A *Pondful* of Possibilities...

Reimagining Winnipeg's Residential Stormwater Retention Ponds as Urban Agricultural Assets

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Capstone Report

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I acknowledge that my current place of residence, the City of Winnipeg is located within Treaty 1 territory, on the original lands of Anishinaabeg, Cree, Oji-Cree, Dakota, and Dene Peoples, and on the homeland of the Métis Nation. I feel welcomed and privileged to walk these lands and drink the water from Shoal Lake 40 First Nation on Treaty 3 territory. I respect the Treaties that were made on these territories, acknowledge the harms and mistakes of the past, and endeavour to move forward in partnership with Indigenous communities in a spirit of reconciliation and collaboration.

Figure 1: Aerial view of the stormwater retention ponds at Island Lakes, Winnipeg. Source Google Earth (Google Earth)

Abstract

Baker et. al.'s (2009) research indicates that North American cities have great potential for integrating urban agriculture into under-utilized urban open spaces such as, along transport and infrastructural components, under utility corridors, and in vacant lots. This study argues that suburban Winnipeg's residential stormwater retention ponds are also capable of accommodating urban agricultural activities. Many potential uses of these retention ponds, for instance, active transportation, recreation, winter activities, and being biodiversity assets can be identified. Growing and harvesting plants for biofuel, fodder, and food in these retention ponds, while following low impact, chemical-free, and environmentally safe techniques, can improve the water quality of retained stormwater, which is a growing concern in the region. Other benefits of urban agricultural activities, including reduction in greenhouse gas emissions due to fossil fuel displacement and shortening of supply chains, may be leveraged to support Canada's commitment to end all greenhouse gas emissions by 2050 (Government of Canada, 2021). Additionally, growing food locally may increase food security and equity, and support multiculturalism (Hough, 2004). This is especially relevant to Winnipeg where 11.5 % of the population faced food insecurity in 2018 (Canadian Centre for Policy Alternatives, 2018). This study leverages a review of literature, research precedents, and the City's Policy Documents, along with on-site observations, to identify key concerns and suggest ways to mitigate them. This study finds that concerns regarding biological and technical feasibility, economic viability, safety and liability concerns, and NIMBYism challenge the integration of urban agriculture with residential stormwater retention ponds in suburban Winnipeg. To overcome these challenges, this study recommends that the City revise its policy documents, invest in pilot research projects, and leverage partnerships with community and educational institutions, industry leaders, Indigenous organizations, and advocacy groups to support urban agriculture in Winnipeg.

[Keywords: urban agriculture, stormwater green infrastructure, circular economy, stormwater retention ponds, bioremediation, water quality, stormwater management, edible landscapes, reconciliation]

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Contents

List of Acronyms

ACW	Aboriginal Council of Winnipeg
AFA	Aphanizomenon flos-aquae
CIER	Centre for Indigenous Environmental Resources
COP 26	26th United Nations Climate Change Conference of the Parties
CSR	Corporate Social Responsibility
FAR	Floor Area Ratio
FCM	Federation of Canadian Municipalities
FMM	Food Matters Manitoba
FTW	Floating Treatment Wetlands
ICC	Indigenous Chambers of Commerce
IISD	International Institute of Sustainable Development
ILDI	Indigenous Leadership Development Institute
ISGI	Integrated Stormwater Green Infrastructure
MDPI	Multidisciplinary Digital Publishing Institute
MHBA	Manitoba Home Builders Association
MSBA	Manitoba School Board Association
NIMBY	Not In My Back Yard
OFCM	Organic Food Council of Manitoba
UDI	Urban Development Institute of Manitoba
USA	United States of America

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Ch.1 Introduction

The Canadian federal government has committed to end all net greenhouse gas emissions as a part of the *Canadian Net Zero Emissions Accountability Act,* which became law on 29th June 2021. The deadline for reaching this goal was reiterated in the recent COP 26 Summit as 2050 (Government of Canada, 2021). This is a mammoth task requiring participation from all stakeholders, including individuals, institutes, industries, and all levels of governments, including the City of Winnipeg.

The current research identifies one pathway to move closer to this goal by integrating urban agriculture into Winnipeg's stormwater green infrastructure. One area to consider for this integration is the city's stormwater retention ponds. This research argues that Winnipeg's suburban stormwater retention ponds may be used to grow crops for food, fodder, and biofuel and this agricultural activity may have additional benefits.

This introductory chapter briefly discusses the current state, uses, and untapped potential of stormwater retention ponds in sections 1.1,1.2, and 1.3. Section 1.4 introduces the relevance of this potential to Winnipeg and section 1.5 presents an overview of the entire capstone report. Key research questions, methods, sequence of tasks undertaken, and limitations are discussed in sections 1.6, 1.7, 1.8, and 1.9.

1.1 Stormwater Retention Ponds

Stormwater retention ponds are depressions in the ground, constructed to collect stormwater run-off. Here, water is retained before it is released into the larger stormwater management network (Forman, 2014). This retention reduces the risk of the stormwater infrastructure being overwhelmed at peak events, allows debris and suspended particulate to settle, and water percolation into the ground, further reducing flooding risk (City of Winnipeg, 2022). Along with stormwater run-off, contaminants, such as heavy metals and hydrocarbons from driveways, residual fertilizers, pesticides and herbicides from lawns and backyards, and organic matter including leaf litter, fecal remains, and dirt find their way into retention ponds (see section 2.3).

These retention ponds can be found in both urban and rural contexts and form an essential part of residential subdivision design in suburban Winnipeg. The design of these ponds has evolved over time to become better integrated into the landscape layout of the neighborhoods. Recent iterations of suburban stormwater retention ponds function as biodiversity assets by mimicking natural wetlands. This research argues there is potential to advance the role of retention ponds further by layering additional uses.

1.2 Potential Additional Uses

In more recent iterations of residential neighbourhood design, stormwater retention ponds have become well connected and accessible from various corners of the community by a trail system. Recreational green spaces, groves, and gazebos with congregational amenities have been integrated into the peripheries of these retention ponds. This integration opens doors to conceive additional uses occurring within the ponds and surrounding public green open spaces. Apart from being biodiversity assets, stormwater retention ponds could have other possible uses including:

- Sustainability assets by containing constructed aquifers, phytoremediation, and mechanical treatment zones. (This represents an extension of current ecological uses)
- Active recreational assets used for water sports including swimming, fishing, etc.
- Winter activity assets used for walking, skating, hockey, curling, ice-fishing, etc.
- Active and alternative transportation assets used for canoeing, etc.
- Socio-cultural and congregational assets used for community events, and
- Urban agriculture.

It is noteworthy to acknowledge that certain activities listed above would be challenged by water quality concerns. For example, swimming in the retained water can only be safe if the water quality is comparable to that of a public swimming pool. Catching fish or growing plants for human or animal consumption would be safe only if these plants are free of undesirable toxins. Recreational activities, including canoeing, might also result in occasional water contact. The quality of retained water may need to conform to public health and safety guidelines, such as *Guidelines for Canadian Recreational Water Quality* (Health Canada, 2012).

In an ideal world, stormwater retention ponds may be used for each of the activities stated above. Activities like skating and curling may be limited to winter, while others, such as agriculture and canoeing may occur simultaneously. Retention ponds, when used as multi-use open spaces, may offer a rich experience to users and become more productive urban assets. While some uses are gradually finding their way into the design of these retention ponds (see section 3.4), the perception of retained water as collected and often toxic waste deters others.

The current research sought to identify ways to modify this perception by using these waters as a productive resource for growing agricultural produce. The next section briefly introduces the benefits and relevance of urban agriculture in stormwater retention ponds.

1.3 Urban Agriculture, a Worthy Candidate

Urban agriculture has been regarded as a means to build climate resilience in urban ecosystems (Hough, 2004; Deksissa, et. al., 2021). The benefits of urban agriculture may also be leveraged to increase food security and equity in communities (Hough, 2004). Additional social and economic benefits investigated in section 2.2, merit consideration of urban agriculture as a worthy alternative for additional use for suburban Winnipeg's stormwater retention ponds.

Baker et. al. (2009) indicate the availability of under-utilized land in North American cities, such as large urban rooftops, unfrequented portions in public parks, under utility corridors, along transport infrastructural components, as abandoned rail lines, ex-industrial precincts, which can be used for urban agriculture. With so much urban under-utilized land, why should retention ponds be considered suited for urban agriculture?

While, these opportunities, in the form of under-utilized land, do exist, some particular characteristics may make suburban residential stormwater retention ponds better suited for urban agriculture. These include:

- Ample availability of water;
- Availability of nutrients (such as Nitrogen and Phosphorous);
- Availability of harvestable plants, including cattail (for production of biofuel, mulch, and other uses); and
- Availability of people to operate, maintain, benefit, and take pride in such activities.

Additionally, precedents for urban under-utilized lands being used for agriculture exist, for example, Lufa Farms in Montreal where large industrial rooftops have been converted into urban farms (Lufa Farms, n.d.). However, this research found limited local examples or precedents, where urban waterbodies have been used for agriculture. International Institute of Sustainable Development's (IISD) and Native Plant Solutions' collaborative project employing *Floating Treatment Wetlands* (FTWs) or floating cattail bio-platforms at Netley Libau marshes (Grosshans, 2014), Pelican Lake (Grosshans et.al. 2019) and Fort Whyte Alive (Native Plant Solutions, n.d.) are some noteworthy local precedents.

These local precedents, although limited, do suggest that urban agriculture in suburban stormwater retention ponds can be explored. However, various aspects and challenges like water quality concerns need to be considered to better understand this opportunity. This capstone examines these challenges and identifies possible solutions in Chapter 6.

The arguments presented above, in favour of urban agriculture in Winnipeg's stormwater retention ponds, do not mean that the City of Winnipeg should consider these waters as industrial aquatic farms, being operated via conventional agricultural techniques, where fertilizers and toxins, in the form of insecticides and pesticides, may be excessively used to increase production and protect crops. This would jeopardize the ecological health of retention ponds (see section 2.3). The arguments presented above do not mean that the City should sacrifice the ecological health of retention ponds for the sake of increased yields by eliminating animals, such as waterfowl, which may be perceived as pests.

Conventional agricultural techniques including crop monocultures depend heavily on fossil fuels. These techniques reduce microbial content and productivity of soil and increase the risk of soil erosion. Consequently, the yield depends heavily on chemical fertilizers, which flow and accumulate into waterbodies and risk regional ecological health (Hough, 2004). This is not the type of agriculture recommended in this research.

Principles of agroecology (Deksissa, et. al., 2021) and permaculture (Forman, 2014) inspire agricultural practices presented in this research, including co-cultivation of species, maintaining high biodiversity, and using organic by-products as raw materials for other processes. Here, animals such as water foul are recognized as a source of fertilizer, rather than as pests, and thus not only tolerated but welcomed.

The definition of urban agriculture must be expanded to include plants grown for animal fodder, biofuel production, and medicinal uses, in addition to food for human consumption. Additionally, this research does not argue that the entire retention pond should be used for agriculture. Instead, urban agriculture could be one of the activities occurring in these ponds.

1.4 Why is this Relevant for Winnipeg?

One important condition for the relevance of urban agriculture is food insecurity. In 2018, 11.5% of people in Winnipeg faced food insecurity (Canadian Centre for Policy Alternatives, 2018). Further, racialized, and recent immigrant households are much more likely to face these challenges. Also, one in six children in the City lives in food-insecure households (Canadian Centre for Policy Alternatives, 2018).

Long and convoluted supply chains for food shelved at Winnipeg's supermarkets have repeatedly caused public health emergencies including Salmonella outbreaks (CBC News, 2020). Recently, COVID 19 pandemic situation and its consequent effects have further highlighted the fragile nature of these long supply chains (Hui et al., 2022). By reducing dependence on food grown outside the region, a more robust food supply system can be built. Given this context, urban agriculture appears to provide unique opportunities to improve Winnipeg's food security, reduce risks associated with public health emergencies and build a robust food supply system.

Winnipeg Food Council (2018) reported that city-owned allotments for gardening have increased from 161 with 87% occupancy in 2012 to 234 plots with 100% occupancy in 2018. This increase in allotment gardens is a testament to their popularity among the residents of Winnipeg. COVID-19 pandemic may have further increased the number of community gardens in Winnipeg (Geary, 2020). This upward trend suggests that the people of Winnipeg appreciate various economic, health, and ecological benefits of urban agriculture.

1.5 Overview

This capstone report is structured in seven chapters, each having a varying number of sections. The first chapter builds the premise and describes the context and relevance of this research. Chapter One also presents research questions and discusses ways to answer them. A sequence of tasks undertaken is presented in section 1.7 in the form of a flowchart.

An extensive literature review, where overarching principles of urban ecology are understood and inform the theoretical framework of this study, follows in Chapter Two. This chapter also reviews scholarly articles and research precedents that facilitate a more nuanced understanding of additional aspects of urban agriculture and urban stormwater management.

Chapter Three records direct observations from visits to Winnipeg's selected stormwater retention ponds. Permitted uses and planting details and the evolution of these ponds with time are also captured in this chapter. In Chapter Four City's policy documents are briefly reviewed to identify gaps and potential amendments to policies.

The lessons learned from Chapters Two, Three, and Four or the Literature Review, Stormwater Retention Pond Audit, and Policy Scan were analyzed to inform a list of five kinds of challenges to urban agriculture in suburban Winnipeg's stormwater retention ponds in Chapter Five. Possible solutions to overcome these challenges are also sought in this chapter.

Chapter Six provides recommendations informed by solutions identified in Chapter Five. This concluding chapter also revisits the research questions and presents answers. This study culminates with the identification of additional research directions and reflection on possible outcomes.

1.6 Research Questions

Two key research questions were formulated to closely examine the potential of urban agriculture in Winnipeg's retention ponds. These are:

Q1 In what ways could suburban Winnipeg's residential stormwater retention ponds become urban agricultural assets?

Q2 Do Winnipeg's policy documents, guidelines, and instructions inhibit or make urban agriculture in stormwater retention ponds possible? Are there any amendments needed?

The first question guides the literature review and demands to know the *whys* and *hows* associated with urban ecology, urban agriculture, and urban agriculture's intersection with stormwater management. The second question directs an inquiry regarding the City's approach towards stormwater and urban agriculture, facilitating the identification of gaps and potential amendments to policies. Research methods employed to obtain data and sequencing of tasks undertaken are discussed in the next sections (1.7 & 1.8).

1.7 Research Methods

The first question considers the connection between Winnipeg's stormwater retention ponds and urban agriculture. To understand the fundamentals behind and to develop a conceptual level understanding of both these components, a study of overarching principles of urban ecology was deemed essential. This also helped to identify opportunities, associated challenges, and potential solutions. Thus, a **literature review** of these principles was conducted and forms the theoretical framework for this inquiry. This literature review follows the structure suggested by Creswell (1994) to include an introduction, separate reviews of various topics, and a collective summary at the end. For details refer to Chapter 2.

Another valuable source of information on emerging techniques and practices in agriculture was scholarly articles. These discussed data from recent experiments including yield, nutritional value, and monetized benefits of growing and harvesting specific crops in retained stormwater. Since enough literature was available on this front, a literature review of these **research precedents** was chosen to be another research method. In line with Grey's (2004. p. 52) suggestion, this review "*provides an up-to-date understanding"* of methods and nominee crops for urban agriculture in retention ponds. For further details refer to section 2.5.

It was crucial to understand the present form and usage of Winnipeg's retention ponds on the ground. An understanding of their chronological evolution unique to Winnipeg's context was also needed. As no literature, scholarly or otherwise, was found about Winnipeg's retention ponds, visiting selected ponds, and recording primary data via **direct observations** was found to be the most effective way forward. *Field notes* in the form of audit entries (see section 3.2) were generated by collecting descriptive data based on *primary observation* and *recollection* of information from photographs taken while visiting selected retention ponds (Grey, 2004. pp. 244-245). Data from the City of Winnipeg's Open Data Portal informed these audit entries to generate and analyze a pool of primary data. For further details refer to Chapter 3. This third research method provided answers for both, the first and the second questions.

The City of Winnipeg's policy documents, including *OurWinnipeg 2045* (City of Winnipeg, 2021), *CompleteCommunities 2.0* (City of Winnipeg, 2021), *Sustainable Water and Waste* (City of Winnipeg, 2011), and *A Sustainable Winnipeg* (City of Winnipeg, 2011) were reviewed briefly to understand how these documents approach urban agriculture in stormwater retention ponds. This brief **policy review**, referred to here as the Policy Scan was the fourth method for this research. This Policy Scan (see Chapter 4) records where and how many times key terms and their synonyms have been stated in these policy documents. The vision statements, goals, and objectives stated in these policy documents were also examined for explicit and implied reference to urban agriculture.

Although not conducted currently, due to lack of time, interviews with working professionals from the fields of planning, landscape architecture, and engineering design would benefit potential future iterations of this research. The list of interviewees could include officials from the City of Winnipeg's Planning & Property Department, Water & Waste Department, and Public Works Department to understand their perspectives on this subject matter. Representatives from Winnipeg's advisory and advocacy organizations such as Winnipeg Food Council (WFC), Food Matters Manitoba (FMM), Save Our Seine River Environment, industry leaders from business organizations, including Organic Food Council of Manitoba (OFCM), and leaders from Indigenous organizations, including Centre for Indigenous Environmental Resources (CIER) could be interviewed to gain additional knowledge. Experts from educational, research, and specialist professional agencies for example the University of Manitoba, International Institute for Sustainable Development (IISD), and Native Plant Solutions could also be included in the list of interviewees.

1.8 Sequencing

The lessons learned from the Literature Review, including research precedents, the stormwater retention pond audit, and the policy scan were analyzed to identify challenges and find solutions (see Chapter 5 for details). Initially, this research was going to include design guidelines to equip retention ponds for growing and harvesting plants for food, biofuel, and fodder.

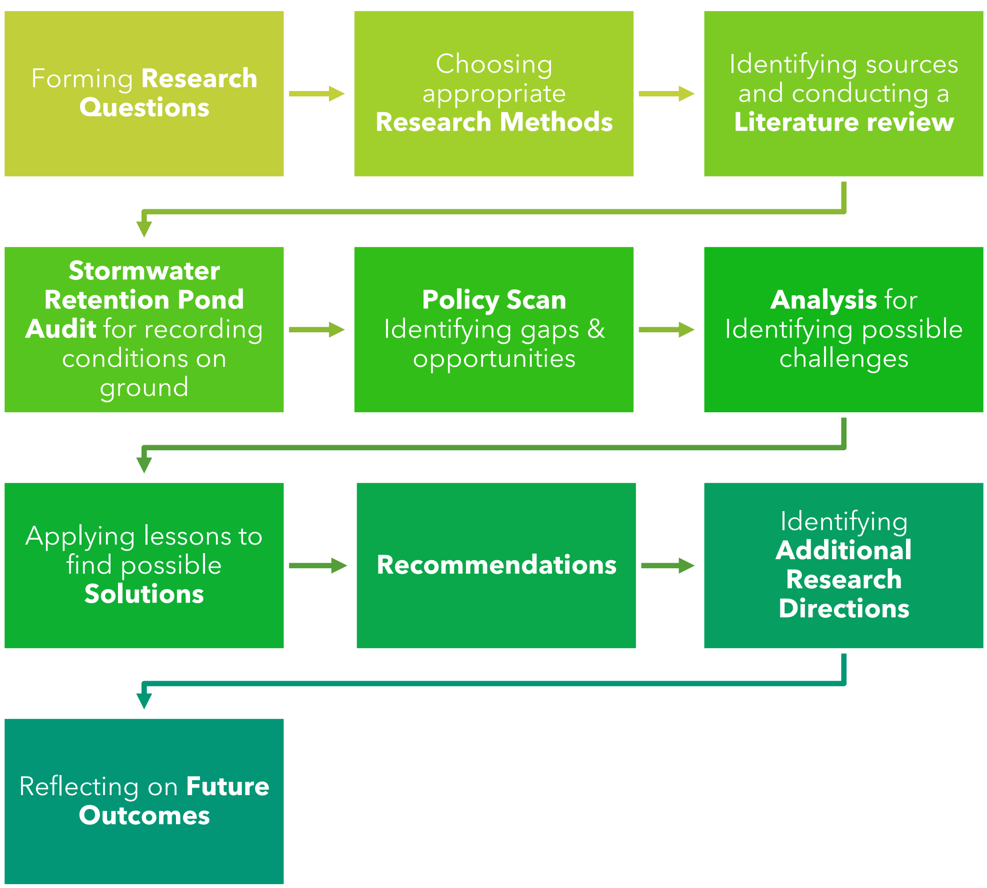

Figure 2: A methodology flowchart showing the sequence of tasks undertaken for this research

During the research, it was inferred that discussing and remedying various challenges to urban agriculture in stormwater retention ponds would be more fruitful. Design guidelines on their own might have no basis or foundation until these crucial questions are brought to light. The revised methodology indicating the sequence of undertaken tasks is summarized in the flowchart in Figure 2. The next section states various factors that may have limited the findings of this research.

1.9 Limitations

As the period of this capstone project was limited to eight months, most data analyzed in this research is secondary. Including and analyzing data from published books and peer-reviewed journals ensured the quality and facilitated quick results. Due to limited time, research methods requiring ethics approval, such as surveys or interviews, were not conducted, but it is recognized these methods could well inform future research advancing the subject.

The author's limited exposure to the City of Winnipeg, and experience in a winter context may have limited insights for findings in this research. Although the study does not directly discuss the winter context and its impact on recommendations and opportunities identified, connections between similar endeavours in other winter cities, and research precedents from Winnipeg's surrounding geographic region, are made. Site visits were limited in number, one to each precedent, during the fall season.

This research was also limited by public health restrictions due to COVID 19 pandemic. This restricted in-person conversations with the advisory panel, colleagues, and other experts. These conversations were however done extensively online. The next chapter presents a review of selected literature and summarizes lessons learned.

Ch. 2 Literature Review

This chapter presents a review of a variety of sources including books on overarching principles of urban ecology, scholarly articles on the intimate connection between food, water, and energy, and research precedents regarding experiments that illuminate cutting edge technological advances in growth and usage of specific plants with the help of retained stormwater.

This review is structured into five sections. The first two sections (2.1 and 2.2) draw upon overarching principles of urban ecology from Hough's (2004) & Forman's (2014) seminal works *Urban Ecology: Science of the cities* and *Cities and Natural Processes* to build an understanding of urban agriculture and urban stormwater green infrastructure. These sections describe components, challenges, and opportunities related to urban agriculture and stormwater infrastructure. The third section (2.3) discusses the interface and opportunities arising from the overlap of urban agriculture and urban stormwater green infrastructure.

Various ways to convert these opportunities into action are identified in the fourth section (2.4). This section is informed by Beatley's (2010) suggestions regarding ways to include individuals, community and educational institutions, and civic administration to alleviate socio-cultural, regulatory, and operational barriers to urban agriculture as presented in *Biophilic Cities* (Beatley, 2010). The fifth section (2.5) presents a review of research precedents that help nominate crops for urban agriculture in stormwater retention ponds. The last section (2.6) summarises lessons learned from this literature review.

2.1 Urban Agriculture: Opportunities, Challenges & Benefits

Building on the work of Hough (2004) & Forman (2014), this section identifies existing agricultural opportunities in contemporary cities, and reports on various associated challenges, and describes the social, ecological, and economic benefits of urban agriculture. While building a case for urban agriculture, Hough (2004) illustrates the difference between contemporary *Industrialized agricultural practices* and *traditional mixed farming practices.*

2.1.1 *Industrialized Agricultural Practices* vs *Traditional Mixed Farming Practices*

Hough (2004) describes the nature of contemporary agriculture and its adverse effects on the environment. As *industrial agricultural practices* depend extensively on fossil fuels for the production and distribution of food, Hough (2004) does not recommend these practices for urban agriculture. These practices should be replaced by *traditional mixed farming practices* (Hough, 2004. p.161). Traditionally, farming of mixed crops benefited not only from each other but also from the presence of animals on the same lot. While the animal excreta provided nutrients for the plants, agricultural residue provided fodder for animals (Hough, 2004. p. 160). This spirit of circularity was the backbone of the ecological sustainability of *traditional mixed farming practices*.

Contemporary industrial agricultural processes engage in monoculture of a limited number of plants and use genetically modified crops, large amounts of fossil fuels to manage large-scale operations, and toxic chemicals to deter the growth of unwanted plants, animals, and microorganisms, to increase yield (Hough, 2004). These processes have the following detrimental effects:

- Reduction in soil health by extensive tilling, loss of desirable microbes, and nutrient deficiency.
- Water and soil contamination by chemicals such as pesticides, herbicides, and insecticides.
- Loss of biodiversity both within species of the same crop plant and throughout the farm.

Extensive farming operations in rural areas are highly dependent on excessive demand from urbanized areas, which are more often in distant regions (Hough, 2004. p. 162). This gap between the food-growing areas and consuming centres has increased tremendously in the last century. In many North American cities, food products on the supermarket shelves have often traveled many hundreds or thousands of kilometers by air, land, and sea, due to the distance between the production areas and the consumption areas, and processing and packaging needs. The energy spent in these processes, when added to the total energy needed for growing food, does not equate to the energy we receive by consuming it. Hough (2004. p.162) calls these hidden '*environmental costs*'.

Forman (2014) reiterates this idea while describing '*foodsheds*'. He states that urban agriculture can help reduce the '*food shed*' or the region that contributes to food available in a particular city. As of 2000, the *foodshed* of an average American city has already grown to 2400 km (Forman, 2014. p.348). Growing food within the city can significantly reduce the *foodshed* while reducing transportation costs and associated greenhouse gas emissions, in turn forming a key component of contemporary climate change mitigation strategies.

2.1.2 Additional Benefits

Hough (2004) identifies hidden '*social costs'* associated with contemporary food systems and argues that urban agriculture can help reduce these costs. The costs associated with social imbalances caused by the *industrial agricultural practices* such as increasing pressure on rural areas to grow more, urban migration and reducing rural population, loss of green and social spaces in the city are included as '*Social costs'* (Hough, 2004. p.162). Hough argues that hidden '*social*' and '*environmental*' costs increase the ecological footprint of contemporary food and render contemporary agricultural practices and food systems inefficient and unsustainable (2004, p.163).

With these arguments, Hough (2004) states that urban agriculture can contribute to urban food self-sufficiency. Growing food in cities has proven to be an effective way for the economically challenged city dwellers to offset otherwise prohibitive costs of their food (Hough, 2004. p.167) by maintaining a small balcony garden or community garden lot or allotment. Forman (2014. p.348) underpins this idea by stating that urban food production can also increase food security in the city. Other benefits of urban agriculture include supporting multiculturalism in cities (Hough, 2004). As of 2011, immigrants made up 9.6 % of the population of Winnipeg, half of which arrived in or after 2006, urban agriculture can be leveraged to support multiculturalism in the city.

2.2 Urban Green Infrastructure: Challenges, Components & Opportunities

To investigate whether retention ponds can be used as urban agricultural assets, the components, material flows, and processes happening within these stormwater infrastructure components need to be understood. Forman (2014) writes extensively about the significance, material flows, and conditions of urban waterbodies. Waterbodies, such as wetlands, ponds, and creeks can play an important role in restoring the ecological health of urban waters through the processes of *settling, filtration, absorption, assimilation,* and *decomposition* (Forman, 2014. p.174).

2.2.1 Challenges

Degrading quality of urban stormwater is challenging these above-mentioned processes due to pollution and contamination. As stormwater run-off from hard paved surfaces and lawns is quick, water does not get the time to percolate in or get filtered while it travels through urban vegetation (Forman, 2014. p.173). As a result, many contaminants find their way into urban waters such as:

- Heavy metals, hydrocarbons, oil, dirt, and occasional debris from driveways and pavements.
- Residual fertilizers from lawns and planted areas including nitrogen and phosphorus compounds.
- Residual chemicals from planted areas including insecticides, pesticides, fungicides, herbicides, etc.
- Organic matter, including leaf litter, fecal remains from rodents, pets, waterfowl, and other urban animals including associated microbial matter, live and dead insects, etc.

While some undesirable elements such as heavy metals and chemicals directly threaten the aquatic and soil flora and fauna by increasing the toxicity of urban waters and soil, excessive nutrient enrichment (or *eutrophication*) causes increased growth of some aquatic organisms including blue-green algae, anaerobic bacteria, laminae. Excessive growth of floating aquatic plants reduces sunlight penetration and dissolved oxygen levels in waterbodies gradually killing all other aquatic life (Forman, 2014. p.174).

Hough (2004) also recognizes that stormwater retention ponds may tend to become eutrophic leading to a profusion in algal growth, consequent loss of aquatic diversity, and degradation of the ecological health of the waterbody. Reiterating Forman's (2014) statements, Hough (2004) argues that anthropogenic eutrophication is the result of unfiltered contaminated or nutrient-rich urban stormwater being allowed to flow through unvegetated surfaces and lawns into urban water bodies. Anthropogenic eutrophication may be reversible and can be remedied by corrective measures by governments brought to action by advocacy groups and grassroots movements (Hough, 2004. pp. 28-29).

2.2.2 Components of Stormwater Green Infrastructure

Forman (2014) describes the components of a stormwater green infrastructure and discusses their role in maintaining the quality of retained stormwater. A stormwater *retention pond* is a constructed basin where stormwater is collected, retained, and treated before it is released further into the stormwater network. A *bioretention pond* has additional biological features riparian vegetation, trees for shading, reducing evaporation losses, and providing habitat for urban fauna (Forman, 2014. pp.179,180).

Other components, including *detention basins* and *biofilters*, may be added to the system to improve the water quality of the retained water. A *detention basin* collects the water from large paved areas for example parking lots and driveways. These basins allow undesirable elements to filter out or settle down before the detained water flows into the *bioretention ponds* (Forman, 2014. pp.180,181). A *biofilter* is a small basin containing specialized plants and microorganisms that clean the water through *phytoremediation* and *bioremediation*. Roof rainwater, which is comparatively cleaner than ground surface run-off can be collected separately, stored for irrigation use, or be allowed to flow slowly over aggregate or vegetated surfaces to let it get percolated and filtered (Forman, 2014. p. 170).

2.2.3 Retained Stormwater, Waste or Resource?

Hough (2004) argues that nutrient-rich stormwater must be viewed as a resource rather than waste. Many communities in Southeast Asia and China have been benefiting by investing in aquaculture, or fish farming. Wastewater from the city is collected in natural estuaries or human-modified ponds and used for fish and plant production (Hough, 2004). Forman (2014. pp. 344, 345) also acknowledges this prospect by identifying urban waterbodies as a potential urban agricultural asset with opportunities for aquaculture and fish production.

While these precedents of urban agriculture in stormwater green infrastructural components, such as retention ponds, do build a strong case, degrading water quality due to pollution from urban run-off challenges this potential. Aquatic plant populations, including algae and bacteria, can remedy this situation by removing unwanted Nitrogen, Phosphorus, and heavy metals from retained stormwater (Hough, 2004). This principle is being applied in many cities to clean urban wastewater by letting it flow through natural or constructed wetlands (Hough, 2004).

2.3 Interface Between Urban Agriculture & Stormwater Green Infrastructure

This section explores the interrelationship between urban food, energy, and water and presents arguments in support of overlapping urban agriculture and urban stormwater green infrastructure. Two scholarly articles, inform this section. The first is titled *The Global Food-energy-water Nexus*, by D'Odorico et.al. (2018), and the second is titled *Integrating Urban Agriculture and Stormwater Management in a Circular Economy to Enhance Ecosystem Services*, by Deksissa et. al. (2021). These two articles combine the principles of urban ecology and tenants of circular economy to build key arguments.

2.3.1 Food-Energy-Water Nexus

Novel and innovative solutions may be required to mitigate forthcoming global food and water insecurity resulting from increasing completion for freshwater due to the following reasons (D'Odorico et. al, 2018):

- Dietary patterns across the world are changing to include more meat, dairy, and other water-intensive food products.
- Increased industrial agriculture practices requiring additional chemicals and fossil fuels for the production and distribution of food threaten the availability of clean freshwater.
- Increasing dependence on new types of fossil fuel energy sources including shale oil, shale, gas, oil sands, etc. may further reduce the availability of freshwater. These energy sources require more water for energy production. D'Odorico et. al (2018) also remark that an increasing bio-fuel energy industry may compete with agriculture for water and fertile soil.

The relationships between food and water, water and energy, and food and energy need to be understood to mitigate the above-mentioned forthcoming insecurities. Industrial agriculture contributes between 19% to 30% of global greenhouse gas emissions (D'Odorico et. al., 2018. p.466). Additionally, exorbitant quantities of water are virtually transferred as food when produce is transported from production regions of the world to different consumption centers. This conceptual '*virtual water*' (D'Odorico et. al., 2018. p.491) can help better visualize challenges generated by contemporary industrial agricultural practices and food systems.

D'Odorico et. al., (2018) recommend looking at alternative sources of water for the agriculture and energy sectors; decreasing the environmental impact of agriculture by increasing crop diversity; incorporating principles of agroecology, hydroponics, and aquaponics; and investing more in circular economy by ensuring waste from food, water, and energy sectors is utilized as raw material by another sector, as mitigative strategies.

2.3.2 Overlapping Stormwater Green Infrastructure & Urban Agriculture

As urban ecosystems are becoming increasingly vulnerable due to climate change, Deksissa et. al. (2021) recommend exploring innovative overlaps between stormwater green infrastructure and urban agricultural opportunities to build climate resiliency in cities. The integration of urban agriculture and urban stormwater infrastructure can build ecological efficiency in both (Deksissa et. al., 2021). To support their arguments, Deksissa et. al. (2021) conduct an extensive literature review and present three findings as below:

- A resilient urban ecosystem can be equated to a resilient urban environment and thus be considered better equipped to mitigate the effects of climate change. Resiliency in the urban ecosystems can be achieved by integrating means to deliver urban ecological services with other urban systems, such as stormwater infrastructure (Deksissa et. al., 2021. p.5).
- This integration can be achieved by ensuring urban agriculture follows the principles of circular economy. As sustainable urban agriculture practices can use the by-products of the urban stormwater management system, their integration can have dual benefits. These benefits include an increase in the availability of water for irrigation and an increase in the quality of urban stormwater due to bioremediation. Other ways of using urban stormwater for food production include hydroponics, or growing plants directly in water, and aquaponics where fish farming is incorporated into the system (Deksissa et. al., 2021. p.6).
- To achieve this overlap, stormwater infrastructure can be used as urban agricultural assets by converting piped or grey stormwater infrastructure into green infrastructure (swales, constructed wetlands, bioretention ponds, etc.) to form Integrated Stormwater Green Infrastructure (ISGI). As the water gets filtered close to the source of stormwater and has sufficient opportunity to percolate, this integration reduces stormwater management costs and flood risks (Deksissa et. al., 2021. p.7).

Thus, Integrated Stormwater Green Infrastructure (ISGI) can be leveraged to mitigate the challenges of urban water quality degradation, food insecurity, and climate change

(Deksissa et. al., 2021. p.11). The next section discusses how governments, community institutions, and individuals can support the integration of urban agriculture with suburban retention ponds.

2.4 Converting Opportunities into Action

The sections above present various benefits of integrating urban agriculture into urban stormwater infrastructure components such as retention ponds. This section builds on Beatley's (2010) recommendations including suggested ways to involve city administrations, community and education institutions, and individuals in this integration process. Beatley (2010. p.100) remarks that urban agriculture is a key component of biophilic strategies as it allows residents to be in close contact with nature and experience their intimate relationship with soil, plants, air, and water while producing food.

2.4.1 Role of Education & Community Institutions

Schools and other educational institutes can bring about desired behavioral change by seeking future citizens at an early age and inculcating in them, the love for nature (Beatley, 2010). Many schools including Noranda Primary School in Perth, Australia, Sidwell Friends School in Washington, DC, USA, and the Stenurten Ecological Daycare in Copenhagen, have adjusted curricula to introduce new programs to produce environmentally sensitive youth (Beatley, 2010. pp.125-126).

Community institutions, for example, zoos, botanical gardens, and universities are diversifying their role to create room for biophilic activities while creating more opportunities for engagement with nature (Beatley, 2010). In the United States of America, the Western North Carolina Nature Centre, Ashville, North Carolina, Lewis Ginter Botanical Garden, Richmond, Virginia, and Cleveland Botanical Garden, Ohio operate initiatives such as *Junior Naturalist Program*, *Learning Farms*, and *Green Corps*, respectively. With these initiatives, community members, including students, can engage with nature and participate in urban agricultural activities (Beatley, 2010. pp.143-145). Beatley (2010) writes that such endeavours can be amplified by collaborating with non-government organizations and advocacy groups.

2.4.2 Role of City Administrations

City administrations can get involved by funding and managing demonstrative projects such as the '*Garden for a time'* in Paris (Beatley, 2010. p.133). Beatley (2010) suggests that the city's parks division could explore opportunities to carve out space for urban agriculture in existing green open spaces. City administrations could also mandate a percentage of areas in residential subdivisions to be earmarked for biophilic activities. The actions of city administrations in Davis, Portland, Chicago, Boston, and Toronto can be studied as precedents in this regard (Beatley, 2010. pp.131-133).

Beatley (2010) states that cities must find innovative solutions to overcome regulatory barriers to support urban agriculture. The New York City administration has formed new agencies such as NY Green Task Force to analyze the codes and permitted activities in neighbourhoods. They are further tasked with proposing recommendations to overcome challenges to sustainable activities, including solar energy installations, installation of native vegetation, and urban agriculture (Beatley, 2010. p.137). The City of London has dedicated a portion of the city's parks spaces for growing food, to support an urban farming and biodiversity strategy built into its policies (Hough, 2004. p.187).

2.4.3 Unique Solutions for Operational & Socio-Cultural Barriers

Unique land management practices such as *Community Roots*, where enthusiasts from residential neighbourhoods manage vegetable patches in other people's backyards may be leveraged to support urban agriculture (Beatley, 2010, p. 101). Similar operational models, based on mutual informal relationships could be useful for managing vegetation riparian zones abutting private backyards.

Socio-cultural barriers to the integration of urban agriculture with retention ponds might be the hardest to overcome. These result from fear of the wild, an inflated feeling of insecurity towards self and loved ones, xenophobia, and inherent cultural and class bias. These causes can be remedied by public education and public awareness programs (Beatley, 2010). Beatley (2010) further suggests Jane Jacob's "*more eyes on the street*" approach to guide the design of neighbourhoods. Increased density and compactness of neighbourhoods can result in *more eyes on the ponds*, and merits consideration. Incentives including density bonuses may encourage developers to build denser neighbourhoods (Beatley, 2010. p. 49). Community volunteer watch programs and encouraging activity outdoors may also reduce perceived safety risks (Beatley, 2010). The next section gathers information from various research precedents to list aquatic crops for stormwater retention ponds.

2.5 Research Precedents

This section reviews various scholarly articles that help nominate crops for urban agriculture in stormwater retention ponds such as cattail (Grosshans, 2014; Berry 2016), duckweed (Xu et. al., 2012; Hochman et. al. 2018), algae (Supraja et.al., 2020), tomatoes (Supraja et.al., 2020), and other herbs and vegetables.

2.5.1 Cattail, a Champion for Circular Economy

Grosshans' (2014) research builds an excellent case for cattail harvesting in Canadian prairie wetlands. With the International Institute of Sustainable Development's (IISD) experiments in the Netley Libau marshes and Pelican Lake, Manitoba, multiple ecological and economical benefits of cattail harvest were recorded (Grosshans et.al., 2019). Cattail bio-accumulates excessive Phosphorus and Nitrogen within its stocks. After harvesting, these stocks can be converted into pellets, transported, and combusted to produce energy (Grosshans, 2014). Other techniques including gasification are also being evaluated.

Cattail as a bioenergy source can be effectively used to displace coal and other fossil fuels, leading to an overall reduction in greenhouse gas emissions. Phosphorus can be recovered from the residue and used as fertilizer or raw material for other processes. Regular removal of plants from waterbodies improves habitat conditions for fauna and other plants by allowing for more space and sunlight penetration. Excessive nutrients, when removed from wetlands, can further increase the ecological health of waterbodies by deterring cyanobacterial growth associated with eutrophication (Grosshans, 2014)

Direct economic and monetized benefits of cattail harvests are recorded by Berry (2016). Farmers were able to increase their income by selling harvested cattail from constructed retention ponds by $642.70/hectare of harvestable cattail/year (Berry, 2016. p.76). Additional monetized benefits equivalent to $7,014/hectare of harvestable cattail/year (Berry, 2016. p.76) were recorded, corresponding to multiple ecological heath benefits to the surroundings. Additionally, slope stabilization benefits and reduced flooding risks were equated to an additional $10,000 to $12,000/hectare of retention system/year. These cost returns were expected to increase over time (Berry, 2016. pp. 74-88.). This study analyzed data from the Province of Manitoba. Similar gains may be expected by such endeavours in the city of Winnipeg.

2.5.2 Opportunities for Other Biofuel Crops

Supraja et.al. (2020) elucidate the potential uses of algae harvested from waterbodies. Algal biomass is a rich source of fats, which can be extracted for biodiesel production, a rich source of proteins and can be used to produce food supplements, and a rich source of carbohydrates, which can be harvested as feedstock to produce bioethanol and biohydrogen (Supraja et.al., 2020, p.1).

Xu et. al., (2012) consider duckweed, a floating leafy aquatic plant, as another alternative crop for biofuel production. A comparison of dry biomass yields of various biofuel crops found duckweed's dry biomass yield to be second, only to that of algae (Xu et. al., 2012. p. 595). When assessed as a protein source in comparison to other fodder crops, it ranked higher than alfalfa and lower than soybean meal. On the other hand, starch content in duckweed was found to be as high as 75% of its dry weight. These qualities also make duckweed an excellent fodder crop (Xu et. al, 2012, p.591).

Cultivating duckweed for fodder and biofuel can free up arable land for other crops (Xu et. al, 2012. p.589). Selecting the right one, out of the 37 existing species of duckweed may be crucial to the success of the process. There can be significant variations in results, both regarding the output of biomass and sensitivity to varying temperatures depending on which varieties are chosen (Xu et. al, 2012). Other research indicates that crops, such as romaine lettuce, kale (Tikasz et al., 2019), and basil (Kim & Yang, 2020) can also be grown in retained stormwater.

2.5.3 Benefits of Co-Cultivation

Fish-associated microalgal presence in the growth medium in aquaponic systems has been found beneficial for food crops, including tomatoes. Supraja et.al. (2020) record an increase in the nutritional value of the products when co-cultivated. This increase in nutritional values is due to a symbiotic relationship between algae and plants that allows for better sharing of nitrogen, phosphorous, and dissolved oxygen (Supraja et.al., 2020. p.2). Although this research analyses data in a hydroponic environment, similar gains may be expected in an urban aquatic condition.

2.6 Lessons Learned

This literature review helped an understanding of urban agriculture and urban stormwater green infrastructure along with their associated challenges and opportunities. While the literature reviewed is extensive and discusses various aspects of urban agriculture and urban stormwater green infrastructure, some gaps can be identified. Research undertaken for this study did not uncover any detailed information regarding urban agriculture in an aquatic context such as in retained stormwater. An exploration of the opportunities and challenges of urban *aquatic* agriculture (that in cities' waters rather than on land) would have been a valuable addition to these sources. Nevertheless, lessons learned can still be applied to form the theoretical backbone of this research. These lessons are as follows:

2.6.1 Towards Edible and Productive Urban Landscapes

i. Industrial agriculture can be inefficient and unsustainable. Agricultural techniques based on *traditional mixed farming practices* and growing food locally can reduce the ecological footprint and provide opportunities for waste economies to exist.

ii. Beyond environmental and economic benefits, urban agriculture has social benefits by providing shared urban greenspace and helping economically challenged households to reduce expenditure on food. Urban agriculture can ensure greater food security and reduce food inequity in urban areas.

iii. Urban neighbourhoods can integrate urban agriculture to build edible and productive landscapes.

2.6.2 Retained Stormwater: a Valuable Resource

i. Urban stormwaters are subject to water quality issues due to unchecked, polluted, nutrient-rich stormwater run-off flowing into retention ponds.

ii. *Detention ponds* and *biofilters* can be plugged into the stormwater infrastructure to improve the quality of retained stormwater. Aquatic plants and microbes in bioretention ponds can further improve water quality. These plants can be harvested for a variety of uses such as mulch, compost, biofuel, animal fodder, and food.

iii. Many cities have been traditionally growing edible plants and fish in nutrient-rich tidal marshes or purpose-built ponds. Although this practice called aquaculture, now faces challenges of degrading water quality, as cities become more and more polluted, applications of this practice can inform innovative solutions for integrating urban agriculture in stormwater retention ponds.

iv. Retained stormwater can be viewed as a nutrient-rich resource rather than waste.

2.6.3 Integrating Urban Agriculture and Stormwater Green Infrastructure

i. The forthcoming food and water insecurities due to competition between energy and food sectors for freshwater can be eased out by decreasing the ecological impacts of agriculture on the environment.

ii. Practicing sustainable agriculture, informed by the principles of agroecology, including increasing crop diversity and small-scale farming informed by local and Indigenous knowledge while moving away from soil tilling and agrochemicals can further reduce the environmental impacts of agriculture.

iii. Exploring innovative means of agriculture, including hydroponics and aquaponics, and investing in making the economy more circular by ensuring that waste from one sector is used as raw material for the other, will help support the integration of urban agriculture with stormwater green infrastructure.

i. The integration of urban agriculture with stormwater green infrastructure may have various benefits including:
   a. Increase in local food production. This can limit *virtual water trade* and the energy consumption associated with it.
   b. Reduction of *foodshed* of consumed food items.
   c. Increase in quality of urban stormwater and reduction of flood risk.
   d. Increase in ecological services of urban stormwater infrastructure.
   e. Increase in opportunities for green energy production by biofuels, further reducing dependence on greenhouse emissions.

2.6.4 Role of City Administrations, Community Institutions, and Individuals

i. City administrations can promote urban agriculture by investing in demonstrative projects; providing incentives to developers like density bonuses; and revisions to codes to remove regulatory barriers.

ii. Community and educational institutions, and advocacy groups can collaborate with the city administration to develop the capacity for urban agriculture in the community.

iii. Socio-cultural barriers to urban agriculture may be remedied by investing in community education and community engagement initiatives.

iv. Dense and compact neighbourhood design principles and neighbourhood volunteer programs can be applied to increase the perception of safety in and around urban open spaces.

2.6.5 Lessons from Research Precedents

i. Growing and harvesting plants like cattail, duckweed, and algae for various objectives such as biofuel, fodder, and food supplements can be economically profitable and beneficial for the ecological health of urban waters.

ii. The nutritional value of food products may increase when they are co-cultivated with microalgae. This builds a positive case for urban *aquatic* agriculture in retention ponds. Nominations of other crops including wild rice, kale, lettuce and potato, and beetroot are further investigated in the Analysis and findings chapter.

The next chapter presents an audit of the site conditions, such as planting details, permitted activities, and other details regarding stormwater retention ponds in five selected neighbourhoods in Winnipeg.

Ch. 3 Stormwater Retention Pond Audit

In this chapter, details including size, year of construction, planting, and permitted uses regarding residential stormwater retention ponds in selected neighborhoods of Winnipeg have been recorded and analyzed to look for commonalities, and differences. This data has been collected via three sources:

- On-site observations were recorded while visiting retention ponds once each in the fall of 2021. These observations were made while walking around retention ponds. Photographs taken at the time of the visit were consulted to confirm these observations.
- City of Winnipeg's open data portal was referred to for collecting data such as areas of ponds and neighbourhood developments.
- Websites maintained by developers and neighborhood associations were examined to collect information such as the year of construction, details about the design team, etc.

Site observations and other information as stated above were tabulated as audit entries for each precedent. Audit entries are included as Tables 1-5 in section 3.2. A brief narrative about each retention pond accompanies these audit entry tables. Information from the audit entries was analyzed to identify commonalities and variations in design, planting, and usage. Section 3.3 discusses the findings from this analysis including the evolution of suburban Winnipeg's stormwater retention ponds.

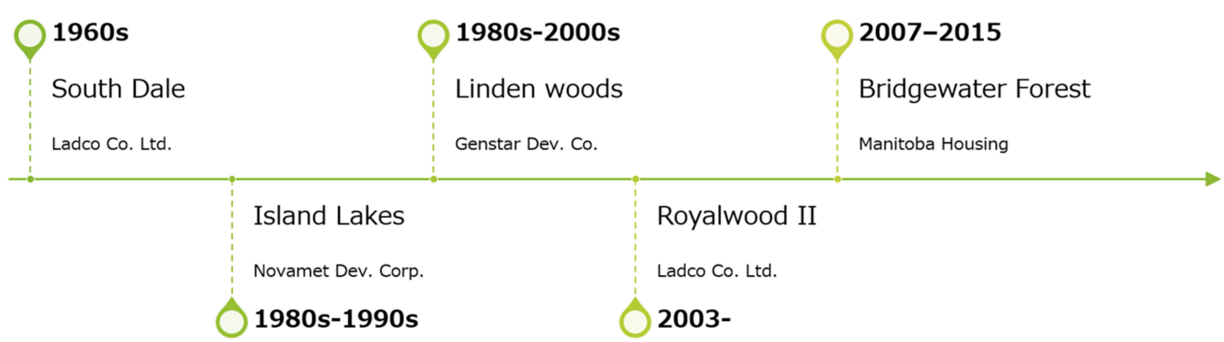

Figure 3: A timeline depicting selected precedents for suburban Winnipeg's Stormwater Retention Pond Audit

3.1 Selection of Precedents

The stormwater retention ponds in the neighbourhoods of Southdale, Island Lakes, Linden woods, Royalwood II, and Bridgwater Forests were selected as precedents for this audit. The first precedent, in the Southdale neighbourhood, which was the first residential subdivision to be planned with stormwater retention ponds, was constructed in the 1960s (Ladco Company Ltd., n.d.). As the design of retention ponds in Bridgwater Forest & Royalwood II neighbourhoods is exemplary, (see section 3.2 for details) these were included in the list of selected precedents. Construction of the last precedent, in the Bridgwater Forest neighbourhood was started in 2007 (Anaka, 2013). The neighbourhoods of Island Lakes & Linden woods were selected for this audit as this helps in tracing the evolution of the design of retention ponds from the 1960s to the late 2000s.

As the construction period of these five precedents spanned across the last six decades, their selection benefited an understanding of the chronological evolution of the design of retention ponds in Winnipeg. Figure 3 presents a timeline indicating these neighbourhoods along with their developers and the year of construction.

3.2 The Audit

Audit entry tables along with a brief narrative describing the stormwater retention ponds in each precedent are presented in this section. To support the narrative, site photographs and satellite images for the five neighbourhoods have also been included.

3.2.1 Southdale

Figure 4: The greens open space surrounding the retention ponds at South Dale is dominated by lawns

Southdale was Winnipeg's first neighbourhood to include retention ponds in its layout. Four thin linear ponds are located in the center of the subdivision. Their shape is simple and functional. Two small recreational green open spaces are attached to the shorter edges of these ponds. The surrounding open space of these retention ponds is planted with and maintained as lawns. Minimal shrub and reed planting was observed at the edge of the pond. The surrounding open space does contain specimen trees, benches, and warning signs to inform residents about permitted activities in these ponds as seen in figure 4. Remains of a metal railing along the pond boundaries were observed, hinting that these ponds were fenced earlier.

Figure 5: Satellite image of the neighbourhood of South Dale. Source: Google Earth (Google Earth).
a. retention ponds, b. park spaces

Table1: Audit entry for Southdale

Southdale		
DETAILS	Time period	1960s
	Developer	Ladco Company Ltd.
	Design Team	
AREAS	Total Development	258.46 Ha
	Ponds	11.72 Ha
	Pond area as % of total development	4.5%
RETENTION POND	Slopes	Moderate, continuous (not stepped, no apparent variation in grading)
	Planting details	Mostly lawn, water edged with shrubs at certain points, could have been added later. specimen trees are noted.
	Materials and design details	No hardscape; traces of a protective railing can be found in some areas.
	Presence of fauna	Geese
ADDITIONAL USES	Ponds	Just visual, some benches face the ponds.
	Surrounding open space	At one location, the pond abuts the school playground. Private backyards surround the other sides of the ponds.
REMARKS	Fountain for aeration.	
	Access to ponds is mostly via private backyards, here too, it doesn't seem to be engaged with much.	
	The shape of the ponds is simple and functional.	
	Extensive mown area with minimal vegetated edge and no revetement for edge protection.	

3.2.2 Island Lakes

In Island Lakes, the ponds seem better integrated with the layout of the residential lots. A ring of ponds with fingers extending into the subdivision forms the center of the neighbourhood. These fingers make the edge of the ponds long and convoluted. The layout allows for the maximum number of ponds facing lots, that would have been sold at a premium. Although the slopes surrounding the ponds are mostly planted with lawn, tree and shrub clumps are still present.

Reeds such as cattail have been planted at the periphery of the ponds in clumps, but do not form a continuous strip. These seem to have been added later. Aggregate revetment at the shore of the pond has been added, possibly for bank stabilization. This revetement is about 1 m wide. Approximately a third of the pond's shoreline is open to residents and contains walking trails connecting the various ends of this subdivision. The rest of the pond periphery abuts private backyards.

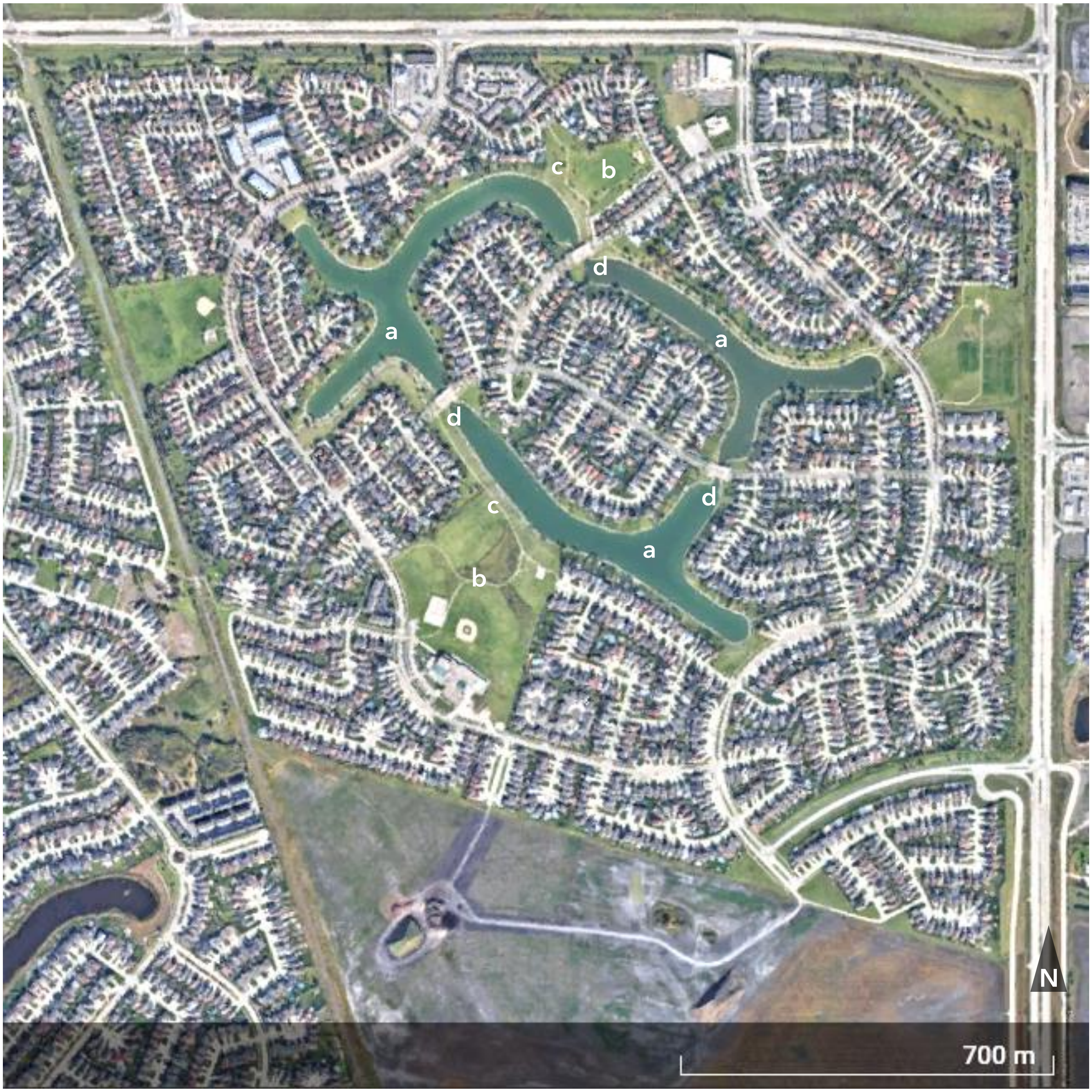

Figure 6: A satellite image of the neighbourhood of Island Lakes. Source: Google Earth (Google Earth)
a. retention ponds, b. park spaces, c. trails, d. bridges

Table 2: Audit entry for Island Lakes

Island Lakes		
DETAILS	Time period	1980s-1990s
	Developer	Novamet Development Corporation
	Design Team	
AREAS	Total Development	239.69 Ha
	Ponds	15.59 Ha
	Pond area as % of total development	6.5 %
RETENTION POND	Slopes	Moderate & continuous, gradual at areas where the pond abuts public green open spaces.
	Planting details	Mostly lawn, shrub beds, and tree clumps exist but are not extensive
	Materials and design details	Concrete pavers for walkways, Grass-jointed concrete cavity pavers for maintenance vehicles can be seen. 1 m wide aggregate revetment onshore
	Presence of fauna	Geese, rabbit, squirrel
ADDITIONAL USES	Ponds	Mostly visual, prohibited activities can be seen on cautionary signs.
	Surrounding open space	On two sides, trails run along the greens connecting two park spaces that abut the ponds. Private backyards abut the rest of the ponds.
REMARKS	Seems more integrated into the layout plan.	
	Trails connect park spaces to the ponds.	
	Bridges provide another way to engage with the waters	
	Interconnected lakes, but with no islands or reedbeds	
	The finger-like extensions make the edges of the ponds very long	

3.2.3 Linden woods

Figure 7: Note the aggregate revetment at the shore edge and reed planting at the retention pond at Linden woods

The stormwater ponds at Linden woods are also well integrated into the layout of the subdivision. One large, linear and contiguous waterbody in the center has again allowed the developer to carve out the maximum number of pond facing lots. The slopes and peripheries of the ponds are planted and maintained as lawns, but tree and shrub clumps are indeed present. The shoreline of the pond has a 1.5 m wide aggregate revetment, as seen in Figure 7, probably to check shoreline degradation and increase the ease of maintenance. Reeds and wetland grasses are planted beyond this aggregate revetment into the pond.

Figure 8: A satellite image of the neighbourhood of Linden woods. Source: Google Earth (Google Earth)
a. retention ponds, b. park spaces, c. trails, d. bridges

The retention ponds are surrounded by public greens on both sides, half of the pond's periphery is accessible by trails that connect the entire neighborhood. This peripheral park space has sufficient street furniture, often strategically placed in aggregate courts and decks overlooking the pond. Two bridges further increase the aesthetics of the pond-side. Although geese, rabbits, and squirrels were easily spotted, more animals could have been present.

Table 3: Audit entry for Linden woods

Linden Woods		
DETAILS	Time period	1980s-2000s
	Developer	Genstar Development Company
	Design Team	Interdisciplinary Engineering Company (IDE)
AREAS	Total Development	306.58 Ha
	Ponds	12.39 Ha
	Pond area as % of total development	4.1%
RETENTION POND	Slopes	Moderate, slope shallows out towards the top.
	Planting details	Mostly lawn, large clumps of shrubs, trees do exist, reeds surround the water body at certain locations, reed bed is not continuous, could have been planted later.
	Materials and design details	Water is skirted by aggregate revetment, about 1.5 m wide. Reeds between the revetment and the water.
	Presence of fauna	Geese, other birds, rabbits, squirrels
ADDITIONAL USES	Ponds	The layout of the lots is set around the lakes, water is celebrated at certain points such as on the bridge, decks, and small aggregate courts overlooking the ponds, but it seems to be only visual, prohibited activities can be seen on cautionary signs, active engagement doesn't seem to be permitted.
	Surrounding open space	About half of the retention pond abuts public green park space, the trails running along are fairly continuous, seem to be the primary trails stitching the greens and the ponds together, Private backyards abut the rest of the ponds, but stop before the planted edge nest to the aggregate bed.
REMARKS	Seems more integrated into the layout plan, well connected via trails	
	Bridges provide another way to engage with the waters	
	Vantage points overlooking the pond have been used well as small pause points and decks.	
	One continuous central lake, but with no islands within	
	A large fountain is placed in the most conspicuous location.	
	Recreational greens are connected to the lake greens.	

3.2.4 Royalwood II

Figure 9: The retention ponds at Royalwood II are replete with grassland and riparian vegetation.

The stormwater retention ponds in the second phase of the neighborhood of Royalwood were the first in Winnipeg to be designed and constructed as naturalized wetlands (Ladco Company Ltd., n.d.). The usual linear disposition of these ponds was continued to gain the maximum number of pond facing lots. Careful consideration seems to have been taken while designing the planting scheme of these ponds. Lawns are limited to the upper reaches of the slopes and the transitional area between the pond and the surrounding green open space is planted with a prairie grass meadow community of including species such as little bluestem. The lower reaches of the slopes are planted with riparian grasses like cattail. The width of the reed area varies between 4 to 5 m. See Figure 9 for the naturalized visual character of these ponds are planted with riparian grasses.

Figure 10: Informative signage regarding the role of wetlands, Royalwood II

Figure 11: A satellite image of the neighbourhood of Royalwood, phase II. Source: Google Earth (Google Earth). a. retention ponds, b. park spaces, c. trails, d. grassland vegetation

The presence of large trees and shrubs was also noted. These create diverse conditions suitable for various birds, waterfowl, and aquatic animals, which can be easily spotted. The ponds also contain small islands planted with reeds. These provide a protected habitat for fauna. Floating plants such as duckweed were also observed during the visit but in limited quantity.

Informative signages, as seen in figure 10, explaining the importance of wetlands were also noted. These may increase public education and awareness regarding the benefits of wetlands. The developers' and designers' intention to utilize these retention ponds as ecological assets in addition to stormwater infrastructure components and an element of visual aesthetics is clearly seen. Due to limited space, no trails or public greens run along the longer edges of the two ponds, which themselves are narrower than in previous precedents and also not interconnected.

Table 4: Audit entry for Royalwood II

Royalwood II		
DETAILS	Time period	2003-
	Developer	Ladco Company Ltd.
	Design Team	Scatliff Miller Murray | Native Plant Solutions
AREAS	Total Development	123.42 Ha
	Ponds	5.44 Ha
	Pond area as % of total development	4.4%
RETENTION POND	Slopes	Moderate, continuous, and planted
	Planting details	Lawn limited to the upper portion of the slope, lower slopes planted with shrubs, reeds, native prairie grasses such as Little bluestem, and reeds such as cattail.
	Materials and design details	Minimal to no hardscape.
	Presence of fauna	Ducks, Geese, other water foul, rabbits, squirrels, sparrows, other birds
ADDITIONAL USES	Ponds	The layout of the lots is set around two linear naturalized ponds; the ponds have also been used as a means to educate residents about the benefits of such a pond by signboards. Beyond being a visual and a passive educational element, active engagement, with water for recreational or agricultural endeavors, does not seem to be permitted as per the cautionary signs.
	Surrounding open space	Shorter edges of the ponds fade into small public greens, longer edges abut private backyards.
REMARKS	The first precedent of Retention ponds as constructed wetlands in Winnipeg.	
	Planting of the pond edges has been given significant attention.	
	Informative signages add opportunities for public education.	
	Retention ponds are utilized as ecological & biodiversity assets.	
	No revetement as grassland and riparian vegetation stabilize banks.	

3.2.5 Bridgwater Forest

The last and the most recent precedent studied in this audit was the neighbourhood of Bridgwater Forest, developed by Manitoba Housing in association with private stakeholders. The construction of its first phase began in 2007 (Anaka, 2013). The neighbourhood contains five retention ponds in two clusters. Three large linear ponds form a series from which two are connected and can be also enjoyed from a pedestrian bridge. The planting surrounding these ponds is similar in composition to that found in Royalwood II.

Figure 12: One of the connected stormwater retention ponds at Bridgwater Forest

Similar to Linden woods, a trail network connects open green space on one side of the ponds to other parts of the subdivision. Consequently, the surrounding open green space forms the primary open space for the community. Recreational facilities, gazebos with open gym equipment, paved courts with street furniture, and connecting trails to the urban forest can be found in these surrounding open green spaces.

Information about the planting scheme and wetlands can be found on small plaques. Existing forests have been preserved and integrated into the landscape design of the layout (see figure 13). The overflow of these ponds drains into other components of the stormwater management system, which ultimately drains into the Red River. The retention ponds in Bridgwater Forest appear to be the most evolved iteration among the five precedents studies. While these ponds are an ecological, infrastructural, aesthetic, and educational asset for the community, they may have the potential to be much more.

Figure 13: A satellite image of the neighbourhood of Bridgwater Forest. Source: Google Earth (Google Earth)
a. retention ponds, b. parkscapes, c. trails, d. bridge, e. grassland vegetation f. existing forest

Table 5: Audit entry for Bridgwater Forest

Bridgwater Forest		
DETAILS	Time period	2007-2015
	Developer	Manitoba Housing
	Design Team	Stantec | Native Plant Solutions
AREAS	Total Development	137.67 Ha
	Ponds	6.02 Ha
	Pond area as % of total development	4.3%
RETENTION POND	Slopes	Moderate, planted
	Planting details	Lawn limited to the upper portion of the slope, lower slopes planted with shrubs, reeds, native prairie grasses such as Little bluestem, and reeds such as cattail.
	Materials and design details	Hardscape is limited to walkways of brushed concrete, bridges, and gazebos with an outdoor gym & kids' play equipment
	Presence of fauna	Ducks, Geese, other water foul, rabbits, squirrels, sparrows, other birds
ADDITIONAL USES	Ponds	Three linear ponds form a continuous waterbody, central to the design of the layout; two other separated ponds on the south-western corner. Retention ponds are an aesthetic, ecological, and educational resource. Active engagement with water, for recreational or agricultural endeavors, does not seem to be permitted as per the cautionary signs.
	Surrounding open space	One of the longer edges contains a walking trail connecting the entire neighborhood. Recreational greens and existing forests intersect this linear park system. Surrounding open space can also be accessed from the backyards of pond-facing lots.
REMARKS	Stormwater retention ponds are well integrated into the design of the open spaces.	
	Riparian planting replete with grasses and reedbeds	
	Recreation facilities, gazebos, play courts abut the pond peripheries.	
	Existing forests have been retained and incorporated into the layout.	
	Forested area well connected to the pond-side greens	
	Seems like the most evolved iteration yet.	

3.3 Lessons Learned

From the details regarding stormwater retention ponds in Winnipeg's selected neighbourhoods stated above, the evolution of their design and role can be understood. With time, these ponds have become better integrated with the layout of the subdivision. Design elements, including bridges, decks, and look-out points with benches provide opportunities to utilize the visual aesthetic value of these ponds. The linear arrangement of retention ponds has allowed developers to maximize the number of pond-facing lots.

Since the early 2000s, there has been a shift in the way these retention ponds are valued. The naturalization of retention ponds has led them to be used as biodiversity and ecological assets. The revision in the planting scheme of these ponds, with the addition of prairie grassland community of plants and riparian vegetation such as cattail, has been the most significant action indicating this shift in perception of these ponds. In some of the earlier constructed ponds (Southdale and Island Lakes), reed planting seems to have been added later, to make them less attractive to geese (City or Winnipeg, n.d.). The addition of these plants facilitates bioremediation or natural cleaning of water as discussed in section 2.2.

3.3.1 Permitted and Prohibited Activities

Figure 14: One of the many identical warning signs at Winnipeg's suburban stormwater retention ponds.

The Stormwater Retention Pond Audit helps to identify many similarities regarding the design and usage of these retention ponds. The gradient of the open space surrounding these retention ponds seems identical in selected precedents.

Another element common to all these retention ponds is the white warning sign that describes permitted and prohibited activities in the ponds. As evident from figure 14, the list of prohibited uses of the retained water in all these locations included *swimming in, wading, or letting pets into* these retention ponds. These restrictions may be in place to avoid incidents such as drowning in these ponds. Further, toxins potentially present in the retained water (see section 2.2.1) may cause other health issues. The potential toxicity of retained water also seems to be the reason behind other restrictions such as consuming fish from these ponds and irrigation of private lawns from retained water. Usage rights, ownership issues, and maintaining a minimum amount of water in these ponds, may also have contributed to these restrictions. The restriction on the *use of power boats* and or *dumping litter or stones* into the ponds seem to be driven by minimizing public nuisance and harm to the ponds' plant and animal life.

Although the City of Winnipeg may have reasons behind these usage restrictions, these restrictions may have contributed to the under usage of these ponds. Activities such as canoeing and kayaking, even when permitted, were not observed happening in these ponds.

3.3.2 Area Allocation

While ponds in the newer precedents were found to be better integrated into the subdivision layout, the area allocation for these has reduced slightly, from 4.5% of the total neighbourhood in Southdale to 4.3% in Bridgwater Forest. Island Lakes stands out as an anomaly with this percentage being 6.5%. While this reduction from 4.5% to 4.3% may not be very remarkable, it is noteworthy that the recommended percentage of these ponds, when developed as constructed wetlands should be a minimum of 5% of the total area of the neighbourhood assuming that all of it is draining into the retention ponds (City of Winnipeg, 2001). Perhaps driven by extracting the maximum number of sellable lots, the developers do not seem to be inspired enough to allocate more than 4.5% of the total area to retention ponds. If additional economically beneficial activities are allowed in these ponds, developers may feel inspired to not only meet the recommended 5% allocation but also go beyond it.

3.3.3 Additional Opportunities

While the newer iterations of these retention ponds (Royalwood II & Bridgwater Forests) do contain a diverse selection of riparian and grassland plant communities, lawns still exist in other common green spaces in the neighbourhoods. The literature review (see section 2.1) has already noted the advantages of replacing these unrequired lawn patches with vegetated landscapes including an increase in the quality of retained water. Figure 15 shows one such common area where this replacement may be executed. Other suggestions to make these areas better suited for the integration of urban agriculture are discussed further in Chapter 5.

To conclude, the design of suburban Winnipeg's stormwater retention ponds is dynamic and has been adapted to suit different sensibilities over time. This adaptability can be further exploited to integrate additional functions into these ponds. Integrating urban agriculture as an additional use may help solve contemporary problems, such as climate change (see Chapter 2 for details). For this integration, urban stormwater must be viewed as a resource rather than a waste. The next chapter inspects Winnipeg's policy documents to understand their approach to urban stormwater and urban agriculture.

Figure 15: Common areas between lot boundaries and grassland-riparian vegetation at Bridgwater Forest, currently maintained as lawns could be replaced with native species.

Ch. 4 Policy Scan

City of Winnipeg's Policy Documents & Technical Instructions

In this chapter, the City of Winnipeg's policy documents including its development plan *OurWinnipeg 2045* (City of Winnipeg, 2021) and direction strategy plans *CompleteCommunities 2.0* (City of Winnipeg, 2021), *Sustainable Water and Waste* (City of Winnipeg, 2011), and *A Sustainable Winnipeg* (City of Winnipeg, 2011) have been reviewed briefly to understand if urban agriculture in suburban stormwater retention ponds is prohibited, permitted, or encouraged in the City's policy documents.

In addition to statements in the City's policy documents listed above, other technical instructions including design and maintenance considerations for retention ponds are prescribed in *Stormwater Management Criteria*. A list of permitted activities and other instructions are also available on the City of Winnipeg's Website. The statements from these two sources are included in this Policy Scan in section 4.3 as '*City of Winnipeg's Technical Instructions*'.

4.1 Policy Documents

In 2011, the City adopted the first iteration of its current development plan called *OurWinnipeg* (City of Winnipeg, 2011). With this plan, four direction strategy plans were also adopted. These were *CompleteCommunities, Sustainable Transportation, Sustainable Water and Waste,* and *A Sustainable Winnipeg* (City of Winnipeg, 2011). The Development Plan has been updated and is now called *OurWinnipeg 2045*. *CompleteCommunities* is now available as *Complete Comunities2.0* (City of Winnipeg, 2021). As per the City's website, both updates are in the second reading stage of the adoption phase and are expected to be approved soon. *Sustainable Water and Waste* and *A Sustainable Winnipeg* have not been updated since 2011.

This Policy Scan records where and how many times '*urban agriculture*', including its synonyms such as '*urban farming*' and '*city farming*' have been used. This search was done via the inbuilt 'Find' (CTRL+F) command in Adobe Acrobat Reader. The vision statements, goals, and objectives stated in these policy documents were further examined for explicit and implied reference to urban agriculture and multiple uses of stormwater green infrastructure and retained water.

4.2 Identifying Gaps

This section examines the vision statement, goals, and policies stated in Winnipeg's four policy documents to identify gaps in relation to urban agriculture. These gaps are summarized in Table 6 below.

Table 6: Identifying gaps in Winnipeg's Policy Documents

	OurWinnipeg 2045 (2021)	***Complete-Communities 2.0*** (2021)	***Sustainable Water and Waste*** (2011)	***A Sustainable Winnipeg*** (2011)
How many times is *urban agriculture* (including synonyms such as urban farming, city farming, etc.) mentioned?	Once. In Policy 2.15, as a way to reduce waste production to support *Environmental Resilience*, one of the six localized goals for Winnipeg. (p. 23)	0 (Agriculture is only considered as an activity fit for greenfield, ex-urban or rural areas)	0	0
Is the term *urban agriculture* used or alluded to in the vision?	No, the vision is too high level to incorporate such specifics	no	no	no
Is the term '*urban agriculture*' used or alluded to in the objectives and actions?	Yes, once, in Policy 2.22, as a means to achieve greater food security (p.14). Protection of *local food systems* is also mentioned in objective 5 for achieving *Environmental Resilience,* one of the six localized goals for Winnipeg (p. 21)	no	no	no
Are stormwater retention ponds identified as potential urban agricultural assets	no	no	no	no

OurWinnipeg 2045, discusses objectives and policy directions to achieve the City's six broad goals. These goals are *Leadership and Good Governance, Environmental Resilience, Economic Prosperity, Good Health and Well-being, Social Equity, City Building* (City of Winnipeg, 2021. p.8). The objectives under the goal *Environmental resilience* relate to the concerns discussed in this capstone project.

OurWinnipeg 2045 does recognize "*Safeguarding and enhancing the capacity of the urban forest and urban agriculture*" as an "*essential component of achieving environmental sustainability*" (City of Winnipeg, 2021. p.14) but does not explain how this capacity can be increased. Ways to integrate urban agriculture with other activities and land uses are also not identified in the Plan. The Plan does not provide a framework for identifying such opportunities and associated challenges.

OurWinnipeg 2045 acknowledges climate change as one of the biggest challenges in contemporary times and states "*government regulation, policy, resource allocation….and resident behaviours and awareness"* must be adapted to mitigate the effects of climate change (City of Winnipeg, 2021. p.21). This statement builds a strong case for urban agriculture in retention ponds as it can be leveraged to build environmental resiliency and mitigate climate change. Urban agriculture's potential as a tool for climate change mitigation has already been demonstrated in the literature review (see Chapter 2). The Plan also recommends that the City must work towards providing opportunities to "*protect and respect…local food systems"* (City of Winnipeg, 2021. p.21) but does not define what would constitute a *"local food system".* This lack of clarity in the document diminishes the achievability of the vision.

Although the vision statement in *CompleteCommunities 2.0* (City of Winnipeg, 2021. p.9) includes "*to ensure…an environmentally…. sustainable future*", the means stated to achieve an environmentally sustainable future do not include urban agriculture. *Sustainable Water and Waste's* (City of Winnipeg, 2011. p.2) vision statement includes "*to maintain or enhance the quality of…natural environments*" but does not describe or give examples of *natural environments*. The vision statement does not list ways to enhance the quality of natural environments. A *Sustainable Winnipeg*'s (City of Winnipeg, 2011. p.7) vision statement is too high level and does not make any direct connections to urban agriculture or environmental resilience.

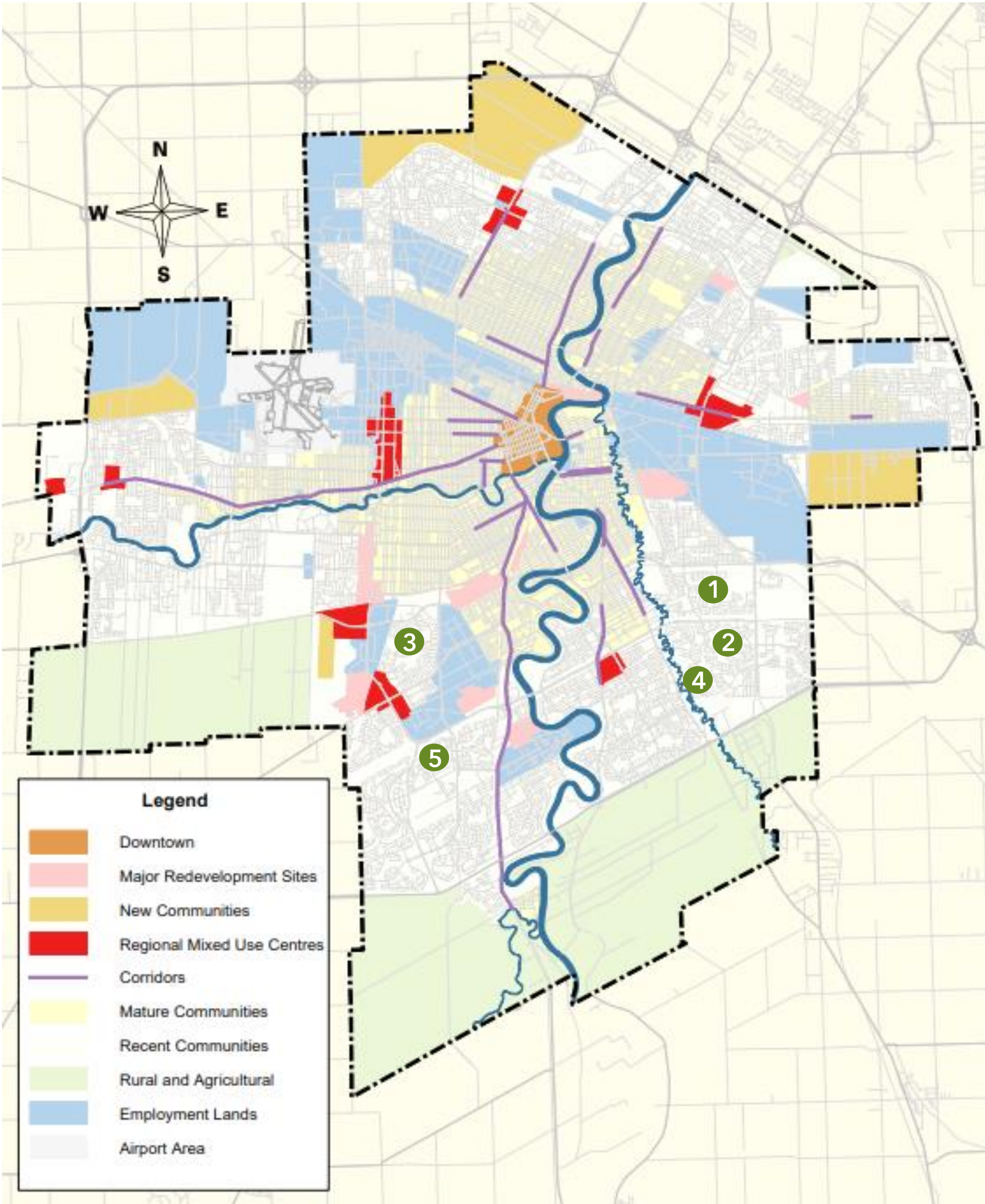

Figure 16: Urban Structures Map, showing the location of neighbourhoods visited in the Audit. Source: City of Winnipeg, 2021(Complete Communities 2.0). Neighbourhoods visited in the Stormwater Retention Pond Audit are indicated by green circles. These are 1. South Dale, 2 Island Lakes, 3. Linden woods, 4. Royalwood (Phase II) and 5. Bridgwater Forest.

The Scan reveals that *urban agriculture,* its synonyms *urban farming* and *city farming,* are not even mentioned once in *CompleteCommunities 2.0*, *Sustainable Water and Waste* and *A Sustainable Winnipeg* (City of Winnipeg 2021, 2011). Refer to Table 6 for more details. The reason for this exclusion seems to be that these documents do not consider agriculture as an urban activity. These Direction Strategies recommend agricultural activity only on land that has not yet been urbanized.

Similar gaps can be identified in *Complete Communities 2.0's* (City of Winnipeg, 2021) vision statement. The statement acknowledges that the "*integration of transportation planning, land uses, built forms, and urban design"* is the means to "*ensure a socially, environmentally, and economically sustainable future"* (City of Winnipeg, 2021. p.9). However, no reference is made to urban agriculture, local food production, or circular economy, each of which have important social, environmental, and economic dimensions and have been recognized as key tools for building climate resilience in many other cities.

CompleteCommunities 2.0 (City of Winnipeg, 2021) recognizes ten kinds of urban structures in Winnipeg. Each urban structure has its separate vision, goals, and policies. The goals and policies for urban structure *D1 Established Neighbourhoods*, discuss direction strategies for neighbourhoods in suburban Winnipeg, including those selected in the audit (see section 3.3) under the subheading *Recent Communities* (City of Winnipeg, 2021. p.88). Figure 16 indicates the locations of these five selected communities on a map showing Winnipeg's various urban structures with green dots.

Complete Communities 2.0 recommends that *Recent Communities* must be "*able to achieve high standards of sustainability in planning, design, construction, and management*" by *"incorporating green design principles and opportunities to conserve and enhance natural features and biodiversity; promote biodiversity through the incorporation, expansion, and enhancement of natural features and ecologically significant areas"* (City of Winnipeg, 2021. p.87). The addition of the phrase *integrating opportunities for urban agriculture* would have added value here.

Sustainable Water and Waste states that the City will continue to prefer stormwater retention facilities over a conventional piped system (City of Winnipeg, 2011. p. 44). The Direction Strategy also states that the City will be more inclined to consider innovative iterations of retention ponds that safely integrate other uses such as recreation. (City of Winnipeg, 2011. p.44). This inclination is encouraging, as it reflects the City of Winnipeg is open to integrating additional opportunities with retention ponds, one of which may be urban agriculture.

Sustainable Water and Waste also states that naturalized ponds or those with "*wetland type of shoreline environment*" shall be preferred "*as they have been shown to be less attractive to urban geese"* (City of Winnipeg, 2011. p.45). Although *Sustainable Water and Waste* (City of Winnipeg, 2011) does recommend capturing stormwater in rain barrels for irrigation or using stormwater for growing plants in rooftop gardens, it does not discuss using the retention ponds themselves for water supply or other uses.

The silence on this topic in *A Sustainable Winnipeg* (City of Winnipeg, 2011), an otherwise well-rounded document, is concerning.

4.3 City of Winnipeg's Technical Instructions

Two additional sources of information were reviewed, to understand the City's expectations from suburban stormwater retention ponds. These were i) *Stormwater Management Criteria* (City of Winnipeg, 2001), a guidebook that prescribes engineering design requirements for stormwater retention ponds, including side slopes, minimum width and depth, and extent of public access, and ii) the directions for the use of stormwater retention ponds available on the City's website under Water and Waste Department's section *Retention Ponds*.

Among the engineering design requirements, while the slope requirement and minimum width may not restrict the usage of the pond for urban agriculture, the minimum depth of 2.5 m might challenge the establishment of some plant species, including wild rice. This challenge and ways to mitigate it are discussed in sections 5.1 and 5.2. This minimum depth of 2.5 m also increases the actual and perceived safety threat for people. Activities, where one needs to be close to retention ponds, might be considered unsafe by residents as drowning incidents are not unheard of (Bruch & McGuckin, 2018). Due to these concerns, the City prohibits most activities in and around these ponds.

Currently, the minimum pond size is prescribed to be 5% of the total watershed area, with the minimum set as 1 Ha (2.5 acres) (City of Winnipeg, 2001). This minimum prescription has become the default maximum that the developers would allow for these ponds, to maximize the sellable area and number of lots. To allow for more uses and activities to happen in and around these ponds, shallower slopes and larger areas for these ponds may be needed.

Stormwater Management Criteria recommends using the peripheries of these ponds for activities such as snowshoeing, cycling, and hiking and using the ponds for kayaking, canoeing, or paddle boating (City of Winnipeg, 2001). Table 3, titled *Appropriate Uses for Various Frequencies of Inundation* in this criteria document states that areas, where the maximum frequency of inundation is 5 years, can be used for picnics, sports, and other recreational activities, but areas, where the maximum frequency of inundation is 2 years, can only be used for riparian vegetation (City of Winnipeg, 2001). It is noteworthy that the City already undertakes timely clipping and clearing of the reeds in this riparian vegetation zone. If the list of permitted activities in *Appropriate Uses for Various Frequencies of Inundation*, is made to include *agriculture*, the City can collect these clippings and use them for biofuel production. Similarly, if other plants are allowed to be grown, they can be harvested and used for fodder, food, or biofuel, as seen fit.

The section *Retention ponds*, from the City of Winnipeg's Waste & Water Department's website, informs further on restrictions on usage of retained water. The section states that activities like kayaking, canoeing, and paddle boating in the retention ponds are allowed, but using retained water to irrigate landscaped areas in the neighbourhood is not allowed, primarily due to water quality concerns. These concerns are further discussed in section 5.1. Allowing the retained water to be used for irrigation of common areas may help to justify some of the operating costs if these ponds are used for urban agriculture. This retained water would thus be used as a resource rather than waste.

Table 7: Some opportunities for integrating urban agriculture in stormwater Retention ponds in Stormwater Management Criteria (City of Winnipeg, 2001) and directions available on the City's website under the section Retention ponds, Water & Waste Dept. (City of Winnipeg, 2022)

	Sections or phrases for potential revision	Rationale
Stormwater Management Criteria, 2001	Revision to minimum area allocation for retention ponds (5%)	Larger area allocation may encourage innovative integration of other uses to these ponds, including urban agriculture.
	Revision to minimum depth requirement (2.5 m)	Reduced depth may help reduction of the actual and perceived safety threats for people engaging with these ponds.
		Reduced depths may reduce challenges to the establishment of plant species such as wild rice.
	Addition to the list of permitted activities within areas where the maximum frequency of inundation is 2 years and those where it is 5 years	An addition of *agriculture* to the list of permitted uses in these areas may increase the probability of them being used for urban agriculture.
Directions for use, *Retention ponds*, Water & Waste, City of Winnipeg's website	Addition to the list of use of retained water	Allowing the retained water to be used for irrigation of common areas may help to justify some of the operating costs if these ponds are used for urban agriculture.
		This permission will also encourage the city to maintain higher water quality.

Table 7 identifies some opportunities for revision to specific phrases or requirements stated in these two documents along with the rationale behind that suggestion. These suggestions also inform the recommendations in section 6.1.

4.4 Lessons Learned

With this Policy Scan, one may conclude that *OurWinnipeg 2045's* (City of Winnipeg, 2021) reference to urban agriculture is tokenistic as the goals and policies in the plan do not elaborate on how or where urban agriculture can be integrated into the city.

There is a clear gap between *OurWinnipeg 2045* (City of Winnipeg, 2021) and the three Direction Strategies reviewed in this Policy Scan. Urban agricultural possibilities, while mentioned in *OurWinnipeg 2045* (City of Winnipeg, 2021), have not been identified or more importantly, not incorporated in the vision, goals, and policies in *CompleteCommunities 2.0* (City of Winnipeg, 2021), *Sustainable Water and Waste* (City of Winnipeg, 2011) or *A*

Sustainable Winnipeg (City of Winnipeg, 2011). This gap demonstrates that the City does not consider urban agriculture a priority.

This lack of consideration is also evident in the City's design and technical recommendations regarding stormwater retention ponds. Neither of the two sources, *Stormwater Management Criteria* (City of Winnipeg, 2001) or instructions from section *Retention Ponds* from *Water & Waste Dept* on the City of Winnipeg's website recommend agriculture as a permitted or encouraged activity in and around these ponds.

Using stronger language to support urban agriculture and incorporating it into the visions, goals, and policies stated in these four policy documents can help the City in leveraging urban agriculture for ecological, social, and economic benefits. Table 8 identifies some sections in these four policy documents where urban agricultural opportunities in retention ponds can be integrated into these documents. Table 7 in section 4.3 indicates some opportunities to revise certain recommendations stated in *Stormwater Management Criteria* (City of Winnipeg, 2001) and section *Retention ponds* from the City's website.

The alignment of these Direction Strategies with each other has been leveraged to achieve the common vision, but without a separate *Urban Agriculture Strategy*, these Direction Strategies have failed to expand further on the vision statement set forth by the City in *OurWinnipeg 2045* (City of Winnipeg, 2021). As the literature review demonstrates that urban agriculture can be leveraged to build climate resiliency, food security, and increase circularity in the city's waste economy, this exclusion of urban agriculture is counter-productive.

Other municipalities in Canada continue to develop and implement their own urban agriculture strategies. The City of Edmonton adopted *Fresh* (City of Edmonton, 2012) a city-wide food and urban agriculture strategy in November 2012. This strategy document identifies opportunities and challenges for growing food in Edmonton while exploring ways to create more demand for city-grown food. In this process, the City of Edmonton has been able to leverage its partnership with private sector entrepreneurial organizations, the University of Alberta, and various advocacy organizations to achieve a common goal.

Table 8: Identifying opportunities for integrating statements to support urban agriculture in stormwater retention ponds in Winnipeg's Policy Documents

	Our Winnipeg 2045 (2021)	***Complete-Communities 2.0*** (2021)	***Sustainable Water and Waste*** (2011)	***A Sustainable Winnipeg*** (2011)
Identified sections where policies, objectives, and other statements to support urban agriculture in stormwater retention ponds can be integrated.	The document can elaborate more on how to identify potential areas for urban agriculture.	The vision statement can include language to encourage urban agriculture in Stormwater Retention Ponds	Policy 1 Densification in Section 08-4 Stormwater management and flood protection supporting policies can include "bioremediation by plants in stormwater retention ponds" (p.53)	Section 4 *Opportunity for Change* can include urban agriculture as one of the potentials (pp. 10-15)
	The document can encourage multiple uses of infrastructure components including Green Stormwater infrastructure.	Definition of complete communities can benefit from the addition of "*supporting urban agricultural opportunities*" or similar language (p.18)	Section 06 *Stormwater Management and Flood Protection System* can include Direction 06-4c "*Encourage leveraging urban agriculture to better water quality or retained stormwater*" (p.45)	Addition of Direction 7 *"Identifying opportunities or urban agriculture, and leveraging these opportunities to achieve greater sustainability"* to Section 1 *The Foundation: Leading by Example* (p.19)
		New Communities, by including *"identifying and integrating opportunities for urban agriculture in the open space design of the communities such as stormwater retention ponds and their surrounding open spaces"* (p. 94)		Addition of Direction 10 *"Explore opportunities or urban agriculture, in existing open spaces including Green Stormwater Infrastructure"* to section 9 *Continue to Respect and Value our Natural and Built Environment* (p. 41)

The City of Mississauga's Parks, Forestry, and Environment Division is currently working towards creating an urban agriculture strategy (City of Mississauga, 2022). Other smaller communities have also started developing their urban agriculture strategies. Strathcona county in Alberta adopted *Strathcona County Urban Agriculture Strategy* as the first step in implementing an *Agriculture Master Plan*. While Winnipeg's Policy documents were an admirable effort for 2011, it is disheartening that these have not moved much as of 2021. The lessons from this section inform the recommendations in section 6.1.

The next chapter presents an analysis of various potential challenges to the integration of urban agriculture into stormwater retention ponds and suggests some remedial measures informed by the Literature Review, Stormwater Retention Pond Audit, and this Policy Scan.

Ch. 5 Analysis and Findings

From the literature review, the current research has found that urban agriculture, following principles of *traditional mixed farming practices* may be leveraged to mitigate the effects of climate change (Hough, 2004) by minimizing emissions associated with the transfer of *virtual water* (D'Odorico et. al., 2018). City-grown food products may have significantly smaller *foodsheds* (Forman, 2014) and consequently low *environmental and social costs* (Hough, 2004). Integrating urban agriculture can also build food security (Hough, 2004).

Further, integrating stormwater green infrastructure and urban agriculture may benefit both the food and water sectors by making each more ecologically sustainable and economically efficient (Deksissa et. al., 2021). The review also informs that retained stormwater can be directly or indirectly used to grow a variety of crops including cattail, duckweed, algae, tomato, lettuce, kale & basil (Grosshans, 2014; Supraja et.al., 2020; Xu et. al., 2012; Tikasz et al., 2019; Kim & Yang, 2020). Innovative techniques including aquaponics, hydroponics, and co-cultivation of different kinds of crops can be applied to amplify the benefits of urban agriculture.

The Stormwater Retention Pond Audit (see Chapter 3) demonstrated that Winnipeg's stormwater retention ponds have evolved over time to become better integrated with the subdivision design, and better hosts for urban flora and fauna. Opportunities to integrate additional uses, such as urban agriculture, can be identified and may have ecological, economic, and social benefits. In Chapter 5, it is revealed that while Winnipeg's Development Plan acknowledges that leveraging urban agriculture for various positive outcomes may be beneficial, the City's Direction Strategies do not refer to urban agriculture at all.

An important question arising with this discussion is: *Can Winnipeg harness this untapped potential for leveraging urban agriculture to avail the above-mentioned benefits? If so, how? What challenges, in this path, can be identified and how does one begin to find ways to overcome these challenges?* These questions are an extension of, and help answer Q1 (see section 1.6). The next section identifies these challenges and describes them in detail.

5.1 Identifying Challenges

This section identifies six kinds of challenges that may deter the use of suburban retention ponds as urban agricultural assets. The identification of these challenges has been supported by the theorizing based on the literature review, personal industry experience, logical reasoning, and critical thinking.

5.1.1 Biological Feasibility

Section 2.1 describes the undesirable elements that find their way into urban stormwater. Eutrophication caused by an abundance of phosphorus, caused by excessive use of fertilizers in residential landscapes is of substantial concern. This nutrient enrichment may also be aided by excreta from waterfowl and feces from pets (Hough, 2004). Other pollutants including heavy metals, dust, and hydrocarbons might also flow into retention ponds with run-off from vehicular surfaces (Forman 2014).

With these water quality concerns present would it be biologically possible to grow plants in retained stormwater? This question can be understood in three parts. 1) Are there any useful aquatic plants that may be grown in these ponds? 2) Will these plants survive and grow in retained waters that may be potentially contaminated? If not, how can we make the water suitable for their growth? 3) if grown for food or animal fodder, will these plants be suitable for consumption or other uses given that they grow in potentially toxic waters? This third part is critical as certain pollutants such as heavy metals may get bioaccumulated into the harvested parts of the plants. Section 5.2.1 refers back to Chapter 2, to look for answers to these questions.

5.1.2 Economic Viability

For urban agricultural endeavours to be successfully conducted in Winnipeg's stormwater retention ponds, these activities must be proven economically viable. Such activities can not be expected to be conducted fully on public money. To make entrepreneurs and business organizations interested, such ventures must be able to fund themselves and make a profit. Indirect monetized benefits from urban agricultural activities may be considered to add to the economic viability. Additionally, there must be a demand for this locally grown produce. This locally grown produce must be able to compete with alternatives available in the market. Some remedies to these concerns are discussed in section 5.2.2.

5.1.3 Technical Feasibility

There could be many technical issues that may render these processes impracticable. This includes concerns about the depth of stormwater ponds, fluctuating water levels, and issues with the harvesting processes. The City of Winnipeg's technical guidelines require these ponds to be 2.5 m deep or deeper (City of Winnipeg, 2001). As wild rice varieties are naturally found in waters with depths between 0.6 and 2 m (Agro-Man, 1984, p.22), this depth may not be suitable for wild rice cultivation. Further, the water level in retention ponds may fluctuate seasonally. This fluctuation may further challenge crop yields. Agriculture Manitoba's wild rice farming manual briefly alludes to a significant reduction in yields, if water level fluctuations exceed 0.3 m annually (Agro-Man, 1984, p.22).

The City of Winnipeg's maintenance regime of these ponds includes clearing of weeds and grasses by "*large paddle wheel driven barges* or harvesters which "*cannot work in waters shallower than 0.6 m*" (City of Winnipeg, 2022). This limitation indicates that the current harvesting techniques may not fully support the harvest of a variety of crops and the City may need to look for innovative growing and harvesting techniques. Ways to overcome these challenges are discussed in section 5.2.3.

5.1.4 Safety & Liability Concerns

Stormwater retention ponds in suburban developments in Winnipeg are surrounded by houses. Here people of all age groups and abilities, along with their pets reside. Even when retention ponds currently are not used much (see section 3.3.1) incidents of drowning in these ponds are noted in local news (see section 4.3). If these ponds are used for growing and harvesting plants, a greater number of people will be in close contact with these ponds. This may increase the chances of such incidents. In addition to this risk, perceived safety risks may be greater than the actual risk itself. This perception of risk may also challenge the success of urban agricultural activities.

These waterbodies are maintained by the City. Safety incidents might invite negative publicity, additional liability, and legal expenses. If not addressed, these concerns might make the City lose interest in propositions that may be profitable or beneficial otherwise.

5.1.5 NIMBYism & Public Opinion

Another daunting challenge to urban agricultural activities can be dealing with undesirable public opinion and NIMBYism. Listening to and alleviating residents' concerns and reservations regarding agricultural activities in their communities may prove to be critical to the success of these activities. Residents might be concerned about potential annoyances such as noise or the movement of strangers in the community. NIMBYist residents might feel it is beneficial to grow food in Winnipeg but not behind their backyards. Such opinions obviously matter. These opinions affect the larger public voice, which in turn empowers the city councillors, who get to make decisions. Some suggestions to overcome these challenges are discussed in section 5.2.5.

5.2 Finding Possible Solutions

After discussing the possible challenges, this section explores solutions for each type of concern. These solutions inform findings that are summarized in table 9 at the end of this chapter and contribute to recommendations in Chapter 6. Solutions to some challenges are beyond the scope of this research and shall need additional research. These additional research directions have been listed in section 6.3.

A declaration by the City of Winnipeg, to commit to integrating urban agriculture into various urban structures including the stormwater retention ponds may help mitigation of all the identified challenges. With this declaration, the language of the City's policy documents, guidelines, and instructions on the website should be revisited. Some suggestions for revisions have already been provided in tables 7 and 8 (see sections 4.3 and 4.4). Additional barriers may be noted once urban agricultural activities begin in retention ponds. Before beginning a city-wide operation or rewording policies, the City may engage in a pilot initiative. Section 6.1.4 identifies three options for such a pilot in Winnipeg.

5.2.1 Biological Feasibility

From the literature review, it is well established that many plants can be grown in retained stormwater. Each candidate plant along with its potential use is discussed below. The second and the third concerns in section 5.1.1, i.e., survival of the plant due to pollution and nutrient-rich environment in these waters and the presence of bioaccumulated toxins, both are essentially related to water quality. Section 2.2.2 builds on Hough's (2004) suggestions regarding the use of various additional components, such as *bio-filters* and *detention basins* that may be integrated into the stormwater management system to remove undesirable elements.

Stormwater from roads, parking lots, and driveways can be collected first in *detention basins* where dust, debris, and other undesirable particles can settle down (Hough 2004). This water can be independently tested for undesirable elements including heavy metals, oils, and synthetic rubber. Techniques for removal of these particles may be too expensive to apply to the entire retained stormwater and may potentially be applied to this smaller quantity in detention basins. Although the existing stormwater management systems in suburban residential Winnipeg may already have detention basins, these were not observed while visiting the selected precedents and were not noted in the Stormwater Retention Pond Audit. The City's technical instructions (see section 4.3) do not mandate or recommend these additional basins.

Stormwater flowing through detention basins along with the run-off from landscaped areas may be allowed to pass through *biofilters* in smaller sedimentation basins, where plants such as cattail absorb heavy metals by phytoremediation. Although bioretention ponds already have plants for phytoremediation, if the removal of undesirable toxins is done in smaller basins before the water enters the larger retention ponds, the quality of retained water may significantly improve and facilitate the production of toxin-free food.

It is also essential that sufficient data be collected from a preliminary study to ensure that plants grown in retention ponds having these pre-treatment components are safe for consumption as food or other uses. An important opportunity recognized in the current research is taking an incremental approach, where urban agriculture in retention ponds is introduced in phases. It seems logical to harvest plants only for biofuel till the time data gathered from these experiments shows a consistent absence of toxins in the produce. This may be followed by the cultivation of fodder and food crops. This is further elaborated in section 6.1.

Section 2.5 discusses research precedents helpful in nominating some crops to be grown and harvested in stormwater retention ponds. These are discussed below:

i. Cattail

As discussed in section 2.5.1 research has already proven cattail farming's multiple ecological and economical benefits (Grosshans, 2014; Grosshans et.al. 2019). Cattail is known to be a fast-growing, phytoremediating reed, which bioaccumulates excess phosphorous, that would have otherwise fueled excessive growth of cyanobacteria, cutting off sunlight for all other forms of life (Forman, 2014). These reeds can be harvested, dehydrated to form pellets, and combusted to obtain energy (Grosshans, 2014). The phosphorus from the ashes can be recovered and used again. Other processes for harnessing bioenergy such as *gasification* are also being developed.

Cattail forms part of the existing planting schemes of the stormwater retention ponds in newer neighbourhoods (see Section 3.2). Other neighbourhoods have also started planting cattail along the shoreline as this vegetative structure makes pond edges less attractive and accessible for geese (City of Winnipeg, 2022). This makes cattail an ideal candidate. Techniques for growth and harvesting are discussed in section 5.2.3.

ii. Duckweed

Research precedents (see section 2.5.2) show that the production and harvesting of duckweed is another alternative for generating biofuel (Xu et. al., 2012; Hochman et. al.2018). A fast-growing, floating plant, duckweed has 37 species, many of which are being explored for biofuel production (Hochman et. al., 2018). Duckweed can be pelletized for boilers or used as feedstock for biogas, by-products of which can further be used for methanol production (Hochman et. al., 2018). Like cattail, duckweed can also reduce heavy metal toxicity and remove excess nitrogen and phosphorous from retained stormwaters. Section 2.5.2 further informs that high protein varieties of duckweed can also be used to replace alfalfa as fodder crops (Xu et. al., 2012). Additionally, recent research suggests that duckweed is rich in Vitamin B12 and may be used to manufacture vegan vitamin supplements (Morrison, 2020).

iii. Algae

Hough (2004) writes that Cyanobacteria or blue-green algae thrive in eutrophicated waterbodies. Section 2.5.2 discusses that Cyanobacteria are an excellent source of fats and can be harvested as biomass for bio-energy production (Supraja et.al., 2020). Microalgal varieties such as *Aphanizomenon flos-aquae* or AFA, and Spirulina have long been regarded as super-foods (Spolaore et al., 2006). Like cattail and duckweed, algae also remove excess nutrients from ponds, leaving them cleaner and with better ecological health. These qualities make algae another excellent nominee in this category.

iv. Wild rice

Although regions to the north and east of Winnipeg have been found to be better suited for the production of wild rice, Winnipeg has been included as a potential growth area in Agriculture Manitoba's (Agro-Man, 1984) provincial guidebook on growing wild rice. Therefore, varieties of wild rice may be tested as crops for agriculture in retention ponds. Being endemic to this region, wild rice is culturally significant for many Indigenous Peoples in North America. Exploring its cultivation may open other doors for reconciliation as stated in section 6.1.6.

v. Tomato

Section 2.5.3 notes that new research suggests tomatoes, irrigated with algae-rich retained stormwater are higher in nutritional value than those conventionally cultivated (Supraja et.al., 2020). Consequently, tomatoes are another nominee for food crops in this category. Needless to say, human or animal consumption of tomatoes must only be permitted if they are free of toxins.

Section 2.5 also notes other plants that may be included in this list, such as lettuce, kale, and basil. Additional research may further inform the extension of this list of nominees

5.2.2 Economic Viability

Section 2.5.1 presents Berry's (2016) and Grosshans's (2014) research documenting the direct and monetized benefits of cattail production, harvesting, and bioenergy production. Similar benefits may be experienced from duckweed and algae farming. Data gathered by additional research can verify these benefits and help assess overall profitability. Additionally, energy production from biofuels is often more economical than other green energy sources. For example, Hochman et. al., (2018) found energy production from duckweed to be 20-25% cheaper than other green energy sources such as solar and wind.

Such ventures may be made more attractive and profitable to private entrepreneurs by offering subsidies on raw materials or equipment used for urban agriculture in retention ponds. Section 2.4 informs that conditional additional buildable FAR or density bonuses offered by the City may encourage investment in urban agricultural ventures in existing or proposed subdivision developments. The City can further collaborate with advocacy groups and industry partners to work on creating more demand for locally produced biofuel, fodder, and food.

5.2.3 Technical Feasibility

There are a variety of ways to overcome harvesting and water level fluctuation challenges. Some of these ways are discussed below. Data gathered by additional research can help verify these suggestions and present new ways to mitigate these challenges.

The water level may be controlled mechanically where fluctuations challenge the growth of plants. Another solution to this challenge could be growing produce on small floating islands. The International Institute for Sustainable Development (IISD) and Native Plant Solutions have been engaged with pilot projects utilizing *Floating Treatment Wetlands* (FTWs) also referred to as *floating bio platforms* at Netley Libau marshes and FortWhyte Alive respectively (Grosshans et al., 2019; Native Plant Solutions, n.d.). These agencies and their prior research pilots may be referred to for more information.

Indigenous knowledge and techniques may be leveraged to overcome operational challenges. In areas where mechanized harvesting is difficult, traditional *wild ricing* practices may be explored. These include knockers or wooden sticks to thresh out rice kernels into canoes (Minnesota Historical Society, 2020). These low investment and low impact techniques are labour-intensive. Partnerships with First Nations and Indigenous organizations may be leveraged to reduce labour and processing costs.

Other innovative ways of indirectly using retained stormwater for growing plants such as hydroponics and aquaponics, discussed by Deksissa et. al. (2021) and Forman (2014) can also be leveraged to produce crops (see section 2.3). Section 2.4 also discusses Innovative land management and land sharing practices based on mutual informal relationships, such as those used by *Community Roots* (Beatley, 2010). These land management practices can be leveraged to increase aquatic agriculture, especially in areas where ponds directly abut backyards.

5.2.4 Safety & Liability Concerns

During this research, only limited ways to reduce risks associated with these ponds becoming safety hazards, have been found. Revisiting City's recommendations for reducing the 2.5 m minimum depth requirement may be a starting point. Section 5.1.3 already states how this may help in making more area of the pond available for the cultivation of specific crops including wild rice.

Section 2.4 also discusses Beatley's (2010) recommendations including *Jane Jacobs's more eyes on street* approach for making urban parks safer. A variation of this approach may be applied to retention ponds, resulting in *more eyes on the ponds*. In other words, a denser and more compact subdivision layout, with more storied houses, and proportionately more townhouses rather than single-family homes, may lead to more windows facing the ponds. More windows may increase the perception of safety and encourage more active usage of retention ponds. Community volunteers or professionals may be trained for emergency action.

Another way to increase the perception of safety may be by using less stern language on the warning signs and on the City's website. For instance, instead of saying *"This water is not safe for swimming, wading, or drinking"* the signs could say *"swimming and wading permitted at your own risk…water may contain toxins and irritants."*. An interesting comparison would be assessing the perceived risks of similar activities such as swimming and wading in the Assiniboine or Red Rivers. Toxins and pollutants that might harm potential swimmers, would eventually find their way into these rivers and then Lake Winnipeg. Surprisingly, such warning signs are absent from parks along the Assiniboine River, including Munson Park and the Riverwalk Trail, and the Red River including Don Togo Park. Importantly, by following the recommendations of this research, water quality is expected to improve significantly and reduce health concerns.

The City may explore collaborating with trained professional agencies or private entrepreneurs to manage urban agricultural operations in retention ponds. This may help reduce liability in case of incidents. On the other hand, if the operations are solely run by community members, perceived security risks due to the presence of strangers in the neighbourhoods may be eliminated.

5.2.5 NIMBYism & Public Opinion

Winnipeggers like to grow plants, both for food and other uses. This is evident from the increased popularity of community gardens in the city. The pandemic has further fueled this demand (Geary, 2020). Nevertheless, there might be reservations towards urban agricultural activities occurring in suburban residential stormwater retention ponds, due to reasons discussed in section 5.1.5.

The challenges associated with NIMBYism can be daunting and difficult to overcome. While advocacy organizations may be an effective tool for generating public opinion, they alone might not be able to bring about change. The role of the City of Winnipeg's various departments such as Community Services, Sustainability, or Innovation & Technology in organizing public education and awareness initiatives becomes important here. The City of Winnipeg through its Public Works Department may invest in a demonstrative project (Beatley, 2010) and advertise its benefits to generate favourable public opinion.

Opportunities to involve community and educational institutions including zoos, botanical gardens, and universities may be leveraged to develop capacity for urban agriculture in the City by organizing training workshops or offering to collaborate in operating urban agricultural operations (see section 2.4). The City can also lobby the Provincial Government and school boards for a shift in the school curricula to accommodate more opportunities for encouraging the culture of growing food personally.

5.3 Summary of Findings

Table 9 summarizes the findings from the analysis above. These findings inform the recommendations in section 6.1.

Table 9: A tabulated summary of findings listing challenges, key concerns, and possible suggestions.

Challenges	Key concerns	Possible suggestions
Biological Feasibility	Are there any useful aquatic plants that may be grown in these ponds? Will these plants survive in potentially toxic retained waters? If not, how can we make the water suitable for their growth? If grown for food or animal fodder, will these plants be suitable for consumption or other uses?	• Cattail, duckweed, algae, wild rice, tomato, lettuce, kale, and basil can be grown in or adjacent to retention ponds. • Increasing water quality by revisiting regulations on management (design operation, irrigation, and management) of residential landscapes including permitted fertilization, and pest control methods. • Increasing water quality by mandating the use of stormwater quality checks such as limiting lawn percentage, and mandating the inclusion of *biofilters* and separate *detention basins*. • Building a system of collecting and analyzing water quality data from selected sites.
Economic Viability	Can profit be made from such ventures? Can we prove other monetized benefits?	• Collecting data from executed projects and commissioning new projects to monitor profitability. • Creating demand by branding and strategically positioning locally grown food, fodder, and biofuel. • Incentivizing and subsiding to make it more attractive.

		• Looking for ways for industry involvement such as Corporate Social responsibility.
Technical Feasibility	What technical considerations must one be mindful of while operating and how can these challenges be resolved?	• Cultivating plants on Floating Treatment Wetlands (FTWs), independent of water level fluctuations. • Using water level control mechanisms. • Employing Innovative yet tested cultivation techniques such as hydroponics and aquaponics. • Employing Innovative harvesting & land management techniques • Investing in the formation of a task force for identification and barrier removal for urban agriculture.
Safety & Liability Concerns	Will agriculture in retention ponds be safe? How can the perceived safety risks and liability concerns be minimized?	• Revisiting design considerations and guidelines. • Investing in additional research on risk management. • Revisiting language on warning signs and on the website.
NIMBYism & Public Opinion	How can NIMBYistic attitudes be addressed? How can favorable public opinion be generated?	• Investing in public engagement and awareness initiatives. • Involving school kids and youth in awareness drives. • Involving public and community institutions, such as zoos, and botanical gardens, to collaborate with neighborhood associations for capacity building. • Advertising benefits demonstrative projects.

6. Conclusion

This concluding chapter is structured into four sections. In the first section (6.1) recommendations informed by the findings from Chapter 5 are presented. Section 5.2 states the need for additional research to find mitigative measures for various challenges. These research directions have been listed in the second section (6.2) of this chapter. Answers to the two research questions, from section 1.7 are formulated in the third section (6.3). The last section (6.4) reflects further on the possible outcomes of exploring the directions presented in this capstone report.

6.1 Recommendations

This section builds on the possible solutions to various challenges presented in Chapter 5 to form recommendations. Recommendations of similar nature have been grouped together. This research recommends that the City of Winnipeg may:

6.1.1 Revise the City's Policy Documents:

i. Revise the language in the City's Development Plan, *OurWinnipeg2024* (City of Winnipeg, 2021), to better integrate urban agriculture into its goals, policies, and actions. Some revisions are suggested in Table 8 in Chapter 4. These suggestions may be built upon to refine the policy language in Winnipeg's Development Plan. A literature review of policy documents from other exemplary North American cities, including Edmonton and Montreal, may be conducted to aid this revision process.

ii. Revise the language in Winnipeg's Direction Strategies: *CompleteCommunities 2.0* (City of Winnipeg, 2021), *Sustainable Water and Waste* (City of Winnipeg, 2011), and *A Sustainable Winnipeg* (City of Winnipeg, 2011) to integrate urban agriculture into vision statements, goals, actions, and objectives, including revisions to the definition of *Complete Communities*. Revisions identified in Table 8 in Chapter 4 may be built upon to facilitate the revision process.

iii. Work towards creating a bespoke *Urban Agriculture Direction Strategy* for Winnipeg. This strategy may include reference to desirable characteristics of agriculture, such as being based on the principles of permaculture, environmental stewardship, and *traditional mixed farming practices*. This strategy should include opportunities for growing plants on land, in water, on rooftops, etc., and for a variety of uses beyond food, including bioenergy production, animal feed, horticultural, medicinal, and wellness purposes, etc. This strategy may include opportunities for aquaculture and animal husbandry in the city. Best practices and similar strategy documents from other cities and municipalities in North America including those from Edmonton, Mississauga, and Strathcona County may be studied as precedents to facilitate this process.

iv. Align Winnipeg's other strategies and initiatives including *Winnipeg Parks Strategy DRAFT* (City of Winnipeg, 2021), and *Winnipeg's Climate Action Plan* (City of Winnipeg, 2019) with the revised Development Plan, Direction Strategies, and the recommended newly created *Urban Agriculture direction strategy*.

6.1.2 Revise the City's Technical Instructions

i. Re-evaluate the current design guidelines for retention ponds including the minimum depth requirement (2.5 m) and prescribed area allocation (5% of the total drainage area) recommended in *Stormwater Management Criteria* (City of Winnipeg, 2001), to make them better suited for integration of urban agriculture (see section 3.3.2).

ii. Mandate permissible levels of undesirable elements in retained stormwater to ensure better water quality. Established federal public health and safety guidelines, such as *Guidelines for Canadian Recreational Water Quality* (Health Canada, 2012) may be referred to for water quality standards. Mandate additional features like *biofilters* and separate *detention basin*s may make these permissible levels more achievable.

iii. Recommend landscape management guidelines for suburban neighbourhoods to reduce or eliminate the dependence on chemicals such as fertilizers, insecticides, and pesticides. Prescribe alternative organic products for fertilization or pest control in these guidelines. Consider making these recommendations mandatory later, if required.

iv. Recommend planting guidelines that limit non-usable lawns and encourage the use of native and pollinator-friendly plants. Allow irrigation of common landscape areas in neighbourhoods by retained water, especially during droughts, if water quality permits.

6.1.3 Commence Additional Initiatives to:

i. Establish a special task force mandated to identify barriers to and opportunities for urban agriculture in Winnipeg. The current research helps nominate the City's stormwater retention ponds as one such opportunity. This task force may be comprised of experts from specialist organizations including the University of Manitoba and the International Institute of Sustainable Development (IISD).

ii. Evaluate the costs and benefits of offering incentives to developers including additional buildable FARs or density bonuses, to encourage denser neighbourhoods, and consequently increase the perceived safety of using retention ponds for agricultural activities. Evaluate the costs and benefits of offering subsidies to increase the profitability of urban agricultural activities in the city.

iii. Develop a system of collection and analysis of water quality and quantity data from retention ponds in various locations in the city. Build a repository of collected data over time, to be studied to understand and predict water quantity and quality variation across the city. This repository may help identification of vulnerable ponds and times of the year.

iv. Re-evaluate the language of warning signs placed along the retention ponds, to look for alternative phrasing to help reduce perceived risks associated with using retention ponds for agricultural activities (see section 5.2.4). Use this evaluation to look for similar alternative phrasing for instructions and descriptions in the section *Retention Ponds* from *Water & Waste Department* on the City of Winnipeg's website.

v. Explore potential partnerships with community and education institutions to leverage their expertise and resources for building capacity for urban agriculture in Winnipeg. This capacity-building may include investing in public education and awareness initiatives.

vi. Seek regional partners or sister municipalities for sharing vision, expertise, and data to support the integration of urban agriculture in municipal policies, and lobby:
   - Senior levels of governments for funding and required revisions to legislative provisions to remove barriers to urban agriculture.
   - Manitoba School Boards Association (MSBA), for re-evaluating school curricula to better integrate urban agriculture in school education.

6.1.4 Invest in *Winnipeg's Aquatic Agriculture Pilot Research Project*

The City of Winnipeg may invest in a pilot research project to gather and analyze data regarding the growth, harvesting, and usage of various agricultural crops including those nominated in section 5.2.1. This pilot research project may further inform regarding operational challenges associated with urban agricultural activities in stormwater retention ponds. Data gathered and analyzed by this pilot research project may support informed decision-making regarding potential policy and by-law amendments to support urban agriculture in the city. The City may engage in the following tasks:

i. Identify primary collaborators

A tripartite collaboration of the City's Public Works Department, a community or education institution (such as a local zoo or university), and a neighbourhood association may be best suited for this pilot research project. Including these three parties can help leverage the City's administrative and financial powers, the institution's expertise and community presence, and neighbourhood's residents and retention ponds to operate and manage this pilot research project.

Preliminary studies including expert opinions, public surveys, and focus groups could inform the choice of the location of this pilot research project. The current research identifies three options for such a collaboration by pairing a nearby public institution with a neighbourhood. Options for these triads are 1) City of Winnipeg | FortWhyte Alive | Residents of Whyte Ridge; 2) City of Winnipeg | Assiniboine Zoo | Residents living around Edward Shindelmen Park, South Tuxedo; 3) City of Winnipeg | University of Manitoba | Residents living around Alex bridge Park, Fort Richmond. These options may be considered along with other locations suggested by the proposed preliminary studies.

ii. Partner with other agencies

Data gathered and techniques employed by projects conducted earlier by the International Institute of Sustainable Development (IISD) and Native Plant Solutions (see 5.2.3) may be built upon to inform this proposed pilot research project. Other expert agencies including Prairie Climate Centre, and the University of Manitoba's Department of Agriculture and biosystems, Faculty of Environment or Architecture may be partnered with for technical advice, and the collection and analysis of data from this pilot research project.

iii. Phase operations incrementally

Adopting an incremental approach while planning phases for the proposed pilot research project may be beneficial (Section 5.2.1). Table 10 presents suggested phasing and actions for

Winnipeg's Aquatic Agriculture Pilot Research Project. The intensity and kind of actions indicate the expected improvement in the quality of retained water in each phase.

Table 10: Suggested phasing and actions for Winnipeg's Aquatic Agriculture Pilot Research Project

Phase	Suggested Actions
Preliminary	• Create public awareness regarding the relevance and operations of the pilot research project. • Incentivize chemical-free, organic maintenance for open green spaces in the neighbourhood. • Harvest biomass from ponds in the form of cattail, duckweed, or algae. • Repeat checks on water quality.
Intermediate I	• Public participation in operations. • Establish chemical-free, organic maintenance regimes for open green spaces in the neighbourhood. • Continue biomass harvesting from ponds. • Repeat checks on water quality. • Establish experimental planting beds for terrestrial crops in appropriate locations within common open space. Irrigate these crops with retained stormwater from the ponds. • Collect data for the presence of toxins from harvested crops. • Discard or compost crop produce after data collection.
Intermediate II	• Irrigate common landscaped areas from retained stormwater (if water quality allows) • Establish experimental Floating Treatment Wetlands (FTWs) for growing food crops in retention ponds • Monitor the quality of produce. • Continue biomass harvesting. • Continue established chemical-free, organic maintenance regimes. • Repeat water quality checks.
Advanced	• Establish '*aquatic farms*' with aquatic crops planted in the pond. • Continue food production from FTWs. • Monitor the quality and yield of produce. • Continue biomass harvesting. • Continue established chemical-free, organic maintenance regimes. • Repeat water quality checks. • Record financial outcomes.

6.1.5 Seek Funding Opportunities

The current research acknowledges that a lack of funds may challenge the activities suggested in this section, especially if the City operates alone. To mitigate these challenges the City may:

i. Seek funding partners, such as the Winnipeg Foundation, Winnipeg Food Council, University of Manitoba, or IISD to support required research and operations for urban agriculture.
ii. Identify and apply for Provincial funds and grants including those available under *Innovation Grant Program*. Identify and apply for similar Federal and non-government funding opportunities. Seek funding from the Federation of Canadian Municipalities (FCM) under various programs including the *Green Municipal Fund*.
iii. Approach industry partners and associations, such as Manitoba Home Builders Association (MHBA), Organic Food Council of Manitoba (OFCM), and Indigenous Chambers of Commerce (ICC) for investment. Leverage the business sector's Corporate Social Responsibility (CSR) for funding opportunities.
iv. Employ innovative techniques for raising money, including crowdfunding, expedited by non-profit and advocacy organizations such as Save Our Seine River Environment, Food Matters Manitoba, and Manitoba Eco-Network to add to the available resources.

6.1.6 Seek Opportunities for Advancing Reconciliation

Partner with various Indigenous organizations, including the Center for Indigenous Environmental Resources (CIER), Indigenous Leadership Development Institute (ILDI), Aboriginal Council of Winnipeg (ACW), and the Neeginan Centre to leverage Indigenous knowledge, farming, and land management techniques to:

i. Identify and employ innovative operational models to increase Indigenous food sovereignty
ii. Identify and employ innovative problem solving to develop low-impact harvesting techniques based on traditional *wild ricing* and food gathering practices.
iii. Reduce ecological impacts and build environmental resilience in the recommended agricultural activities and actions.
iv. Reduce operational costs and increase profitability.

6.2 Additional Research Directions

Various additional research directions originate from the discussions in this report. Perusing these directions may help recalibrate the recommendations of the current report and present additional solutions to mitigate challenges to urban agriculture in Winnipeg. These are listed below:

i. *What are the impacts of winter-associated phenomena, including low temperatures, snow thawing in spring, and winter associated activities such as winter sports, use of de-icing salts, etc. on identified opportunities for integration of urban agriculture in Stormwater retention Ponds? How can these impacts be mitigated?*

ii. *How can multiple uses, including those for ecosystem services, active transportation, winter recreation, and urban agriculture be integrated into residential stormwater retention ponds? What challenges and opportunities arise due to these multiple usages? How can best practices for these activities to occur simultaneously be determined? How can adequate area allocation for ponds and surrounding green open spaces be assessed?*

iii. *What concerns, apart from the barriers discussed above (see section 5.1) challenge the integration of urban agriculture into stormwater retention ponds?*

iv. *Apart from suburban residential retention ponds, how can urban agriculture be integrated into other components of stormwater green infrastructure? How can techniques like hydroponics and aquaponics, using retained stormwater be applied, to identify additional opportunities for urban agriculture in Winnipeg?*

v. *What additional measures may help optimization of safety risks and reduce perceived risks associated with urban activities in retention ponds? How can emergency services be delivered effectively to further reduce these risks?*

vi. *How do Winnipeggers actually feel about urban agriculture in retention ponds? If needed, how can desirable public opinion be generated? Are residents of some parts of the city more inclined or agreeable to these activities than others?*

vii. *What reconciliation opportunities can be identified while integrating urban agriculture into Winnipeg's stormwater green infrastructure? What barriers to these opportunities exist? How can ways to overcome these barriers, be determined?*

viii. *Which additional, high-value crops, apart from those identified in the current research can be grown in retained water?*

6.3 Addressing Research Questions

This section revisits the two main research questions and uses the findings from the current research to formulate answers. These questions are:

Q1 In what ways could suburban Winnipeg's residential stormwater retention ponds become urban agricultural assets?

This research has established that Winnipeg's residential stormwater retention ponds can be potentially used to grow and harvest crops for biofuel, fodder, and food. However, concerns regarding biological and technical feasibility, economic viability, safety and liability concerns, and NIMBYism challenge this potential. The current research lists some suggestions to overcome these challenges and identifies additional research to expand the list of suggestions. The City of Winnipeg may explore recommendations provided in Section 6.1 to support the integration of urban agriculture into suburban retention ponds. These include identifying and leveraging partnership opportunities with community and educational institutions, industry leaders, Indigenous organizations, and advocacy groups.

Q2 Do Winnipeg's policy documents, guidelines, and instructions inhibit or make urban agriculture in stormwater retention ponds possible? Are there any amendments needed?

The answer to this question is complicated. The City's development plan *OurWinnipeg 2045*'s (City of Winnipeg, 2021) reference to urban agriculture seems tokenistic as the goals and policies do not elaborate on how or where urban agriculture can be integrated into the city. The direction strategies, *CompleteCommunities 2.0* (City of Winnipeg, 2021), *Sustainable Water and Waste* (City of Winnipeg, 2011) or *A Sustainable Winnipeg* (City of Winnipeg, 2011) do not refer to urban agriculture at all. However, efforts to build environmental resilience, reduce greenhouse gas emissions and increase social equity, all of which may be achieved through the integration of urban agriculture in the city, have been alluded to in these Direction Strategies. Thus, the City's policy documents neither inhibit nor make urban agriculture in stormwater retention ponds possible.

The City's Technical Instructions including *Stormwater Management Criteria* (City of Winnipeg, 2001) and statements on the section *Retention Ponds* from *Water & Waste Department* on the City of Winnipeg's website, do not include agriculture in the list of permitted activities for these retention ponds. As various benefits of integrating urban agriculture in stormwater retention ponds have been identified (see Chapter 2), the language of the City's Policy -+3Documents and Technical Instructions may be amended to better support this integration.

6.4 Reflecting on Possible Outcomes

This closing section reflects on possible outcomes of exploring the directions suggested in this research. The current research has identified ways to utilize suburban Winnipeg's stormwater residential ponds as urban agricultural assets by integrating urban agriculture into stormwater green infrastructure. This integration is expected to have three direct and various additional indirect benefits. Figure 17 indicates these benefits in a Venn diagram.

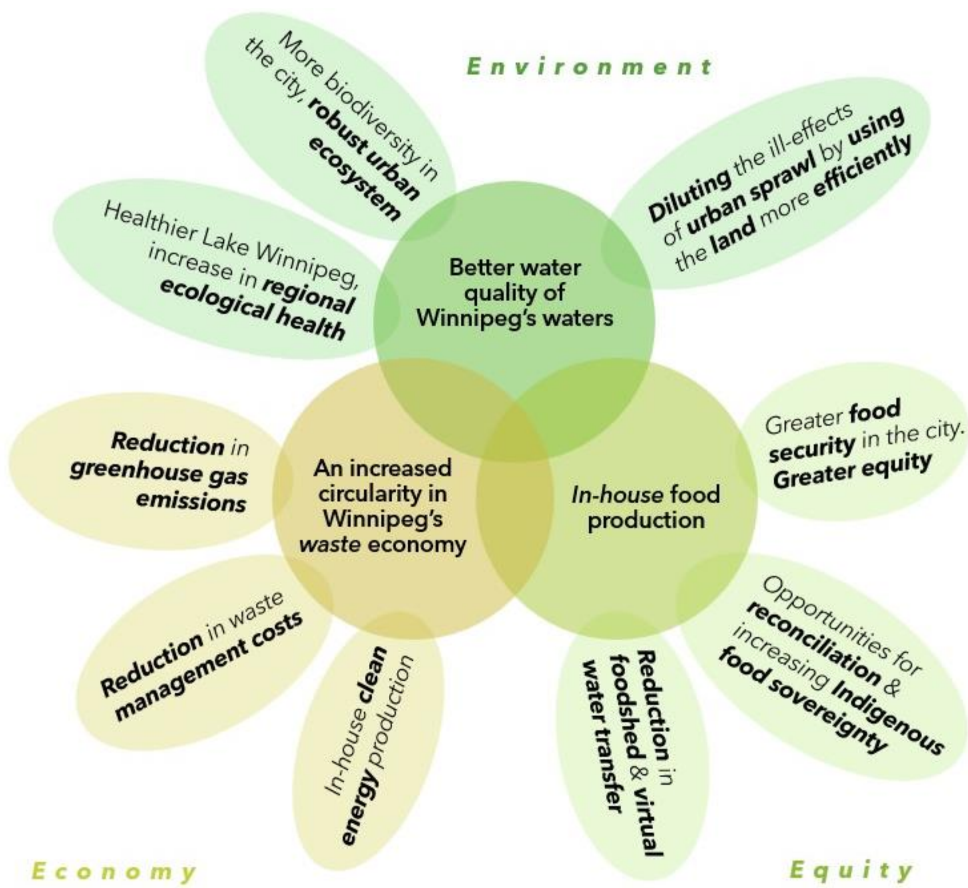

Figure 17: A Venn diagram indicating possible outcomes of exploring the directions suggested in this research.

Increased production of bioenergy, fodder, and food within the city is one of the primary benefits of urban agriculture in Winnipeg. This in-house production should reduce the *foodsheds* of consumed products and long-distance transfer of *virtual water* by reducing dependence on imported food. By consuming locally grown food, and fossil fuel displacement for energy production, greenhouse gas emissions are expected to decrease.

Integrating urban agricultural activities into stormwater green infrastructure may result in an increased circularity in Winnipeg's waste and energy economy. This increase would help divert less waste to processing plants, consequently reducing waste management costs. A direct benefit would be an increase in the quality of urban waters and consequently an improvement in the ecological health of Winnipeg's urban ecosystem, potentially increasing urban biodiversity. This improvement is expected to contribute to the ecological health of the entire region, including its rivers, wetlands, and lakes such as Lake Winnipeg.

An increase in city-grown food production may help increase food security and potentially reduce food inequity in Winnipeg. Additional opportunities for reconciliation and increasing Indigenous food sovereignty may be accomplished by partnering with Indigenous organizations such as CIER and applying Indigenous knowledge.

Lastly, it may be argued that by growing and harvesting usable plants in the City's residential stormwater ponds, Winnipeg's suburbs will be used more efficiently, perhaps diluting the ill effects of urban sprawl.

A ***pondful*** of possibilities indeed!

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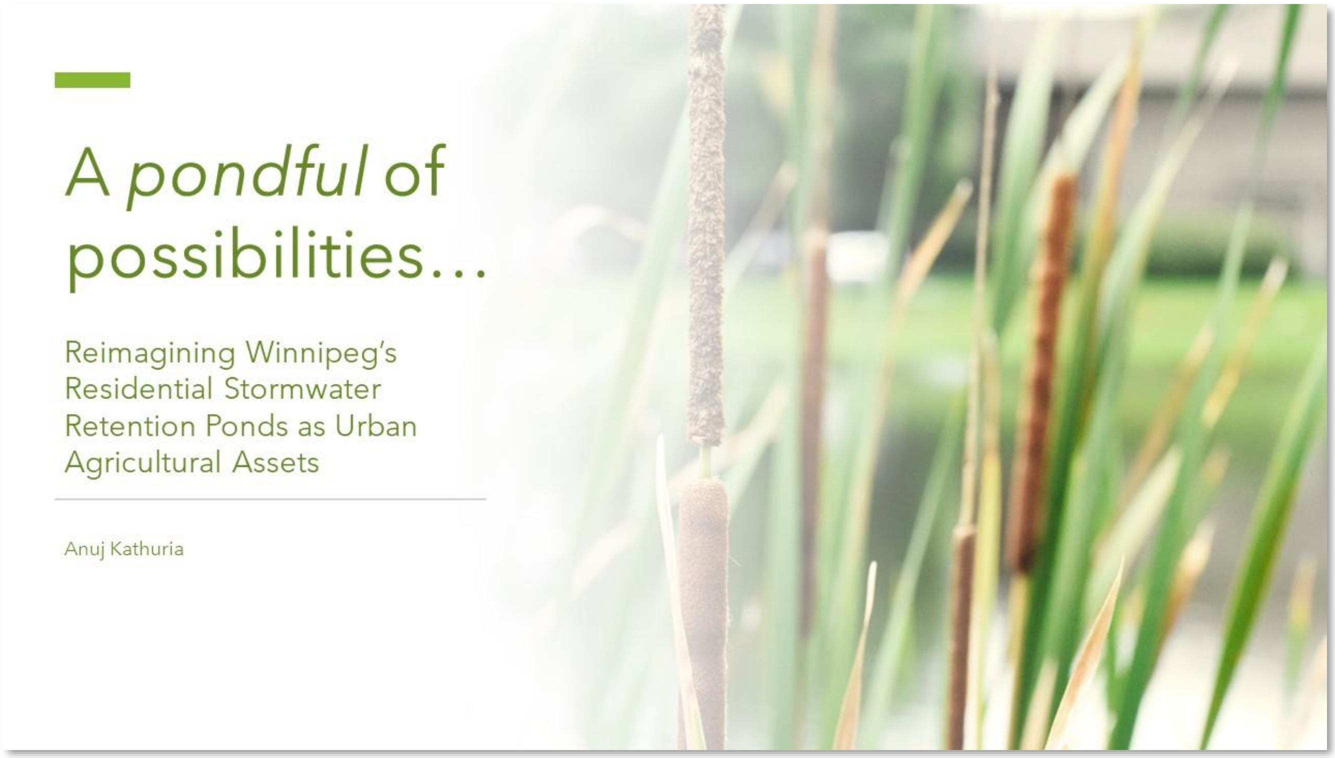
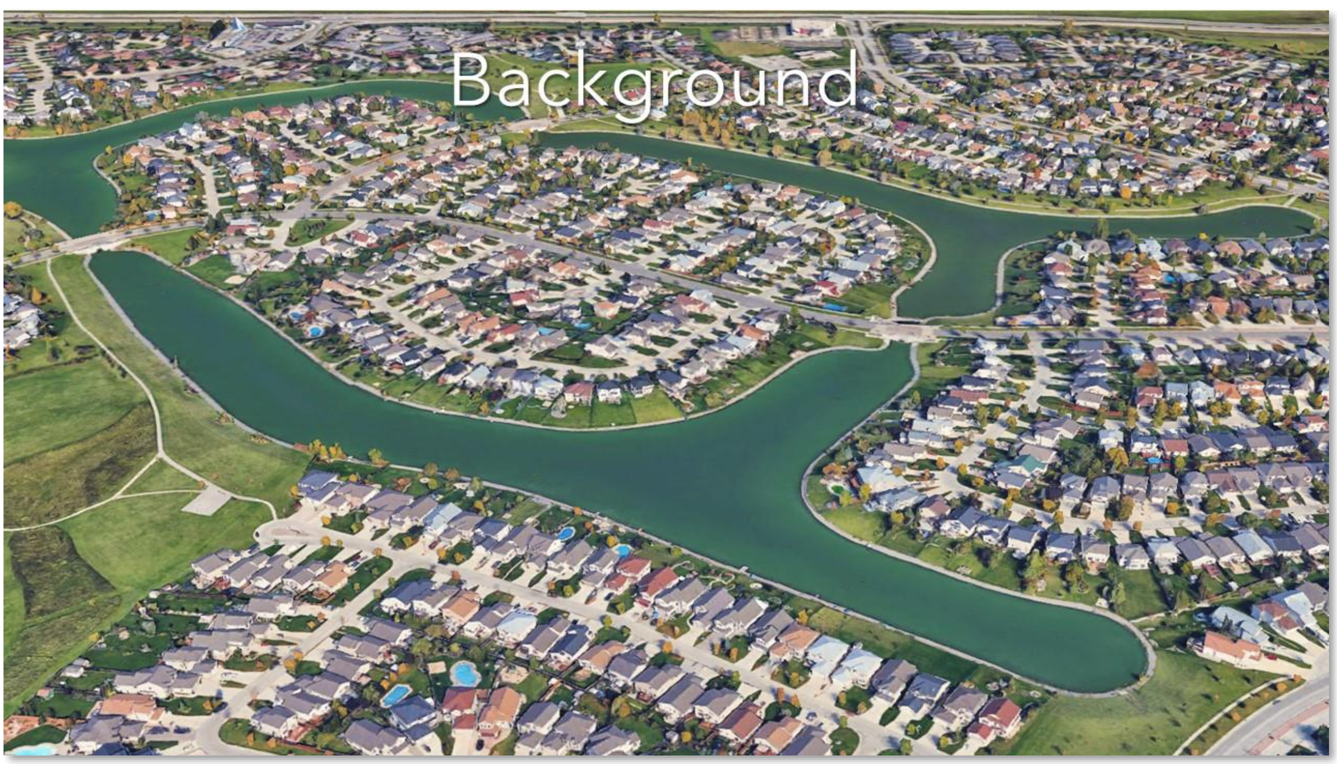
Appendices

i. Slides from the Final Presentation





Research Questions

Q1 In what ways could suburban Winnipeg's residential stormwater retention ponds become urban agricultural assets?

Q2 Do Winnipeg's policy documents, guidelines, and instructions inhibit or make urban agriculture in stormwater retention ponds possible? Are there any amendments needed?

Research Methods

Literature Review

- Principles of Urban Ecology
- Integrated Stormwater Green Infrastructure
- Research Precedents

Stormwater Retention Pond Audit

- Southdale
- Island Lakes
- Linden woods
- Royalwood II
- Bridgwater Forest

Policy Scan

- City's Development Plan
- City's Direction Strategies
- Technical Instructions

Key Recommendations

- Revise the City's Policy Documents & Technical Instructions. Work towards Winnipeg's *Urban Agriculture Direction Strategy*
- Partner with educational institutions, research specialists, and citizens' groups for capacity building and additional pilot research projects.
- Seek investment partners like business organizations and community institutions, while lobbing Provincial and Federal Governments for grants.
- Leverage partnerships with Indigenous Organizations to Identify opportunities to advance reconciliation.

Challenges & Solutions

Technical Feasibility

- Integrating water level control mechanisms
- Exploring innovative growth, harvesting, and land management techniques
- Identifying and removing regulatory barriers

Safety & Liability Concerns

- Revisiting design guidelines for retention ponds
- Investing in additional research on risk management.
- Revisiting language on warning signs

NIMBYism & Public Opinion

- Investing in public engagement and awareness initiatives.
- Involving school kids and youth in awareness drives.
- Collaborating with community institutions for capacity building.

Conclusion

> *Winnipeg's residential stormwater retention ponds can be potentially used to grow and harvest crops for biofuel, fodder, and food. Concerns regarding biological and technical feasibility, economic viability, safety and liability concerns, and NIMBYism challenge this potential.*
>
> *City of Winnipeg may revise its Policy Documents, invest in pilot research projects, and leverage partnerships with community and educational institutions, industry leaders, Indigenous organizations, and advocacy groups to overcome these challenges and support the integration of urban agriculture into Winnipeg's urban open space.*

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