Business Case for Natural Assets in the Region of Peel: Benefits to Municipalities and Local Communities

Published: August 2020

Copyright © 2020 Credit Valley Conservation. All rights reserved

1255 Old Derry Road, Mississauga, Ontario L5N 6R4 | **cvc.ca** | T 905-670-1615 | TF 800-668-5557 | F 905-670-2210

Acknowledgements

We thank our partners, the Region of Peel and the Friends of the Greenbelt Foundation, for their financial contributions to this project. We also thank the Region of Peel, the City of Brampton, the Town of Caledon, the City of Mississauga and Toronto and Region Conservation Authority for their project contributions.

We would like to acknowledge the Credit Valley Conservation Authority (CVC) staff, without whose assistance we would have been unable to complete this project, especially Kamal Paudel, Parastoo Hosseini, Tatiana Koveshnikova, Julien Gordon, Lauren Moretto, Scott Sampson, Joe Pierson, Sakshi Saini, Amanjot Singh, Gayle Soo Chan, Alex Waterfield and Shanice Badior.

Our special thank you to the CVC staff who worked on developing and testing a Rapid Natural Asset Condition methodology, including Scott Sampson, Kelsey Mc Neill, Jon Nodwell and Sally Bets.

The preparation of this study was carried out with assistance from the Government of Canada and the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

Credit Valley Conservation
inspired by nature

Memo

Date: August 2020

Re: Business Case for Natural Assets in the Region of Peel: Benefits to Municipalities and Local Communities

---

The purpose of the Business Case for Natural Assets (BC4NA) project was to build evidence and develop guidance for the Region of Peel and lower-tier municipalities for effectively identifying, measuring and managing the contribution of natural assets (wetlands, forests and other green space) to municipal services delivery and community well-being while reducing their vulnerability to climate change impacts. This work recognizes that natural systems play an important role in helping communities and municipalities to mitigate and adapt to the issues posed by a changing climate and other pressures, while delivering important services such as flood mitigation and heat island reduction.

The Business case assessment for natural assets study developed: a prototype asset registry that identifies and quantifies the natural assets within the study areas; a series of spreadsheet models that compare the cost of management actions to the value of services derived from the same natural assets; and a web-based interactive dashboard that summarizes the costs and benefits (Return on Investment) of natural asset management actions. The approach developed in this study provides municipalities with a guiding example of accounting for natural assets in a way that is consistent with asset management processes.

It is important to note that this is new innovative work and the developed framework and the process for quantifying benefits and costs of managing natural assets was the primary focus of this report. Especially considering limited data/ available research when developing some components of this tool, existing output numbers in the current version of the dashboard are to serve as placeholders or general estimates. Future versions of the BC4NA dashboard will include improvements to methodologies and calculations, and incorporate these changes to the classifications, ecosystem service calculations, and valuations.

In this type of innovative work, gaps and limitations are expected. Please be advised that the following with respect to the methodology were noted after completion of the report. These items, in addition to those mentioned in Section 9 "Limitations and Areas for Improvement" of the BC4NA report, will be addressed in future iterations of the project:

1. Cultural woodland (CUW) and wet meadow (WET) Ecological Land Classification (ELC) types are to be reassigned to different National Ecosystem Service Classification System (NESCS) land cover categories in future versions of the project. This will likely have an impact on existing outputs of the ecosystem service calculations and valuations.
2. The methodology for calculating stormwater retention capacities is being refined by Emmons and Oliver Resources Consulting to improve measurements and valuation of stormwater retention by natural assets to better simulate actual conditions using supplementary data.
3. Location-specific cost information is currently lacking, so some cost values in the spreadsheet models and the dashboard were thoughtfully assumed based on complementary data and experience. An ongoing project led by CVC in partnership with Beacon Environmental, however, is costing the life cycle of management and restoration of natural assets. Outputs of this project could result in new costing information that will be applied to future iterations of the BC4NA project, including the cost-benefit models and the dashboard, for more accurate estimates.
4. There is some uncertainty associated with the probability values employed in the models for damages due to the relevant risks. This is a result of a lack of existing research regarding these probability risks. However, the assumed probabilities were logically considered, and future research will better address the uncertainty associated with these values.

Notwithstanding the areas of the improvement noted above, this project has pushed the frontier in quantifying and valuing natural asset ecosystem service outputs, including flood mitigation and heat island reduction. It also demonstrated that natural systems can help communities and municipalities to mitigate and adapt to the issues posed by the changing climate and other such pressures. Long term, this project and future developments will help municipal partners to:

- develop a proactive and comprehensive infrastructure strategy that should include natural assets and will help to reduce their vulnerability to climate change;
- inform on-the-ground implementation of natural asset conservation and restoration projects to help local communities to adapt to and mitigate the impacts of climate change;
- optimize infrastructure asset management decisions to ensure that services continue to be provided under climate change scenarios;
- incorporate triple-bottom-line considerations in community planning by looking at the economic, social and environmental benefits and costs of natural assets; and
- achieve their risk and vulnerability reduction goals as part of their climate change strategies.

Contents

Appendices

Figures

Tables

BUSINESS CASE FOR NATURAL ASSETS IN THE REGION OF PEEL

Business Case Model Guidance Document

Green Analytics Corp.

Report completed on: December 31, 2019

Submitted by:
Green Analytics
www.greenanalytics.ca

Guelph Office

41 Verney Street
Guelph, ON N1H 1N5
P. 226.820.0233
jeff.wilson@greenanalytics.ca

Head Office (Edmonton)

Unit 413, 3428 99 Street
Edmonton, AB T6E 5X5
P. 887.353.6835
contact@greenanalytics.ca

WWW.GREENANALYTICS.CA

1 Introduction

Green Analytics was commissioned by Credit Valley Conservation (CVC) to help build a business case for natural assets (BC4NA) in the Region of Peel. Natural assets are the stock of natural resources or ecosystems typically characterized by common ecosystem land cover types such as water, forests, wetlands, and grasslands. Natural assets also include air, soil, and the assemblage of flora and fauna that make up ecosystems. The stock of natural assets in a location produce a flow of valuable goods and services over time. For instance, a wetland (the stock) can absorb flood water, providing flood protection (the flow) to people and property downstream. These flows are referred to as ecosystem services. Ecosystem services are typically defined as the benefits people obtain from nature. They are measurable and result in improvements to human well-being. In the case of flood protection, for example, the benefit that can be measured is avoided flood damages.

The natural assets of the Region of Peel provide many ecosystem services to the people residing in the area. Services include improved air quality from the purifying effects of trees, reduced flood impacts by riparian areas, carbon storage and sequestration, recreational opportunities, clean water from the filtering effects of wetlands and forests, amenity benefits from natural landscapes and pollination benefits. These services are likely significant contributors to the health and well-being of the residents of the Region of Peel. Thus, it is imperative that they be taken into consideration when making land-use and resource development decisions. Their value should be measured, tracked and considered along with other, more traditional, assets (e.g. financial and infrastructure assets) to allow decision makers to make informed decisions about their management and use. Thus, the purpose of this study is to assess and value the natural assets within the Region of Peel taking a case study approach and to build a modelling framework and interactive tool to allow users to explore the business case for alternative natural asset management actions. The case study communities are Alton Village in Caledon and Mount Pleasant in Brampton. The key deliverables for the BC4NA project are:

- An **asset registry** that identifies and quantifies the natural assets within the study area
- A series of **spreadsheet models** for measuring the cost of natural asset management actions in relation to the value of services derived from the same natural assets
- A web-based **interactive dashboard** that summarizes the costs and benefits of natural asset management actions

The deliverables identified above build on each other. The asset registries are an input into the spreadsheet models. The spreadsheet models are an input into the interactive dashboard. This combination of deliverables is leading edge in the field of natural asset valuation and assessment. Combining a registry framework of the sort developed for this project with models and an online dashboard that demonstrate the business case for management actions is a first in Canada. The models and dashboard should thus be considered a starting place for future work in this area. Assumptions employed in the models, while sometimes crude, can be positioned as placeholders to be improved and refined in future iterations. The approach employed to achieve the deliverables above involved the following high-level tasks:

1. Natural assets within the case study areas were identified and quantified.
2. The services derived from the natural assets in the study areas were identified, quantified and valued (monetized) and built into an asset registry.

3. Key risks that could have negative impacts on the assets were identified.
4. Alternative management actions to overcome the risks were defined.
5. Enhancement opportunities to increase the quantity of natural assets and hence the services derived from them were identified.
6. The present value of the services from the assets under three management scenarios (Do Nothing, Maintain and Enhance) were estimated.
7. The present value of the costs of the management scenarios were estimated.
8. Benefit cost ratios for the management scenarios were estimated.

This report provides details on the approaches for each of the tasks identified above. It is organized as follows:

- Chapter 2 presents detailed results from the natural asset registries for the case study communities.
- Chapter 3 contains a general description of the condition assessment component of the business case and mentions . a prototype approach that CVC has developed for municipalities to rapidly assess the condition of existing natural assets[1].
- Chapter 4 is focused on the risk assessment and articulates the priority risks identified for the case study communities.
- Chapter 5 describes the approach employed to establish management actions for the communities given the risks under consideration.
- Chapter 6 presents the approach employed to establishing cost estimates for the management actions as well as the costs currently employed in the business case models.
- Chapter 7 is a brief overview of the business case for natural assets online dashboard.
- Chapter 8 presents a sample of results from the models demonstrating the business case for management actions.
- Chapter 9 discusses modelling limitations and identifies items that can be considered for future iterations of the business case models and dashboard.
- Chapter 10 contains a list of relevant references.
- Chapter 11 articulates the equations employed in the business case models providing details for each tab (worksheet) in the models.

[1] This approach is described in more detail in the Appendices A, B, and C of this report

2 Case Study Natural Asset Registries

As is noted above, the case study communities are Alton Village in Caledon and Mount Pleasant in Brampton. Figure 1 shows the location of the case study communities in the context of the CVC's jurisdictional boundaries.

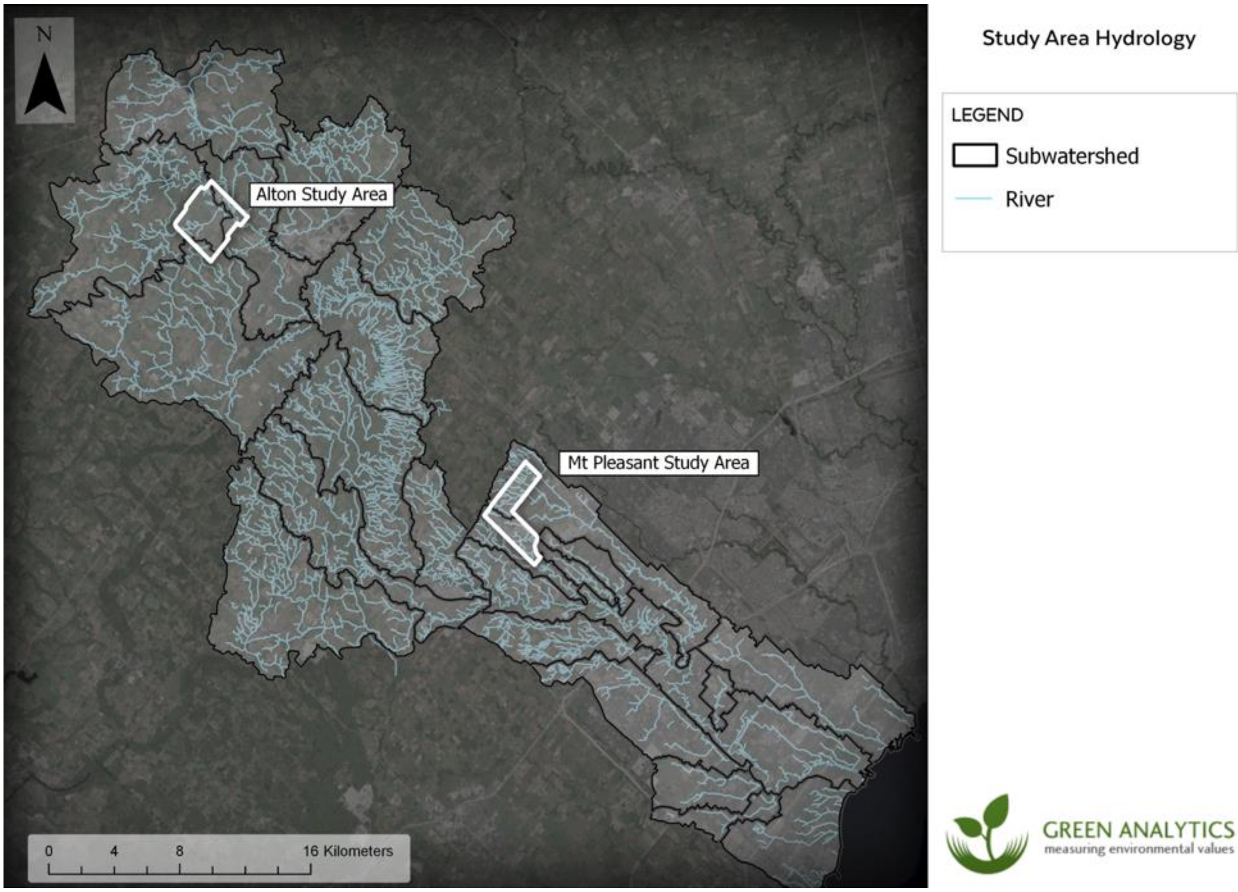


Figure 1. Location of the Case Study Areas

The approach to establishing the BC4NA began with the identification, quantification and valuation of natural assets within the case study areas. This section of the report presents the approach and findings used for the identification, quantification and valuation of the natural assets; the findings of which are contained in asset registries for each case study area. The figure below provides a general overview for the approach employed to create the asset registries. The steps in the approach are elaborated on in this document.

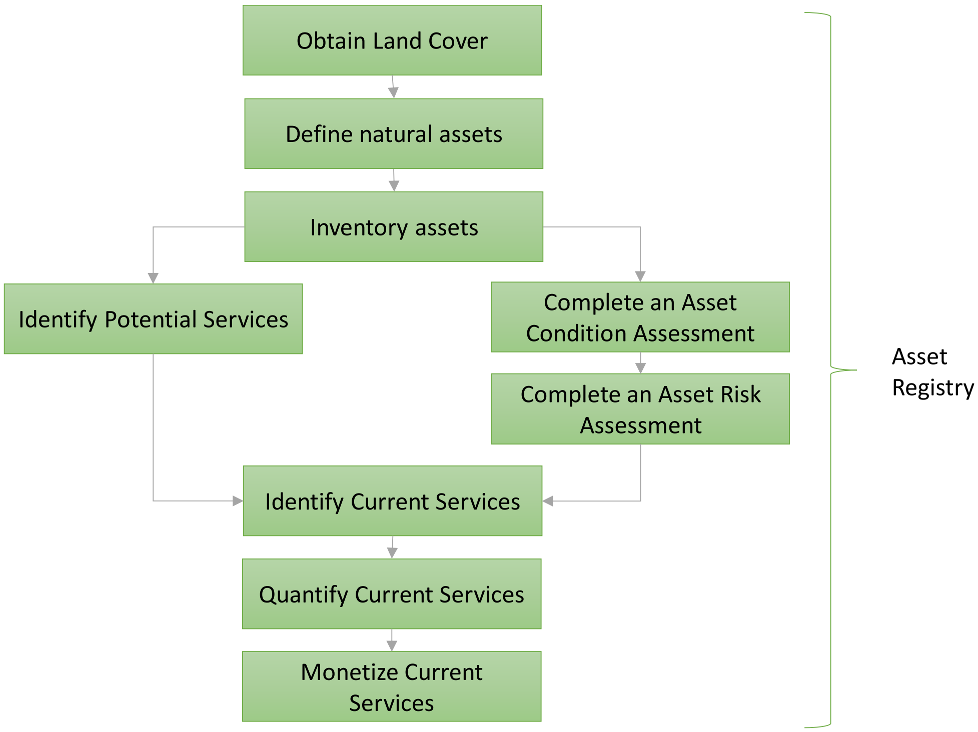


Figure 2. Overview of Approach for Creating a Natural Asset Registry

2.1 Defining Natural Assets

As a first step toward defining the natural asset accounts within the study area, a list of potential accounts was developed. The accounts were organized in keeping with the conceptual framework of the National Ecosystem Services Classification System (NESCS) - developed by the U.S. Environmental Protection Agency.[2] Figure 3 demonstrates the links between environmental goods and services and beneficiaries as captured by the NESCS framework.

In the NESCS, final ecosystem goods and services are captured as distinct pathways linking the ecological systems that produce ecosystem services to the human systems that directly use them. The NESCS uses the concept of the flow of final services that are generated through unique linkages between the supply of ecosystem services (generated by the environment and associated end-products) and the demand for ecosystem services (generated by specific direct use or non-use from specific user types). Using the NESCS, an accounting framework for the assessment and valuation of the natural assets in the two case study communities (Alton Village and Mount Pleasant) was developed.

[2] http://www.epa.gov/eco-research/national-ecosystem-services-classification-system-framework-design-and-policy

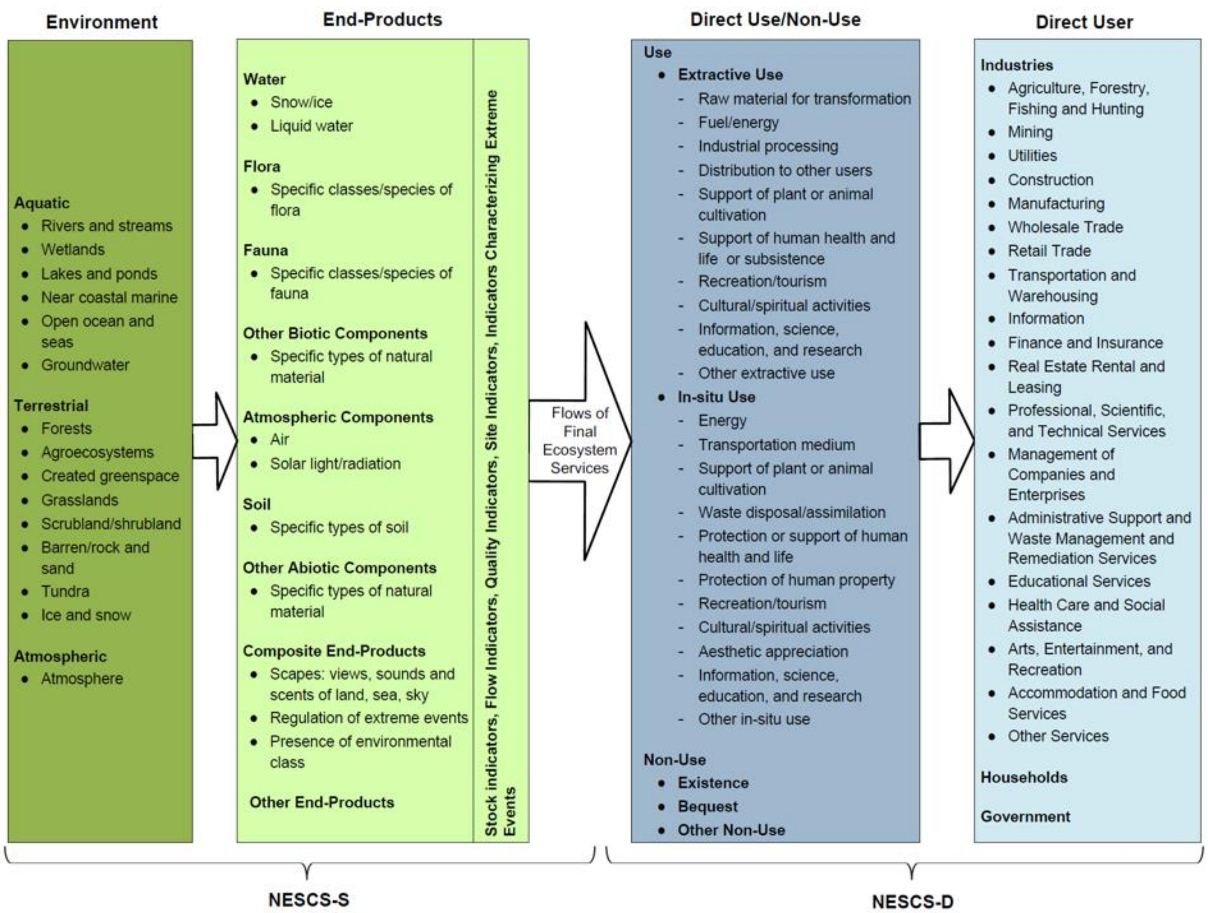


Figure 3. Depiction of the NESCS Linkages between Environmental Goods and Services (NESCS-S, where S=supply) and Beneficiaries (NESCS-D, where D=demand).

The ecological land classification (ELC) was used as the primary basis for defining the natural assets in the case study communities. Table 1 links ELC types with NESCS natural asset classes for all ELC types within CVC jurisdiction.

Table 1. Defining Natural Assets by ELC Type and by NESCS Environmental Subclass

ELC CODE	ELC TYPE	NESCS
AA	Active aggregate	NA
TPA	Airport	NA
TAS	Carbonate shrub talus	Scrubland/shrubland
TAT	Carbonate treed talus	Scrubland/shrubland
TPC	Collector	NA
CIC	Commercial / industrial	NA
MOC	Commercial / industrial open space	Created greenspace
FOC	Coniferous forest	Forest
CUP3	Coniferous plantation	Forest
SWC	Coniferous swamp	Wetland

CON	Construction	NA
CUH	Cultural hedgerow	Agroecosystem
CUM	Cultural meadow	Grassland
CUS	Cultural savannah	Grassland
CUT	Cultural thicket	Grassland
CUW	Cultural woodland	Grassland (or Forest)?
FOD	Deciduous forest	Forest
CUP1	Deciduous plantation	Forest
SWD	Deciduous swamp	Wetland
CII	Educational / institutional	NA
SAF	Floating-leaved shallow aquatic	Open water
URB	General urban	NA
URH	High density residential	NA
URR	High rise residential	NA
TPH	Highway	NA
AI	Inactive aggregate	NA
MOI	Institutional open space	Created greenspace
AGI	Intensive agriculture	Agroecosystem
LF	Landfill	NA
URL	Low density residential	NA
MT	Major trail	NA
MOS	Manicured open space	Created greenspace
MA	Marsh	Wetland
URM	Medium density residential	NA
FOM	Mixed forest	Forest
CUP2	Mixed plantation	Forest
URX	Mixed residential	NA
SAM	Mixed shallow aquatic	Open water
SWM	Mixed swamp	Wetland
AGN	Non-intensive agriculture	Agroecosystem
OAO	Open aquatic	Open water
BBO	Open beach / bar	Barren/rock and sand
BLO	Open bluff	Barren/rock and sand
CBO	Open clay barren	Barren/rock and sand
FEO	Open fen	Wetland
RBO	Open rock barren	Barren/rock and sand
SBO	Open sand barren	Barren/rock and sand
MOO	Other open space	Created greenspace
MOP	Private open space	Created greenspace
TPX	Railroad	NA

MOR	Recreational open space	Created greenspace
TPR	Regional road	NA
URE	Residential estate	NA
RD	Rural development	NA
BBS	Shrub beach / bar	Barren/rock and sand
BLS	Shrub bluff	Scrubland/shrubland
BOS	Shrub bog	Wetland
CBS	Shrub clay barren	Barren/rock and sand
FES	Shrub fen	Wetland
SAS	Submerged shallow aquatic	Open water
SWT	Thicket swamp	Wetland
BBT	Treed beach / bar	Barren/rock and sand
BLT	Treed bluff	Barren/rock and sand
BOT	Treed bog	Wetland
CLT	Treed cliff	Barren/rock and sand
FET	Treed fen	Wetland
WET	Wet meadow	Wetland

The detailed accounts for the natural assets and their associated services for the case study communities were housed in an asset registry database. The asset registry is an object-oriented database containing an organized framework of natural assets in Alton and Mt. Pleasant (the registry is housed in a mySQL database). This core registry is organized by asset polygons and sub-polygons which contain asset categories, subcategories, management actions, services, risk assessments and condition ratings.

In Alton, asset sub-polygon boundaries were dictated by the boundaries of the underlying ELC data. The ELC categories contained within Alton were aggregated to match the NESCS Land Cover categorization framework. Multiple sub-polygons may be combined to form a primary asset polygon.

In Mt. Pleasant, the sub-polygon boundaries were dictated by the approved block plan boundaries which represents the ultimate area of natural assets and allocation of residential, commercial, and institutional buildings[3].. Similar to Alton, multiple sub-polygons may be combined to form a primary asset polygon.

The various tables within the database contain linkages that allow for assets to be associated with their respective services, management actions, and risk and condition ratings. Additional tables exist to capture the outputs of the modelling scenarios, in which the output values flow back to the assets. Figure 4 demonstrates the asset registry configuration.

[3] Due to ongoing development of the area, this information was more up-to-date, and thus more applicable to define existing natural assets, than ELC data.

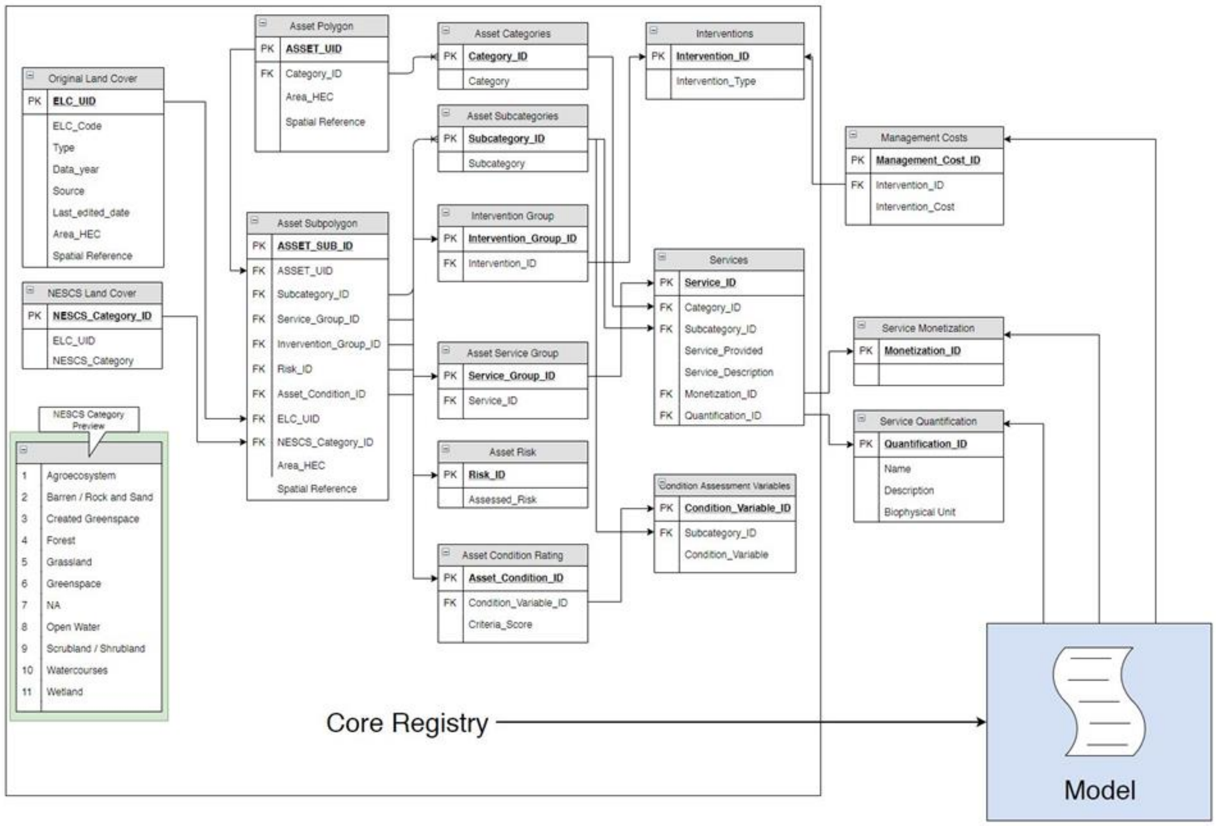


Figure 4. Configuration of the Natural Asset Registry Database

Table 2 lists the benefits provided by the natural assets that are included in the database. The table links the various benefits/services to municipal services. It also identifies quantification metrics and relevant natural assets.

Table 2. Benefits/Services Included in the Natural Asset Database

Benefit Provided by Natural Assets	Link to Municipal Service Provision/Policy Objectives	Quantification Metric	Relevant Natural Asset Types
Stormwater quantity reduction and quality improvement	Explicit link to stormwater management (SWM)	Estimate peak flow and total suspended solid reduction performance	Forests; wetlands; grassland
Recreation provision and tourism attraction	Supports parks and recreation services, can support municipal tourism objectives	Estimated number of visits	Forests; wetlands; grassland; greenspace Asset would be organized / defined around parks, trails, and other continuous areas of natural and semi-natural cover
	Link to public health through physical/mental wellbeing improvements	Estimated amount of physical exercise per resident	
Reduction of heat stress/urban heat island (Mt. Pleasant only)	Linked with public health and has a strong policy relevance to municipalities' climate change adaptation objectives	Estimate number of heat / cooling degree days	Forests, wetlands, greenspace, and other natural urban areas
Air quality improvement	Link to public health	Estimated pollutant concentration reduction	Forests, wetlands, greenspace, and other natural urban areas
Carbon sequestration	Strong policy relevance to climate change mitigation objectives	Tonnes of carbon sequestered	Forests; wetlands; grassland; pasture
Aesthetic appreciation	Strong link to tourism objectives and property tax collection	Property value increase	Forests; wetlands; grassland; greenspace Asset would be organized / defined around ravine areas, or other continuous stretches of natural cover

By utilizing a combination of the spatial data along with this database, the modelling and scenario results can be displayed in a user-friendly dashboard interface, which allows a user to make selections and easily visualize the modelling outputs through a mapping interface.

The asset registry contains monetized values for the services provided by the assets in the case study areas. The approaches used to establish the value of the specific services captured in the BC4NA are articulated below.[4] These value estimates were derived largely via benefit transfer, which involves applying existing values elicited at other sites, periods of time, or from different populations (known as the study site) to the site under study (known as the policy site). Such transfers are prone to error, as sites are inherently different, although they are necessary given limited resources to conduct original valuation research (see Trenholm et al. (2019) for a recent transfer assessment in Southern Ontario, although in the

[4] See Chapter 11 for more detail on how these values were applied in the Alton and Mt. Pleasant case studies.

context of transfers of Willingness to Accept[5]). Note however, that transfer error can be reduced by using values from similar sites or contexts, such as jurisdictions (Boyle et al. (2010), among others, provide guidance). Furthermore, test-retest studies provide evidence for valid and reliable transfers across time (these studies test the similarity of values estimated at different points in time). To date, the longest intervals used in test-retest show stable values across 30 years for recreational willingness to pay elicited via a contingent valuation survey and 8 years for drinking water quality willingness to pay elicited via a choice experiment survey (Price et al. 2016; Neher et al. 2017)[6]. Despite this evidence, the use of transfers is a limitation. If the resources become available for original valuation research in the region, then these values may be substituted for those discussed in this report. Alternatively, a meta-analysis could be conducted for each service as this approach to benefit transfer is potentially less prone to error. Both were beyond the scope or resources allocated to the current project.

2.1.1 Carbon Sequestration

- Annual sequestration rates per hectare (tonnes C/hectare) for different land cover types were determined after a review of the literature[7].
- Sequestration rates by land cover type were applied to the area of land for each land cover type (Table 3 and Table 4 for Alton and Mount Pleasant, respectively).

Table 3. Sequestration Rates by Land Classification for Alton

ELC_CODE	NESCS	Sequestration (tC/HA/yr)
CUW	Grassland	1.19
SWD	Wetland	4.73
CUM	Grassland	0.53
SWM	Wetland	2.06
CUS	Grassland	0.53
SWT	Wetland	2.02
CUP3	Forest	1.19
CUT	Grassland	0.53
FOC	Forest	1.29
MA	Wetland	2.06
SWC	Wetland	2.06
FOM	Forest	1.23
FOD	Forest	1.55
WET	Wetland	2.06

[5] This is a stated preference method for valuation of ecosystem services which involves hypothetical questions to identify people's preferences and collective "willingness to accept" compensation for loss of services.
[6] Transfers across time are unavoidable. For instance, Rosenberger's (2016) Recreation Use Values Database, which is used for benefit transfers, contains studies dating back to 1958 (though most are from the 1980's onward), while Haider et al. (2019) use willingness to pay values elicited via choice experiment in Metro Vancouver in the early 2000's to value reductions in visual air quality in B.C.'s Lower Mainland during several subsequent forest fire seasons.
[7] Sources include Bernal and Mitsch (2012), Wotherspoon et al. (2013), Foote and Grogan (2009), Sun et al. (2016), Smith et al. (2001), Lal (2007), Akala and Lal (2000), City of Toronto (2013), Mitsch et al. (2011), Anderson and Mitsch (2006), Lu et al. (2015), Peichl et al. (2006), Thevathasan and Gordon (2004), Winans et al. (2015), Bruce et al. (1999), and Olbermann et al. (2006).

Table 4. Sequestration Rates by Land Cover Type for Mount Pleasant

Cover	Sequestration (tC/HA/yr)
Woodland	1.32
Wetland	2.50
Grassland/Meadow	0.70

- A forecast social cost of carbon per tonne of carbon sequestered ($/tonne) was obtained from Environment and Climate Change Canada (2016)[8] (Table 5).

Table 5. Forecast Social Cost of Carbon (2018 CAD)

Year	Calendar Year	Social Cost of Carbon (per tC)
1	2020	$182
2	2021	$186
3	2022	$190
4	2023	$193
5	2024	$197
6	2025	$201
7	2026	$205
8	2027	$208
9	2028	$212
10	2029	$216
11	2030	$220
12	2031	$224
13	2032	$228
14	2033	$232
15	2034	$236
16	2035	$240
17	2036	$245
18	2037	$249
19	2038	$253
20	2039	$257

- A per hectare value of carbon sequestration in a given year for a given land cover type in the study areas was calculated by taking the product of the carbon sequestration rates, from Tables 3 and 4, and the per unit price of carbon from Table 5.

2.1.2 Recreation

- Per hectare dollar values for recreation associated with certain land covers were obtained from Voigt et al. (2013), a report prepared for the Ontario Ministry of Natural Resources.
- Values applied from this report were for suburban forests ($2,045.75), urban/suburban fresh wetlands ($10,447.06), as well as for grassland / pasture ($78.29). All values were in 2018 Canadian dollars and did not differ by study site.

---

[8] The social cost of carbon is a monetary measure of the global damage expected from climate change from the emissions of an additional tonne of carbon dioxide in the atmosphere in a given year. For the purposes of this study, tonnes of carbon dioxide were converted to tonnes of carbon using equivalent mass. Moreover, a 3% discount rate was applied to these values and they were inflated to 2018 CAD values. See Environment and Climate Change Canada (2016) for more information.

- The per hectare values for recreation were applied to the total area of each relevant land cover type within the case study areas as listed in Tables 6 and 7 for Alton and Mt. Pleasant, respectively.

Table 6. Recreation Values by Land Cover for Alton[a]

Land Cover Type		Value
NESCS Code	ELC Code	
Grassland	CUW, CUM, CUS, CUT	$78.29
Wetland	SWD, SWM, SWT, MA, SWC, WET	$10,447.06
Forest	CUP3, FOC, FOM, FOD	$2,045.75

[a] Spatial data beyond the codes in this table was not available.

Table 7. Recreation Values by Land Cover for Mt. Pleasant[a]

Land Cover Type	Value
Grassland/Meadow	$78.29
Wetland	$10,447.06
Woodland	$2,045.75

[a] Spatial data beyond the land cover types in this table was not available.

2.1.3 Air Quality

- Per hectare dollar values of air quality improvements linked to forested assets were derived from an existing Air Quality Benefits Assessment Tool (AQBAT) analysis conducted by the CVC for 5%, 25%, and 50% changes in the forested area of Fletcher's Creek watershed from 2019 to 2061 (Julien Gordon, personal communication, June 28, 2019). For this analysis, a medium population growth was assumed.
- These values were obtained for each percent change in forested area by averaging the annual per hectare values of the total value of improved health across the years of the analysis resulting from reductions in multiple pollutants (CO, NO_2, O_3, PM2.5, and SO_2). The average annual per hectare value calculated for each pollutant was then summed together yielding an average for reductions in all pollutants (Table 8).

Table 8. Deriving Air Quality Values from CVC's AQBAT Model of Fletcher's Creek[a]

Pollutant	Value by Increase in Forest Cover					
	5% (213.9 Hectares)		25% (1,069.5 Hectares)		50% (2,139 Hectares)	
	Total Value	Annual Mean	Total Value	Annual Mean	Total Value	Annual Mean
CO	$49,714	$1,156	$254,472	$5,918	$520,089	$12,095
NO_2	$123,520,246	$2,872,564	$617,520,745	$14,360,948	$1,228,873,738	$28,578,459
O_3	$960,688,686	$22,341,597	$4,809,120,999	$111,840,023	$9,584,630,220	$222,898,377
PM2.5	$607,019,498	$14,116,733	$3,041,639,422	$70,735,801	$6,060,856,289	$140,950,146
SO_2	$52,618,103	$1,223,677	$261,394,977	$6,078,953	$525,782,536	$12,227,501
Sum	**$1,743,896,247**	**$40,555,727**	**$8,729,930,616**	**$203,021,642**	**$16,874,880,336**	**$404,666,578**
Annual / HA	**$189,601**		**$189,829**		**$189,185**	

[a] The time horizon used for the AQBAT analysis was from 2019 to 2061

- The values resulting from each of the three percent changes in forest cover were then averaged yielding a single average annual per hectare value of $189,538.28 (2018 Canadian dollars) that was applied to forested parcels. This value was applied to Alton and Mt. Pleasant.

2.1.4 Stormwater

- Annual per hectare dollar values of stormwater infiltration and retention of open green space, wetland, and forest — given the existing climate — were obtained from a local pilot study by CVC (2018). For the pilot study on stormwater capacity of natural assets in Ontario's Peel Region, CVC (2018) rely on replacement cost values of $175 per m^3 of stormwater estimated for replacing natural asset stormwater services in Gibsons, B.C. with detention ponds (capital costs) for palustrine and riverine wetlands, as well as forests and open space. For isolated wetlands they estimate the replacement cost at $460 per m^3 of stormwater which represents the lifecycle cost of an infiltration chamber (assessed via the Low Impact Development Lifecycle Costing Tool).[9] They then convert these to a values per hectare (Table 9). This per hectare value was converted to an annual amount by amortizing these amounts over the effective life of detention ponds or infiltration chambers.
- Bélanger (2008) reports on the effective life of various landscape strategies for dealing with urban stormwater in Toronto; they report an effective life of between 20 and 50 years for detention ponds. Though they do not report on infiltration chambers, they report the that the lifespan for an infiltration trench, which is a similar stormwater infrastructure, ranges from 5 to 10 years. The midpoint of the range for stormwater detention ponds — 35 years — was employed as the amortization period of the capital costs of constructing stormwater detention ponds, while the midpoint of 7.5 years was applied for infiltration chambers. It was assumed that capital costs are distributed equally across the years of the pond's effective life.
- In addition, Bélanger (2008) notes minimal operation and maintenance costs for detention ponds so these are not included in annual estimates. The cost estimate of CVC (2018) for the infiltration chamber should include these costs since they were estimated via a lifecycle costing tool.

Table 9. Stormwater Capacity Values

Asset Type	Existing Climate		Projected Climate	
	Hectare	Hectare / Year	Hectare	Hectare / Year
Forests	$61,425	$1,755	$68,075	$1,945
Open Green Spaces	$22,050	$630	$23,450	$670
Wetlands				
Palustrine	$43,050	$1,230	$45,850	$1,310
Isolated	$81,213	$10,828	$92,306	$12,307
Riverine	$3,850	$110	$4,200	$120

- For Alton, the wildfire spatial data did not contain information on the specific types of wetland. In this case an average of the three per hectare wetland values in Table 9, $4,056.13 per hectare per year for the existing climate, was used to estimate the value of wetland stormwater services.

[9] https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/low-impact-development/low-impact-development-life-cycle-costs/

2.1.5 Real Estate

- Per hectare dollar values for the influence of assets on local real estate prices were derived by transferring relationships from three studies on the value of generic open space, parks, or natural areas (Bolitzer and Netusil 2000; Acharya and Bennett 2001; vom Hoffe et al. 2018). These relationships were in terms of % change in a property's value given a change in the area of open space in a circular buffer surrounding the property.[10]
    - Bolitzer and Netusil (2000) assessed the influence of urban and suburban open space, from an inventory of natural areas within 457m of single family dwellings in Portland, OR.
    - Acharya and Bennett (2001) assessed the influence of multiple types of open space within 1,600m of single family dwellings in New Haven County, CT.[11]
    - vom Hoffe et al. (2018) assessed the influence of all types of urban and suburban parks within 500m of single family dwellings in Cincinnati, OH.
- Independent analyses were completed for Alton and Mt. Pleasant. For each community, three distinct values were estimated for general open space using the relationships from the aforementioned studies and then an average of these values was calculated. The analyses for Alton and Mt Pleasant proceeded as follows:
    - The area of natural assets in the buffer of each affected dwelling was calculated using GIS[12]
        - To maintain some consistency with the source studies, dwelling types included detached, semi-detached, and townhouses (or similar). Apartment-style dwellings were excluded.
    - Dwelling values were estimated using average sales prices for each relevant dwelling type sold in 2018 for Caledon and Brampton (Brampton Real Estate Board 2018).
    - For each affected dwelling, the share of the price associated with the area of assets in its buffer was estimated by applying the relationship from each of the three studies identified above (% change in price given change in open space area).
    - The total real estate value of the assets in the study sites was calculated by summing these per property values.
    - A per hectare dollar value was calculated by dividing this total value by the area of the assets.
    - An average per hectare dollar value was calculated by taking the mean of the estimates arrived at via the three studies yielding $27,390.67 for Alton and $321,883.92 for Mt. Pleasant (2018 Canadian dollars).
- Due to the nature of the source studies obtained, the estimated value does not differentiate between the type of asset (i.e., forest, wetland, and meadow are treated the same).

---

[10] DSS Management Consultants Inc (2009) transferred a hedonic relationship from Minnesota when valuing upland greenspace and ravines in the Credit River watershed. Since these values are estimated using linear distance of a property from these natural features they are not on a per hectare basis that is required for input into the current study.

[11] Open space included: turf/grass; soil/grass/hay; grass/hay/pasture; soil/corn; soil/ tobacco; grass/tobacco; deciduous forest; coniferous forest; deep water; shallow water; nonforested wetland; bare soil; low coastal marsh; and high coastal marsh.

[12] An affected dwelling is a structure whose buffer intersects with the natural assets in either Alton or Mt Pleasant. Affected dwellings may include those outside of these sites whose buffer intersects with the assets Alton or Mt Pleasant as their values are also influenced by these assets.

2.1.6 Urban Heat Island

- Per hectare dollar values for the influence of assets on air temperatures were derived by first estimating an asset's influence on daily high air temperatures as per Kroeger et al. (2018) and then valuing this influence by estimating the reduction in heat-related mortality and applying the value of a statistical life.
- Kroeger et al. (2018) use a comprehensive review of the literature to determine a green space's cooling intensity in Celsius as a function of its size (change in maximum daily temperature) as well as how this cooling influences air temperatures in adjacent areas during June, July, and August. They use this information to assess the return on investment in terms of urban cooling related to tree planting in multiple American cities (including those in the Midwest and Northeast regions adjacent to Southern Ontario).
    - While Kroeger et al.'s (2018) focus is on planting trees, in many cases their source data on cooling intensity is derived from studies that compare air temperatures in parks or similar areas made up of multiple types of land cover to adjacent urban reference points (the mean cooling intensity could be thought of as the average intensity of multiple covers). Thus, the business case assessment uses this data to represent cooling intensity for all types of assets in the case study areas.
- The valuation of assets for urban heat reduction in Alton and Mt Pleasant proceeded as follows:
    - Since cooling intensity and cooling influence on adjacent areas is related to green space size, connected natural assets were joined to create continuous conglomerations of assets.
    - These conglomerations were grouped into four size classes according to their "park width distance" which is the square root of the conglomeration's area.
        - Size Class 1: <30m
        - Size Class 2: 30m to <90m
        - Size Class 3: 90M to <270m
        - Size Class 4: 270m or more
    - Each size class has a different cooling intensity within its boundaries as well as area of influence beyond the conglomeration's edge. The latter is represented as the mean percent cooling intensity remaining in three buffers: a 'high' intensity buffer immediately adjacent to the conglomeration; a 'medium' intensity buffer surrounding the high intensity buffer; and a 'low' intensity buffer surrounding the medium intensity buffer (Table 10).

Table 10. Buffer Dimensions and Cooling Intensity by Size Class

Size Class	Buffer Dimensions (metres from asset edge)			Cooling Intensity			
	High	Medium	Low	In Asset	Buffer: High	Buffer: Medium	Buffer: Low
1	0 to 30	None	None	1.055 °C	39%	n/a	n/a
2	0 to 30	30< to 40	40< to 50	2.143 °C	49%	27%	20%
3	0 to 50	50< to 80	80< to 160	2.445 °C	59%	40%	26%
4	0 to 150	150< to 250	250< to 500	3.283 °C	59%	40%	26%

- Each conglomeration was buffered according to the dimensions in Table 10 via GIS.
- The number of residential units in each conglomeration and buffer was calculated via GIS based on the location of existing buildings within the conglomeration and buffer.[13]
- The change in maximum daily air temperatures in June, July, and August for each residential unit attributable to the assets was assigned according to the cooling intensities in Table 10. There are 14 different cooling intensities depending on the size class, buffer, and whether a residence is in the asset.[14]
- A dollar value was assigned to this temperature change:
  - The cooling intensity of the assets was linked to a reduction in mortality using Ontario-specific information from Chen et al. (2016) which was then valued using the Treasury Board Secretariat of Canada's (2007) value of a statistical life.
    - The population of households in each patch and buffer was estimated by multiplying the number of residences by the average household size for the agglomerated dissemination area in which the site is contained (Statistics Canada 2019).
    - The number of non-accidental deaths per year in each buffer was estimated by multiplying the estimated population by the five year average of the rate of non-accidental death for Ontario (Statistics Canada 2019).
    - The reduction in non-accidental deaths attributable to the assets was estimated by multiplying the relevant temperature reduction by the change in non-accidental mortality related to an increase in maximum temperature (2.2% per 5 °C increase) from Chen et al. (2016).
    - This change in accidental deaths was valued by applying the Treasury Board Secretariat of Canada's (2007) value of a statistical life ($6.11 million in 2004 CAD [inflated to 2018]).
  - A per hectare value of urban cooling attributable to natural assets at each site was calculated by dividing the total value, obtained via either approach, by the area of the assets at the site, yielding $1,239.87 for Alton and $16,948.75 for Mt. Pleasant (2018 Canadian dollars).

The asset registry is used to generate a series of outputs that depict and describe the assets and their services. Such outputs are presented below for each community.

2.2 Natural Assets in Alton

The subwatersheds surrounding the Alton case study are largely made up of agroecosystems (Figure 5).

[13] There will be a degree of error associated with this approach for Mount Pleasant given that the natural assets were quantified based on the approved plan while the number of buildings is based on existing buildings, not approved .
[14] In certain cases a residence may fall within more than a single buffer. In this case the residence was assigned to the size class buffer yielding the largest reduction in temperature. We assume that there are no larger decreases in temperature resulting from interactions of buffers.

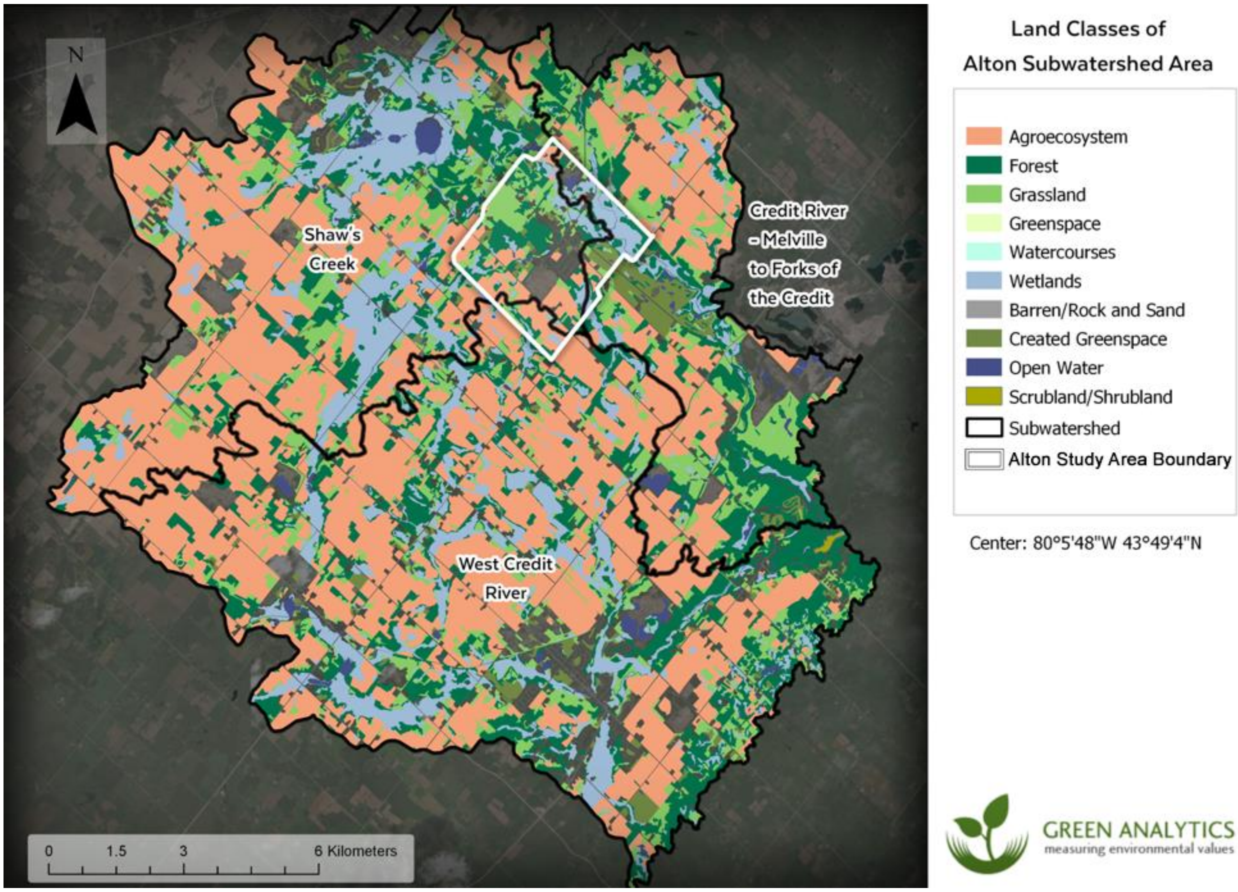


Figure 5. Alton Village Study Area and Associated Subwatersheds.

Within the case study area, the land is characterized by a range of land cover types including grasslands, forests and agroecosystems (Figure 6).

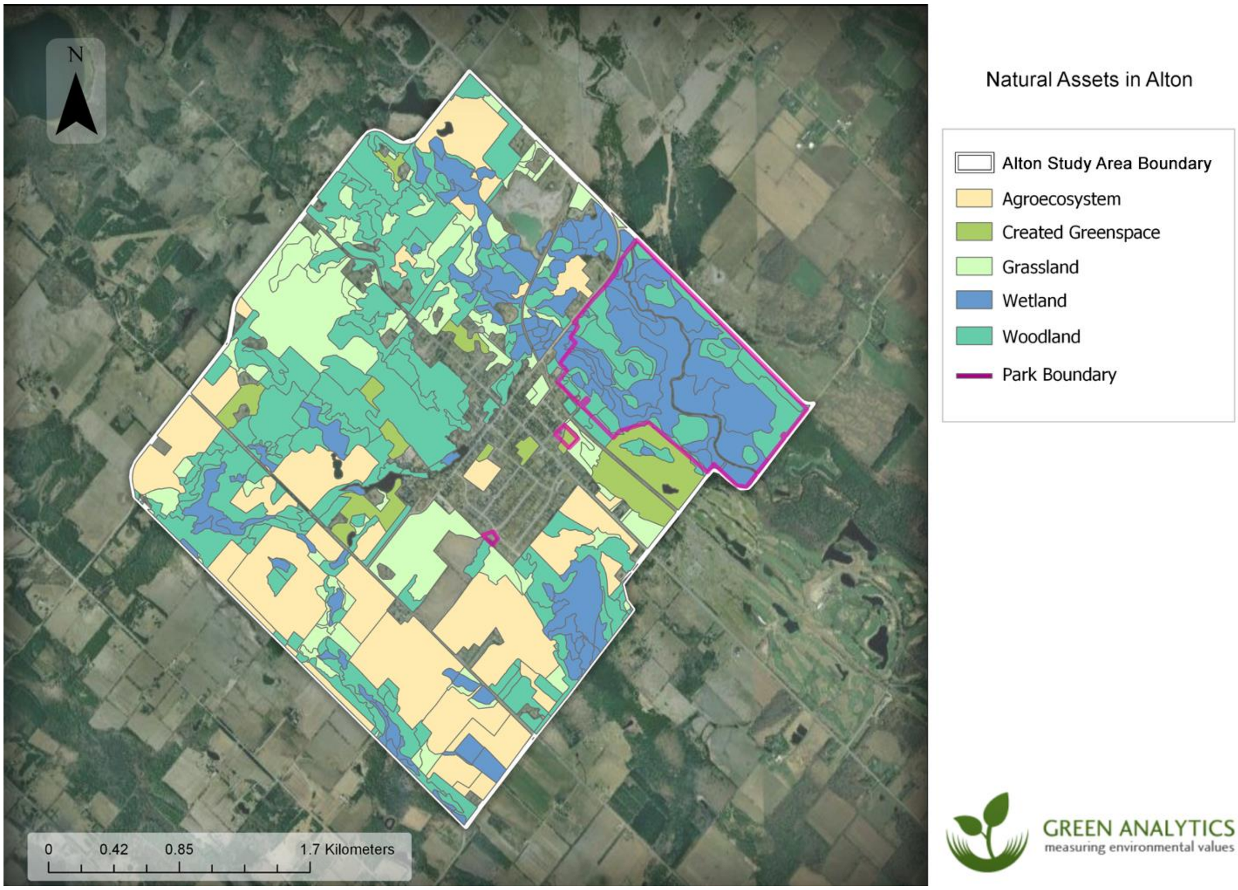


Figure 6. Natural Assets Within the Alton Village Study Area

2.2.1 Stormwater

Stormwater assets for Alton are demonstrated in Figure 7 and are comprised of a combination of wetlands, woodlands and open greenspace.

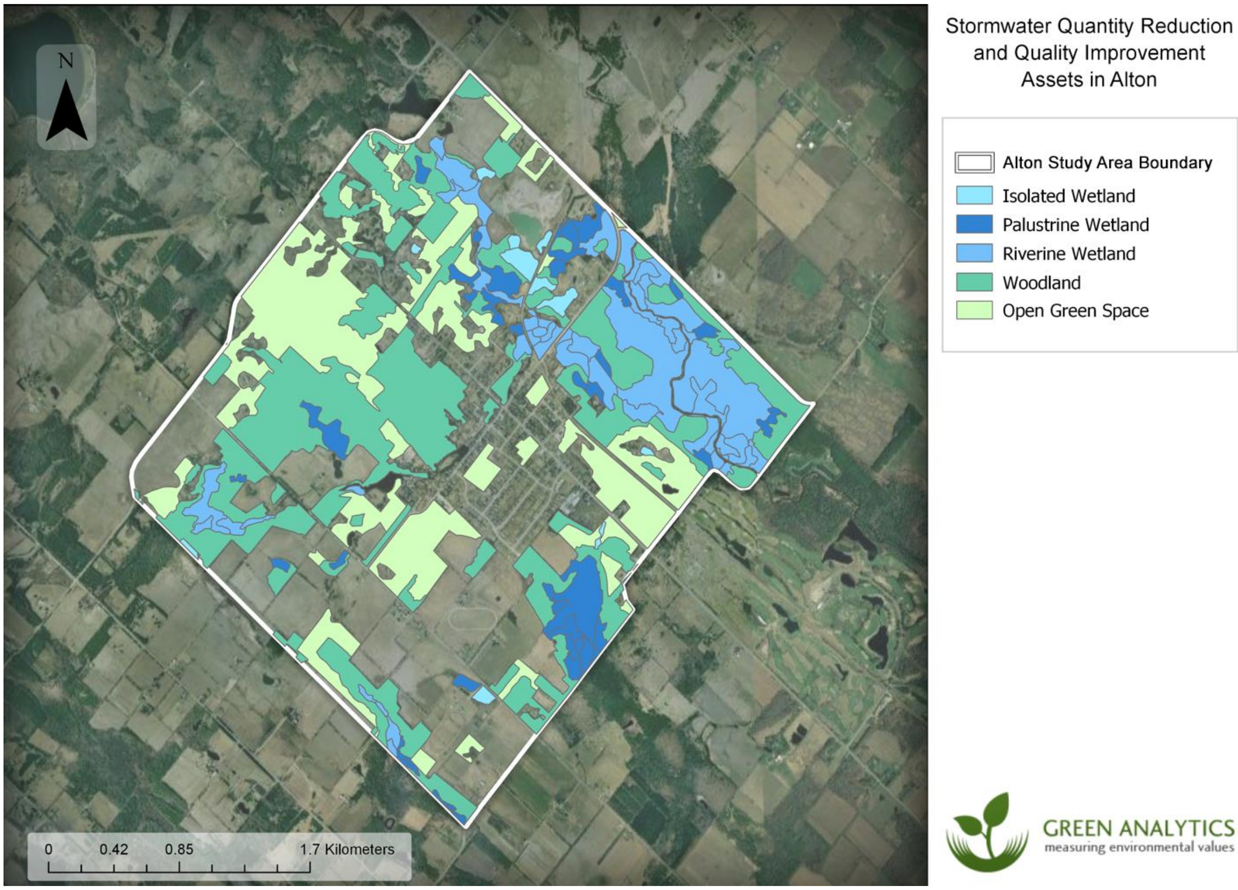


Figure 7. Stormwater Assets in Alton

Table 11 equates the natural assets presented above into area (hectares) and value (millions of dollars).

Table 11. Area and Value of Stormwater Services Provided by Natural Assets in Alton

Asset Type	Count of Asset Polygon	Total Area of Assets (ha)	Value of Service ($ Millions)
Woodland	52	278	52.9
Isolated Wetland	11	10	28.1
Palustrine Wetland	40	51	5.5
Riverine Wetland	50	108	93.0
Open Space	32	195	88.2

2.2.2 Air Quality and Urban Heat Reduction

Air quality assets, which are comprised of forested lands, for Alton are demonstrated in Figure 8.

Figure 8. Air Quality Assets in Alton

The forest, wetlands, and created greenspace assets that deliver reductions in heat stress/urban heat islands are depicted in Figure 9.

Figure 9. Heat Stress/Urban Heat Island Reduction Assets in Alton

Table 12 equates the forest assets presented in the figures above into area (hectares) and value.

Table 12. Area and Value of Air Quality and Heat Stress Reduction Services Provided by Natural Assets in Alton

Asset Type	Count of Asset Polygon	Total Area of Asset (ha)	Value of Air Quality Service ($ per year)	Value of Heat Reduction Service ($ per year)
Forest	159	322	25,760	1,240

2.2.3 Carbon Sequestration

Carbon sequestration assets for Alton are demonstrated in Figure 10. They are comprised of a combination of grasslands, wetlands, woodlands, agroecosystems and forests.

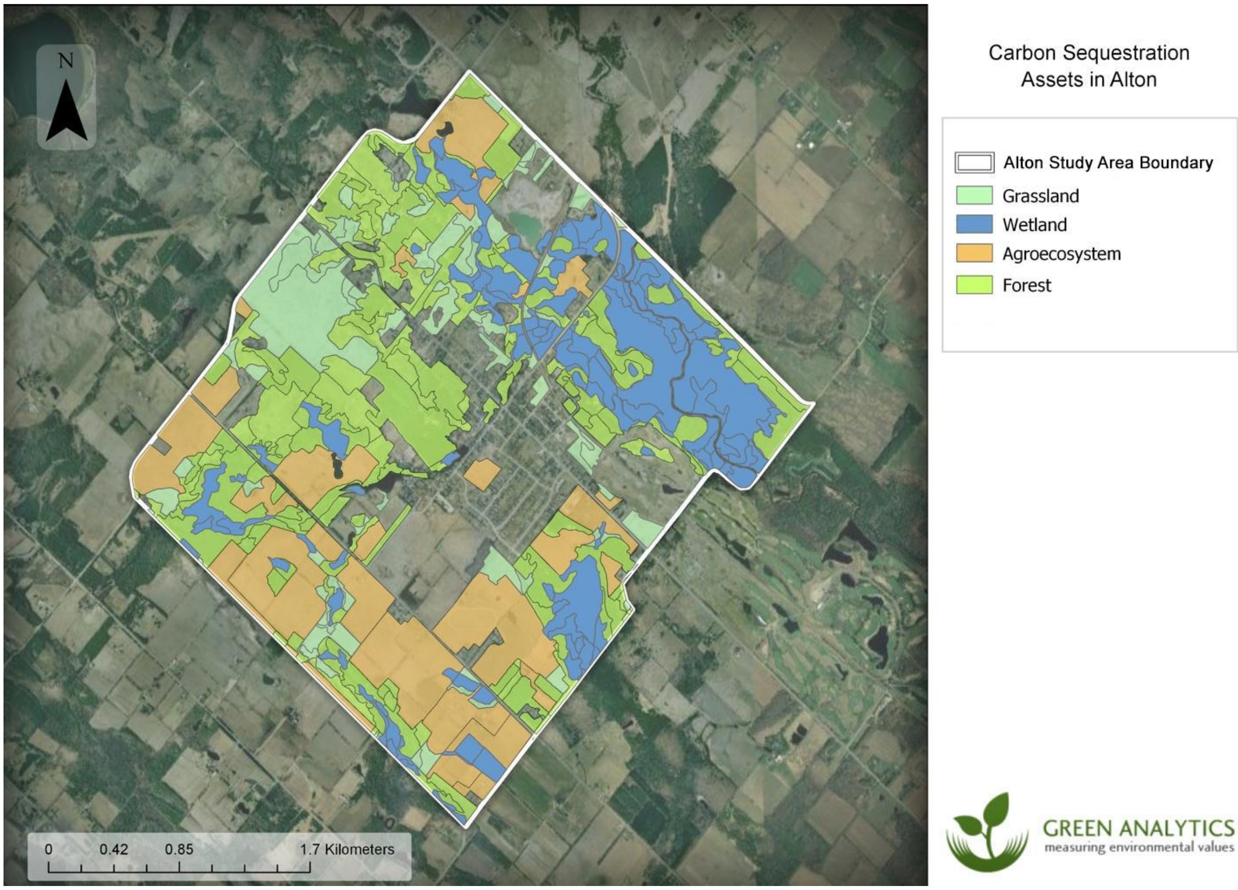


Figure 10. Carbon Sequestration Assets in Alton

Table 13 equates the natural assets presented in the figure above into area (hectares) and value, demonstrating the value the natural assets provide in terms of carbon sequestration.

Table 13. Area and Value of Carbon Sequestration Services Provided by Natural Assets in Alton

Asset Type	Count of Asset Polygon	Total Area of Asset (ha)	Service Value ($ per year)
Agroecosystems	30	229	18,333
Forest	159	322	38,860
Grassland	66	115	9,268
Wetland	107	179	60,937

2.2.4 Recreation

Recreation assets, which are comprised of city parks, for Alton are demonstrated in Figure 11.

Figure 11. Recreation Assets in Alton

Table 14 equates the natural assets presented in the figure above into area (hectares) and value, demonstrating the value of the recreation services provided by city parks in Alton.

Table 14. Area and Value of Recreation Services Provided by Natural Assets in Alton

Asset Type	Count of Asset Polygon	Total Area of Asset (ha)	Service Value ($ per Year)
Parks	3	133	28,728

2.2.5 Property Value

Aesthetic appreciation assets for Alton are demonstrated in Figure 12. They are comprised of a combination of created greenspace, grasslands, forests, open water and wetlands.

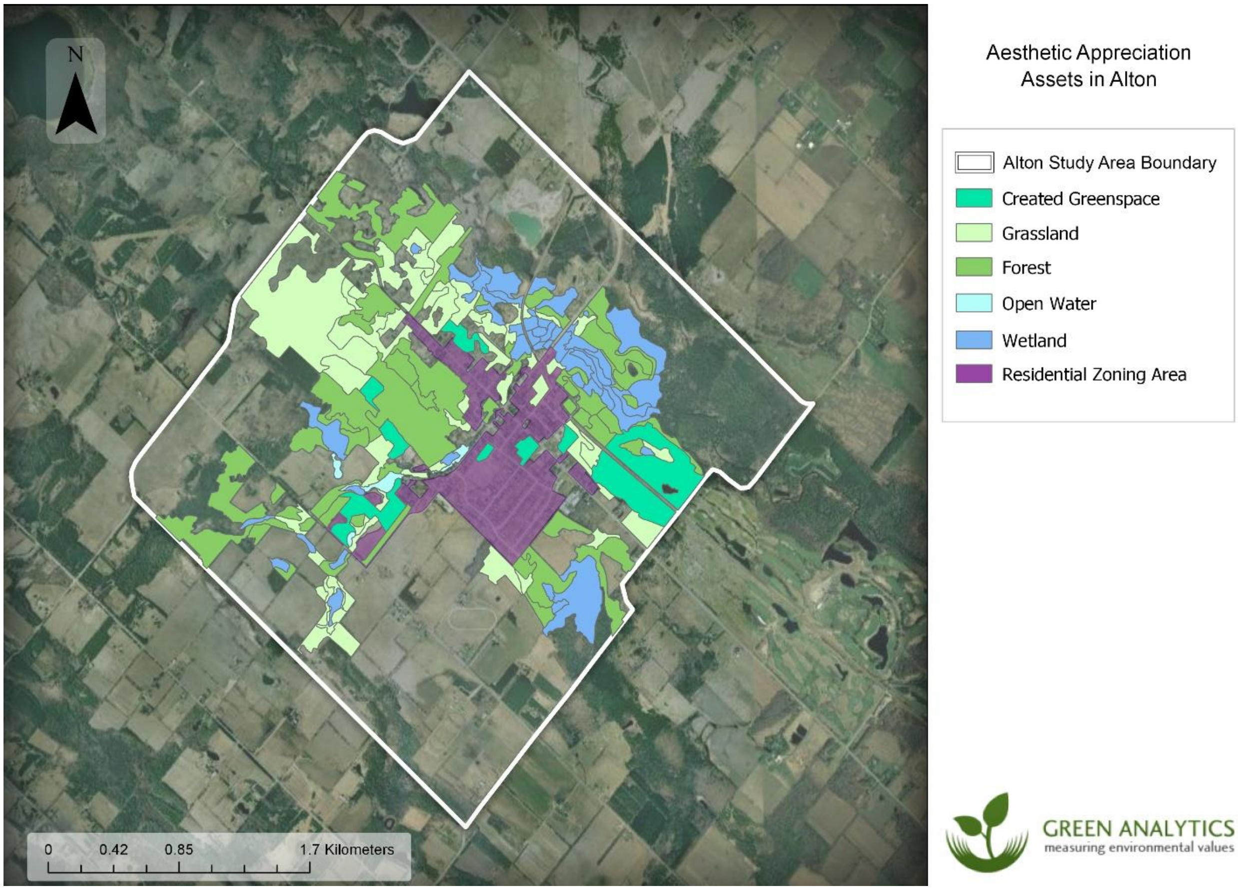


Figure 12. Aesthetic Appreciation Assets in Alton

Table 15 equates the natural assets presented above into area (hectares) and value.

Table 15. Area and Value of Aesthetic Appreciation Services Provided by Natural Assets in Alton

Asset Type	Total Are of Asset (ha)	Service Value ($ per Year)
Created Greenspace	42	174,264
Forest	150	620,341
Grassland	113	468,836
Open Water	4	14,914
Wetland	63	263,235

2.3 Natural Assets in Mount Pleasant

Relative to the Alton case study, the Mount Pleasant case study is more urban in nature. A large created greenspace is located within the Mount Pleasant case study. The case study community is fairly representative of the surrounding subwatersheds, which are characterized by wetlands, forests and grasslands as well as numerous created greenspaces (Figure 13). While Figure 13 depicts the current land cover based on the most recent ecological land classification data, some existing areas are planned for development.

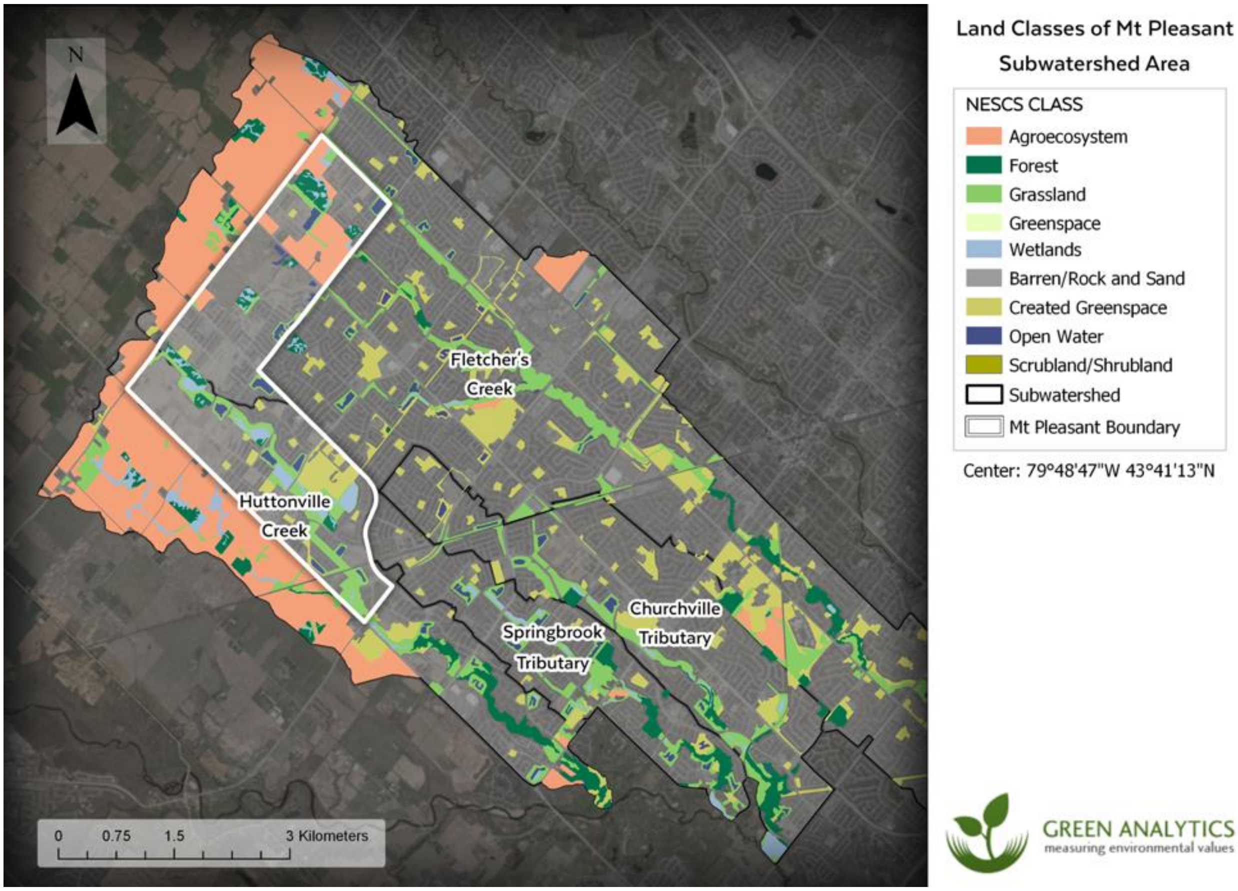


Figure 13. Mount Pleasant Study Area and Associated Subwatersheds.

Land cover types that are prominent in the Mount Pleasant case study include grasslands, created greenspace, wetlands, and woodlands (Figure 14).[15]

Figure 14. Natural Assets Within the Mt. Pleasant Study Area

[15] Based on the approved plan for Mount Pleasant.

2.3.1 Stormwater

Storm water assets for Mount Pleasant are demonstrated in Figure 15 and are comprised of a combination of wetlands, woodlands and open space. The final approved plan for the Mount Pleasant area is used to define assets for this case study community.

Figure 15. Stormwater Assets in Mount Pleasant

Table 16 equates the natural assets presented above into area (hectares) and value (millions of dollars).

Table 16. Area and Value of Stormwater Services Provided by Natural Assets in Mount Pleasant

Asset Type	Count of Asset Polygon	Total Area of Asset (ha)	Service Value ($ millions)
Woodland (Forest)	23	37	5.1
Wetland (Isolated)	27	9	20.8
Wetland (Palustrine)	46	25	2.5
Open Space	16	67	26.6

2.3.2 Air Quality and Urban Heat Reduction

Air quality assets, which are comprised of woodlands, for Mount Pleasant are demonstrated in Figure 16.

Figure 16. Air Quality Assets in Mount Pleasant

Table 17 equates the natural assets presented above into area (hectares) and value.

Table 17. Area and Value of Air Quality Services Provided by Natural Assets in Mount Pleasant

Asset Type	Count of Asset Polygon	Total Area of Asset (ha)	Service Value ($ per year)
Woodland	23	27	2,960

The forest, wetlands, and created greenspace assets that deliver reductions in heat stress/urban heat islands are depicted in Figure 17.

Figure 17. Heat Stress/Urban Heat Island Reduction Assets in Mount Pleasant

Table 18 equates the forest assets presented in the figures above into area (hectares) and value.

Table 18. Area and Value of Heat Stress Reduction Services Provided by Natural Assets in Mount Pleasant

Asset Type	Count of Asset Polygon	Total Area of Asset (ha)	Service Value ($ per year)
Woodland	23	37	45,875
Wetland	30	30	37,196
Grassland	23	37	45,875

2.3.3 Carbon Sequestration

Carbon sequestration assets for Mount Pleasant are demonstrated in Figure 18. They are comprised of a combination of grasslands, wetlands and woodlands.

Figure 18. Carbon Sequestration Assets in Mount Pleasant

Table 19 equates the natural assets presented above into area (hectares) and value.

Table 19. Area and Value of Carbon Sequestration Services Provided by Natural Assets in Mount Pleasant

Asset Type	Count of Asset Polygon	Total Area of Asset (ha)	Service Value ($ per Year)
Woodland	23	37	4,477
Grassland	23	37	6,960
Wetland	30	30	19,123

2.3.4 Recreation

Recreation assets, which are comprised of parks, for Mount Pleasant are demonstrated in Figure 19.

Figure 19. Recreation Assets in Mount Pleasant

Table 20 equates the natural assets presented above into area (hectares) and value.

Table 20. Area and Value of Recreation Services Provided by Natural Assets in Mount Pleasant

Asset Type	Count of Asset Polygon	Total Area of Asset (ha)	Service Value ($ per Year)
Parks	24	55	111,430

2.3.5 Property Value

Aesthetic appreciation assets for Mount Pleasant are demonstrated in Figure 20. They are comprised of a combination of grasslands, parks, wetlands and woodlands.

Figure 20. Aesthetic Appreciation Assets in Mount Pleasant

Table 21 equates the natural assets presented above into area (hectares) and value.

Table 21. Area and Value of Aesthetic Appreciation Services Provided by Natural Assets in Mount Pleasant

Asset Type	Count of Asset Polygon	Total Are of Asset (ha)	Service Value ($ per Year)
Wetland	30	30	124,470
Woodland	23	37	153,513
Grassland/Meadow	103	87	360,963
Parks	24	55	228,195

3 Condition Assessment

A condition assessment examines how well an asset is functioning as well as its ability to provide services, which is recorded in asset registries. Asset condition rating systems have been developed to help municipalities to assess the condition of traditional built assets within their jurisdictions. As an example, the Regional Municipality of York uses the definitions in Table 22 for condition rating.[16] For the most part, the same rating systems can be used for natural assets.

Table 22. Condition Rating System for Traditional Built Assets

Grade	Description	Condition Criteria	Criteria Description
VG	Very Good	Fit for the future	Well maintained, good condition, new or recently rehabilitated.
G	Good	Adequate for now	Acceptable, generally approaching mid-stage of expected service life
F	Fair	Requires attention	Signs of deterioration, some elements exhibit deficiencies.
P	Poor	Increasing potential of affecting service	Approaching end of service life, below standard, significant deterioration.
VP	Very Poor	Unfit for sustained service	Near or past service life, advanced deterioration, assets may be unusable.

The criteria description can be translated to be more relevant for natural assets. For instance, natural asset condition criteria could be defined as:

- **Very Good:** Well maintained, good condition, no signs of deterioration in ecological conditions.
- **Good:** Ecological conditions appear to be sufficient, some minor localized (or isolated) impacts noticeable, which may be a warning sign of possible decline.
- **Fair:** Clear signs of deterioration in ecological function and service influencing factors.
- **Poor:** Condition is below standard with large portion/s of the system exhibiting significant deterioration in ecological function.
- **Very Poor:** Widespread signs of advanced deterioration, unlikely the natural asset is providing any functional service.

The condition of the natural asset influences the level of ecosystem services provided and the ability of the asset to respond to future pressures and threats. The baseline condition provides the foundation for scenario analysis and modelling to understand the impact of potential threats or positive interventions on

[17] The term "fire spread days" are days when conditions are present (e.g., heat, winds and prolonged lack of precipitation) that enable fires to spread once they have ignited (Podur & Walton, 2011). Wang et al (2017) indicates that measures of daily fire spread potential account for weather patterns (e.g., rain-free periods) and fuel flammability, and provide an accurate assessment of fire-conducive conditions and a different perspective on the magnitude of present and future extreme fire weather conditions.

changes in level of service provision. Benefits that may result from investment, planning or policy decisions (positive interventions) can improve the condition of assets resulting in a subsequent increase in service provision and/or increase in the resiliency of natural assets. Alternatively, negative impacts can result in an impoverished condition decreasing the level of service provision provided by the natural asset. To determine the current condition of the natural assets, condition variables by asset subcategory are identified that provide an indication of natural asset health.

CVC developed a process - a Rapid Condition Assessment Method (RCAM) - to identify key condition variables that influence natural assets and their service outputs in the case study communities (see Appendix A:, Appendix B:, and Appendix C:). The condition assessment will continue to progress under the direction of CVC.

4 Risk Assessment

Along with results from condition assessments, results from risk assessments are entered into asset registries. Risk assessments identify potential risks to assets along with their likelihood of occurring and relative impact.

4.1 Risk Assessment Approach

This section of the report identifies the priority risks identified for the case study communities. To provide context, the process for identifying the risks is first articulated. Three workshops were held to discuss and identify key risks in the case study communities. The first workshop, which was held with CVC staff, was used as a test case. It informed revisions to the workshop agenda and flow for the subsequent workshops. The second workshop for the Alton case study was attended by staff from the Town of Caledon and CVC and the third workshop targeted City of Brampton's and CVC's staff with knowledge applicable to the Mount Pleasant case study. The workshops started with a review of a set of preliminary risks identified for the relevant natural assets. Participants were given the opportunity to add risks to the list. The full range of risks were then discussed by workshop participants and a set of priority risks that would be explored in the BC4NA project was established. The preliminary list of risks, risks identified in the workshops and the final list of priority risks are presented below for the case study communities.

4.2 Risks in Alton

The preliminary list of risks to natural assets that were presented during the Alton workshop were organized around two main pressures in the area: (i) climate change, and (ii) population growth and development pressure.

Risks related to climate change that were discussed during the Alton workshop include:

- Average summer temperature increase and precipitation decrease resulting in:
  - Habitat and species loss
  - Spread of invasive species
- Increased intensity and duration of precipitation resulting in:
  - Flooding and water quality issues
  - Increased runoff in urban areas
- Shifting temperature and precipitation patterns resulting in:
  - Increased freezing rain
  - More freeze thaw cycles
  - Increased road salting

Risks related to population growth and development discussed during the Alton workshop include:

- Conversion of natural assets for other uses (e.g. development, agriculture)
- Increased development with septic wastewater servicing - increased nutrient loading to natural assets which impairs wetland habitat
- Encroachment / human pressures:
  - Unauthorized trail and recreational use (and overuse)
  - Dumping and littering

In addition to the risks above, workshop participants identified two other key risks for Alton:

- Changing ground water levels as a result of the communities no longer pumping as much drinking water from within the community. Alton now pumps some drinking water from Caledon Village. Since the community is not drawing as much water and wetter spring seasons are increasing groundwater water levels, this could cause a shift in vegetation systems and impacts to septic systems.
- Risk of wildfire due to changing weather patterns.

To proceed with the business case analysis, the results of the workshop discussion (i.e. the list of risks above) where analyzed in conjunction with available literature to determine priority risks to be included in the business case assessment. Priority risk selection was based on the following criteria:

- Level of concern / severity expressed by workshop participants in relation to the risk
- Feasibility of modelling changes in the service benefits
- Ability to link asset management options with changes in service levels

Based on the criteria above, the priority risks chosen for the Alton case study include risk of fire and risk of damage to natural assets due to excessive use of salt on roads. These risks were employed in the business case assessment for the Alton case study.

4.3 Risks in Mount Pleasant

The preliminary list of risks to natural assets within the Mount Pleasant study area presented to the workshop participants were organized around the main pressures in the area: (i) climate change, and (ii) population growth and development pressure.

Risks related to climate change that were discussed during the Alton workshop include:

- Average summer temperature increase and precipitation decrease resulting in:
  - Habitat and species loss
  - Spread of invasive species
- Increased intensity and duration of precipitation resulting in:
  - Flooding and water quality issues
  - Increased runoff in urban areas
- Shifting temperature and precipitation patterns resulting in:
  - Increased freezing rain
  - More freeze thaw cycles
  - Increased road salting

Risks related to population growth and development discussed during the Alton workshop include:

- Encroachment / human pressures:
  - Unauthorized trail and recreational use (and over-use)

- Dumping and littering

In addition to the risks identified above, workshop participants identified two other key risks:

- Negative impacts of wildlife on urban natural areas (e.g. beavers and Canada Geese)
- Spills and contamination

To proceed with the business case analysis, the results of the workshop discussion (i.e. the list of risks above) where analyzed in conjunction with available literature to determine priority risks to be included in the business case assessment. Priority risk selection was based on the following criteria:

- Level of concern / severity expressed by workshop participants in relation to the risk
- Feasibility of modelling changes in the service benefits
- Ability to link asset management options with changes in service levels

Based on the criteria above, the priority risks chosen for the Mount Pleasant case study include spread of invasive species, risk of asset loss due to excessive use of salt on roads, and encroachment, overuse, and dumping. These risks were employed in the business case assessment for the Mount Pleasant case study.

5 Management Actions and Service Benefit Trajectories

To develop a business case for natural assets it is important to understand the service benefit trajectories, or in other words, the benefits that are realized from the services provided by the assets over time. This section of the report presents the approaches employed to model the management scenarios providing details on how the service benefit trajectories were calculated. For the purposes of the business case assessment, three service benefit trajectory scenarios were defined:

1. Do Nothing – The Do Nothing scenario assumes that no management actions are taken. In this case, the identified risks have a negative impact on the quantity of assets and hence the services derived from them.
2. Maintain – The Maintain scenario assumes that management actions are taken to ensure that the quantity (area) of the assets remains the same given the relevant risks. In other words, management actions under the Maintain scenario are designed to counter the loss of areas resulting from the Do Nothing scenario.
3. Enhance – The Enhance scenario assumes that actions are taken to increase the quantity (area) of the assets relative to the Maintain scenario.

Figure 21 provides an overview of the approach employed to estimating the service benefit trajectories resulting from each of the management action scenarios.

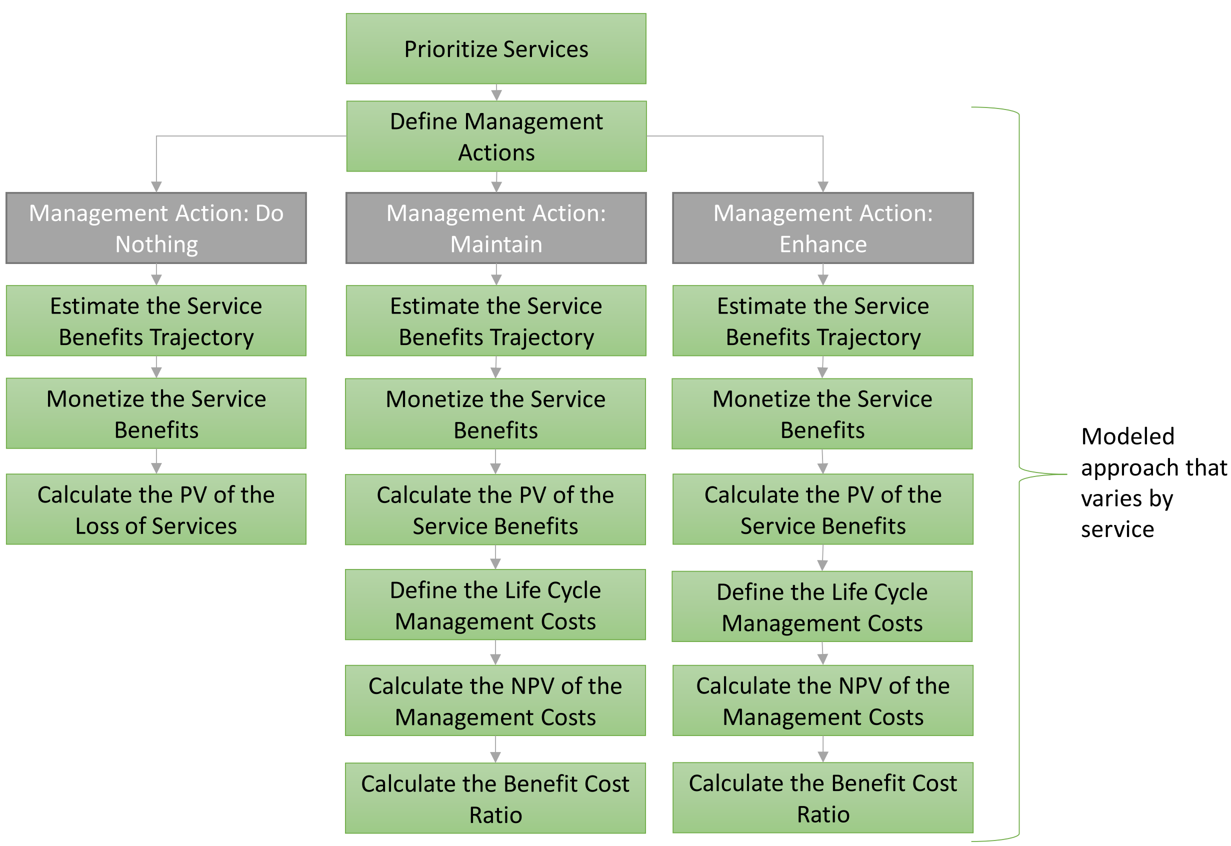


Figure 21. Modelling Framework for Modelling Natural Asset Management Actions

Note that the Maintain and Enhance management alternatives are mutually exclusive in that they apply to spatially different areas (Figure 22). The Maintain management scenario applies to existing assets that are already part of the community's Natural Asset System. In this case, management interventions involve maintaining the assets' current stream of benefits. The Enhance management scenario applies to areas that are not yet considered part of the community's Natural Asset System. In this case, management interventions involve adding to the existing Natural Asset System by expanding its area, for instance by planting forests on non-forested parcels, thus increasing the Natural Asset System's stream of benefits.

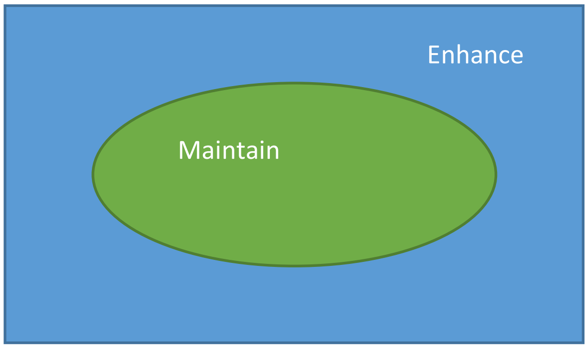


Figure 22. Spatial Illustration of the 'Maintain' and 'Enhance' Management Alternatives Within the Context of a Natural Asset System

The Natural Asset System subject to the maintain management actions is represented by the green oval area, while additions to this system as part of the Enhance scenario is the remaining blue area of the rectangle. Given the spatial configuration of the Maintain scenario relative to the Enhance scenario, these two scenarios can be pursued simultaneously with no risk of double counting the service benefit values or management action costs. This is in contrast to the Do Nothing and Maintain scenarios, which apply to the same spatial area and thus are alternative scenarios (they can not be pursued simultaneously).

5.1 Management Scenarios for Alton

The sub-sections below provide details on the management scenarios for the Alton case study.

5.1.1 Do Nothing

Under the Do Nothing scenario, the assumption is that no management actions are taken and the natural assets within the case study communities are vulnerable to the selected risks. To simulate the expected impact of risks under the Do Nothing scenario, the business case models employ probability values that are intended to reflect the likelihood (in any given year) of the risk damaging the natural assets to the point where they are no longer capable of delivering ecosystem services over a 20-year period. Annual probabilities were informed by a review of the relevant literature (cited below for each priority risk). However, there is a high degree of uncertainty associated with the probability values. They do not reflect local- or site-specific conditions and in some cases, they are simply rough proxies/educated guesses. Thus, the probabilities should be interpreted as placeholder values that can be adjusted by users more familiar with local conditions and risk profiles or improved in future iterations of the business case models and dashboard.

To recognize the uncertainty associated with the probabilities employed in the business case models, the models and the accompanying dashboard demonstrate the implications of low, medium and high likelihoods for the priority risks. The annual probabilities presented for the Do Nothing scenarios are set to reflect low likelihood of damage due to risks. Medium probabilities were derived by multiplying the low probability values by an arbitrary factor of 2.5. High probabilities were derived by multiplying the low probability values by an arbitrary factor of 5. All of the probabilities as well as the margins between low, medium and high probabilities can be adjusted by users and/or refined in future iterations of the models.

1.1.1.1 Fire Risk Assumption Details

Risk profiles were established for the Do Nothing scenario for the risk of fire. Predicting the likelihood of a forest fire occurring in southern Ontario is challenging as current fire management practices differ from those used historically meaning that historic fire regimes cannot be used to accurately predict the likelihood of a natural fire occurring today and in the future. Human impacts on natural fire regimes in southern Ontario have altered ecosystem processes and structure at all scales, with the result that the effects of these changes are not fully understood (Van Sleeuwen, 2006). Wang et al. (2017) states that “fires are discrete events that are more strongly influenced by conditions during the event frame than by seasonal averages or totals“, and estimates that *fire spread*[17] *days could experience a 2-to-3-fold increase under a high CO_2 forcing scenario in eastern Canada* (in other words, the number of sequential days when burning conditions are conducive for spread could increase by 200-300% in eastern Canada by the 2080s). Although estimating the likelihood of increasing fire spread days doesn’t predict the likelihood of a fire occurring, it provides the timeframe and predicted likelihood of the conditions for which fires are likely to spread if they do occur. This information was thus employed as a rough proxy (placeholder) for measuring the risk posed by fires in the study area.

The business case models incorporate the fact that some woodlands are more susceptible to fires (e.g., conifer plantations) than others (e.g., deciduous forests) and that they represent a greater risk (note that the probabilities reflect the risk of fire without management or enhancement; they do not reflect the risk of fire in a managed plantation). As a result, the assumed risk profile varies depending on woodland type.

Table 23 presents the modelled assumptions for the risk of fire. Using the information from Wang et al (2017), thoughtful assumptions were used to establish the probability that at least one fire occurs in a 20-year period. This value is adjusted for the different woodland assets (i.e. 95%, 83% and 67% for high, moderate and low risk assets, respectively). To support the business case analysis, an expected annual loss value needs to be estimated from this 20-year probability. Thus, the probability of at least one fire occurring over the 20-year period, was adjusted to an annual probability. This was done using binomial probability distribution to determine the chance of a fire occurring in any given year based on the 20-year probability. This per year chance of fire is reported in the table below and is assumed to remain constant over the 20-year period.

[17] The term “fire spread days” are days when conditions are present (e.g., heat, winds and prolonged lack of precipitation) that enable fires to spread once they have ignited (Podur & Walton, 2011). Wang et al (2017) indicates that measures of daily fire spread potential account for weather patterns (e.g., rain-free periods) and fuel flammability, and provide an accurate assessment of fire-conducive conditions and a different perspective on the magnitude of present and future extreme fire weather conditions.

Table 23. Estimated Risk of Damage Due to Increased Fire Spread Days for the Do Nothing Scenario

Probability Metric	Assumed probability of a fire event*		
	High Risk Woodland Assets (CUP1, CUP2)	**Moderate Risk Woodland Assets (FOC, CUW, FOM)**	**Low Risk Woodland Asset (FOD)**
Probability of at least one fire happening over a 20-year period	95%	83%	67%
Probability of a fire event occurring in any given year	13.95%	8.55%	5.35%

The map below (Figure 23) shows Alton's natural assets by fire risk classification. Note that to calculate the expected loss from the fire risk under the Do Nothing scenario, it was assumed that 100% of the high risk area has a 13.95% chance of being destroyed in any given year. Similarly, it was assumed that 100% of the moderate risk area has an 8.55% chance of being destroyed in any given year and that 100% of the low risk area has a 5.35% chance of being destroyed in any given year.

Figure 23. Map of Fire Risk Areas

The table below summarizes the Do Nothing assumptions relevant to the fire risk. In keeping with the figure above, Table 24 demonstrates that within the study area there is 129 hectares of high risk woodland, 143 hectares of moderate risk woodland and 50 hectares of low risk woodland. To estimate the damage due to fire under the Do Nothing scenario, these areas were multiplied by the respective annual probability values (i.e. 13.95% for high risk woodlands, 8.55% for moderate risk woodlands and 5.35% for low risk woodlands) over the 20-year timeframe.[18]

Table 24. Summary of Do Nothing Assumptions

Asset	Assumptions
Woodlands	If a fire occurred, the following area of woodlands could be lost: 129 ha of high risk woodland 143 ha of moderate risk woodland 50 ha of low risk woodland
	Lost area is weighted (or multiplied) by the likelihood of fire event
	40 years of reduced services as a result of woodland damage (until full re-growth).[19]

1.1.1.2 Excessive Salt Use Assumption Details

To identify assets (including forest, wetland and grassland areas) that could be damaged by urban runoff and salt loading, a GIS process was established to identify the "area of influence" where impacts could result from sources of urban runoff and salt loading. The process began with identifying the locations and areas where salting takes place. Assumed sources of potential risk are paved surfaces within the study areas (demonstrated in Figure 24). The following assumptions are made to establish the risk profile for excessive salting:

- Assume natural assets within the area of influence and downstream of these sources are susceptible to salt risks, and that the likelihood of damage increases with greater proximity to the source.
- Identify natural assets within prescribed areas of influence from the pollutant source areas using distances reflective of current environmental planning and impact assessment parameters. Generally, areas located downhill and within 40 to 60 ft (12.2 to 18.3 m) of heavily traveled, salt-treated highways are primary candidates for salt-related damage (Transportation Research Board, 1991). Further research conducted by the Transportation Research Board provides parameters for which road salt may affect natural assets:
    - 10m - The distance from paved surfaces that contain the greatest concentration of road salts.

[18] The spatial dataset used for assessing stormwater services in Alton is different than that used for other services. Specifically, the spatial dataset for stormwater services differentiates between wetlands types, but it does not distinguish between different forest types. This means that it was not possible to assign different risk ratings to the forested area in Alton based on the type of forest present. Thus, in the case of stormwater services and the risk of fire in Alton, all forested areas were assigned a moderate risk level.

[19] Fully restoring a mature forest can take generations. Restoring old-growth forest on lands cleared for agriculture could take several hundred years or more, although this could be accelerated through targeted management (MNR, 1999a). However, most forests in southern Ontario have been harvested at some point in recent history, and many are being managed as either plantations or by private landowners, conservation authorities of land trusts under the Managed Forest Tax Incentive Program (MFTIP). Older, managed plantations (i.e., 40+ years) often contain regeneration from local natural seed sources (Elliott, 1998) and therefore could be determined to be "self-sustaining" for the purposes of this analysis.

  - 35m – The distance from paved surfaces within which salt-sensitive trees (i.e., broad-leaved species including maples and black walnut) showed growth reductions as a result of salt damage.
  - 150m – the greatest distance that salt spray can be expected to travel downwind under extreme wind conditions. However, the literature reviewed indicated that the effects of road salt beyond 75 m are negligible.
- Establish a risk profile of permanent damage over the 20-year period for each of the distance bounds. To take a conservative approach, one of the most sensitive and common tree species was used as a proxy for negative impacts from salt. If less sensitive species are present in significant quantities within the area of influence, impacts will be reduced. The likelihood estimates were thus established using sugar maple as sugar maple is the most common/dominant tree likely to be proximal to paved surfaces in the study area. As well, sugar maple is one of the most salt-sensitive species (50% likelihood of severe damage to a roadside tree; 15% when it's within 35m).

There was no time horizon for damage from salt in the literature. For the purposes of this study, cumulative probabilities of mortality (permanent damage to assets) were assumed to be 50% and 15%, for assets within 10m and 35m, respectively. Table 25 presents the assumed risk of salt applications on roads resulting in permanent damage at least one time over a 20-year period. The assumption for the risk of salt is the same as that for fire. Namely, it is assumed that the salt applications reach a point where the nature of the impact is sufficient to render the assets unable to deliver services. This is in contrast to a scenario where damage occurs gradually and accumulates thereby increasing year over year. In other words, the business case model for salt assumes damage occurs in a single season as opposed to resulting from cumulative exposure to salt. Thus, the assumptions employed in the models for the risk of salt damage reflect the likelihood that salt applications reach a point at which damage is, for all intents and purposes, permanent.[20] As was done for the fire risk, the probability of damage occurring at least one time in a 20-year period was adjusted to an annual probability using a binomial probability distribution. This per year chance is reported in the table below and is assumed to remain constant over the 20-year period.

Table 25. Assumed Likelihood of Permanent Damage from Salt by Area of Influence Under the Do Nothing Scenario

Probability Metric	Probability (in %) of permanent damage to assets within varying Areas of Influence	
	0 to 10m	10 to 35m
Probability of damage from salt over a 20-year period	50%	15%
Probability of salt damage occurring in any given year	3.41%	0.81%

Figure 24 shows at the overlap between Alton's natural assets and the area of influence from salted surfaces. To calculate the expected loss from the salt risk under the Do Nothing scenario, it is assumed that 100% of land within the 0 to 10m buffer has a 3.41% of being destroyed in any given year. Similarly, it is assumed that 100% of the area within the 10 to 35m buffer has a 0.81% change of being destroyed in any given year.

[20] The business case spreadsheet models allow users to easily adjust the annual probability values for any given risk. Thus, users can adjust the probability values for salt if a different approach to that employed here is desirable.

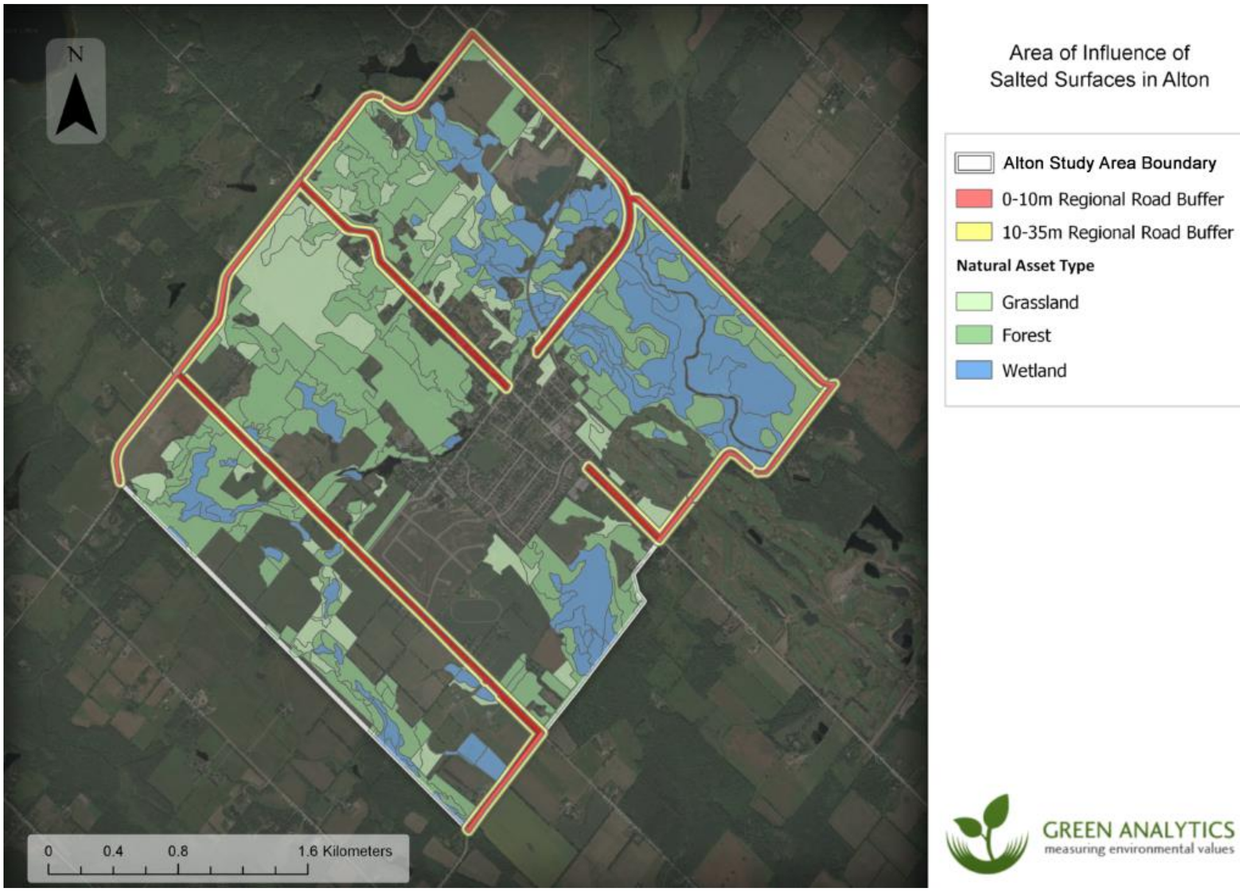


Figure 24. Map of Areas of Influence Related to Salt Damage

The table below summarizes the Do Nothing assumptions for the salt risk. In keeping with the figure above, Table 26 demonstrates that within the study area there is 7.2 hectares of woodlands within the 0 to 10m buffer and 16.6 hectares of woodlands within the 10 to 35m buffer. To estimate the damage due to salt under the Do Nothing scenario, these areas were multiplied by the respective annual probability values (i.e. 3.41% for land within 0 to 10m and 0.81% for land within 10 to 35m) over the 20-year timeframe. The same approach was taken for wetlands and grasslands.

Table 26. Summary of Do Nothing Assumptions

Asset	Assumptions
Woodlands	7.2 ha of affected/lost area within 0 to 10 m of salt application 16.6 ha of affected/lost area within 10 to 35m of salt application
	Lost area is weighted by the likelihood of salt damage
Wetlands	2.2 ha of affected/lost area within 0 to 10 m of salt application 6.4 ha of affected/lost area within 10 to 35m of salt application
	Lost area is weighted by the likelihood of salt damage
Grasslands	2.7 ha of affected/lost area within 0 to 10 m of salt application 5.9 ha of affected/lost area within 10 to 35m of salt application
	Lost area is weighted by the likelihood of salt damage

5.1.2 Maintain

The second part of the Alton workshop considered how to define the Maintain scenario. For the Maintain scenario, the focus was on how the significant risks can be mitigated through alternative management actions. Specifically, the objective was to identify the key management actions that would maintain the service levels provided by the natural assets in the face of the chosen risks.

Very similar management actions were identified in the Alton and Mount Pleasant workshops. Potential actions relevant to Alton identified and discussed at the workshop are provided below. These management actions help mitigate risks to natural assets. As such, they informed the Maintain scenario for the natural assets.

Management actions for the Maintain scenario discussed at the Alton workshop include (note that the actions below are not focused solely on the priority risks for Alton; they reflect the range of risks discussed during the Alton workshop):

- Assess areas for the presence of species that are vulnerable to invasive species – remove and replace with more resilient natural species
- Riparian buffer plantings to manage stream temperature
- Use restoration of natural heritage systems to offset declines in affected areas
- Establish monitoring programs
- Labour intensive removal of invasive species (e.g. buckthorn)
- Herbicide treatments to remove or control invasive species
- Provide incentive programs for septic system upgrades
- Treatment of natural areas for salination impacts (treatments are cost-prohibitive)
- Trail closures
- Using brush piles to discourage unauthorized trail use

- Plantation management to control fire risk:
    - Management actions to shift plantation to hardwood/deciduous forests
    - Build fire management ponds in plantations (increases moisture and offers water source for firefighting)
    - Brush cleanups
    - Education of landowners on plantation management to avoid fire damage
- Education and/or incentive programs for landowners to plant natural species
- Citizen science initiatives to increase engagement/execution of management options
- By-laws:
    - Restrict growing of invasive species in gardens
    - Require septic system inspections
    - Restrict / control tree-cutting
- Salt management plans / technology tools to optimize and minimize salt usage
- Setbacks for properties to put them further from assets

Given the priority risks identified for Alton (i.e. fire and excessive salt use), the table below identifies relevant management actions for the Maintain scenario. These actions are assumed to counter the risks that cause asset degradation in the Do Nothing scenario. Specifically, for this scenario, management actions are assumed to counter 90% of the risk identified in the Do Nothing scenario. Ninety percent was chosen because it is likely unreasonable to assume that all damages can be countered, but also recognizes that through proper management, risk can be significantly reduced. This value can be adjusted in the business case models by the user for sensitivity or other purposes.

Table 27. Management Actions for Alton under the Maintain Scenario

Risk	Management Action/s
Fire	Removing fuel, thinning forests, creating fire breaks and actively managing plantations
Excessive Salt Use	Adjusting road maintenance practices

5.1.3 Enhance

The Enhance scenario assumes that management actions are taken to increase the quantity (area) of the assets. This scenario is not about countering risks. It is about creating new natural assets. Thus, the Enhance scenario can be pursued at the same time as the Do Nothing scenario or the Maintain scenario. For woodlands, the Enhance scenario assumes an increase in the area of land under woodland based on CVC's reforestation prioritization areas. For wetlands and grasslands, the Enhance scenario assumes that the area of wetlands and grassland increases based on CVC's naturalization prioritization areas. Table 28 summarizes the Enhance assumptions for Alton.

Table 28. Enhance Scenario Assumptions for Alton

Asset	Reforestation Area (ha)	Naturalization Area (ha)
Woodlands	3	3
Grasslands	14	20
Agroecosystems	32	18
Created Greenspace	11	16

5.2 Management Scenarios for Mount Pleasant

The sub-sections below provide details on the management scenarios for the Mount Pleasant case study.

5.2.1 Do Nothing

Under the Do Nothing scenario, the assumption is that no management actions are taken and the natural assets within the case study communities are vulnerable to the select risks.

1.1.1.3 Invasive Species Assumption Details

To determine the impact of invasive species risk on natural assets, assets were classified into different risk categories based on the invasive species (including insect pests and pathogens) identified in literature.[21] and City of Brampton Tree Preservation By-law 317-2012 – Schedule "A". Tree pests that are most likely to result in loss of woodland area in Mount Pleasant (and the trees/woodlands they typically affect) include:

- Emerald Ash Borer (ash)
- Asian Longhorned Beetle (maple)
- Verticillium and Oak Wilts (maple and oak)
- Dutch Elm Disease (elm)
- Beech Bark Disease (beech)
- Garlic Mustard/European Buckthorn

Given the target tree species for these invasive species and their distribution in woodland types throughout the study area, woodland types were categorized based on the likelihood that loss of these assets would occur if no action was to take place:

- High Risk: Deciduous Forests
- Moderate Risk: Cultural Woodlands and Mixed Forests
- Low Risk: Coniferous Forests, Coniferous Plantations and Mixed Plantations

It was assessed that woodlands in Mount Pleasant are dominantly upland deciduous forest types. As such, all woodland assets in Mount Pleasant are assumed to be high risk.

[21] https://forestinvasives.ca (Note that Emerald Ash Borer has already devastated local ash tree populations), http://www.invadingspecies.com/category/invaders/forest-pests-pathogens/

A similar approach was applied for wetlands and grasslands, whereby priority invasive species identified for these assets (i.e., phragmites for wetlands; and, dog-strangling vine and sweet white clover for grasslands) were used to determine the level of risk to specific habitat types in the study area. Risk categories for invasive species in wetlands were thus identified as:

- High Risk: Marshes and Wet Meadows
- Moderate Risk: Swamps
- Low Risk: Bogs and Fens

Given the target wetland types for wetland invasive species, notably the small marshes and wet meadows that represent most (if not all) of the wetland communities in Mount Pleasant, all wetland assets in Mount Pleasant are assumed to be high risk based on the likelihood that loss of these assets would occur if no action was to take place.

Risk categories for invasive species in grasslands were identified as:

- High Risk: Grasslands
- Moderate Risk: Scrublands/shrublands
- Low Risk: Created Greenspaces

Grassland assets in Mount Pleasant consist entirely of either scrubland/shrubland meadow communities associated with narrow floodplains and fallow agricultural fields (based on a review of aerial imagery). Given these characteristics, the narrow outlines of the features and the prevalence of anthropogenic influences in close proximity to these communities, all grassland assets in Mount Pleasant were considered moderate risk based on the likelihood that loss of these assets would occur if no action was to take place.

Assumed risk profiles were then established for the Do Nothing scenario. Likelihoods were estimated based on the expansion rates of the most aggressive invasive species for each of the asset types (i.e., garlic mustard for woodlands; phragmites for wetlands; and, dog-strangling vine for grasslands), as determined through a review of the literature. The findings of the literature review for each of these species are summarized here.

<u>Woodlands:</u> Garlic mustard (*Alliaria petiolate*) represents an aggressive threat that can invade relatively undisturbed woodlands, notably upland deciduous forests as found in Mount Pleasant. Once established, it can displace native wildflowers like trilliums and trout lily and hinder other plants (including trees) by interfering with the growth of fungi that bring nutrients to the roots of the plants (OFAH/OMNRF, 2012a). Garlic mustard has two distinct life stages over its first two years. In the first year, it grows only a cluster of leaves shaped like a rosette, while a strong root system develops. Plants that survive the winter produce flowers and hundreds of seeds in their second year. Dense stands produce more than 60,000 seeds per square metre. Stands of garlic mustard can double in size every four years.

<u>Wetlands:</u> *Phragmites australis subsp. australis*, or “phragmites” has been described as Canada’s worst Invasive plant (Toronto Star, 2012). Invasive phragmites is an aggressive plant that spreads quickly and out-competes native species for water and nutrients. It releases toxins from its roots into the soil to hinder the growth of and kill surrounding plants. While it prefers areas of standing water, its roots can grow to

extreme lengths, allowing it to survive in relatively dry areas (OFAH/OMNRF, 2012b). It is, simply put, a nightmare for the small marshes and wet meadows in Mount Pleasant as it has the potential to completely consume these habitats if left unchecked. The spread of phragmites begins slowly with a lag time between establishment and rapid expansion of about 10 to 15 years (Gucker, 2008). After this lag, it can expand at an exponential rate of 50% annually until 90-95% of a wetland feature is covered (Wilcox et al, 2003 and Gucker, 2008), at which point expansion will slow until the affected wetland eventually becomes a monoculture of phragmites. In some locations along the St. Lawrence River in Quebec, this process took less than 20 years (Lalong et al, 2007).

Grasslands: Dog-strangling vine refers to two invasive plants native to Eurasia – black swallowwort and pale swallowwort (*Cynanchum rossicum* & *Cynanchum louiseae*) that grow aggressively up to two metres high by wrapping around trees and other plants or trailing along the ground. Dense patches of the vines can “strangle” plants and small trees. These plants prefer open sunny areas, such as the scrubland/shrubland meadow communities that constitute grasslands in Mount Pleasant. The vine will also invade ravines, hillsides, fence lines, stream banks, roadsides and utility corridors. Dog-strangling vine plants can produce up to 28,000 seeds per square metre (OFAH/OMNRF, 2012c), with the result that unchecked populations can double in area about every eight years. The seeds are easily spread by the wind, and new plants can grow from root fragments, making it difficult to destroy.

Table 29 presents the modelled assumptions for the risk of invasive species. As was done for the other risks, the risk assumptions are based on an estimated probability that the risk will destroy the assets at least one time in the 20-year period. The probability that invasive species will destroy the natural assets at least one time in a year 20-year period is presented below by asset type (i.e. woodlands, wetlands and grasslands). The values employed are educated guesses informed by the literature review presented above, but are somewhat arbitrary in nature. To support the business case analysis, an expected annual loss value needs to be calculated from the 20-year probability. Thus, the probability of the assets being destroyed by invasive species at least one time in the 20-year period, was adjusted to an annual probability. This was done using binomial probability distribution to determine the chance of invasive species damage occurring in any given year based on the 20-year probability.[22] This per year chance is reported in the table below and is assumed to remain constant over the 20-year period.

[22] The business case spreadsheet models allow users to easily adjust the annual probability values for any given risk. Thus, users can adjust the probability values for invasive species if a different approach to that employed here is desirable (for example one that reflects cumulative damage that increases annual).

Table 29. Assumed Likelihood of Invasive Species Damage by Level of Risk for the Do Nothing Scenario

Probability Metric	Probability of damage to assets from invasive species		
	Woodlands (High Risk)	Wetlands (High Risk)	Grasslands (Moderate Risk)
Probability of damage from invasive species happening at least one time in a 20-year period	55.5%	95%	9.5%
Probability of invasive species damage occurring in any given year	3.92%	13.95%	0.5%

Figure 25 demonstrates the spatial distribution of the areas at risk from invasive species damage. To calculate the expected loss from the risk of invasive species under the Do Nothing scenario, it is assumed that 100% of the woodlands area in the figure has a 3.92% change of being destroyed in any given year. Similarly, it is assumed that 100% of the wetlands area in the figure has a 13.95% change of being destroyed in any given year and that 100% of the grasslands area has a 0.5% chance of being destroyed in any given year.

Figure 25. Map of Invasive Species Risk Areas

Table 30 summarizes the assumptions for impacts to relevant assets under the Do Nothing scenario. In keeping with the figure above, Table 30 demonstrates that within the study area there is 37.3 hectares of high risk woodlands, 30.3 hectares of high risk wetlands and 86.6 hectares of moderate risk grasslands. To estimate the damage due to invasive species under the Do Nothing scenario, these areas were multiplied by the respective annual probability values (i.e. 3.92% for woodlands, 13.95% for wetlands and 0.5% for grasslands) over the 20-year period.

Table 30. Summary of Do Nothing Assumptions

Asset	Assumptions
Woodlands	37.3 ha of affected/lost woodland area (e.g., area potentially affected by Asian Longhorned Beetle (maple), Verticillium and Oak Wilt (maple and oak), Dutch Elm Disease (elm).[23], Beech Bark Disease (beech), Garlic Mustard/European Buckthorn (upland deciduous forests)
	Lost area is weighted by the likelihood of invasive species damage
Wetlands	30.3 ha lost/affected area (e.g., area of Phragmites or Purple Loosestrife)
	Lost area is weighted by the likelihood of invasive species damage
Grasslands	86.6 ha lost/affected area (e.g., area of Dog-strangling Vine, Japanese Knotweed or Sweet White Clover)
	Lost area is weighted by the likelihood of invasive species damage

1.1.1.4 Urban Runoff and Excessive Salt Use Assumption Details

To identify assets (forest, wetland and grassland areas) that could be damaged by urban runoff and salt loading, a GIS process was established to identify the "area of influence" where impacts could result from sources of urban runoff and salt loading. The process began with identifying the locations and areas where salting takes place. Assumed sources of potential risk are paved surfaces within the study area (as shown in Figure 26). The following assumptions are made to establish the risk profile for damage due to salting:

- Assume natural assets within the area of influence and downstream of these sources are susceptible to salt risks, and that the likelihood of damage increases with greater proximity to the source.
- Identify natural assets within prescribed areas of influence from the pollutant source areas using distances reflective of current environmental planning and impact assessment parameters. Generally, densely wooded areas located downhill and within 40 to 60 ft (12.2 to 18.3 m) of heavily traveled, salt-treated highways are primary candidates for salt-related damage (Transportation Research Board, 1991). Further research conducted by the Transportation Research Board provides parameters for which road salt may affect natural assets:
  - 10m - The distance from paved surfaces that contain the greatest concentration of road salts.
  - 35m – The distance from paved surfaces within which salt-sensitive trees (i.e., broad-leaved species including maples and black walnut) showed growth reductions as a result of salt damage.
  - 150m – the greatest distance that salt spray can be expected to travel downwind under extreme wind conditions. However, the literature reviewed indicated that the effects of road salt beyond 75 m are negligible.
- Establish a risk profile of permanent damage over the 20-year period for each of the distance bounds. Using a conservative assumption, likelihood estimates are established using sugar maple as they were the most common/dominant tree likely to be proximal to paved surfaces in

[23] Tree pests identified in the City of Brampton Tree Preservation By-law 317-2012 – Schedule "A" Tree Pests

the study area, as well as being one of the most salt-sensitive species (50% likelihood of severe damage to a roadside tree; 15% when it's within 35m).

- There was no time horizon for damage in the literature. For the purposes of this study, probabilities of mortality (permanent damage to assets) were assumed to be 50% and 15%, for assets within 10m and 35m, respectively.

Table 31 presents the assumed risk of salt applications resulting in permanent damage at least one time over a 20-year period. To support the business case analysis, an expected annual loss in value needs to be estimated from the probability that permanent damage will occur at least one time in the 20-year timeframe. This was done using binomial probability distribution. This per year chance is reported in the table below and is assumed to remain constant over the 20-year period.

Table 31. Assumed Likelihood of Permanent Damage from Salt by Area of Influence Under the Do Nothing Scenario

Probability Metric	**Probability (in %) of permanent damage to assets within varying Areas of Influence**	
	0 to 10m	**10 to 35m**
Probability of damage from salt occurring at least one time over a 20-year period	50%	15%
Probability of salt damage occurring in any given year	3.41%	0.81%

Figure 26 shows the overlap between Mount Pleasant's natural assets and the area of influence from salted surfaces. To calculate the expected loss from the salt risk under the Do Nothing scenario, it is assumed that 100% of land within the 0 to 10m buffer has a 3.41% of being destroyed in any given year. Similarly, it is assumed that 100% of the area within the 10 to 35m buffer has a 0.81% change of being destroyed in any given year.

Figure 26. Map of Areas of Influence Related to Salt Damage

Table 32 summarizes the assumptions for impacts to relevant assets under the Do Nothing scenario. In keeping with the figure above, Table 32 demonstrates that within the study area there is 0.1 hectares of woodlands within the 0 to 10m buffer and 1.9 hectares of woodlands within the 10 to 35m buffer. To estimate the damage due to salt under the Do Nothing scenario, these areas were multiplied by the respective annual probability values (i.e. 3.41% for land within 0 to 10m and 0.81% for land within 10 to 35m) over the 20-year timeframe. The same approach was taken for wetlands and grasslands.

Table 32. Summary of Do Nothing Assumptions

Asset	Assumptions
Woodlands	0.1 ha of affected/lost area within 0 to 10 m 1.9 ha of affected/lost area within 10 to 35 m
	Lost area is weighted by the likelihood of salt damage
Wetlands	0.04 ha of affected/lost area within 0 to 10 m 0.54 ha of affected/lost area within 10 to 35 m
	Lost area is weighted by the likelihood of salt damage
Grasslands	2.8 ha of affected/lost area within 0 to 10 m 18.3 ha of affected/lost area within 10 to 35 m
	Lost area is weighted by the likelihood of salt damage

1.1.1.5 Encroachment, Overuse, and Dumping Assumption Details

In the face of this risk, lack of management actions lead to negative impacts to some woodland, wetland and grassland areas. To identify the areas most likely impacted, natural assets were overlaid with known trails to calculate and map the area of influence. This was done assuming that impacts are most likely to occur within a 10m buffer of a trail.

In this case, the likelihood of damage occurring is less relevant since damage is more a function of overuse and misuse of the natural assets. For the purpose of supporting the business case, it is assumed that natural assets within the area of influence from trails would experience complete damage within a specified time frame in the absence of proper management actions. Three timeframe assumptions were explored: area of influence is completely damaged by (i) year 10, (ii) year 15, and (iii) year 20.

Figure 27 shows at the overlap between Mount Pleasant's natural assets and the area of influence from encroachment, overuse, and dumping. Note trail data was only available for the initial phase of the Mount Pleasant development area.

Figure 27. Map of Areas of Influence Related to Encroachment, Overuse, and Dumping

Table 33 summarizes the assumptions for impacts to relevant assets under the Do Nothing scenario.

Table 33. Summary of Do Nothing Assumptions

Asset	Assumptions
Woodlands	2.1 ha of affected/lost area within 10m of trails
	Area of influence is completely damaged by (i) year 10, (ii) year 15, and (iii) year 20
Wetlands	0.9 ha of affected/lost wetland area within 10m of trails
	Area of influence is completely damaged by (i) year 10, (ii) year 15, and (iii) year 20
Grasslands	9.3 ha of affected/lost area within 10m of trails
	Area of influence is completely damaged by (i) year 10, (ii) year 15, and (iii) year 20

5.2.2 Maintain

Through the Mount Pleasant workshop, a number of potential management actions were identified. The management actions, identified below, are intended to mitigate risks to natural assets. As such, they inform the Maintain scenario for the natural assets.

Management actions to mitigate risks in Mount Pleasant (note that the management actions listed below are not limited to those that apply to the priority risks; they reflect the range of risks identified and discussed during the Mount Pleasant workshop):

- Assess areas for the presence of species that are vulnerable to invasive species – remove and replace with more resilient natural species
- Establish monitoring programs
- Labour intensive removal of invasive species (e.g. buckthorn)
- Herbicide treatments to remove or control invasive species
- Treatment for salination impacts (cost-prohibitive management actions)
- Trail closures, using brush piles to discourage unauthorized trail use
- Education and/or incentive programs for adjacent landowners to plant natural species
- Citizen science initiatives to increase engagement/execution of management options
- By-laws:
    - Restrict growing invasive in gardens
    - Restrict / control tree-cutting
- Salt management plans / technology tools to optimize and minimize salt usage
- Setbacks for properties to put them further from assets

Given the priority risks identified for Mount Pleasant (i.e. invasive species, excessive salt use and encroachment, overuse and dumping), Table 34 identifies relevant management actions for the Maintain scenario. These actions are assumed to counter the risks that cause asset degradation in the Do Nothing scenario. Specifically, for this scenario, management actions are assumed to counter 90% of the risk identified in the Do Nothing scenario. Ninety percent was chosen because it is likely unreasonable to assume that all damages can be countered, but also recognizes that through proper management, risk can be significantly reduced. This value can be adjusted in the business case models.

Table 34. Maintain Management Actions for Mount Pleasant

Risk	**Management Action/s**
Invasive Species	Species removal, restoration of disturbed area and replanting with native species; spraying
Excessive Salt Use	Adjusting road maintenance practices, and planting salt tolerant plants along sidewalks and roadways
Encroachment, Overuse ad Dumping	Collection of garbage; signage; clear trail delineation; outreach & education; blocking of unsanctioned trails; and by-law enforcement staff time to address encroachment issues

5.2.3 Enhance

There are limited enhancement opportunities within the Mount Pleasant area as it is undergoing significant planned development, and most natural areas are in relatively healthy condition for an urban setting. During the workshop, one key enhancement opportunity was identified: the creation of natural grassland or meadow areas by eliminating mowing maintenance in designated areas. This action was thus pursued as the key Enhance scenario for Mount Pleasant.[24]

[24] Grasslands and meadows do not provide the same recreational opportunities as manicured greenspace and thus do not have the same recreational value. Similarly, the two types of landcover will not likely influence real estate prices equally. For instance, grasslands or meadows are be perceived negatively by certain landowners or homeowners (Trenholm et al. 2017). On the other hand, manicured greenspace is likely to be perceived positively by most homeowners.

6 Cost of Management Actions

To establish cost estimates for the management actions assumed to be applied under the Maintain and Enhance scenarios, three approaches were employed. A literature review was conducted to identify possible cost estimates from the scientific and grey literature. Web-based research was undertaken to identify possible cost estimates from relevant organizations (e.g. invasive species management organizations, municipal governments). A series of emails were sent to relevant municipal staff in the study areas to seek region and location-specific cost information. For the emails, preliminary introductions were made by CVC staff to four key individuals in the study areas. These individuals then provided specific names to follow up with; the names were targeted at the various management costs that were being addressed. The emails sent to the target individuals led to the identification of others with relevant expertise. All leads were followed up with in an attempt to identify relevant management cost estimates. A total of twenty emails were sent to various individuals over the course of a three-week period. While evidence of the effort required to manage invasive species was provided by one individual, no cost estimates resulted from this process. The cost values presented in this section should thus be considered placeholder values. They are not location- or site-specific. While they are within the ranges of values identified through the literature and web-base searches, they are somewhat arbitrary in their selection. They can be modified by users as better information is obtained for future iterations of the business case models.

6.1 Cost of Maintain Management Actions in Alton

In the case of Alton, management cost estimates were sought to address the risks of salt use and wildfire. The cost estimates identified through the literature and web-based searches are presented for these risks below, along with the cost estimates ultimately employed in the business case models.

6.1.1 Salt

Note that the business case for addressing risks related to salt was explored for both Alton and Mount Pleasant. Three management actions that address the risk of excessive salt use were identified through web-based and literature reviews, namely: 1) adjusting road maintenance practices; and 2) adjusting stormwater management to trap salt; and 3) planting salt tolerant plants along sidewalks and roadways. Cost estimates for these actions are summarized below. A literature review identified practices, equipment and operations used in winter maintenance from the Clear Roads research agency in the United States (Table 35). Other practices include applying substances such as beet juice, sand, etc.

Table 35. Select Practices, Equipment, and Operations Technology Options for Winter Road Maintenance[25]

Item	Description
Deicing	Granular or liquid materials are applied to the road surface to melt existing snow and ice, or to prevent future snow and ice from bonding to the road.
Prewetting at the spreader	The solid deicer (e.g., salt) is coated with a liquid before it spread on the road. Doing so accelerates the solid's transition into brine on the road and also reduces bounce and scatter. While coating can be done at the depot, applying the coating on the truck with a prewetting spreader only prewets the solid material at the time of use.
Anti-icing	The road is treated with a brine prior to a storm in order to prevent snow and ice from bonding with pavement
Zero velocity spreader	Input from sensors (e.g., road temperature) is used to adjust the velocity of the materials being spread on the roadway. Reduces the amount of materials used.
Open and closed loop spreader controls	Open and closed loop spreaders adjust material usage based on vehicle speed.
Slurries	Fine salt is mixed with water, creating a slurry or brine, which is then applied to the road. A salt slurry generator is installed on the truck which grinds salt fed from the hopper and then mixes it with water.
Spreader calibration	Different materials require different application rates. Thus, optimal material use can be achieved if spreaders are calibrated to the specific material being applied to the roadway or sidewalk.

The second set of management actions relates to the use of salt tolerant plants along roadsides and sidewalks. While a review of the literature and web-based information did not identify the costs of replacing vegetation, there are several lists of salt tolerant trees. For instance, Appleton et al. (2015) list several trees and shrubs that tolerate salty soils and salt spray drift for use in Virginia (along with cold hardiness zone). Credit Valley Conservation (2018) maintains a similar list. The relevant costs incurred would be those associated with removing existing salt intolerant vegetation (e.g., tree removal) and then planting salt tolerant species.

The information above demonstrates the range of cost values obtained from an initial review of the literature. CVC expressed a preference for modelling a salt reduction scenario involving alternative de-icers (rather than examining the use of salt tolerant species and trapping salt).[26] Thus, additional literature and web-based research was undertaken to obtain cost and effectiveness data for such alternatives.

There has been a push to reduce the amount of road salt (NaCl) used on Canadian transportation infrastructure through the adoption of best management practices (e.g., the Code of Practice for the Environmental Management of Road Salts [Environment Canada 2012]). Such actions reduce the amount of salt applied to transportation infrastructure, as well as salt drifting into adjacent areas, while maintaining road surfaces at a safe level. In certain instances, the initial investment required as part of these changes is offset by reduced operation costs (e.g., see Kelly et al. (2010) for an example of retrofitting applicators on trucks that paid for itself in the first year). Thus, to further substantially reduce the risk of winter road and sidewalk maintenance activities to adjacent natural assets an alternative to road salt is likely most appropriate. Fay et al. (2015) have estimated that the benefit of certain

[25] Clear Roads (2013).

[26] Personal communication, Julien Gordon, December 20, 2019, via email.

maintenance practices, including switching to alternative magnesium or calcium chloride de-icers, exceeds the costs (although they include benefits such as reduced vehicle corrosion). Alternatives such as magnesium and calcium chlorides also still effect roadside vegetation, though lesser amounts of these alternatives are required at lower temperatures relative to NaCl (Kelting et al. 2010). For instance, Kelting et al. (2009) note that NaCl is largely ineffective below 15 degrees Fahrenheit, while the magnesium and calcium variants require about a third of the amount of NaCl to melt a similar amount of snow and ice at low temperatures (although the relative effectiveness varies with temperature). Kelly et al. (2010) note that magnesium and calcium chlorides cost about 2.4 and 5.7 times the price of salt, respectively. Kelly et al. (2010) also review various alternative de-icers, including Calcium Magnesium Acetate (CMA) which has little effect on vegetation (more expensive de-icers with similar properties are also available). Kelting et al. (2010) note that with experience, roads can be treated with the same amount of CMA as NaCl. However, CMA is very expensive (19.3 times as expensive as road salt) and can result in decreased aquatic oxygen.

To explore this alternative action, the BC4NA spreadsheet models we used to estimate the costs of switching from NaCl to an alternative de-icer, specifically CMA, as it has the least impact on vegetation, for the study areas (Table 36).[27] This involved estimating the difference between the costs of de-icing with NaCl and the costs of using this alternative. Doing so required information on: the distance of roads and lanes in Mt. Pleasant and Alton adjacent to natural assets (216.4 and 64 lane kilometers respectively)[28]; the average daily amount of salt applied per distance of lane; the length of the period requiring road salt (assumed to be November 15 to March 15); and the cost of NaCl. As part of their effort to build a Winter Severity Model for Canadian Winter Road Maintenance (that also predicts the amount of salt required per lane distance per day), Suggett et al. (2007) report on daily average salt use per lane kilometer for various communities across Canada. This includes the City of Toronto (0.0601 per day per lane kilometer) as well as the City of London (0.0318 per lane kilometer) and London's surrounding area (0.1046). In the absence of current local data specific to Mt. Pleasant or Alton, an average of these three Ontario values was employed (0.0655 per day per lane kilometer). The cost of salt varies year to year depending on supply and demand, for instance the price increased substantially in 2018 due to supply constraints (CBC 2018). A value of $50 per ton was employed in an attempt to reflect the cost of a bulk purchase price of a long term contract. Following Kelley et al. (2010) the cost of CMA was assumed to be 19.3 times as much as NaCl, and following Kelting et al. (2010) it was assumed to be applied at 1:1 ratio to road salt (i.e., the operator is experienced). These parameters are employed in the spreadsheet models provided to CVC.

Table 36. The Annual Cost of CMA Relative to Road Salt for Mt. Pleasant and Alton

Community	Lane KMs	Days	Salt (NaCl)				Annual CMA Cost	Increased Annual Cost Using CMA
			Daily Tons per Lane KM	Annual Tons	Cost per Ton	Annual Cost		
Mt. Pleasant	216.4	121	0.0655	1715	$50.00	$85,743	$1,654,836	$1,569,094
Alton	64	121	0.0655	507	$50.00	$25,354	$489,326	$463,972

[27] Aside from potential issues with decreased aquatic oxygen, CMA is likely best able to achieve a 90% reduction in risk from winter road maintenance to adjacent vegetation. Furthermore, despite requiring less at lower temperatures other alternatives are still chloride-based and thus have negative effects on vegetation similar to NaCl.

[28] Spatial data was lacking on the number of lanes for each road, so we assumed that they had two lanes. This is clearly a simplification as certain roads contain more lanes, especially in Mt. Pleasant, and does not account for turning lanes.

The additional annual costs of CMA are quite large, which illustrates an issue with substantially reducing the effect of road salt on adjacent natural assets by altering winter road maintenance — it is very expensive (assuming a 3% discount rate over 20 years the *additional* cost of CMA is $23,344,149 for Mt. Pleasant and $6,902,735 for Alton, which compares to a 20 year cost of using NaCl of $1,275,637 for Mt. Pleasant and $377,199 for Alton). These costs outweigh any specific benefit, even for reductions in the probability of a threat as large as 90%. Thus, the analysis did not demonstrate a business case for reducing the risk of salt given the cost of salt reduction strategies involving alternative de-icers. If an alternative action can be determined to have an incremental cost less than the associated service benefit from maintaining an asset, a business case could be made for switching from the current winter road maintenance routines based on road salt. For example, $MgCl_2$ has the potential to result in a yearly chloride reduction of around 20% when applied at appropriately low temperatures while saving 4% of the existing salt budget.[29] Actual implementation in the business case would require refinement of these and other relevant assumptions, particularly related to the comparative effectiveness of $MgCl_2$ and the temperature assumptions for Alton and Mount Pleasant. If amenable assumptions can be established, then a business case resulting in a positive net present value will result.

The cost estimates for salt management, like all of the cost values in the business case models, can be adjusted.

6.1.2 Fire

The risk of wildfire can be reduced by removing fuel, thinning forests and creating fire breaks (among other actions). There are costs associated with such actions. Drawn from the literature, cost estimates for actions that reduce the risk of fire are presented below. This information has been used to inform fire management cost assumptions in the models. If local information is available on fire management costs, the models can be updated accordingly.

While Ontario-specific cost information was not identified in a review of the literature or via email correspondence with local representatives, some relevant cost data was obtained for other regions. Specifically, the following cost estimates were identified:

- The BC Forest Practices Board (2015) pegged the average cost of fuel management in the wildland urban interface at $10,000 per hectare, unchanged since 2009. This cost reflects, in part, the use of hand-based, rather than mechanical, treatments due to local resistance to the latter.
- Using data from Ohlson et al. (2006) the following per hectare costs were derived: $1,250/ha for mechanical treatment of 80ha; $606/ha for mechanical and prescribed burn treatment of 165 ha; and $588/ha for mechanical and prescribed burn treatment of 425 ha.
- In the United States, Stockmann et al. (2010) incorporated the costs of silvicultural treatments in their economic assessment wildfire mitigation in western Montana. They obtained cost data, in US dollars, from the local National Forest for several treatment options (table below).

[29] Personal communication Tatiana Koveshnikova, January 7, 2020, via email.

Table 37. Costs and Revenues of Silvicultural Treatments for Reducing Wildfire Risk

Cost	Amount ($)
Ecosystem maintenance burns, hand line construction, hand line overhead	259/455/ha
Prethining overhead	36/ha
Thinning – timber stand improvement	162/ha
Timber stand improvement overhead	20/ha
Ecosystem management thin and underburn, hand line construction, hand line overhead	344/ha
Monitoring	2/ha

Hoover and Bracmort (2015) report on the cost for reducing fire risks in the US (Table 38). The average cost from 2010 to 2014 is $330 (USD) with no adjustment for inflation.

Table 38. Cost Per Hectare of Federal Agency Hazardous Fuel Treatments in the United States

Program	2010	2011	2012	2013	2014	Mean
FS	$265	$312	$299	$283	$298	$291
DOI	$392	$457	$452	$531	$398	$446
TOTAL	$301	$350	$341	$331	$324	$330

The literature review and web-based research demonstrate the range of cost estimates that were available to inform cost estimates for managing fire risks. Recognizing that the forest regime in Caledon is different from that in British Columbia, the following placeholder cost values were employed in the Alton model for the risk of fire:

- The per hectare cost of reducing the probability of wildfire was rooted in the average treatment costs in Table 38 ($375 2018 CAD) which was then increased to $500 to reflect larger treatment costs observed by Ohlson et al. (2006) and the BC Forest Practices Board (2015).
- Each parcel was not expected to be treated every year so treatments were set to occur roughly every 10 years (years 1, 10, and 20).

6.2 Cost of Maintain Management Actions in Mount Pleasant

In the case of Mount Pleasant, management cost estimates were sought to address the risks of salt use, invasive species and trail overuse/dumping. The cost estimates identified through the literature and web-based searches are presented for these risks (with the exception of salt which is presented in section 6.1.1 above) below, along with the cost estimates ultimately employed in the business case models.

6.2.1 Invasive Species

A literature review and web-based search were conducted to identify potential cost values related to the management of invasive species. Cost information that was obtained is summarized here. Vyn (2018) surveyed Ontario municipalities and conservation authorities about their expenditures on invasive species control in 2016/2017. A sample of their results is presented in Table 39.

Table 39. Survey Results on Expenditures by Ontario Municipalities and CAs on Invasive Species Management

Municipality	Expenditure	Breakdown			Population	Land	$ Per Capita
		Prevention	Detection	Control			
Regional Municipality of York	$1,186,500	48%	2%	50%	1,109,909	1,762	$1.07
Town of Arnprior	$55,000	5%	0%	95%	8,795	13	$6.25
Town of Bracebridge	$4,000	0%	25%	75%	16,010	628	$0.25
Town of East Gwillimbury	$180,000	2%	0%	98%	23,991	245	$7.50
Town of Midland	$7,000	20%	50%	30%	16,864	35	$0.42
Town of Minto	$5,897	0%	0%	100%	8,671	300	$0.68
Town of Newmarket	$514,300	0%	0%	100%	84,224	38	$6.11
Town of Pelham	$85,000	10%	0%	90%	17,110	126	$4.97
Town of Tillsonburg	$30,000	0%	0%	100%	15,872	22	$1.89
Township of Georgian Bay	$15,000	0%	0%	100%	2,499	547	$6.00
Township of Huron-Kinloss	$125,000	5%	5%	90%	7,069	440	$17.68
Township of King	$227,100	0%	0%	100%	24,512	333	$9.26

Expenditures on invasive species management can also be obtained from budget documents. For instance, Brampton's (2017) budget and business plan documents demonstrate that the city spent $2,703,000 on emerald ash bore in 2017.

According to the Ontario Invasive Plant Council (nd) over the period from 2007 to around 2012, the provincial government spent from $865 to $1,112 per hectare on controlling the invasive Phragmites plant.

A private company in the United States, Invasive Plant Control Inc (2011), lists the price of several on-the-ground invasive species management options for a contract with the US General Services Administration (a federal government organization responsible for tendering). They include multiple types of control services ranging in cost from just over $200 to nearly $6,000 USD per acre (Table 40).

Table 40. Invasive Plant Control, Inc List of Management Prices

Service	Infestation Level	Price per Acre
Invasive Tree and Bush Control – Basal Bark Application	High	$3,949.40
Invasive Tree and Bush Control – Basal Bark Application	Medium/Low	$1,974.70
Invasive Tree and Bush Control – Foliar Spray with Backpacks	Medium	$1,488.58
Invasive Tree and Bush Control – Cut and Treat	High	$5,954.33
Invasive Tree and Bush Control – Cut and Treat	Medium	$2,962.05
Invasive Tree and Bush Control – Cut and Treat	Low	$1,390.35
Invasive Tree and Bush Control – Foliar Spray with RTVs/ATVs (with spraygun)	High	$1,482.03
Invasive Tree and Bush Control – Foliar Spray with RTVs/ATVs (with spraygun)	Medium/low	$740.51
Forbs, Ferns and Grass Control - Foliar Spray with backpacks	High	$2,599.35
Forbs, Ferns and Grass Control - Foliar Spray with backpacks	Medium	$1,482.03
Forbs, Ferns and Grass Control - Foliar Spray with backpacks	Low	$296.21
Forbs, Ferns and Grass Control - Foliar Spray with ATVs/RTVs (with spraygun)	High	$1,314.79
Forbs, Ferns and Grass Control - Foliar Spray with ATVs/RTVs (with spraygun)	Medium	$740.51
Forbs, Ferns and Grass Control - Foliar Spray with ATVs/RTVs (with spraygun)	Low	$293.18
Forbs, Ferns and Grass Control - Foliar Spray with Truck, ATVs/RTVs of Tractor Boom	High, Medium, Low	$219.43
Herbaceous Weed Control – Cut and Treat Stumps	High	$5,954.33
Herbaceous Weed Control – Cut and Treat Stumps	Medium	$2,962.05
Herbaceous Weed Control – Cut and Treat Stumps	Low	$1,496.14
Invasive Vine Control	High	$2,977.16
Invasive Vine Control	Medium	$1,488.58
Invasive Vine Control	Low	$299.23
English Ivy Treatment	High	$4,956.90
English Ivy Treatment	Medium/Low	$1,496.14

The literature review and web-based search (the results of which are presented above) were used to establish a range of possible cost values from which an educated guess was employed to establish the following placeholder cost values that were used in the Mount Pleasant model for invasive species (these values can be adjusted in the future should location- or region-specific information become available):

- For wetlands, invasive species management costs were set at the mid-range of historical costs of controlling invasive Phragmites in Ontario ($1,000 per hectare).
- For woodlands the management cost was set at $500 per hectare as per an estimate for the US on the cost of removing hazardous fuels from forests.[30]
- The costs of invasive species management for grasslands was set at $100 per hectare.

Invasive species management was set to occur roughly every 10 years (years 1, 10, and 20).

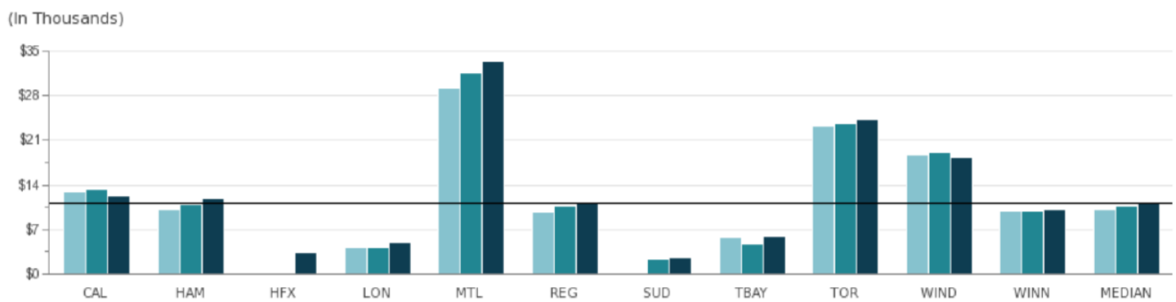
[30] The United States Department of Interior notes that hazardous fuel reduction also works to control invasive species (Hoover and Bracmort 2015).

These assumptions can be adjusted in the models and refined in future iterations of the business case assessment.

6.2.2 Overuse

The costs involved in addressing encroachment, overuse, and dumping of/on natural asset areas cover such activities as: collection of garbage; signage; clear trail delineation; outreach and education; blocking of unsanctioned trails; and by-law enforcement staff time to address encroachment issues.

Cost data for these activities was obtained from a study by Municipal Benchmarking Network Canada. The study documents the operating costs for parks and natural areas in 11 Canadian municipalities. Their most recent report finds that median cost to operate maintained and natural parkland in 2017 was $11,058 per hectare (Figure 28) (MBN Canada 2018). Various factors influence this cost including: demographics; geography; maintenance levels; service standards; and weather conditions. Note that these costs are not broken out by parkland type — maintained parkland costs more to operate than natural parkland and the latter likely better reflects the attributes of the natural assets considered in the Business Case for Natural Assets study.



2015	$12,897	$10,199	N/A	$4,117	$29,359	$9,642	N/A	$5,776	$23,240	$18,639	$9,934	$10,199
2016	$13,272	$10,868	N/A	$4,212	$31,672	$10,731	$2,255	$4,677	$23,642	$19,027	$9,905	$10,800
2017	$12,400	$11,808	$3,335	$4,895	$33,549	$11,058	$2,456	$5,854	$24,351	$18,372	$10,148	$11,058

Source: PRKS315 (Efficiency)

Figure 28. Expenses per Hectare of Parkland for Operations in Canadian Cities

The business case model does not employ the cost values presented in the figure above since the averages are skewed to the high side given that they include manicured parks (for instance, expenses in Toronto over the past three years are nearly $25,000 per hectare). Furthermore, the costs may differ by land cover type.

Instead, the business case model employs costs of $1,000 per hectare for wetlands, $500 per hectare for woodlands, and $100 per hectare for grasslands. These values were chosen as rough orders of magnitudes given the costs presented in the figure above. The cost figures can be adjusted in the models should location- or site-specific data become available. These costs are currently set to occur roughly every 10 years (years 1, 10, and 20). The cost assumptions can be adjusted by the user and further refined in future iterations of the business case model.

6.3 Cost of Enhance Management Actions

The costs of the enhancement differs by intervention. For forest-based enhancements, the CVC provided reforestation and naturalization costs per hectare (Table 41). These costs include planting (seedling for reforestation or potted plants for naturalization) in year 0 as well as monitoring and maintenance infill in years 1 or 2. Since the year of these costs is unknown it is assumed to be 2018.

Table 41. Reforestation and Naturalization Costs of Forest-Based Enhancements (2018 CAD)

Item	Year	Cost per Hectare	
		Reforestation	Naturalization
Planting	0	$3,000.00	$33,402.00
Monitoring only	1	$1,200.00	None provided
Monitoring and maintenance infill	2	$2,100.00	$7,880.00

The cost of maintaining the enhanced asset, for instance fuel reduction treatments for the forests, were also included to better reflect the assumption of no damage over the enhancement's 20 year time horizon ($500 per hectare in years 10 and 20).

For grassland or meadow-based enhancements, (Table 42). The schedule is based on planting in year 0 an CVC's checkpoints for Native Grassland Restoration Program (CVC n.d.). The costs of site preparation and seeding were obtained by averaging those from the Nature Conservancy (2017a, 2017b) for restoring and annual dominated field to utility meadow or restoring degraded grassland to utility meadow in Minnesota. These costs were $1,132 and $1,517 per acre (2013 USD), respectively, which averages to $1,324.50. Adjusting for currency in 2013, inflating to 2018, and converting to hectares yields $3,271.88. The costs for restoring the annual dominated field including "…mow[king] once prior to seeding, harrow[inga], broadcast seed[ing] and cult pack[ing]" while the costs for restoring degraded grassland include mowing once, spot-treatment with herbicides, and a prescribed burn of the entire site. The costs do not include site assessment and project planning, nor do they include the fixed cost of hydrologic restoration (such as tile removal) since it is unlikely manicured greenspace is tiled. The monitoring and maintenance costs in years 2 and 5 are assumed.

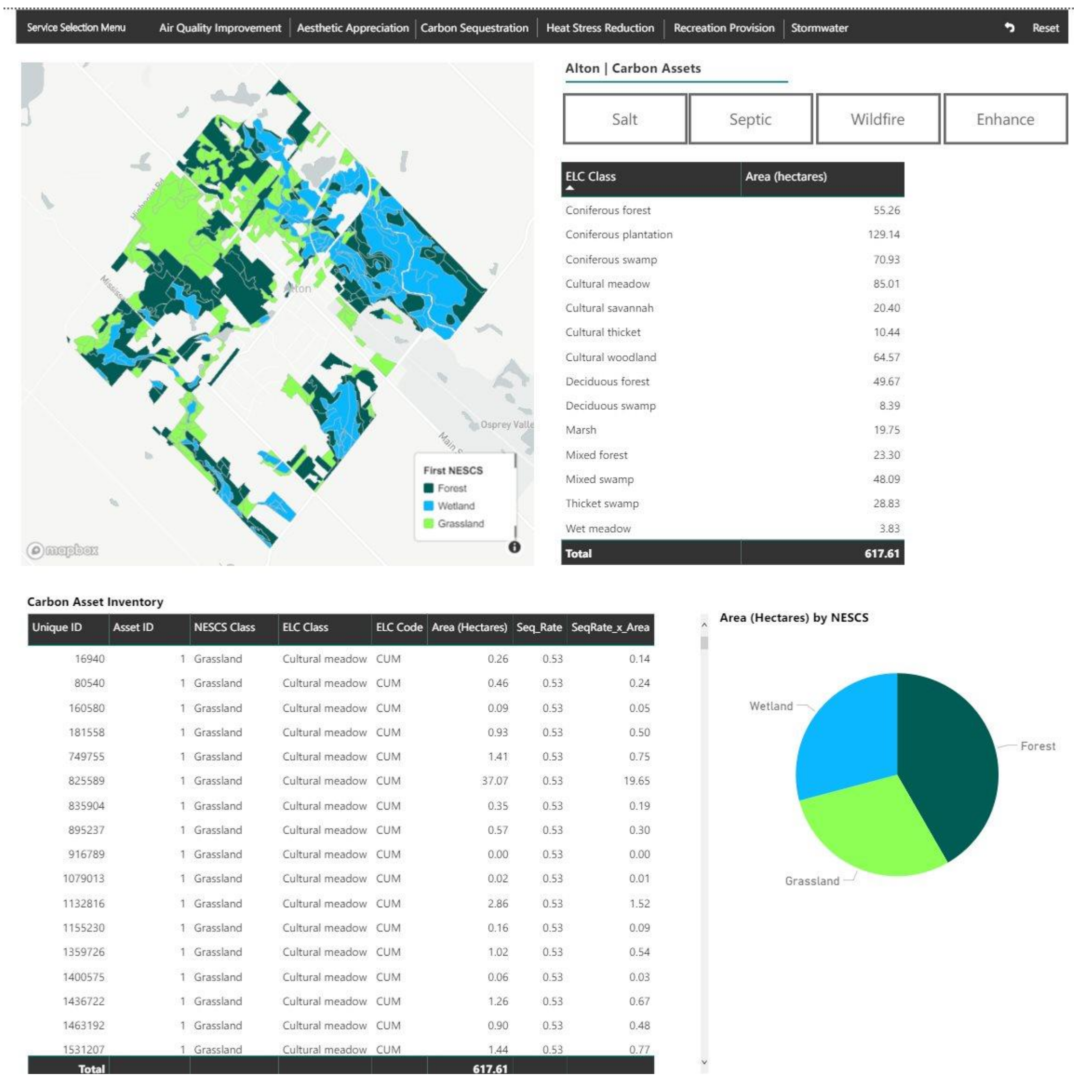
Table 42. Reforestation and Naturalization Costs of Forest-Based Enhancements (2018 CAD)

Item	Year	Cost per Hectare
Site preparation and seeding	0	$3,271.88
Monitoring and maintenance	2	$500
Monitoring and maintenance	5	$500

The cost of maintaining the enhanced asset, for instance removing invasives, were also included to better reflect the assumption of no damage over the enhancement's 20-year time horizon ($500 per hectare in years 10 and 20).

7 Business Case for Natural Assets Dashboard

This report is accompanied by a Business Case for Natural Assets Dashboard. The dashboard is a first of its kind asset management tool, specifically designed to track and value natural assets under alternative management scenarios. The dashboard communicates the business case for asset management in an interactive and visually detailed and appealing manner. The dashboard builds the foundation for future and ongoing work in the area of natural asset management. The Alton dashboard can be accessed at the following link: http://go.greenanalytics.ca/alton; the Mt Pleasant dashboard can be accessed at the following link: http://go.greenanalytics.ca/mtpleasant[31]. A screen shot of one of the dashboards is presented below for illustrative purposes.



[31] Please note that that the dashboard is currently in transition from being hosted by Green Analytics to being by CVC. The links provided in the report will expire within the next few months. For the updated link please contact tatiana.koveshnikova@cvc.ca or info@cvc.ca.

8 Results

This section of the report presents illustrative results from the BC4NA dashboard. Results are presented for each of the service/risk combinations for the Do Nothing and Maintain scenarios as well for the Enhance scenario. Given the uncertainty associated with the probability of the risks occurring, the BC4NA dashboard allows users to choose between low, medium and high probability values. The results presented here reflect the medium probability values from the BC4NA dashboard.

As is articulated in this document, there are numerous assumptions that impact the results of the analysis. Key assumptions relate to the probability of risks occurring and the cost of the management actions. The higher the probability of the risk and the lower the cost of management, the more economically justifiable the management action will be. Users can adjust probabilities and the cost assumptions in the BC4NA spreadsheet models.

8.1 Business Case for Natural Assets in Alton

Table 43 contains present values for the services under the various management scenarios for Alton. The table contains total service values under the three management scenarios as well as the increase in service values associated with Maintain (in this case the increase in service value is the difference between the total value of services under the Maintain scenario and the Do Nothing scenario) and Enhance (in this case the increase in service value is the difference between the total value of services under the Enhance scenario and a baseline scenario where naturalization and reforestation do not occur).

Table 43. Business Case for Natural Assets Results for Alton, Medium Risk Probabilities, 2018 CAD

Service	Management Action	Present Value of Services
Stormwater	Total Service: Do Nothing	
	Salt	$11,915,490
	Wildfire	$11,791,054
	Total Service: Maintain	
	Salt	$11,943,175
	Wildfire	$11,930,730
	Increased Service: Maintain	
	Salt	$27,685
	Wildfire	$139,676
	Total Service: Enhance	$1,543,166
	Increased Service: Enhance	$826,200
Recreation	Total Service: Do Nothing	
	Salt	$10,826,891
	Wildfire	$40,569,355
	Total Service: Maintain	
	Salt	$10,891,717
	Wildfire	$40,843,636
	Increased Service: Maintain	
	Salt	$64,826
	Wildfire	$274,281
Carbon Sequestration	Total Service: Do Nothing	
	Salt	$1,407,078
	Wildfire	$3,523,259
	Total Service: Maintain	

	Salt	$1,415,426
	Wildfire	$3,552,841
	Increased Service: Maintain	
	Salt	$8,348
	Wildfire	$29,582
	Total Service: Enhance	$375,321
	Increased Service: Enhance	$217,044
Air Quality	Total Service: Do Nothing	
	Salt	$298,405,710
	Wildfire	$708,776,162
	Total Service: Maintain	
	Salt	$300,280,747
	Wildfire	$724,196,208
	Increased Service: Maintain	
	Salt	$1,875,037
	Wildfire	$15,420,046
	Total Service: Enhance	$122,777,359
	Increased Service: Enhance	$115,679,495
Property Value	Total Service: Do Nothing	
	Salt	$101,647,187
	Wildfire	$235,806,192
	Total Service: Maintain	
	Salt	$102,238,393
	Wildfire	$238,012,336
	Increased Service: Maintain	
	Salt	$591,205
	Wildfire	$2,206,144
Urban Heat Island	Total Service: Do Nothing	
	Salt	$4,601,171
	Wildfire	$10,721,737
	Total Service: Maintain	
	Salt	$4,627,933
	Wildfire	$10,819,025
	Increased Service: Maintain	
	Salt	$26,762
	Wildfire	$97,288

Table 44 demonstrates the present value of the increase in services resulting from the Maintain (relative to Do Nothing) and Enhance (relative to no reforestation or naturalization) scenarios in relation to the present value of the cost of management actions. Net present values are presented for Maintain and Enhance along with benefit-cost ratios. Under the Maintain scenario, each set of management actions targeting a particular risk results in a string of multiple services. For example, management actions that reduce the risk of wildfire result in increased stormwater management, carbon sequestration, air quality and property value. The table below thus does not differentiate between service types, but rather presents results by risk for all relevant services combined. Also note that because the Enhance scenario targets a different spatial location than the Maintain scenario, these two scenarios can be pursued at the same time without the risk of double counting the benefits or the costs.

Table 44. Present Value (2018 CAD) of Service Gains and Costs, Net Present Value (2018 CAD) and Benefit Cost Ratios for Maintain and Enhance Scenarios

Risk	Present Value of Service Gains	Present Value of Cost	Net Present Value	Benefit Cost Ratio
Maintain				
Salt	$2,593,863	*	*	*
Wildfire	$18,167,018	$292,007	$17,875,011	62.21
Enhance	$116,722,739	$2,673,678	$114,049,061	44

* As noted in section 6.1.1 a range of costs were explored for management actions related to reducing the risk of salt. Unfortunately, the analysis revealed that the cost of salt management using alternative de-icing materials are not justified in relation to the value of the services gained. If alternative management actions can be identified that are less than or equal to the value of the service gains, then a business case can be made for reducing the risk of salt damage to natural assets. The spreadsheet models are set up to allow users to adjust the cost assumptions as well as the probability values associated with the risks. Lower costs and higher probabilities will result in a stronger business case.

8.2 Business Case for Natural Assets in Mount Pleasant

Table 45 contains present values for the services under the various management scenarios for Mount Pleasant. The table contains total service values under the three management scenarios as well as the increase in service values associated with Maintain (in this case the increase in service value is the difference between the total value of services under the Maintain scenario and the Do Nothing scenario) and Enhance (in this case the increase in service value is the difference between the total value of services under the Enhance scenario and a baseline scenario where naturalization and reforestation do not occur). The results for dumping assume the assets experience damage in year 15 (the BC4NA dashboard contains results for dumping assuming damage occurs over 10 years and 20 years in addition to 15 years).

Table 45. Business Case for Natural Assets Results for Mount Pleasant, Medium Risk Probabilities, 2018 CAD

Service	Management Action	Present Value of Services
Stormwater	Total Service: Do Nothing	
	Salt	$1,443,147
	Invasives	$1,369,932
	Dumping	$1,426,118
	Total Service: Maintain	
	Salt	$1,458,164
	Invasives	$1,450,806
	Dumping	$1,459,792
	Increased Service: Maintain	
	Salt	$15,017
	Invasives	$80,874
	Dumping	$33,674
Recreation	Total Service: Do Nothing	
	Salt	$5,941,566
	Invasives	$4,190,382
	Dumping	$5,821,282
	Total Service: Maintain	
	Salt	$5,945,399
	Invasives	$5,770,280
	Dumping	$5,945,825

	Increased Service: Maintain	
	Salt	$3,833
	Invasives	$1,579,899
	Dumping	$124,542
Carbon Sequestration	Total Service: Do Nothing	
	Salt	$809,240
	Invasives	$671,638
	Dumping	$777,445
	Total Service: Maintain	
	Salt	$811,294
	Invasives	$797,534
	Dumping	$811,522
	Increased Service: Maintain	
	Salt	$2,054
	Invasives	$125,896
	Dumping	$34,078
	Total Service: Enhance	$111,425
	Increased Service: Enhance	$49,186
Air Quality	Total Service: Do Nothing	
	Salt	$104,901,414
	Invasives	$94,734,739
	Dumping	$101,499,852
	Total Service: Maintain	
	Salt	$105,014,826
	Invasives	$103,998,158
	Dumping	$105,027,427
	Increased Service: Maintain	
	Salt	$113,411
	Invasives	$9,263,419
	Dumping	$3,527,575
Property Value	Total Service: Do Nothing	
	Salt	$734,998,097
	Invasives	$664,916,916
	Dumping	$703,289,596
	Total Service: Maintain	
	Salt	$737,884,473
	Invasives	$730,876,346
	Dumping	$738,205,172
	Increased Service: Maintain	
	Salt	$2,886,377
	Invasives	$65,959,431
	Dumping	$34,915,575
Urban Heat Island	Total Service: Do Nothing	
	Salt	$38,701,210
	Invasives	$35,011,096
	Dumping	$37,031,603
	Total Service: Maintain	
	Salt	$38,853,191
	Invasives	$38,484,179

	Dumping	$38,870,078
	Increased Service: Maintain	
	Salt	$151,982
	Invasives	$3,473,083
	Dumping	$1,838,474

Table 46 demonstrates the present value of the increase in services resulting from the Maintain (relative to Do Nothing) and Enhance (relative to no reforestation or naturalization) scenarios in relation to the present value of the cost of management actions. Net present values are presented for Maintain and Enhance along with benefit-cost ratios. The table below does not differentiate between service types, but rather presents results by risk for all relevant services combined. Also note that because the Enhance scenario targets a different spatial location than the Maintain scenario, these two scenarios can be pursued at the same time without the risk of double counting the benefits or the costs.

Table 46. Present Value (2018 CAD) of Service Gains and Costs, Net Present Value (2018 CAD) and Benefit Cost Ratios for Maintain and Enhance Scenarios

Risk	**Present Value of Service Gains**	**Present Value of Cost**	**Net Present Value**	**Benefit Cost Ratio**
Maintain				
Salt	$3,172,674	*	*	*
Invasives	$80,482,602	$130,662	$80,351,939	615.96
Dumping	$40,473,919	$6,443	$40,467,476	6,282.08
Enhance	$49,186	$25,903	$23,283	1.90

* As noted in section 6.1.1 a range of costs were explored for management actions related to reducing the risk of salt. Unfortunately, the analysis revealed that the cost of salt management using alternative de-icing materials are not justified in relation to the value of the services gained. If alternative management actions can be identified that are less than or equal to the value of the service gains, then a business case can be made for reducing the risk of salt damage to natural assets. The spreadsheet models are set up to allow users to adjust the cost assumptions as well as the probability values associated with the risks. Lower costs and higher probabilities will result in a stronger business case.

9 Limitations and Areas for Improvement

This project involved the completion of an asset registry that identifies and quantifies the natural assets within the study area, a series of spreadsheet models that measure the cost of natural asset management actions in relation to the value of services derived from the same natural assets, and a web-based interactive dashboard that summarizes the costs and benefits of natural asset management actions.

This project has pushed the frontier in the field of natural asset quantification and valuation. It is leading edge in Canada and as such has laid a solid foundation for future work in this area. Because of the leading edge nature of the project, a number of limitations and areas of improvement exist. The bullet points below summarize a number of areas that may be the focus of future refinements and improvements to the BC4NA registry, models and dashboard.

- The BC4NA models measure quantitative changes in natural assets; qualitative changes are only captured if they can be presented in quantitative terms such as when an asset is so degraded that it becomes useless in terms of its ability to provide a service. Future work may consider ways to incorporate qualitative as well as quantitative changes in natural assets in the models.
- Location-specific cost information is currently lacking. The current iterations of the BC4NA models rely on information drawn from the literature, web-based searches and educated guesses. In many cases, cost values should be interpreted as placeholder values that could be refined in future iterations of the models.
- There is a high degree of uncertainty associated with the probability values employed in the models for damages due to the relevant risks. The current values were informed by literature and web-based searches as well as educated guesses. For all risks, annual probabilities were derived using bionomial probability distributions. This may not be the best or most appropriate approach to establishing annual likelihood values for all of the risks. It is based on the premise that damage reaches a point where the natural asset is no longer able to deliver services and does not account for the possibility that the natural asset may be degraded and thus deliver a reduced level of service for multiple years rather than no service whatsoever. Future work may consider a) refining the probability values to be more location and site-specific, and b) alternative approaches to assigning annual probability values (e.g. annual linear increases in risk).
- The valuation of the natural assets is based on value transfer approaches, which can be associated with degrees of uncertainty depending on how applicable the transferred values are to the study site. Future iterations of the models may consider opportunities to improve the value transfer approach (e.g. through use of a meta-analysis) or options for primary data collection to obtain site and case study specific valuation data.
- The asset registry contains biophysical units for some of the services included in the BC4NA models but their position in the registry is not consistent across services and it is therefore difficult to present such results in the BC4NA dashboard or to extract such results for presentation in a report format. Future work may consider options for re-organizing the asset registry to make it easier to extract the biophysical units for the relevant services.
- The recreation values employed in this study do not differentiate between created/manicured greenspace and other land cover types, yet it is likely the case that such values differ. Future work

may consider options for increasing the precision of the recreational values to account for value differences between land cover types.

- The current models allow users to account for opportunity cost of lost agricultural land (default value set to zero) but opportunity cost values are not included for other land cover types. Future work may consider options for adding values for other land cover types.

10 Business Case for Natural Assets Models

The value of the services derived from the natural assets (Section 4) under the alternative management scenarios (Do Nothing, Maintain and Enhance) are put into the cost of alternative actions (Maintain and Enhance) in the business case for natural assets models. This section of the report provides an overview of the spreadsheet tools developed for the business case assessment in the communities of Alton and Mt. Pleasant, Ontario.

Two sets of Excel spreadsheets were developed to analyze the benefits and costs of management alternatives targeted at maintaining (Maintain) and enhancing (Enhance) natural assets in the Ontario communities of Alton (Caledon) and Mt. Pleasant (Brampton). Multiple services and threats were included in this analysis and they differed by the management alternatives (i.e. Maintain versus Enhance) as well as the community. Services, risks and assets relevant to the Maintain scenario are presented in Table 47.

Table 47. Services, Risks and Relevant Natural Assets for the Maintain Spreadsheet Tools

Service	**Risks**		**Relevant Natural Asset Group**
	Alton[a]	**Mt. Pleasant**	
Amenity (Real Estate)	□ Wildfire □ Salt	□ Wildfire □ Invasive Species □ Trail Encroachment	□ Forest □ Wetland □ Grassland / Meadow
Air Quality	□ Wildfire □ Salt	□ Wildfire □ Invasive Species □ Trail Encroachment	□ Forest
Cooling (Urban Heat Island)	□ Wildfire □ Salt	□ Wildfire □ Invasive Species □ Trail Encroachment	□ Forest □ Wetland □ Grassland / Meadow
Carbon Sequestration	□ Wildfire □ Salt	□ Wildfire □ Invasive Species □ Trail Encroachment	□ Forest □ Wetland □ Grassland / Meadow
Recreation	□ Wildfire □ Salt	□ Wildfire □ Invasive Species □ Trail Encroachment	□ Forest □ Wetland □ Grassland / Meadow
Stormwater Management	□ Wildfire □ Salt	□ Wildfire □ Invasive Species □ Trail Encroachment	□ Forest □ Wetland □ Grassland / Meadow

[a] Though initially considered, and a tool developed, the Septic Overflow threat was removed from consideration and is thus not reviewed in this document.

Services, risks and assets relevant to the Enhance scenario are presented in Table 48. A smaller set of services was modeled for the Enhance management alternative. In some cases, such as for Amenity and Cooling services, there is limited data on the value of alternative covers (i.e., forest or meadow cover has the same per unit value as the current land cover). Furthermore, much or all of the enhanced land is private, which limits modelling enhanced opportunities for recreational opportunities.

Table 48. Services Enhanced Via Additions to the Natural Asset System

Service	Reason Included	Enhancement
Air Quality	Forest cover purifies air more than current covers	□ Reforestation (Alton) □ Naturalization (Alton)
Carbon Sequestration	Forest or grassland/meadow cover sequesters more than current covers	□ Reforestation (Alton) □ Naturalization (Alton) □ Grassland / Meadow (Mt. Pleasant)
Stormwater Management	Forest cover captures more stormwater than current covers	□ Reforestation (Alton) □ Naturalization (Alton)

For each community, for the Maintain scenarios, there is a spreadsheet for each risk and service combination (as well as for low, medium and high probabilities of the risk resulting in negative impacts to the assets). For each community, for the Enhance scenarios, there is a spreadsheet for each service.

The purpose of this guide is to provide an overview of the spreadsheet tools and to demonstrate the calculations used; each tab in the two spreadsheets is discussed below. Note that the spreadsheet tools are designed such that key parameters or assumptions can be changed (such cells are shaded gray).

The overview of the Maintain spreadsheet tool is presented first, followed by the Enhance spreadsheet tool.

10.1 The Maintain Management Alternative

Two primary scenarios were modeled to estimate the economic efficiency of maintaining the natural assets at each site against the applicable risks, namely:

- A Do Nothing scenario that represents the estimated stream of benefits given no intervention to maintain the natural assets.
- A Maintain scenario that represents the estimated stream of benefits as well as the costs given interventions to maintain the natural assets.

Note that a Baseline scenario was also modeled to act as a reference for the two scenarios identified above. The outputs of the Baseline scenario were not included in the assessment of economic efficiency.

10.1.1 Summary Output Tab

The 'Summary Output Tab' presents the total present value benefits (PVB) and costs (PVC) in 2018 Canadian dollars, which are summed over the affected parcels and time horizon output in the 'Detailed Output' tab.

- *Baseline PVB* ($PVB_{Baseline}$): sum of the present value benefits of the flow of services from the existing natural asset system given no probability of a threat (i.e., the present value benefit of a continuous flow of services at their current level).[32]
- *Do Nothing PVB* ($PVB_{Nothing}$): sum of the expected present value benefits of the flow of services from the existing natural asset system given the status quo probability of a threat.

[32] We currently include this PVB Baseline referenced as "Baseline" in the Excel worksheet's Summary Output page for Maintain. This is likely not needed, but is useful for reference to check calculations, and it likely causes some confusion with the other use of "Baseline" mention in footnote 1 so it can be dropped.

- *Maintain PVB ($PVB_{Maintain}$)*: sum of the expected present value benefits of the flow of services from the existing natural asset system given the reduced probability of a threat.
- *Maintain PVC (PVC)*: sum of the present value costs of interventions to maintain the natural asset system at or near its baseline level (to reduce the probability of threats).
- The benefit of the intervention to maintain the assets is the difference between '*Maintain PVB*' and '*Do Nothing PVB*'

These present value benefit and cost estimates are included in the calculation of the Net Present Value (NPV) and Benefit Cost Ratio (B/C) economic efficiency criteria which themselves are used to inform decisions on natural asset management options (i.e., deciding whether to maintain the assets).

- Net Present Value: $NPV = PVB - PVC = (PVB_{Maintain} - PVB_{Nothing}) - PVC$
    - A positive NPV indicates that the benefits of the 'Maintain' intervention exceed its costs.
- Benefit Cost Ratio: $B/C = PVB/PVC = (PVB_{Maintain} - PVB_{Nothing})/PVC$
    - A ratio larger than 1 indicates that the benefits of the 'Maintain' intervention exceed its costs.

Note that the user cannot change anything in this worksheet.

10.1.2 Detailed Output Tab

The 'Detailed Output Tab' contains input data on each parcel, for instance its size and the threat to the natural asset located on the parcel (this input data can be changed by the user). Benefits or costs are calculated for each parcel (*p*) and each year (*t=1,…,20*) over a 20 year horizon according to relationships outlined below. A discount rate (*r*) is applied to adjust these values to the present year and at the end of the annual stream of benefits or costs, these values are summed yielding a present value over the time horizon for the parcel. Columns are included in the spreadsheet tool to account for benefits or costs in year *t* as well as for the present value aggregated over all years.

Baseline

The 'Baseline' scenario, which as noted above provides a reference point for the Do Nothing and Maintain scenarios, is calculated by multiplying the parcel's area by the annual benefit per hectare of its cover (Equation 1).[33] The same calculation is used for each threat and service with the exception of carbon which is expanded upon in the variable descriptions that follow this equation.

$$PVB\ Baseline_p^t = \sum_{t=1}^{20} \frac{(HA_p)(Service\ Benefit\ Per\ HA)}{(1+r)^t} \qquad [1]$$

- HA_p is the area of the parcel *p*
- $Service\ Benefit\ Per\ HA$ is the average annual value of the service flow per hectare
    - Aside from the carbon sequestration service, average service benefits are calculated outside of the spreadsheet tool.

[33] The 'Baseline' is used to check the 'Do Nothing' and 'Maintain' scenarios as the aggregate present value benefits of these latter two scenarios should be smaller than that of the 'Baseline' scenario since they are weighted.

- For carbon, the Service Benefit Per HA in time *t* for parcel *p* is calculated by multiplying the carbon sequestration rate specific to the parcel's cover by the social cost of carbon (SCC) in year *t*. This structure applies to all remaining calculations based on the Service Benefit Per HA involving carbon sequestration.
  - $Service\ Benefit\ Per\ HA_p^t = \left(Sequestration_p\right)(SCC^t)$
- r and t are the discount rate and year, respectively

Do Nothing

The Do Nothing scenarios, which differ by threat, are calculated by adjusting the parcel's value by the status quo (SQ) likelihood of the threat or the lifespan of the parcel's service flow. In the case of Salt, Fire, and Invasive Species the threat is represented as the SQ probability of the threat occurring in year *t*. For Trail Encroachment, the threat is represented as the SQ lifespan of the asset in years; the asset declines linearly over time until it no longer provides a flow of services at either year 10, 15, or 20 (the values are thus weighted by the percent of baseline service-flow in year *t*).

Salt

Equation 2 was used to calculate the Do Nothing benefit for a parcel *p* in time *t* given a Salt threat. Variable descriptions follow.

$$PVB\ Nothing_p^t = \sum_{t=1}^{20} \frac{\left((1 - ProbSQ_{35}^t)(HA_p^{35}) + (1 - ProbSQ_{10}^t)(HA_p^{10}) + (HA_p^e)\right)(Service\ Benefit\ Per\ HA)}{(1+r)^t} \qquad [2]$$

- $ProbSQ_{35}^t$ is the status quo probability of threat in year *t* for the 10m to 35m transit corridor buffer
- HA_p^{35} is the area of parcel *p* in the 10m to 35m buffer
- $ProbSQ_{10}^t$ is the status quo probability of threat in year *t* for the 0m to 10m transit corridor buffer
- HA_p^{10} is the area of parcel *p* in the 0m to 10m buffer
- HA_p^e is the area of parcel *p* not in a buffer
- $Service\ Benefit\ Per\ Hectare$ is the average annual value of the service flow per hectare
- r and t are the discount rate and year, respectively

Wildfire

Equation 3 was used to calculate the Do Nothing benefit for a parcel *p* in time *t* given a Wildfire threat. Variable descriptions follow.

$$PVB\ Nothing_p^t = \sum_{t=1}^{20} \frac{\left(\left(1 - (Prob_{Fire})(ProbSQ_p^t)\right)(HA_p)\right)(Service\ Benefit\ Per\ HA)}{(1+r)^t} \qquad [3]$$

- $Prob_{Fire}$ is the probability of a fire starting in any given year on any given parcel
- $ProbSQ_{Risk}^t$ is the status quo probability of threat (wildfire spread) in year *t* given the parcel-specific likelihood of fire (either low, moderate, or high)
- HA_p is the area of the parcel *p*

- $Service\ Benefit\ Per\ HA$ is the average annual value of the service flow per hectare
- r and t are the discount rate and year, respectively

Invasive Species

Equation 4 was used to calculate the Do Nothing benefit for a parcel *p* in time *t* given an Invasive Species threat. Variable descriptions follow.

$$PVB\ Nothing_p^t = \sum_{t=1}^{20} \frac{\left((1 - ProbSQ_{Cover}^t)(HA_p)\right)(Service\ Benefit\ Per\ HA)}{(1+r)^t} \qquad [4]$$

- $ProbSQ_{Cover}^t$ is the status quo probability of threat in year *t* for given the parcel's cover (either woodland, wetland, or grassland)
- HA_p is the area of the parcel *p*
- $Service\ Benefit\ Per\ HA$ is the average annual value of the service flow per hectare
- r and t are the discount rate and year, respectively

Trail Encroachment

Equation 5 was used to calculate the Do Nothing benefit for a parcel *p* in time *t* given a Trail Encroachment threat. Variable descriptions follow.

$$PVB\ Nothing_p^t = \sum_{t=1}^{20} \frac{\left((RemainSQ_{Life}^t)(HA_p)\right)(Service\ Benefit\ Per\ HA)}{(1+r)^t} \qquad [5]$$

- $RemainSQ_{Life}^t$ is the status quo percent of baseline service flow remaining in year *t* given the assumed lifespan
- HA_p is the area of the parcel *p*
- $Service\ Benefit\ Per\ HA$ is the average annual value of the service flow per hectare
- r and t are the discount rate and year, respectively

Maintain

The Maintain scenarios, which also differ by threat, are similarly calculated by adjusting the parcel's value by the likelihood of the threat or the lifespan of the parcel's service flow. However, this adjustment is weighted such that the probability of a threat in year *t* is lessened by 90% or, in the case of the lifespan of the parcel's service flow, the service-flow in year *t* is 100% of the baseline.

Salt

Equation 6 was used to calculate the Maintain benefit for a parcel *p* in time *t* given a Salt threat. Variable descriptions follow (although only the probability differs).

$$PVB\ Maintain_p^t = \sum_{t=1}^{20} \frac{\left((1 - ProbM_{35}^t)(HA_p^{35}) + (1 - ProbM_{10}^t)(HA_p^{10}) + (HA_p^e)\right)(Service\ Benefit\ Per\ HA)}{(1+r)^t} \qquad [6]$$

- $ProbM_{35}^{t}$ is the maintain (M) probability of threat in year *t* for the 10m to 35m transit corridor buffer
- HA_{p}^{35} is the area of parcel *p* in the 10m to 35m buffer
- $ProbM_{10}^{t}$ is the maintain (M) probability of threat in year *t* for the 0m to 10m transit corridor buffer
- HA_{p}^{10} is the area of parcel *p* in the 0m to 10m buffer
- HA_{p}^{e} is the area of parcel *p* not in a buffer
- $Service\ Benefit\ Per\ HA$ is the average annual value of the service flow per hectare
- r and t are the discount rate and year, respectively

Wildfire

Equation 7 was used to calculate the Maintain benefit for a parcel *p* in time *t* given a Wildfire threat. Variable descriptions follow (although only the probability differs).

$$PVB\ Maintain_{p}^{t} = \sum_{t=1}^{20} \frac{\left(\left(1 - (Prob_{Fire})(ProbM_{p}^{t})\right)(Hectares_{p})\right)(Service\ Benefit\ Per\ HA)}{(1+r)^{t}}$$

- $Prob_{Fire}$ is the probability of a fire starting in any given year on any given parcel
- $ProbM_{Risk}^{t}$ is the maintain (M) probability of threat (wildfire spread) in year *t* given the parcel-specific likelihood of fire (either low, moderate, or high)
- HA_{p} is the area of the parcel *p*
- $Service\ Benefit\ Per\ HA$ is the average annual value of the service flow per hectare
- r and t are the discount rate and year, respectively

Invasive Species

Equation 8 was used to calculate the Maintain benefit for a parcel *p* in time *t* given an Invasive Species threat. Variable descriptions follow (although only the probability differs).

$$PVB\ Maintain_{p}^{t} = \sum_{t=1}^{20} \frac{\left((1 - ProbM_{Cover}^{t})(HA_{p})\right)(Service\ Benefit\ Per\ HA)}{(1+r)^{t}} \quad [8]$$

- $ProbM_{Cover}^{t}$ is the maintain (M) probability of threat in year *t* for given the parcel's cover (either woodland, wetland, or grassland)
- HA_{p} is the area of the parcel *p*
- $Service\ Benefit\ Per\ HA$ is the average annual value of the service flow per hectare
- r and t are the discount rate and year, respectively

Trail Encroachment

Equation 9 was used to calculate the Do Nothing benefit for a parcel *p* in time *t* given a Trail Encroachment threat. Variable descriptions follow.

$$PVB\ Maintain_p^t = \sum_{t=1}^{20} \frac{\left((RemainM_{Life}^t)(HA_p)\right)(Service\ Benefit\ Per\ HA)}{(1+r)^t} \qquad [9]$$

- $RemainM_{Life}^t$ is the maintain (M) percent of baseline service flow remaining in year *t* given the assumed lifespan
- HA_p is the area of the parcel *p*
- $Service\ Benefit\ Per\ HA$ is the average annual value of the service flow per hectare
- r and t are the discount rate and year, respectively

Costs

If an area-based intervention is used to maintain the asset, then costs in year *t* for an intervention on parcel *p* as well as the present value of this stream are also included in this tab. Area-based interventions are used to maintain assets against the Fire, Invasive Species, and Trail Encroachment threats. Interventions to maintain the asset against a Salt threat can either be linear (using less salt in road and sidewalk maintenance) or area-based (planting salt-tolerant vegetation or intercepting salt-laden runoff). The present value costs are calculated according to Equation 10 for area-based interventions and Equation 11 for a linear intervention; variable definitions follow.

$$PVC\ Maintain_p^t = \sum_{t=1}^{20} \frac{(HA_p)(Cost\ Per\ HA^t)}{(1+r)^t} \qquad [10]$$

- HA_p is the area of the parcel *p*
- $Cost\ Per\ HA^t$ is the cost per hectare to maintain an asset against a threat in year *t*
    - For the Wildfire threat the costs do not differ by forest type, while interventions against Invasive Species and Trail Encroachment are specific to cover type (forest, wetland, or grassland) since costs may differ by cover
- r and t are the discount rate and year, respectively
-

$$PVC\ Maintain_p^t = \sum_{t=1}^{20} \frac{(HA_p)(Cost^t)}{(1+r)^t} \qquad [11]$$

- HA_p is the area of the parcel *p*
- $Cost^t$ is the cost to maintain an asset against a threat (Salt) in year *t*
- r and t are the discount rate and year, respectively

10.1.3 Parameters Tab

The ‘Parameters Tab’ contains one-off parameters that are incorporated into the calculations in the ‘Detailed Output Tab’ or the ‘Risk Tab’, such as the discount rate and the reduction in the probability of the threat resulting from the interventions to maintain the asset.

- *Discount Rate*: the discount rate (*r*) represents the time-value of money (having a dollar now is worth more than the same dollar in the future). Although currently set at 3%, the discount rate can be changed by the user. Since the forecast carbon price has a built-in rate of 3%, changing this rate does not affect the calculated benefits of carbon sequestration (in this case $r = 0\%$ in the equations). This parameter is incorporated into the 'Detailed Output Tab' as noted in the relevant section above.

- *Risk Reduction*: this value represents the reduction in the probability of a threat. Although currently set at 90%, the reduction in risk can be changed by the user. This parameter is incorporated into the 'Risk Tab' as noted in the relevant section below.
- *Likelihood of Fire Occurring*: this value represents the probability of a wildfire starting; it only applies to the wildfire threat and thus only appears in the wildfire spreadsheets. Although currently set at 10%, the reduction in risk can be changed by the user. This parameter is incorporated into the wildfire calculations as $Prob_{Fire}$ as noted in the 'Detailed Output Tab' description above.
- *Carbon Value Approach*: this dropdown cell is used to select the approach to carbon pricing; it only applies to the carbon sequestration spreadsheets. The user can select 'Constant' or 'Forecast' to choose an approach based on a constant carbon value or a forecast value, respectively. It is currently set at 'Forecast'

10.1.4 Asset Tab

The 'Asset Tab' contains data on the per hectare values of each type of asset. These values are used to populate the 'Annual Benefit Per Hectare' variable in the 'Detailed Output Tab'. As explained above in the 'Detailed Output Tab', aside from the spreadsheet for the carbon sequestration service, this tab contains annual dollar values per hectare. For carbon sequestration, this tab contains annual sequestration values per hectare.

- The spreadsheet tool allows for values to differ by cover type. However, for many services, the same values are used due to a lack of data differentiating benefits by land cover (e.g., real estate values are based on open-space hedonic studies treating forest, wetland, and grassland similarly)
  - For Alton, cover type refers to forest, wetland, or grassland Ecological Land Classification (ELC) classes
  - For Mt. Pleasant, cover type refers to Woodland, Wetland, or Grassland/Meadow since ELC classes were not available for this site

10.1.5 Carbon Tab

The 'Carbon Tab', which is specific to the carbon sequestration spreadsheets, contains data on the carbon value. A constant carbon value and a forecast value in year t, respectively, consistent with the constant and forecast approaches reviewed above for the 'Parameters Tab', are contained within the 'Carbon Tab'.

10.1.6 Risk and Life Tabs

The 'Risk Tab' contains data on the probability of the threat eliminating the asset's service flow in year t for the Salt, Wildfire, and Invasive Species threats. The status quo probability can be set by the user, while the probability given an intervention to maintain the asset is calculated by multiplying the status quo probability by the Risk Reduction set in the 'Parameters Tab'.

- For the Salt threat, the probability depends on the year as well as the buffer, the latter representing the perpendicular distance from the transportation corridor.
- For the Wildfire threat, the probability depends on the likelihood of wildfire spread, which is a function of the parcel's cover
- For the Invasive Species threat, the probability depends on the type of cover, either woodlands, wetlands, or grasslands/meadow

The 'Life Tab' contains data on the proportion of the baseline service flow remaining in year *t* for the Trail Encroachment threat. Both the status quo and maintain service flows remaining can be set by the user.

- The proportion of the baseline service flow remaining differs according to three different asset lifespans (10, 15, and 20 years). Currently the status quo service flow is set to decline linearly until it reaches the end of the asset's lifespan, while the service flow given the intervention to maintain the asset is set at 100%.

10.1.7 Maintain Cost Tab

The 'Maintain Cost Tab' contains data on the costs of the interventions used to maintain the assets. Depending on the approach, the data included in this tab either represents per hectare or annual costs of the intervention. Per hectare costs are included for area-based interventions and are incorporated into cost calculations in the 'Detailed Output Tab' for the Wildfire, Invasive Species, and Trail Encroachment threats. Annual costs for each year *t* are included for linear (winter road maintenance) interventions for the Salt threat. These annual costs are not incorporated into calculations in a separate worksheet since they do not depend on a parcel's area. Rather, the annual linear costs are discounted directly in the 'Maintain Cost Tab' and then incorporated directly into the 'Summary Output Tab'. Finally, the inputs for both of these costing approaches can be changed by the user.

- For the Wildfire threat, there is a single column for per hectare cost data entry (i.e., costs are assumed not to vary by cover type since the focus is forests)
- For the Invasive Species and Trail Encroachment threats, there are columns for per hectare cost data entry for each type of cover: woodland, wetland, and grassland/meadow (i.e., costs are allowed to vary by cover type)
- For the Salt threat, there is a single column for annual linear cost data entry (i.e., costs are incurred each year and do not vary by cover type) and area-based cost estimates for area-based maintain actions.

10.2 The Enhance Management Alternative

Two scenarios were modeled to establish the economic efficiency of enhancing (adding to) the natural asset systems at each site. Unlike the Maintain management alternative, Enhance does not build in the probability of threats via a Do Nothing scenario. However, the spreadsheet includes the option to build this probability into the modelling of the Enhance scenario (it will only work for threats that affect the entire parcel rather than a portion). The costs of maintaining the enhanced assets are presently built into the models. The two scenarios employed to estimate the economic efficiency of enhancing (adding) natural assets are:

- A 'Baseline' scenario that represents the stream of benefits flowing from the current cover. The values considered in this baseline are local agricultural rent (alternative values can be incorporated into subsequent iterations of the spreadsheet).
- An Enhance scenario that represents the estimated stream of benefits as well as the costs given interventions to expand the area of natural assets via planting forests in Alton or changing manicured greenspace to grassland/meadow in Mt. Pleasant.

10.2.1 Summary Output Tab

Similar to the Maintain management alternative's spreadsheet, the 'Summary Output Tab' presents the total present value benefits (PVB) and costs (PVC) in 2018 Canadian dollars, which are summed over the affected parcels and time horizon output in the 'Detailed Output' tab.

- *Baseline PVB ($PVB_{Baseline}$)*: sum of the present value benefits of the value of the existing land cover on the enhanced parcels
- *Enhance PVB ($PVB_{Enhance}$)*: sum of present value benefits of the stream of services flowing from the area added to the natural asset system (i.e., the area enhanced via forest or grassland/meadow)
- *Enhance PVC ($PVC_{Enhance}$)*: sum of the present value costs of interventions to enhance and maintain the natural asset system; $PVC_{Enhance} = PVC_{Intervene} + PVC_{Maintain}$
    - *PVC Intervention ($PVC_{Intervene}$)*: present value costs of forest planting or changing manicured greenspace to meadow/grassland interventions to convert the area to forest and enter it into the natural asset system
    - PVC Maintain *($PVC_{Maintain}$)*: present value costs of interventions to maintain the newly added asset at its current level (limit probability of threats)
- The benefit of the intervention to enhance the natural asset system is the difference between '*Enhance PVB*' and '*Baseline PVB*'

These present value benefit and cost estimates are included in the calculation of the Net Present Value (NPV) and Benefit Cost Ratio (B/C) economic efficiency criteria which themselves are used to inform decisions on natural asset management options (i.e., deciding whether to enhance the natural asset system).

- Net Present Value: $NPV = PVB - PVC = (PVB_{Enhance} - PVB_{Baseline}) - PVC_{Enhance}$
    - A positive NPV indicates that the benefits of the 'Enhance' intervention exceed its costs
- Benefit Cost Ratio: $B/C = PVB/PVC$=$(PVB_{Maintain} - PVB_{Baseline})/PVC_{Enhance}$
    - A ratio larger than 1 indicates that the benefits of the 'Enhance' intervention exceed its costs

Note that the user cannot change anything in this worksheet.

10.2.2 Enhance Output Tab

The 'Enhance Output Tab' is similar to the 'Detailed Output Tab' reviewed above for the Maintain management alternative's spreadsheet. It contains input data on each parcel to be enhanced, for instance its size, current cover, and in the case of Alton, the type of forest planting intervention. Benefits or costs are calculated for each parcel (*p*) and each year (*t=1,…,20*) over a 20 year horizon according to relationships outlined below. A discount rate (*r*) is applied to adjust these values to the present year and at the end of the annual stream of benefits or costs, these values are summed yielding a present value over the time horizon for the parcel. Columns are included in the spreadsheet tool to account for benefits or costs in year *t* as well as for the present value aggregated over all years.

Baseline

The benefits of the 'Baseline' scenario are valued by multiplying the parcel's area by the annual benefit per hectare of its current cover (Equation 12).[34] The same calculation is used for each service with the exception of carbon which is expanded upon in the variable descriptions that follow this equation.

$$PVB\ Baseline_p^t = \sum_{t=1}^{20} \frac{(HA_p)(Baseline\ Service\ Benefit\ Per\ HA_p + Baseline\ Land\ Benefit\ Per\ HA_p)}{(1+r)^t} \quad [12]$$

- HA_p is the area of the parcel *p* that is added to the natural asset system
- $Baseline\ \underline{Service}\ Benefit\ Per\ HA_p$ is the average annual value of the service flow per hectare for the parcel *p*'s baseline cover
    - Aside from the carbon sequestration service, average service benefits are calculated outside of the spreadsheet tool
    - For carbon, the Service Benefit Per HA in time *t* for parcel *p* is calculated by multiplying the carbon sequestration rate specific to the parcel's cover by the social cost of carbon (SCC) in year *t*. This structure applies to all remaining calculations based on the Service Benefit Per HA involving carbon sequestration (including under the Enhance scenario).
        - $Service\ Benefit\ Per\ HA_p^t = (Sequestration_p)(SCC^t)$
- $Baseline\ \underline{Land}\ Benefit\ Per\ HA_p$ is the average annual rental value of the land per hectare for the parcel *p*'s baseline cover. It is included to incorporate the opportunity cost of the parcel's land use.
    - This value should represent the best and highest use of the land.
    - Presently this value equals $0 since data is not available for all land covers. As data becomes available these cells can be updated.
- r and t are the discount rate and year, respectively

Enhance

Calculations for the Enhance management alternative's spreadsheet tool are based on the service, rather than the threat. These calculations are reviewed below.

Air Quality and Stormwater Management

Equation 13 was used to value the air quality and stormwater management benefits of the Enhance intervention for a parcel *p* in time *t*. Since the flow of air quality and stormwater management services are both increased by planting forests, these benefits were only valued for Alton. Variable descriptions follow.

[34] The 'Baseline' is used to check the 'Do Nothing' and 'Maintain' scenarios as the aggregate present value benefits of these latter two scenarios should be smaller than that of the 'Baseline' scenario since they are weighted.

$$PVB\ Enhance_p^t = \sum_{t=1}^{20} \frac{(1 - ProbE^t)(HA_p)\left((Growth^t)(Enhance\ Service\ Benefit\ Per\ HA_p) + (1 - Growth^t)(Baseline\ Service\ Benefit\ Per\ HA_p)\right)}{(1+r)^t} \quad [13]$$

- $ProbE^t$ is the probability of threat in year *t* to the entire parcel. This probability is presently set at 0.
    - The superscript *t* represents years since planting
- HA_p is the area of the enhanced parcel *p*
- $Growth^t$ is a percent weight that accounts for an increased service flow resulting from the forest's growth over time. It is a linear function relating forest age to service provision; the weight is 0% at age 0 years and reaches 100% at age 30 years. Since planting a forest does not immediately eliminate the existing land cover's sequestration, this weight is also used to phase out the current cover's carbon sequestration service provision.
    - The superscript *t* represents years since planting
- $Enhance\ Service\ Benefit\ Per\ HA_p$ is the average annual value of the service flow per hectare resulting from the enhancement of parcel *p*
- $Baseline\ Service\ Benefit\ Per\ HA_p$ is the average annual value of the service flow per hectare for parcel *p*'s current land cover
- r and t are the discount rate and year, respectively

Carbon Sequestration

Alton

Equation 14 was used to value the carbon sequestration benefits of the Enhance intervention for a parcel *p* in time *t*. In Alton, this Enhance intervention involves planting forest via reforestation or naturalization. Variable descriptions follow.

$$PVB\ Enhance_p^t = \sum_{t=1}^{20} \frac{(1 - ProbE^t)(HA_p)\left((Growth^t)(Enhance\ Service\ Benefit\ Per\ HA_p) + (1 - Growth^t)(Baseline\ Service\ Benefit\ Per\ HA_p)\right)}{(1+r)^t} \quad [14]$$

- $ProbE^t$ is the probability of threat in year *t* to the entire parcel. This probability is presently set at 0.
    - The superscript *t* represents years since planting
- HA_p is the area of the enhanced parcel *p*
- $Growth^t$ is a percent weight that accounts for an increased service flow resulting from the forest's growth over time. It is a linear function relating forest age to service provision; the weight is 0% at age 0 years and reaches 100% at age 30 years. Since planting a forest does not immediately eliminate the existing land cover's sequestration this weight is also used to phase out the current cover's carbon sequestration service provision.
    - The superscript *t* represents years since planting
- $Enhance\ Service\ Benefit\ Per\ HA_p$ is the average annual value of the service flow per hectare resulting from the enhancement of parcel *p*
- $Baseline\ Service\ Benefit\ Per\ HA_p$ is the average annual value of the service flow per hectare for parcel *p*'s current land cover

- r and t are the discount rate and year, respectively
    - If the Forecast carbon value is used then $r = 0\%$

Mt. Pleasant

Equation 15 was used to value the carbon sequestration benefits of the Enhance intervention for a parcel *p* in time *t*. In Mt. Pleasant, this Enhance intervention involves reducing mowing on 10% of the manicured open space or park with the status quo management kept for the remainder of the parcel. Unlike with forests in Alton, the carbon sequestration benefits of a grassland / meadow intervention are assumed to occur in full in the first year. Variable descriptions follow.

$$PVB\ Enhance_p^t = \sum_{t=1}^{20} \frac{(1 - ProbE^t)\left((HA_p^{10})(Enhance\ Service\ Benefit\ Per\ HA_p + Mowing\ Cost\ Per\ HA_p) + (HA_p^e)(Baseline\ Service\ Benefit\ Per\ HA_p)\right)}{(1+r)^t} \quad [15]$$

- $ProbE^t$ is the probability of threat in year *t* to the entire parcel. This probability is <u>presently set at 0</u>.
    - The superscript *t* represents years since planting
- HA_p^{10} is the area of the enhanced parcel *p* on which grasslands/meadow are established
- $Enhance\ Service\ Benefit\ Per\ HA_p$ is the annual value of the service flow per hectare resulting from the enhancing the portion of parcel *p*
- $Mowing\ Cost\ Per\ HA_p$ is the annual cost of maintaining manicured open space or park. It is included to account for the reduced cost of maintaining 10% of the parcel's manicured greenspace.
- HA_p^e is the area of the enhanced parcel *p* on which the current land cover is kept
- $Baseline\ Service\ Benefit\ Per\ HA_p$ is the average annual value of the service flow per hectare for parcel *p*'s current land cover
- r and t are the discount rate and year, respectively
    - If the Forecast carbon value is used then $r = 0\%$

Costs

The costs of the interventions in year *t* on parcel *p* as well as the present value of this stream are also included in the 'Enhance Output Tab'. The interventions used to enhance the natural asset systems in Alton and Mt. Pleasant are all area-based (planting a forest or growing grassland / meadow). Area-based interventions are also used to maintain the enhanced assets against threats. The present value costs are calculated according to Equation 16; variable definitions follow.

$$PVC\ Maintain_p^t = \sum_{t=1}^{20} \frac{(HA_p)(Cost\ Per\ HA^t)}{(1+r)^t} \quad [16]$$

- HA_p is the area of the parcel *p*
- $Cost\ Per\ HA^t$ is the cost per hectare of planting forest or creating grassland/meadow and maintaining the enhanced asset against a threat in year *t*
    - In Alton the per hectare costs to plant a forest differ by reforestation and naturalization interventions, while the per hectare cost of maintaining the enhanced asset does not differ by intervention type
- r and t are the discount rate and year, respectively

10.2.3 Parameters Tab

The 'Parameters Tab' contains one-off parameters that are incorporated into the calculations in the 'Enhance Output Tab', such as the discount rate.

- *Discount Rate*: the discount rate (*r*) represents the time-value of money (having a dollar now is worth more than the same dollar in the future). Although currently set at 3%, the discount rate can be changed by the user. Since the forecast carbon price has a built-in rate of 3%, changing this rate does not affect the calculated benefits of carbon sequestration (in this case $r = 0\%$). This parameter is incorporated into the 'Enhance Output Tab' as noted in the relevant section above.
- *Carbon Value Approach*: this dropdown cell is used to select the approach to carbon pricing; it only applies to the carbon sequestration spreadsheets. The user can select 'Constant' or 'Forecast' to choose an approach based on a constant carbon value or a forecast value, respectively. It is currently set at 'Forecast'.
- *Current Manicured Mowing Cost Per Year*: this value represents the costs to maintain manicured open space or park via mowing. It is currently set at $400 though can be changed by the user. This option is included for Mt. Pleasant only. Note that the costs of implementing the enhance intervention are changed in the 'Enhance Input Tab'.

10.2.4 Enhance Input Tab

The 'Enhance Input Tab' is the location of the data on forest growth weights (Alton only), per hectare asset values (for services and land), probability of threat to the enhanced cover, and the costs of the 'Enhance' intervention as well as maintaining the enhancement.[35] These data, which can be changed by the user, are used to populate the equations listed above in the section reviewing the 'Enhance Output Tab'. As explained above in the section about the 'Enhance Output Tab', aside from the spreadsheet for the carbon sequestration service, the assets service and land values are in terms of annual dollar values per hectare. For carbon sequestration, service values are in terms of annual sequestration per hectare while land values are in annual dollars per hectare. Each type of data is reviewed in order of appearance in the worksheet, starting at the left and moving right, for each community.

Alton

- The Forest Growth Weights relate anticipated forest and related service growth to time over a 20-year period. These weights are used to populate the $Growth^t$ variable as reviewed above for the 'Enhance Output Tab'. Two columns are included, one for the reforestation intervention and one for the naturalization intervention.
    - The user is also able to set the age of planted stock for a naturalization intervention in this part of the 'Enhance Input Tab'
- Asset Values are included for the enhanced parcel's current cover as well as for forest planted via reforestation or naturalization. These values are used to populate the $Enhance\ Service\ Benefit\ Per\ HA_p$, $Baseline\ Land\ Benefit\ Per\ HA_p$ and $Baseline\ Service\ Benefit\ Per\ HA_p$ variables as reviewed above for the 'Enhance Output Tab'.

[35] The 'Enhance Input Tab' essentially combines the data from the 'Maintain' management alternative spreadsheet's 'Asset Tab', 'Risk Tab', and 'Maintain Cost Tab' in a single worksheet.

However, for many services the same values are used due to a lack of data differentiating benefits by land cover. For carbon, the service values are in terms of carbon sequestration and not dollars and enter equations a bit differently as explained at the beginning of the overview of the 'Enhance Output Tab'.

    - Cover type refers to forest, wetland, or grassland Ecological Land Classification (ELC) classes

- Probability of Damage (i.e., probability of threat) are included to account for the likelihood that a threat eliminates the entire enhanced parcel's service flow in year t over the 20-year period. It is used to populate the $ProbE^t$ variable as reviewed above for the 'Enhance Output Tab'.
- Enhance Costs are included for the reforestation and naturalization interventions as well as for maintaining the asset against threats over the 20-year period. These values are used to populate the $Annual\ Cost\ Per\ HA$ variable as reviewed above for the 'Enhance Output Tab'.

Mt. Pleasant

- Asset Values are included for the enhanced parcel's current Manicured Open Space or Park cover as well as for the Grassland/Meadow enhancement. These values are used to populate the $Enhance\ Service\ Benefit\ Per\ HA_p$, $Baseline\ Land\ Benefit\ Per\ HA_p$ and $Baseline\ Service\ Benefit\ Per\ HA_p$ variables as reviewed above for the 'Enhance Output Tab'. For carbon, the service values are in terms of carbon sequestration and not dollars and enter equations a bit differently as explained at the beginning of the overview of the 'Enhance Output Tab'.
- Probability of Damage (i.e., probability of threat) are included to account for the likelihood that a threat eliminates the entire enhanced parcel's service flow in year t over the 20-year period. It is used to populate the $ProbE^t$ variable as reviewed above for the 'Enhance Output Tab'.
- Enhance Costs are included for the grassland/meadow intervention as well as for maintaining the asset against threats over the 20-year period. These values are used to populate the $Annual\ Cost\ Per\ HA$ variable as reviewed above for the 'Enhance Output Tab'.

10.2.5 Carbon Tab

The 'Carbon Tab', which is specific to the carbon sequestration spreadsheets, contains data on the carbon value. A constant carbon value and a forecast value in year t, respectively, consistent with the constant and forecast approaches reviewed above for the 'Parameters Tab', are contained within the 'Carbon Tab'.

11 Reference List

Bélanger, P. (2008). Urban Stormwater Economics: A Comparative Cost-Benefit Study of Site Technologies & Strategies for the City of Toronto.

Brampton Growth Management Program. 2006. Development Outlook Report. Part 1: Report 2006. 39 pages. Accessed at: https://www.brampton.ca/EN/Business/planning-development/Documents/PLD/Growth%20Management/2006_Development_Outlook_Report_SEPT_28_2006.pdf

CBC (2018). Rise in road salt prices hits local contractors. Accessed on January 6, 2020 from: https://www.cbc.ca/news/canada/ottawa/ottawa-contractors-road-salt-price-hike-1.4934369

City of Brampton. 2002. Planning and Design Guidelines. Brampton PathWays Master Plan Volume Two of Three. Final Report. June 2002. 165 pages.

City of Brampton. 2010. By-law 45-2010 to adopt Secondary Plan Area 51, Chapter 51(A). Mount Pleasant Secondary Plan. 105 pages.

City of Brampton. 2012. Office Consolidation Tree Preservation By-law 317-2012. A by-law to conserve and protect trees on private land within the City of Brampton and to repeal By-law 38-2006. 15 pages.

Cumming Cockburn Limited. 2000. Hurricane Hazel and Extreme Rainfall In Southern Ontario. ICLR Research Paper Series – No. 9. Report prepared for the Institute for Catastrophic Loss Reduction. 27 pages.

[CVC] Credit Valley Conservation (n.d.). Native Grassland and Habitat Restoration. Accessed on December 16, 2019 at: https://cvc.ca/your-land-water/tree-planting-and-habitat-restoration-services/native-grassland-and-habitat-restoration/native-grassland-and-habitat-restoration/

[CVC] Credit Valley Conservation (2018). Municipal Natural Assets Initiative: Region of Peel Pilot (EPA-SWMM Modeling report). Accessed on September 19, 2019 from: https://mnai.ca/media/2018/07/MNAI_Peel-final.pdf

DSS Management Consultants Inc. (2009). The Impact of Natural Features on Property Values. Report Submitted to Credit Valley Conservation. Accessed on December 16, 2019 at: https://cvc.ca/wp-content/uploads/2011/07/CVC-NatFeatRpt-Mar31_09.pdf

Elliott, K.A. 1998. The Forests of Southern Ontario. In The Forest Chronicle, Vol. 74, No. 6, November/December 1998, pp 850-854.

Environment Canada (2012). Five-year Review of Progress: Code of Practice for the Environmental Management of Road Salts. Catalogue Number En14-54/2012E-PDF. Accessed on January 6, 2020 from: http://publications.gc.ca/collections/collection_2012/ec/En14-54-2012-eng.pdf

Environment and Climate Change Canada. 2016. Technical Update to Environment and Climate Change Canada's Social Cost of Greenhouse Gas Estimates. Accessed from: http://oaresource.library.carleton.ca/wcl/2016/20160502/En14-202-2016-eng.pdf.

Fay, L., Veneziano, D., Muthumani, A., Shi, X., Kroon, A., Falero, C., ... & Petersen, S. (2015). Benefit-Cost of Various Winter Maintenance Strategies (No. CR 13-03). Accessed on January 6, 2020 from: http://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.13-03_Final.pdf

Gucker, Corey L. 2008. Phragmites australis. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.fed.us /database/feis/plants/graminoid/phraus/all.html [2019, August 28].

Hanley, N., Barbier, E. B., & Barbier, E. (2009). Pricing nature: cost-benefit analysis and environmental policy. Edward Elgar Publishing.

Kelly, V. R., Findlay, S. E., Schlesinger, W. H., Menking, K., & Chatrchyan, A. M. (2010). Road salt: Moving toward the solution. The Cary Institute of Ecosystem Studies. Accessed on January 6, 2020 from: https://www.caryinstitute.org/sites/default/files/public/reprints/report_road_salt_2010.pdf

Kelting, D. L., & Laxon, C. L. (2010). Review of effects and costs of road de-icing with recommendations for winter road management in the Adirondack Park. Adirondack Watershed Institute. Accessed on January 6, 2020 from: https://www.adkwatershed.org/sites/default/files/road_salt-_final_dlk.pdf

Kesik, T. & Miller, A. (2008). Toronto Green Development Standard Cost Benefit Study. Toronto, Canada: The Faculty of Architecture, Landscape, and Design at the University of Toronto. https://www2.daniels.utoronto.ca/sites/daniels.utoronto.ca/files/old/Kesik_TGDS_CB-Study_Oct2008_Appendix_D.pdf

Lelong, Benjamin; Lavoie, Claude; Jodoin, Yvon; Belzile, Francois. 2007. Expansion pathways of the exotic common reed (Phragmites australis): a historical and genetic analysis. Diversity and Distributions. 13(4): 430-437.

Nature Conservancy (2017a). Restoring Your Annual-Dominated Field to Utility Meadow. Accessed on December 16, 2019 at: https://www.nature.org/content/dam/tnc/nature/en/documents/Restoration-Guide-Annual-Dominated-to-Utility-Meadow.pdf

Nature Conservancy (2017b). Restoring Your Degraded Grassland to Utility Meadow. Accessed on December 16, 2019 at: https://www.nature.org/content/dam/tnc/nature/en/documents/Restoration-Guide-Degraded-Grassland-to-Utility-Meadow.pdf

McConnell, K. E. (1990). Double counting in hedonic and travel cost models. *Land Economics*, *66*(2), 121-127.

Ontario Federation of Anglers and Hunters (OFAH) and Ontario Ministry of Natural Resources and Forestry OMNRF). 2012a. Ontario's Invading Species Awareness Program: Garlic Mustard. Accessed at http://www.invadingspecies.com/garlic-mustard/

Ontario Federation of Anglers and Hunters (OFAH) and Ontario Ministry of Natural Resources and Forestry OMNRF). 2012b. Ontario's Invading Species Awareness Program: Invasive Phragmites. Accessed at http://www.invadingspecies.com/invasive-phragmites/

Ontario Federation of Anglers and Hunters (OFAH) and Ontario Ministry of Natural Resources and Forestry OMNRF). 2012c. Ontario's Invading Species Awareness Program: Dog-strangling Vine. Accessed at: http://www.invadingspecies.com/dog-strangling-vine/

Ontario Ministry of Natural Resources (OMNR). 1999a. Extension Notes – The Old Growth Forests of Southern Ontario. Queen's Printer for Ontario. ISSN 1198-3744. R.P. (5k P.R., 99 05 30). Order Number: LRC 26.

Ontario Ministry of Natural Resources (OMNRb). 1999b. Extension Notes – Managing Regeneration in Conifer Plantations to Restore a Mixed, Hardwood Forest. ISSN 1198-3744. R.P. (5k P.R., 99 05 03). Order Number: LRC 25.

Podur, Justin A and B. Mike Wotton. 2011. Defining fire spread event days for fire-growth modelling. International Journal of Wildland Fire 2011, 20, 497–507.

Scherer, T. Date undetermined. What to do with Flooded Septic Systems. North Dakota State University. https://www.ag.ndsu.edu/flood/home/what-to-do-with-flooded-septic-systems-1. Accessed August 25, 2019.

Suggett, J. M., Hadayeghi, A., Mills, B., Andrey, J. C., & Leach, G. (2007). Development of winter severity indicator models for Canadian winter road maintenance. Transportation Association of Canada. Accessed on January 6, 2020 from: https://www.tac-atc.ca/sites/default/files/site/doc/Bookstore/ptm-wintersev-finalpub.pdf

Transportation Research Board. 1991. Special Report 235 – Highway Deicing, Chapter 4: Road Salt Impacts on the Environment. Committee on the Comparative Costs of Rock Salt and Calcium Magnesium Acetate (CMA) for Highway Deicing. National Research Council, Washington, D.C. pp. 69-82.

Toronto Star. 2012. Phragmites australis is Canada's worst invasive plant. Article written by feature writer Leslie Scrivener and published Aug. 11, 2012. Accessed at: https://www.thestar.com/news/insight/2012/08/11/phragmites_australis_is_canadas_worst_invasive_plant.html.

Trenholm, R., Haider, W., Lantz, V., Knowler, D., & Haegeli, P. (2017). Landowner preferences for wetlands conservation programs in two Southern Ontario watersheds. *Journal of environmental management*, *200*, 6-21.

Van Sleeuwen, M. 2006. Natural fire regimes in Ontario. Ontario Ministry of Natural Resources, Queen's Printer for Ontario, Toronto. 143p.

Wang, X., Parisien, M.-A., Taylor, S. W., Candau, J.-N., Stralberg, D., Marshall, G. A., Flannigan, M. D. (2017). "Projected changes in daily fire spread across Canada over the next century." Environmental Research Letters, 12(2), 025005.

Wilcox, Kerrie L. , S.A. Petrie, L.A. Maynard, and S. W. Meyer. 2003. Historical Distribution and Abundance of Phragmites australis at Long Point, Lake Erie, Ontario. Journal of Great Lakes Research 29(4):664–680. Internat. Assoc. Great Lakes Res., 2003, pp 664-680.

Appendix A: Rapid Condition Assessment

Over the course of this project, CVC has identified a gap in data and knowledge regarding the condition assessment of natural assets. In general, municipal asset managers rely on condition assessments to help prioritize interventions on assets at risk of failure. The availability of this type of information for natural assets is limited. Additionally, performing in-depth ecological assessments for the entire inventory of natural assets is not feasible for many municipalities due to resource constraints.

As part of this study, CVC developed a prototype of a Rapid Condition Assessment Methodology (RCAM) in consultation with CVC ecologists in order to address this gap. The RCAM is a collection of protocols for each natural asset type for municipal staff with no background in ecology or hydrology to collect field data which supports the assessment of natural asset condition. The RCAM has been designed to be simple enough that it can be done cost-effectively and quickly by staff with limited ecological survey experience but produces data which flags at-risk assets for more in-depth assessment by qualified personnel. The RCAM has also been developed to be compatible with the Ecological Land Classification (ELC) system. A draft sample protocol for the RCAM has been included in **Appendix B:** Rapid Condition Assessment Methodology Draft Sample Protocol. The RCAM has been tested at sample locations in Mount Pleasant and Alton locations in October 2019. The ranking system produced by the RCAM is compatible with standard asset management condition assessment frameworks in use by municipalities (City of Brampton and the Town of Caledon). The calculation of condition scores has been automated using a prototype excel calculator, of which screenshots have included in **Appendix C:** Rapid Condition Assessment Methodology Score Calculator Tool Screenshots. The scoring system has been designed to be adaptable and easily adjustable as more data is collected and more expert input is included.

Appendix B: Rapid Condition Assessment Methodology Draft Sample Protocol

Site Name			
Asset ID			
Date (YYYYMMDD)			
Time (24:00)			
Surveyor(s)			
Easting		Northing	
Photo(s)			
Area (ha)			

Forest	Plantation	Successional Woodland	Meadow
Treed Swamp	Shrub Swamp	Marsh	Aquatic
Fen	Bog	Other	

Definitions & Pictures to be developed

		Dominant Species List – Optional species in order of decreasing abundance (for "Ab", fill with: ">>" much greater than, ">" greater than, "=" equal to)							
Layer (see Figure B-1 and Figure B-2)	**Cover %**	**Species 1**	**Ab**	**Species 2**	**Ab**	**Species 3**	**Ab**	**Species 4**	**Ab**
Canopy trees									
Sub-canopy									
Tall shrubs & Saplings									
Low shrubs & Seedlings									
Forb									
Graminoid									
Emergent									
Floating– leaved aquatic									
Free- floating									
Submergent									
Open water									
Manicured Lawn									
Bare Soil or Rock									
Impervious cover (e.g. roads, parking lots, buildings)									

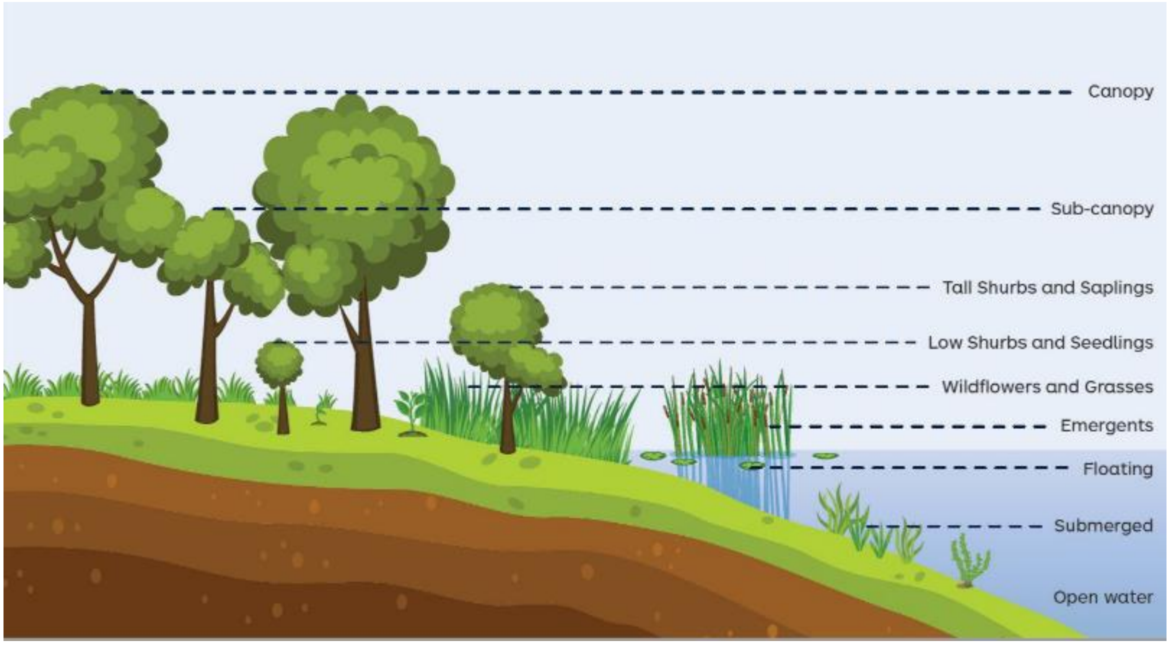


Figure B-1. Types of vegetation [adapted from OWES (MNRF 2014)].

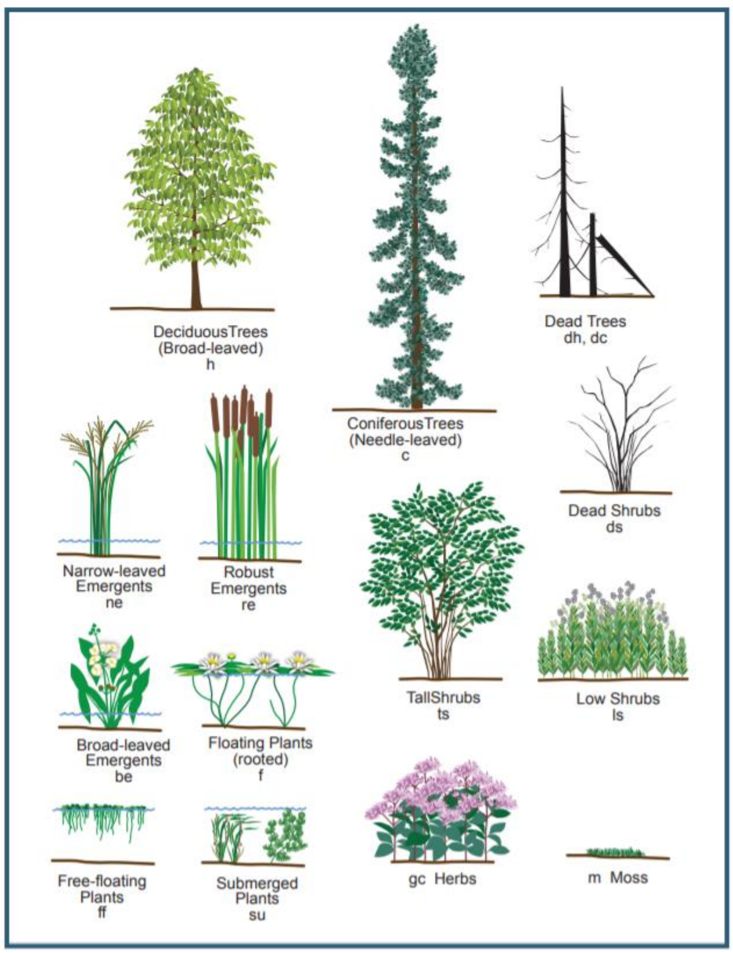


Figure B-2. The composition of an ecosystem and vegetation layers.

Size Class Distribution Estimate Percentage to closest 10 % (dbh – Diameter at 1.3 m) = 100%

0-10 cm		10–25 cm		25-50 cm		>50 cm	

Open Water Type (see Figure B-3)	1	2	3	4	5	6	7	8	None

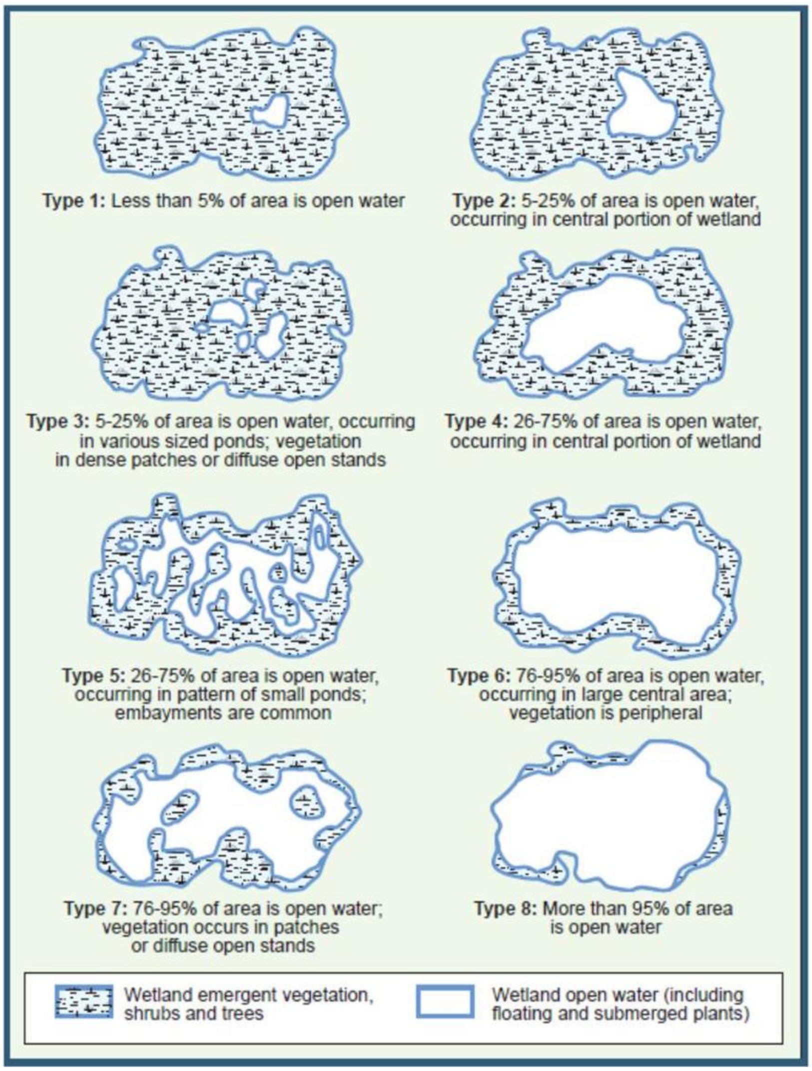
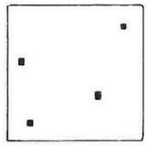
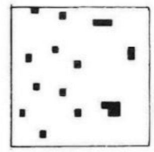
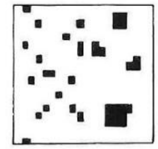


Figure B-3. Percent open water within a wetland [adapted from OWES (MNRF 2014)].

Indicator	Good (5 points)	Fair (3 points)	Poor (1 point)
Canopy (see Figure B-4)	Generally greater than 75% cover with few canopy gaps	Cover 60-75% with many or few canopy gaps	Cover >60 with many canopy gaps
Sub-canopy	number of sub-canopy trees roughly equal to number of canopy trees	Canopy trees greatly outnumber sub-canopy trees	Sub-canopy generally absent
Saplings and Shrubs	Abundant and Widespread shrub layer	Occasional or localized	Sparse or absent
Ground Vegetation (see Error! Reference source not found.**)**	>50% cover	25-50% cover	<25% cover
Tree size	Mix of tree sizes with some exceeding 40cm	Most trees between 20-40	Most trees are under 20cm DBH
	Sum of points ( ) / 5 = Category Score ( )		
Indicator	**Good (5 points)**	**Fair (3 points)**	**Poor (1 point)**
Tree Crown Mortality	< 10 % of trees have severe canopy decline	10 – 25% of trees have severe canopy decline	> 25 % of trees have severe canopy decline
Standing Dead Wood	At least 10% of standing trees are dead (2 of 20 trees).	Approximately 5% of standing trees are dead (1 of 20 trees).	Less than 5% of standing trees are dead (fewer than 1 of 20 trees).
Downed Dead Woody	Enough downed wood is present that you are constantly stepping over it while walking through the forest	Occasional downed wood	Virtually no downed wood
	Sum of points ( ) / 5 = Category Score ( )		
Unauthorized Trails	None or Few and Faint	Occasional and clearly visible	Many and clearly visible
Dumping	None or light Local or widespread	Moderate Widespread	Heavy Widespread
Encroachment	None or light Local or widespread	Moderate Widespread	Heavy Widespread
Browse	None or light	Moderate	Heavy
	Local or widespread	Widespread	Widespread

Other Impacts	None or light Local or widespread	Moderate Widespread	Heavy Widespread
			
	Sum of points( ) / 5 = Category Score ( )		
Indicator	**Good (5 points)**	**Fair (3 points)**	**Poor (1 point)**
Ground Layer – Presence	No Priority Invasives Present Garlic Mustard, DSV, Hogweed, Knotweed	One priority Invasive Present Garlic Mustard, DSV, Hogweed, Knotweed	10 or more priority invasives Garlic Mustard, DSV, Hogweed, Knotweed
Ground Layer – Abundance	Priority invasives cover <5%	Priority invasives cover 5-50%	Priority invasives cover >50%
Shrubs and Saplings	Buckthorn is occasional or absent	Buckthorn abundant localized locations	Buckthorn is dominant throughout
Canopy	Canopy is free of invasive species Norway Maple, Black Locust	Occasional invasives in the canopy Norway Maple, Black Locust	Canopy is dominated by invasive species Norway Maple, Black Locust
	Sum of points( ) / 4 = Category Score ( )		

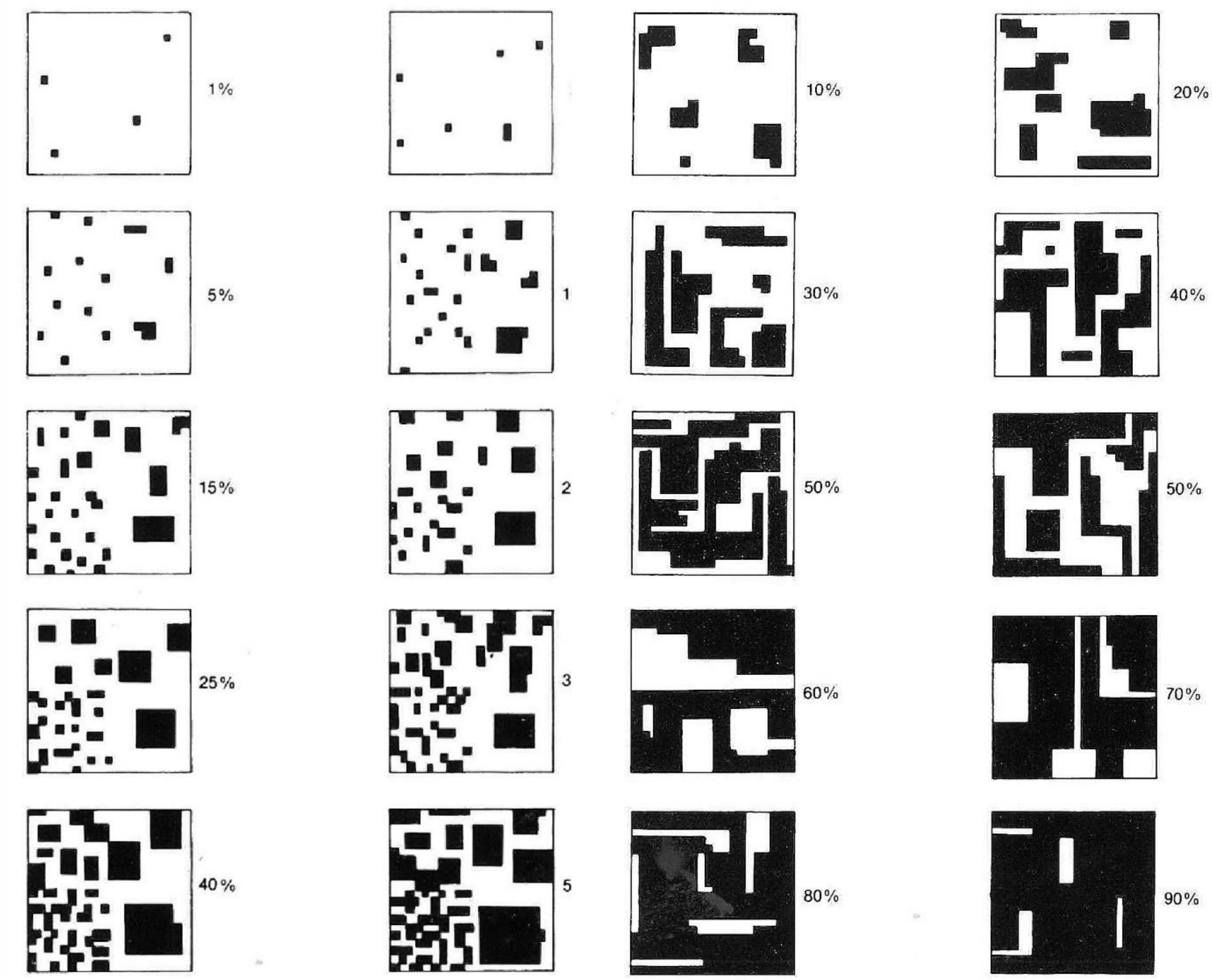


Figure B-4. Percent relative cover [adapted from the Field Manual for Describing Soils in Ontario (OCSRE 1993)].

References

Ontario Centre for Soil Resource Evaluation (OCSRE). 1993. Field Manual for Describing Soils in Ontario. 4th edition. Ontario Center for Soil Resource Evaluation. Publication No. 93-1.

Ontario Ministry of Natural Resources and Forestry (OMNRF). 2014. Ontario Wetland Evaluation System, Southern Manual. 3rd Edition, Version 3.3.

Appendix C: Rapid Condition Assessment Methodology Score Calculator Tool Screenshots

Site Information		Score (If Applicable)		Condition Score
Site Name	Creditview Sandlewood 2			2.453846154
Asset ID	2			
Date	9/20/2019			
Start Time (24:00)	11:30:00 AM			
End Time (24:00)				
Surveyor 1	SS			
Surveyor 2 (optional)	TK			
Surveyor 3 (optional)	KM			
Surveyor 4 (optional)	JG			
Ecosystem Type	Meadow			
Natural Area Size (ha)	3.2	3		
Natural% in 100m buffer (Placeholder)				
Easting (UTM)	594010			
Northing (UTM)	4837004			
Strata Observations				Weighted Average Strata Score
Strata	Observed Percent Cover	Score		0.9
Canopy trees	0%	0		
Sub-canopy	0%	0		
Tall shrubs & Saplings	25%	3		
Low shrubs & Seedlings	10%	1		
Wildflowers & Grass-like	90%	5		
Emergent	0%	0		
Floating–leaved aquatic	0%	0		
Free-floating	0%	0		
Submergent	0%	0		
Open water	0%	0		
Manicured Lawn	0%	0		
Bare Soil or Rock	0%	0		
Impervious cover	0%	0		

Site Name	Asset ID	Ecosystem Type	Condition Score	Natural Asset Size (ha)	Asset size subscore	Strata subscore	Open Water subscore	Indicator subscore	Date
0	0	0	Please input natur	0		Please complete o	Please select open wate	Please complete obs	1/0/1900
Creditview Sandlewood	1	Deciduous Swamp	3.93	5.3	5	2.1	0	4.692307692	9/20/2019
Creditview Sandlewood	2	Meadow	2.45	3.2	3	0.9	0	3.461538462	9/20/2019
Huttonville Creek East 1	3	Meadow	1.72	1.5	1	0.7	0	3.461538462	9/20/2019
Huttonville Creek East 2	4	Pond	1.37	0.3	0	1	1	3.461538462	9/20/2019
Alton Grange 1	5	Plantation	2.21	1	1	1.1	0	4.538461538	10/18/2019
Alton Grange 2	6	Successional Wooc	2.01	1.6	1	0.5	0	4.538461538	10/18/2019
Alton Grange 3	7	Plantation	3.51	8.6	5	1.3	0	4.230769231	10/18/2019
Alton Grange 4	8	Treed Swamp	2.21	1	1	1.1	0	4.538461538	10/18/2019
Alton Grange 5	9	Shrub Swamp	1.69	0.8	0	1	0	4.076923077	10/18/2019

Indicator Responses and Scoring

Tree size responses	Mix of tree sizes with some exceeding 40cm	Most trees between 20-40	Most trees are under 20cm DBH	N/A	
Tree size scoring	5	3	1		0
Tree Crown Mortality responses	< 10 % of trees have severe canopy decline	10 - 25% of trees have severe canopy decline	> 25 % of trees have severe canopy decline	N/A	
Tree Crown Mortality scoring	5	3	1		0
Standing Dead Wood responses	At least 10% of standing trees are dead (2 of 20 trees).	Approximately 5% of standing trees are dead (1 of 20 trees).	Less than 5% of standing trees are dead (fewer than 1 of 20 trees).	N/A	
Standing Dead Wood scoring	5	3	1		0
Downed Dead Woody responses	Enough downed wood is present that you are constantly stepping over it while walking through the forest	Occasional downed wood	Virtually no downed wood	N/A	
Downed Dead Woody scoring	5	3	1		0
Unauthorized Trails responses	None or Few and Faint	Occasional and clearly visible	Many and clearly visible	N/A	
Unauthorized Trails scoring	5	3	1		0
Dumping responses	None or light Local or widespread	Moderate Widespread	Heavy Widespread	N/A	
Dumping scoring	5	3	1		0
Encroachment responses	None or light Local or widespread	Moderate Widespread	Heavy Widespread	N/A	
Encroachment scoring	5	3	1		0
Browse responses	None or light Local or widespread	Moderate Widespread	Heavy Widespread	N/A	
Browse scoring	5	3	1		0
Other Impacts responses	None or light Local or widespread	Moderate Widespread	Heavy Widespread	N/A	
Other Impacts scoring	5	3	1		0
Ground Layer - Presence of Garlic Mustard, DSV, Hogweed, Knotweed responses	No Priority Invasives Present	One priority Invasive Present	2 or more priority invasives	N/A	
Ground Layer - Presence of Garlic Mustard, DSV, Hogweed,	5	3	1		0
Ground Layer - Abundance responses	Priority invasives cover <5%	Priority invasives cover 5-50%	Priority invasives cover >50%	N/A	
Ground Layer - Abundance	5	3	1		0
Shrubs and Saplings responses	Buckthorn is occasional or absent	Buckthorn abundant localized	Buckthorn is dominant throughout	N/A	
Shrubs and Saplings scoring	5	3	1		0
Canopy - Presence of Norway Maple, Black Locust responses	Canopy is free of invasive species	Occasional invasives in the canopy	Canopy is dominated by invasive species	N/A	
Canopy - Presence of Norway Maple, Black Locust scoring	5	3	1		0

Indicator Weights

Tree size	1
Tree Crown Mortality	1
Standing Dead Wood	1
Downed Dead Woody	1
Unauthorized Trails	1
Dumping	1
Encroachment	1
Browse	1
Other Impacts	1
Ground Layer - Presence of Garlic Mustard, DSV,	1
Ground Layer - Abundance	1
Shrubs and Saplings	1
Canopy - Presence of Norway Maple,	1