

Valuation of Ecological Services in the Rideau Valley Watershed

Nina Handa

Major paper submitted to the
Department of Economics
In partial fulfillment of the requirements
For the MA degree in economics

Department of Economics
Faculty of Graduated and Postdoctoral Studies
University of Ottawa

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Table of Contents

Acknowledgements	viii
Abstract	ix
List of tables	x
1. Introduction	1
2. The Rideau Valley Watershed	2
2.1 Geographic Context of the Rideau Valley Watershed	2
2.2 Ecosystems and Land Uses in the Rideau Valley Watershed	4
2.2.1 Human Settlement Ecosystem and Land Use	4
2.2.2 Wetland Ecosystem	5
2.2.3 Forest Ecosystem	6
2.2.4 Cropland Ecosystem	8
2.2.5 Pasture Ecosystem	8
2.2.6 Water Ecosystem	8
2.2.7 Alvar Ecosystem	8
2.2.8 Mines and Quarries Land Uses	9
2.2.9 Land Use in the Rideau Valley Watershed	9
2.3 Threats to Natural Capital in the Rideau Valley Watershed	10
2.3.1 Highly Exposed Aquifers	10
2.3.2 Water Supply	10
2.3.3 Wetland Loss	11
2.3.4 Population Growth	11
2.3.5 Nutrient Loading	12
2.3.6 Livestock	12

2.3.7	Storm Water Runoff	12
2.3.8	Climate Change	13
3.	Ecological Goods & Services Provided by Rideau Valley Ecosystems	13
3.1	Gas Regulation	14
3.2	Climate Regulation	15
3.3	Disturbance Regulation	15
3.4	Water Regulation	16
3.5	Water Supply	16
3.6	Soil Retention	16
3.7	Soil Formation	17
3.8	Nutrient Regulation	17
3.9	Waste Treatment	18
3.10	Pollination	19
3.11	Biological Control	19
3.12	Nursery/Refugia function	19
3.13	Food Production	20
3.14	Raw Materials	20
3.15	Genetic Resources	20
3.16	Recreation	21
3.17	Cultural	21
4.	The Economic Valuation Methodology	21
4.1	The Natural Capital Valuation Framework	22
4.2	Ecosystem Goods and Services & Total Economic Valuation	23

4.3	Methods for Calculating the Value of Ecosystem Goods and Services	23
4.3.1	Market Price Method	24
4.3.2	Productivity Method	24
4.3.3	Hedonic Pricing Method	24
4.3.4	Travel Cost Method	25
4.3.5	Cost Analysis Method	25
4.3.6	Shadow Prices for Environmental Constraints	26
4.3.7	Benefit Transfer Method	26
4.3.8	Contingent Valuation Method	26
4.4	Ecosystem Services and Valuation Methods	27
5	Examples of Investments in Natural Capital	27
5.1	New York City: Investing in Watershed Protection	27
5.2	Panama Canal: Investing in Erosion Control & Sediment Retention	28
6.	The Value of Natural Capital in the Rideau Valley Watershed	28
6.1	The Value of Ecological Goods & Services Provided by Wetlands	29
6.1.1	Gas Regulation	29
6.1.2	Climate Regulation	30
6.1.3	Disturbance Regulation	30
6.1.4	Water Regulation	31
6.1.5	Water Supply	31
6.1.6	Erosion Regulation	31
6.1.7	Nutrient Cycling	31
6.1.8	Waste Treatment	32

6.1.9	Pollination	32
6.1.10	Biological Control	33
6.1.11	Habitat/Refugia	33
6.1.12	Food Production	33
6.1.13	Raw Materials	33
6.1.14	Genetic resources	33
6.1.15	Recreation	34
6.1.16	Cultural	34
6.1.17	Total Value of the Watershed's Wetlands	34
6.2	The Value of Ecological Goods & Services Provided by Forests	35
6.2.1	Gas Regulation	35
6.2.2	Climate Regulation	35
6.2.3	Water Regulation	36
6.2.4	Pollination	36
6.2.5	Biological Control	37
6.2.6	Erosion Control and Sediment Retention	37
6.2.7	Average Global Summary Valuations for Forests	37
6.2.8	Total Value of the Watershed's Forests	39
6.3	The Value of Ecological Goods & Services Provided by Cropland	39
6.3.1	Climate Regulation	39
6.3.2	Soil Formation	40
6.3.3	Cultural	40
6.3.4	Average Global Summary Valuations for Croplands	40

6.3.5	Total Value of the Watershed's Cropland	41
6.4	The Value of Ecological Goods & Services Provided by Pasture & Abandoned Fields	41
6.4.1	Climate Regulation	41
6.4.2	Nutrient Cycling	42
6.4.3	Average Global Summary Valuations for Pastures & Abandoned Fields	42
6.4.4	Total Value of the Watershed's Pastures & Abandoned Fields	43
6.5	The Value of Ecological Goods & Services Provided by Surface Water	44
6.5.1	Average Global Summary Valuations for Surface Water	44
6.5.2	Total Value of the Watershed's Surface Water	44
6.6	Total Value of the Rideau Valley Watershed's Ecological Goods & Services	45
7	Problems with Natural Capital Framework	45
7.1	Biophysical Linkages	45
7.2	Lack of Data	46
7.3	Uniqueness of each Ecosystem	46
7.4	Multiplier Effect	47
7.5	Joint Products Valuation	47
7.6	Natural Wealth	47
7.7	Using Average Cost in Valuations	48
7.8	Contingent Valuation	49
7.9	Non-Utilitarian Ethical Framework	49

8	Conclusion	49
	Appendix A: Average Global Summary Values	51
	Tables	52
	References	60

Acknowledgments

The author would like to thank Andrea Klyko from the Rideau Valley Conservation Authority for her assistance and Professor Philippe Crabbé for his supervision.

Abstract

Watersheds provide humans with many ecological goods and services such as clean water, erosion control, carbon sequestration and biodiversity that are not valued by the markets. The valuation of ecological benefits economically is a challenge for the formulation of sustainable and efficient development policies. By assigning an economic value on all or some of nature's ecological goods and services, the natural capital framework attempts to improve decision-making for managing, preserving, and restoring natural environments. This paper applies the natural capital framework in order to value some of the ecological goods and services of the Rideau Valley Watershed. It will first describe the watershed, identify its ecosystems and their ecological goods and services, and assign values to some of these goods and services, following the methodology adopted for the Credit River Watershed in Canada. Wherever the Credit River methodology is incomplete, the benefit transfer methodology will be used. The paper will conclude by identifying gaps in the data and shortcomings of the methodologies used.

List of Tables

Table 1: Land Use in the Rideau Valley Watershed (Section 2.2.9)	52
Table 2: Ecosystem Services & Total Economic Evaluation (Section 4.2)	53
Table 3: Ecosystem Services & Evaluation Methods (Section 4.4)	54
Table 4: Carbon Storage Rates for Wetlands (Section 6.1.1)	55
Table 5: The Value of Wetlands (Section 6.1.16)	55
Table 6: The Value of Gas Regulation in Forests (Section 6.2.1)	56
Table 7: The Value of Forests (Section 6.2.8)	56
Table 8: The Value of Croplands (Section 6.3.5)	57
Table 9: The Value of Pastures & Abandoned Fields (Section 6.4.4)	57
Table 10: The Value of Surface Water (Section 6.5.2)	58
Table 11: The Total Value of the Watershed Ecosystems (Section 6.6)	59

1 Introduction

Amidst mounting concerns "about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development"(WCED, A/RES/42/187), the United Nations created the World Commission on Environment and Development (WCED), also called the Brundtland Commission, in 1983. In 1987, WCED released its influential report called "Our Common Future", also known as the Brundtland Report, which discussed the issue of the relationships between the environment and development (WCED, "Our Common Future: Chairman's Foreword"). The report's conclusion is that effective development policies needed to be environmentally sustainable. Effective development policies must consider both economic and ecological factors. Social equity between and within generations also has to be addressed. Policies must focus on changes in resource extraction and in the distribution of their costs and benefits (WCED, "Our Common Future, Chapter 2"). Development is defined, as sustainable if present needs are met without compromising the needs of future generations. This broad definition of sustainable development was welcomed with wide support and agreement "if only because no one could seriously advocate 'unsustainable non-development'"(Fenech et al. (2003), 4). Nevertheless, this influential report brought sustainable development into the political discourse.

The economist J.R. Hicks defined income as the "maximum amount that a community can consume over some time period and still be as well off at the end of the period as at the beginning"(Sahu et al. (2005), 482). Until recently, this definition applied only to human made capital. With the understanding that much of nature's

capital, its resources, its sink capacity for waste, and its life support systems, are neither limitless nor fully substitutable, this definition of income should also apply to nature's resources. Nature's goods and services can only be conserved if they can be shown to be of value and, in some uses, of greater value than in proposed alternative uses. In order to maximize the long-term value of the asset, both human made and nature made capital endowments need to be properly depreciated and conserved through investment (Hawken et al. (2010), 158). The natural capital framework attempts to value nature made capital endowments i.e. ecological goods and services.

The major paper attempts to value the Rideau Valley watershed's ecological goods and services using the natural capital framework. First, the watershed's geographic situation, land use, and ecological threats are described. Second, methodology is discussed. Third, the paper attempts to calculate the Rideau Valley watershed's ecological value. Fourth, problems with the natural capital framework are discussed. The paper concludes that despite shortcomings, the natural capital framework, it fulfills an important role by attempting to improve decision making in the ecological sphere.

2 The Rideau Valley Watershed

The geographic context of the Rideau Valley Watershed will be described and its main component ecosystems, identified.

2.1 Geographic Context of the Rideau Valley Watershed

The Rideau Valley Watershed is a complex system of lakes, rivers, wetlands and streams located in Eastern Ontario, Canada. The watershed consists of approximately

4234 square kilometres of land (Hardie, “FWD: Watershed Information”). The Rideau Valley watershed is part of the Mixed-Wood Plains, which is an eco-zone that encompasses the lower Great Lakes and the St Lawrence River Valley. It is characterized by a combination of gentle topography, fertile soils, warm growing season and abundant rainfall. Only pockets of forests are left after centuries of agriculture, logging and urbanization. About half of Canada’s population lives in this eco-zone (Natural Resources Canada, “The Atlas of Canada - Forested Ecozones”).

Its longest river, the Rideau River, a tributary of the Ottawa River, is 136 kilometres long (RVCA, “Watershed”). Major tributaries of the Rideau River are the Tay River, the Irish Creek, the Kemptville Creek, the Steven’s Creek and the Jock River. The watershed water ecosystem is part of the St Lawrence River drainage basin, a part of the Atlantic Ocean drainage basin (Natural Resources Canada, “The Atlas of Canada - Drainage Patterns”). The watershed is part of the Saint Lawrence Lowlands eco-region, characterized by deep, arable soils deposited during the last glaciation (Natural Resources Canada, “The Atlas of Canada - Borderlands / St. Lawrence Lowlands”). The watershed is divided into three sub-regions; Upper Rideau, Middle Rideau and Lower Rideau.

The Upper Rideau Region contains the Rideau Lakes and Tay River sub-watersheds. It is on mostly Precambrian Bedrock with some sections of Palaeozoic bedrock. Glaciers that left long narrow depressions created the region’s 59 lakes and many watercourses. Its total area is 1,249 km² (Mississippi-Rideau Source Protection Region (2008), 45).

The Middle Rideau region, primarily a riverine system, contains the Kemptville Creek and the Middle Rideau River sub-watersheds. This region is Palaeozoic bedrock

consisting mainly of limestone. Its total area is 1,274 km² (Mississippi-Rideau Source Protection Region (2008), 45).

The Lower Rideau region is also a riverine system and contains the Jock River and the Lower Rideau River sub-watersheds. The Lower Rideau has mostly clay soils with sand and gravel deposits and limestone and sandstone bedrock outcroppings. Its total area is 1,326 km² (Mississippi-Rideau Source Protection Region (2008), 45).

2.2 Ecosystems and Land Uses in the Rideau Valley Watershed

The Rideau Valley Watershed contains forest, cropland, pasture, wetlands, water and developed lands ecosystems. An ecosystem is a system formed by the interaction of a community of organisms including humans with their physical environment (Millennium Assessment (2003), 49).

2.2.1 Human Settlement Ecosystem and Land Use

Presently, only about 4.5% of the watershed is classified as being settlement and development land. Settlement and developed land is defined as clearings for human settlement and economic activity, and major transportation routes. Approximately 620,000 people live in this watershed including part of the City of Ottawa (RCVA, “What Do Conservation Authorities Do?”). Most people, outside of the City of Ottawa, depend directly on the watershed for their water (RCVA, “What Do Conservation Authorities Do?”). The watershed population is also expected to increase. Settlement and development land use across the watershed is not uniform. Perth, Kemptville, Smith Falls

and the amalgamated City of Ottawa contain much of the settlement and development land use (Mississippi-Rideau Source Protection Region (2008), 83).

2.2.2 Wetland Ecosystems

Wetlands play an important role in the Rideau Valley Watershed. The watershed is approximately 12 percent wetlands. There are five types of wetlands in the watershed: deciduous swamps, conifer swamps, open fens, freshwater coastal marsh/inland marshes, treed bogs.

The watershed's most common wetland type is the deciduous swamp. Deciduous swamps are defined as hardwood swamps that occur along rivers, in old lakebeds and other low-lying areas (OMAFRA, "Introduction to the Ontario Land Cover Database"). Approximately 7 percent of the watershed is classified as deciduous swamp.

Conifer swamps are also common at 2.6 percent. They are defined as swamps with dense conifer tree or shrub cover (OMAFRA, "Introduction to the Ontario Land Cover Database").

The watershed also has open fens, freshwater coastal marsh/inland marsh, and treed bogs. Open fens are non-treed grassy fens or fens with open pools. Treed bogs are bogs with tree cover, which can be of low to high density (OMAFRA, "Introduction to the Ontario Land Cover Database"). Freshwater Coastal Marsh/Inland Marsh includes seasonal marshes, cattail marshes, and grassy meadow marshes. Seasonal marshes in spring are flooded but often by fall are dry. They may appear to be more deeply flooded than other types of inland marshes. Cattail marshes usually seem to be drier than flooded seasonal marshes. Grassy meadow marshes usually seem to be drier than seasonal

marshes and cattail marshes (OMAFRA, “Introduction to the Ontario Land Cover Database”).

The watershed has bogs, swamps, fens and marshes each with their different types of hydrology. Bogs receive all water from atmosphere while fens and some swamps receive considerable groundwater inputs. Swamps and treed bogs are subject to evapotranspiration that is controlled by the conduction of water through the tree canopy. Fens and marshes are subject to evaporation that is controlled by grassy plants. Treeless bogs are subject to limited use of evaporation. Bogs, fens, swamps, and marshes have different soil types, which affects their water storage capacity (Novitzki, “Wetland Functions, Values, and Assessment”). Wetlands are distributed unevenly across the watershed. Within the Middle and Upper Rideau areas there are substantive wetlands while within the Lower Rideau area there are few remaining wetlands and those that remain are significant (Mississippi-Rideau Source Protection Region (2008), 70).

2.2.3 Forest Ecosystems

The watershed is approximately 39 percent forest consisting of dense deciduous forest, dense coniferous, mixed forest mainly coniferous, mixed forest mainly deciduous, sparse coniferous forest, and sparse deciduous forest. Woodland coverage within the Lower Rideau is lower (Mississippi-Rideau Source Protection Region (2008), 45).

Dense deciduous forests comprise 15.7 percent of the watershed. They are defined as having a largely continuous forest canopy, which is composed of at least 80 percent of deciduous species (OMAFRA, “Introduction to the Ontario Land Cover Database”).

Dense coniferous forests comprise 5 percent of the watershed. They are defined as having a largely continuous forest canopy, which is composed of at least 80 percent of coniferous species (OMAFRA, "Introduction to the Ontario Land Cover Database").

Mixed forest - mainly deciduous consist of largely continuous forest canopy containing coniferous and deciduous species, with deciduous species comprising more than 50 percent of the canopy (OMAFRA, "Introduction to the Ontario Land Cover Database"). The watershed land use consists of about 7.7 percent mixed forest - mainly coniferous which is defined as consisting of largely continuous forest canopy containing coniferous and deciduous species, with coniferous species comprising more than 50 percent of the canopy (OMAFRA, "Introduction to the Ontario Land Cover Database").

About 4 percent of the watershed is classified as Sparse Deciduous Forest. It is defined as a patchy or sparse forest canopy, with approximately 30 to 40 percent canopy closure, which is composed approximately 80 percent of deciduous species (OMAFRA, "Introduction to the Ontario Land Cover Database").

The watershed contains a small area of land classified as Sparse Coniferous Forest at 0.9 percent. Sparse Coniferous Forest is defined as a patchy or sparse forest canopy, with approximately 30 to 40 percent canopy closure, which is composed of approximately 80 percent of coniferous species (OMAFRA, "Introduction to the Ontario Land Cover Database"). Coniferous plantations are defined as mature conifer plantations, mostly pines, which occur in evenly spaced rows (OMAFRA, "Introduction to the Ontario Land Cover Database"). Only 0.1 percent of the watershed's land is defined as coniferous plantation.

2.2.4 Cropland Ecosystem

The watershed consists of approximately 18 percent cropland. Cropland is defined as row crops, hay or open soil located in areas of agricultural land use. The largest crop produced in Eastern Ontario is hay (OMAFRA, “Eastern Ontario Region at a Glance”). Not surprising since the top two categories of farms in the region are beef cattle ranching and farming, and dairy cattle and milk production. These two categories account for about 50 percent of reported farm cash receipts (OMAFRA, “Eastern Ontario Region at a Glance”).

2.2.5 Pasture Ecosystem

Another 16.5 percent of land is classified as pasture and abandoned fields. Pasture and abandoned fields are defined as open grassland with sparse shrubs. It includes some agricultural land use (OMAFRA, “Introduction to the Ontario Land Cover Database”).

2.2.6 Water Ecosystem

Water has an important role in the Rideau Valley Watershed. The Rideau Canal, a UNESCO world heritage site, is partly located in the watershed. With over 100 lakes, the watershed has a large seasonal population that depends on water (Mississippi-Rideau Source Protection Region (2008), 100). Water is defined as including all water body types from deep to shallow and clear to sedimented (OMAFRA, “Introduction to the Ontario Land Cover Database”). Approximately 6.8 percent of the watershed’s land is classified as water.

2.2.7 Alvar Ecosystem

Alvar are defined as homogenous areas of dry grassland, which grow on thin soils over a limestone substrate. They are mapped only where they occur in clusters

(OMAFRA, “Introduction to the Ontario Land Cover Database”). In the watershed, 3.24 percent of land is classified as Alvar. They only exist in the North American Great Lakes Basin and in the eastern European Baltic region. Many plants, insects, and reptiles only exist in alvars. Ontario has almost 75 percent of North American alvars (Nature Conservancy of Canada, “Alvars of Ontario”).

2.2.8 Mines and Quarries Land Uses

Mine tailings, quarries, and bedrock outcrops are defined as clearings for mining activity, aggregate quarries, and bedrock outcrops (OMAFRA, “Introduction to the Ontario Land Cover Database”). This type of land use is very limited in the watershed consisting of only 0.25 percent.

2.2.9 Land use in the Rideau Valley Watershed

For more detailed information about land use in the Rideau Valley watershed see table 1 (page 52). This paper employs land use data, which was collected approximately from 1999 to 2001. Land use data was collected using the RADARSAT satellite. This satellite, according to the Canadian Space Agency, is a “sophisticated Earth observation satellite developed by Canada to monitor environmental changes and the planet's natural resources” (Canadian Space Agency, “CSA – RADARSAT – 1.”). The satellite images were used to classify land into different uses by the Ministry of Natural Resources using a remote sensing software (Klymko, “FW: Watershed Information”).

2.3 Threats to Natural Capital in the Rideau Valley Watershed

This section describes threats to the Rideau Valley watershed's natural capital. If the Rideau Valley watershed's ecosystem is not protected it will not be able to provide society with its many goods and services.

2.3.1 Highly Exposed Aquifers

The Rideau Valley Watershed has highly vulnerable aquifers since it mainly consists of exposed bedrock, shallow soil or permeable overburden deposits. The RVCA considered 89 percent of the watershed's aquifers are highly vulnerable because contaminants can quickly move into drinking water aquifer, creating potential risk for private wells users (Mississippi-Rideau Source Protection Region (2008), iii).

There are many potential threats towards the watershed's drinking water. There are three main areas of threat: direct introduction, landscape activities, and storage of potential contaminants. Direct introduction threats include sewage treatment plant bypasses. Landscape activities threats include road salt application and storm water management systems. Storages of potential contaminants threats include manure, fertilizers, pesticides, and fuels (Mississippi-Rideau Source Protection Region (2008), 149).

2.3.2 Water Supply

The watershed has several users competing for water. Water takings and other diversions must be properly evaluated for impacts to the environment. Wetlands are sensitive aquatic ecosystems that can easily be adversely affected. Conservative and precautionary policies need to be applied taking into account the ecosystem location, ecosystem factors, and hydrological factors (Mississippi-Rideau Source Protection

Region (2008), 101). Otherwise, the watershed health may be threatened. Water takings can be a threat to the watershed particularly if the water is moved outside of the watershed. For example, the City of Ottawa officials wrote a letter to Ontario's Ministry of Natural Resources stating that an application by OMYA Ltd. had "the potential to limit growth in the Perth area due to water removal from the watershed" (City of Ottawa, "Application to Take Water from Tay River" 4).

2.3.3 Wetland Loss

The loss of wetlands would be detrimental to the Rideau Valley watershed's health as they provide many unique functions, which are discussed later. Wetlands are important ecosystems, which cannot be recreated by humans. They contain anaerobic soils. Often the water above these soils contains less oxygen. Wetland organisms must have anatomical, morphological, physiological or behavioural adaptations to allow them to obtain, preserve, or accumulate oxygen. Macrophytes, plants that grow in or near water, are important in creating the wetland's physical structure and have a role in modifying local environment conditions (Valk (2006), 4).

2.3.4 Population Growth

The City of Ottawa predicts it will have a high level of growth and a need for 60% more dwellings in Ottawa by 2021 (City of Ottawa, "Population & Dwelling Projections"). This will mean land will move from rural use to urban use in the loss of agricultural land, forests and wetlands and indirectly leading to decreased water flow to wetlands. Population growth places the greatest strain on the watershed. According to the RVCA, in spite of conservation efforts, already development pressures and increases in leisure waterway use is degrading aquatic habitat and quality of riverbanks (RVCA

(2005), *Lower Rideau Watershed Strategy: Executive Summary*, 5). With a greater population: there will also be greater demand for water use. Increased sewage leads to increased risk of water contamination. Increased water and air pollution will adversely affect the health of the watershed's ecosystems including humans.

2.3.5 Nutrient Loading

Nutrient loading from both rural and urban lands is a threat to the watershed. Nutrient loading occurs when the watershed's ecosystem contains too much phosphorous and/or nitrogen. This creates an overgrowth of aquatic plant and algae, a phenomenon called eutrophication (RVCA (2005), *Lower Rideau Watershed Strategy: Executive Summary*, 5). There are also health concerns. Specifics are discussed later on in the paper.

2.3.6 Livestock

When livestock accesses stream banks and water bodies they can cause erosion and contaminate the water with bacteria through their faeces. For example, sampling by the RVCA, in one area of the watershed, found that 31 percent samples failed the Provincial water quality objectives for excess *E. coli* (Mississippi-Rideau Source Protection Region (2008), 111).

2.3.7 Storm Water Runoff

Storm water runoff is a potential threat to the watershed. Storm water runoff happens when rain or melted snow flows over the ground. Paved and built surfaces prevent storm water runoff from soaking into the ground (EPA, "After The Storm: What Is Stormwater Runoff?"). Presently the City of Ottawa has an outdated system of pipes that allow storm water and untreated sewage to mix. The treatment plant is not equipped to handle heavy overflow, meaning that contaminated mix often enters the watershed

untreated. Between April and November 2008, about 895 million litres of this toxic mix entered into the watershed untreated (Ottawa Citizen, “\$250M Storage System for Stormwater Runoff OK’d”). Recently, a new storm water management strategy has been announced by the City of Ottawa. \$251.64 million will be spent to build massive underground storage system to hold surplus storm water and sewage (Ottawa Citizen, “\$250M Storage System for Stormwater Runoff OK’d”) The predicted expansion of the Ottawa region will likely increase the threat of storm water runoff.

2.3.8 Climate Change

A better understanding of impact of climate change is needed. Global climate change will likely affect changes in temperature, precipitation, growing seasons, plant communities and subject animals to new diseases. Droughts, floods and other extreme weather events will affect the watershed. Society’s change of behaviour in order to try and combat climate change is also likely to have an impact. Changes in precipitation patterns may increase the risk of flooding thus increasing the need to control water runoff.

3. Ecological Goods and Services Provided by Rideau Valley Ecosystems

The Rideau Valley ecosystem provides many ecological goods and services that can be broadly classified into 17 categories (Costanza et al. (1997), 254). This section describes each category and the function of each of its component ecological good and service in the context of the watershed.

3.1 Gas Regulation

Gas regulation is the maintenance of air quality (Costanza et al. (1997), 254).

Forests play an important role in air quality since they absorb carbon monoxide, harmful ground ozone, nitrogen dioxide, sulphur dioxide and filter fine particulate matter.

Ground level ozone harms humans, animals, and plants. In humans exposure has been shown to increase hospital admissions and has even led to premature death. In plants it reduces growth rates, affects reproduction; it even causes crop losses. Ozone can contribute towards increases in greenhouse gases and can contribute to climate change (Ontario Ministry of the Environment, “Air – Ozone”).

Carbon monoxide exposure, in humans, has been shown to reduce blood’s ability to transmit oxygen to body tissues adversely affecting the brain, heart and general health (Ontario Ministry of the Environment, “Air - Carbon Monoxide”).

Nitrogen dioxide and sulphur dioxide can contribute in the formation of smog and acid rain, which can cause lake acidification, damaged trees and crops. An increase in the air’s nitrogen dioxide and sulphur dioxide levels decreases the lungs’ defences against bacteria making them more susceptible to infections and aggravates asthma (Ontario Ministry of the Environment, “Air - Nitrogen Dioxide”).

Fine particulate matter occurs by burning fuel or by complex atmospheric chemical reactions. Hairs in our nose and air passages cannot remove fine particulate when we breathe in reducing our capacity to fight infections and causing health problems like irritated eyes, throat and lungs. Corrosion, damage to vegetation and reduced visibility also can be caused by fine particulate matter (Ontario Ministry of the Environment, “Air - Particulate Matter”).

3.2 Climate Regulation

Climate regulation occurs through local or global temperature, precipitation, and other biologically mediated climatic processes (Costanza et al. (1997), 254). An influential factor in climate regulation is storing and sequestering carbon.

Carbon stored refers to the quantity of carbon contained by an ecosystem. For example, trees store carbon until its wood is burnt, fell or is decomposed, then its carbon is released. Forests, as they grow, use photosynthesis that increase carbon stores by removing carbon from the atmosphere.

Carbon sequestration refers to the amount of carbon stored by an ecosystem annually after subtracting the carbon released into the atmosphere due to respiration, disturbance and decomposition (Heimann et al., “Terrestrial Ecosystem Carbon Dynamics and Climate Feedbacks”).

Annually, wetlands store carbon at rates up to 20 times faster than in terrestrial systems (Vall (2006), 142). This is attributed in part to slower decomposition rates due to the wetland’s anaerobic conditions. Wetlands contain up to 40 percent of global soil carbon (Valk (2006), 142). Carbon storage rates depend on the type of wetland. Fens store the most carbon while swamps store the least.

3.3 Disturbance Regulation

Disturbance regulation refers to the ecosystem’s ability to respond to environmental fluctuations such as storms and floods (Costanza et al. (1997), 254). Wetlands and forests assist in storm protection and flood control.

Forests decrease a flood’s downstream peak, resulting in a lower but longer duration event. The delaying effect of flood flows is mainly due to the vegetation’s

roughness. The nature of the vegetation is important because of the type of frictional effects it has. Thus trees create more of a physical barrier than bushes because the latter can be flattened during high flows whereas trees cannot (Thomas et al. (2007), 1).

The United States' Environmental Protection Agency (EPA) describes wetlands as 'natural sponges' that trap and gradually discharge surface water, rain, snowmelt, groundwater and floodwaters (EPA, "Wetlands and People"). Wetlands located near and downstream of urban areas are especially important because pavement and buildings increase the rate and volume of surface water runoff. Protecting and restoring wetlands can often improve flood control, which decreases or negates the need for expensive dredge operations and levees. For example, along the Mississippi river most of wetlands have been filled or drained, decreasing the ability to store floodwater from over 60 days to now only 12 days (EPA, "Flood Protection").

3.4 Water Regulation

Water regulation is the organization of hydrological flows. An example of this ecosystem service is water for irrigation or industrial use (Costanza et al. (1997), 254).

3.5 Water Supply

The ecological service of water supply is defined as the storing and retention of water. This includes filtering, retaining and storing fresh water as well as providing fresh water for drinking, irrigation and industrial use (Costanza et al. (1997), 254).

3.6 Soil Retention

Erosion control refers to preventing soil loss while sediment retention refers to silt being stored in wetlands and lakes (Costanza et al. (1997), 254).

Forests are important in soil retention because a tree's taproot stabilizes the soil and a tree's foliage absorbs rainfall, which in turn prevent compaction and erosion of bare soil (De Groot et al. 399). This helps purify water and lessens the environmental impacts of erosion (Ducks Unlimited Canada, "Environmental Impacts of Wetlands & Marshes"). Agricultural land is more prone to soil erosion because tilled agricultural fields are exposed to wind between growing seasons. Approximately 30% of agricultural soil erosion is caused by the wind (OMAFRA, "Soil Erosion - Causes and Effects").

Wetlands can trap up to 70 per cent of sediments found in runoff. This is important to purify our water and lessen the environmental impacts of erosion (Ducks Unlimited Canada, "Environmental Impacts of Wetlands & Marshes").

3.7 Soil Formation

Soil formation refers to the creation of soil (Costanza et al. (1997), 254). Natural soil formation is a renewable resource, however it occurs over very long time period. It takes between 200 to 1,000 years to form 1 inch of topsoil. Soil develops when organisms decay, when solid rock erodes, and when sediments are deposited by erosion.

3.8 Nutrient Regulation

Nutrient regulation is an important life support regulation function involving the atmosphere, land and water. In nature, there are approximately 90 chemical elements. It is estimated that life depends on the continuous cycle of about 30-40 chemical elements. Some examples are carbon, oxygen, hydrogen, nitrogen, sulphur, and phosphorous. Nutrient cycling is needed for the maintenance of 'healthy' and productive soils (De Groot et al. (2002), 399). The most important cycles in wetlands are carbon, nitrogen, sulphur, and phosphorus (Valk (2006), 125).

3.9 Waste Treatment

Wetlands and forests have an important role in keeping our water clean. Studies have shown that every dollar invested in waste treatment can save from US\$7.50 to US\$200 in costs for new water treatment and filtration (Bos et al. (2004), 23).

A wetland's ecosystem acts like 'free' water purification plants since they can remove harmful impurities from the water (De Groot et al. (2002), 397). According to Ducks Unlimited, up to 92 per cent of phosphorus and 95 per cent of nitrogen draining from the surrounding watershed can be removed by water passing through a healthy wetland (Ducks Unlimited, "Environmental Impacts of Wetlands & Marshes").

An excessive amount of nitrogen and phosphorus is harmful towards humans, animals and plants. Over fertilized water creates an overgrowth of weeds, algae, and cyanobacteria (Agriculture and Agri-Foods Canada, 83). It can cause a body of water to become eutrophic. An example of eutrophication is each summer excessive amounts of nitrogen and phosphorus create a "dead zone" the size of New Jersey where the Mississippi River empties into the Gulf of Mexico ("Eutrophication").

The Trust for Public Land and the American Water Works Association produced a study called "Protecting the Source: Conserving Forests to Protect Water" found the need to treat surface water supplies depends upon a watershed's forest cover percentage. They found that water treatment costs increase 20 percent for every 10 percent loss in forest coverage (Ernst et al. (2004), 4). If the watershed's wetlands and forests were not protected, resources would have to be invested in treatment processes that are required to remove nitrogen and phosphorus.

3.10 Pollination

Pollination occurs when pollen is transferred from a plant's male part to the female part. Many pollinating insects are dying. In the past 50 years, half of the honeybee colonies have died (Hawken et al. (2010), 158). This is partly due to loss of habitat, toxic chemicals, climate change, and imported parasites and diseases. The majority of our food supply depends upon insects to perform this transfer since 80 percent of plants that we eat are not self-pollinating (Canadian Wildlife Federation, "About Pollination and Pollinators").

3.11 Biological Control

Biological control refers to the pest control service provided by forest birds. If forest birds did not consume pests there would be an increase in crop loss and pesticide use.

3.12 Habitat/Refugia

Many mammals, birds, fish, amphibians, invertebrates and reptiles depend on wetlands. However, the majority of Ontario's wetlands have disappeared. Agricultural and urban development has filled in approximately 70 per cent of wetlands (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 33). In Canada, more than 50 species of mammals depend on wetlands for water, hydrophytic vegetation, food, escape cover, or for breeding (Natural Resources Canada, "The Atlas of Canada – Wetlands"). More than 200 bird species depend on wetlands for food, breeding, nesting and habitat (Natural Resources Canada, "The Atlas of Canada – Wetlands"). Swamps in Canada's Prairies provide habitat for approximately half of all North America's waterfowl (Ducks Unlimited Canada, "Wetlands for

Tomorrow”). Amphibians depend upon wetlands for breeding and hibernating, which is essential for their survival. Many turtle species reside exclusively in wetlands. Bass, carp, northern pike, perch and pickerel are among the many fish species that are dependent on the wetlands to reproduce and/or to live. In Canada, one third of endangered species live in or near wetlands (Natural Resources Canada, “The Atlas of Canada – Wetlands”). Eastern Ontario’s Forests provide habitat to 24 plants, 3 insects, 15 reptiles, 31 birds and 4 mammals, which are considered species at risk (Eastern Ontario Model Forest, *State of Eastern Ontario's Forests*).

3.13 Food Production

Food production includes hunting, gathering, and subsistence farming or fishing (Costanza et al. (1997), 254). Many people forage the forest for food.

3.14 Raw Materials

Raw materials are defined as material obtained in its natural form (Costanza et al. (1997), 254). For example, forests provide lumber, a raw material.

3.15 Genetic Resources

Genetic resources are defined as sources of biological materials and products that are distinctive (Costanza et al. (1997), 254). This includes ornamental species, genetic support, and medicine derived from nature.

According to Ecological Society of America,

“Eighty percent of the world’s population relies upon natural medicinal products. Of the top 150 prescription drugs used in the U.S., 118 originate from natural sources: 74 percent from plants, 18 percent from fungi, 5 percent from bacteria, and 3 percent from

one vertebrate (snake species). Nine of the top 10 drugs originate from natural plant products.” (Ecological Society of America (2000), 2)

Many commercial crops need genetic support of uncultivated crops. “In order to maintain the productivity of these cultivars, or to change and improve certain qualities such as taste, resistance to pests and diseases, and adaptation to certain environmental conditions, regular inputs of genetic material from their wild relatives and primitive (semi) domesticated ancestors remains essential” (De Groot et al. (2002), 401).

3.16 Recreation

Recreation is defined as recreational activities in nature including eco-tourism, sports fishing and other outdoor pursuits. Outside of the City of Ottawa, about 80 to 100 percent of tourism in the watershed, outside the City of Ottawa, is related to natural resources (Mississippi-Rideau Source Protection Region (2008), 112).

3.17 Cultural

Cultural is defined as providing opportunities for non-commercial uses including aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems (Costanza et al. (1997), 254).

4. The Economic Valuation Methodology

Economic valuation methodology is discussed in this section. The natural capital framework is described and then ecological goods and services are classified using the framework. Methods for calculating value are discussed and then appropriate methods of valuation are indicated for each ecological good and service classification.

4.1 The Natural Capital Valuation Framework

The natural capital framework tries to place a monetary value on all of the services and goods an ecosystem provides. Nature's ecological benefits include treating of waste, filtering water as well as providing life services such as clean air and water.

One way of valuing an environmental resource or ecosystem is to use a total economic value (TEV) framework, which takes into account both use values and non-use values. Use values include direct and indirect use values. Non-use values are mainly non-instrumental (deontological) existence values, which have a "good of their own" (Bengston (1994), 524).

Use values are instrumental (utilitarian) values that include direct and indirect use values as well as option values (which are essentially, insurance premia one is willing to pay for the availability of a good or service if and when needed either for oneself or for one's descendants). Option values are neglected in this study.

Direct Use Value:

When an ecosystem's good is actually consumed, it is a direct use good.

Market goods include products, which are sold in commercial markets and are measured in a country's gross domestic product. An example would be the value of wheat.

Non-market ecological goods and services include products, which are not sold in commercial markets and therefore not included in the gross domestic product. An example is people foraging in forests for medicinal plants for personal consumption.

Indirect Use Value:

When the use of an ecosystem's good or service does not alter its physical characteristics, it is called an indirect or non-consumption good. Many public goods are indirect use goods. An example is a wetland for flood control. The value of the service of flood control that a wetland provides would be a non-use value. Since markets often do not exist for these services their availability is taken for granted and their role in production processes is not accounted for. These values are generally not included in GDP and can be difficult to calculate.

4.2 Ecosystem Goods and Services & Total Economic Valuation

Table 2, on page 53, provides a list of ecosystem good and services aggregated in broad categories and their total economic valuation type.

4.3 Method's for Calculating the Value of Ecosystem Goods and Services

There are numerous methods that are used to place an economic value on ecological goods and services. Essentially, these methods attempt to estimate the willingness-to-pay, or consumer surplus in the absence of income effects, for an environmental good or service one does not have. There are two types of valuation methods for non-marketed ecological goods and services. One is not generally able to distinguish among the components of the total value. There are indirect methods based on behaviour observation and direct methods based upon individuals' questioning.

4.3.1 Market Price Method

The market price method estimates the value of ecosystem goods and service that are bought and sold in commercial markets. Since many of nature's goods and services are not bought and sold in commercial markets and since many have public good or open-access resource features, market prices have very limited usefulness in calculating nature's value. Also, even if marketed, their full economic value may not be completely reflected in market transactions due to market imperfections and/or policy failures.

4.3.2 Productivity Method

The productivity method estimates the value of the ecological good or service that an ecosystem adds as an input to commercially marketed goods through the market value of its substitute if one is available. Qualitative or quantitative changes in the ecosystem goods or services will alter the production function, change input costs and shift consumer and producer surplus. These input cost changes represent the economic value of the ecosystem good or service. For this method to be valid, the ecosystem resource is replaced by a perfect substitute. For example, water quality affects the price of providing clean drinking water. Otherwise filtering would provide clean water but, possibly, at a higher cost.

4.3.3 Hedonic Pricing or Wage Method

Hedonic pricing method is used to estimate the non-market values for ecosystem characteristics and services. It does this by comparing the market prices of two goods or services that only differ by the ecosystem characteristics and services. Similarly, the same method could be used for wages. If the ecosystem characteristic is the only difference between the goods or services or wages then the price or wage difference must be the

ecosystem characteristic or service value (e.g. environmental radiations). Hedonic pricing method is often used to assess the value added to housing prices by local environmental characteristics (Garrod et al. (1999), 312).

4.3.4 Travel Cost Method

The travel cost method is used to estimate the value of a recreational activity. Its basic premise is that expenses¹, such as time and travel costs, that people incur to visit the site represents the 'price' of site or activity access. A demand curve – an inverse relationship between costs and attendance – can then be plotted. For example, calculating the cost to the recreational fisher, in time and travel, would be the value of protecting a fish habitat for recreational fishing.

4.3.5 Cost Analysis Method

The cost analysis methods of ecosystem valuation use theoretical situations where currently performed ecosystem services are ceased. Cost analysis methods consist of damage cost avoidance, replacement cost method and substitute cost method. The damage cost avoided method tries to estimate avoided costs by preserving an ecosystem's services. It often uses dose-response curves between doses of a pollutant and the corresponding environmental damage, available in the environmental literature, to estimate the environmental damage, which is then converted into monetary values (e.g. health costs). The replacement cost method evaluates the opportunity costs of replacing ecosystem services. It is necessary to identify another method for providing the same services and calculate the cost of construction for that project. For example, the cost of keeping an endangered species in a zoo could be compared to protecting it in the wild.

¹ Expenses are estimated through surveys.

The substitute cost methods evaluates the cost of providing substitute services (King et al., “Damage Avoided, Replacement, and Substitute Cost Methods”).

4.3.6 Shadow Prices for Environmental Constraints

This method requires the building of an economic optimization model in which environmental goods and services enter as constraints. The constraints’ shadow prices correspond then to the unit rents of the environmental good or service in perfect competition.

4.3.7 Benefit Transfer Method

Benefit transfer method uses estimates from one environment to estimate values in a different environment. This method can be used incorrectly. However, if similar features exist for the service being valued it can give realistic estimates. Without benefit transfer method often there would be no estimate since valuations are expensive (Secretariat of the Convention on Biological Diversity (2007), 20).

4.3.8 Contingent Valuation Method

The contingent valuation method involves asking survey respondents how much they would be willing to pay for particular ecosystem attributes or services (willingness to pay) or to depart (willingness to accept) from an environmental good or service – that they have access to. The method is the only one capable of including non-use and existence values into the total economic value of an ecosystem. Contingent valuations can be difficult to conduct, expensive and time consuming. They require a survey methodology, reference scenario building and are subject to multiple biases (King et al., “Contingent Valuation”).

4.4 Ecosystem Services & Valuation Methods

A list of ecosystem goods and services with the corresponding valuation methods is provided in Table 3, on page 54.

5 Examples of Investments in Natural Capital

This section gives examples of how investing in natural capital can make economic sense.

5.1 New York City: Investing in Watershed Protection

The Catskill/Delaware watershed is the largest unfiltered surface water supplier in the world (NYC Environmental Protection, “About Watershed Protection”). It supplies 1.3 billion gallons of water to New York City daily, meeting 90% of the city’s water needs (Wilson (2008), *Ontario’s Wealth*, 14). The Water system is both cost-effective and flexible since operating costs are not so tied to changes in power costs (NYC Environmental Protection, “History of New York City’s Water Supply System”). In the early 1990s, the EPA mandated stronger requirements for public water systems. New York City had to build a filtration system for its unfiltered water or it had to meet certain criteria in order to avoid filtration. Rather than building new infrastructure, New York City chose to invest in the natural ecosystem services of the watershed with a cost between US\$1 billion and US\$1.5 billion. Protecting the watershed had a better rate of return and a shorter payback period. Building a filtration system would have cost US\$6 to \$8 billion in building costs and another US\$300 million annually in operating costs. They developed a comprehensive watershed protection program that consists of regulations and incentive programs. Three main programs were implemented: a watershed agricultural

program, a watershed forestry program, and a watershed easement program. This included purchasing land, pollution reduction, and conservation easements that would allow the natural ecosystems to purify the water (Canadian Model Forest Network, 5).

5.2 Panama Canal: Investing in Soil Retention

The Panama Canal, an important shipping route, used to circumvent the long passage around the tip of South America was being threatened by deforestation. The lower absorption capacity of deforested land surrounding the Panama Canal meant there was an increased risk of flooding. Deforestation also caused increased sediment levels in the canal. Removing silt and the vegetation it creates was very expensive.

Using the Panama Canal became riskier, which meant that shipping companies had to pay insurance companies increasingly high premiums. There was even a risk of closure. ForestRe, an insurer specializing in forest risks, persuaded insurance and major shipping companies to finance a 25-year bond to restore the region's forest ecosystem. Insurance companies benefit by bearing a smaller risk of paying out damages, while shippers enjoy lower insurance premiums (Irwin et al. (2007), 43).

6. The Value of Ecological Goods and Services Provided by Ecosystems

This section attempts to value the Rideau Valley watershed's many ecological goods and services by using the classification system and numerous valuation methods described earlier.

6.1 The Value of Ecological Goods & Services Provided by Wetlands

6.1.1 Climate Regulation

Carbon store was calculated using avoided cost. The Intergovernmental Panel on Climate Change (IPCC) found that the average cost of global damages due to atmospheric carbon dioxide is \$52 per tonne of carbon (Wilson (2008), *Lake Simcoe Basin's Natural Capital: the Value of the Watershed's Ecosystem*, 24). Using wetland carbon storage rates from Canada's Soil Organic Carbon Database, the value of carbon storage was calculated. The avoided cost of carbon, \$52 per tonne, was multiplied by average carbon storage rates, tonnes per hectare. The resulting figure was made into a 20-year annuity with a 5 percent annual interest rate (Wilson (2008), *Lake Simcoe Basin's Natural Capital: the Value of the Watershed's Ecosystem*, 25). The Rideau Valley Watershed's wetlands are valued at approximately \$31.3 million per year in carbon store alone. For more information see Table 4: Carbon Storage Rates for Wetlands, on page 55.

Carbon sequestration was calculated using avoided cost. Global studies have shown that wetlands sequester carbon at a rate of 0.2 to 0.3 tonnes of per hectare per year. Carbon sequestration is valued at \$13 per hectare (Wilson (2008), *Lake Simcoe Basin's Natural Capital: the Value of the Watershed's Ecosystem*, 25). This calculation multiplies avoided cost of carbon, \$52 dollars, by carbon sequestration's average rate of 0.25 tonnes. The total estimated value is worth approximately \$658,000 (wetland area x \$13). Carbon sequestration rates have been found to be higher in other studies including a study in the Ottawa River Valley that found annual net carbon sequestration rates of 0.7 tonnes

per hectare (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 30).

6.1.2 Disturbance Regulation

Rideau Valley Conservation Authority estimates that all the watershed's wetlands reduce the 1:100 year flood by roughly 10%. If all of the Valley's non-protected wetlands, both local significant wetlands and non-evaluated wetlands, would be lost, the 1:100 year flood would increase about 4% locally across the watershed (RVCA, *Watershed Briefs*). This indicates the importance of protecting the remaining non-protected wetlands. Based on an average value derived from four different studies, flood control by wetlands is worth \$4,039 per hectare of wetland (Wilson (2008), *Ontario's Wealth Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 31). The total annual value is \$204 million.

6.1.3 Water Regulation

A summary of average global value found that water regulation is valued at \$25.65 per hectare (Costanza et al. (1997), 256).² Transferring this value to the Rideau Valley watershed, the ecological service of water regulation is worth \$1.3 million annually. The benefit transfer method of valuation that uses a summary of average global values for water regulation would be justified since there has been no study on the value of water regulation in the Rideau Valley watershed.

6.1.4 Water Supply

The global average value of water supply is \$6497 per hectare, annually (Costanza et al. (1997), 256).³ Using this value, the water supply is worth \$328.3 million annually.

6.1.5 Soil Retention

Avoided cost or replacement cost could be used to calculate the value of soil retention. Sedimentation or erosion rates for wetlands are not available for the Rideau Valley Watershed.

6.1.6 Nutrient Cycling

The value of nutrient cycling can be calculated using replacement value. A study could find the cost to cycle nutrients in the absence of wetlands.

6.1.7 Waste Treatment

A study of Vancouver's water treatment system found that removing phosphorus costs \$22 to \$61 per kilogram of phosphorus while removing nitrogen costs \$3.00 to \$8.50 per kilogram (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 32). Exact absorption levels for phosphorus and nitrogen are not possible because they depend on the wetland type, location, plant composition, and soil characteristics (Olewiler (2004), 14). The national average for excess phosphorus and nitrogen levels are 14.3 kg and 46.4 kg (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 32).

Treatment of phosphorus and nitrogen by wetlands is worth at least \$454 and maybe as high as \$1267 per hectare annually. Using average treatment cost for excess

² US\$15 in 1994 see appendix a

³ US\$3800 in 1994 see appendix a

nitrogen, the annual value is \$435 per hectare (Wilson (2008), *Ontario's Wealth Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 32). The water contamination risk by phosphorus is not available for Ontario; however, the national average is 14.3 kilograms per hectare per year. Using average water treatment costs to remove excess phosphorus, each hectare is worth \$2,581 per year (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 32). Waste treatment of nitrogen and phosphorous is approximately \$3,017 per hectare (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 32). Annually, waste treatment by wetlands is worth about \$152.5 million. This value of waste treatment is based on replacement value.

6.1.8 Pollination

Each year, in Canada, insects provide pollination services worth \$1 billion for fruits and vegetables alone (Canadian Wildlife Federation). Studies estimated that 30 per cent of crop productions depend upon pollination. By multiplying the total value of farm crops in the watershed by 30 per cent, we could find the annual value of pollination services for the watershed (Wilson (2008), *Lake Simcoe Basin's Natural Capital: the Value of the Watershed's Ecosystem Services*, 28). This value would be for the whole watershed.

6.1.9 Biological Control

Biological control can be valued using replacement cost. The cost of replacing pest control services provided by wetland birds with chemical pesticides or genetic engineering could be used as a proxy for the value of biological control.

6.1.10 Habitat/Refugia

Based on the average annualized wetland habitat restoration costs for Great Lakes Sustainability Fund, restoring habitat's is valued at \$5,830 per hectare annually (Wilson (2008), *Lake Simcoe Basin's Natural Capital: the Value of the Watershed's Ecosystem Services*, 26). This value was calculated using avoided cost of damaged to habitat. Transferring this valuation to the Rideau Valley watershed, this service would be worth 294.6 million per year.

6.1.11 Food Production

Direct market pricing can be used to value food produced by the watershed's wetlands. Costanza's et al's summary of average global values food production at \$437.72 per hectare (Costanza et al. (1997), 256).⁴ The total annual value of food production in the Rideau Valley watershed would be worth approximately \$22.1 million.

6.1.12 Raw Materials

By researching what raw materials are extracted in the watershed and getting their market prices, raw materials can be valued using the direct market pricing. The average global value is \$181.25 per hectare (Costanza et al. (1997), 256).⁵ Transferring this value to the Rideau Valley watershed, raw materials are worth \$9.2 million per year.

6.1.13 Genetic Resources

Genetic resources are not possible to value.

6.1.14 Recreational

Recreation derived from nature includes eco-tourism, sports fishing and other outdoor pursuits. While there is no data specific to the watershed, in 2004, more than 18

⁴ US\$256 in 1994 see appendix a

⁵ US\$106 in 1994 see appendix a

million people visited eastern Ontario and spent approximately \$2.1 billion.

Approximately half of these tourists visited the City of Ottawa while the remainder took in the surrounding counties (Eastern Ontario Model Forest). For example, about 100,000 people visit Mer Bleue bog each year (NCC 2). The Ramsar Convention on Wetlands recognizes the Watershed's Mer Bleue bog as being of international importance (NCC 1). Costanza et al summary of average global value estimates that the recreational value of a hectare of wetlands is \$981 (Costanza et al. (1997), 256).⁶ Transferring this value to the Rideau valley watershed, the recreational value is worth 49.6 million annually.

6.1.15 Cultural

Culture includes aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems that are derived from nature. Culture can be valued using contingent valuation. A study could ask residents of the Rideau Valley watershed how much they were willing to pay to protect the wetlands. The average global value estimates that culture is worth \$1506.39 per hectare (Costanza et al. (1997), 256).⁷ The total value is \$76.1 million.

6.1.16 Total Value of the Watershed's Wetlands

Each year, the Rideau Valley watershed's wetlands provide at least \$1.17 billion in ecological goods and services including \$328.4 million in water supply services. Values of ecological goods and services from wetlands are provided in table 5 on page 55.

⁶ US\$574 in 1994 see appendix a

⁷ US\$881 in 1994 see appendix a

6.2 The Value of Ecological Goods and Services Provided by Forests

6.2.1 Gas Regulation

Gas regulation's value was calculated using avoided cost pricing. The study used CITYgreen software to assess the amount of carbon monoxide, ozone, nitrogen dioxide, particulate matter and sulphur dioxide removed from the atmosphere by the tree canopy, based upon the quantity and quality of trees (American Forests). Damages are valued from a low of \$1.25 per hectare per year for carbon monoxide to a high of \$227.59 per hectare for ozone (Wilson, *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 22). The RVCA does not have access to the CITYgreen software. However, if we transfer the study's values we find that the value of increased air quality provided by the Rideau Valley watershed's forests are worth \$377.14 per hectare for a total value of \$62.2 million yearly. Values of gas regulation in forests are provided in table 6 on page 56.

6.2.2 Climate Regulation

Carbon storage was calculated using avoided cost. The Greenbelt study's forests are part of the cool temperate eco-climatic zone, like the Rideau Valley watershed, which store approximately 220 tonnes of carbon per hectare (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 21). Using IPCC's average cost of global damages due to atmospheric carbon dioxide (\$52 per tonne of carbon in 2005 Canadian dollars), carbon stored has been calculated as a 5 percent annuity investment over 20 years giving it a value of \$919 per hectare (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-*

services, 21). Transferring this valuation, the service of carbon storage provided by the Rideau Valley watershed's forests is worth \$151.6 million dollars yearly.

Carbon sequestration's value can be calculated using avoided cost. Studies have estimated that on average 0.75 tonnes of carbon per hectare/ per year is sequestered. Using the social cost of carbon is \$52 per tonne, carbon sequestration is valued at \$39 per hectare of forest (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 21). If this value is transferred to the Rideau Valley watershed, it would be worth \$6.45 million dollars yearly. Forest carbon sequestration rates fluctuate and are not stagnant as the estimates suggest. Canadian Forest Service's Carbon Budget Model for forestlands can be used to improve estimates of forest carbon per hectare (Kennedy et al. (2009), 27).

6.2.3 Water Regulation

The value of water regulation by forests could be calculated using replacement value. A study of the forest cover's water runoff control could assess the replacement construction costs if current forest cover changed to urban land use. The savings then could be annualized by converting them into a 20 year annuity. A study of Ontario's Greenbelt found disturbance regulation is worth \$1523 per hectare (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 23). This value cannot be transferred to the Rideau Valley watershed.

6.2.4 Pollination (Seed Dispersal)

Seed dispersal can be calculated using avoided cost. Seed dispersal by birds, mammals, and wind is an essential service for the natural regeneration of trees. The value of seed dispersal can be estimated using replacement cost. The cost of replacing these

services by human planting is valued at \$537 per hectare annually (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 28). The total value of seed dispersal is \$88.6 million.

6.2.5 Biological Control

Replacing forest birds' pest control services with chemical pesticides or genetic engineering would cost \$25.97 per hectare annually. This U.S. Forest Service study used replacement cost (Wilson (2008), *Ontario's Wealth Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 28). Transferring this value to the Rideau Valley watershed, this service is worth \$4.3 million annually.

6.2.6 Soil Retention

Erosion control can be valued using avoided cost. No value for erosion control in the Rideau Valley Watershed presently exists. The value could be calculated using avoided cost. The cost acquired from higher levels of sedimentation or erosion rates from agricultural lands would give us the avoided cost of soil retention.

6.2.7 Average Global Summary Values for Forests

- Disturbance regulation is valued at \$3.42 per hectare (Costanza et al. (1997), 256).⁸ The total value of this service is \$564,192 annual.
- Water supply is valued at \$5.13 per hectare (Costanza et al. (1997), 256).⁹ Transferring this value to the Rideau Valley watershed, the annual total is \$846,289.

⁸ US\$2 in 1994 see appendix a

⁹ US\$3 in 1994 see appendix a

- Soil formation is valued at \$17 per hectare, annually (Costanza et al. (1997), 256).¹⁰ Using this value, the Rideau Valley watershed provides soil formation worth \$2.8 million per year.
- Nutrient cycling is valued at \$617.26 per hectare, annually (Costanza et al. (1997), 256).¹¹ Transferring this value to the Rideau Valley watershed, nutrient cycling is worth \$101.8 million per year.
- Waste treatment is valued at \$148.76 per hectare (Costanza et al. (1997), 256).¹² Using this value, waste treatment is worth \$24.5 million annually in the Rideau Valley watershed.
- Food production by forests is worth \$73.52 per hectare (Costanza et al. (1997), 256).¹³ Using this estimate, food production by forests in the Rideau Valley watershed would be worth \$12.1 million each year.
- Raw materials produced by forests are worth \$235.96 per hectare of forest (Costanza et al. (1997), 256).¹⁴ Using this value as a proxy for the Rideau Valley watershed's forests, raw materials would be valued at \$38.9 million.
- Genetic resources have been valued at \$27.36 per hectare of forest (Costanza et al. (1997), 256).¹⁵ Annually, the Rideau Valley watershed's forests would be worth \$4.5 million in genetic resources alone.

¹⁰ US\$10 in 1994 see appendix a

¹¹ US\$361 in 1994 see appendix a

¹² US\$87 in 1994 see appendix a

¹³ US\$43 in 1994 see appendix a

¹⁴ US\$138 in 1994 see appendix a

¹⁵ US\$16 in 1994 see appendix a

- The recreational value of a hectare of forest is worth \$112.85 annually (Costanza et al. (1997), 256).¹⁶ Transferring this value to the Rideau Valley watershed's forests, the recreational value would be \$18.6 million annually.
- The cultural worth of a hectare of forest is \$3.42, annually (Costanza et al. (1997), 256).¹⁷ The total annual cultural worth of the forests in the Rideau Valley watershed is \$564,200.

6.2.8 Total Value of the Watershed's Forests

Each year, Rideau Valley watershed's forests provide ecological goods and services worth at least \$518.5 million including \$151 million in carbon storage. Values of ecological goods and services from forests are provided in table 7 on page 56.

6.3 The Value of Ecological Goods and Services Provided by Croplands

6.3.1 Climate Regulation

Climate regulation was valued using avoided cost. Organic carbon stored in agricultural soils was assessed using spatial analysis of the Canadian Soil Organic Carbon Database (Kennedy et al. (2009), 27). The average soil carbon content is 80 tonnes of carbon per hectare. Using IPCC's cost of carbon, the value of carbon storage is \$350 per hectare of croplands (Kennedy et al. (2009), 27). The total value of carbon stored is \$26.5 million.

¹⁶ US\$66 in 1994 see appendix a

¹⁷ US\$2 in 1994 see appendix a

6.3.2 Soil Formation

The value of soil formation was calculated using avoided cost. Earthworms, in cropland and pastures, aid in soil formation. A study has estimated the service of soil formation is worth an estimated \$6.06 per hectare per year (Wilson (2008), *Lake Simcoe Basin's Natural Capital: the Value of the Watershed's Ecosystem Services*, 29).

Transferring this value to the Rideau Valley watershed, soil formation in croplands is worth \$458,633 per year.

6.3.3 Cultural

Culture, derived from nature, can be valued using contingent valuation. A survey of residents of Eastern Canada found that they were willing to pay \$311.47 per hectare, annually, for farmland preservation (Wilson, *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 39).¹⁸ Using this value, the Rideau Valley watershed is worth at least \$23.6 million annually.

6.3.4 Average Global Summary Values

- Pollination is worth \$23.94 per hectare, annually (Costanza et al. (1997), 256).¹⁹ Using this valuation, pollination amounts to \$1.8 million.
- Biological Control is worth \$41.04 per hectare (Costanza et al. (1997), 256).²⁰
The total value of this service is \$3.1 million.
- Food Production is worth \$92.33 per hectare (Costanza et al. (1997), 256).²¹
The total value of food production for the Rideau Valley watershed is \$7 million.

¹⁸ CAN\$97 per acre in 1991, $2.47 * 1.3 * 97 = \$311.47$ (2.47 hectares = acre, 1.3 inflation index to 2005)

¹⁹ US\$14 in 1994 see appendix a

6.3.5 Total Value of the Watershed's Croplands

The croplands of the Rideau Valley watershed provide ecological goods and services worth at least \$64.4 million dollars each year. Values of ecological goods and services from croplands are provided in table 8 on page 57.

6.4 The Value of Ecological Goods & Services Provided by Pastures & Abandoned Fields

6.4.1 Climate Regulation

Pastures and abandoned fields store 105 tonnes of carbon per hectare based on the results of a Canadian grassland study (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 35). Using IPCC's average avoided cost of carbon, the value of carbon store for pastures and abandoned fields is \$438 per hectare annually (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-services*, 35). The Rideau Valley watershed stores 7.3 million tonnes of carbon. The total value of carbon storage is worth about \$30.5 million. Carbon storage was valued using avoided cost.

Land permanently covered has higher carbon sequestration levels than tilled land. Permanent cover is estimated to increase carbon sequestration by 0.5 tonnes carbon, or 1.8 tonnes of carbon dioxide, per hectare annually when compared to conventional crop cover (Wilson, *Lake Simcoe* 26). The value of carbon sequestration is \$28.46 per hectare annually (Wilson (2008), *Ontario's Wealth, Canada's Future: Appreciating the Value of*

²⁰ US\$24 in 1994 see appendix a

²¹ US\$54 in 1994 see appendix a

the Greenbelt's Eco-services, 35). The total value of carbon sequestration is worth about \$2 million. Carbon sequestration was valued using avoided cost.

6.4.2 Nutrient Cycling

The Canadian Urban Institute found that nutrient cycling is valued at \$23.50 per hectare (Wilson (2008), *Lake Simcoe Basin's Natural Capital: the Value of the Watershed's Ecosystem Services*, 30). Transferring this valuation to the Rideau Valley watershed, the total value of nutrient cycling is \$1.6 million.

6.4.3 Average Global Summary Values

- Gas regulation is valued at \$11.97 per hectare, annually (Costanza et al. (1997), 256).²² The total value of this function for the Rideau Valley watershed is \$834,000. Gas regulation can be valued using avoided cost. By assessing the amount of harmful gases removed from the atmosphere and assigning avoided cost values to the different gases, the value of gas regulation by pastures and abandoned fields can be calculated.
- Water regulation is valued at \$5.13 per hectare (Costanza et al. (1997), 256).²³ The total value of water regulation is worth about \$357,000.
- Soil retention is valued at \$49.59 per hectare (Costanza et al. (1997), 256).²⁴ The total value of erosion control and sediment retention is about \$3.5 million.
- Soil formation is valued at \$1.71 per hectare (Costanza et al. (1997), 256).²⁵ The total value of soil formation is \$119,000.

²² US\$7 in 1994 see appendix a

²³ US\$3 in 1994 see appendix a

²⁴ US\$29 in 1994 see appendix a

²⁵ US\$1 in 1994 see appendix a

- Waste treatment is valued at \$148.76 per hectare (Costanza et al. (1997), 256).²⁶ The total value of waste treatment is worth about \$10.4 million.
- Pollination is valued at \$42.75 per hectare (Costanza et al. (1997), 256).²⁷ The total value of pollination is \$3 million.
- Biological control is valued at \$39.33 per hectare (Costanza et al. (1997), 256).²⁸ The total value of biological control is \$2.7 million.
- Food Production is valued at \$114.56 per hectare (Costanza et al. (1997), 256).²⁹ The total value of food production is about \$8 million.
- Recreation is valued at \$3.42 per hectare (Costanza et al. (1997), 256).³⁰ The total value of recreation is worth approximately \$238,000.

6.4.4 Total Value of the Watershed's Pastures & Abandoned Fields

Each year, the Rideau Valley watershed's pastures and abandoned fields provide at least \$63.2 million in ecological goods and services including \$30.5 million through the service of carbon storage. The value of ecological goods and services from pastures and abandoned fields forests are provided in table 9 on page 57.

²⁶ US\$87 in 1994 see appendix a

²⁷ US\$25 in 1994 see appendix a

²⁸ US\$23 in 1994 see appendix a

²⁹ 67 usd 1994 see appendix a

6.5 The Value of Ecological Goods and Services Provided by Surface Water

6.5.1 Average Global Summary Values for Surface Water

- Water Regulation is valued at \$9310.19 per hectare (Costanza et al. (1997), 256).³¹ The total value of water regulation is \$267.1 million annually.
- Water Supply is valued at \$3619.77 (Costanza et al. (1997), 256).³² The total value of water supply is \$103.9 million, annually.
- Waste Treatment is valued at \$1137.06 per hectare (Costanza et al. (1997), 256).³³ The total value of waste treatment is \$32.6 million, annually.
- Food Production is valued at \$70.10 per hectare (Costanza et al. (1997), 256).³⁴ The total value of food production is \$2 million per year.
- Recreation, based in nature, is valued at \$393.27 per hectare (Costanza et al. (1997), 256).³⁵ The total value of recreation is worth \$11.3 million per year.

6.5.2 Total Value of the Watershed's Surface Water

Each year, the Rideau Valley watershed's surface water provides \$416.9 million in ecological goods and services. Values of ecological goods and services from surface water are provided in table 10 on page 58.

³⁰ US\$2 in 1994 see appendix a

³¹ US\$5,445 in 1994 see appendix a

³² US\$2,117 in 1994 see appendix a

³³ US\$665 in 1994 see appendix a

³⁴ US\$41 in 1994 see appendix a

³⁵ US\$230 in 1994 see appendix a

6.6 Total Value of the Rideau Valley Watershed's Ecological Goods and Services

Table 11, on page 59, brings all these ecosystem goods and services together for the Rideau Valley watershed as a whole. Each year, these are valued at over Can \$(2005) 2 billion. Their capitalized value over 20 years at 5% annually would amount to about Can \$(2005) 25 billion.

7 Problems with the Natural Capital Framework

This section discusses some of the shortcomings of the natural capital framework, which include both valuation and ecological problems.

7.1 Biophysical Linkages

Another problem with natural capitalism is that biophysical linkages between land use and water resources are often not understood or may not have even been studied. According to Paul Hawken et al, "Since it is not possible to determine precisely which species are needed to maintain soil or other living systems, there is no way to state with any confidence which organisms we can do without (if any)" (Hawken et al. (2010), 151). If we do not know what nature needs and in what quantities how can we put a realistic value on it? For example, consider the US\$200 million Biosphere 2 experiment. The world's best scientific minds designed a sealed, glass enclosed, 3.15-acre structure including a desert, a tropical rainforest, a savannah, a wetland, a farm field, and an ocean with a coral reef. For two years, eight scientists were to live entirely off the land inside the dome. All air, water, and nutrient recycling took place within the structure. At the end of 17 months, most of the insects, pollinators, reptiles and mammals became extinct and

the air's oxygen level dropped to 17,500-foot altitude. Oxygen had to be injected into the enclosed manmade ecosystem. The \$200 million ecosystem had difficulty keeping eight people alive for 24 months and yet every three seconds, eight people are added to the Earth (Hawken et al. (2010), 147).

7.2 Lack of Data

Any assessment ideally should lead to an economic valuation of all benefits and costs associated with each good and service provided by an ecosystem however this is not realistic. Often data is not available or it is old. For example, the report "Valuing New Jersey's Natural Capital: An Assessment of the Economic Value of the State's Natural Resources" released in 2007 used data for land use from 1995-1997 (New Jersey Department of Environmental Protection (2007), 34). The amount of natural capital is constantly changing; in ten years land use has changed. Another example, OMYA ltd, a calcite producing plant, used 75 years old flow data to apply for a permit to take water from the Tay River in Perth, Ontario (City of Ottawa, "Application to Take Water from Tay River" 4)

7.3 Uniqueness of Each Ecosystem

Technically, each ecosystem is unique. Wetlands do not all have the same hydrological function. A wetland's role in a drainage basin's hydrological setting has to be assessed using a wetland's unique hydrological function (Mississippi-Rideau Source Protection Region (2008), 69). However it would not be realistic or feasible to study each wetland's ecosystem individually. Yet if we do not understand relationships at the micro level how can one put a realistic value on it?

7.4 Multiplier Effect

We have limited information about how nature's services and goods influence other sectors. Changes in indirect or induced economic benefits or costs may affect other markets creating secondary effects, also called the multiplier effect. For example, if in a certain area logging no longer existed secondary markets would be affected creating a negative multiplier effect.

7.5 Joint Products Valuation

There is the potential problem of double counting nature's goods and services. This is especially problematic when we are trying to value a product as a good and as a service. For example, forests provide numerous services, such as carbon sequestration, but they also provide a good, timber. How much of each can a given forest provide at the same time? Studies such as "Valuing New Jersey's Natural Capital: An Assessment of the Economic Value of the State's Natural Resources" argue that a forest which is sustainably managed can supply both over the long term in rough constant proportion (New Jersey Department of Environmental Protection (2007), 15).

7.6 Natural Wealth

Over an extended period of time, natural capital assets produce goods and services. Natural capital assets values should be capitalized values of their goods and services when produced sustainably and, therefore, in perpetuity. The natural capital's value for future goods and services provided should be 'discounted'. Some studies like "Valuing New Jersey's Natural Capital" capitalize the values of goods and services using a constant value for the latter in perpetuity, discounted at 3 percent (New Jersey Department of Environmental Protection (2008), 43). Other studies like "Natural Credit:

Estimating the Value of Natural Capital in the Credit River Watershed”, use a capitalized value over 10 years at 2 percent (Kennedy et al. (2009), 21). The discount rate reflects the yield on long-term bonds. There is a whole fractious economic literature on discount rates for public projects. Some literature even argues that no discount rate should be used at all for environmental assets with the odd consequence that their capitalized value becomes infinite. Discount rates are an essential allocative tool for intertemporal allocation of resources over relatively short horizons. For longer horizons, one needs to use other decision criteria and ethical frameworks.

7.7 Using Average Cost in Valuations

As the level of depletable natural capital declines, its value should increase (Hotelling’s rule). Society’s willingness to pay for the remaining natural capital would likely increase. Values are calculated using average cost rather than marginal cost since it is difficult to obtain marginal values. This can create an underestimation of what nature is truly worth. For example, the cost of a glass of tap water in Ottawa is 0.06325 cents (City of Ottawa, “New Water Rate FAQs”) but if available water were to become scarce the value would surely increase.

7.8 Contingent Valuation

Contingent valuation is based upon what people say they would do, as opposed to what people are observed to do. Mark Sagoff, In *the Economy of the Earth*, argues, contingent valuation is like a jury trial where each juror, without hearing evidence, votes for a verdict. They lack the grounded understanding of environmental tradeoffs that is required for meaningful value judgements (Sagoff (1988), *The Economy of the Earth*, 88).

7.9 Non-utilitarian Ethical Frameworks

Moral and social values promoted through education influence society's relationship with the environment and, therefore, its perceived needs. There are other ethical frameworks dealing with our relationships with nature besides the utilitarian one. The Brundtland Report acknowledges that "Perceived needs are socially and culturally determined, and sustainable development requires the promotion of values that encourage consumption standards that are within the bounds of the ecological possible and to which all can reasonably aspire" (WCED, "Our Common Future, Chapter 2"). The Brundtland Report argues that education, institutional development, and law enforcement have a role. However, it acknowledges that differences in economic and political power have contributed to resource depletion and environmental stress (WCED, "Our Common Future, Chapter 2").

8 Conclusion

The Rideau Valley watershed provides many ecological goods and services that are being threatened. Pollutants from livestock, storm water runoff, and nutrient loading

threaten its highly exposed aquifers. Population growth in the watershed threatens the ecosystem and water supply. The natural capital framework was developed because often the value of nature's capital, its' ecological goods and services, were not fully considered in policy decisions. Natural capital investments can help conserve the environment while depreciating it like any other capital asset. Two significant examples given in this report are the filtering New York City's water by protecting its watershed and erosion control and silt retention in the Panama Canal by planting trees. The report' analysis, using the natural capital framework, found that the Valley's wetlands, forests, croplands, pastures and surface water provide ecological goods and services worth at least \$2.2 billion annually or have a capitalized value of about Can \$(2005) 25 billion. The Valley's wetlands alone provided ecological goods and services worth about \$1.2 billion annually. Numerous problems affect the value assessment of nature. Ecological problems include not fully understanding biophysical linkages, and the uniqueness of each ecosystem. Valuation problems include using average cost in valuations, and inadequate data. All valuation methodologies have their drawbacks. However, it is important to value an ecosystem's goods and services because the natural capital framework attempts to improve decision-making for managing, preserving, and restoring natural environments.

Appendix A

Costanza et al figures were originally in US dollars.

According to the Bank of Canada, prices inflated 24.82 percent from 1994 to 2005.

(see http://www.bankofcanada.ca/en/rates/inflation_calc.html).

In 1994, the average rate of exchange for 1 US dollar was 1.3698.

Original value * 1.2482 * 1.3698

Tables

Table 1: Land Use

Class	Hectare	Percentage
<u>Forest ecosystem</u>		
Dense Coniferous Forest	21162.02921	4.998%
Dense Deciduous Forest	66521.54495	15.711%
Mixed Forest Mainly Coniferous	32407.19657	7.654%
Mixed Forest Mainly Deciduous	24265.99158	5.731%
Sparse Coniferous Forest	3658.546567	0.864%
Sparse Deciduous Forest	16628.16218	3.927%
<u>Coniferous Plantation</u>	<u>325.195323</u>	<u>0.077%</u>
Total Forests:	164968.6664	38.962%
Cropland	75682.07296	17.875%
Pasture and Abandoned Fields	69665.93696	16.454%
<u>Wetlands</u>		
Conifer Swamp	11024.63287	2.604%
Deciduous Swamp	29845.01975	7.049%
Freshwater Coastal Marsh / Inland Marsh	3789.773511	0.895%
Open Fen	4540.196682	1.072%
<u>Treed Bog</u>	<u>1332.246169</u>	<u>0.315%</u>
Total Wetlands:	50531.86898	11.935%
Water	28692.2234	6.777%
Settlement and Developed Land	19087.77788	4.508%
Alvar	13735.40897	3.244%
Mine Tailings, Quarries, and Bedrock Outcrop	1036.377485	0.245%
TOTAL:	423400.333	100.000%

Source: Klymko, Andrea. "Watershed Information." Message to the author. 4 Mar. 2010.

E-mail.

Data was supplied by Klymko from the Rideau Valley Conservation Authority.

Table 2: Ecosystem Goods and Service & Total Economic Valuation

	Ecosystem Services	Total Economic Valuation
Environmental Goods	<ul style="list-style-type: none"> • Food production • Fresh water • Fuel • Raw materials 	<ul style="list-style-type: none"> • Direct use – Consumptive • Direct use – Consumptive • Direct use – Consumptive • Direct use – Consumptive
Regulating Services	<ul style="list-style-type: none"> • Gas regulation • Climate regulation • Disturbance regulation • Water regulation • Water supply • Erosion control 	<ul style="list-style-type: none"> • Indirect use • Indirect use • Indirect use • Indirect use • Indirect use • Indirect use
Supporting Services	<ul style="list-style-type: none"> • Nutrient cycling • Soil formation • Waste treatment • Genetic resources • Habitat/refugia • Biological control • Pollination 	<ul style="list-style-type: none"> • Indirect use • Indirect use • Indirect use • Indirect use – Option value • Indirect use • Indirect use • Indirect use
Cultural Services	<ul style="list-style-type: none"> • Aesthetic • Spiritual • Educational • Recreational 	<ul style="list-style-type: none"> • Direct use • Direct use • Direct use • Direct use

Source: Secretariat of the Convention on Biological Diversity. *An Exploration of Tools and Methodologies for Valuation of Biodiversity and Biodiversity Resources and Functions.*

Table 3: Ecosystem Service & Valuation Methods

Ecosystem Service	Valuation Method
Gas regulation	• Avoided cost
Climate regulation	• Avoided cost
Disturbance regulation	• Avoided cost
Water regulation	• Avoided cost or Factor income
Water supply	• Direct market pricing or Replacement cost
Erosion control	• Avoided cost or Replacement cost
Soil formation	• Avoided cost
Nutrient cycling	• Replacement cost
Waste treatment	• Replacement cost or Contingent valuation
Pollination	• Replacement cost, Factor income or Avoided cost
Biological control	• Replacement cost, Factor income, or Direct market pricing
Refugia	• Avoided cost
Food production	• Direct market pricing, factor income or contingent valuation
Raw materials	• Direct market pricing, factor income or contingent valuation
Genetic resources	• Direct market pricing or Factor income
Recreation	• Direct market pricing, contingent valuation, factor income, travel cost, or hedonic pricing
Cultural	• Contingent valuation or Hedonic pricing (for aesthetics)

Source: De Groot, Rudolf S., Matthew A. Wilson, and Roelof M.J. Boumans. "A Typology for the Classification, Description and Valuation of Ecosystem Functions, Good and Services." *Ecological Economics* 41 (2002): 393-408. Print.

Table 4: Carbon Storage Rates for Wetlands

Type of Wetland	Area (ha)	Carbon Storage (tonnes/ha)	Annualized Value (per ha)	Total Value Annualized
Swamp	40869.65262		125 \$ 521.58	\$ 21,316,793.41
Marsh	3789.773511		171 \$ 713.52	\$ 2,704,079.20
Fen	4540.196682		312 \$1,301.86	\$ 5,910,700.45
Bog	1332.246169		232 \$ 968.05	\$ 1,289,680.90

Total (C\$ 2005): 50531.86898 \$ 31,221,253.97

Source: Wilson, Sara J. *Lake Simcoe Basin's Natural Capital: the Value of the Watershed's Ecosystem Services*, prepared for the Friends of the Greenbelt Foundation

Table 5: The Value of Wetlands

Ecological Goods & services	Bog	Marsh	Swamps	Fen	Total \$
Climate regulation:					
Carbon storage	\$ 968.05	\$ 713.52	\$ 521.58	\$ 1,301.86	\$ 31,221,258.12
Climate regulation:					
Carbon sequestration	\$ 13.02	\$ 13.02	\$ 13.02	\$ 13.02	\$ 657,924.95
Disturbance regulation	\$ 4,038.51	\$ 4,038.51	\$ 4,038.51	\$ 4,038.51	\$204,073,462.31
Water regulation	\$ 25.65	\$ 25.65	\$ 25.65	\$ 25.65	\$ 1,296,142.47
Water supply	\$ 6,497.47	\$ 6,497.47	\$ 6,497.47	\$ 6,497.47	\$328,329,309.37
Soil retention					
Soil formation					
Nutrient cycling					
Waste treatment	\$ 3,017.00	\$ 3,017.00	\$ 3,017.00	\$ 3,017.00	\$152,454,651.79
Pollination					
Biological control					
Habitat/Refugia	\$ 5,830.00	\$ 5,830.00	\$ 5,830.00	\$ 5,830.00	\$294,600,802.10
Food production	\$ 437.72	\$ 437.72	\$ 437.72	\$ 437.72	\$ 22,118,810.14
Raw materials	\$ 181.25	\$ 181.25	\$ 181.25	\$ 181.25	\$ 9,158,901.44
Genetic resources					
Recreation	\$ 981.46	\$ 981.46	\$ 981.46	\$ 981.46	\$ 49,595,009.13
Cultural	\$ 1,506.39	\$ 1,506.39	\$ 1,506.39	\$ 1,506.39	\$ 76,120,703.65
Total per ha \$/ha/yr	\$ 23,496.52	\$ 23,241.99	\$ 23,050.05	\$ 23,830.33	
Total value (C\$ 2005)	\$ 31,303,239	\$ 88,081,796	\$ 942,047,476	\$ 108,194,464	\$ 1,169,626,975

Table 6: The Value of Gas Regulation in Forests

	Kilograms (per Hectare)	Value (\$ per Kilogram)	Value (per Hectare)	Total Value (\$ per Year)
Carbon monoxide	1.2	\$ 1.04	\$ 1.25	\$ 206,210.83
Ozone	30.3	\$ 7.51	\$ 227.59	\$ 37,545,218.78
Nitrogen Dioxide	7.5	\$ 7.51	\$ 56.34	\$ 9,294,334.66
Particulate Matter	16.8	\$ 5.01	\$ 84.25	\$ 13,898,610.14
Sulphur Dioxide	4.2	\$ 1.83	\$ 7.71	\$ 1,271,908.42
Total (C\$ 2005):	60	\$ 6.29	\$ 377.14	\$ 62,216,282.84

Source: Sara Wilson, *Ontario's Wealth Canada's Future: Appreciating the Value of the Greenbelt's Eco-Services*, prepared for the David Suzuki Foundation.

Table 7: The Value of Forests

Ecological goods and services	Value (\$ per Hectare)	Total Value
Gas regulation	\$ 377.14	\$ 62,216,284.20
Climate regulation (carbon stored)	\$ 919.00	\$ 151,606,207.73
Climate regulation (carbon sequestration)	\$ 39.11	\$ 6,451,924.68
Disturbance regulation	\$ 3.42	\$ 564,192.85
Water regulation		
Water supply	\$ 5.13	\$ 846,289.28
Soil retention		
Soil formation	\$ 17.00	\$ 2,804,467.39
Nutrient cycling	\$ 617.26	\$ 101,828,561.24
Waste treatment	\$ 148.76	\$ 24,540,739.35
Pollination (seed dispersal)	\$ 537.00	\$ 88,588,175.79
Biological control	\$ 25.97	\$ 4,284,236.36
Habitat/Refugia		
Food production	\$ 73.52	\$ 12,128,496.62
Raw materials	\$ 235.96	\$ 38,926,007.37
Genetic resources	\$ 27.36	\$ 4,513,542.81
Recreation	\$ 112.85	\$ 18,616,714.41
Cultural	\$ 3.42	\$ 564,192.85
Total Value (\$ per Hectare)	\$ 3,142.90	
Total C\$(2005)		\$ 518,480,032.94

Table 8: The Value of Croplands

Ecological goods and services	Value (\$ per ha)	Total Value
Gas regulation		
Climate regulation	\$ 350.00	\$ 26,488,724.50
Disturbance regulation		
Water regulation		
Water supply		
Soil retention		
Soil formation	\$ 6.06	\$ 458,633.34
Nutrient cycling		
Waste treatment		
Pollination	\$ 23.94	\$ 1,811,828.76
Biological control	\$ 41.04	\$ 3,105,992.15
Habitat/refugia		
Food production	\$ 92.33	\$ 6,987,725.52
Raw materials		
Genetic resources		
Recreation		
Cultural	\$ 311.47	\$ 23,572,694.34
Total C\$ (2005):	\$ 824.84	\$ 62,425,598.62

Table 9: Total Value of Pastures & Abandoned Fields

Ecological goods and services	Value (\$ per ha)	Total Value
Gas regulation	\$ 11.97	\$ 833,901.27
Climate regulation:		
Carbon stored	\$ 438.00	\$ 30,513,680.39
Climate regulation:		
Carbon sequestration	\$ 28.46	\$ 1,982,692.57
Disturbance regulation		
Water regulation	\$ 5.13	\$ 357,386.26
Water supply		
Soil retention	\$ 49.59	\$ 3,454,733.81
Soil formation	\$ 1.71	\$ 119,128.75
Nutrient cycling	\$ 23.50	\$ 1,637,149.52
Waste treatment	\$ 148.76	\$ 10,363,504.78
Pollination	\$ 42.75	\$ 2,978,218.81
Biological control	\$ 39.33	\$ 2,739,961.30
Habitat/refugia		
Food production	\$ 114.56	\$ 7,980,929.74
Raw materials		
Genetic resources		
Recreation	\$ 3.42	\$ 238,257.50
Cultural		
Total:	\$ 907.18	\$ 63,199,544.69

Table 10: The Value of Surface Water

Ecological goods and services	Value (\$ per ha)	Total Value
Gas regulation		
Climate regulation		
Disturbance regulation		
Water regulation	\$ 9,310.19	\$267,130,051.38
Water supply	\$ 3,619.77	\$103,859,249.50
Soil retention		
Soil formation		
Nutrient cycling		
Waste treatment	\$ 1,137.07	\$ 32,625,066.46
Pollination		
Biological control		
Habitat/refugia		
Food production	\$ 70.10	\$ 2,011,324.86
Raw materials		
Genetic resources		
Recreation	\$ 393.27	\$ 11,283,790.70
Cultural		
Total:	\$ 14,530.40	\$416,909,482.89

Table 11: The Total Value of the Watershed's Ecosystems

Ecological goods & services	Wetlands	Forests	Croplands	Pasture	Water	Total
Gas regulation		\$62,216,284		\$833,901		\$63,050,185
Climate regulation: Carbon storage	\$31,221,258	\$151,606,208	\$26,488,725	\$30,513,680		\$239,829,871
Climate regulation: Carbon sequestration	\$657,925	\$6,451,925		\$1,982,693		\$9,092,548
Disturbance regulation	\$204,073,462	\$564,193				\$204,637,655
Water regulation	\$1,296,142			\$357,386	\$267,130,051	\$268,783,579
Water supply	\$328,329,309	\$846,289			\$103,859,250	\$433,034,848
Erosion control				\$3,454,734		\$3,454,734
Soil formation		\$2,804,467	\$458,633	\$119,129		\$3,382,229
Nutrient cycling		\$101,828,561		\$1,637,150		\$103,465,711
Waste treatment	\$152,454,652	\$24,540,739		\$10,363,505	\$32,625,066	\$219,983,962
Pollination		\$88,588,176	\$1,811,829	\$2,978,219		\$93,378,224
Biological control		\$4,284,236	\$3,105,992	\$2,739,961		\$10,130,189
Habitat/refugia	\$294,600,802					\$294,600,802
Food production	\$22,118,810	\$12,128,497	\$6,987,726	\$7,980,930	\$2,011,325	\$51,227,288
Raw materials	\$9,158,901	\$38,926,007				\$48,084,908
Genetic resources		\$4,513,543				\$4,513,543
Recreation	\$49,595,009	\$18,616,714		\$238,258	\$11,283,791	\$79,733,772
Cultural	\$76,120,704	\$564,193	\$23,572,694			\$100,257,591
Total:	\$1,169,669,928	\$518,480,033	\$62,425,599	\$63,199,545	\$416,909,483	\$2,230,641,638

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