CITY OF SASKATOON

NATURAL CAPITAL ASSET VALUATION

PILOT PROJECT

City of Saskatoon

May 2020

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Meghan Mickelson

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INTRODUCTION

Natural Capital refers to the stocks of water, soil, animals, plants or ecosystems that contribute to the provision of one or more services required for the health, well-being, and long-term sustainability of a community and its residents[1]. These are commonly referred to as natural assets.

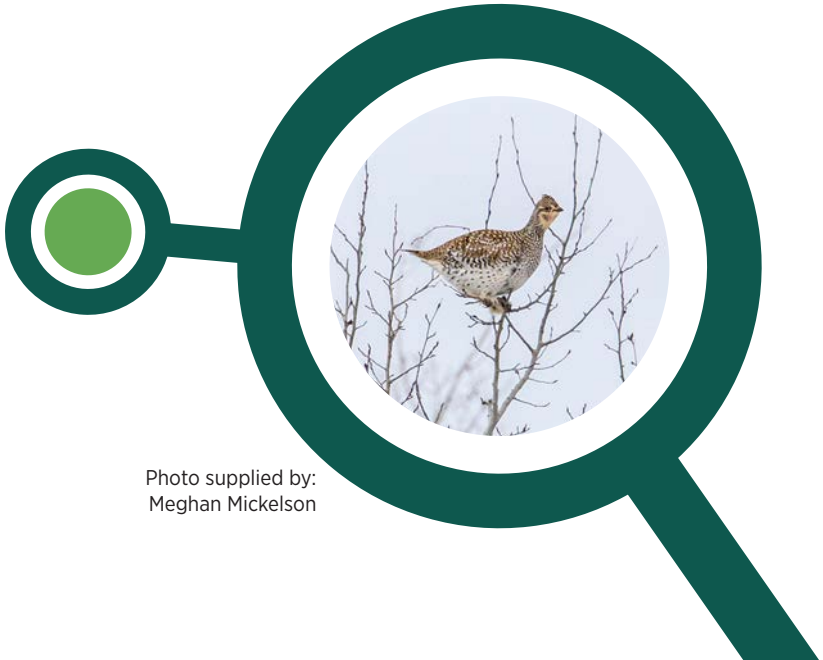
The City of Saskatoon (the City) includes a significant number of natural assets within city limits: more than 1,400 wetlands (1,207 ha), a portion of the South Saskatchewan River (388 ha), grasslands (1,285 ha), and forest/shrublands (577 ha)[2]. These natural assets offer a wide range of benefits to the community in the form of supporting, regulating, cultural, and provisioning ecosystem services. However, these benefits have not been explicitly recognized or managed and valued to ensure these services are available in the future.

Canadian municipalities are increasingly recognizing the services provided by natural assets and are including them in asset management strategies. Emerging evidence shows that identifying, valuing, and managing natural assets as part of an overall asset management strategy can save capital and operating costs and reduce risks caused by climate change, such as mitigating disruptive climate impact through leveraging regulating services provided by ecosystems.

The City implemented the Natural Capital Asset Valuation (NCAV) Pilot Project as an initial step toward evaluating the ecosystem services of Saskatoon's natural assets. The objectives of this project are to:

- Develop a proposed framework for valuation of natural assets;
- Create an inventory of municipal natural assets for Saskatoon;
- Conduct a basic vulnerability assessment for natural assets within city limits; and
- Complete a pilot valuation for these natural assets.

This report presents the proposed framework for valuation of natural assets, the results of the inventory of natural assets, vulnerability assessment results, and the results of the pilot valuation.



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1 Municipal Natural Asset Initiative, 2017. Defining and Scoping Municipal Natural Assets.
2 Meewasin, 2019. Natural Areas Inventory for the City of Saskatoon.

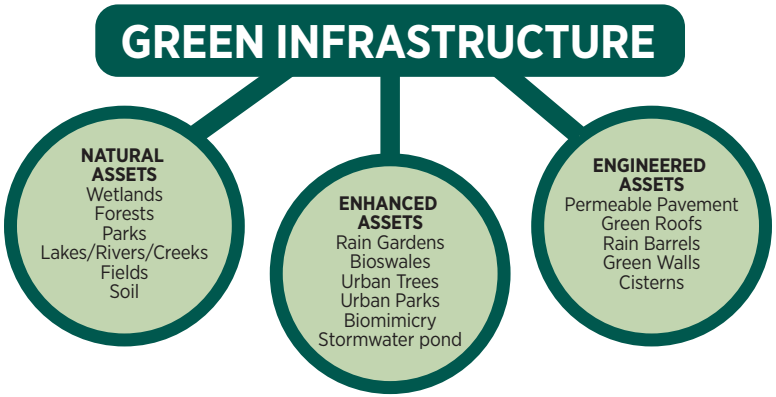
Photo supplied by: Julia Adamson

BACKGROUND

Green Infrastructure and Natural Assets

Green infrastructure is a system of natural, enhanced, and engineered assets that provide municipal and ecosystem services by protecting, restoring, or emulating nature. Three main asset types are identified below.

Figure 1: *Green Infrastructure Asset Types as categorized by the Municipal Natural Assets Initiative.*



Engineered assets incorporate nature-inspired design into the built environment to support ecosystem function or greater connectivity to natural and enhanced assets. The value of these types of assets are typically well established, as they are designed and built for a specific function in a way that the current system of accounting can easily track.

Enhanced assets are designed places and features that modify natural assets for improved human use in an urban context. Municipalities actively manage enhanced assets like parks and the urban forest, so there is some understanding of the value of the designed and built portion of these assets.

Natural assets are ecological resources such as land, air, water, flora and fauna, typical to the Canadian prairie and Saskatoon region. Natural assets may occur within a natural area, or may occur individually in other types of areas. In the Saskatoon area, natural assets include the South Saskatchewan River, swales, wetlands, grasslands, and forest/shrubland. Many municipalities do not actively manage natural assets to the same extent as other assets. The value of these assets is often poorly understood in financial terms, and is not easily tracked by current accounting systems.

Managing Municipal Natural Assets

Many municipalities are turning to asset management principles to improve overall management of critical assets. This typically involves creating an inventory of existing assets, determining their current state, and preparing a plan to maintain or replace the assets. This process improves the ability of municipalities to make informed decisions about asset management and finances.

Healthy natural assets, when used effectively and/or further enhanced, have the potential to provide services similar to engineered assets. However, most local governments do not apply financial asset management to this class of assets. There is a lack of widespread understanding of the services provided by the natural assets that are (or could be) used by municipalities, as well as a lack of knowledge about how to value these services and track them in a way that is compatible with engineered assets. Further, the City does not currently include natural assets in the annual financial statements as they are not a reporting requirement under the Public Sector Accounting Board (PSAB) standards.

Natural Asset Management in Saskatoon

The City has recently developed several important plans that point to the need for better understanding of our natural assets. In 2019, the *Low Emissions Community Plan* and the *Corporate Climate Adaptation Plan* were produced; each one acknowledging the role that natural assets can play in carbon sequestration and resiliency linked to climate change.

Saskatoon's Green Infrastructure Strategy was presented to Council in February 2020. This strategy introduced the concept of a planned Green Network for the City that would help to address pressure from urban growth as well as climate-related impacts such as invasive pests, flooding, heat, and drought. This pilot project is a first step towards addressing Initiative 4.5 of the Strategy, to "*evaluate the ecosystem services of the Green Network through the Natural Capital Valuation process*."

Photo supplied by: Meghan Mickelson

Natural Capital Asset Valuation Pilot Project

The valuation of Natural Capital Assets is a new field to analyze the value of natural assets so they can be accounted for in ways that are comparable to engineered and enhanced assets.

In Canada, the Natural Capital Lab (Lab) was formed in 2014 as a partnership between the Chartered Professional Accountants of Canada (CPA), TD Canada Trust, and the Cooperators. The purpose of the Lab was to innovate and experiment with new approaches to valuing Canada's natural capital. The Lab partnered with the Municipal Natural Assets Initiative (MNAI) to develop case studies of natural capital strategies in Canadian municipalities, including the City of Saskatoon.

In April 2018, the City received a grant from the Federation of Canadian Municipalities (FCM) for the Natural Capital Asset Valuation project.

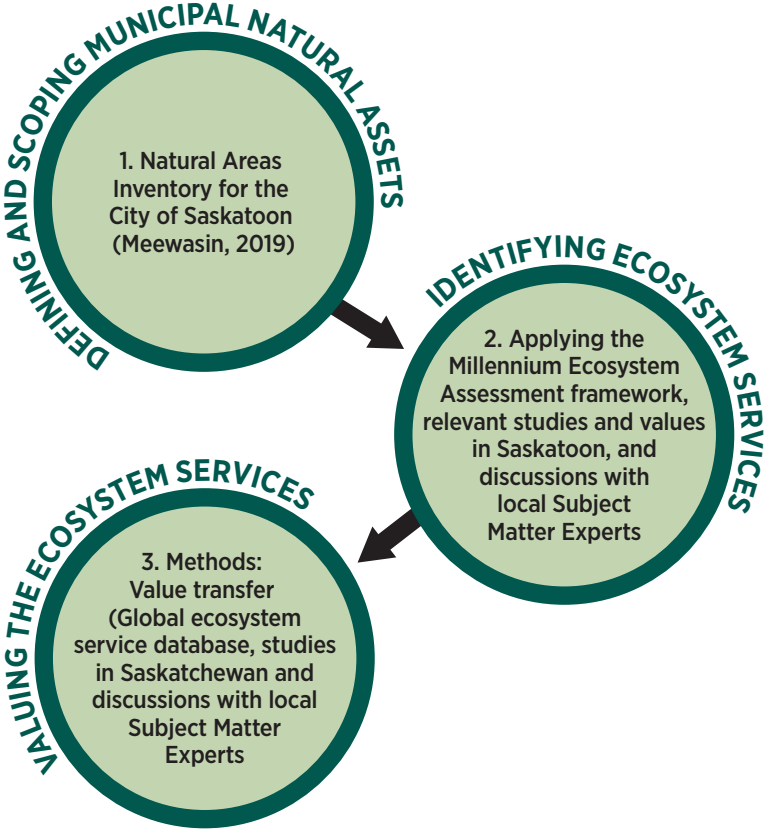
Did you know?

The Municipal Natural Assets Initiative (MNAI) was launched in 2015 to support and guide local governments across Canada in identifying, valuing, and accounting for natural assets in their financial planning and asset management programs, and in developing leading-edge, sustainable and climate resilient infrastructure.

VALUATION FRAMEWORK

Development of the proposed framework for the valuation was carried out in three stages as illustrated in the figure below.

Figure 2: *Overview of Development Stages for the Valuation Framework*



Defining and Scoping Municipal Natural Assets

Identification/inventory is one of the first steps toward effective management of municipal natural assets. A *Natural Areas Inventory* was completed in partnership with the Meewasin Valley Authority[3] and is used as the basis of the valuation pilot project.

Figure 3 illustrates the location of Saskatoon's major natural assets, which includes aquatic, grassland, and forest and shrubland assets, but does not represent all the urban forest and grassed areas (like parks). Altogether, these systems occupy a total area of 3,461 ha, or 14% of the total City area.

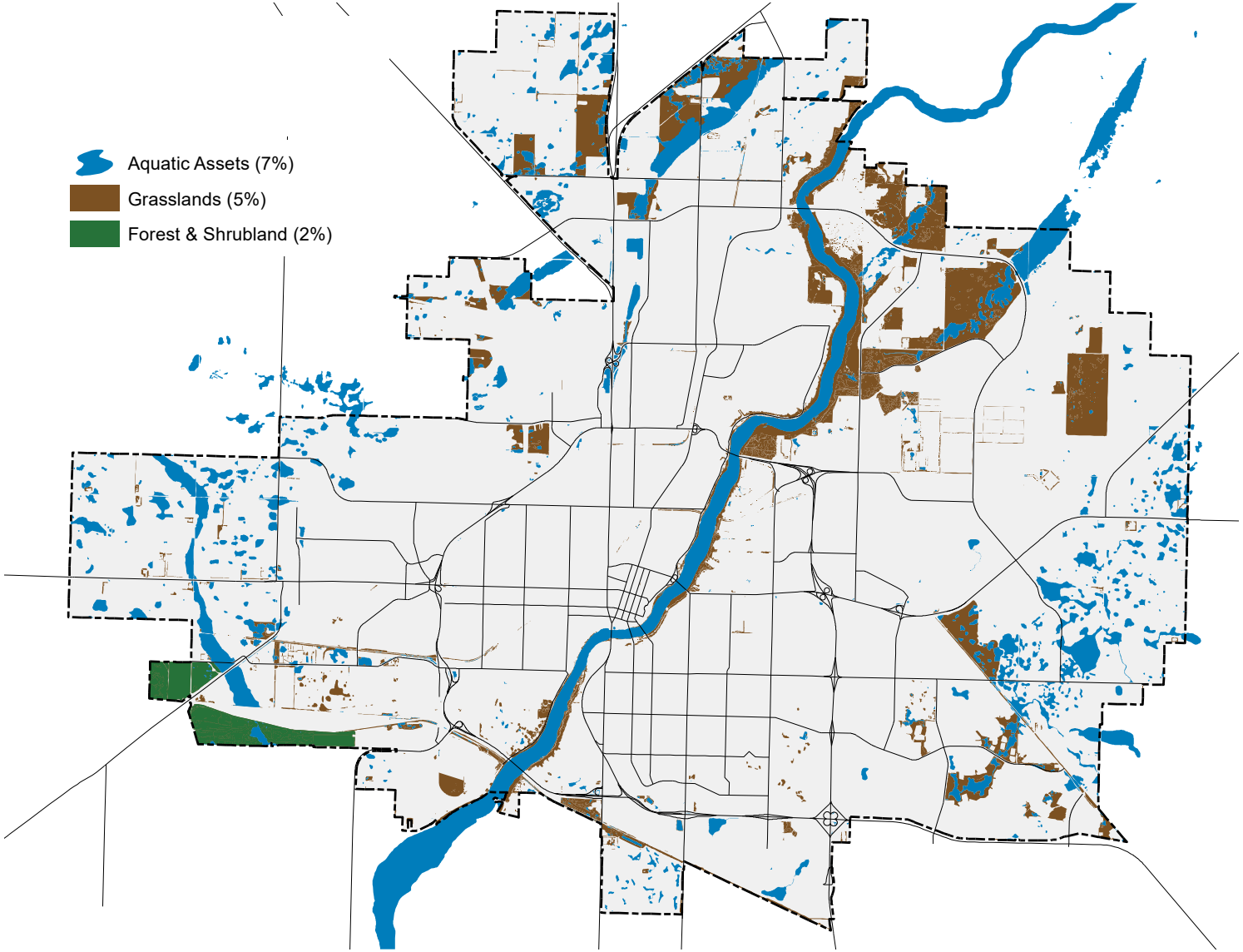
Natural assets defined in the *Natural Area Inventory* were considered eligible for valuation. Assets with a mix of aquatic, grassland, and forest/shrubland were given priority for the pilot. Information about the individual natural assets was compiled to determine how much information would be available for valuation purposes. Ultimately, two natural assets were chosen for the valuation pilot:

- Area 1: the Small Swale
- Area 2: Richard St. Barbe Baker Afforestation area, including the Northwest Section of Chappell Marsh

These assets will be described in more detail in later sections of this report.

3 Meewasin, 2019. Natural Areas Inventory for the City of Saskatoon.

Figure 3: *Major Natural Assets within the City of Saskatoon*



Identifying Ecosystem Services

Ecosystem services are the benefits provided to people by green infrastructure. For example, the South Saskatchewan River provides drinking water and electricity for urban residents and businesses. Wetlands incorporated into the storm water network help purify the community's water and store carbon. Grassland vegetative communities provide benefits that link directly to human food systems including soil stabilization, carbon sequestration, livestock nutrition, and habitat for pollinating insects. Trees purify the air and sequester carbon as they grow. Natural areas can provide space for both relaxation and recreation.

The *Millennium Ecosystem Assessment* [4] is a United Nations framework that categorizes ecosystem services into four broad areas: Provisioning, Regulating, Cultural, and Supporting Services. Understanding these services is essential to improving our ability to manage natural assets.

4 Alcamo, J., 2003. Ecosystems and human well-being: a framework for assessment. Island Press.

Photo supplied by: City of Saskatoon

Figure 4: *Ecosystem Services as Categorized by the Millennium Ecosystem Assessment[5].*

Supporting services are necessary for the production of all other ecosystems, such as habitat for fauna and flora, maintenance of genetic diversity, and soil formation.

Regulating services are obtained from regulation of ecosystem processes. Examples include climate regulation (including carbon sequestration), flood control, water purification, pollination, and biological control (pest and disease control).

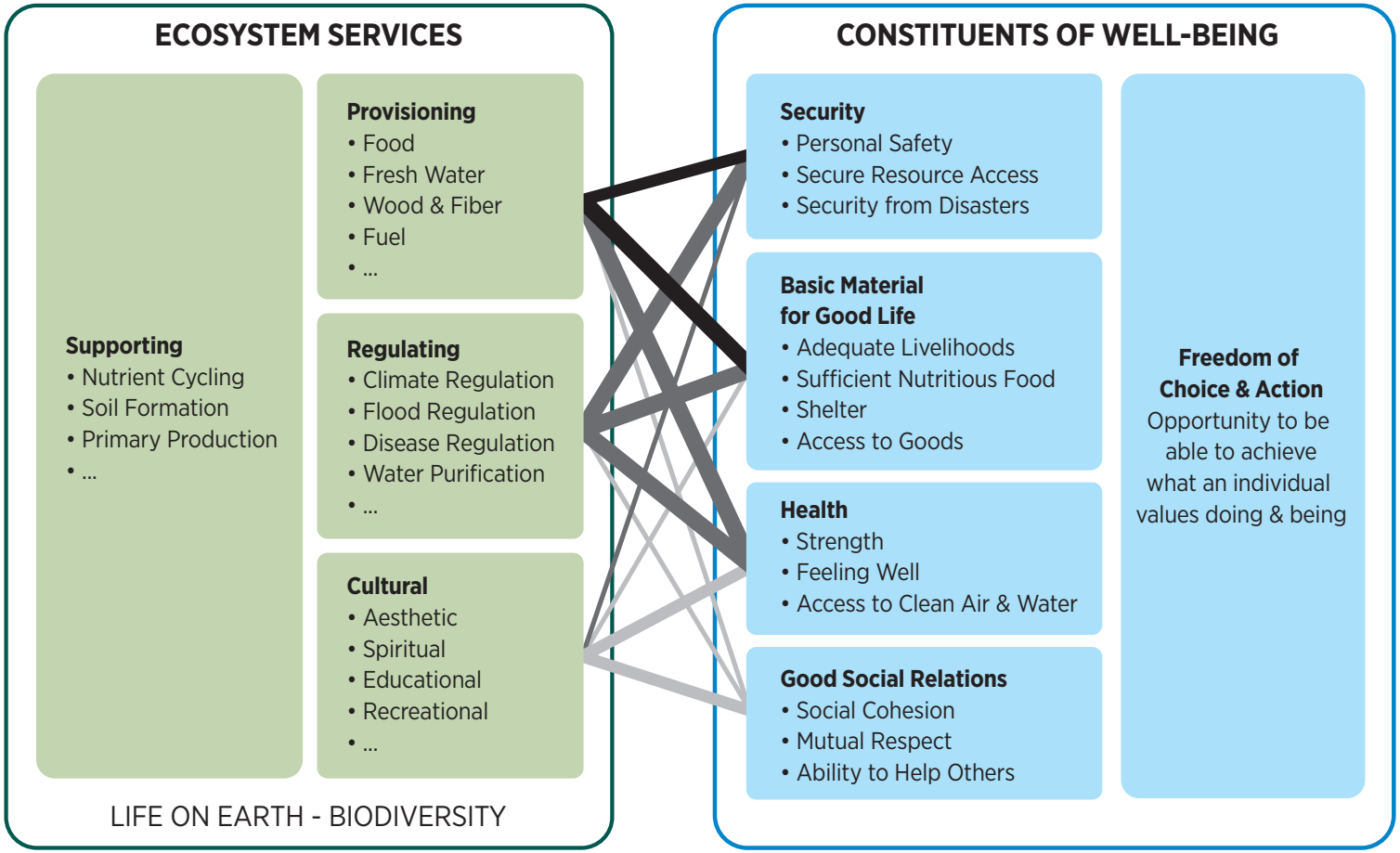
Cultural services include recreational, spiritual, educational, and cultural heritage.

Provisioning services refer to products obtained directly from the ecosystems, such as food, forage, wood, and water.

Natural assets provide services that are the foundation for human well-being, including water security, food, health, disease regulation, and economic development opportunities. The following figure illustrates how these ecosystem services are closely linked to human well-being.

5 City of Saskatoon, 2020. Saskatoon's Green Infrastructure Strategy: Towards an Interconnected Green Network.

Figure 5: *Linkages Between Ecosystem Services and the Constituents of Well-Being*



Source: Millennium Ecosystem Assessment

The Economics of Ecosystems and Biodiversity organization (TEEB) is a global initiative with the objective of incorporating the value of biodiversity and ecosystem services into decision-making. The organization provides guidance for a structured approach to valuation, which was used to identify the specific suite of ecosystem services that were utilized in this pilot valuation.

Table 13 in Appedix 1 summarizes the ecosystem services that were chosen for the pilot valuation framework. There are a multitude of services that natural assets can provide; the listed services were chosen and priortized based on the typology and definitions from TEEB[6], the availability of local studies and information on the services, and discussions with subject matter experts within the City and from other organizations.

Photo supplied by: Meghan Mickelson

Valuing Ecosystem Services

The **value (benefit) transfer method** was used to assign values to ecosystem services for the pilot. This method involves transferring an existing value estimated for a similar ecosystem. For this pilot, values were transferred from other studies that have been completed in Saskatchewan, or from the global ecosystem service value database maintained by TEEB.

The value transfer method was selected for this pilot study given the amount of information available about Saskatoon's natural assets and the organization's relative inexperience with managing these assets. Value transfer works well when the existing values' site is similar to the study site. However, this method has limitations if there is no suitable study that has already been completed elsewhere, or if there is general lack of information/ understanding about how to describe a particular service in financial terms. It should also be noted that the transfer method does not capture the full value of services where several factors might influence the value.

The library of original values used for the transfer method in the pilot study can be found in Appendix 3 of this report. All values presented in this study have been converted to 2020 Canadian dollars.

6 TEEB – The Economics of Ecosystems and Biodiversity (2011). TEEB Manual for Cities: Ecosystem Services in Urban Management. www.teebweb.org

Other methods that were considered for the valuation were:

- **Willingness to pay:** refers to the price the consumer is willing to pay for the service. This method is typically used for estimating services such as biodiversity protection and recreational services. For example, the price that a community is willing to pay to protect a habitat or threatened/endangered species can be used to value the habitat service. There was very little information available about willingness to pay for ecosystem services in the Saskatoon area; the only information available consisted of preliminary findings from a study done by a University of Saskatchewan graduate student on the Northeast Swale in Saskatoon[7]. Since the research results have not been peer reviewed and published yet, they were not used for this valuation pilot.

- **Replacement cost:** estimates the value of replacing one or more ecosystem services with engineered or enhanced assets. For example, biological control services provided by birds can be valued as the cost of pesticide or other engineered controls since they can help reduce insect pest populations. This method can also be used to estimate the cost of replacing the carbon sequestration value of a natural asset by planting trees. The retention of flood water by a wetland could be valued as the cost of constructing flood control and/or water quality improvement measures to provide the same level of service. The replacement cost method was not used for valuing storm water services in this pilot because the storm water management functions and capacity of the wetlands are not understood well enough.

- **Hedonic price analysis:** identifies the factors that influence the price of an item. For example, a study in Calgary[8] found that the value of property adjacent to a wetland was increased by about $5,136 (1.3% of house value) in McKenzie Towne and $4,309 (1.1% of house value) in Copperfield. Similar studies[9] have found that proximity to streams has a greater influence on price than proximity to lakes. A recent study[10] undertaken by a graduate student at the University of Saskatchewan included a hedonic regression of the housing market surrounding the Northeast Swale. However, the regression analysis indicated that there were no statistically significant impacts of proximity to the Northeast Swale on nearby housing prices. Subsequently, there was no comparable hedonic price value to apply for the Pilot.

Photo supplied by: Meghan Mickelson

7 Nijhum, F.Q., Westbrook, C.J., Belcher, K., Noble, B.F., 2020. Evaluation of alternative future scenarios of Saskatoon's Northeast Swale to develop ecosystem services based SEA framework (PowerPoint Presentation).
8 Raudsepp-Hearne, C., Claesson, G. and Kerr, G., 2011. Ecosystem Services Approach Pilot on Wetlands. Government of Alberta, Canada.
9 Mahan, B.L., Polasky, S. and Adams, R.M., 2000. Valuing urban wetlands: a property price approach. Land economics, pp.100-113.
10 Read, S.L., 2019. Natural Capital Asset Valuation of the Meewasin Northeast Swale for the Preservation of Saskatoon's Natural Resources. Master thesis. University of Saskatchewan. 124 pages.

Photo supplied by: Julia Adamson

VULNERABILITY ASSESSMENT

Identifying vulnerabilities is an important step in natural asset planning and management[11]. Collaborative risk analysis workshops were held in February and May 2019 with staff from across the corporation.

Risk identification focused on service areas that the City is currently responsible for. Assessment of the risks then connected impacts on civic operations with the severity and likelihood of consequence, considering climate change expectations for Canada and Saskatoon over the next 25 years. The following figure outlines details for the four-point Overall Risk Level (ORL) scale[12] that was used for the assessment.

Photo supplied by: Meghan Mickelson

Figure 6: *Overall Risk Level Scale*

HIGH	**Consequences**: Major to Catastrophic – Service area functionality would get worse and/or become unmanageable. Significant ($$$$) and/or substantial ($$$$$) staff and cost interventions would be required for correction. **Likelihood:** Likely to Almost Certain - Event could occur about once or multiple times per year.
MEDIUM	**Consequences**: Minor to Major – Service area functionality could stay the same or could become worse. Slight ($$) to significant ($$$$) staff and cost interventions would be required for correction. **Likelihood:** Possible to almost certain – Event could occur once every 10 years and/or could occur multiple times per year.
LOW	**Consequences**: Minor to Moderate – Service area functionality could stay the same or become slightly worse. Slight ($$) to some ($$$) staff and cost interventions would be required for correction. **Likelihood:** Unlikely to Likely – Event could occur once in the next 10 to 25 years and/or about once per year.
VERY LOW	**Consequences**: Insignificant to Moderate – Service area functionality will stay the same or become slightly worse. Little ($) to some ($$$) staff and cost interventions would be required for correction. **Likelihood:** Rare to Unlikely – Event only occurs in exceptional circumstances within the next 25 years and/or could occur once in the next 10 to 25 years.

11 MNAI, 2018. Primer on Natural Asset Management for FCM's 2018 Sustainability Communities Conference. https://mnai.ca/media/2018/01/FCMPrimer_Jan1_2018.pdf

12 The risk analysis does not consider "perfect storm scenarios" or "risk velocity". Perfect storm scenarios are those where a number of events considered 'rare' and having 'catastrophic' consequences occur together. Risk velocity adds a third dimension to traditional approaches and tracks "the speed at which exposure can impact an organization". Siew Quan, N.G. and Chiang, A. (2017). Risk management at the speed of business.

A summary of the risks specific to natural assets can be found in the appendices of this report. The resulting vulnerability implications for Saskatoon's natural and enhanced assets are summarized below:

The majority of high and medium risks are driven by the expectation of warmer overall temperatures and more frequent extreme heat and rainfall events for the Saskatoon region. It should be noted that all risk estimates for identified climate impacts would likely increase over time if actions to address conditions were delayed or avoided. In addition, climate change and biodiversity loss can compound to create a higher threat level than either risk alone.

Table 1: *Climate Change Vulnerability Assessment for Major Natural Assets*

Natural Asset	Service	Hazards	Risk
Aquatic (Wetlands)	Habitat	Heat stress, increasingly frequent freeze-thaw cycles	High
	Storm water management	Severe heavy precipitation events	High
	Recreation	Higher demand because of longer warm season	Medium
Grassland	Habitat	Heat stress, increasingly frequent freeze-thaw cycles	High
	Habitat	Uncontrolled wildfire	Low
	Habitat	Larger and more diverse pest populations	Medium
	Recreation	Higher demand because of longer warm season	Medium
	Forage Production	Reduced soil health	Low
Forest & Shrub-land	Habitat	Heat stress, increasingly frequent freeze-thaw cycles	High
	Habitat	Uncontrolled wildfire	Low
	Recreation	Higher demand because of longer warm season	Medium

PILOT VALUATION RESULTS

Two natural assets, both located within City limits, were chosen for the valuation pilot:

AREA 1: the Small Swale

This asset is a glacial channel scar that connects to the South Saskatchewan River and includes native grassland as well as a wetland complex. The figure below shows the location of Area 1 in the northeast quadrant of the City.

Figure 7: *Location of Area 1*

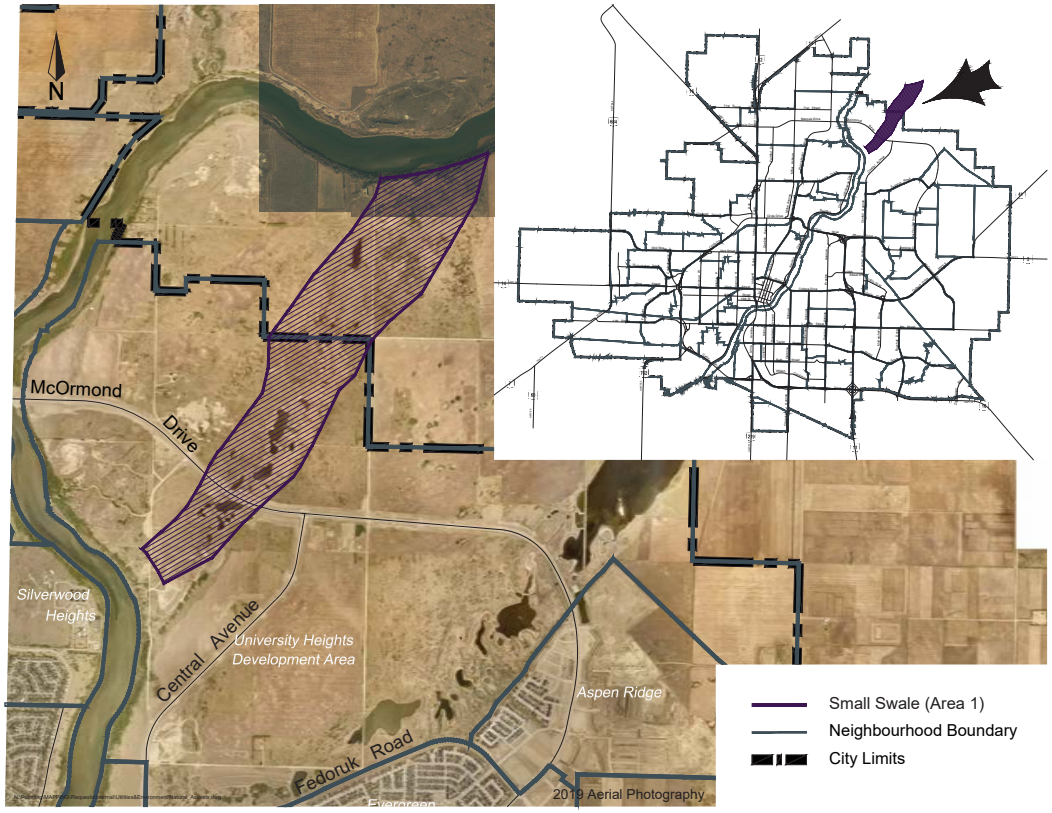


Table 2: *Land Cover Types with in Area 1*[13]

Land Cover	Area (ha)	%
Wetland	18	11
Grassland	144	89
Forest/Shrubland	0	0
Total	162	100

13 Stantec, 2013. North Central/North East Natural Area Screening Study

AREA 2:
the Richard St. Barbe Baker Afforestation Area, including the Northwest Section of Chappell Marsh

This asset is located in the southwest quadrant of the City and consists of wetlands, native grasslands, and forest/shrubland. The figure below shows the location of the asset.

Figure 8: *Location of Area 2*

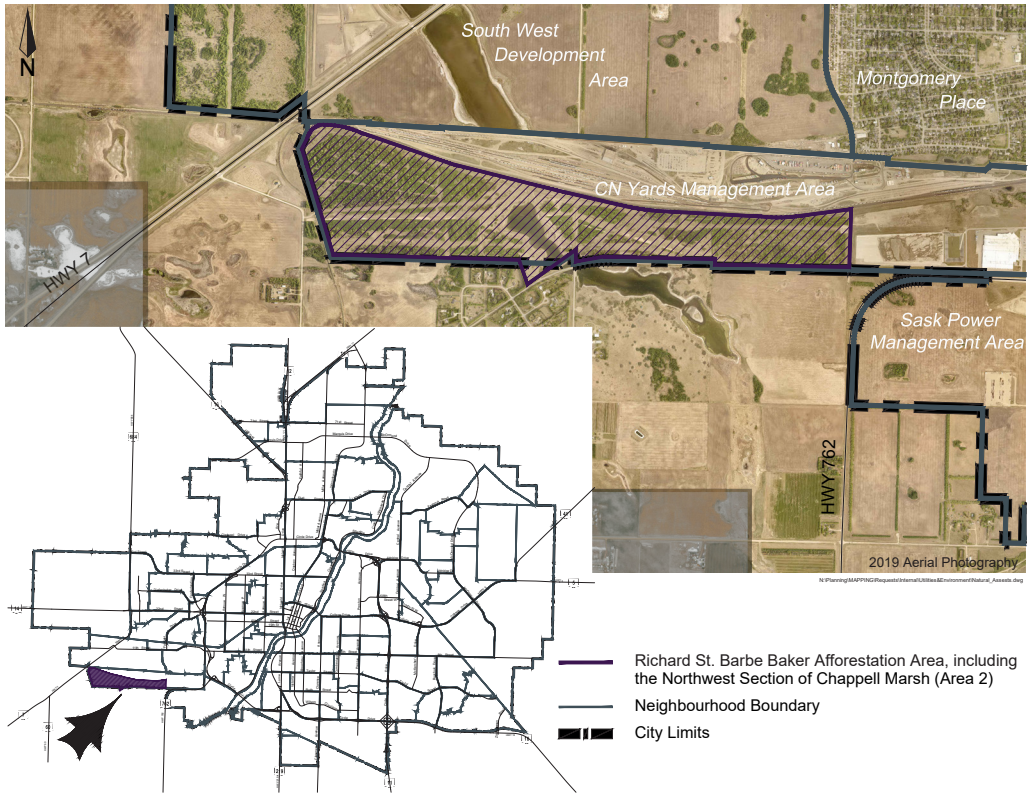


Table 3: *Land Cover Types within Area 2.*[14]

Land Cover	Area (ha)	%
Wetland	7	5
Grassland	67	51
Forest/Shrubland	58	44
Total	132	100

14 The land covers and their extent were defined based on the land cover map of the Canopy Assessment for Saskatoon 2018.

Supporting Services

Habitat: Provides everything that an individual plant or animal needs to survive.

Areas 1 and 2 both provide habitat for a variety of important plant and animal species, summarized in the following table. Most of these, with exception of the Ruddy Duck and the mammals, are species at risk.

Photo supplied by: Meghan Mickelson

Table 4: *Flora and fauna observed* [15, 16, 17, 18, 19, 20]

	Area 1	Area 2
Plants	Western Red Lily	Yellow Lady's slipper
	Marsh Felwort	
Birds	Sharp-tailed Grouse (lek/ breeding ground observed)	Horned Grebe
	Rusty Blackbird	Rusty Blackbird
	Short-billed Dowitcher	Red-necked Phalarope
	Peregrine Falcon	Harris's Sparrow
	Osprey	Bank Swallow
	Barn Swallow	Barn Swallow
	Turkey Vulture	Ruddy Duck
	Yellow Rail	Bobolink
	Common Nighthawk	
	Short-eared Owl	
Amphibians	Northern leopard frog	Barred tiger salamander
Mammals	White-tailed deer	Muskrat
	Badger burrow	
	Coyote	
	Squirrel	

15 Stantec, 2013. The North Central/North East Natural Area Screening Study, City of Saskatoon
16 Grillz, R, (2020, February 18) "FW: Updated Species list – Small Swale" (email)
17 Adamson, J (2020, March 26) " NCAV Comments" (email)
18 (2020, January 24) "Saskatoon –Small Swale" retrieved from https://ebird.org/hotspot/L4664203
19 Adamson, J (2020, January 15) "Chappell Marsh Conservation Area. A compilation report submitted by on behalf of the Friends of the Saskatoon Afforestation Areas Inc" (email)
20 Golder Associates (2012). The City of Saskatoon West and South West Sector Natural Area Screening Study

Table 5: *Supporting Services Valuation for Areas 1 and 2*

SUPPORTING SERVICES			
Land cover	**Area (ha)**	**Value ($ /ha /year)**	**Value ($ /year)**
Area 1			
Wetlands	18	29,394	529,100
Grasslands	144	5	700
Forest/Shrubland	0	0	0
Total			**$529,800**
Area 2			
Wetlands	7	29,394	205,800
Grasslands	67	5	300
Forest/Shrubland	58	0	0
Total			**$206,100**

Valuation Gaps:

1. Area 2 contains forest/shrubland, however no suitable study could be found in a similar enough area to apply the value transfer method. This means that the table above presents only a conservative estimate of the total value of supporting services in this area.

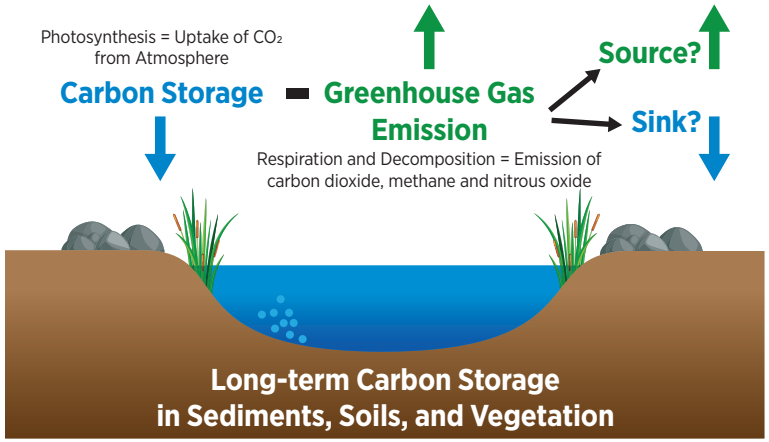
Regulating Services

Carbon Sequestration and Storage: Ecosystems regulate the global climate by storing and sequestering greenhouse gases

Saskatoon's *Low Emissions Community Plan* highlights the role of green infrastructure in capturing and storing carbon, including wetlands, grasslands and urban forests[21]. It is important to determine the amount of carbon sequestered by these ecosystems in the City as part of the overarching plan to reduce greenhouse gas emissions.

Wetlands are huge carbon sinks; they lock a vast amount of carbon into the soil which prevents it from being released into the atmosphere and contributing to global warming and subsequently climate change[22]. While wetlands only occupy 3% of the total global area, they store 30% of the total soil carbon in the world[23].

Figure 9: *Wetland carbon sequestration*



21 City of Saskatoon, 2019. The Low Emissions Community Plan. 120 pages. https://www.saskatoon.ca/sites/default/files/documents/low_emissions_report-aug8_web.pdf
22 https://boreal.ducks.ca/estimating-carbon-sequestration-wetlands/
23 USGCRP, 2018: Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 878 pp., https://doi.org/10.7930/SOCCR2.2018.

Prairie grasslands are also a large carbon storage reservoir. Through soil carbon sequestration, carbon dioxide is transferred into the grassland soil and stored as carbon in roots and soil organic matter. At a global scale, grasslands store 34% of the global terrestrial stock of carbon ecosystems, second to forests (39%)[24]. In Saskatchewan, it was estimated that the total area of forage land in the province sequesters 44,560,033 tonnes of CO_2e[25]. The values of carbon sequestration of wetlands and grasslands used in the valuation are defined by a study on the history of soil organic carbon in the St. Denis National Wildlife Area, which has comparable conditions to the Areas 1 and 2[26].

Forests and shrublands, unlike wetlands and grasslands, store carbon mostly in the form of continuously growing tree biomass. The values of carbon sequestration by forests/shrublands used in the valuation are defined by a study assessing carbon storage and sequestration by Canada's urban forests using high resolution earth observation data. The wetlands and grasslands in Area 1 are estimated to store about 82,904 tonnes CO_2e in their soil, and the wetlands, grasslands, and forest/shrubland in Area 2 are estimated to store about 54,081 tonnes CO_2e in their soil and biomass.

Moderation of extreme events: Extreme weather events or natural hazards include floods, storms, tsunamis, avalanches and landslides. Ecosystems and living organisms create buffers against natural disasters, thereby preventing possible damage. This study focused specifically on the buffer that Area 1 and 2 provides in storm water management.

Wetlands are like a big natural sponge - they help to control flooding by regulating the flow of water by providing surface water storage during spring snowmelt and periods of high rainfall[27]. This water infiltrates into surrounding soils and can recharge ground water resources. Both Area 1 and 2 have the capacity to provide storm water management services.

Grasslands can help manage storm water runoff and mitigate flooding by storing water on their surface and underground[28]. One study showed that soil water infiltration was reduced by 51-57% due to the conversion of grasslands to croplands and grazing land[29].

24 Ranchers Stewardship Alliance Inc. 2013 What Are Native Prairie Grasslands Worth?
25 Saskatchewan Forage Council, 2010. The Value of Saskatchewan's Forage Industry A Multi-Level Analysis.
26 Bedard-Haughn, A., Jongbloed, F., Akkerman, J., Uijl, A., De Jong, E., Yates, T. and Pennock, D., 2006. The effects of erosional and management history on soil organic carbon stores in ephemeral wetlands of hummocky agricultural landscapes. Geoderma, 135, pp.296-306.
27 Pattison-Williams, J.K., Pomeroy, J.W., Badiou, P. and Gabor, S., 2018. Wetlands, flood control and ecosystem services in the Smith Creek Drainage Basin: A case study in Saskatchewan, Canada. Ecological economics, 147, pp.36-47
28 http://multisar.ca/the-value-of-native-prairie/
29 Sirimarco, X., Barral, M.P., Villarino, S.H. and Laterra, P., 2018. Water regulation by grasslands: a global meta-analysis. Ecohydrology, 11(4), p.e1934.

Photo supplied by: Meghan Mickelson

Waste Water treatment: Ecosystems such as wetlands filter both human and animal waste and act as a natural buffer to the surrounding environment. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced

Wetlands are considered the kidneys of the earth – provided there is healthy riparian vegetation, they have the ability to reduce nutrient loading and eutrophication in adjacent water bodies by storing and accumulating the nutrients into sediment layers and plant biomass. Several studies confirmed that wetlands can reduce nitrogen and phosphorus loading in the water flowing through them with the average rate of 58-67%[30]. Prairie wetlands can play a critical role in mitigating non-point source pollution; urban wetlands in particular can treat dusts and pollutants such as heavy metals from storm water runoff[31].

Nutrient removal of wetlands are done through a combination of physical, chemical and biological processes. The physical process involves settling particles (sedimentation), releasing a gas into the atmosphere (volatilization), and diffusing into another liquid or solid (absorption). Chemical processes include transformations by microbes of nutrient forms and chemical precipitation, in which a solid compound is formed out of a liquid through a chemical reaction. The main biological processes are uptake of nutrients (or assimilation) by plants, algae, and bacteria[32].

Photo supplied by: Meghan Mickelson

Forests and grasslands with strong root systems can also act as biological filters to keep water clean[33]. Recently, instead of investing $8 billion to construct a new water filtration plant, New York City paid $1.8 billion to private landowners to apply sustainable farming practices and protect 80,000 acres of watersheds sourcing their drinking water[34]. With well vegetated fields and riparian areas within the watersheds to uptake nutrients and decrease phosphate and sediment runoff, the water supply was protected for the long term and the City did not have to build the new treatment plant or save $300 million in annual operating cost.

30 J. Fisher, M. C. Acreman. Wetland nutrient removal: a review of the evidence. Hydrology and Earth System Sciences Discussions, European Geosciences Union, 2004, 8 (4), pp.673-685.
31 Zhang, Z., Cui, B. and Fan, X., 2012. Removal mechanisms of heavy metal pollution from urban runoff in wetlands. Frontiers of Earth Science, 6(4), pp.433-444.
32 http://www.wetlands-initiative.org/nutrient-removal
33 https://www.wri.org/blog/2017/03/3-surprising-ways-water-depends-healthy-forests
34 Lerner, S. and Poole, W., 1999. The economic benefits of parks and open space: How land conservation helps communities grow smart and protect the bottom line. San Francisco: The Trust for Public Land.

Pollination: Insects and wind pollinate plants and trees which is essential for the development of fruits, vegetables, and seeds. Animal pollination is a service mainly provided by insects but also birds and bats.

Pollination is one of the key regulating ecosystem services. More than three quarters of the leading types of global food crops rely on animal pollination for ensuring crop quality and yield[35]. Globally, pollination services provided by insect pollinators had an estimated value of $203 billion in 2005[36]. In Canada, the value of honey bees for crop pollination alone is estimated at over $2 billion annually[37].

Grasslands are valuable in providing important habitats for insects that pollinate agricultural crops, such as canola and flax, in the region. In the absence of animal pollinators, canola crop yields can be 40 to 90% less than yields with pollinators[38]. One study has indicated that increasing natural lands adjacent to crops by 4% would increase crop profits by 37% and decrease 20% of used cultivation land[39]. Therefore, it is vital to preserve natural assets within and adjacent to agro-ecosystems.

There were no valuation studies found on pollination services provided by wetlands or forest/shrubland.

Biological Control: Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, frogs and fungi all act as natural controls.

Wetlands, grasslands and forests provide habitat for predators that control agricultural pests. Examples of predators in Area 1 and Area 2 that provide biological control services are presented in the table below.

Table 6: *Predators in Area 1 and 2 that provide biological control services.*

Birds	Barn Swallow
	Tree Swallow
	Baird's Sparrow
	Western Meadowlark
	Yellow Warbler
	Savannah Sparrow
Insects	Ladybugs
	Dragonflies
	Damselflies
Spiders	Grass Spiders
	Banded Garden Spider

35 IPBES (2016). The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. S.G. Potts, V. L. Imperatriz-Fonseca, and H. T. Ngo, (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 552 pages.

36 Costanza, R., de Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S. and Turner, R.K., 2014. Changes in the global value of ecosystem services. Global environmental change, 26, pp.152-158.

37 https://honeycouncil.ca/industry-overview/

38 Gallai, N. and Vaissière, B., 2009. Guidelines for the economic valuation of pollination services at a national scale. Guidelines for the economic valuation of pollination services at a national scale, Food and Agricultural Organization (2009).

39 Morandin, L.A. and Winston, M.L., 2006. Pollinators provide economic incentive to preserve natural land in agro-ecosystems. Agriculture, Ecosystems & Environment, 116(3-4), pp.289-292.

There are many birds that eat insects such as swallows and warblers. For example, Barn Swallows can eat up to 850 insects per day[40].

Some insects are useful for control of weeds and against pest insects. Ladybugs are a good example as their larvae eat aphids, mealybugs, and other plant sucking pests. A ladybug can eat 50 aphids per day and 5,000 aphids during its lifetime[41]. In Saskatchewan, the seed weevil has been used to control scentless chamomile since 1992, by reducing up to 40% of the seed production[42]. Also, wetland insects such as dragonflies and damselflies are natural predators of mosquitoes.

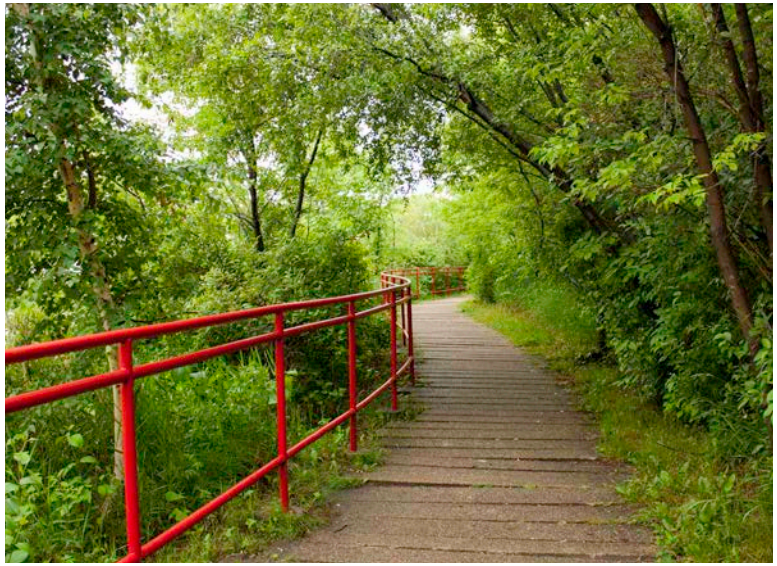


Photo supplied by: City of Saskatoon

Air Quality Regulation: Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere.

Trees can produce oxygen and water vapor and remove a wide range of pollutants such as carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter. One study showed that trees in 86 cities in Canada could remove a total of 16,500 tonnes of air pollution, which was estimated to positively affect human health at a value of $227.2 million in 2018[43].

Grasslands, forest and shrub-lands can directly sequester pollutants such as nitrogen dioxide, ozone, particulate matter, and sulfur dioxide to improve air quality. These areas are valuable for human health value by removing pollutants. A study in the United States estimated that grasslands, forest, and shrublands provide the annual values for human health of $175 million USD, $93 million USD and $19.4 million USD, respectively[44].

40 https://www.birdnote.org/show/barn-swallow-natural-pest-control
41 https://www.planetnatural.com/aphids-ladybugs/
42 https://www.dal.ca/faculty/agriculture/oacc/en-home/resources/pest-management/weed-management/organic-weed-mgmt-resources/weeds-biological-control.html
43 Nowak, D.J., Hirabayashi, S., Doyle, M., McGovern, M. and Pasher, J., 2018. Air pollution removal by urban forests in Canada and its effect on air quality and human health. Urban Forestry & Urban Greening, 29, pp.40-48.
44 Gopalakrishnan, V., Hirabayashi, S., Ziv, G. and Bakshi, B.R., 2018. Air quality and human health impacts of grasslands and shrublands in the United States. Atmospheric Environment, 182, pp.193-199.

***Table 7**. Regulating Services Valuation for Areas 1 and 2*

REGULATING SERVICES			
Land cover	**Area (ha)**	**Value ($ /ha /year)**	**Value ($ /year)**
Area 1			
Wetlands	18	2,581	46,500
Grasslands	144	621	89,400
Forest/Shrubland	0	861	0
Total			**$135,900**
Area 2			
Wetlands	7	2,581	18,100
Grasslands	67	621	41,600
Forest/Shrubland	58	861	49,900
Total			**$109,600**

Photo credit: Creative Commons

Valuation Gaps:

1. Carbon sequestration: Wetlands valuation assumes that individual wetlands are performing carbon sequestration at a similar rate as the study site, however it must be noted that the health of these ecosystems is not known.

2. Carbon sequestration: In Area 2, the unit value based on the study on Canadian Urban Forest transferred to forest/shrubland may not be accurately representative.

3. Storm water management service: the unit value based on the average of all wetlands in Canada in the international database may not accurately capture the storm water management service value provided by wetlands in Saskatoon.

4. Storm water management: no useable value was found for the provision of this service by forest/shrubland.

5. Pollination: no usable value was found for the provision of this service by wetlands or forest/shrubland.

6. Biological Control: no usable value was found for the provision of this service by wetlands.

Cultural Services

Recreation and mental and physical health: Walking and playing sports in green space is not only a good form of physical exercise but also lets people relax. The role that green space plays in maintaining mental and physical health is increasingly being recognized, despite difficulties of measurement.

Areas 1 and Area 2 offer many recreational services to Saskatoon residents including bird watching, wildlife viewing, winter fat tire biking, snowshoeing, cross-country skiing, and dog walking.

- The two natural areas are considered birding hotspots. Birders view several waterfowl species in the Chappell Marsh wetlands such as Ruddy Duck, Lesser Scaup, and Tundra Swans[45].
- Observations in fall 2019/winter 2020 indicate the Small Swale is very popular by numerous hikers and dog walkers who use the land without permission. The hill slopes at the Small Swale were also observed to be used by families for tobogganing this past winter[46].
- Grasslands and wetlands in Area 1 and Area 2 are unique landscapes for scenic and wildlife viewing.
- There are numerous visitors from across Saskatchewan and other provinces that have visited the Richard St. Barbe Baker Afforestation Area in Area 2 for fat tire biking. During the winter this year, there were an average of 1500 check-ins to the site per month through an online trail app, which is estimated to account for 25% of actual usage, and is the highest amount recorded to date[47].
- A large number of dog walkers use the Off-leash Dog Park within the Richard St. Barbe Baker Afforestation Area for recreational purposes year-round.

Green space plays an important role in public health improvement. An international study of 34 cities suggested that for more prosperous cities, green spaces were associated with better public health[48]. Many studies demonstrate strong correlations between a neighbourhood green space and the improvement of physical and mental health[49]. A national cohort study in Canada[50] and another study in Ontario[51] discovered that the increases in residential green space were associated with reduced risks of dying from several causes of death among urban Canadians; the strongest association was found for respiratory disease mortality. A recent study also found that connecting with nature for just 20 minutes each day will significantly reduce stress hormone levels[52]. Therefore, increasing and managing urban green spaces can be considered as a strategic public health intervention.

45 Adamson, J (2020, January 15) "Chappell Marsh Conservation Area. A compilation report submitted by on behalf of the Friends of the Saskatoon Afforestation Areas Inc" (email)
46 Personal Communication from Renny Grilz, Resource Management Officer, Meewasin Valley Authority
47 Provided by Jeff Hehn. https://www.trailforks.com/region/st-barbe-winter-trails-man-of-the-trees/ridelogstats/
48 Amano, T., Butt, I. and Peh, K.S.H., 2018. The importance of green spaces to public health: a multi-continental analysis. Ecological applications, 28(6), pp.1473-1480:
49 WHO report 2016: Urban Green Infrastructure and Public Health: Review the evidences?
50 Crouse DL, Pinault L, Balram A, et al. Urban greenness and mortality in Canada's largest cities: a national cohort study. Lancet Planet Health 2017; 1: e289–97:
51 Villeneuve PJ, Jerrett M, G. Su JG, et al. A cohort study relating urban green space with mortality in Ontario, Canada. Environ Res 2012; 115: 51–58:
52 MaryCarol R. Hunter, Brenda W. Gillespie, Sophie Yu-Pu Chen. Urban Nature Experiences Reduce Stress in the Context of Daily Life Based on Salivary Biomarkers. Frontiers in Psychology, 2019; 10 DOI: 10.3389/fpsyg.2019.00722

It is estimated that physical inactivity linked to lower walkability and lack of access to recreational areas contributes to 3.3% of global deaths[53]. In addition, a study by Queen's University in 2012[54] found that physical inactivity costs tax payers in Canada $6.8 billion annually, or 3.7% of total health care costs. Therefore, increasing accessibility to urban green space could bring benefits to municipalities in both health and financial terms.

In Saskatoon, about 53% of the population live within a 3 minute walk of an urban green space, 28% within a 3-5 minute walk, 17% within a 5-10 minute walk, and 1% within a walk of greater than 10 minutes[55]. Unfortunately, there is no data available about the number of users of the two pilot areas, therefore this service could not be given a value for this pilot project.

In the future, the two natural areas could certainly provide additional recreational and health services to the growing population that is planned for the area. Thousands of people are expected to live in a future neighbourhood south of Area 1 (University Heights neighbourhood 3).

Area 2 could provide many benefits to about 50,000 to 70,000 additional residents within eight future neighbourhoods. Thus, these natural areas will likely play even more important roles in providing recreational and health services in the future.

Aesthetic appreciation and inspiration for culture, art and design: Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science.

The two areas studied are also important in providing education services to our communities.

- The Saskatoon Nature Society has been banding birds and monitoring bat populations for decades at Richard St Barbe Baker Afforestation Area.
- The Nature City Festival, Jane's Walk Festival, and Bioblitz take place annually in Saskatoon. In 2019, the Nature Festival engaged more than 3,500 persons and 300 volunteers[56]. Several "Bioblitz" events have been organized in Area 1 to teach citizen scientists how to identify and document plants and animals to support biodiversity conservation.
- Both Area 1 and Area 2 are unique places for public education and research on the value of prairie potholes and grasslands[57].
- The unique natural, historical and cultural resources of Richard St. Barbe Baker Afforestation Area and Chappell Marsh in Area 2 have been in the public school curriculum and are a great place for conducting field trips for students in Saskatoon.

53 https://www.who.int/sustainable-development/cities/health-risks/urban-green-space/en/
54 Janssen, I., 2012. Health care costs of physical inactivity in Canadian adults. Applied Physiology, Nutrition, and Metabolism, 37(4), pp.803-806.
55 Meewasin Valley Authority, 2019. Natural Inventory of the City of Saskatoon.
56 2019 Festival Report. Wild About Saskatoon. https://static1.squarespace.com/static/5c71743f7a1fbd5b042b91c3/t/5d15154531a0d90001b17a3e/1561662840902/NatureCity2019FestivalReport.pdf
57 The Friends of the Saskatoon Afforestation Areas Inc , 2019. Heritage Value, Historic Place, Character Defining Elements Sources for Heritage Value and Statement of Significance. A report submitted to City of Saskatoon Register of Historic Places.

- Police services uses Area 2 for training and competition. Saskatoon Search and Rescue and Saskatoon Nature Society as well as some wilderness survival skills training groups also use the Richard St. Barbe Baker Afforestation Area for training.

- Nature Saskatchewan's Nature Quest program is led by a forester who would like to use the Richard St. Barbe Baker Afforestation Area in Area 2 for its outdoor activities.

As mentioned above, the planned growth for these two areas will likely further increase their use and importance for education, aesthetic appreciation, and inspiration.

Added Value to Property: Natural assets such as wetlands provide amenity value to neighbouring properties and increase property value.

Natural assets can add value to neighbouring properties. Based on taxation data, property prices in ten areas of the City have been analyzed to better understand correlations between different variables, including proximity to natural assets. The results show that proximity to parks, rivers, and lakes is positively associated with property values. The table below summarizes the correlations between neighbourhood and environmental characteristics.

Photo supplied by: City of Saskatoon

Table 8: *Correlations between proximity to natural assets and property prices in Saskatoon*

Neighbourhood Characteristics	Correlation to Property Prices
Arterial Road, Backing Arterial, Backing Highway, Berm, Wall, Major Collector, Cul-De-Sac, Backing Apartment, Opposite Apartment, Backing Commercial, Opposite Commercial, Backing Row House, Opposite Row House	Negative
Mobile home on titled lot, zoning	Negative - Significant
Environmental Characteristics	
Backing Park, Lake, River	Positive – Significant
Front River	Positive – Significant

The design of many houses in Saskatoon have already integrated environmentally-influenced features that increase their value. For example, walk-out basements are included with Aspen Ridge lots that back onto the Northeast Swale greenway. Currently, there are no residential properties backing on to Area 1 or Area 2, therefore designed value-added to property has not been calculated for this pilot. However, since there are plans to develop neighborhoods in proximity to both areas, the potential positive impact on property values is high and should be monitored.

Historical/heritage: Many landscapes have historical and heritage importance.

Previous heritage resource assessments have concluded that the heritage resource potential for the majority of Area 1 is low. However, adjacent to Area 1 there are features such as the Batoche Trail and evidence of limestone quarrying activities that were common to the area during Saskatoon's early history[58]. There is also potential for surface archaeological finds such as stone circles (tepee rings)[59]. According to a land allocation inquiry using the Government of Saskatchewan's Developers' Online Screening Tool (2018), the majority of Area 1 is considered to be heritage-sensitive and further screening by the provincial Heritage Conservation Branch will be required prior to development[60].

Area 2 also has significant heritage value and strong connection with the community. The afforestation area was named after Richard St. Barbe Baker, who was an internationally known forestry advisor and conservationist. Chappell Marsh was named in honour of Benjamin Thomas Chappell, a member of the community who was instrumental in supporting the Saskatoon Exhibition[61]. There have also been some archeological findings in the area. The Old Bone Trail, east of Chappell Marsh, passes directly through Richard St. Barbe Baker Afforestation Area.

58 Ernest G. Walker, 1983. Saskatoon Perimeter Archaeocological Resources Assessment. The City of Saskatoon.
59 Stantec, 2003. The "Small Swale" Resource Overview.
60 The City of Saskatoon, 2018. Saskatoon's Green Strategy: Attachment 4 - Small Swale.
61 The Friends of the Saskatoon Afforestation Areas Inc , 2019. Heritage Value, Historic Place, Character Defining Elements Sources for Heritage Value and Statement of Significance. A report submitted to City of Saskatoon Register of Historic Places.

Table 9: *Cultural Services Valuation for Areas 1 and 2*

CULTURAL SERVICES			
Land cover	**Area (ha)**	**Value ($ /ha/year)**	**Value ($ /year)**
Area 1			
Wetlands	18	26	500
Grasslands	144	26	3,700
Forest/Shrubland	0	26	0
Total			**$4,200**
Area 2			
Wetlands	7	26.07	200
Grasslands	67	26.07	1,700
Forest/Shrubland	58	26.07	1,500
Total			**$3,400**

Photo supplied by: City of Saskatoon

Valuation Gaps:

1. The analysis of cultural services was hampered by a general lack of information. Anecdotally, many visitors and groups are reported to use these areas on an annual basis. However, no organizations are tracking the number of users that access the two areas for various purposes. It was therefore not possible to calculate a value for recreation, education, or improved health services.

2. The international database provided a unit value for recreational services provided by ecosystems in Canada. This was used as the basis for the cultural services valuation, but does not likely capture the full service value for these two areas.

3. The project team was unable to access property sales information for privacy reasons. Therefore, there was no information available to calculate the estimated added value to property for the pilot project.

4. There was an inability to calculate historical/heritage value because there is a general lack of understanding about how to express this value in financial terms.

5. Overall, the cultural value has been underestimated for this pilot project. More work needs to be done to highlight and acknowledge cultural services in qualitative terms.

Provisioning Services:

Forage Production: Grasslands provide food for livestock.

In the last few years, the Meewasin Valley Authority has done a grazing and burning program for the conservation of the nearby Northeast Swale, and have defined that area's carrying capacity for grazing[62]. The valuation for this pilot project will therefore use these carrying capacity results to estimate forage production value.

Table 10: *Provisioning Services Valuation for Areas 1 and 2*

PROVISIONING SERVICES			
Land cover	**Area (ha)**	**Value ($/ha /year)**	**Value ($ /year)**
Area 1			
Wetlands	18	0	0
Grasslands	144	426	61,300
Forest/Shrubland	0	0	0
Total			**$61,300**
Area 2			
Wetlands	7	0	0
Grasslands	67	426	28,500
Forest/Shrubland	58	0	0
Total			**$28,500**

62 Meewasin Valley Authority, 2013. Meewasin master plan 2013.

Valuation Gaps:

1. There is currently no recorded use of natural resources in either the wetlands or forest/shrubland in Area 1 or Area 2, so values cannot be calculated for those land covers.

Photo supplied by: Meghan Mickelson

Summary

Table 11: *Total Annual Value of Ecosystem Services for Area 1 and Area 2*

NCAV SUMMARY TABLE							
		Supporting	Regulating	Cultural	Provisioning	All Services	
Land Cover	Area (ha)	Value ($/year)	Value ($/year)	Value ($/year)	Value ($/year)	Value ($/ha/year)	Value ($/year)
Area 1							
Wetlands	18	529,100	46,500	500	0	32,002	576,100
Grasslands	144	700	89,400	3,700	61,300	1,078	155,100
Forest/Shrubland	0	0	0	0	0	887	0
Total	**162**	**529,800**	**135,900**	**4,200**	**61,300**		**731,200**
Area 2							
Wetlands	7	205,800	18,100	200	0	32,002	224,100
Grasslands	67	300	41,600	1,700	28,500	1,078	72,100
Forest/Shrubland	58	0	49,900	1,500	0	887	51,400
Total	**132**	**206,100**	**109,600**	**3,400**	**28,500**		**347,600**

Valuation Gaps:

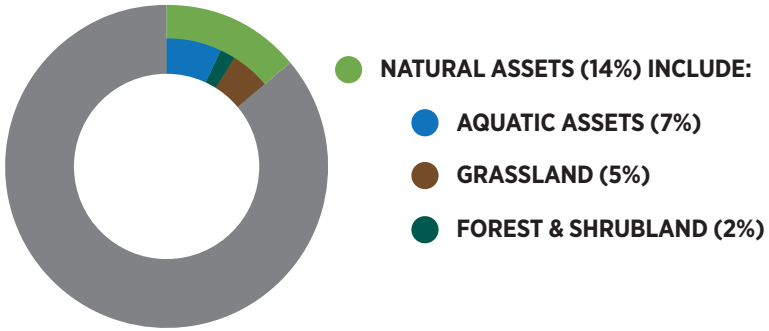
It must be noted that the value transfer method of valuation is limited in its ability to fully capture the full value of ecosystem services in the two pilot areas. The main limitation is that values are based on the currently available data. In some cases, values were available for transfer from local studies in comparable areas, but in other cases the only available values were from an international database, and are generally low and do not provide local context. In several cases, especially for cultural services, no value was estimated because of the lack of information.

Extrapolation to Other Natural Assets

The following figure shows the breakdown of Saskatoon's major natural assets by area. Of the total footprint of the natural areas:

- 7% are aquatic assets (2% is the South Saskatchewan River, 5% is wetlands)
- 5% are grasslands
- 2% are forest and shrubland (urban forest, an enhanced asset, is not included)

Figure 10: *City of Saskatoon Natural Assets as a Proportion of the City Footprint*[63]



The two natural assets chosen for the valuation pilot contained a mixture of aquatic assets (wetlands), grasslands, and forest/shrubland. The ecosystem service values used in this pilot can be extrapolated to the remainder of the assets in these classes if we assume that:

- The set of ecosystem services provided by these asset types are consistent throughout the city; and
- The transfer values used in the pilot are relevant to all similar natural areas throughout the city.

Where sub-asset types were very different than the others in the same class, a different valuation method was used. For example, the South Saskatchewan River is not similar to the wetlands in the Aquatic Assets class, so a separate transfer value was found in the international database to express the value of the River.

The following table summarizes the potential value of all natural assets in these three classes based on the results of this pilot valuation.

Table 12: *Total Annual Value of Ecosystem Services for Natural Areas in Saskatoon*

Natural Assets		Area (ha)	Unit value ($/ha/year)	Total ($/year)
Aquatic	River	388	19,702[64]	7,644, 400
	Wetlands	1,207	32,002	38,626,400
Grassland		1,285	1,078	1,385,200
Forest/Shrubland		577	887	511,800
TOTAL				**$48,167,800**

63 City of Saskatoon, 2020. Saskatoon's Green Infrastructure Strategy: Towards and Interconnected Green Network.
64 Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), pp.253-260.

Photo supplied by: Julia Adamson

CONCLUSION

Benefits and Challenges for Implementation

Municipal Ecosystem service valuation is a new field to analyze the value of natural assets which compliments asset valuation for traditional infrastructure. Both the *Municipal Natural Assets Initiative* and the *Canadian Environmental Accounting Standards* are contributing to best practice to formalize natural asset management. Municipal Ecosystem service valuation includes:

- Identify and quantify the value (with greater accuracy) of ecosystem services provided by natural assets;
- Develop a framework for natural asset accounting;
- Develop indicators to track ecosystem health by measuring the status of natural assets;
- Identify risks to ecosystem services, such as the loss of soil or water quality;
- Prioritize actions to strengthen natural assets; and
- Manage and fund natural assets consistently.

Challenges to the implementation of natural asset management in the City include:

- Lack of policy to direct valuation of natural assets;
- Lack of experience in applying this new approach to asset management;
- Lack of information about the use and health of natural assets in general; and
- Inability to reflect natural assets in the financial statements of the corporation as these values cannot currently be audited.

Next Steps

There is an opportunity for management of natural assets to be considered at the same time as improvements to management of engineered and enhanced assets. As well, future natural asset valuation for the City aligns with or benefits from actions and initiatives proposed by the *Green Infrastructure Strategy*, the *Corporate Climate Adaptation Plan*, and the *Low Emissions Community Plan*, as they address several of the challenges and gaps identified with this pilot. Specific examples are listed below.

Green Infrastructure Strategy:

Action 1: Design the Green Network to reflect our collective history, honour cultural diversity, and create a sense of belonging for all.

- 1.1. Complete an Intangible Cultural Heritage Assessment to better understand community uses of the Green Network.
- 1.2. In partnership with the community, complete a Traditional Land Use and Traditional Knowledge assessment to identify cultural elements in the Green Network, and establish ways to conserve, honour, and revitalize these elements.

Action 11: Protect, restore, and manage significant natural areas.

- 11.1. Identify natural areas and make management decisions for these sites regarding avoidance, minimization, or compensation.
- 11.2 Protect significant natural areas using a variety of available protection tools.
- 11.3. Integrate natural assets into the urban fabric while conserving ecosystem function.
- 11.4. Develop and implement site specific management plan, including restoration of natural areas when required.

Action 13: Improve biodiversity and ecosystem health throughout the Green Network.

- 13.4. Establish ongoing biodiversity monitoring and reporting with partners.

Action 14: Integrate natural waterbodies and drainage courses into development using green infrastructure.

- 14.1: Incorporate wetlands and natural drainage paths into the storm water network in greenfield development areas.
- 14.2. Identify how green infrastructure can increase the storm system's capacity to respond to intense rain events.
- 14.3 Evaluate opportunities to increase naturalization of existing storm ponds to improve water quality and habitat, while balancing community recreation and other uses.
- 14.4. Consult with affected organizations when designing storm water infrastructure to mitigate impacts to natural areas and cultural elements within the watershed.

Corporate Climate Adaptation Plan:

Action L: Consider Green Infrastructure on Par with Grey Infrastructure

- Support increased integration of green infrastructure into all available aspects of urban development and through implementation of the Green Infrastructure Strategy and Urban Forestry Management Plan.

The Low Emissions Community Plan:

Benefits of a Low Emissions Community: Utilizing natural infrastructure aids in sequestering carbon and providing other ecological benefits such as enhanced biodiversity, water purification, pollination and pest management, preservation of cultural and natural history, city beautification and improved mental, physical and spiritual health for residents.

APPENDIX 1

Table 13: *Ecosystem Services Identified for Valuation*

Type	Service	Description
SUPPORTING	**Habitat**	Provides everything that an individual plant or animal needs to survive.
REGULATING	**Carbon sequestration and storage**	Ecosystems regulate the global climate by storing and sequestering greenhouse gases.
	Moderation of extreme events	Extreme weather events or natural hazards include floods, storms, tsunamis, avalanches and landslides. Ecosystems and living organisms create buffers against natural disasters, thereby preventing possible damage. For example, wetlands can soak up flood water whilst trees can stabilize slopes. Coral reefs and mangroves help protect coastlines from storm damage. Note: this study focused on storm water management.
	Waste water treatment	Ecosystems such as wetlands filter both human and animal waste and act as a natural buffer to the surrounding environment. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced.
	Pollination	Insects and wind pollinate plants and trees which is essential for the development of fruits, vegetables and seeds. Animal pollination is a service mainly provided by insects but also birds and bats.
	Biological control	Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, frogs and fungi all act as natural controls.
	Local climate and air quality regulation	Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere..
CULTURAL	**Recreation and mental and physical health**	Walking and playing sports in green space is not only a good form of physical exercise but also lets people relax. The role that green space plays in maintaining mental and physical health is increasingly being recognized, despite difficulties of measurement.
	Aesthetic appreciation and inspiration for culture, art and design	Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science.
	Added value to property	Natural assets provide amenity value to neighbouring properties and increase property value.
	Historical/heritage	Many natural assets have historical and heritage importance.
PROVISIONING	**Forage production**	It describes the material or energy outputs from ecosystems such as food, raw material, fresh water, medicinal resources. For example, grasslands provide food for livestock.

Photo supplied by: City of Saskatoon

APPENDIX 2

Table 14: *Ranked Climate Change Risk Analysis Results*

Rank	Climate Change Driver	Impact on Natural Assets in Existing Service Areas	Overall Risk Level
2	Warmer	Increased heat stress on plants and the urban forest	**High**
3	Wetter	Increased demand on the storm water management system	
5	Warmer	Reductions in plant health overall and winter survival rates due to increasingly frequent freeze-thaw cycles	
10	Warmer	Loss of plant and urban wildlife diversity due to heat stress, water availability reductions and habitat losses	**Medium**
11	Wetter	Severe heavy precipitation events could overwhelm the storm water management system and cause water to infiltrate the sanitary sewer system causing health concerns, property damage, environmental damage (including river pollution), and regulatory fines or consequences including/up to prosecution	
13	Warmer	Drought conditions	
15	Warmer	Increased loss of plant and tree species due to larger and more diverse pest populations	
16	Warmer	Longer annual operation and maintenance periods for outdoor pools, golf courses, the Saskatoon Forestry Farm Park and Zoo, campgrounds, parks, green spaces, public lands, and right of way areas	
18	Wetter	Increased need for roadway and sidewalk salt and sanding due to increasingly frequent freezing rain or safe citizen mobility may be compromised. (impacts to green spaces, river)	
19	Warmer	Increased instances of freezing rain can create challenges for tree limb stability and power line functionality.	
33	Warmer	Reduced availability of water resources impacting quality and cost of water treatment	**Low**
35	Wilder	Forest, bush and grass fire conditions are present more often	
38	Wetter	Slope stability concerns around river valley	
40	Warmer	Reductions in soil health	
44	Warmer	Reduction in local food production capacity under extreme heat and dry conditions	
46	Wetter	High river levels creating water seepage into waste water treatment plant through storm water outfalls	**Very low**

The full ranked risk analysis for all civic operations can be found online in the *Local Actions: Climate Projections & Possible Impacts Report* at **www.saskatoon.ca.**

A **high** level of risk/vulnerability was identified for:

- Plants in general, and for enhanced assets such as the urban forest and the storm water management system, which includes wetlands.

A **medium** level of risk/vulnerability was identified for:

- Plant and wildlife diversity due to heat stress, reductions in water availability, and habitat loss, as well as increases in pest populations.
- Pollution of the river or other enhanced assets resulting from severe heavy precipitation events that could contribute to sanitary sewer flows.
- Natural and enhanced assets in higher demand for recreational purposes linked to longer and hotter summers, or susceptible to increased use of road salts.
- Trees impacted by freezing rain resulting in broken limbs.

A **low to very low level** of risk/vulnerability was identified for:

- River water levels either very low or very high.
- Forest, brush, and grass fires.
- Slope stability along the river.
- Reduced soil health and ability to produce food locally.

Photo supplied by: Julia Adamson

APPENDIX 3

Table 15: *Library of Values*

SUPPORTING SERVICES			
	Value	**Units**	**Source**
Habitat			
Wetland	**17,000**	US$ ha^{-1} yr^{-1}	Brander, L.M., Florax, R.J. and Vermaat, J.E., 2006. The empirics of wetland valuation: a comprehensive summary and a meta-analysis of the literature. Environmental and Resource Economics, 33(2), pp.223-250. Brander's meta analysis provides a value of US$17,000/wetland ha/year in 2006. It is US$ 22,224.73/ha/year (or CAD $29,394.43/ha/year) in 2020.
Grassland	**4.6**	US$ ha^{-1} yr^{-1}	Kulshreshtha, S., Undi, M., Zhang, J., Ghorbani, M., Wittenberg, K., Salvano, A.E., Kebreab, E. and Ominski, K., 2015. Challenges and opportunities in estimating the value of goods and services in temperate grasslands—a case study of prairie grasslands in Manitoba, Canada. Agroecology. InTech Publishers, Rejeka, Croatia, pp.147-169. Habitat value of grassland was US$ 4.6/ha/year in 2015. It is CAD$5/ha/year in 2020.
REGULATING SERVICES			
	Value	**Units**	**Source**
Carbon sequestration and storage			
Wetland	**5.31**	tonnes C ha^{-1} yr^{-1}	It took between 24-36 years for wetlands to reach historic SOC levels after abandonment of cultivation. The average carbon sequestration of wetland 5.31 tonnes C/ha/year (19.47 tonnes CO_2e./ha/year)
Grassland	**4.10**	tonnes C ha^{-1} yr^{-1}	Bedard-Haughn, A., Jongbloed, F., Akkerman, J., Uijl, A., De Jong, E., Yates, T. and Pennock, D., 2006. The effects of erosional and management history on soil organic carbon stores in ephemeral wetlands of hummocky agricultural landscapes. Geoderma, 135, pp.296-306. The average carbon sequestration of grassland: 4.10 tonnes C/ha/year (15.05 tonnes CO_2e./ha/year)

Forest and Shrubs	**2.77**	tonnes C ha^{-1} yr^{-1}	Pasher, J., McGovern, M., Khoury, M. and Duffe, J., 2014. Assessing carbon storage and sequestration by Canada's urban forests using high resolution earth observation data. Urban forestry & urban greening, 13(3), pp.484-494. The average carbon sequestration of forest is 2.77 tonnes C/ha/year (10.17 tonnes CO_2e./ha/year)
Waste water treatment			
Wetland			
Phosphorous retention	**1.14**	kg ha^{-1} yr^{-1}	Pattison-Williams, J.K., Pomeroy, J.W., Badiou, P. and Gabor, S., 2018. Wetlands, flood control and ecosystem services in the Smith Creek Drainage Basin: A case study in Saskatchewan, Canada. Ecological economics, 147, pp.36-47. Treatment cost of phosphorous: 450CAD$ kg-1 (O'Grady, D., 2008. Point to non-point phosphorus trading in the South Nation River watershed. In: Environmental Economics and Investment Assessment II, WIT Transactions on Ecology and the Environment. WIT Press, Southampton, UK, pp. 189–195. http://dx.doi.org/10.2495/EEIA080191.) Treatment cost of nitrogen: 57CAD$ kg-1 (Stephenson, K., Aultman, S., Metcalfe, T., Miller, A., 2010. An evaluation of nutrient nonpoint offset trading in Virginia: a role for agricultural nonpoint sources? Water Resour. Res. 46, W04519. http://dx.doi.org/10.1029/2009WR008228.)
Nitrogen removal	**1.28**	kg ha^{-1} yr^{-1}	
Grassland	**26.80**	CAD$ ha^{-1} yr^{-1}	Benefit transfer from Olewiler, N. (2004). The Value of Natural Capital in Settled Areas of Canada. The value of nutrient removal of grassland in 2004 was CAD$26.8/ha/year. It is CAD$35.49/ha/year in 2020.
Moderation of extreme events **(Storm water management)**			
Wetland	**926**	CAD$ ha^{-1} yr^{-1}	Van der Ploeg, S. and R.S. de Groot (2010) The TEEB Valuation Database – a searchable database of 1310 estimates of monetary values of ecosystem services. Foundation for Sustainable Development, Wageningen, The Netherlands. ESDV provides a value of CAD$ 571-926 / ha/year in Canada in 2010. It is CAD$1,100.58/ha/year in 2020

Grassland	**3**	US$ $ha^{-1}yr^{-1}$	Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), pp.253-260. Flood control service was USD$3/ha/year in 1994. It is US$ 5.29 /ha/year in 2020 (or CAD$7/ha/year in 2020)
Pollination			
Grassland	**25**	US$ ha^{-1} yr^{-1}	Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), pp.253-260. Pollination service value was US$25/ha/year in 1994. It is US$43. 52/ha/year in 2020 (or CAD$57.7/ha/year)
Biological control			
Grassland	**23**	US$ ha^{-1} yr^{-1}	Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), pp.253-260. Biological control of grassland is 23US$/ha/year in 1994. It is US$40.04/ha/year in 2020 (or CAD$53.07/ha/year)
Forest and Shrubs	**4**	US$ ha^{-1} yr^{-1}	Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), pp.253-260. Biological control of forest is US$4/ha/year in 1994. It is US$6.98/ha/year in 2020 (or CAD$10.05 /ha/year)
Local climate and air quality regulation			
Wetland	**133**	US$ ha^{-1} yr^{-1}	Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), pp.253-260. Gas regulation service value of wetland was US$133 /ha/year in 1994. It is US$234.7 /ha/year in 2020 (or CAD$310.41/ha/year) in 2020.

Grassland	**7**	US$ ha^{-1} yr^{-1}	Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), pp.253-260. Gas regulation service value of wetland was US$7 /ha/year in 1994. It is US$12.35 /ha/year in 2020 (or CAD$16.33 /ha/year in 2020.
Forest	**511**	CAD$ ha^{-1} yr^{-1}	Nowak, D.J., Hirabayashi, S., Doyle, M., McGovern, M. and Pasher, J., 2018. Air pollution removal by urban forests in Canada and its effect on air quality and human health. Urban Forestry & Urban Greening, 29, pp.40-48. Pollution removal value of urban forest is 3.72g/m2/year with an average value of per ha canopy cover is CAD$511 in 2017 or CAD$546.14 in 2020.
CULTURAL SERVICES			
	Value	**Units**	**Source**
Recreation and mental and physical health			
Wetland	**18.06**	CAD$ ha^{-1} yr^{-1}	Van der Ploeg, S. and R.S. de Groot (2010) The TEEB Valuation Database – a searchable database of 1310 estimates of monetary values of ecosystem services. Foundation for Sustainable Development, Wageningen, The Netherlands. The recreational service for all types of ecosystems in Canada was 18.60CAD/ha/year in 2002. It is 26.07 CAD/ha/year in 2020.
Grassland	**18.06**	CAD$ ha^{-1} yr^{-1}	
Forest	**18.06**	CAD$ ha^{-1} yr^{-1}	
PROVISIONING SERVICES			
	Value	**Units**	**Source**
Forage production			
Grassland	**1.42**	Animal Unit Month ha^{-1} yr^{-1}	Meewasin, 2015. Meewasin master plan 2015. The North Swale has significant carrying capacity of grazing: Stocking rate of the North East Swale is **1.42 Animal Unit Month per Ha (AUM/ha)**. Minimum and maximum carrying capacity in Northeast Swale: 91 and 163 AUM. Price: 35 per AUM.

APPENDIX 4: ACKNOWLEDGEMENTS

Saskatoon has a diversity of people and stakeholders with many different approaches and interactions with its assets. As such, it was important to consult a variety of technical experts, internal stakeholders, and community members to ensure the valuation incorporated many people's experiences and interpretations. The City of Saskatoon would like to thank everyone who took the time to provide feedback and expertise.

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Saskatoon