agencies, first responders, city workers, and citizens. Updating flood zone maps was recommended with high importance, along with gaining knowledge about the risks and impacts of flooding, to enable them to propose mitigation measures (DSCR, 2017).

In 2014, the City of Montreal was the first Canadian city to join The Rockefeller Foundation’s 100 Resilient Cities. In June 2018, the city released its ‘Resilient City Strategy’. The document described thirty specific actions categorized under various objectives. The objectives most pertinent to my project (p 27-54, City of Montreal, 2018) are to:

- *Strengthen the community’s capacity to adapt and react to natural and anthropogenic risks*
- *Ensure improved consideration of risks in land use and infrastructure planning*
- *Develop and sustain infrastructures to ensure the maintenance of services and essential systems*
- *Collaborate and share expertise in order to promote informed decision-making*
- *Establish interactive communications between authorities and the public to circulate information daily and alert citizens in the event of a disaster*

The City of Montreal was lucky to be selected as one of the 100 Resilient Cities. Unfortunately, The Rockerfeller Foundation announced that they would cease funding of their global climate-resilience initiative on August 1st, 2019. (Berkowitz, 2019). Hopefully Montreal will continue to pursue its objectives to achieve resilience, even without the support of the 100 Resilient Cities network.

NGO’s + Universities

In Ek et al.’s (2016) report about flood risk governance, the authors divide flood management into four categories: risk prevention (ie. spatial planning), flood defence (ie. dikes, dams, pumps, sandbags), flood mitigation (ie. building regulations, urban drainage, green infrastructure), and flood preparation (warning systems, mapping, knowledge building). In their key findings, the authors offer design principles to support societal resilience to flooding. They recommend that flood risk prevention includes discouraging development in flood zones, and if they must be developed, that the area be adaptive without further increasing the risk of flooding. Flood defence and mitigation should be integrated according to local circumstances. Finally, flood preparation (forecast and warning system) should be transmitted with enough time to act and learning opportunities should be provided to the community (in social groups and through institutions) (Ek et al., 2016).

In addition to highlighting the socio-economic risks of floods, Moudrak and Feltmate (2017) further support Ek et al. (2016), by proposing twenty best practices for new flood-resilient communities in Canada. Their report intends to set a standard for new residential communities; reducing liability and improving local coordination and planning, construction quality and public awareness. Intended for municipalities, developers and homebuilders, their report is supported by The Standards Council of Canada (Moudrak & Feltmate, 2017).

As mentioned in section 1.3, on July 5th, 2019 the Council of Canadian Academics (2019) released “Canada’s Top Climate Change Risks: The Expert Panel on Climate Change Risks and Adaptation Potential”. The report addresses the most pressing risks of climate change in Canada and determines which of the risks have the greatest potential to be reduced through adaptation measures. This research addresses three areas facing climate change associated risks: physical infrastructure, human health & wellness, and ecosystems.

1.6. **Relevance**

Sociocultural relevance

The population of the Greater Montreal Area continues to rise in cohesion with its rate of urbanization. Canadians will not shy away from their popular waterfronts, even in the face of climate change and all the risks that it carries. Ahern (2011) emphasizes the importance of “social learning and meaningful social engagement and participation in decision-making and policy setting” (p. 343). Instead of putting up walls or redirecting the problems associated with flooding, adaptive solutions need to be found to create resilient communities. Adopting flood adaptive solutions can boost the local economy – driving the need for creative solutions in myriad business practices and its associated labour force. Creating resilient communities increases property values and contributes to the health and wellness of the local population.

Environmental relevance

According to the Expert Panel on Climate Change Risks and Adaptation Potential, “since 1948, Canada’s annual average temperature over land has increased by approximately 1.7°C – roughly double the global average level of warming” (2019, p. ix). Climate change is becoming more apparent as Canadians experience intensified extreme weather events. These extreme weather events are growing in frequency, impacting natural and human systems. The natural systems are our lifeline and greatest source of mitigation for climate change risks (Panel, 2019). In 2017, the European Environment Agency (2017) published a report on green infrastructure and flood management. Table 1 (adapted from their ‘overview matrix and ranking of green versus grey infrastructure measures’), elaborates on the direct and indirect effects of wetland restoration & management and flood plain restoration. The indirect effects, or ecosystem benefits, illustrate the importance of restoring and managing vital landscapes associated with rivers and lakes.

Resilient Landscapes

In the last few decades Montrealers have escaped the city and begun migrating to the ‘cottage country’ waterfronts of Greater Montreal. As these areas urbanized and four-season houses filled the landscape, the need to protect properties from seasonal flooding became evident. Flood defence took a ‘fail-safe’ approach (Ahern, 2011) – concrete retaining walls and dikes were constructed along the waterfronts. Recently, intensifying weather events has created the need to implement resilient solutions that are ‘safe-to-fail’ (Ahern, 2011). Adaptive urban planning and landscape design strategies are essential for building urban resilience capacity in the face of climate change. Innovative alternative landscapes – such as floodplains and wetlands – must be integrated along side vernacular landscapes, in order to support the expanding city and growing population of Montreal.

	Direct and indirect effects of wetland restoration & management and floodplain restoration												
	Direct effects			Indirect effects (ecosystem benefits)									
The effect scores range from 1-3, where 1 represents a low effect, 2 represents a medium effect, and 3 represents a high effect.	Storing and slowing run-off	Storing and slowing river water	Reducing run-off	Water storage	Fish stocks and recruiting	Natural biomass production	Biodiversity preservation	Climate change adaptation	Groundwater recharge	Erosion control	Filtration of pollutants	Recreational opportunities	Aesthetic/cultural value
Wetland restoration and management	3	2	1.7	2	3	2	3	2	2	1	2	2	2
Floodplain restoration	3	3	2.3	3	3	3	3	2	3	3	2	3	3

Table 1: *Direct and indirect effects of wetland restoration & management and floodplain restoration*

1.6. **Thesis Outline**

This design-oriented research report consists of eight chapters. Chapter 1 introduces the Greater Montreal Area, its geographic location within the context of Quebec, Canada, the Ottawa River flood basin and the Saint Lawrence watershed. The urban growth patterns and the history of flooding are described, along with the precautionary measures undertaken by governing and non-governing bodies, and the top climate change risks in Canada. The subsequent chapters illustrate the theoretical framework guiding the research (chapter 2) and the research design (chapter 3), which includes the research questions, objectives and methods. Chapter 4 details the design feedback event and my reflection following the experience. The case study is identified in chapter 5; analysing the baseline conditions and further assessing the impact of the floods through site visits. Chapter 6 delves into nature-based solutions, like green infrastructure and Room-for-the-River, which motivated my design principles. Chapter 7 tests the design principles on the case study: the municipalities of Saint-Joseph-du-Lac, Pointe-Calumet, and Sainte-Marthe-sur-le-Lac. The alternative floodscapes are evaluated and an all-encompassing design is illustrated. Chapter 8 concludes the report with a discussion and recommendation.

Theoretical Framework


2

"A more strategic than normative concept, because, to be effective, resilience must be explicitly based on, and informed by, the environment, ecological, social, and economic drivers and dynamics of a particular place, and it must be integrated across a range of linked scales."

- Ahern, 2011, p. 342

2.1 **Resilience Theory**

Developed societies function on a 'fail-safe' mentality, where science and technology are relied upon to maintain socio-economic needs, improve health and safety, and rehabilitate ecosystems and the natural environment. Ahern (2011) challenges this 'fail-safe' mentality and asks, "how can a static landscape condition be sustainable in a context of unpredictable disturbance and change" (p. 342)? Resilience theory proposes a new perspective, a 'safe-to-fail' approach that designs systems strategically to anticipate, contain and minimize failures. Ahern (2011) defines resilience as "the capacity of a system to respond to change or disturbance without changing its basic state" (p. 342).

It is anticipated that by 2050, 70% of the world's population will be living in urban environments (Ahern, 2011; Staddon et al., 2018). In developed countries aging infrastructure is gradually being replaced and expanded; while in developing countries new infrastructure is being constructed. Increasingly harsh weather events, augmented by climate change, are being felt across the globe, but more so in densely populated urban environments. '100 Resilient Cities' defines urban resilience as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience" (What is Urban Resilience?, n.d., para. 2).

There is an opportunity to conceive resilient urban environments, made possible through urban plans, landscape designs and planning policies. Green infrastructure and nature-based solutions are considered key ideas to build resilience capacity (Ahern, 2011; Staddon et al., 2018), which will be discussed further in chapter 6: design motivation.

2.2 **Non-equilibrium Theory**

Equilibrium ecology, interpreted as the 'balance-of-nature' metaphor, advocates that the Earth system is partially self-regulated to maintain conditions for life (Briske, Illius, & Anderies, 2017). Holling (1973) argues that the equilibrium-centered view does not maintain a realistic understanding of system's behavior, and that "the influence of random events upon natural systems further confirm the existence of domains of attraction" (p. 15).

In their article, 'Nonequilibrium ecology and resilience theory', Briske, Illius, & Anderies (2017) recognize a shift in the human perception of nature, which challenges "the prevailing perception of ecosystem stability and rapid, linear recovery following natural or human disturbances" (p. 198). Non-equilibrium theory asserts that landscapes and ecosystems undergo relatively sudden and unpredictable reconfigurations in which component parts merge, separate, or randomly combine (Jelinski, 2005). This was substantiated by "inconsistencies in natural resource management outcomes" (Briske, Illius, & Anderies, 2017, p. 198).

As seen in the introduction (section 1.4.1), Montreal experienced two 1-in-100-year flood events in the last few years; in 2017 and again in 2019. Though the floods were both triggered by rain, they were initiated by different causes. The floods in 2017 were caused by back-to-back spikes in the temperature rising and falling, which created ice jams along the Ottawa River. Two-days of heavy rainfall caused the river to back up and overflow into the lowlands inhabited by waterfront communities. The floods in 2019 were provoked by an unseasonal accumulation of snow across the Ottawa River flood basin. Two weeks of warming temperatures and sporadic rain caused the snow to melt rapidly; an overabundance of melted snow flowed downstream, driving the water level of the Ottawa River and all its tributaries to swell to unprecedented levels.

"Natural and cultural systems are inherently variable, uncertain, and prone to unexpected change."

- Ahern, 2011, p. 341

Comparing these two recent flood events demonstrates the importance of considering the unpredictability of weather events on the landscape, particularly in the face of climate change.

2.3. **Messy ecosystems, orderly frames**

Though not a theory per se, Joan Iverson Nassauer, a well published Minnesotan Landscape Architect, wrote extensively about the socio-cultural challenges of landscape ecology in the United States. Nassauer observed that "We know how to see ecological quality only through our cultural lenses, and through those lenses, it may or may not look like nature. Nature has come to be identified with pictorial conventions of the picturesque, a cultural not ecological concept" (Nassauer, 1995b, p. 161).

"What is good may not look good, and what looks good may not be good."

- Nassauer, 1995b, p. 161

Our cultural perspective of landscapes is conceived "according to the political system in which we operate, the economic use we see for land, our aesthetic preferences, [and] our social conventions" (Nassauer, 1995a, p. 230). As an example, Nassauer mentions a city council, a park board, and engineers referring to wetlands as a new landscape feature, while the residents living by the proposed intervention site referred to them as swamps. The local perception of nature is aligned with the inhabitants social and personal values (Nassauer, 1995a). While the concept of nature is appreciated and sought after, it falls out of the vernacular when it looks too much like nature. To fit cultural expectations, "wetlands are mown and planted with exotic species, prairies are planted with trees, and woodlands are mown and cleared of dead wood" (Nassauer, 1995b, p. 163).

According to Nassauer, "it is a public landscape problem," one that "requires the translation of ecological patterns into cultural language. It requires placing unfamiliar and frequently undesirable forms inside familiar attractive packages. It requires designing orderly frames for messy ecosystems" (Nassauer, 1995b, p. 161). One of the main challenges of my master's thesis is tackling the socio-cultural differences between my internationally inspired flood-adaptation design solutions and the local North American context of my design site.

Pursuing a professional career as a landscape architect in Montreal will involve creating a relationship with vernacular design traditions. The culturally accepted notion of "picturesque nature produces a landscape that looks tended, not wild" (Nassauer, 1995b, p. 163) will need to be an evolving guiding principal in order to be adopted in the local context. Nassauer's 'orderly frames' will be required to establish a recognizable framework for landscape designs.

Research Design

3.1. **Problem Statement**

The island of Montreal sits at the bottleneck of two great rivers converging as they flow towards the Gulf of Saint-Lawrence. The residents of Greater Montreal value their waterfront lifestyle and have established communities along the water's edge, often encroaching upon land prone to flooding. As extreme weather events occur more frequently it is imperative that the government, the infrastructure, the services and the residents adapt to the reality of climate change.

Motivating residents to invest in adaptive landscapes that they value contributes to resilient communities. In addition to accommodating the ebb and flow of seasonal flood waters and extreme flood events, these landscapes provide socio-economic, ecological, environmental and recreational opportunities.

3.2. **Knowledge Gap & Research Objective**

Knowledge Gap

Montreal is a North American city with unpredictable flood events. Having endured two major fluvial flood events within three years obliges all levels of Government to initiate preventative measures. The flood adaptive procedures, the communication systems and the method for maintaining services have yet to be discovered.

Research Objective

1. To explore a typology of nature-based solutions and flood-adaptive infrastructure.
2. To motivate and facilitate the establishment of resilient communities by creating an environment aligned with communal values and the availability of financial resources.

The first objective explores a typology created from the design principles which were derived from the literature study. The second objective is the underlying goal of this research. The proliferation of urban sprawl in Greater Montreal and the intensification of climate change, necessitates the creation of resilient communities. The objective of motivating and facilitating through a typology of alternative solutions aims to spark a discussion, a pilot project, instead of proposing a single design solution. The case study illustrates the potential of resilient communities in a flood plain and in a littoral environment.

3.3. **Research & Design Questions**

Design Question

How can combinations of green (nature-based) and grey (built) infrastructure be used to create resilient communities along the waterfronts of Greater Montreal?

The design question encompasses both research objectives. The purpose is to create different scenarios (combinations) using the typology created from the first research objective. The typology will be derived from the second sub-research question, seen below. The second objective showcases the holistic potential of resilient communities, achieved through the first sub-question. The goal of the design question is to illustrate the resilience capacity of Greater Montreal's waterfront communities.

Research Question

What are the socio-cultural implications of using international flood adaptive landscape solutions in a North American context?

Sub-Questions

1. What kinds of littoral landscapes encompass Greater Montreal?
2. What types of adaptive landscapes offer both protection and value to littoral and flood plain communities?
3. What kinds of socio-cultural obstacles challenge adaptive landscape design?

The first and second sub-question pertain to the design research question. Together they recognize a landscape typology for adaptive landscapes and analyze a site to test the prospective scenarios. The third sub-question concerns the socio-cultural challenges of implementing non-vernacular landscapes, which contributes to answering the primary research question.

3.4. **Research Design**

Constructivist Worldview

When conducting research, it is important for the researcher to understand their worldview considering it guides their process. Creswell (2014), defines worldviews as "a general philosophical orientation about the world and the nature of research that a researcher brings to a study" (p. 6). This research is conducted through a constructivist worldview. Focusing on the specific environments in which people live and work, clarifies the historical and cultural context of the research. My academic, cultural, and personal experiences shape my interpretations of the data collected. The theories employed in the research were generated from recognizing patterns in the findings (Creswell, 2014).

Qualitative Case Study

This qualitative research aims to explore and understand a problem sought out by the researcher (Creswell, 2014). In this study, the problem is socio-cultural and environmental and employs a landscape typology to seek alternative solutions for creating flood resilient communities. A case study enables an in-depth analysis of the processes that guide the problem at hand. The researcher utilizes inductive reasoning to ascertain the complexity of the problem (Creswell, 2014).

Research Strategy

Designing is the primary tool of a landscape architect. The research methods, therefore, comprise both research and design. The research is performed to fulfill a curiosity or a question, while the designs are created in the form of tangible objects or spaces of varying scales. The research strategy for this study employs 'research for design', where research contributes to the reliability and the quality of the design (Lenzholzer et al., 2013). In this case it would be a literature study, which enabled design principles to guide the formation of a typology, as well as an understanding of the socio-cultural implications of nonvernacular landscapes. The second half of the design process tests the design principles in a case-study. This form of research is 'research-on-design', as it is an evaluative process on the 'finished' design (Lenzholzer et al. 2013) – which alternatively is a selection of potential design scenarios.

3.5. **Research Methods**

Literature Study

A literature study was conducted throughout the research, collecting data from secondary sources. Mass media reports and primarily online news publications were used to understand the extent of the flood events described in the introduction (chapter 1) and in the case study (chapter 5). Government and government-supported publications were also referenced for the case study. Earlier research was studied to understand resilience theory, non-equilibrium theory and socio-cultural obstacles, clarifying their applications in my research (chapter 2) and answering sub-question 3. The landscape design (chapter 6) was motivated by a study of nature-based solutions, which are promoted by government and government -supported organizations. Green Infrastructure and the Room-for-the River programme were studied at length, design principles were derived and used to guide the creation of a typology of landscape elements, answering the second sub-question.

Structured Interviews

Two structured interviews were conducted to collect primary data. An interview schedule, with closed and open-ended questions, facilitates the interview process (Kumar, 2014). The first face-to-face interview was conducted in English. The second face-to-face interview was conducted in French, creating several misunderstandings caused by a lack of appropriate vocabulary. Interviews are time-consuming, but they are appropriate for collecting in-depth information (Kumar, 2014). The interviews resulted in a greater understanding of the 2017 flood event, it's impact on waterfront communities and the involvement of the government, as seen in the introduction chapter. Moreover, the interviews informed the third sub-research question.

Questionnaires

Two questionnaires were devised to collect primary data from the design feedback event. The questionnaires, created using google forms, were accessed through a QR code shared with the participants of the design feedback event (chapter 5). Using google forms facilitated the data collection, as the program graphs the results. Both questionnaires were primarily closed questions and ended with an open-ended question. Closed questions provide respondents with ready-made answers that may not truly reflect their opinions, but they do ensure that the data is obtained and easier to analyse (Kumar, 2014).

The goal behind the questionnaires was two-fold: the first questionnaire was designed to explore the participants existing knowledge regarding the 2017 and 2019 floods, and their perception of flood-adaptative strategies. The second questionnaire surveyed the participants willingness to apply flood adaptive strategies to their personal environments. Both questionnaires ended with the same open-ended question, enabling a comparison of their perception of how to create flood resilient communities. Open-ended questions allowed the participants to share what they learned from the flood adaptive design principles. The original intention of the design feedback event was to guide the landscape design principles. Subsequently, they contributed to the third sub-question. The results of the questionnaires and the outcome of the feedback event are discussed in detail in section 5.5.

Landscape Analysis

A landscape analysis was conducted to understand the baseline conditions of the study site. The data source consists of a variety of printed and interactive maps, namely: soil, topology, hydrology, land-use, and the 2017 and 2019 flood maps. Aerial satellite images were also a useful tool to assess the landscape at varying scales, contributing to the first sub-question. A series of maps were created to provide a visual context for the baseline descriptions of the case study (chapter 5).

Site Visits

Five site visits were conducted between April and June 2019. The first two site visits took place prior to the 2019 spring flood event. These two visits were to Anse-a-l'Orme Nature Park, the initial study site established following the 2017 flood event. The third site visit was conducted after the floodwaters had peaked, but the floods were ever-present; waterfront properties on the Lake of Two Mountains remained submerged for several weeks.

The fourth site visit was conducted to investigate the damage caused by the spring floods. Homeowners were hard at work, removing the damaged materials, airing out their homes, and preparing to repair them. This was the most pertinent visit, as it was to Sainte-Marthe-sur-le-Lac – one of the case-study sites. The dike breach had been temporarily repaired, but the destruction it had caused was clearly visible amongst the dozens of abandoned trailer homes that had lost their footings. Grey-brown high-water marks lined houses, fences and trees. Though I had seen dozens of photographs and videos while the flood event was live, reality kicked in when I was standing on site. Details and photographs from the fourth site visit are seen in the case study chapter, section 5.4.

The final site visit resulted a similar experience to the Sainte-Marthe-sur-le-Lac visit. I was considering another waterfront flood plain community as a case-study, but it did not end up in my final selection. Collectively, the site visits contributed to sub-question one.

Landscape Design

The previously listed methods led to a flood adaptive design typology at varying scales. A combination of the typologies was selected to create three alternative landscapes for Pointe-Calumet and Saint-Joseph-du-Lac, and three alternative landscapes for Sainte-Marthe-sur-le-Lac. Portions of the alternative landscapes, also referred to as floodscapes, were highlighted through rendered plans. The plans were further illustrated through aerial or human-perspective visualizations. The final design incorporated all six highlighted floodscapes to create one final alternative floodscape. The final design was evaluated, keeping in mind that the plan wasn't meant to solve the flooding issue, but to motivate a myriad of possibilities offered by design typologies 'toolbox' to create flood resilient communities in Greater Montreal.

3.6. **Methodological Framework**

Design Question

How can combinations of green (nature-based) and grey (built) infrastructure be used to create resilient communities along the waterfronts of Greater Montreal?

Main Research Question

What are the socio-cultural implications of using international flood adaptive landscape solutions in a North American context?

Subquestion 1

What kinds of littoral landscapes encompass Greater Montreal?

Landscape analysis of Pointe Calumet, Saint-Joseph-du-Lac, and Sainte-Marthe-sur-le-Lac
+
Site visits of waterfront communities along the Lake of Two Mountains

Subquestion 2

What types of adaptive landscapes offer both protection and value to littoral and flood plain communities?

Literature Study of Green Infrastructure and Room-for-the-River

Design Typologies Toolbox

Subquestion 3

What kinds of socio-cultural obstacles challenge adaptive landscape design?

Literature Study
+
Structure interviews
+
Questionnaires at Design feedback event

Case Study

Alternative Floodscape

Conclusion
Discussion
Recommendation
Reflection

DESIGN FEEDBACK EVENT:

Flood plain communities of the future


4

4. Design Feedback Event: Flood plain communities of the future

Initially, the research design of this study intended to draw direction from a 'design feedback event', also known as a collective administration (Kumar, 2014). The event was devised to understand the knowledge of participants, regarding flood-mitigation, and to receive feedback about integrating flood-mitigation strategies surrounding the vernacular landscape of Anse-à-l'Orme Nature Park, in western Montreal.

At the stage of the design proposal, the goal of the feedback event was two-fold: first, there was a need to answer sub-question 3 – What can participatory feedback contribute to landscape design?

Where, feedback was received under two conditions:

1. Participants primary emotional response, the general community's response to the discussion, the ambiance or general vibes, the conversations around the objectives.

2. Written feedback from participants in the form of notes indicating their likes, dislikes, interest, disdain and curiosity regarding elements of my design proposals.

The second goal of the feedback event was to guide the design process, by receiving feedback about the tentative design principles.

Invitees

There are many ways to invite people to an event. Several different methods were used to try and attract the most amount of attention. Over 320 invitations were sent/distributed for the feedback event. The following is a breakdown of the varying methods of invitation.
Email invitations were sent to forty-four government employees; which included the Mayor of Montreal, mayors of the five municipalities bordering my (initial) study site, municipal councillors, municipal urban planners, representatives of the department of sustainability and nature park managers. Email invitations were also sent to thirty-two professors from the University of Montreal and Concordia University. The professors specialized in various fields, including: landscape architecture, urban planning, geography and hydrology, climate change, transportation, mapping, land-management and water-management. Finally, ten invitations were sent to local secondary and post-secondary schools, as well as to the heads of communication of a several Montreal NGO's specializing in sustainable development.

In addition, the event was listed on the online events page of the local suburban newspaper. A Facebook event was created, and 114-contacts were invited or added to the event by other invitees. 120-printed invitations were distributed in the mailboxes surrounding the venue. A sign was place at the curb, leading to the venue, advertising the feedback event. The sign was there for 8-hours on the first day and 8-hours on the second day.

4.1. Event structure

The event was hosted at Maison Lantier, a heritage house available as a venue in the suburban municipality of Kirkland, in the northwest of the island of Montreal. The neighborhood bordered Anse-à-l'Orme Nature Park and was not flooded by the 2017 or 2019 floods. The event was open to the public on Friday, May 24th, between 13:00 and 20:00 and again the following day, Saturday, May 25th, from 10:00 to 17:00.

Five stations were indicated using the numbers 1-through-5, printed on A4's. An introduction board explained the project, including the motivation and the intention of the event. This was followed by a mobile questionnaire accessed through a QR code. The tentative design principles were posted on a stand and included six flood adaptive

landscapes and two flood adaptive housing types. A second mobile questionnaire was once again accessed through a QR code. The final stage was to discuss the participants flood experiences, ideas, and questions about the project. Traditionally, there is no one to clarify or further explain a question to the respondents (Kumar, 2014), but in this case I was there if there was any confusion – but denied any help to answer the questions.

The following will describe the questionnaires and the tentative design principles in detail. There was a total of 12 participants – the results of the design feedback event will be shared in section 5.5. The full questionnaires can be seen in appendix I and II.

4.2. **Questionnaire 1**

The first questionnaire, accessed through the accompanying QR code, was designed to explore the attendees understanding of the 2017 and 2019 spring floods. The questions were aimed at discovering their understanding of the importance of flood plains and wetlands their perception of existing flood-adaptation strategies. The questionnaire ended with an open question, seeking the participants' suggestions for creating flood-resilient communities.

4.3. **Questionnaire 2**

The second questionnaire was designed to discover how the participants perceived their place of residence, adapted to harvest rainwater in the form of green roofs, bioswales and rain gardens. They were also asked to share their view on flood adaptive solutions in their built environment. The second questionnaire ended in the same open question as in the first questionnaire, inquiring into the participants views on creating flood-resilient communities.

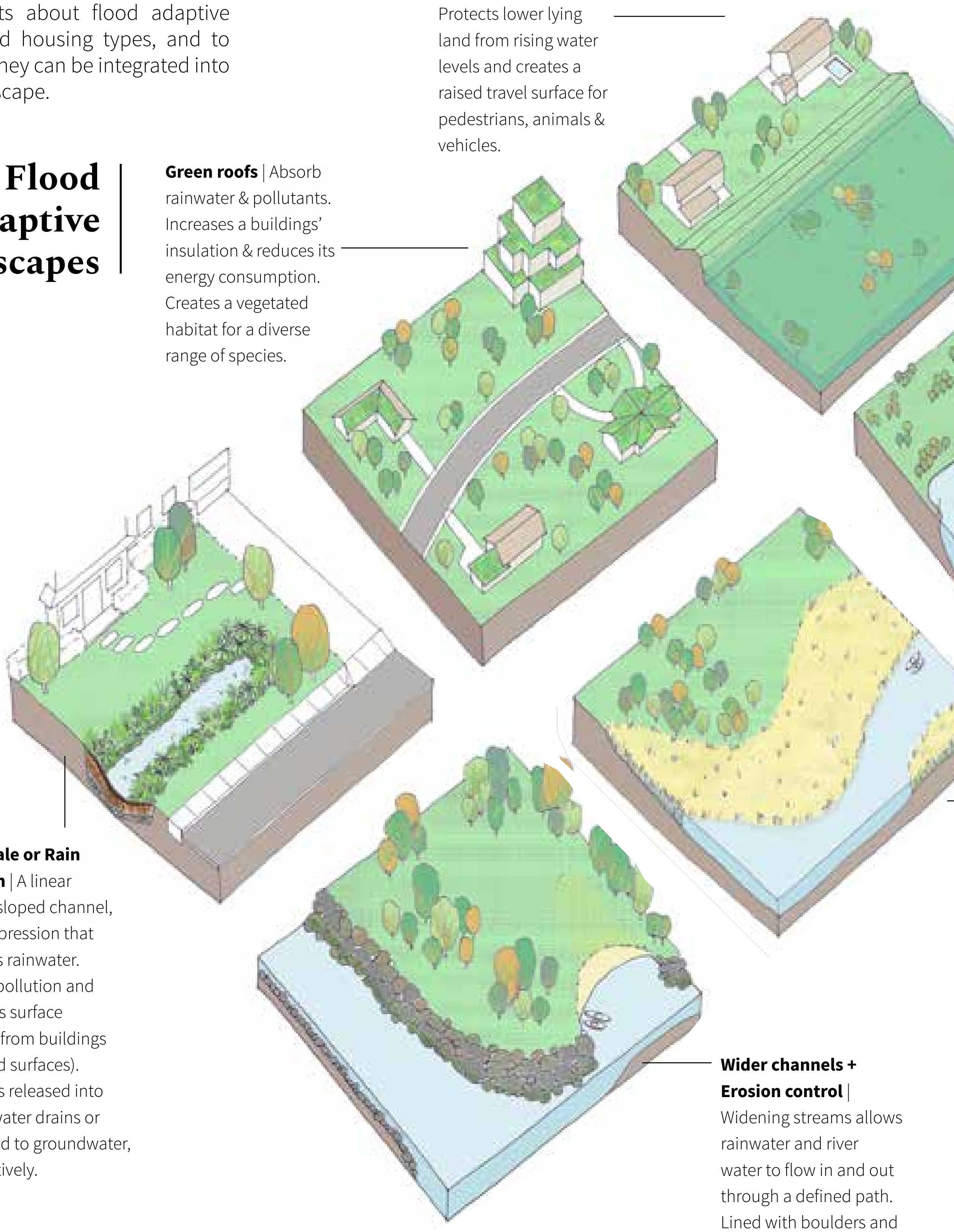
4.4 **Flood Adaptive Design**

The tentative design principles and flood mitigation plan were created to inform the participants about flood adaptive landscapes and housing types, and to illustrate how they can be integrated into a familiar landscape.

Flood Adaptive Landscapes

A dike | A linear earthen "hill" strategically made of clay, sand and earth. Protects lower lying land from rising water levels and creates a raised travel surface for pedestrians, animals & vehicles.

Green roofs | Absorb rainwater & pollutants. Increases a buildings' insulation & reduces its energy consumption. Creates a vegetated habitat for a diverse range of species.



Bioswale or Rain Garden | A linear gently sloped channel, or a depression that collects rainwater. Filters pollution and absorbs surface runoff (from buildings & paved surfaces). Water is released into stormwater drains or returned to groundwater, respectively.

Wider channels + Erosion control | Widening streams allows rainwater and river water to flow in and out through a defined path. Lined with boulders and rocks to reduce erosion.

River Groynes | Linear structures made of boulders, laid perpendicular to the river. Deflects the river current, increasing water flow & reducing ice jams. Collect sediment, creating natural beaches and slows down erosion.

Marshlands | A wetland dominated by grasses, rushes or reeds. Found at the edge of lakes, rivers and streams. Filter sediment and pollution as water flows through and provide habitat for aquatic and terrestrial plants, animals and insects.

Flood Mitigation Plan

The sketchy plan grounded all the flood adaptive landscape types into Anse-à-l'Orme Nature Park and its surrounding neighborhoods. Participants were asked to critique and comment about the various intervention sites.

Flood Adaptive Housing

Amphibious Houses | A flood adaptive house built on a dock-like foundation. Sits within a fixed location and uses flexible pipes. Rises in the event of a flood, buoyed by the floodwater.

Floating Homes | A flood adaptive house built on a dock-like foundation. Does not have a motor but can be pulled to a new location. Anchored to posts - rises and descends with fluctuating water levels.

4.5 **Results**

The feedback event was formulated with the May 2017 floods in mind. The essence of time was experienced with a sense of determination, not with urgency. Less than a month before my design feedback event, southern Ontario and southeast Quebec were struck with the second, more intensified, flood event in the span of three years. The unpredictability of the 1-in-100-year floods impacted the direction of the event.

Over 320 invitations were distributed. Ten participants attended by word of mouth and via the Facebook event. Two participants walked in after viewing the signage placed on the curbside. 12 participants in total. This came as a surprise to me considering the urgency of the issue and the lack of direction from every level of governance. The low attendance represents the general lack of interest in the topic. Utilizing questionnaires with such a low response rate heavily reduces the sample size and is one of the disadvantages questionnaires (Kumar, 2014).

I received a few email responses to my event invitation. The 'Bureau de la transition écologique et de la resilience', Montreal's Department of Sustainability, supported my research and my feedback event. Though a representative was not able to attend, they displayed interest in any innovative ideas that I would propose. In an exchange with an urban planner from a waterfront municipality, they firmly expressed that the dam upriver controlled the water levels, and that the only solution municipalities have is evacuation. Their municipal intervention plan included a surveillance strategy and an allocated X-number of sandbags to a list of houses. They voiced the need to retreat from the rivers edge, where urban developments have infringed upon natural buffers, and instead to allocate those natural spaces to leisure activities. Finally, they shared that political courage was needed.

With regards to the first questionnaire, some interesting discoveries were made. The top five reasons for the 2017 & 2019 flood events (Q6) were listed as: a lack of flood-mitigation infrastructure, climate change, too much rain a short amount of time, overbuilt flood plains, and too much snow. The fifth reason most likely refers to the snow fall that caused the 2019 floods. As a precaution, disappearing marshlands, which is the sixth reason, is also taken into consideration. 59% of the respondents agreed that marshlands and wetlands were 'important for human safety' (Q9). In the open question (Q12), about creating flood-resilient communities, participants expressed the need for: more education, better absorption and drainage of rainwater, updated flood maps, more low-lying areas to accommodate flood waters, and a combination of flood-mitigating adaptive strategies.

The adaptive landscape typology and the flood mitigation plan did not garner the attention surmised during the planning of the event. Several reasons may be considered, including: the style of plan presented during the event, the low number of participants, or a general disinterest or uneasiness in producing an honest response.

The final questionnaire was designed to understand the participants place of residence and their local built environment, with regards to flood adaptive solutions. Living in an amphibious home was the more popular flood adaptive housing type (Q1), and the achievable intervention of choice was planting vegetation to absorb water

(Q2). Participants agreed (Q6) that we could reduce the impact of flooding if our built environment absorbed more water. Half of the participants believed that the floods were a man-made problem (Q7), in comparison to 17% who did not, while the remaining third believed that the floods were a natural phenomenon. 83% of participants agreed that the floods were exasperated by climate change (Q8).

When asked the open question for the second time (Q10), creating flood-resilient communities was envisioned through: education, encouraging the leadership of the government and the participation of citizens to integrate green solutions into flood-prone areas, the protection of wetlands and lowlands to support natural ecosystems and biodiversity, and adapting communities to deal with rising water levels. Surprisingly, two participants expressed that flooded communities cannot be avoided, and that we should not live in flood-prone areas.

Conclusion

In retrospect, it may have proved beneficial to devise a more extensive online questionnaire that could have been emailed or posted on social media and accessed through mobile devices (Kumar, 2014). It is difficult to request individuals to displace themselves and for a topic that is not of great interest to them. An online questionnaire would have been more accessible to a greater number of individuals. On the other hand, hosting a feedback event ensured a high response rate from the actual participants (Kumar, 2014) and they left the event with an increased awareness of their ability to contribute to flood-resilient communities. The aim of the feedback event was to understand the socio-cultural perception of flood-mitigation strategies in a Canadian landscape and I believe that to a certain extent, that was achieved.

4.6 Reflection

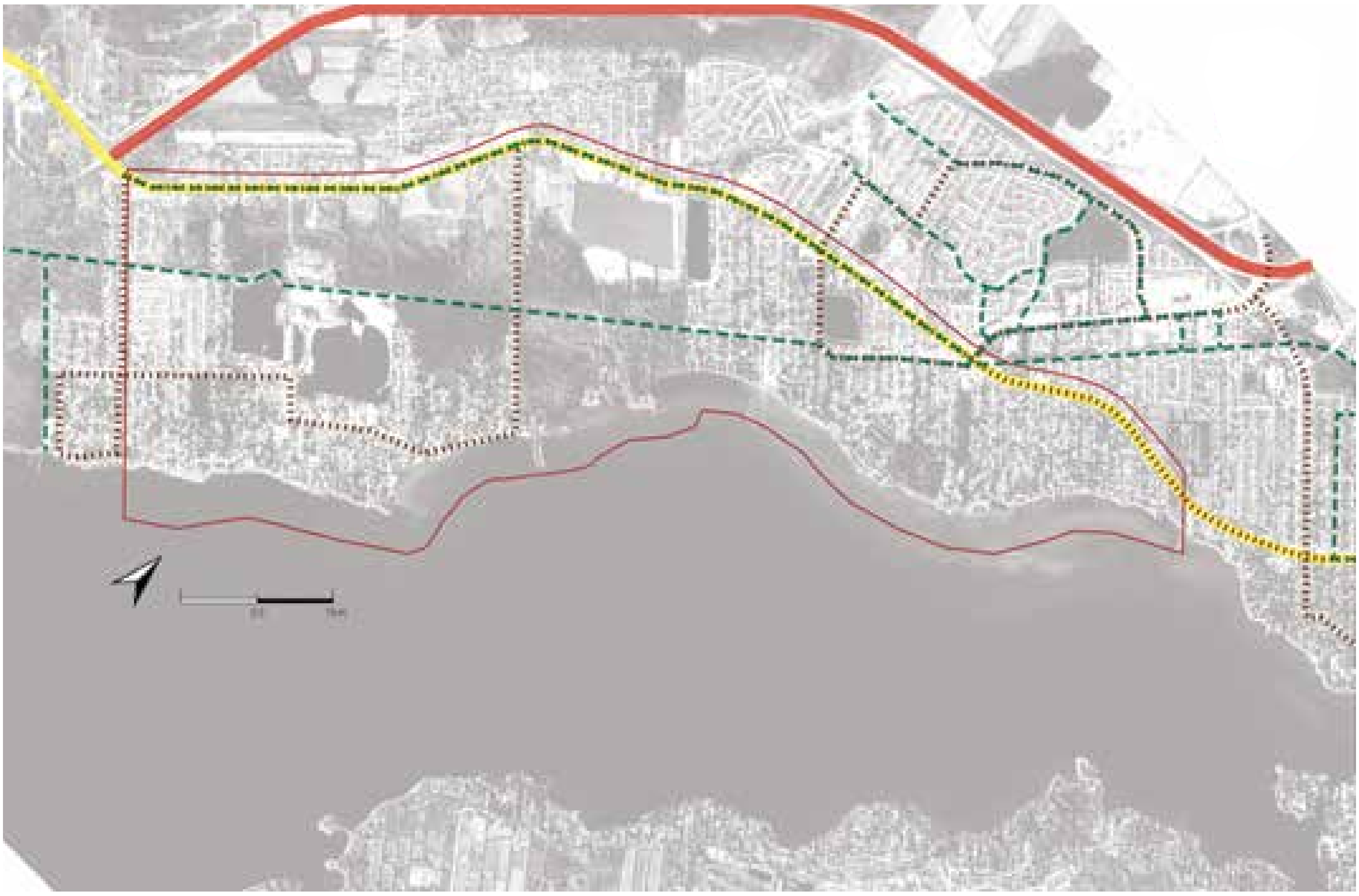
Flooding is not just a problem or issue to be tackled by riverine communities. The problem is dynamic, multi-dimensional and involves more actors than we can imagine – many of whom are unaware of their impact on the problem. Stormwater isn't something that people think about. I sure didn't think about it before learning about it in school. We all just assume that it rains, and the water goes down the drain & then its out of sight. When speaking to Canadians about my concerns with flood-mitigation and riverine communities, many of them voiced that they simply believe that people should move. Canada is a huge country there is no reason why anyone must live in a flood plain.

I didn't see it before, but the more I read about the ongoing issues of riverine floods and flash floods, the more I am realizing that the biggest issue is stormwater management. It isn't only a Canadian issue, but an urbanization issue – we are filling marshlands and other natural water retention basins with impervious surfaces. Housing developments, commercial developments, road network expansions are all guiding stormwater into drains instead of back into the ground. Montreal, like many cities, has piped its stormwater and sewage water together. Normally it travels up island to a "treatment facility" before being pumped into the river. When the pipes overflow during a heavy rainfall or a flash flood, they get backed up and the excess water flows directly into the river. Or into people's homes through any water connection (toilet, sink, tub).

The more I fly back and forth from Montreal to Wageningen, the more I can see that my research is socio-cultural. I feel like I have so many of the answers, or at least so many ideas, but I don't know who cares to hear them. Who has the power, the budget, the will to intervene with the landscape on such a large scale? Who has the political will to impose greenery laws or water retention laws? Water management established through landscape interventions is a normal day in The Netherlands. That is not the case in Montreal.

Case Study

POINTE-CALUMET, SAINT-JOSEPH-DU-LAC & SAINTE-MARTHE-SUR-LE-LAC



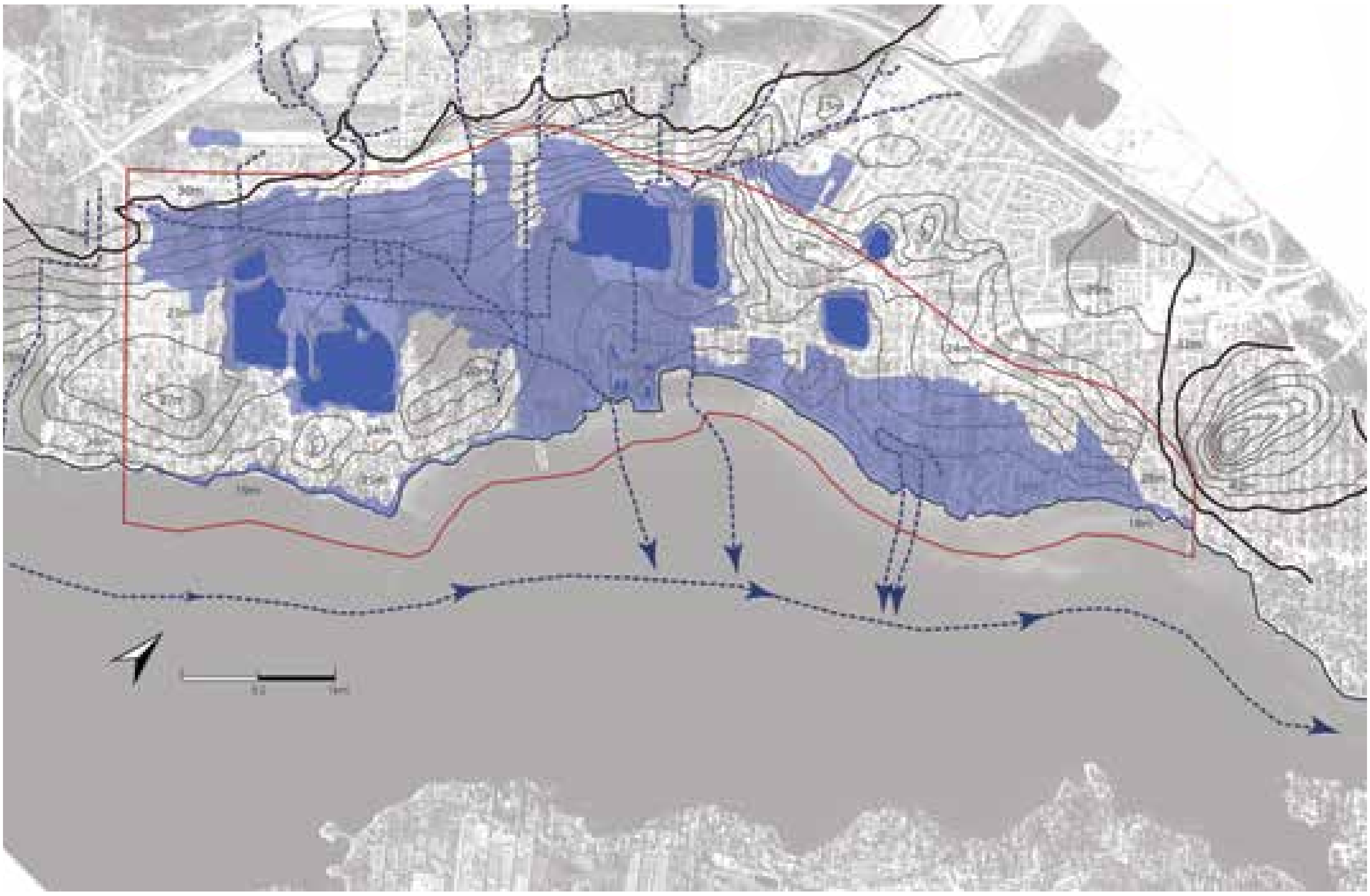
5.1. **Landscape analysis**

Accessibility

The municipality of Sainte-Marthe-sur-le-Lac (henceforth referred to as SML) is located on the north shore of the Lake of Two Mountains, SML is located approximately 50km from downtown Montreal. The town is accessible in 40-minutes via the Autoroute 13 & 640, or in an hour by commuter train and by one of three local busses from the Deux-Montagnes train station. SML has one marina and two public boat ramps.

The municipalities of Pointe-Calumet & Saint-Joseph-du-Lac (henceforth referred to as PC + SJ) are also located on the north shore of the Lake of Two Mountains, southwest of SML. PC and SML share a shoreline. Though they are adjacent to SML, PC + SJ are 90-minutes from downtown Montreal by public transportation and between 45-minutes to an hour by car – one exit after SML on the Autoroute 640. PC has four public boat ramps and two marinas, one on each extremity of their municipal shoreline.

There are two bike paths within the study area. One is located along Route 344 (also known as Chemin d'Oka); a two-way provincial road. The second bike path follows a repurposed Canadian National Railway line; starting at the Deux-Montagnes train station it runs parallel to residential streets through the wetland forest of PC + SJ, and ends in Oka National Park.



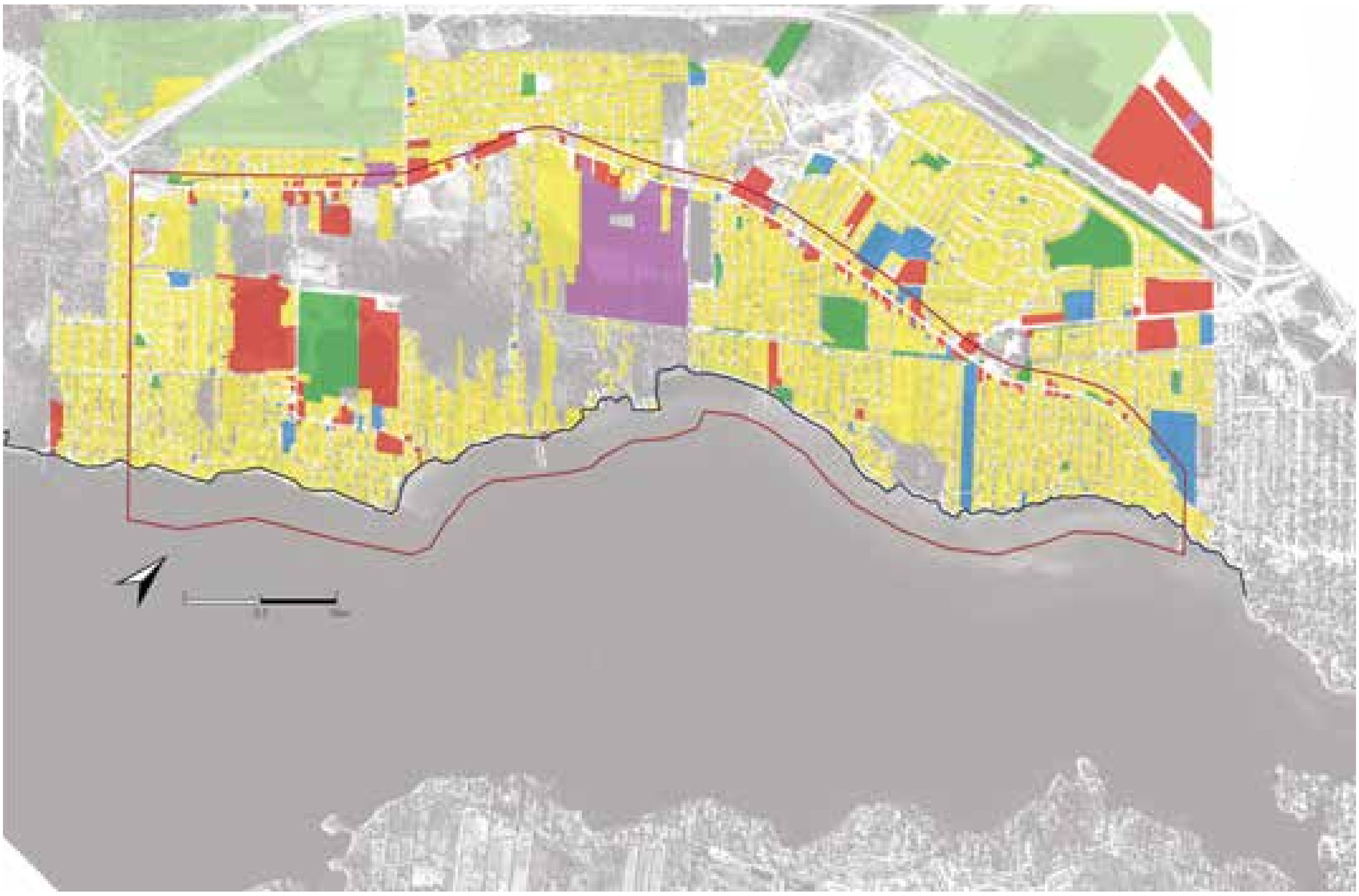
2019 flood extent
Lakes
Topography lines
Topography lines
Stream flow
Site extent

Topography & hydrology

Within the study site, the Lake of Two Mountains is 19-meters above mean sea level (MAMSL). The site steadily rises to an average of 25 MAMSL at the level of Route 344 (seen in yellow in the accessibility map). At the Autoroute 640 (seen in red in the accessibility map), SJ rises to 50 MAMSL and eventually forms a hill which peaks at 227 MAMSL, while SML reaches an average of 30 MAMSL at the Autoroute 640.

A dozen creeks flow through the agricultural fields of SJ, and the neighbouring municipality Deux-Montagnes, which drain into the wetland forest of PC + SJ on their way out to the lake. The wetland forest is a patchwork of pools at 20 MAMSL and hill-like features reaching 31 MAMSL While the study site within SML does not receive any stream water from the hills, rainwater does circulate through Parc de la Frayère and out into the lake.

There are several lakes within the study area – all of which are 400m-800m from the Lake of Two Mountains. PC + SJ have two lakes and a tree-enclosed pond; Lac de la Sablière is encompassed by a camp site and a handful of all-season residences, while Lac des Sables accommodates Super Aqua Club (a waterpark) and Beachclub (an outdoor dance club with a pool, a beach and a wakeboarding cablepark). On the east side of SJ a sand quarry was formed into private lake, which is used for solely for industrial purposes. Adjacent to this sand quarry lake is Lac-Val-des-Sables, home to one of SML's public beaches and the waterfront of a dozen residences. The other lake within the SML study site is a former sand quarry which was transformed into a private lake. It has a public park that lines the southern edge, but a fence restricts public access to the water.

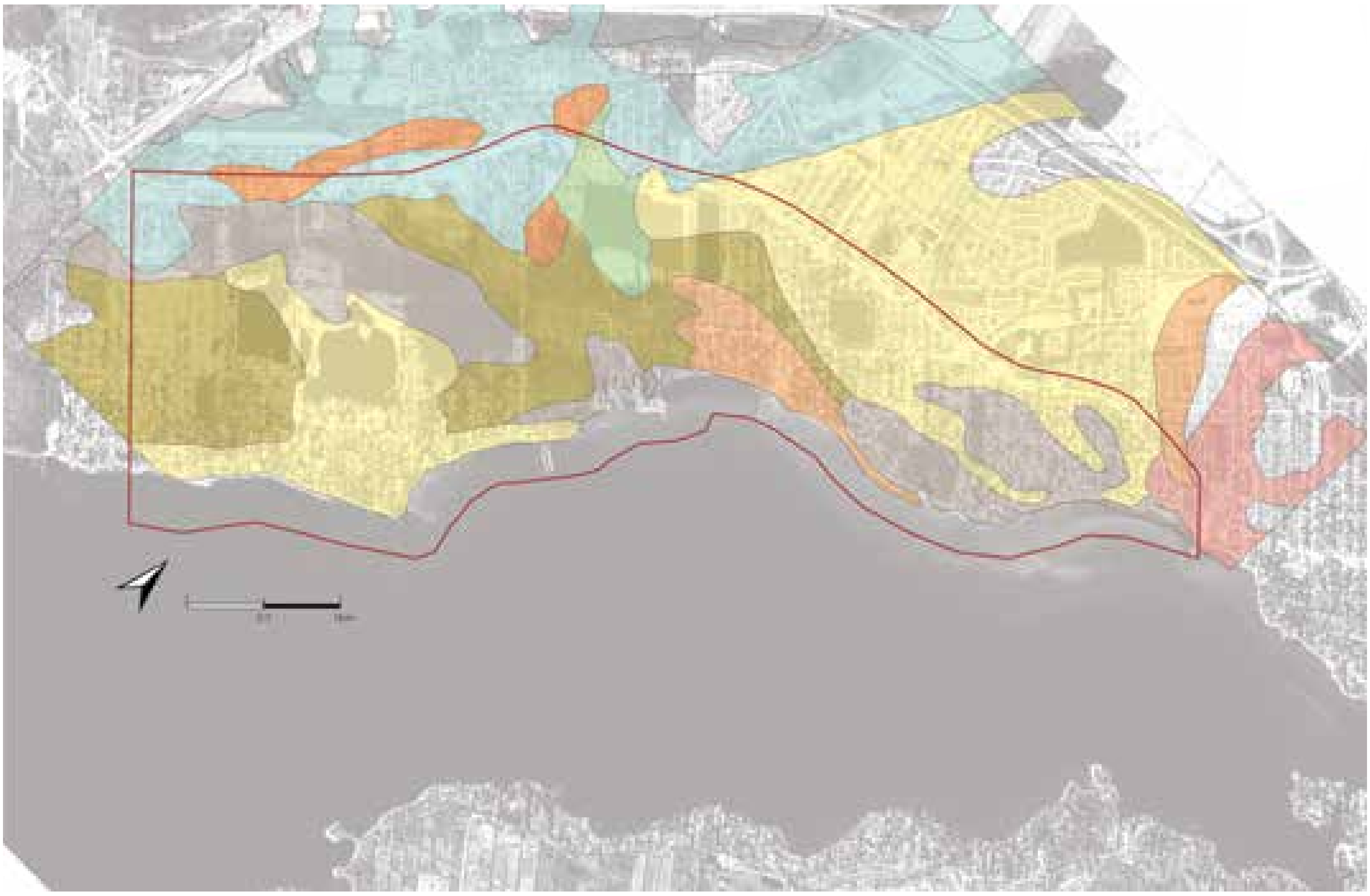


Land use

Within the study area, PC + SJ and SML are dominated by private residences, which are seen in yellow. Route 344 is made prominent by the commercial establishments, seen in red. A sand quarry is located within the large purple zone. Apart from the one commercial strip, there are very few commercial facilities available to the residents. Several public parks (in green) and institutions (in blue) are scattered throughout the residential neighborhoods.

Though they encompass almost half of the site within PC + SJ, the flood plain and wetland forest are undesignated spaces. Several residential streets creep into the space from the lake and from Route 344. A few residential properties, seen as yellow spots, were established in the wetland forest below the sand quarry.

Three recreational facilities, seen in red and green, are located in PC + SJ. The recreational area covers two lakes that house a camp site, a waterpark and a private beach. The rest of the lakes in the study site are detailed in the topography and hydrology section. Agriculture sites, seen in pale green on the north of site, run parallel to the Autoroute 640.



Soil types

The soil types mainly consist of coarse sand and fine gravel over clay (in cream), alluvial soil with a silty surface in a swampy land (in khaki), and peat in swampy land (in grey). The other soil types include fine sand (in peach), silty clay loam (in pale green), loamy sand (in orange), and marine clay (in blue).

Sandy subsoils sweep across the study site, creating the perfect conditions for inland beaches and sand quarries. The waterfront of SML was constructed in a swampy flood plain with a peat subsoil. Peat is also found across the wetland forest of PC + SJ, along with alluvial soil. A limited amount of residences were established within these soil conditions.

5.2. **Population growth**

Historically, PC and SML were cottage country. Residents inhabited the waterfront for three seasons, closed their cottages at the end of autumn, and hoped to return to a house in the spring (D. Legault, personal communication, March 27, 2019). As Montreal urbanized and expanded outwards throughout the 1960's, waterfront towns slowly developed into permanent residential establishments, as seen in section 2.1 (Urban Growth Patterns).

In the 1970's, The Lake of Two Mountains flooded three times. Following the 1976 flood, residents of Sainte-Marthe-sur-le-Lac [SML] decided that they no longer wanted to rebuild their cottages. In 1977, the federal government proposed a layout for a new dike, seen in figure 1. The completion of the dike motivated residents to construct permanent homes. The availability of land, low property taxes and its proximity to the city attracted new residents (Shingler, 2019). In the last thirteen years, SML's population grew from 11,311 to 19,216. A communauté métropolitaine de Montreal [CMM] projection expects the population to reach 26,595 by 2031, as seen in Table 2.

PC's population has remained relatively stable since 2006. Projections show that it will expand in the next decade, though the reason why is not specified. SJ has seen a steady increase in its population. The municipality is well known for apple orchards; attracting visitors during the harvest season. Recently it started to sell agricultural land for residential development.

	2006	*2011*	*2019**	*2031 projection**
City of Montreal	1,620,693	1,649,519	1,757,366	1,931,790
Sainte-Marthe-sur-le-Lac	11,311	15,689	19,216	26,595
Saint-Joseph-du-Lac	4,958	6,195	6,886	9,095
Pointe-Calumet	6,574	6,396	6,494	8,015

Table 2: *Population growth and projection in the Montreal Metropolitan Community*

Figure 1: *1977 flood zone map of Sainte-Marthe-sur-le-Lac, prior to the construction of the dike. (Government of Canada, 1977)*

5.3. **Flood event**

On Saturday, April 27th, 2019, a 20-meter wide channel breached the dike protecting the lakefront municipality of Sainte-Marthe-sur-le-Lac (Bruemmer, 2019). Shortly after the breach, Sûreté du Québec officers, the local police, the fire department and Canadian Forces soldiers went from street to street, evacuating over 6000 residents from 2500 homes in under 45-minutes (Olson, 2019).

The 2017 and 2019 flood events are described in section 1.4.

Left: *Sainte-Marthe-sur-le-Lac under flood waters (Pilon, 2019a).*

Below: *The 20m wide dike breach (Pilon, 2019b).*

5.4. **Site visit**

The site visit was conducted two-months after the dike breach. The most visible signs of the flood event were seen in the temporarily reinforced dikes, the waterlines on the houses and trees, and the left-over debris

Above: A publicly accessible dike was temporarily reinforced with gravel.

Left: A privately accessed dike was temporarily reinforced with sandbags.

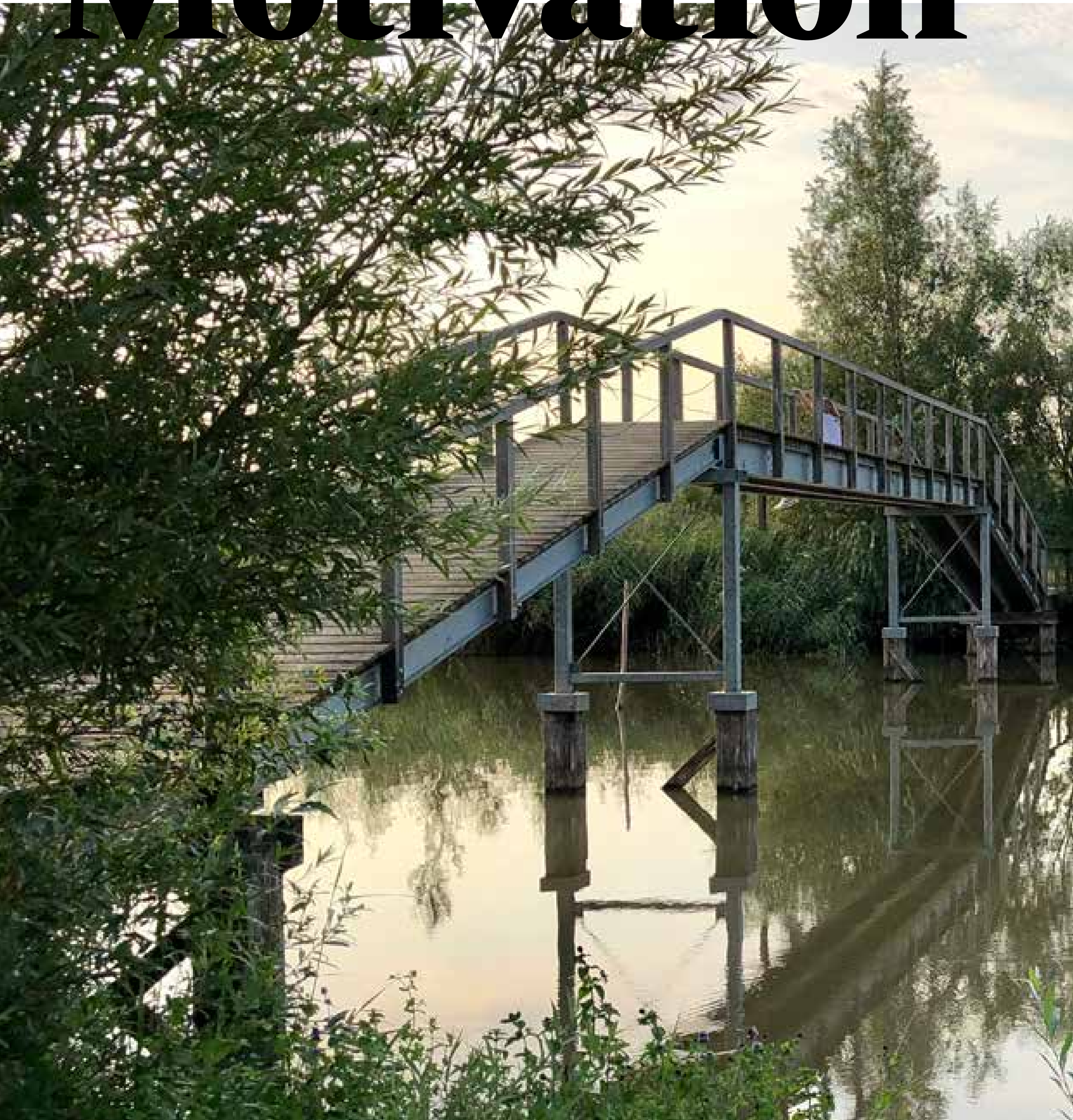
Below: High water lines mark the trees, meters from where the dike breached.

Above: A high water mark is visible across the garage doors and around the side of the house.

Left: A high water mark cuts across the porch railing, the side deck lies dilapidated.

Right: The dike breached at the trailer park. Some trailer homes were heavily damaged and were demolished when the floodwater resided.

Design Motivation




6

The Dutch coastline is 880-kilometers long, while the dike network is over 22,000-kilometers long, covering more than half the country. “For the Dutch, dikes are simply part of life” (LOLA Landscape Architects, n.d.). But for North Americans permanent dikes are still relatively unfamiliar. During the 2017 flood, sandbags were the main method for flood-mitigation in and around The Lake of Two Mountains. Aside from sandbags, some building owners installed sump pumps in their basement (D, Legault, personal communication, March 27, 2019).

Sandbags are a temporary solution. The 2017 and 2019 floods illustrated the importance of seeking long-term solutions to create flood-resilient communities. The flowing chapter investigates the possibilities offered by nature-based solutions and concludes with a toolbox of landscape elements that are used to design flood adaptive landscapes in chapter 7.

6.1. **Nature-based Solutions**

Nature-based Solutions (NbS) is an umbrella concept initiated by the International Union for Conservation of Nature and Natural Resources (IUCN). They are defined as “as actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al., 2016, p. 5).

A literature study is conducted to explore green infrastructure approaches and the Room-for-the-River program, which are both nature-based solutions. The findings of this literature study guide the design principles and consequently, the design typologies.

6.2. **Green Infrastructure**

In 2014, the United Nations Environment Programme (UNEP) published the “Green Infrastructure guide for water management: Ecosystem-based management approaches for water-related infrastructure projects”. The Green Infrastructure (referred to as GI going forth) guide covers a variety of water-management issues and provides holistic solutions. A description of each solution is provided, along with their primary and co-benefits. A breakdown of the initial costs and the maintenance costs are also presented, using a US or EU example and occasional international examples. Finally, international case studies and diagrams or photographs are used to further explain each GI solution.

This thesis project explores the water management issue of moderating extreme events, with a focus on riverine flood control and urban stormwater runoff, as seen in table 3. Traditionally, riverine flood control is tackled using dams and levees, while urban stormwater runoff is solved through stormwater infrastructure. With climate change intensifying and prolonging extreme weather events, it is important to look at long-term solutions that are cost effective

(Cohen-Shacham et al., 2016)

and environmentally friendly. According to UNEP (2014), “the capacity of GI to build resilience to climate shocks and variability has already proven to be affective in a multitude of cases around the globe”. Numerous cases are illustrated throughout the guide.

Much like the GI guide, I review pertinent GI solutions; providing a brief description, their primary and secondary benefits, along with the cost of establishment and their potential challenges. The primary and secondary benefits of each GI solution are also provided in Appendix I, adapted from “Ecosystem services (TEEB* classification)”.

Water management issue		Green Infrastructure solution	W	F	U	Grey Infrastructure equivalent
Moderation of extreme events (floods)	Riverine flood control	Re/afforestation and forest conservation	+			Dams and levees
		Riparian buffers		+		
		Wetland restoration/conservation	+	+	+	
		Constructing wetlands	+	+	+	
		Reconnecting rivers to floodplains		+		
		Establishing flood bypasses		+		
	Urban stormwater runoff	Green roofs			+	Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			+	
		Water harvesting*	+	+	+	
		Permeable pavements*			+	

Table 3: Green Infrastructure solutions
**comprise of built (grey) infrastructure in collaboration with natural elements*
(W = Watershed | F = Floodplain | U = Urban)
Adapted “Overview of GI solutions” table, from “Green Infrastructure: Guide for Water Management” (UNEP, 2014)

“The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative focused on “making nature’s values visible”. Its principal objective is to mainstream the values of biodiversity and ecosystem services into decision-making at all levels. It aims to achieve this goal by following a structured approach to valuation that helps decision-makers recognize the wide range of benefits provided by ecosystems and biodiversity, demonstrate their values in economic terms and, where appropriate, capture those values in decision-making.” -www.teeb.org

Re/afforestation & forest conservation

Reafforestation (or reforestation) is the act of planting trees where a forest once grew; in comparison to afforestation, which is planting trees where there is no historical record of a forest having grown. Re/afforestation increases the ability of soil to absorb water, weakening the effects of potential floods. Forested areas reduce soil erosion and stabilize slopes. In addition, they filter pollutants, regulate the local climate, improve air quality and benefit biodiversity. Forests also provide recreational value and alternative livelihoods for surrounding communities.

The cost of re/afforestation differ based on the location. Through forest management natural regeneration is possible, otherwise the costs include purchasing land, the future trees (as seeds or saplings) and the labour to plant them. The challenges include waiting for a ‘new’ forest to reach maturity and provide the services listed above, and the unpredictability of pests and invasive species, forest fires and other extreme weather events (UNEP, 2014).

Riparian Buffers

Also known as ‘shelter belts’, riparian buffers are strips of vegetated and forested areas established adjacent to rivers, lakes, and other waterbodies, which protect the water quality of aquatic environments by filtering sediments and other pollutants. Riparian vegetation and tree roots reduce soil erosion and stabilize slopes, in addition to absorbing water during flood events. Selecting appropriate vegetation can contribute biodiversity benefits; providing habitat for pollinators and birds, while potentially enhancing agricultural yields.

The cost of establishing riparian buffers varies greatly, depending on whether the land is public or private. Just like with the 'new' forests, the buffers often need to be planted. A buffer's efficiency increases according its width, its length and the size of its forested canopy. The challenges include droughts, which would impact the vegetation and its associated ecosystems, and fallen leaves/ dead vegetation, which could create a toxic environment for aquatic species (UNEP, 2014).

Wetland restoration/conservation

Wetland restoration involves revitalizing wetlands that have been drained and converted to other uses or lost due to human activities. Wetlands that have been drained can be restored, as they retain their soil composition and their hydraulic characteristics. The best way to retain the ecological and economic value of wetlands is to designate them as conservation sites. Wetlands play an important role in climate change – they can store large amounts of water, "minimizing the potential flood damage downstream and [increasing the] resilience to storms, thereby avoiding potential damage to grey infrastructure and human lives" (p. 25, UNEP, 2014). Wetlands trap sediments, create the greatest biodiversity benefits (between all the GI solutions) and provide recreational value and alternative livelihoods for surrounding communities.

The restoration costs of wetlands depend on the level of degradation, in addition to the size and location of the wetlands. The physical restoration is an investment, but the challenge lies with its maintenance; standing water may pose a threat to biodiversity and the surrounding communities (as a mosquito nursery). The long-term management is needed to ensure that the wetland recovers properly and can provide its associated ecosystem services (UNEP, 2014).

Constructing Wetlands

Constructed wetlands are artificial wetlands. They are typically shallow basins planted with dense vegetation and they attempt to mimic the hydrological functions of natural wetlands. While they are commonly designed as wastewater treatment areas (for urban wastewater, industrial wastewater, etc.), they can also store large amounts of stormwater runoff, just like natural wetlands. Constructed wetlands also trap sediments, create habitat for diverse species – predominantly fish, insects and migratory birds – and provide recreational value and alternative livelihoods for surrounding communities.

The costs associated with constructing wetlands depends on the location (size, slope, soil type), the material and labour cost, and most importantly, the function of the wetland. Digging up an artificial wetland site is more costly than damming. Depending on the former land use, pre-treatment may be necessary. Maintenance costs are lower than restored wetlands, and just like with 'new' forests, there is a possibility that invasive species would establish themselves (UNEP, 2014).

Reconnecting rivers to flood plains

Levees (dikes or embankments) are constructed parallel to many rivers, maximizing the use of the adjacent land. Levees require regular maintenance as they erode due to rapid flowing water and become vulnerable to breaching from flood waters. Aside from their costly maintenance, levees disconnect rivers and flood plains, prevent rivers from meandering, and increase the flood risk elsewhere along the levees.

Levees can be setback, reducing flood risks by re-exposing the floodplains and decreasing the water flow. As a result, rivers can meander and create floodplain habitats along the river edge, such as wetlands and forests. These newly accessible flood plains provide recreational value and alternative livelihoods for surrounding communities, while creating an adaptive environment for the intensifying effects of climate change.

Reconnecting rivers to floodplains involve the excavation and construction of new levees. The costs differ depending on the location of the restored floodplain. Conservation funding and flood-management funding can be combined to realize these large-scaled projects (UNEP, 2014).

Flood bypasses

Flood bypasses are another GI solution for reconnecting rivers to flood plains. Flood bypasses are commonly historic floodplains that are reconnected and inundated during major flood events. They provide two forms of flood relief: conveyance and storage. Conveyance is provided by opening a secondary route for the river to flow, which reconnects downstream. The bypass uses vegetation to create resistance, reducing the flow of the water. Another form of flood relief is storage, which functions as a floodwater reservoir. In this case the floodgates to an adjacent floodplain are opened as a flood is rising. These floodplains can safely store water and release it once the flood has peaked and begins declining.

The land use and the associated economic activities in the flood bypass correlates with the frequency (or infrequency) of inundations. Those that are frequently inundated provide environmental benefits; creating opportunities for wetlands, which in turn support natural vegetation, aquatic species, insects and migrating birds. Flood bypasses have the potential to be used as agricultural land or grazing land. In addition, they provide recreational value and alternative livelihoods for surrounding communities.

The two main costs associated with creating flood bypasses are the acquisition of land and the construction works: levees to direct the flood water and a weir or floodgate to manage the flood water. As with other GI solutions, the costs are location dependent and influenced by the characteristics of the floods. Generally, these large-scale projects require a high investment – which can be justified by the reduction of flood damage and the extensive list of co-benefits (UNEP 2014).

Green roofs

Green roofs are building roofs that are partially or fully covered with local and weather resistant vegetation. The roofs are covered in a waterproof membrane, topped with a mix of soil, sand or gravel and toped with plants (and sometimes trees). There are two types of green roofs: extensive roofs and intensive roofs. Extensive roofs have a soil depth of 5-15cm and are mostly aesthetic. Intensive roofs, which have a minimum soil depth of 15cm, accommodate more resilient vegetation including trees and plants with deeper roots.

Green roofs store large quantities of water, reducing stormwater runoff and alleviating the pressure on sewage systems during heavy rainfall. Green roofs combat urban heat island (UHI) effect – lowering the ambient temperature. In addition, they improve air quality (reducing public health stresses), insulate buildings (reducing energy costs), support local biodiversity, support local business initiatives and contribute to creating adaptive cities, in view of climate change.

The cost of installing a green roof primarily depends on its location and the type of roof. Green roof initiatives are occurring in many cities, in which case the material cost and labour costs could be lower. In areas with fewer green roof businesses, it may prove to be most costly. Maintenance is also required, but those costs also vary depending on the roof type and the climate. Once again, the overall benefits outweigh the installation costs (UNEP, 2014).

Green space (bioretention & infiltration)

Rain gardens and bioswales are (typically) found in urban green spaces and incorporate bioretention and infiltration systems into their design. These vegetated systems reduce stormwater runoff and filter excess nutrients and pollutants, which improve water quality and mitigate flooding. Bioswales are linear channels with sloped edges, filled with vegetation to absorb rainwater and pollutants. They are often located adjacent to roads and parking lots. The longer the swale, the cleaner the water. Rain gardens are shallow depressions, typically located the bottom of a slope, often receiving rainwater from bioswales. They are designed to retain large amounts of water and are vegetated with water tolerant plants.

Rain gardens and bioswales, like green roofs, reduce the impact of urban heat island (UHI) effect. On a larger scale they create habitats for local wildlife and can increase the recreational value of green spaces. The installation costs of rain gardens and bioswales are generally low, as are their maintenance costs. Regular inspections are required to ensure that all the elements are functioning properly. When designing these systems, it is important to understand the local hydrology (UNEP, 2014).

Water harvesting

Water harvesting is the redirection and storage of rainwater or stormwater runoff. In situ rainwater harvesting means that the water is stored in the soil. This is often done to replenish groundwater and helps to increase the fertility of the soil. Ex situ water harvesting entails redirecting rainwater, storing it in a reservoir - a dam, a well or a pond - and using at a secondary location. On a residential scale, rainwater can be captured and used as grey water or for irrigation. Water harvesting reduces the pressure on sewage systems and water treatment plants, both of which require a lot of energy. Less energy translates to lower CO_2 emissions and improved air quality.

The costs of water harvesting vary by geographic location and on the design of the system. Investments will also differ in rural environments compared to urban environments. In situ methods may only incur labour and construction costs, while ex situ water harvesting in urban areas will require storage systems, pumps and distribution pipes. Large scale rainwater harvesting can have a negative impact downstream; an understanding of the local hydrology is vital.

Permeable pavements

Permeable, or porous, pavement allows rainwater to penetrate the ground below. They are typically made of concrete or asphalt coarse particles or pavers. Below the permeable surface is a filtration layer (finer sediment) and a storage layer (gravel) that also supplies the structural support. Permeable pavement reduces stormwater runoff, which reduces flood risks and overflowing sewerage systems. They mitigate the urban heat island (UHI) effect and trap pollutants. In colder climates they reduce the need for salt during the winter, savings costs and reducing salt pollution in the water.
Permeable pavements can only be applied to low traffic areas, such as residential roads,

driveways and parking lots. Their installation costs vary, and they require regular maintenance. These porous surfaces need to be vacuum swept every season, to keep them from clogging. The surrounding soil needs to be monitored for increased pollutants. At the same time, rainwater infiltration must be monitored to ensure that negative effects aren't felt downstream (UNEP, 2014).

6.3 **Room-for-the-River**

In 1995, over 250,000 people and 1-million animals had to evacuated from riverside communities in The Netherlands. Instead of further reinforcing the existing dikes, a collaboration was made between provinces, municipalities, and water authorities to create room for the rivers to flood safely. The program would cost over 3.2 billion euros and would implement 9-methods at 34 strategic locations (Zevenbergen et al., 2013). It would take just over 10-years to complete, improving the spatial quality of the river flood plains, enlarging recreational areas around rural and urban communities, in addition to strengthening the economy (Ruimte voor de rivier, n.d.).

The Room for the River book, published by Blauwdruk in 2017, presents the conception and execution of the program. Every project is described in detail and an array of adaptive landscape solutions are proposed.

The following page is a list of design interventions, applicable to Greater Montreal. These were extracted as quotes from Yttje Feddes' chapter, The Added Value of Landscape Design (Sijmons, Feddes, Luiten, & Feddes, 2017, p. 35-47).

The quotes were then used to guide the design principles (section 6.4) and the design typologies (section 6.5).

"relatively large new expanses of water have been

"To start with, extensive soil excavations were needed to lower floodplains, dig channels, relocate dikes or create artificial mounds. These were followed by the construction of new engineering works, such as movable flood barriers, pumping stations and bridges. Finally, the land was re subdivided and landscaped where necessary to optimise aspects such as patterns of ownership and use, the management of natural habitats, the planting structure and routes for through traffic"

– Yttje Feddes, Sijmons et al., 2017, p. 43

Room-for-the-River

The following are quotes from Yttje Feddes' chapter, The Added Value of Landscape Design (Sijmons et al., 2017, p. 35-47).

p. 35

"relatively large new expanses of water have been created near towns, designed in combination with urban waterfronts, footpaths and new buildings.

"farming for nature (natuurboerderij) and recreational paths through the floodplains"

p. 36

"varied woodland fringes and river meadows have developed as a result of lowering the riparian zone between the dunes and the river."
"creating new country estates and design principles for new dikes. [...] principle of removing hard surfacing from the riverbanks."

p. 37

"making floodplains floodable and the development of robust natural habitats."

p.38

"flow has improved by removing summer dikes, levees and obstacles. [...] In almost all cases the contrast between the cultural and the natural landscape has become more pronounced."

p. 39

"In Room for the River projects water levels must be able to recede, so tall vegetation is only permitted in areas where little water flows. But in any case, the landscape-planning design idiom always seeks to create flowing lines that echo the morphology of the river."
"The Room for the River projects also involved considerable excavation, but always with a feel for the size and scale of the area."

p.41

"In polders that are subject to flooding there are rectangular dwelling mounts for architect-designed farmhouses, which have become typical elements of Room for the River."

"A wide range of quirky bridges have been built under the Room for the River programme: creek bridges, dike bridge, bridges in the form of a simple plank, and [...] urban bridges."

"flood protection was not provided by building an embankment but by planting a wide strip of willow coppice."

p.43

"The pursuit of landscape quality turned out to be more tangible than expected: a continuous dike profile, a well laid out recreational link between two existing routes, an attractively finished shoreline of a new channel, or a 'family' of new narrow bridges with a recognisable, gently arches, attenuated bridge deck"

p.45

"a delta dike has been created: an oversized hook in the landscape, designed and built to look like a gigantic grandstand with trees, looking out over the completely new landscape"

"the value of having an architecturally designed artefact [...] expressed the ambition of adding a recognisable, contemporary piece of civil engineering, [creating] favourable conditions for a strong design and careful detailing"

p.46

"Because existing properties and interests were often involved, negotiations were always needed on relocating, extending, remediating, connecting, managing or running these properties, land uses or interests.
Right from the start of the programme it was clear that good relations needed to be cultivated with farmers and conservation organisations. They would have to be offered prospects of improvement, modernisation and upscaling, and where that was not necessary or possible, proportional compensation"

p. 47

"The Room for the River programme enabled an enormous expansion of the outdoor recreational network over land and water. Routes have been laid out, joined up and revamped over and along new dikes, through floodplains and between villages and outlying areas. Marinas have been extended new navigable channels excavated, ferry slips improved, lookout points marked and designed, and outdoor furniture installed. Information boards have been placed with hitherto unknown zeal and enthusiasm. "

"The Room for the River programme has given the landscape surrounding the major rivers an enormous boot in accessibility and with it also publicity. In the wake of the recreational improvements in the visibility of historical and cultural artefacts has also increased in almost all cases. These include old brick factories, dilapidated pumping stations and sluices, historic farms, and old military fortifications and buildings. "

6.4 **Landscape Design Principles**

Underlying principles: safety & quality

Design combinations must be systemic – creating a coherent program inside and outside the floodplain

Existing buildings in the floodplain are removed/relocated as a last resort

New buildings are resilient – a percentage of roof surfaces must be green

New buildings inside the floodplain will have access to a dock, for emergency purposes

Engineering works are minimal, robust and designed as artefacts

Renewable energy and public transportation will be integrated to reduce the effects of climate change

Routing uses the smallest footprint possible – stormwater runoff drains through bioswales + rain gardens

New urban waterfronts and new public parks create recreational environments for the local community and for visitors alike

Multi-functional buildings integrate education and recreational activities

A new dike outlines a flood bypass, reconnecting the Lake of Two Mountains to it's floodplain

Groins will be used to reduce erosion, increase water flow, and mitigate ice jam scenarios

The floodplain is designed using a green infrastructure approach and selected Room-for-the-River principles

Riverine vegetation is laid out to echo river morphology in a recognizable pattern

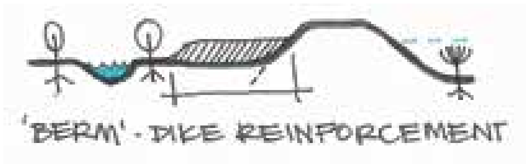
A wildlife sanctuary/nature conservation accommodates migrating birds and local biodiversity

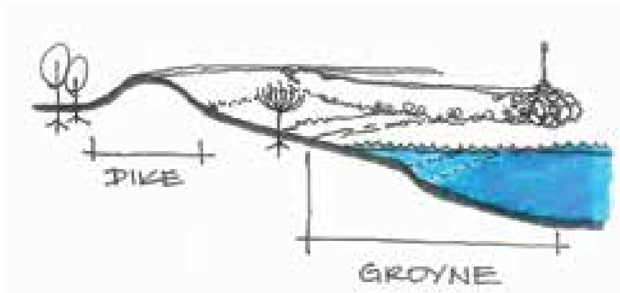
The floodplain design will create opportunities for grazing and alternative livelihoods

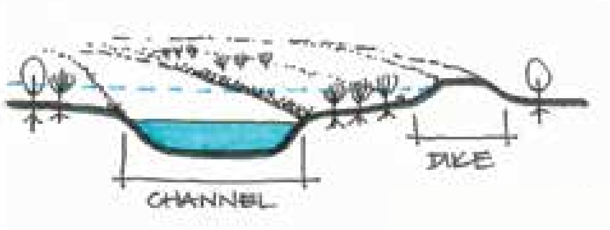
6.5 **Typologies: Design Elements**

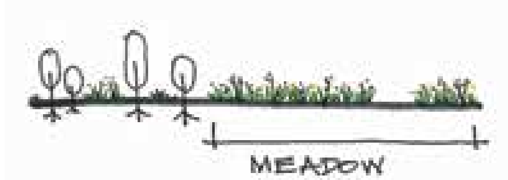
The landscape elements were created from the design principles, which were derived from a literature study of green infrastructure approaches and the Room-for-the-River program. The typologies are categorized into five main groups: flood management, climate change, public space, land-use and resilient architecture. The elements are not fixed to their category, and often fit in with more than group. For illustrative purposes, they only appear once within all five categories. In sections 7.1.4 and 7.2.4, the typologies are combined to form alternative floodscapes, which I define as an urbanized area that is prone to seasonal flooding.

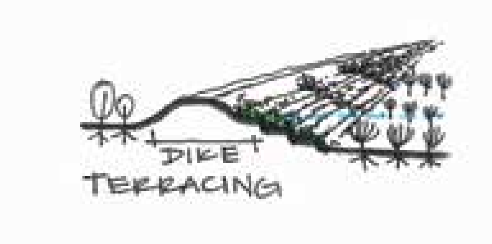
Flood Management

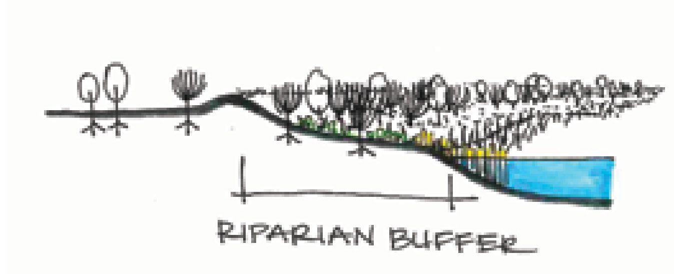


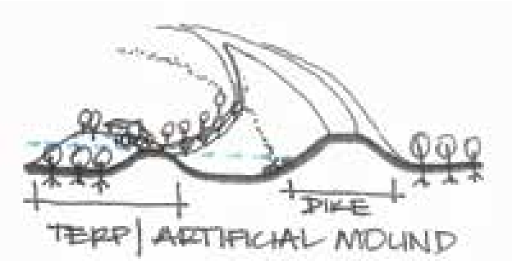


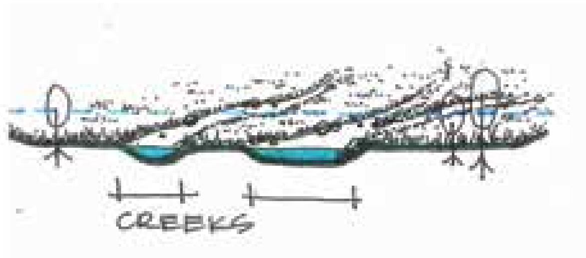


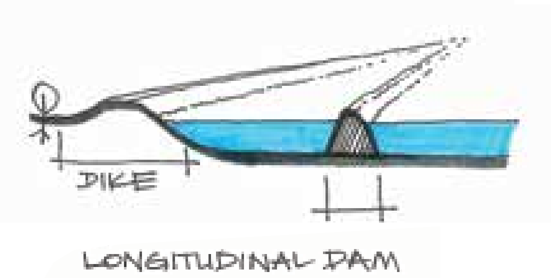

MEADOW


DIKE
TERRACING

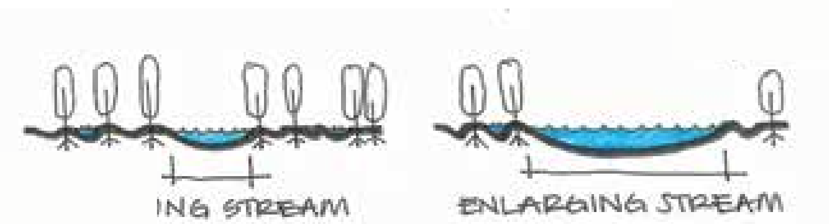

RIPARIAN BUFFER

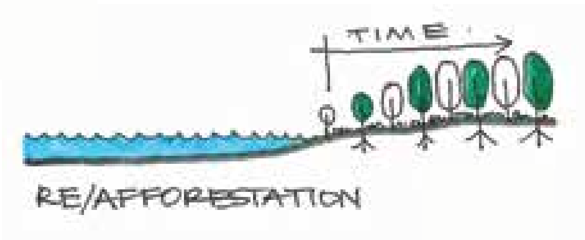

DIKE
TERP | ARTIFICIAL MOUND


CREEKS


DIKE
LONGITUDINAL DAM


WETLAND: REED


ING STREAM
ENLARGING STREAM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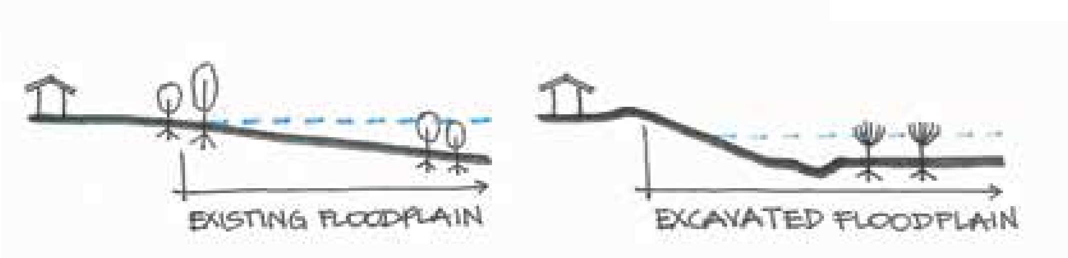
RE/AFFORESTATION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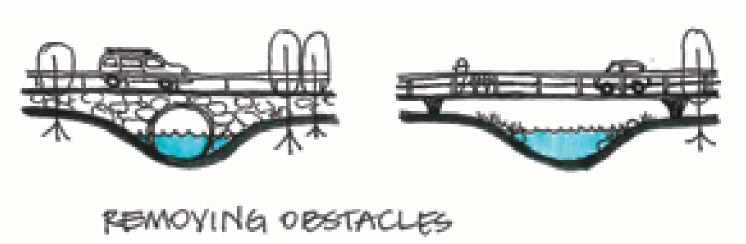
EXCAVATED FLOODPLAIN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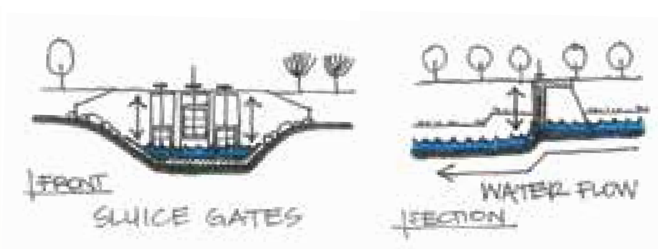
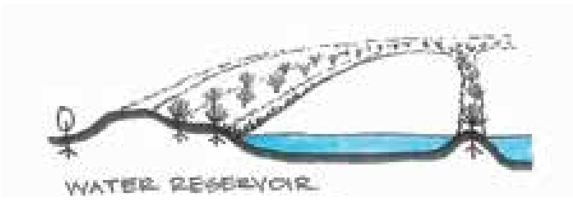
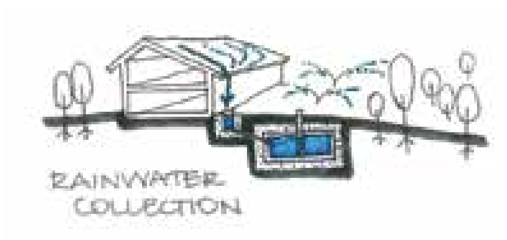
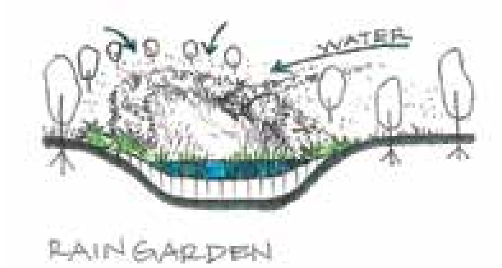
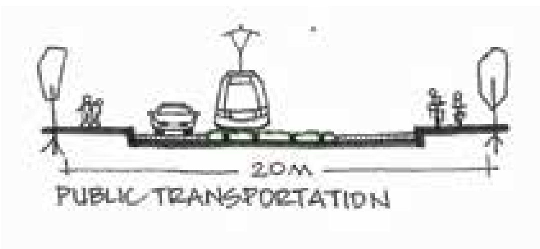

FRONT
SLUICE GATES
WATER FLOW
SECTION

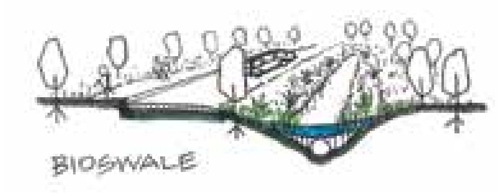
Climate change



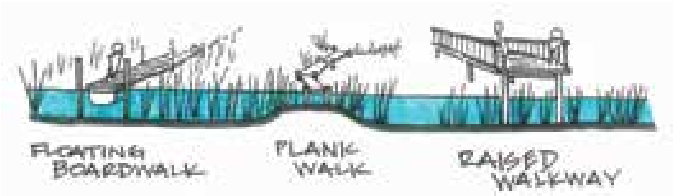


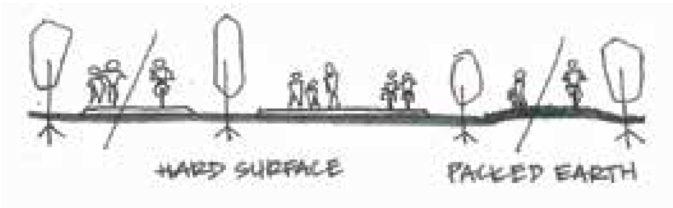


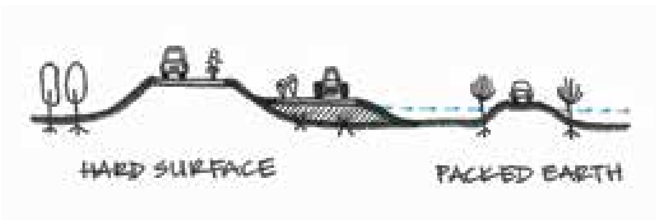


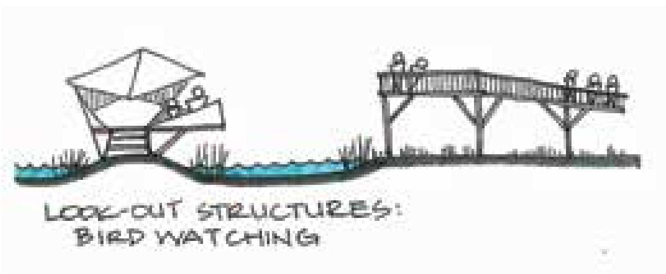


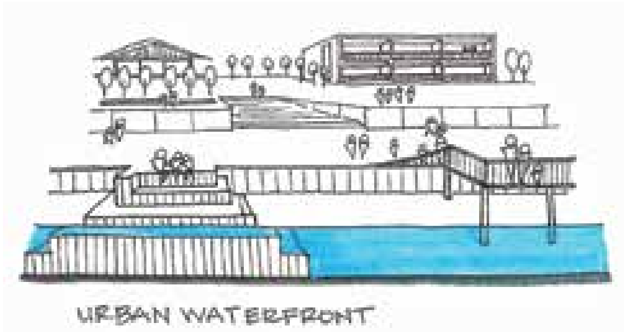
Public space

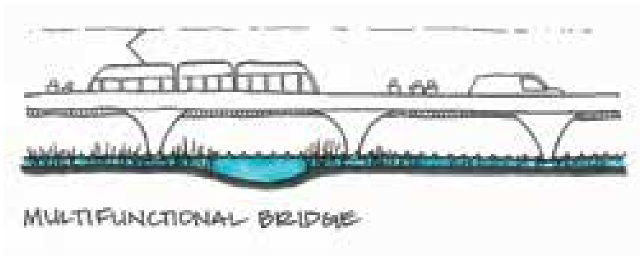




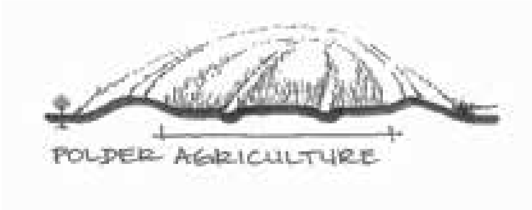


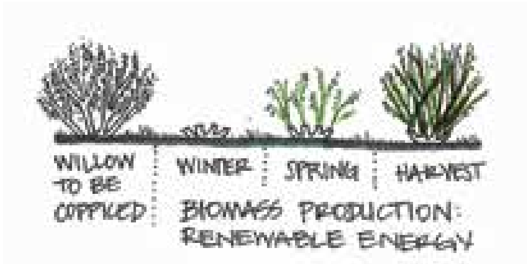




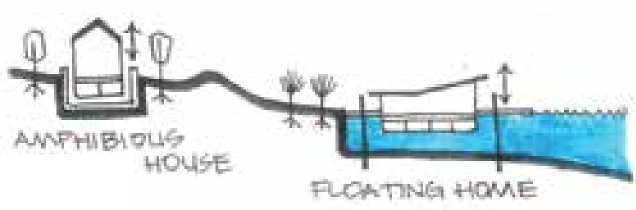


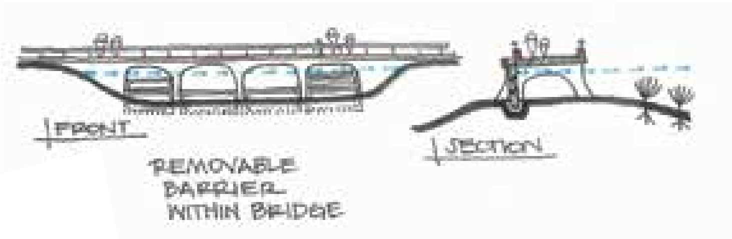
Land use



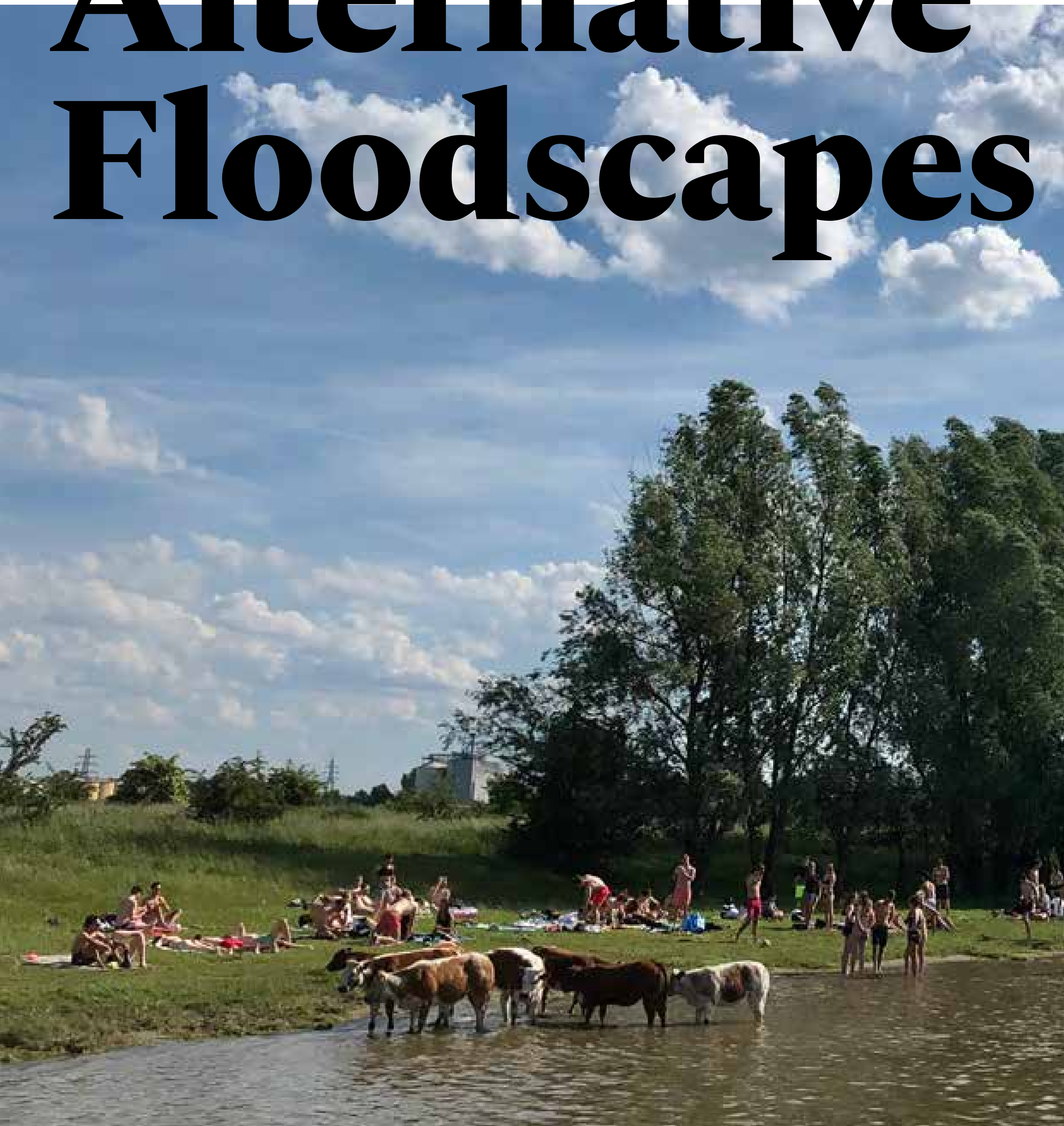


Resilient Architecture





Designing Alternative Floodscapes



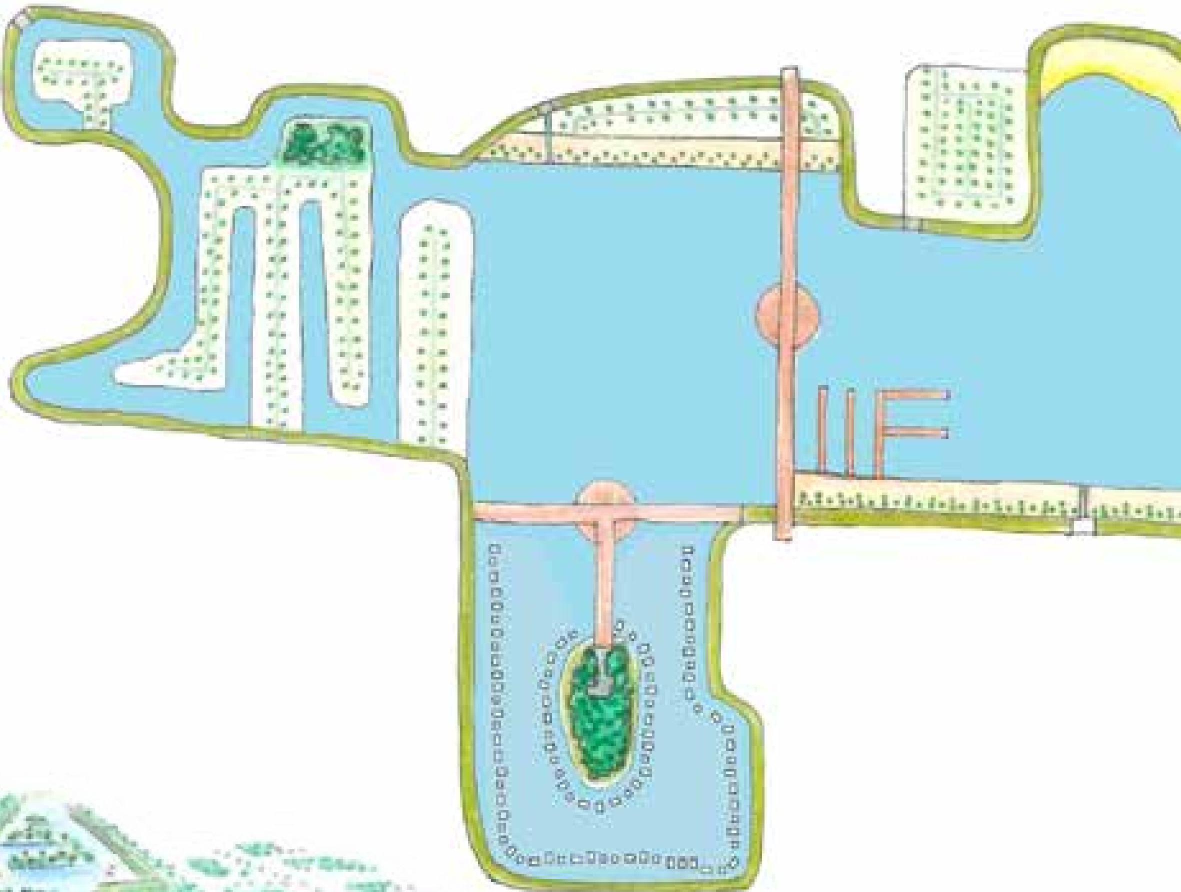
7.1.1 **Pointe-Calumet & Saint-Joseph-du-Lac**

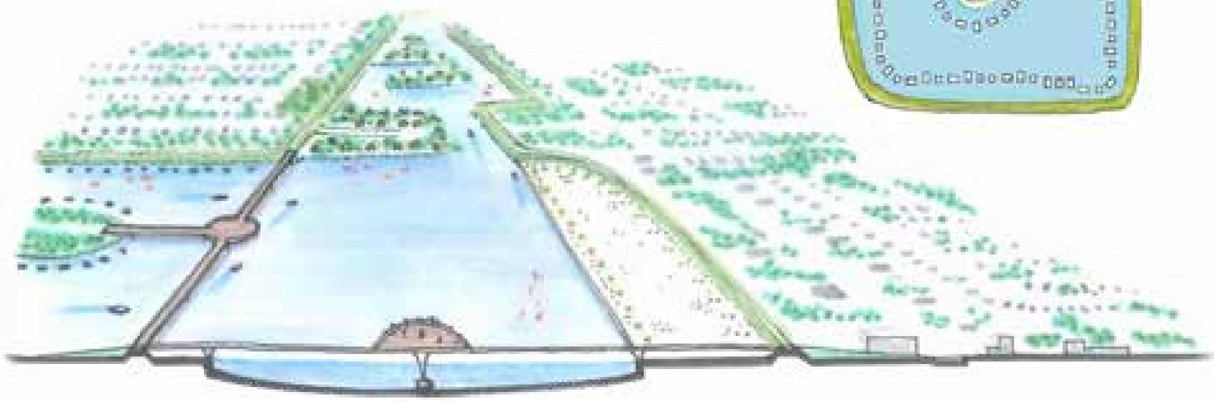
Floodscape A

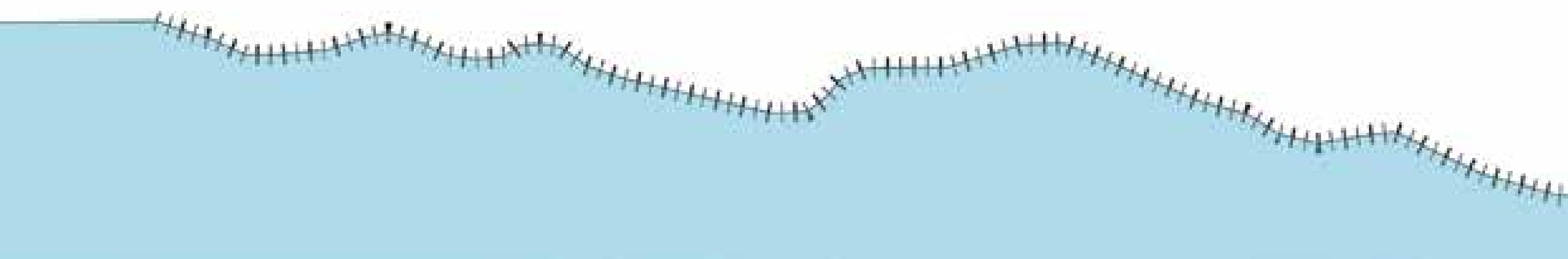
The floodscape illustrates how the landscape elements can be combined and integrated into the landscape. A lake is formed in the floodplain, and accessed through a widened river. Waterfront residences consist of floating homes and amphibious houses. New public spaces include a marina, wetland trails, and a public beach, not to mention the dike route.

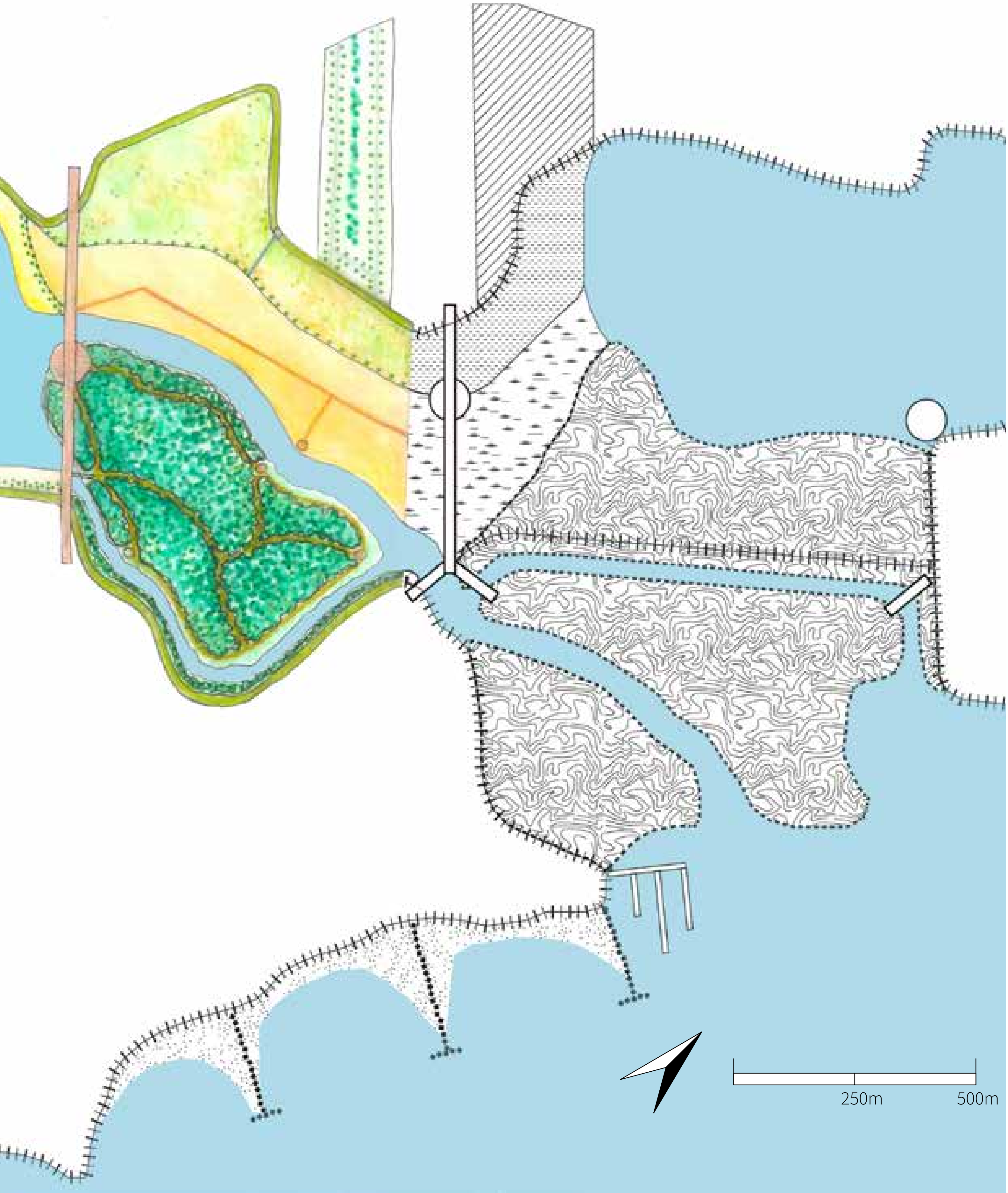
Legend

- Dike
- Water
- Residences
- Sluice
- Groyne
- Bridge
- Tram line
- Wind turbine
- Floating house
- Urban waterfront
- Marina
- Wetland forest
- Walking path
- Nature conservation
- Grazing land
- Marsh
- Public park
- Beach








250m
500m

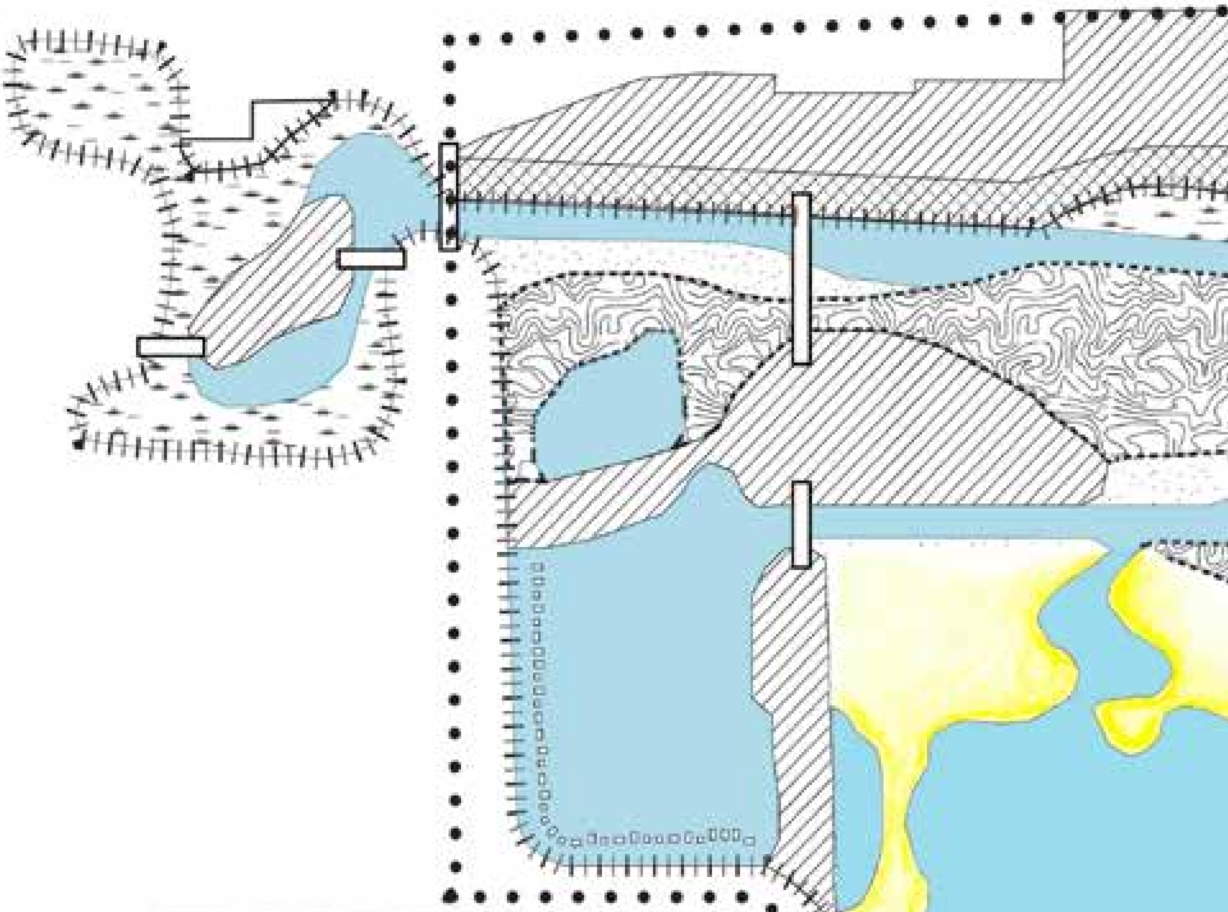
7.1.2 **Pointe-Calumet & Saint-Joseph-du-Lac**

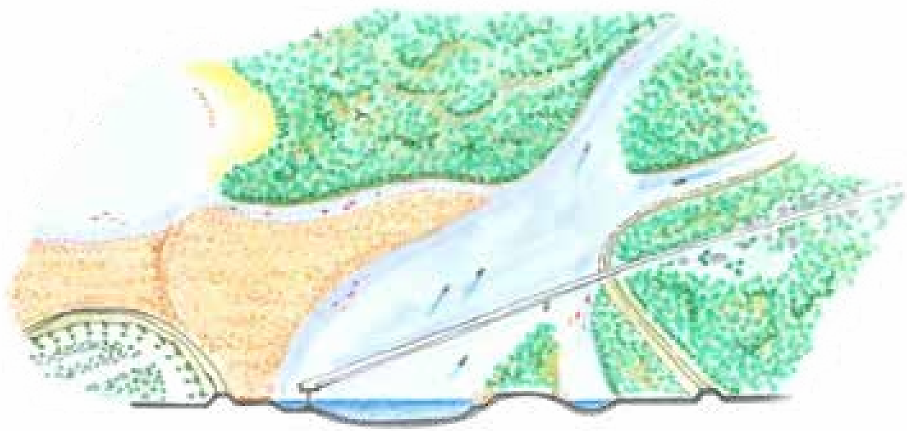
Floodscape B

The floodscape increases public access to wetland landscapes, and includes a tramline and wind turbines for renewable energy. Waterways surround a wetland island and create a lake.

Legend

- Dike
- Water
- Residences
- Sluice
- Groyne
- Bridge
- Tram line
- Wind turbine
- Floating house
- Urban waterfront
- Marina
- Wetland forest
- Walking path
- Nature conservation
- Grazing land
- Marsh
- Public park
- Beach



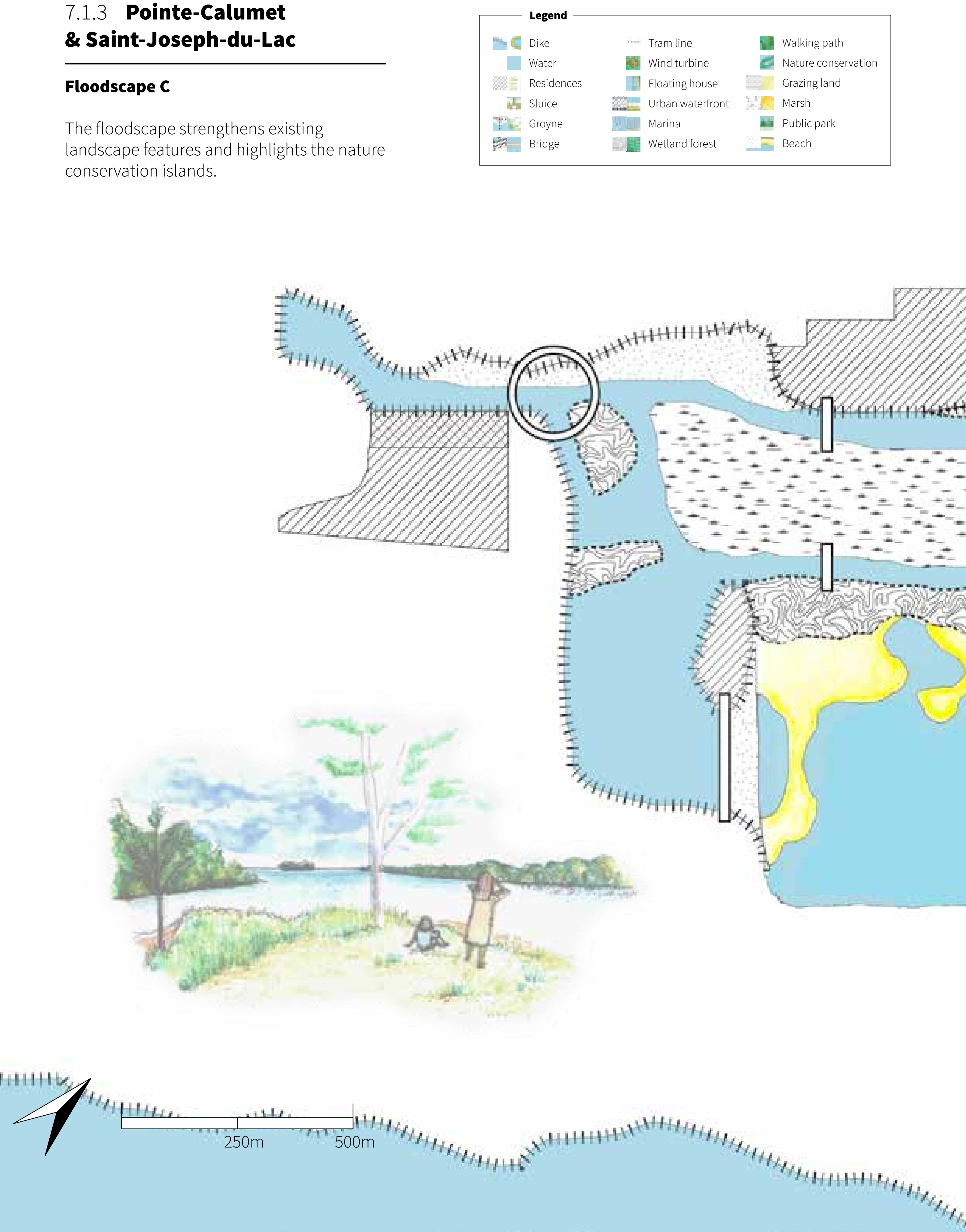


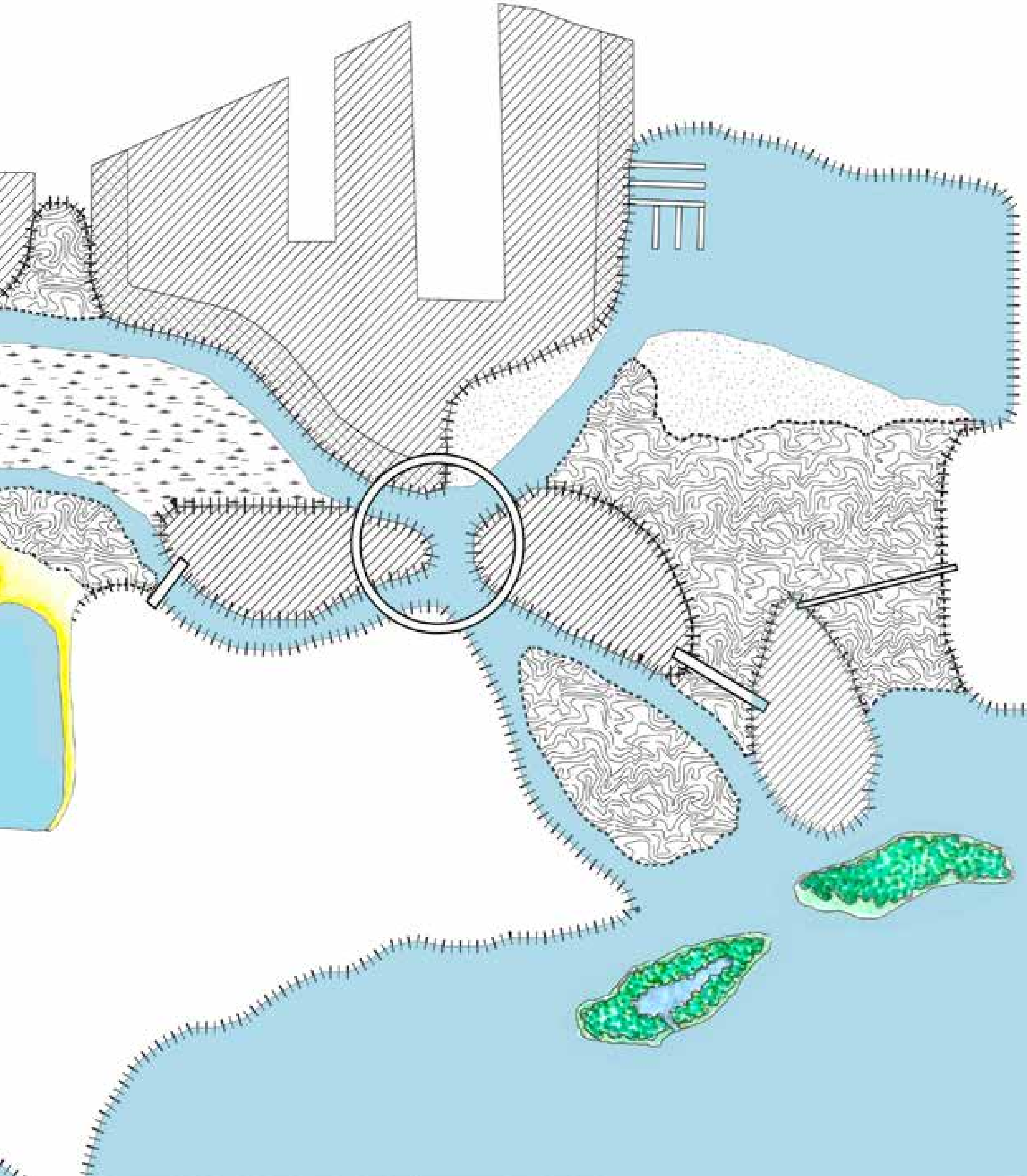

250m
500m

7.1.3 Pointe-Calumet & Saint-Joseph-du-Lac

Floodscape C

The floodscape strengthens existing landscape features and highlights the nature conservation islands.

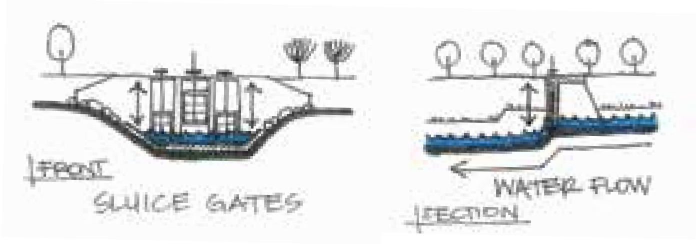




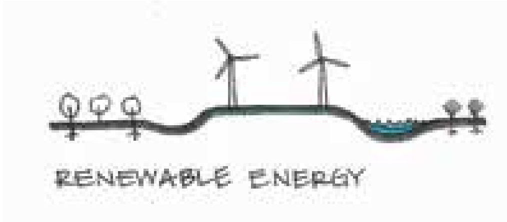
7.1.4 **Pointe-Calumet & Saint-Joseph-du-Lac**

One Design

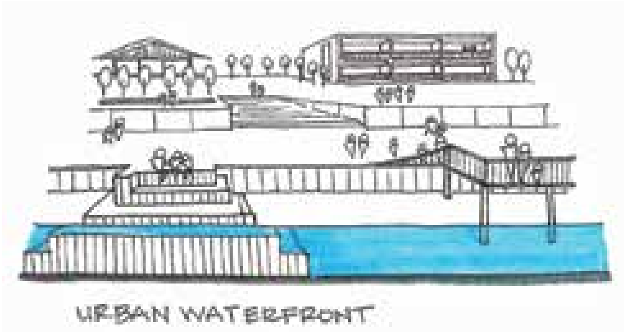
The final design integrates a combination of design elements into the landscape of Pointe-Calumet and Saint-Joseph-du-Lac.

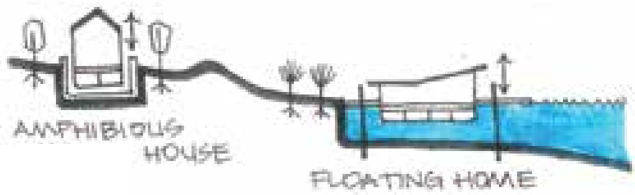


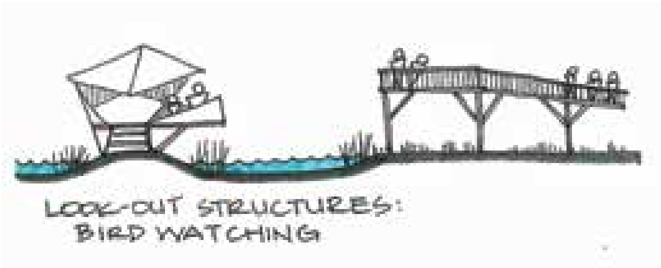

MARINA - WATER ACCESS


RENEWABLE ENERGY

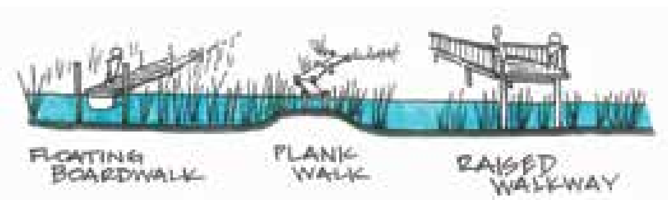

PROTECTED HABITAT

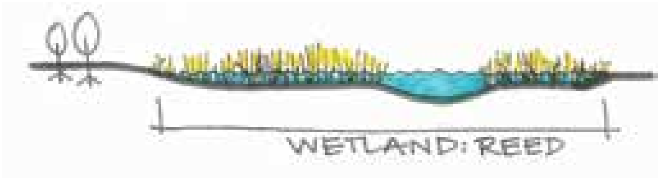

URBAN WATERFRONT


AMPHIBIOUS HOUSE
FLOATING HOME


LOOK-OUT STRUCTURES: BIRD WATCHING


CREEK BRIDGES
DIKE STAIRS


FLOATING BOARDWALK
PLANK WALK
RAISED WALKWAY

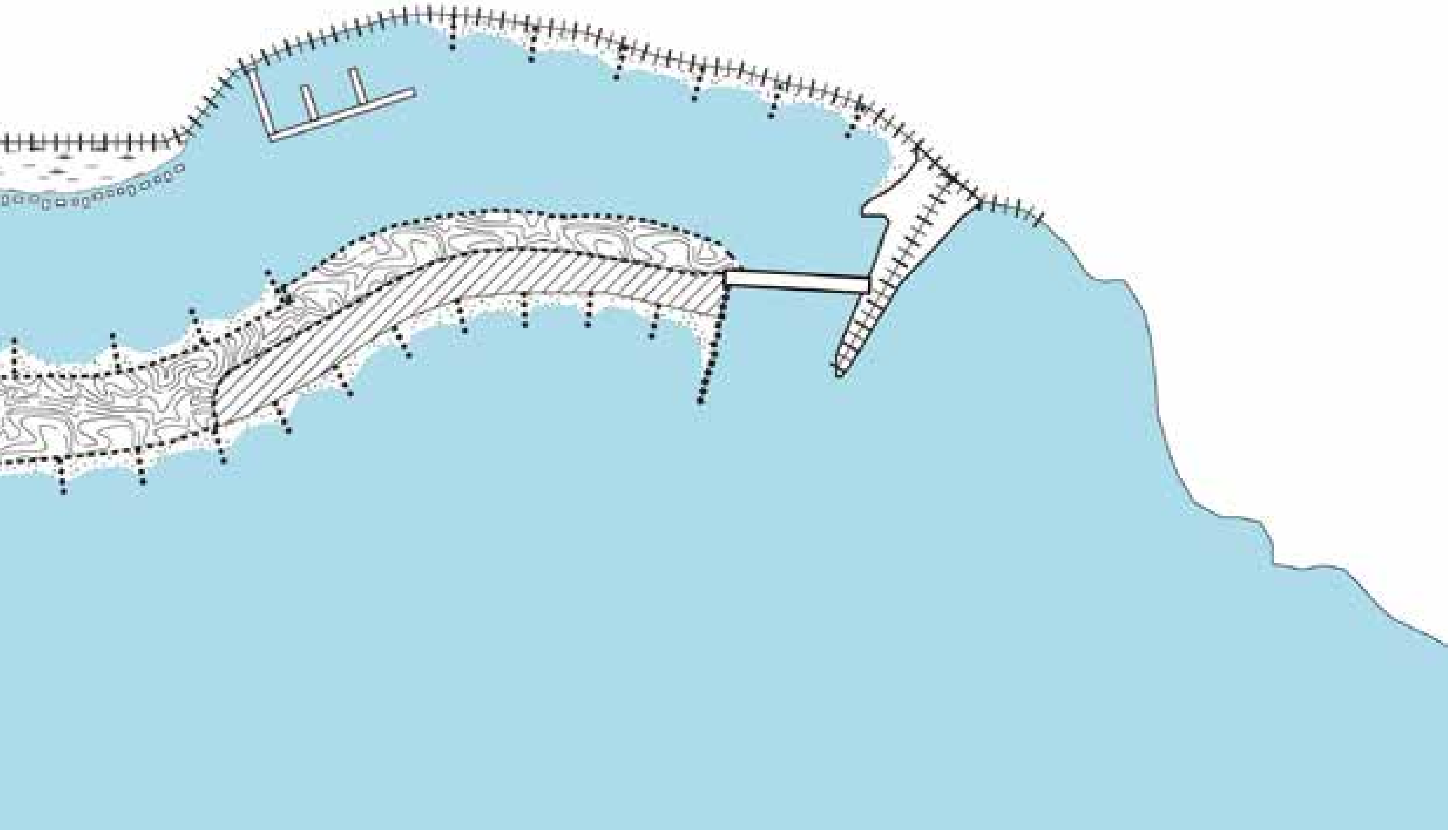

WETLAND: REED


Legend
Dike
Water
Residences
Sluice
Groyne
Bridge
Tram line
Wind turbine
Floating house
Urban waterfront
Marina
Wetland forest
Walking path
Nature conservation
Grazing land
Marsh
Public park
Beach
250m
500m

7.2.1 **Sainte-Marthe-sur-le-Lac**

Floodscape D

A longitudinal barrier is integrated into the shallow sand bar, creating a residential and recreational island. Groynes strengthen the shoreline and floating homes run parellel to the marsh.

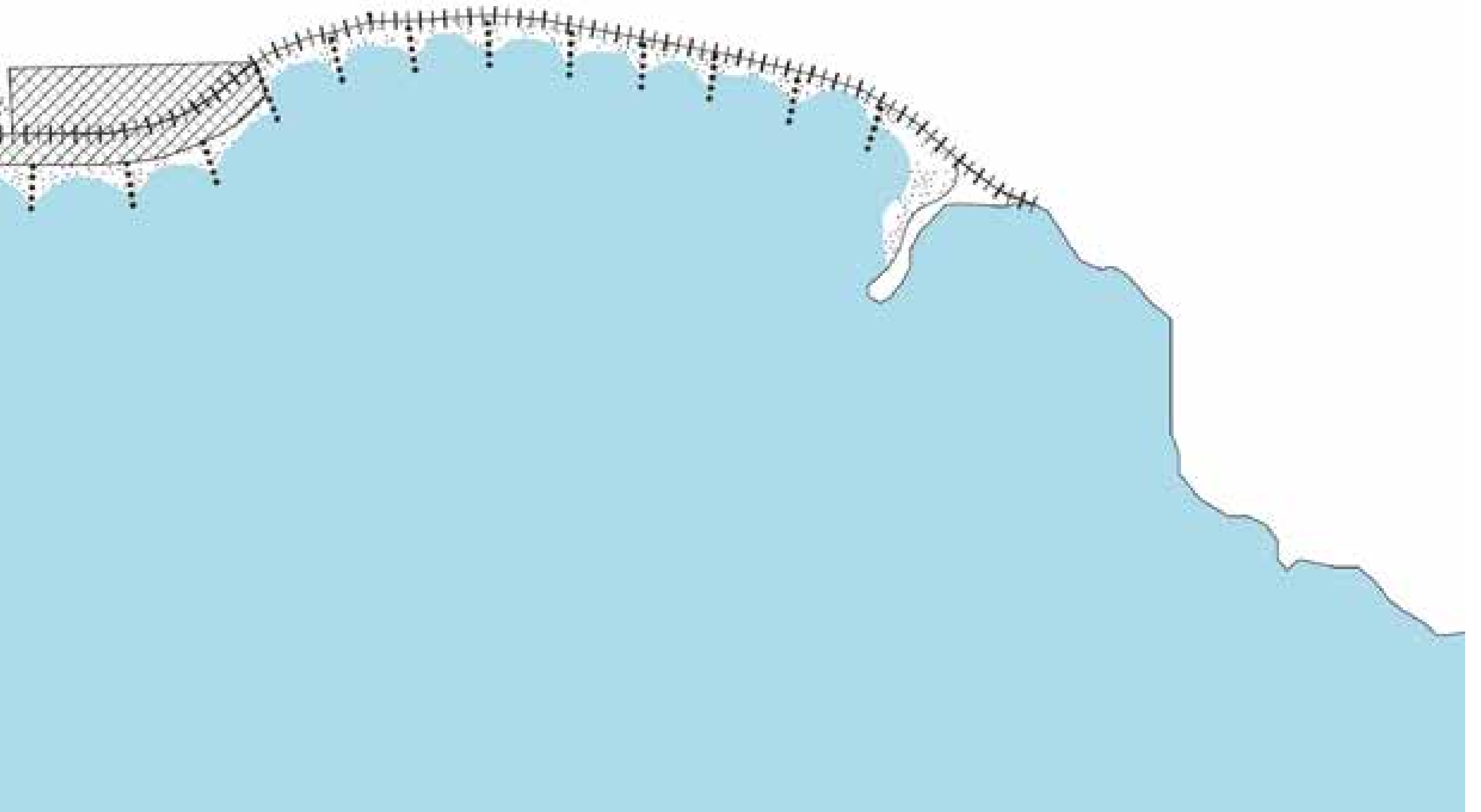



Legend
Dike
Water
Residences
Sluice
Groyne
Bridge
Tram line
Wind turbine
Floating house
Urban waterfront
Marina
Wetland forest
Walking path
Nature conservation
Grazing land
Marsh
Public park
Beach
250m
500m

7.2.2 **Sainte-Marthe-sur-le-Lac**

Floodscape E

A nature conservation island, in the form of a longitudinal barrier, encloses the marsh. Bioswales and rain gardens harvest rainwater, while a commercial crossing on Route 344 is densified and lined with trees.

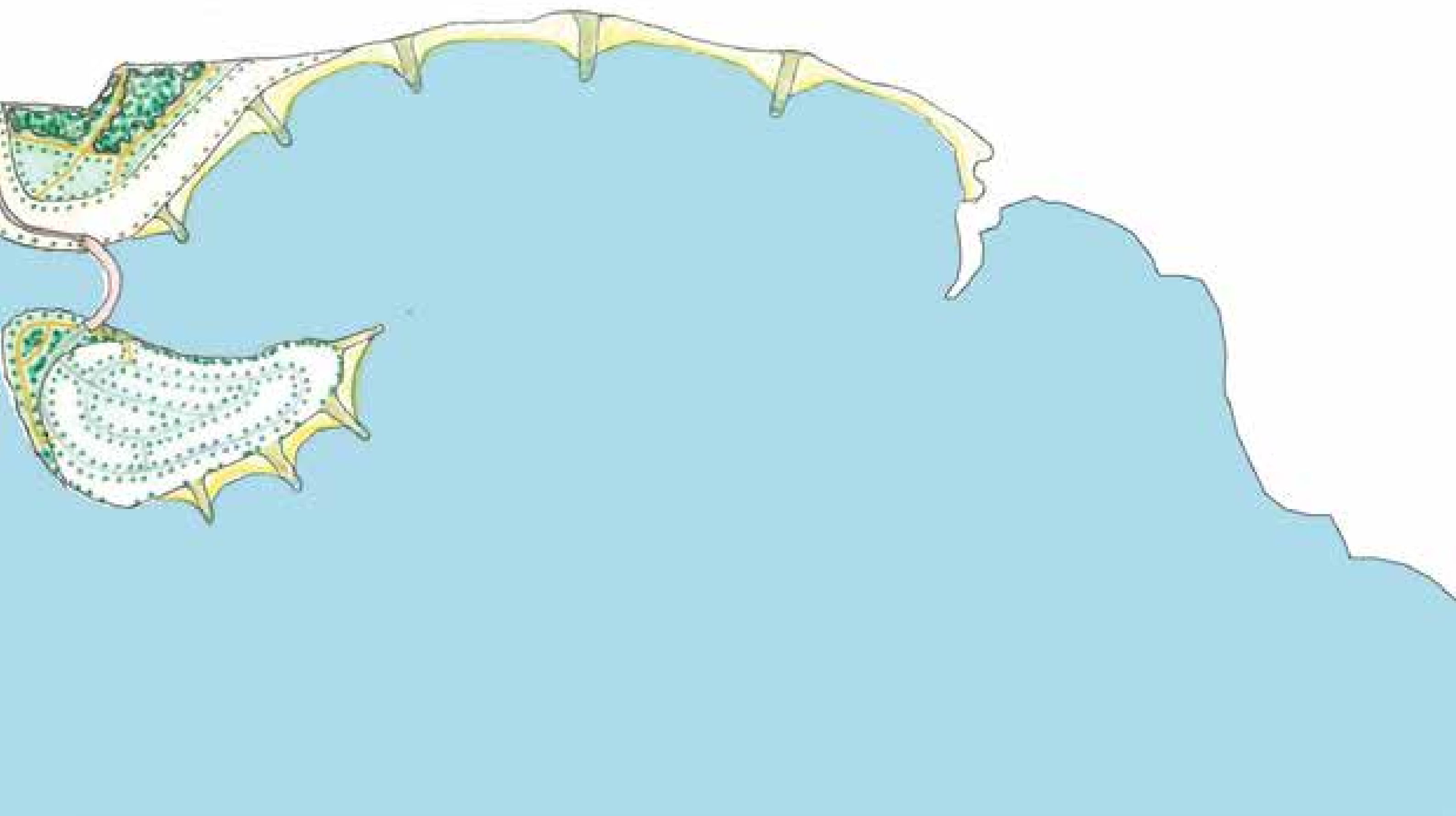



Legend
Dike
Water
Residences
Sluice
Groyne
Bridge
Tram line
Wind turbine
Floating house
Urban waterfront
Marina
Wetland forest
Walking path
Nature conservation
Grazing land
Marsh
Public park
Beach
250m
500m

7.2.3 **Sainte-Marthe-sur-le-Lac**

Floodscape F

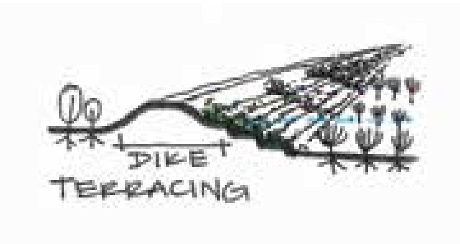
A residential island connects to the urban waterfront via a bridge. Public parks integrate additional vegetation, adjacent to the wetland forest park. The groynes create a selection of public beaches.

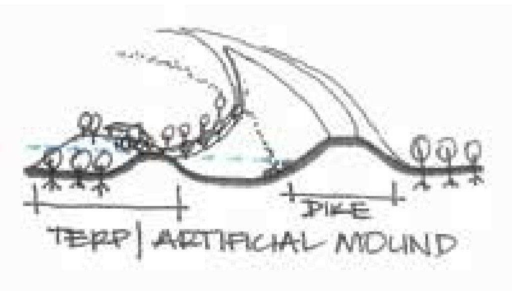


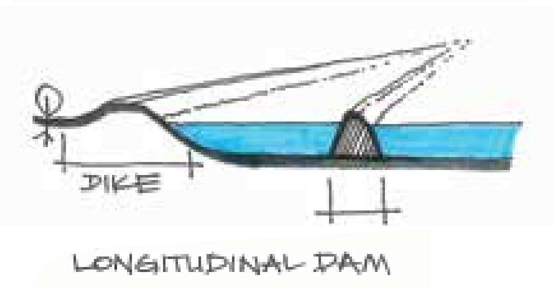
7.2.4 **Sainte-Marthe-sur-le-Lac**

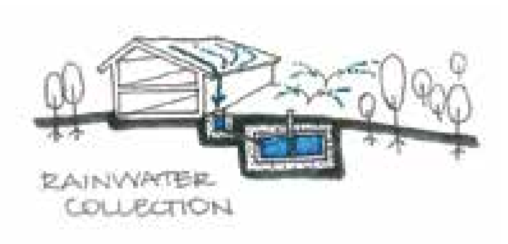
One Design

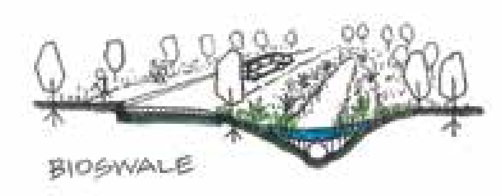
The final design integrates a combination of design elements into the landscape of Sainte-Marthe-sur-le-Lac.

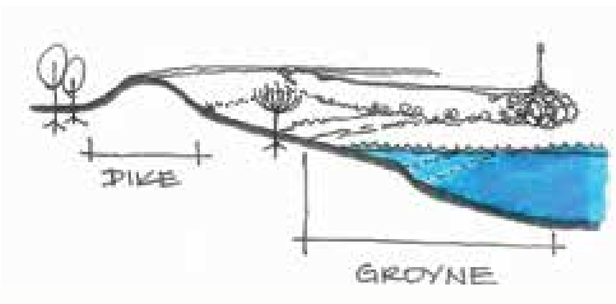


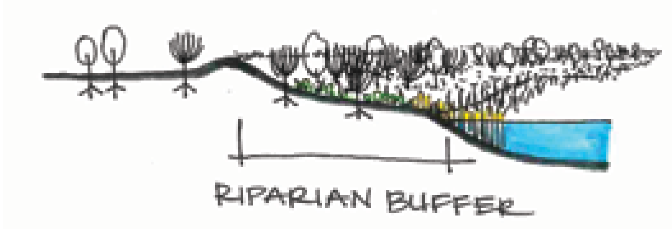


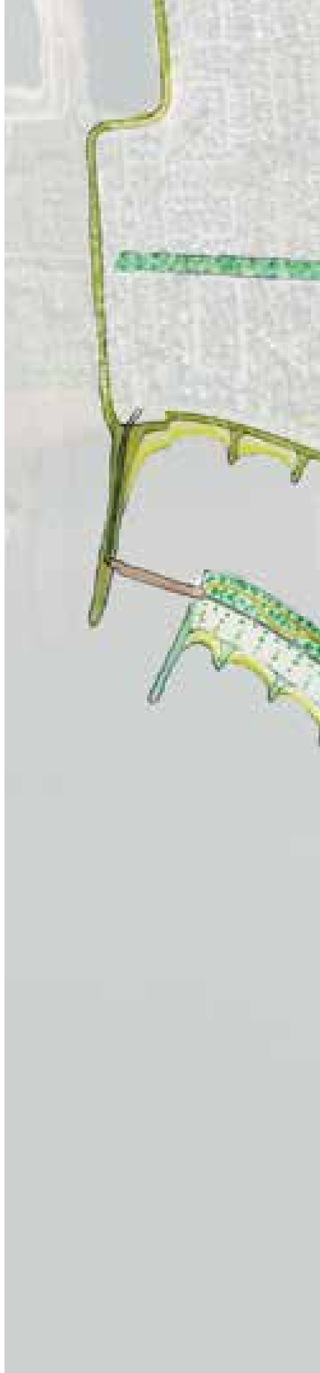




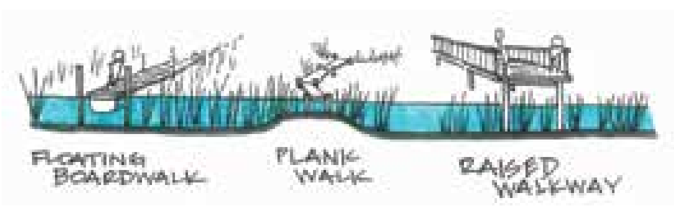









PROTECTED HABITAT


FLOATING BOARDWALK
PLANK WALK
RAISED WALKWAY


URBAN WATERFRONT

7.3 **Alternative floodscapes:**

A landscape design that encompasses all six combinations created for Pointe-Calumet, Saint-Joseph-du-Lac and Sainte-Marthe-sur-le-Lac.

7.4 **Evaluation**

The alternative floodscapes encompass a range of built and natural infrastructures which combine to strengthen the resilience capacity of the existing landscape. The designs are based on an analysis of the study area and a strategic combination of proposed landscape elements (typologies from section 6.6). The landscape elements address flood management, climate change, public space, land-use and resilient architecture.

Six floodscapes exemplify the myriad of possibilities obtained by combining a selection of landscape elements; as a result, the final landscape plan is not intended to solve the issue of flooding in Greater Montreal. Instead, the design aspires to integrate a variety of landscape elements within the vernacular landscapes of the Greater Montreal Area.

Aside from the physical application of the design, flood-resilient landscapes would also boost the local economy; supporting creative industries (urban planning, landscape design, architecture firms), specialty fields (ecologists, engineers), local producers (plant nurseries, material production, outdoor furniture and lighting) and local labour (construction and landscape workers). In addition, a widespread application of green roofs, bioswales and raingardens would stimulate new green business ventures and opportunities.

Incorporating green infrastructure solutions into the landscape creates a variety of ecosystem services related to water management, as seen in Appendix I. Improving the connection between waterbodies, such as The Lake of Two Mountains, and their flood plains reinforces local ecosystems: increasing biodiversity and providing habitat for local and migrating animals. Furthermore, these natural environments moderate extreme weather events and increase the recreational value of the landscape.

Adopting alternative landscapes would only work under certain conditions. Urban densification is needed to generate property taxes, which would provide municipalities with a budget for large scale landscape interventions. Overcoming socio-cultural challenges involves creating awareness amongst citizens and city-workers alike. The cooperation and input of citizens are required to move forward with a plan that suits local landscape values. Greater communication is needed between the hierarchy of governing bodies. Lastly, additional support from universities and NGO's would encourage the recognition of flood resilient communities.

The value of the proposed design lies with the opportunity for every community to integrate a selection of landscape elements into their vernacular landscape. There is no one-size-fits-all approach. Some municipalities, like Pointe-Calumet and Saint-Joseph-du-Lac, surround a floodplain and wetland forest without a designated land-use or any form of flood-management. Other municipalities, like Sainte-Marthe-sur-le-Lac, are built inside a flood plain and rely entirely on a single dike for flood defence.

The spring floods of 2017 and 2019 illustrate the increasing need for flood management solutions in urban environments. Creating flood resilient communities' offer residents piece of mind. Waterfront communities are heavily sought after – providing residents with high quality landscapes that exude safety increases property values and strengthens community relationships.

Conclusio

on

8

8.1. **Conclusion**

As you have seen, the design question explored the combinations of green (nature-based) and grey (built) infrastructure that could be used to create resilient communities along the waterfronts of Greater Montreal. The first and second sub-questions were generated to answer the design question discussed hereinafter. A landscape analysis and site visits determined that urbanized flood plains and non-porous flood prone landscapes encompass Greater Montreal (the first sub-question). While a literature study on Green Infrastructure and Room-for-the-River established a typology that encompassed adaptive landscapes offering both protection and value to littoral and floodplain communities (the second sub-question).

The main research question explored the socio-cultural implications of using international flood adaptive landscape solutions in a North American context. This was answered with the help of the third sub-question which investigated the socio-cultural obstacles that challenge adaptive design. A literature study, structured interviews and a design feedback event were employed to answer the question. Literature by Joan Iverson Nassauer (seen in section 2.3) determined that 'orderly frames' were needed to incorporate unfamiliar landscapes into the cultural language. The structured interviews and design feedback event further illustrated the need to modernize the cultural language of resilient landscapes through education and mediation by governing bodies.

To conclude, the design typology depicted a toolbox of flood adaptive landscape elements. The case study comprises of two sites (over three municipalities) on the Lake of Two Mountains. It tested combinations of the landscape elements, which resulted in six alternatives. My design was created using the aforementioned elements incorporated into orderly frames. The final proposal merged all six designs into one plan, exemplifying a myriad of possibilities to create resilient communities by integrating combinations of green and grey infrastructure in the vernacular landscape.

8.2. **Discussion**

While the objective of this research project was always to alleviate the devastation experienced by the waterfront municipalities of Greater Montreal, the intention slowly shifted from flood-mitigation to flood adaptation and eventually to flood resilience. When I first submitted my research proposal, I was sure that I would be able to derive my design principles by hosting a design feedback event. Unfortunately the event was not as successful as I speculated, possibly due to the urgency of the 2019 spring floods which occurred in the weeks leading up to the feedback event.

Over time, there was a need to cut elements of my project. Sometimes they were redundant elements, such as two additional study sites on the south and western shores of The Lake of Two Mountains. At another occasion, cutting an element was done for the sake of time. I had planned to produce a reference study, based on the success of the uiterwaarden between Wageningen and the Nederrijn. Spending countless study breaks in the *uiterwaarden* contributed heavily to my understanding of the functions of a floodplain. I experienced the *uiterwaarden* during every season of the year and even exeperienced it completely flooded in January 2018.

The research conducted to produce my thesis is pertinent, considering the 2017 and 2019 spring flood events experienced by southern Ontario and southern Quebec. These extreme flood events were both 1-in-100-year floods, exacerbated by urbanization (or sprawl) and the effects of climate change. Quebec's hierarchy of governing bodies is seeking innovating solutions to reduce the impact of flooding on their waterfront communities. They know that creating flood walls or barriers will only relocate the problem. The discussion is ongoing and this research could contribute to the future of flood adaptive communities.

The hindrance on the solutions provided by this research lie with the lack of political will and the corruption that infiltrates the municipalities of Greater Montreal and other municipalities across Quebec. In their paper about establishing Green Infrastructure in the region of Montreal, Dupras et al. (2015) recount that (p. 370):

> ...Police investigations and a public commission held on the construction industry have made public numerous cases of corruption among politicians, entrepreneurs and organized crime causing a significant negative impact on the land and environment, including the intensification of speculation and re-zoning observed over the last few decades.

Therefore, environmental laws and regulations have been difficult to reinforce, contributing to the challenges of implementing a shared regional vision. As a consequence, the lack of political will affects the potential of my research and the design elements that could be used to motivate holistic, resilient communities.

8.3. **Recommendation**

As the urbanization of Greater Montreal continues, and the effects of climate change are felt more and more with every passing season, the potential application of my research to waterfront communities is a realistic possibility. A next step could be to identify a municipality willing to conduct a pilot project. The residents would have to be on board to test the adaptive landscapes. A public consultation would be necessary to inform citizens and answer any questions or concerns expressed by the residents within the pilot project area. Further research would need to be conducted into the design elements; evaluating their value in the cultural landscape of Greater Montreal and exploring whether they have been integrated in other landscapes across Canada.

8.4. **Reflection**

As the saying goes, it is always darkest before the dawn. I believe this applies to the situation experienced by Greater Montreal's communities that were flooded in the last few years. The time to act is now. It is time to take the opportunity created by destruction and turn in into something inspiring and motivating. It is my hope to contribute to the up-and-coming developments that will be seen across Greater Montreal over the next few years.

Studying landscape architecture, in a water-management track, at Wageningen University has opened my eyes to a holistic and systematic picture which I was previously unaware of. The water culture couldn't be stronger than in the Netherlands, which is what motivates me to bring it home to Montreal. During my thesis, I have discovered that the general sentiment regarding the flooded waterfronts across Quebec, is "just move, Canada is big, and you don't have to live in a flood zone". Though this was expressed to me countless times by friends and random acquaintances, I could not agree less.

Montreal is a culturally diverse city; a city of festivals and a city with four distinct seasons, plenty of employment, and educational opportunities, in proximity to waterbodies and in proximity to nature. The waterfront communities on the edge of the city attract young families and retirees alike. Instead of coaxing residents into moving, these communities could be densified, connected to public transportation networks and powered by renewable energy.

We are at a turning point, and there are many paths to chose from. I chose to contribute my time and energy towards creating resilient communities. I may not be a politician (yet), but through the skills I have obtained over the journey of my masters, I can use the power of landscape architecture to design safe, high quality environments, while reducing the effects of climate change.

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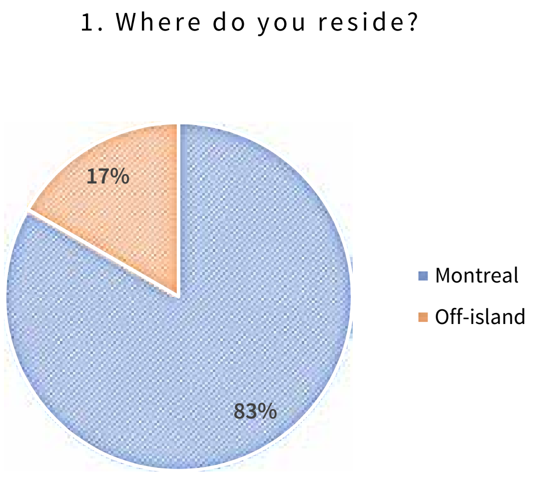
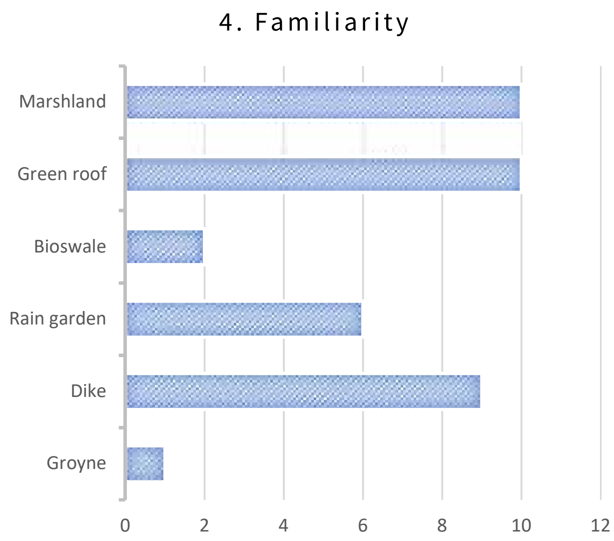
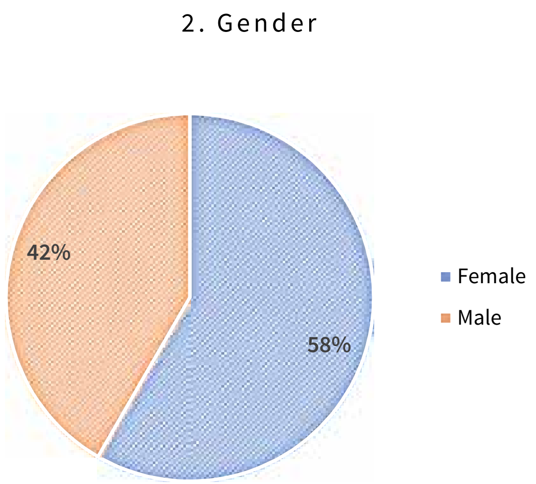
Appendix I.

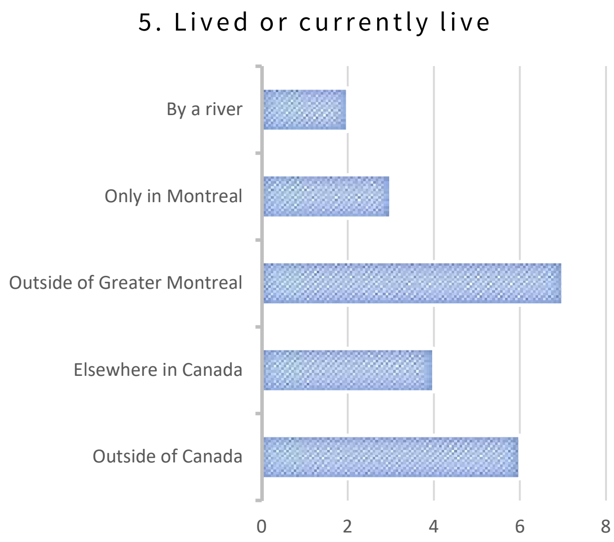
	Ecosystem services related to water management issues: primary & secondary benefits														
	Provisional			Regulating							Supporting		Cultural		
**comprise of built (grey) infrastructure in collaboration with natural elements*	Water supply	Food production	Raw materials	Temperature control	Carbon sequestration + storage	Moderation of extreme events	Water purification	Erosion control (incl. shoreline)	Pollination	Biological control	Habitats for species	Maintenance of genetic diversity	Recreation	Tourism	Aesthetic/cultural value
Green Infrastructure solution															
Re/afforestation & forest conservation															
Riparian buffers															
Wetlands restoration/conservation															
Constructing wetlands															
Reconnecting rivers to floodplains															
Establishing flood bypasses															
Green roofs															
Green spaces (bioretention & infiltration)															
Water harvesting*															
Permeable pavements*															

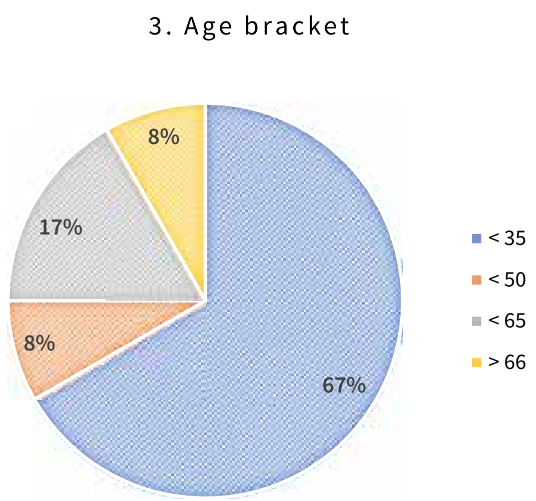
Appendix II

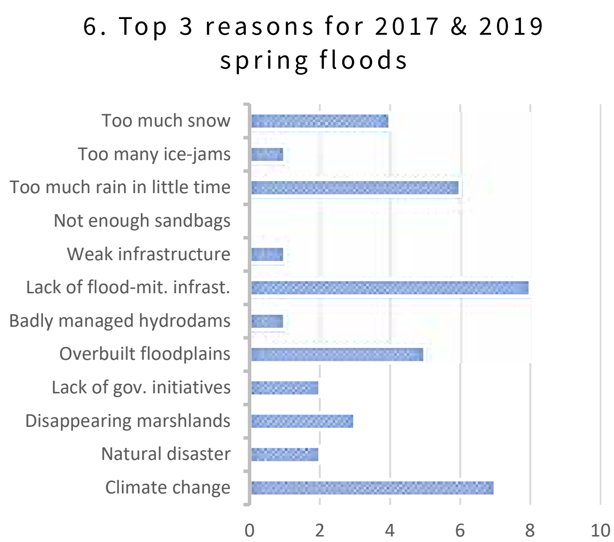

1. Where do you reside?
17%
83%
Montreal
Off-island


4. Familiarity
Marshland
Green roof
Bioswale
Rain garden
Dike
Groyne
0
2
4
6
8
10
12

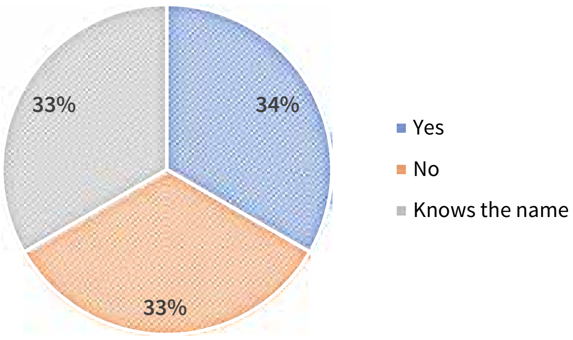

2. Gender
42%
58%
Female
Male


5. Lived or currently live
By a river
Only in Montreal
Outside of Greater Montreal
Elsewhere in Canada
Outside of Canada
0
2
4
6
8

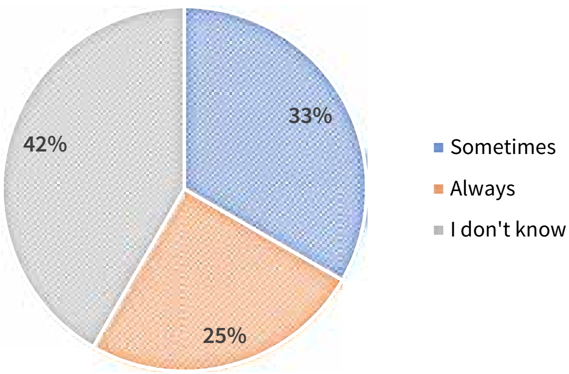

3. Age bracket
8%
17%
8%
67%
< 35
< 50
< 65
> 66


6. Top 3 reasons for 2017 & 2019 spring floods
Too much snow
Too many ice-jams
Too much rain in little time
Not enough sandbags
Weak infrastructure
Lack of flood-mit. infrast.
Badly managed hydrodams
Overbuilt floodplains
Lack of gov. initiatives
Disappearing marshlands
Natural disaster
Climate change
0
2
4
6
8
10

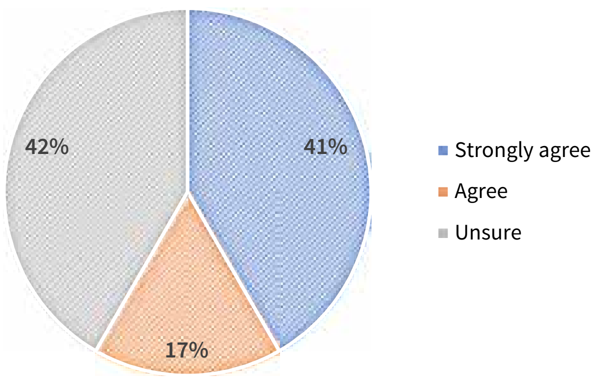
7. Is familiar with Ottawa River drainage basin



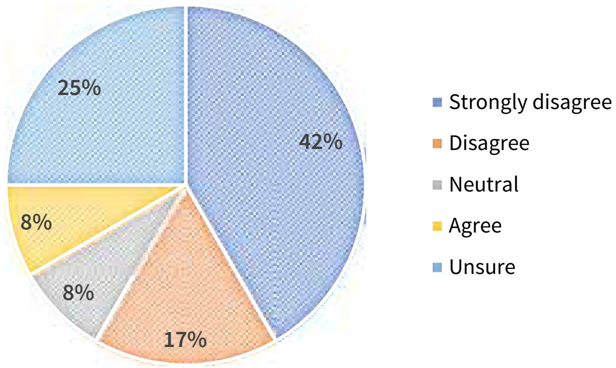
8. Rainwater flows into storm drains and directly into the river



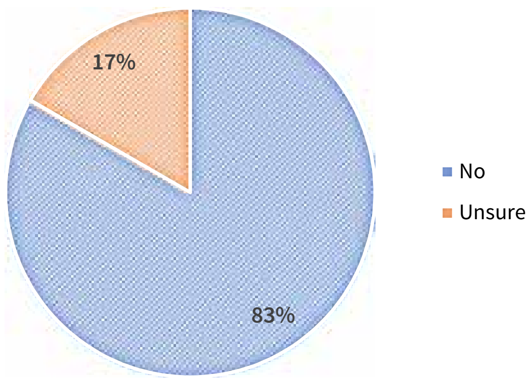
9. Marshlands & wetlands are important for human safety



10. We should continue to build in flood plains



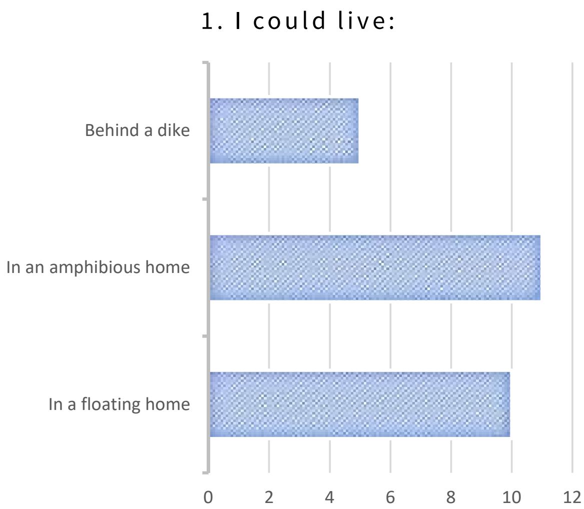
11. I would live in a flood plain

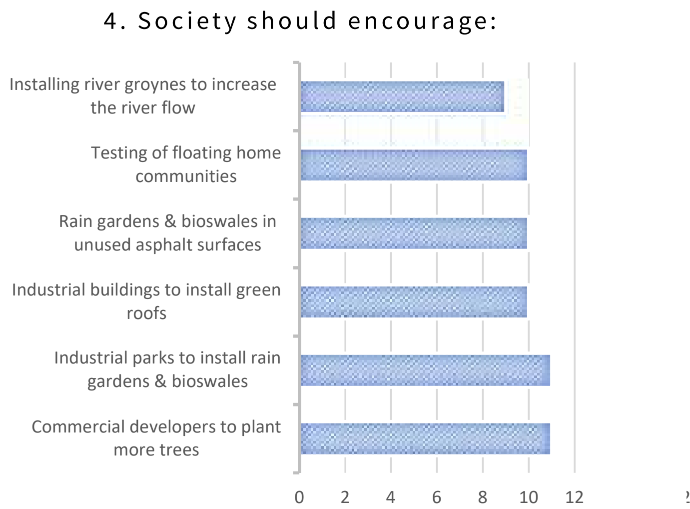


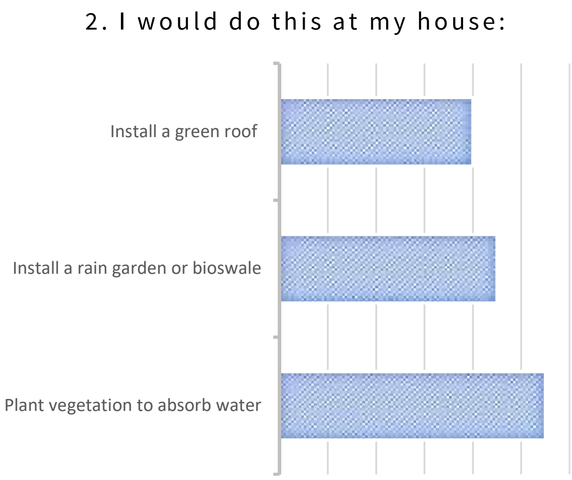
12. How do we avoid river-flooded communities?

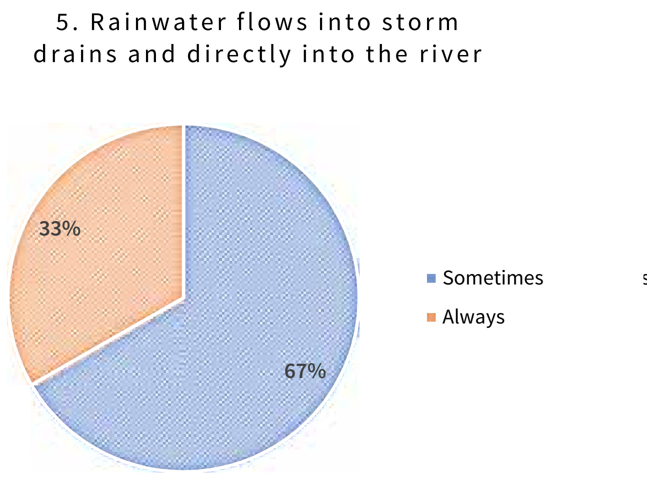
- Open the gates
- Leave more low areas open to absorb more water
- Better preparation in the future
- Build higher banks to the rivers and assure that drainage from storms have somewhere to go
- After being asked these questions, I realize I need to get more informed on the topic
- Flood zone mapping, mitigation and sound design strategies
- Better flood mitigating infrastructure
- Better drainage systems
- I am sure there needs to be a combination of solutions
- Unsure
- Don't live in flood prone areas

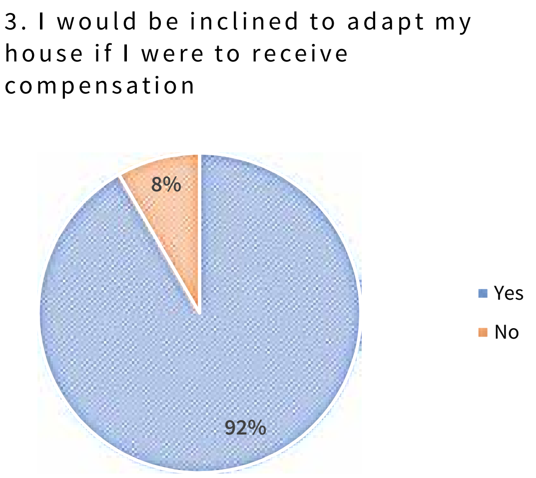
Appendix II

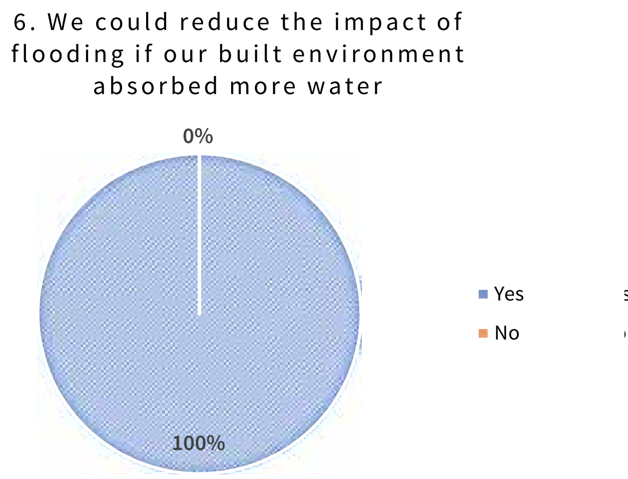

1. I could live:
Behind a dike
In an amphibious home
In a floating home
0
2
4
6
8
10
12


4. Society should encourage:
Installing river groynes to increase the river flow
Testing of floating home communities
Rain gardens & bioswales in unused asphalt surfaces
Industrial buildings to install green roofs
Industrial parks to install rain gardens & bioswales
Commercial developers to plant more trees
0
2
4
6
8
10
12

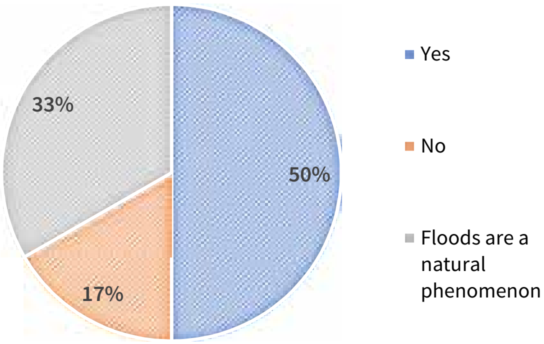

2. I would do this at my house:
Install a green roof
Install a rain garden or bioswale
Plant vegetation to absorb water


5. Rainwater flows into storm drains and directly into the river
33%
67%
Sometimes
Always

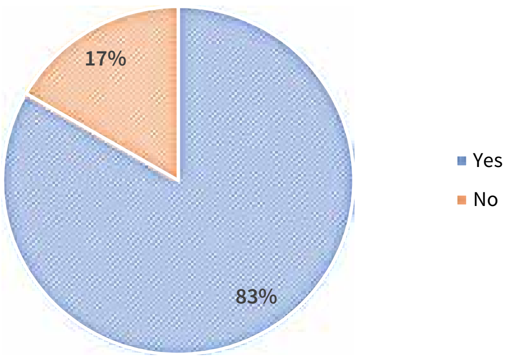

3. I would be inclined to adapt my house if I were to receive compensation
8%
92%
Yes
No


6. We could reduce the impact of flooding if our built environment absorbed more water
0%
100%
Yes
No

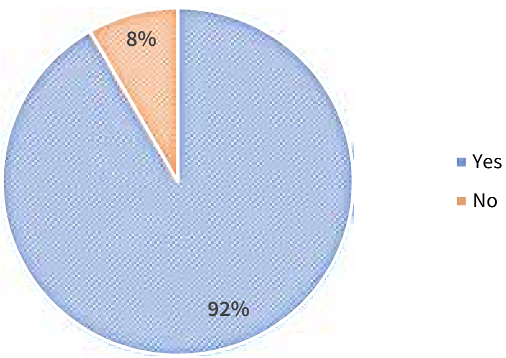
7. The floods are a man-made problem



8. Floods are exasperated by climate change



9. We can create flood resilient communities in flood plains



10. How do we avoid river-flooded communities?

- Water absorption strategies
- Protect wetlands & lowlands from development, leaving them in their natural state which will also support ecosystems: plants, animals, birds, insects, & biodiversity.
- More education s required!
- Build a community that can adapt to rising of the water
- Learn to adapt and better prepare with the government leading the way with options for citizens to participate.
- Create more porous surfaces. More rain gardens, green roofs etc.
- By encouraging the government to integrate green solutions into their flood zone i.e. groynes, amphibious houses, increase permeability, increase parks spaces etc.
- Install river groynes, create bioswales and encourage the planting of porous greenery and create wider channels lined with boulders & rocks.
- Build better systems to adapt to flooding!
- We need to adapt the way we live and the way we build our communities to deal with floods.
- We cannot
- Don't live near flood prone areas