AN OVERVIEW AND UPDATE OF LOW-IMPACT DEVELOPMENTS (LIDS) IN THUNDER BAY

By

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April 2023

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1128909

An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor of Science in Forestry

Faculty of Natural Resources Management

Lakehead University

April 2023

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ABSTRACT

Wells, T. 2022. AN OVERVIEW AND UPDATE OF LOW-IMPACT DEVELOPMENTS IN THUNDER BAY. 43 pp.

Keywords: climate change, flooding, forestry, low-impact developments, rain gardens, storm events, urban, urban water management

Climate change is accelerating at a rapid pace across the globe and with this, flooding in urban environments is also increasing. This means that there is and will be an increasing need for alternative methods of stormwater management. Low impact developments (LIDs) are a green way that cities can manage their stormwater. Thunder Bay has been incorporating LIDs into the stormwater management process to improve its ability to handle urban runoff and prevent flooding. This paper will provide an overview of the LIDs within the city and describe how they function and their benefits. This information can be used to further understand the benefits of LIDs and how they can be implemented in various cities.

ACKNOWLEDGEMENTS

First, I would like to thank my parents if it was not for them, I would not have been able to do this, their support has been crucial in my success, and I could not be more thankful for all they have done for me. Second, I would like to thank my long-time girlfriend Delaney as she has supported me through thick and thin. My friends deserve thanks as they have supported me and are always willing to see me no matter how long it has been. Also, my professors who have been patient and always willing to help me learn.

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INTRODUCTION AND LITERATURE REVIEW

HISTORY OF GREEN INFRASTRUCTURE

Forests have been a key part of human existence since the beginning of time. As our species has drifted away from the natural world and moved into more urban areas our relationship with nature has changed drastically. In the past, we have made a large effort to move as far away from nature as possible, this can be seen clearly in old European cities which can be almost completely devoid of any natural sight as their primary focus was housing and security. Generally, only in areas where the was significant wealth was there a desired implementation of nature in urban areas. Today, however, we understand the importance of nature. As seen in many cities incorporating nature in urban design is becoming more and more popular. As our knowledge has grown the functions of these natural areas in urban settings are increasing. This creates a mutualistic relationship between nature and humans. As we are incorporating nature into our societies it provides us with beneficial functions which improve our quality of life.

The term that is used to describe urban development with the incorporation of nature is green infrastructure. Green infrastructure was first developed in rough concept by the designer of New York's Central Park and Boston's Emerald Necklace, Fredrick Law Olmsted who focused on three main aspects which were ecosystem services and human-well being, environmental restoration, and comprehensive planning. This term has varying definitions but a commonly accepted one is "an interconnected network of greenspace that conserves natural ecosystem values and functions and provides associated benefits to human populations" (Benedict & McMahon, 2002). Green infrastructure stretches over many disciplines such as urban planning, landscape design, ecology and conservation, transportation, and forestry (Firehock, 2010). This type of development has been done in many ways from simply installing some grass or green space to creating intensively planned areas that have multiple benefits for both humans and the natural world. The term green infrastructure was first coined in Florida in 1994 which made the comparison between our grey infrastructure which is hydro, electric, sewer, roads, and other human developments to that of the natural world and how they are just as important, if not more important than the anthropogenic developments (Firehock, 2010).

There are many different types of green infrastructure which are highlighted in Figure 1. This shows some of the common types of green infrastructure that are used within Ontario and compares it to the different types of grey infrastructure.

Figure 1. An Infographic that shows the different types of green infrastructure by the Green Infrastructure Ontario Coalition 2021.

CLIMATE CHANGE

Having multifunctional areas within cities is key, especially in the face of an ever-changing climate. Canada in 2021 alone released 670 megatonnes of carbon dioxide and CO_2 equivalents (Environment and Climate Change Canada, 2023). Globally we are producing around 50 billion tonnes of CO_2 and CO_2 equivalents each year with some countries producing significantly more emissions than others as seen in Figure 2 (Ritchie *et al*, 2020). This is having profound impacts on our climate and causing a change that has not been seen in recent history.

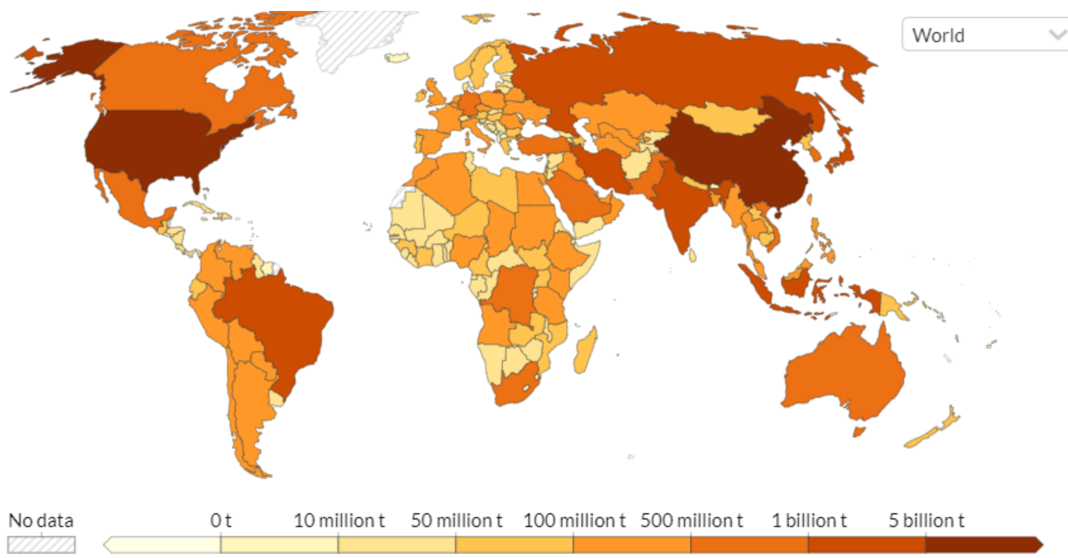

Figure 2. A map of greenhouse gas emissions by country (Ritchie *et al*, 2020)

One of the major impacts of the changing climate is the increase in temperature and precipitation. The increase in temperature has been significant over the past 50 years as the average temperature has gone up 3.3 °C across the country as seen in Figure 3 (Vincent *et al*., 2015). This change in temperature will shift the normal precipitation patterns which means it could be less likely to snow in the winter in some areas but more rain and sustained periods of drought along with increased frequency and intensity of extreme weather events in other parts across the country (Bush and Lemmen, 2019). This will increase urban areas need for stormwater management. These events mean higher chances of flooding and events that could cause damage to urban areas.

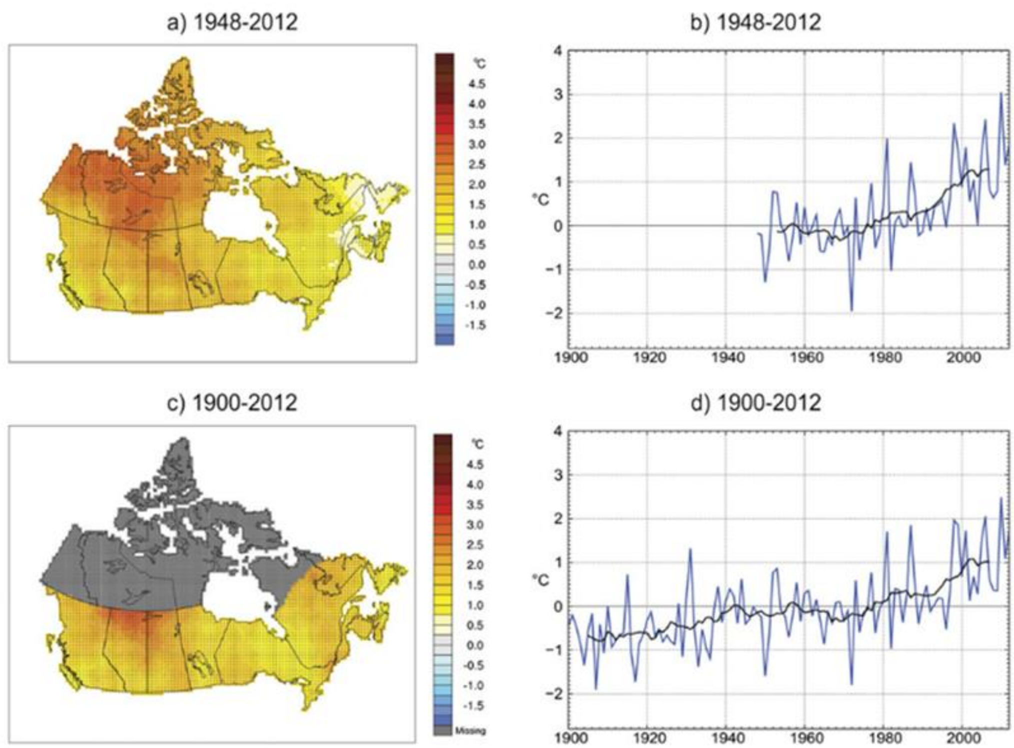

Figure 3. Showing trends of the mean annual increase in temperature across Canada (Vincent *et al*., 2015).

This temperature rise can increase melting in northern zones, increasing the amount of water that urban areas must handle. As the climate continues to change there has been an increase in temperature extremes and precipitation due to human activity (Zhang *et al* 2013 & Stocker, 2014). Zhang *et al*. suggest that humans have increased the annual maximum 1-day precipitation in the Northern Hemisphere by 3.3%. A study by Vincent *et al*. 2015 shows that the annual precipitation has increased in the northern zones of the country as seen in Figure 4. This change in stormwater could be all that is necessary for cities to flood.

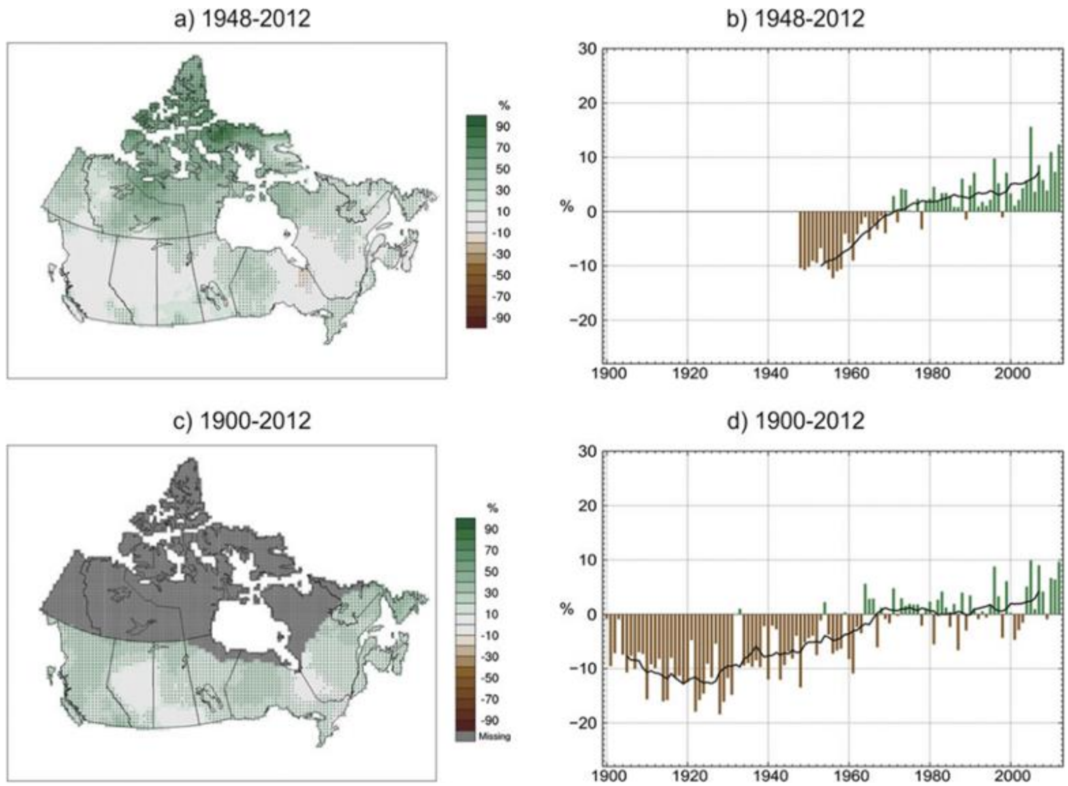

Figure 4. Trends in annual total precipitation from 1948-2012 (Vincent *et al*., 2015).

Flooding impacts cities across the world and climate change only amplifies this disaster. Table 1 which has been pulled from a study conducted by Pour *et al*. in 2020 shows changes in urban flooding that can be expected in the future for cities across the world. Many of these changes are very extreme and pose a danger to urban areas if nothing is done to combat them. Although these changes are from many sources globally some of the same impacts can be expected here in Thunder Bay. Understanding the impact that climate change will have on the local environment will be key to ensuring the safety of urban areas and reduce the risk of flooding.

Table 1. Expected changes in future urban flooding across the globe (Pour *et al.* 2020).

Reference	City	Changes in urban floods
Suttles *et al.* 2018	Urban areas in the Southeast United States	1-day and 100-year floods will be nearly doubled in future
Akter *et al.* 2018	Urban floods in Schijin River Basin, Belgium	The urban runoff will increase by 200%-500%
Guo *et al.* 2018	Urban areas in China	More frequent urban floods due to 50% increase in precipitation on very wet days
Markus *et al.* 2018	Cook County, Illinois, USA	More frequent urban floods due to 5-35% increase in 24-hr 100-year rainfall events
Guerreiro *et al.* 2018	Floods in 571 European Cities	Several cities will experience more than a 50% increase in floods
Zhao, Gao, & Cuo. 2016	Urban areas in San Antonio River Basin, USA	Heavy flooding due to the increase in the median of annual precipitation maximum up to 885 $m^3 s^{-1}$
Supharatid, Aribarg, & Supratid. 2016	Bangkok, Thailand	Increased vulnerability to floods due to the increase in peak rainfall by 100 %
Anandhi *et al.* 2016	South Asian cities	Increased temperature by 0.8–2.1% will cause more urban floods due to melting
Cabrera & Lee. 2018	Davao Oriental, Philippines	Higher flood magnitude due to a 69 % increase in rainfall intensity
Bajracharya, Bajracharya, Shrestha, & Maharjan. 2018	Kaligandaki Basin, Nepal	A 50 % increase in peak floods due to glacier melting under higher temperature
Byun & Hamlet. 2018	Midwest and Great Lakes region, USA	Increased frequency of flooding and stormwater events due to a 30 % increase in precipitation
Alfieri *et al.* 2015	European cities	A 100 % increase in 100-year or above flood peaks
Poelmans, Rompaey, Ntegeka & Willems. 2011	Molenbeek catchment, Belgium	Increase in the flood-affected area by 0.1–7 ha. For a 100-year return period flood event
Zahmatkesh, Karamouz, Goharian, & Burian. 2014	Urbanized Bronx River watershed, USA	Increase in runoff volume up to 40 % and thus, more floods
Mishra *et al.* 2018	Ciliwung River Basin, Jakarta, Indonesia	Increasing flood inundation areas and depths ranging from 6% to 31 %
Januriyadi *et al. 2018*	Jakarta, Indonesia	322—402 % increase in flood risk in 2050 at a significance level of 0.05
Hettiarachchi *et al.* 2018	South Washington Watershed District, USA	10—170 % increase in flood risk with confidence

The specific changes to the local climate within Thunder Bay have been predicted within the city's Climate Change Adaptation Strategy which was developed in 2015. Figure 5 which has been sourced from the City of Thunder Bay's Climate Adaptation Strategy (2015) shows that there will be increases in the average temperatures in and around the city along with an increase in the average annual precipitation. These increases are significant as the average temperature is predicted to increase by 2.7°C by 2050 and up to 4.6°C by 2080 and precipitation is predicted to increase by 50 mm by 2050 and 80 mm by 2080 (City of Thunder Bay, 2015). The impacts of climate change will be felt in the watersheds that surround the city of Thunder Bay.

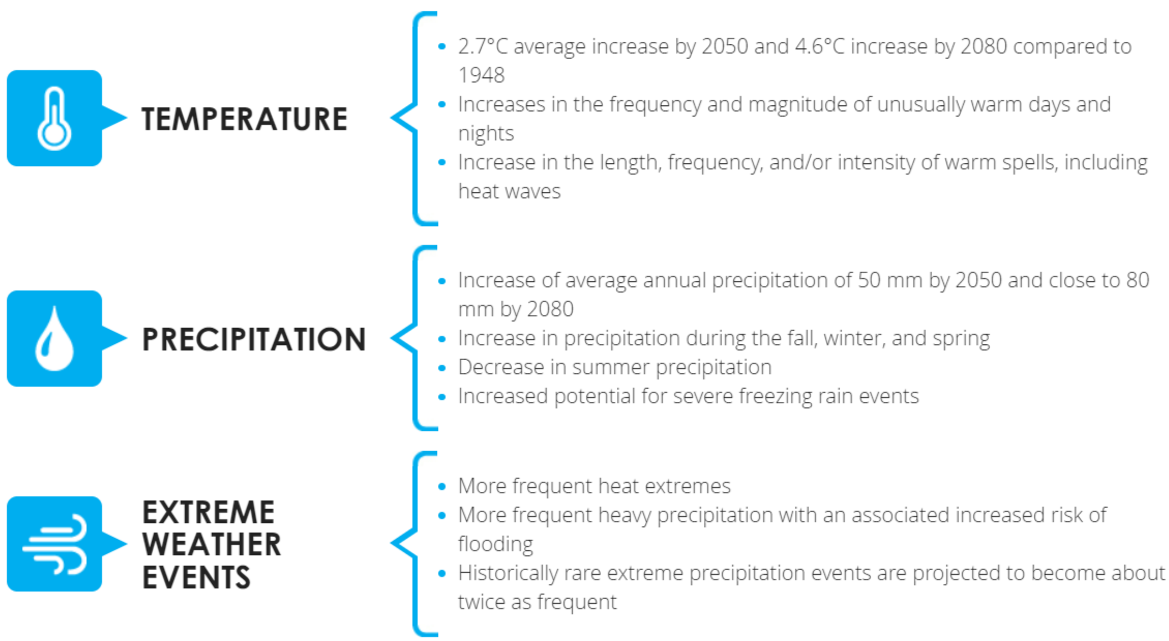

Figure 5. Predicted changes to the local climate in and around the City of Thunder Bay (City of Thunder Bay, 2015).

LOW IMPACT DEVELOPMENTS (LIDS) IN NORTH AMERICAN CITIES

Many cities in North America have started to use these eco-friendly alternatives to deal with stormwater. With climate change increasing the chance of flooding and the amount of stormwater that cities are having to deal with is increasing as well. The Toronto and Region Conservation Authority has begun to implement LIDs into their urban design. They are incorporating many of the same methods that are used here in Thunder Bay such as rain gardens, bioswales, infiltration trenches, and permeable pavement (Toronto and Region Conservation Authority, n.d.). The city of Calgary has also started to develop more LIDs and implement them into their urban design specifically rain gardens, green roofs, permeable pavements, bioswales, and absorbent landscapes (City of Calgary, n.d.). Many regions that have a history of flooding or intense precipitation have begun to implement low impact developments as part of their stormwater management. This is because it deals with pollution picked up in the urban environment while increasing the amount of permeable area that water is able in infiltrate which reduces that chance of flooding and damage to the environment.

Another place that has been pushing the development of low impact developments is the state of Washington. The department of Ecology in the state has created the Washington State Certificate Program. These are online self-paced programs which inform people about LIDs with two main streams which are design and then operations and maintenance. They also offer a rain garden training certificate for non-professionals to better educate themselves about the benefits of LIDs. (Department of Ecology State of Washington, n.d.)

The city of Seattle must deal with large amounts of stormwater due to the climate of the area as it receives an average of 957.58 mm of precipitation per year (Berezow, 2019). As a result of this they have become one of the leaders in LIDs in the U.S. The city has been incorporating LIDs to assist with stormwater management and mitigate the negative environmental impacts that are caused by further human development (Baals, 2020). The city has implemented the use of "Green Stormwater Infrastructure" (GSI) since the year 2000. Since then, they have installed almost 8,000 different projects, have 12 km of GSI, and manage nearly 2,649,788,248 liters of stormwater through GSI across the city (City of Seattle, 2021).

IMPACTS OF LIDs ON STORMWATER MANAGEMENT

Cities that experience a high level of precipitation are in a constant battle with nature. Managing this water is very important to maintain the integrity and stability of urban environments. Low-impact developments allow cities of all sizes to manage their stormwater and runoff sustainably. The major way that LIDs influence stormwater management is by promoting infiltration, this is done by removing pavement and having surfaces that water can penetrate (Environmental Protection Agency, 2012). Allowing water to infiltrate into the soil and slowing it down has many benefits such as allowing pollutants to be absorbed so there is a significantly lower amount that is passed through to natural water systems. Table 2 shows the percentage of pollutants that the NW 110th Cascade Project removes from the water when compared to traditional street drainage. This project replaces around 430 meters of ditches and culverts with stair-stepped natural pools which slow the stormwater and encourage infiltration.

Table 2. Percentage of pollutants that are caught in the NW 110th Cascade project (Horner & Chapman, 2007).

Pollutant	Pollutant Mass Loading Reductions[1]
Total suspended solids	84%
Total nitrogen	63%
Total phosphorus	63%
Total copper	83%
Dissolved copper	67%
Total zinc	76%
Dissolved zinc	55%
Total lead	90%
Motor oil	92%

Many urban environments are lacking natural ecosystem services so finding ways to incorporate these services into the urban environment is key and will make urban areas more resilient. A study done by Elliott *et al.* in 2019 analyzed the linkages between urban green infrastructure and the ecosystem services that they provide. This was done using an expert opinion methodology in which surveys were taken by professional individuals from a variety of backgrounds and their judgment of the ecosystem services provided was recorded along with other comments and information. The study found that one of the most positive services that can be provided by green infrastructure is water quantity mitigation. This shows that LIDs and other types of green infrastructure can positively impact a city's ability to manage stormwater by increasing the amount of runoff that it can handle. This is increasingly important in the face of significant climate change which will drastically increase the number of extreme weather events and overall rainfall that urban areas will face.

A study done in Renton City, WA by Abduljaleel & Demissie (2021) showed that depending on the LIDs used there can be a reduction in the range of 30% to 75% in the amount of runoff that the area has. This can significantly reduce the strain put on traditional stormwater management systems and could be enough to stop flood events and save huge amounts of property and infrastructure. Knowing which watersheds are located around the city will help in understanding the needs of different parts of Thunder Bay and what measures should be taken to reduce the chance of flooding.

LAKEHEAD WATERSHED

The primary watershed that impacts the City of Thunder Bay is the Lakehead watershed which is a massive area that consists of 11,526 square kilometers, within this large area 2,719 square kilometers are under the jurisdiction of the Lakehead Region Conservation Authority (Lakehead Region Conservation Authority, 2023). This encompasses much of the area in and around Thunder Bay, but the city has seven smaller primary watersheds that flow directly through it. These smaller watersheds are the McIntyre River watershed, Neebing River watershed, the McVicar Creek floodplain, the Current watershed, the Pennock watershed, the Kaministquia watershed, and the Mosquito watershed (Lakehead Region Conservation Authority, 2023 & City of Thunder Bay, 2016). Figures 6 and 7 show an overview of the Lakehead watershed along with a more refined view to complete the picture in and around the city.

These watersheds directly impact the city and determine how much water the City of Thunder Bay must deal with. The implementation of LIDs can help manage the flow of these watersheds and make the city more resilient and better prepared for flood situations. The primary concern within these watersheds is ensuring that the infrastructure can handle the 90th percentile rainfall event or the '100-year flood'. The 90th percentile rainfall event within the city is a 29 mm rainfall event over a 24-hour period. Having multiple watersheds within the city means that the management of stormwater becomes more complicated especially when concerning climate change as each will react slightly differently having different impacts on the city. Incorporating multiple ways to manage the stormwater from these systems is vital to the future of Thunder Bay.

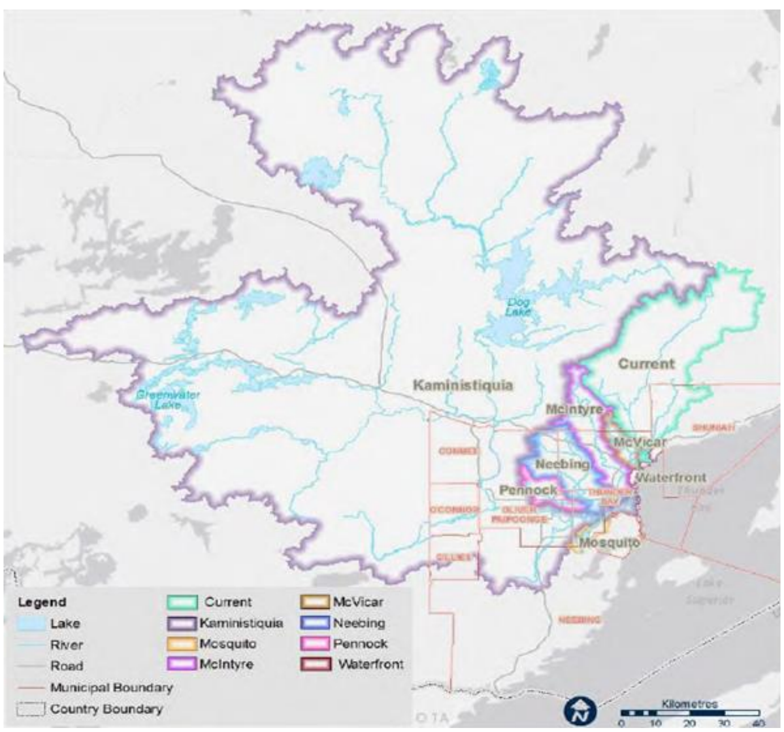

Figure 6. Map of the Lakehead Watershed (City of Thunder Bay 2016).

Figure 7. Overview of watersheds within the city limits of Thunder Bay and the surrounding area (City of Thunder Bay, 2016).

STORMWATER MANAGEMENT IN THUNDER BAY

A major event that caused the city to reconsider how it manages stormwater was when there was a significant rainfall event that flooded the city back in 2012. During this event, 108 millimeters of rain hit the city over 36 hours with 50 millimeters falling in one hour (Vis, 2017). This flooding caused massive damage to the city and its infrastructure, just the city's sewage treatment plant had damage that totaled $58 million. There was also large amount of damage done to private property across the city which totaled in the millions as well.

Traditionally stormwater has been managed in Thunder Bay using the grey infrastructure. This is the combination of large pipe networks, culverts, ditches, grates, and other water collection methods to funnel the runoff collected from the city to a water treatment plant and prevent flooding. Thunder Bay uses all the previously mentioned methods to manage the stormwater in the city. This method of stormwater management is well established in the sense that the benefits, costs, and risks are well understood. The use of only grey infrastructure has drawbacks and environmental impacts that negatively influence the city's ability to manage stormwater.

The challenges that are faced when using grey infrastructure are funding these large public works projects as they require large investments from the city along with regular maintenance. This can eat up the city budget especially if the infrastructure is dated and needs replacing or constant maintenance. Urbanization also presents a problem when concerning stormwater as it creates more impermeable surfaces. Impermeable surfaces will increase the pollution of surface water, increase flooding, and not allow for adequate recharge of the water table (University of Delaware, n.d.). Any runoff that is created by these surfaces then proceeds to pick up many of the pollutants that are present in the urban environment from locations such as parking lots, construction sites, industrial storage yards, and even lawns. To improve stormwater management the city of Thunder Bay is implementing LIDs across the city with the goal of installing around 550 throughout the city to improve stormwater management. This will ensure the city is better equipped to deal with the upcoming changes caused by climate change.

Low-impact developments and green infrastructure are a crucial part of Thunder Bays Stormwater Management Plan. As of the end of 2021, there have been 28 different implementations of LIDs or green infrastructure installed throughout the city. There have also been over 150 rain gardens installed across the city on residential properties according to Ecosuperior (Gillies, 2023). These installations help make the stormwater system within the city more robust and capable of dealing with unusual rainfall events.

Low Impact-Developments (LIDs) are a key component of green infrastructure as they allow cities to focus on incorporating nature into the urban environment while it is providing multiple functions. LIDs are a perfect representation of what all green infrastructure should aim to do as they use nature in a way that benefits both humans and the natural world. LIDs are a long-term sustainable solution to managing stormwater within urban environments.

OBJECTIVE

The objective of this thesis is to provide an overview of the low-impact developments in Thunder Bay along with an update on how many have been built, their locations, the impact that they have on the stormwater collection, and how they compare to the traditional management process.

HYPOTHESIS

Low-impact developments have increased the capacity of Thunder Bay's stormwater management program and made the city more resistant to the negative impacts of climate change. Further development of these areas will increase the city's stormwater management capacity sustainably.

MATERIALS AND METHODS

To analyze the LIDs within Thunder Bay, first an analysis of the Lakehead watershed will be done to determine which ones influence the city. Maps of the various watersheds within the city have been compiled from the city's Stormwater Management Program. An interactive map has been developed using Google Earth and the Green Infrastructure List (City of Thunder Bay, 2021) so the locations of the 28 different installations can be seen throughout the city. This map only shows the public LIDs. The Green Infrastructure List (City of Thunder Bay, 2021) has been obtained from the city's planning and engineering division which is used for obtaining the size and location of each of the developments.

In total 28 LIDs are installed across the city which will improve Thunder Bays stormwater management. The purpose of this study is to analyze some of the aspects of LIDs and how they positively influence the municipalities in which they are installed. Factors such as location, construction, and stormwater management potential are all key when assessing low-impact developments. A comparison will be made between the new green infrastructure and grey infrastructure and an attempt to determine which is a better long-term sustainable solution for stormwater management.

RESULTS

Out of the 28 different low-impact developments throughout the city of Thunder Bay, there are 13 bio-retention systems, 6 bio-filtration systems, 6 infiltration trenches, 1 porous pavement system, 1 parking lot infiltration system, and 1 enhanced swale system. The link provided allows access to the map which can be seen in Figure 8: https://earth.google.com/earth/d/1ZZ_ZUx1u1UaZG-KydEqPQ1fqQcPi7q72?usp=sharing. The interactive map has all the above-mentioned LIDs plotted to show the distribution throughout the city along with a brief description of the different developments and their catchment area. Due to some of the aerial photos not being up to date some of the projects are not shown but the coordinates are provided if anyone wants to visit the sites in person. A list of all the LIDs installed as of the end of 2021 has been provided by the City of Thunder Bay and is presented in the appendix. There is more information about the largest of each of the different types of LIDs in the city presented here along with a description and brief overview.

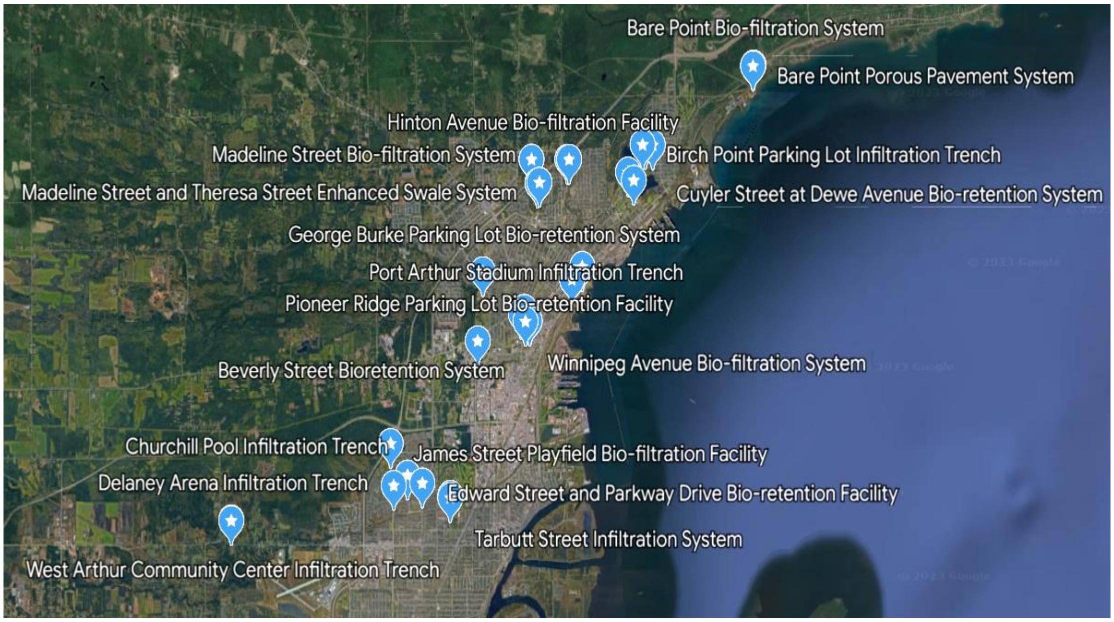

Figure 8. A map of all the current LIDs within the City of Thunder Bay.

The largest LID within the city is the Clayte Street West bio-retention system which has a catchment area of 4.9 ha. This system handles the runoff from the surrounding streets and discharges it into McVicar Creek. Figure 9 shows the basic design of a typical bio-retention system like those implemented in Thunder Bay. This system is a part of the McVicar Creek watershed. The system lowers the amount of direct runoff that is received from the streets and treats the water for any suspended solids that may be picked up from the surrounding areas. This is done by collecting water from the catchment area then allowing the water to infiltrate through the soil and gravel media that have been installed and into the sub-drain which then discharges the water directly into McVicar Creek. The total catchment area of the 13 bio-retention systems that have been implemented throughout the city is 15.61 ha (City of Thunder Bay, 2021).

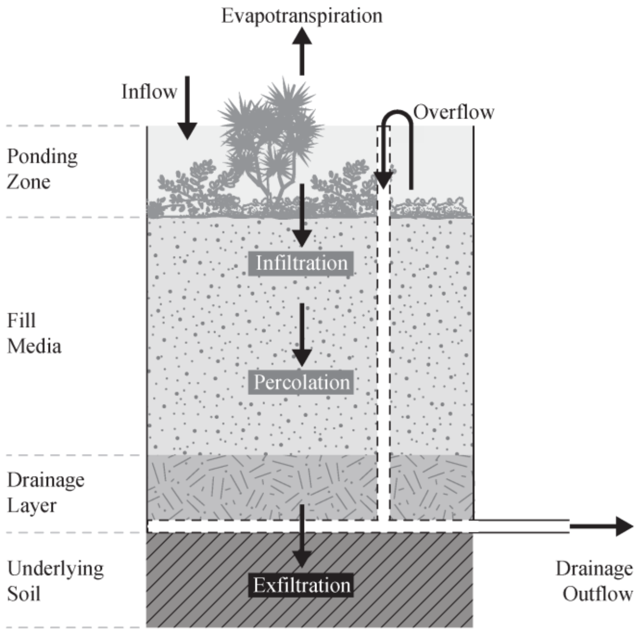

Figure 9. A basic diagram of a bio-retention system (De-Ville *et al*., 2021).

The largest bio-filtration system that is implemented within the city is the James Street Playfield bio-filtration facility which has a catchment area of 3.92 ha and is a part of the Neebing River watershed. This facility receives runoff from the adjacent parking lot and splash pad. This facility is unique when compared to the other bio-filtration systems within the city as the runoff from the parking lot is treated before entering the bio-filtration system using an oil-grit separator which will reduce the contamination received from the parking lot. This system functions similar to the bio-retention systems as it collects water and then allows it to infiltrate through the different media that have been installed and it is discharged through the subdrain. Once the water has flowed through the system it is then discharged into the city's existing stormwater collection systems. The total catchment area within the city from bio-filtration systems is 8.97 ha. These systems are designed similarly to bio-retention systems but are optimized to handle higher flows and more volume. The main difference between the two systems being the soil media that are used. The soil media used in the bio-filtration systems allow for the water to pass through quicker making them better at handling higher flow rates (MacLeod *et al*., n.d.).

The infiltration trenches within the city have a total catchment area that is much smaller than the area of bio-filtration and bio-retention systems but still play a role in mitigating stormwater within the city. The area covered by the 6 infiltration trenches within the city is 2.42 ha with the largest catchment area of any single trench being the Delaney Arena Trench with a catchment area of 0.6 ha, this trench discharges into the Neebing River watershed. These trenches are designed to collect runoff from the surrounding areas and use a combination of physical filters such as rocks, gravel, and geotextile material to filter out any suspended solids and other pollutants. A diagram of the basic design of these systems is provided in Figure 10.

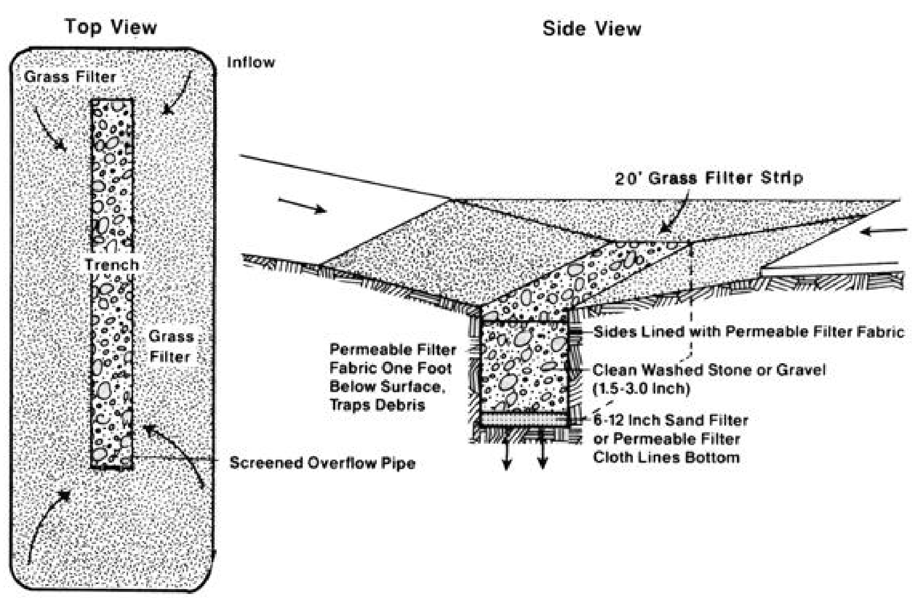

Figure 10. A basic diagram of an infiltration trench (Schueler, 1987).

The last three low-impact developments within the city are all unique. There is a porous pavement system that has a catchment area of 0.05 ha and discharges into the Lake Superior waterfront. This system is a pilot project that the city has implemented which accepts runoff from a small portion of the parking lot and upstream landscaped area while treating the water for suspended solids. This system is a traditional parking lot that has been paved with a special type of asphalt that allows water to infiltrate which reduces the amount of runoff and suspended solids in it. The basic design of one of these systems is shown in Figure 11. An enhanced swale system is also installed within the city which has a catchment area of 0.25 ha and can store 200 m^3 within the floodplain while also treating the water for suspended solids. This installation is the Madeline Street and Theresa Street enhanced swale system which discharges into McVicar Creek. This system is similar to an infiltration trench as it is a channel with various media to remove suspended solids and pollutants, but it is also able to store the water and has more vegetation within to remove other types of pollutants such as heavy metals. A basic diagram of an enhanced swale system can be seen in Figure 12. The final unique system that the city has installed is the Market Square parking lot infiltration system which has a catchment area of 0.29 ha. This system is a sub-surface infiltration trench and sub-drain system underneath the parking lot which receives drainage from the parking lot and then discharges into the existing stormwater collection system.

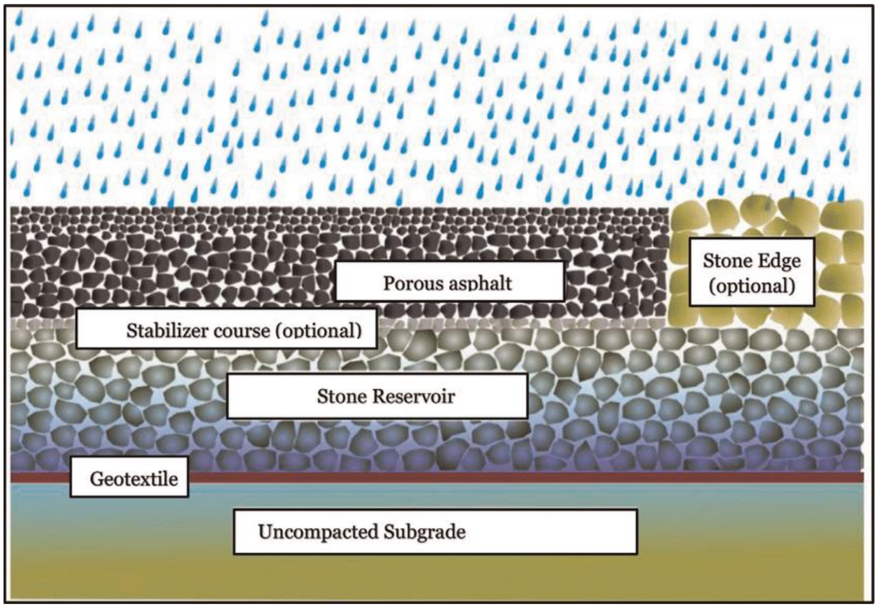

Figure 11. Diagram of a porous asphalt system (Dylla & Hansen, 2015).

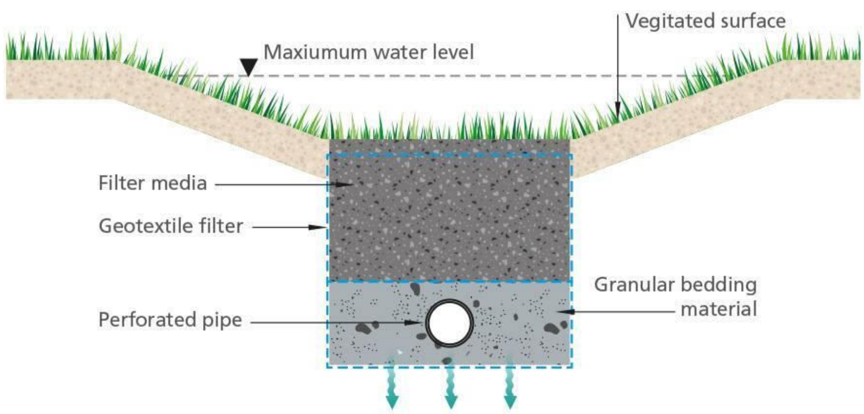

Figure 12. Diagram of an enhanced swale system (PolyPipe, 2023).

DISCUSSION

Green infrastructure within cities has come a long way since its first use. The use of low-impact developments in the management of stormwater shows this clearly. The implementation of low-impact developments within the City of Thunder Bay has improved its ability to manage stormwater sustainably. These developments align with the changing social values as it is becoming more important to implement sustainable methods of managing the relationship between our society and nature. With factors such as a rapidly changing climate, finding ways to improve these issues such as implementing LIDs in stormwater management is key. Systems such as biofiltration and bio-retention that use native plants in combination with the layering of different soil mediums and sub-drains allow for sustainable methods of stormwater management that further the ability of a city to deal with stormwater.

The City of Thunder Bay has implemented a total of six different techniques when it comes to LIDs. Some of them are at a large scale and others at a much smaller scale. This variety shows that these systems can be used in many situations and can provide elegant sustainable solutions to an old problem. Instead of having classic curbs and storm drains, low-impact developments can be used to not only provide water management solutions but also give communities green spaces. With the variety of designs that have been implemented, there is no single one that is the best as each is used in different circumstances. The variety of designs allows for the needs of many different situations to be met and create a unique feel for each one.

A major factor that influences green infrastructure development is the price of installation. In 2023 Thunder Bay has set aside $3.8 million for stormwater management so there is a budget that allows for the implementation of future developments but when factoring in many of the other costs within this area there may only be small amounts of funding to use on future developments (City of Thunder Bay, 2023). A major influence on the cost is typically tearing out old grey infrastructure and replacing it or just the installation of the system. One of the largest developments within the city is the Clayte Street West bio-retention system which cost the city $235 000 (TBnewswatch, 2022). This amount of money is significant for one project but when the cost is weighed against the potential damages that could be caused by flooding it can be justified. One factor that makes the investment into LIDs worth it is the little to no maintenance cost of the systems. Besides allocating small amounts of money for the maintenance of vegetation within some of the systems there is virtually no need for further maintenance. The lack of maintenance can justify the cost of these systems especially for smaller municipalities that might not have as significant of a budget. The cost of implementing low-impact developments could be prohibitive for some smaller towns or cities but for many larger cities the investment is worth the improvement as they not only improve stormwater management but also provide other ecological and social services for the residents.

With the impacts of climate change being felt around the world and in Thunder Bay making sure that the city is prepared is key. Low-impact developments can increase the cities resilience when faced with the extreme weather events and increased precipitation that is predicted in the future. Using systems such as bio-filtration can future proof the city against a changing climate with the ability to handle high flow rates. Porous pavement systems such as the Bare Point systems can increase the Thunder Bay's ability to deal with stormwater and runoff while still maintaining the functional infrastructure needed such as parking lots and roadways. Although many of the systems are installed on a relatively small scale when examining the entire city, they all contribute to the ability to manage stormwater in a new and sustainable manner. If a focus is made to install these systems wherever possible in new developments and even some old ones Thunder Bay will be much better suited to deal with the upcoming changes in the next 50-100 years.

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APPENDIX

Table 1. Green Infrastructure List as of the end of 2021 provided by the City of Thunder Bay.

002 WF-16 – Port Arthur Stadium Infiltration Trench

Location	48°25'27.8"N 89°14'22.1"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Discharge to stormwater collection system and ultimately to Lake Superior via overland ditches.
Outlet location	48°25'25.9"N 89°14'20.8"W Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	0.4 ha.
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29mm)
Design Storm	Local 90th percentile rainfall event (29mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Sub-surface infiltration trench within depressed parking lot island.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

003 NB-30 – West Arthur Community Center Infiltration Trench

Location	48°22'48.3"N 89°21'03.4"W
Watershed/Subwatershed	Lake Superior / Neebing River
Receiver of discharge	Discharge overland to adjacent fields with ultimate flow to the Neebing River.
Outlet location	48°22'47.8"N 89°21'03.5"W
Catchment Area	0.23 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Sub-surface depressed infiltration trench receiving overland runoff from adjacent parking lot

Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

006 NB-56 & NB-57 – Delaney Arena Infiltration Trench

Location	48°22'48.3"N 89°21'03.4"W
Watershed/Subwatershed	Lake Superior / Neebing River
Receiver of discharge	Discharge overland to adjacent fields with ultimate flow to the Neebing River.
Outlet location	48°23'07.2"N 89°15'52.1"W
Catchment Area	0.6 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	2- cell surface infiltration trench that collects runoff from parking lot and outlets to existing landscaped area.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

007 WF-59 – Bare Point Porous Pavement System

Location	48°28'31.4"N 89°09'07.7"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Discharge to adjacent Lake Superior.
Outlet location	48°23'07.2"N 89°15'52.1"W
Catchment Area	0.05 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Pilot project – porous asphalt designed to accept runoff from small portion of parking lot and upstream landscaped area

Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

008 WF-60 – Beverly Street Bioretention System

Location	48°25'18.7"N 89°14'20.3"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Discharge to existing stormwater collection system
Outlet location	48°25'18.0"N 89°14'19.7"W Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	0.2 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent street and discharges to existing stormwater collection system
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

009 NB-166 – Churchill Pool Infiltration Trench

Location	48°23'22.3"N 89°17'02.1"W
Watershed/Subwatershed	Lake Superior / Neebing River
Receiver of discharge	Discharge to existing overland drainage system and ultimately to the Neebing River
Outlet location	48°23'21.6"N 89°17'02.1"W
Catchment Area	0.14ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Sub-surface depressed infiltration trench receiving overland runoff from adjacent parking lot

Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

010 MV-20 – Madeline Street Bio-filtration System

Location	48°27'02.8"N 89°14'03.9"W
Watershed/Subwatershed	Lake Superior / McVicar Creek
Receiver of discharge	Discharge to existing stormwater collection system
Outlet location	48°27'03.4"N 89°14'03.7"W Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	0.13 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-filtration system with sub-drain that receives runoff from adjacent street and discharges to existing stormwater collection system
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

011 WF-58 – Memorial Avenue and Court Street Bio-filtration System

Location	48°25'19.0"N 89°14'14.4"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Discharge to existing stormwater collection system
Outlet location	48°25'18.0"N 89°14'14.6"W Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	0.5 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-filtration system with sub-drain that receives runoff from adjacent parking lot and discharges to existing stormwater collection system

Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

012 MV-1 – Clayte Street West Bio-retention System

Location	48°27'20.8"N 89°13'22.8"W
Watershed/Subwatershed	Lake Superior / McVicar Creek
Receiver of discharge	Discharge to adjacent McVicar creek
Outlet location	48°27'20.2"N 89°13'22.5"W
Catchment Area	4.9 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent streets and discharges directly to McVicar Creek
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

013 MV-25 – Clayte Street East Bio-retention System

Location	48°27'20.8"N 89°13'20.5"W
Watershed/Subwatershed	Lake Superior / McVicar Creek
Receiver of discharge	Discharge to adjacent McVicar creek
Outlet location	48°27'20.2"N 89°13'21.5"W
Catchment Area	0.6 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent streets and discharges directly to McVicar Creek
Receive Emergency Sanitary	No

Overflows	
Notes / Additional Information	

014 WF-61– Bare Point Bio-filtration System

Location	48°28'32.0"N 89°09'07.0"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Overflow to adjacent Lake Superior
Outlet location	48°28'32.0"N 89°09'05.6"W
Catchment Area	0.1 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-filtration system that receives runoff from adjacent roof area and discharges directly to Lake Superior
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

015 CR-68– Cuyler Street at Current Avenue Bio-retention System

Location	48°27'31.9"N 89°11'36.2"W
Watershed/Subwatershed	Lake Superior / Current River
Receiver of discharge	Discharge to adjacent Boulevard Lake (Current River)
Outlet location	48°27'29.1"N 89°11'35.9"W
Catchment Area	3.98 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	021 CR-65 – Birch Point Parking Lot Infiltration Trench
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent streets and discharge from upstream infiltration trench system (021 CR-65 – Birch Point Parking Lot Infiltration Trench) and discharges to Boulevard Lake.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

016 CR-69 & CR-70 – Cuyler Street at Dewe Avenue Bio-retention System

Location	48°27'31.7"N 89°11'25.7"W
Watershed/Subwatershed	Lake Superior / Current River
Receiver of discharge	Discharge to adjacent Boulevard Lake (Current River)
Outlet location	48°27'31.3"N 89°11'24.5"W
Catchment Area	1.55 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent streets and discharges to Boulevard Lake.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

017 MI-62 George Burke Parking Lot Bio-retention System

Location	48°25'56.1"N 89°15'18.7"W
Watershed/Subwatershed	Lake Superior / McIntyre River
Receiver of discharge	Discharge to existing stormwater collection system
Outlet location	48°25'56.0"N 89°15'29.8"W
Catchment Area	0.32 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent parking lot and discharges to stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

018 NB-116 – James Street at Parkway Drive Bio-retention System

Location	48°23'14.8"N 89°17'20.9"W
Watershed/Subwatershed	Lake Superior / Neebing River
Receiver of discharge	Discharge to existing stormwater collection system
Outlet location	48°23'13.4"N 89°17'19.8"W
Catchment Area	0.19 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent streets and discharges to stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

019 WF-62 – MacDougall Street and Algoma Street Bio-retention System

Location	48°27'11.3"N 89°11'59.5"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Discharge to adjacent overland collection and drainage system
Outlet location	48°27'09.6"N 89°11'57.6"W
Catchment Area	0.99 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system that receives runoff from adjacent streets and discharges overland back to street.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

020 WF-63 – MacDougall Street and Court Street Bio-retention System

Location	48°27'05.1"N 89°11'51.6"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Overflow discharge to adjacent existing stormwater collection system
Outlet location	48°27'04.4"N 89°11'51.7"W
Catchment Area	1.13 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system that receives runoff from adjacent streets and discharges to existing stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

021 CR-65 – Birch Point Parking Lot Infiltration Trench

Location	48°27'32.0"N 89°11'39.6"W
Watershed/Subwatershed	Lake Superior / Current River
Receiver of discharge	Discharge to adjacent LID Facility 015 CR-68
Outlet location	48°27'31.6"N 89°11'36.1"W
Catchment Area	0.48 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90^{th} percentile rainfall event (29 mm)
Design Storm	Local 90^{th} percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	015 CR-68– Cuyler Street at Current Avenue Bioretention System
Brief Description of each component of treatment train:	Sub-surface infiltration system with sub-drain that receives runoff from adjacent parking lot and discharges directly to downstream bio-retention system through stand-alone storm sewer system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

022 WF-41 – Waterfront Parking Lot Bio-retention System

Location	48°25'50.2"N 89°13'16.4"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Discharge to existing stormwater collection system.
Outlet location	48°25'51.6"N 89°13'14.4"W
	Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	0.82 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90^{th} percentile rainfall event (29 mm)
Design Storm	Local 90^{th} percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent streets and discharges to existing stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

023 WF-10 & WF-12 – Winnipeg Avenue Bio-filtration System

Location	48°25'24.2"N 89°14'26.5"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Discharge to existing stormwater collection system.
Outlet location	48°25'18.2"N 89°14'26.5"W Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	1.74 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Multi-cell bio-filtration system with sub-drain that receives runoff from adjacent streets and discharges to existing stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

024 NB-66 – Tarbutt Street Bio-retention Facility

Location	48°23'5.56"N 89°16'3.35"W
Watershed/Subwatershed	Lake Superior / Neebing River
Receiver of discharge	Discharge to existing stormwater collection system and

	overflows to adjacent infiltration trench (025 NB-167 – Tarbutt Street Infiltration System).
Outlet location	48°23'6.76"N 89°16'3.13"W
Catchment Area	0.39 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	025 NB-167 – Tarbutt Street Infiltration System
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent streets and discharges to existing stormwater collection system, with major event overflow to adjacent infiltration trench (025 NB-167 – Tarbutt Street Infiltration System).
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

025 NB-167 – Tarbutt Street Infiltration System

Location	48°23'7.21"N 89°16'3.18"W
Watershed/Subwatershed	Lake Superior / Neebing River
Receiver of discharge	Discharge to existing stormwater collection system.
Outlet location	48°23'9.48"N 89°16'2.98"W
Catchment Area	0.57 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	024 NB-66 – Tarbutt Street Bioretention Facility
Brief Description of each component of treatment train:	Surface infiltration trench that collects major storm overflow from upstream bio-retention facility (024 NB-66 – Tarbutt Street Bioretention Facility) and runoff from adjacent park land,and outlets to existing stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

026 NB-100 – Edward Street and Parkway Drive Bio-retention Facility

Location	48°23'16.6"N 89°16'41.7"W
Watershed/Subwatershed	Lake Superior / Neebing River
Receiver of discharge	Discharge to adjacent Neebing River.
Outlet location	48°23'16.0"N 89°16'41.4"WN
Catchment Area	0.46 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent streets and discharges to Neebing River.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

027 MV-24 – Hinton Avenue Bio-Filtration Facility

Location	48°27'20.8"N 89°14'12.0"W
Watershed/Subwatershed	Lake Superior / McVicar Creek
Receiver of discharge	Discharge to nearby McVicar Creek.
Outlet location	48°27'19.2"N 89°14'14.6"W
Catchment Area	2.58 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Quantity – 2-year event (lower basin) and 5-year event (upper basin), Quality – Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	999063 – Hinton Avenue Oil-Grit Separator
Brief Description of each component of treatment train:	Bio-filtration system with sub-drain that receives runoff from adjacent streets and parkland and discharges to McVicar Creek. Lower cell which receives runoff from street also receives pre-treatment through the oil-grit separator (999063 – Hinton Avenue Oil-Grit Separator). The facility also provides 616cu.m. of flood plain storage.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

028 MI-140 – Pioneer Ridge Parking Lot Bio-Retention Facility

Location	48°25'04.0"N 89°15'25.7"W
Watershed/Subwatershed	Lake Superior / McIntyre River

Receiver of discharge	Discharge to existing stormwater collection system
Outlet location	48°25'02.9"N 89°15'25.2"W Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	0.08 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Bio-retention system with sub-drain that receives runoff from adjacent parking lot and discharges to existing stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

031 WF-64 – Market Square Parking Lot Infiltration System

Location	48°26'00.1"N 89°13'02.4"W
Watershed/Subwatershed	Lake Superior / Waterfront
Receiver of discharge	Discharge to existing stormwater collection system.
Outlet location	48°25'58.9"N 89°13'03.0"W Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	0.29 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Sub-surface infiltration trench with sub-drain system under parking lot receiving drainage from parking lot area then discharging to existing stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

032 MV-28 – Madeline Street and Theresa Street Enhanced Swale System

Location	48°27'03.5"N 89°14'01.2"W

Watershed/Subwatershed	Lake Superior / McVicar Creek
Receiver of discharge	Surface discharge to McVicar Creek
Outlet location	48°27'03.8"N 89°14'00.5"W
Catchment Area	0.25 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	N/A
Brief Description of each component of treatment train:	Enhanced swale system that receives runoff from adjacent streets and provides 200cu.m. of flood plain storage (through cut-fill balance), before discharging to McVicar Creek.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	

033 NB-143 – James Street Playfield Bio-Filtration Facility

Location	48°23'46.5"N 89°17'25.1"W
Watershed/Subwatershed	Lake Superior / Neebing River
Receiver of discharge	Connection to existing stormwater collection system.
Outlet location	48°23'46.2"N 89°17'22.8"W Approximate location where system discharges to existing city stormwater collection system.
Catchment Area	3.92 ha
Level of Treatment for suspended solids	Enhanced treatment for TSS.
Treatment for other contaminants, as required	N/A
Level of Volume control	Local 90th percentile rainfall event (29 mm)
Design Storm	Local 90th percentile rainfall event (29 mm)
Reference ECA(s)	N/A
Reference Works as part of treatment train	999070 – James Street Playfield Oil-Grit Separator
Brief Description of each component of treatment train:	Bio-filtration system with sub-drain that receives runoff from adjacent parking lot and splash pad, but parking lot runoff receives pre-treatment through an oil-grit separator (999070 – James Street Playfield Oil-Grit Separator) and discharges to existing stormwater collection system.
Receive Emergency Sanitary Overflows	No
Notes / Additional Information	