Assessing water resource management in provincial land use planning policies in peri-urban regions of Southern Ontario

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Abstract

Urbanization is one of the most significant trends of the 21st century, affecting global economic development, energy consumption, natural resource use and human well-being. Land-use planning is a tool used by local and regional municipalities to address these increasing development pressures. Currently, provincial land use plans for ecologically and economically important regions within the Greater Golden Horseshoe, including the Oak Ridges Moraine Conservation Plan, the Niagara Escarpment Plan and the Greenbelt Plan, are undergoing a Coordinated Land Use Plans Review, which commenced in 2015. Scholarly and grey literature was examined to evaluate these land use plans using criteria based on Integrated Water Resource Management and Monitoring. Select strengths, weaknesses and recommendations were provided for Oak Ridges Moraine, Niagara Escarpment and Greenbelt land use plans to move toward adaptive environmental management.
List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>CAMC</td>
<td>Conservation Authorities Moraine Coalition</td>
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<td>CEW</td>
<td>Citizens Environment Watch</td>
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<tr>
<td>GBP</td>
<td>Greenbelt Plan</td>
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<tr>
<td>ICWE</td>
<td>International Conference on Water and the Environment</td>
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<td>IWRM</td>
<td>Integrated Water Resource Management</td>
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<tr>
<td>MMAH</td>
<td>Ministry of Municipal Affairs and Housing</td>
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<tr>
<td>NEC</td>
<td>Niagara Escarpment Commission</td>
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<tr>
<td>NEP</td>
<td>Niagara Escarpment Plan</td>
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<tr>
<td>ORM</td>
<td>Oak Ridges Moraine</td>
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<tr>
<td>ORMCP</td>
<td>Oak Ridges Moraine Conservation Plan</td>
</tr>
<tr>
<td>PGA</td>
<td>Places to Grow Act</td>
</tr>
<tr>
<td>PPS</td>
<td>Provincial Policy Statement</td>
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<tr>
<td>SOLRIS</td>
<td>Southern Ontario Land Resource Information System</td>
</tr>
<tr>
<td>STORM</td>
<td>Save the Oak Ridges Moraine Coalition</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
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1. Introduction

i. The Problem

Urbanization is one of the most significant trends of the 21st century, affecting global economic development, energy consumption, natural resource use and human well-being. At the core of urbanization is unstructured low-density development, particularly in peri-urban regions, defined as the transition zones between urban and rural areas. Currently in Canada, 90% of Canadians live in the Southern region of Canada, within 200 kilometres of the Canada-U.S. border (Rothwell, 2006). As of 2001, nearly 10 million Canadians lived in six very highly urban watersheds that together occupy just 2.9 percent of Canada’s land mass (Rothwell, 2006).

Inadequate planning, pollution, continuous expansion and competing demands on water resources all contribute to stressors for various bodies of water and watersheds, such as headwaters, sub-watersheds, rivers and lakes (Figure 1).

As a result of urbanization processes, Southern Ontario is comprised of

Figure 1. 2013 Stress Index for tertiary watersheds in Ontario due to human development and activities. This figure was adapted from Chu et al. (2015).
fragmented natural spaces, characterized by residential development dominated with single-family homes, single-use zoning and large road networks for long distance automobile transportation. This has a number of biophysical impacts on the immediate and surrounding natural processes and water resources. For instance, development of road, consisting of impervious surfaces like asphalt and concrete, alter the hydrology of a landscape and exacerbate issues such as stormwater runoff, which pollutes freshwater resources and degrades aquatic habitats (Booth et al., 2004). Urbanization also affects the availability of sediment supplies and stream channel morphology. Other effects also include increased frequency of flooding and peak flow volumes, decreased base flow, increased sediment loadings, changes in stream morphology, increased organic and inorganic loadings, increased stream temperature and loss of aquatic/riparian habitat (Chu et al., 2015). Urbanization alters the hydrological cycle of the land and may reduce recharge of groundwater due to the impermeability of city surfaces. Urban stormwater runoff also contains higher concentrations of heavy metals, organic pollutants, fecal coliform bacteria, nutrients and total suspended solids (Booth and Reinelt, 1993). Increases in nutrient concentration may also accelerate eutrophication especially in lakes and estuaries. This will impact various aquatic ecosystems, ranging from nutrient composition to macroinvertebrates and fish (Booth et al., 2004). Specifically, in terms of water resources, urbanization in the area will cause detrimental ecological effects such as increased contamination, loss of integral aquatic habitats and riparian buffers, changes in natural hydrology of watersheds and disruption of biological communities (Coles, 2012).

Not only does rapid population growth in the Greenbelt region increase the gap between freshwater resources and demand, the urban development provides additional stress on
watersheds and degradation of water resources. Increased flooding, rising demand for potable water associated with depletion of water resources exacerbate socio-economic issues such as inequitable resource distribution and disease prevention programs, particularly for First Nations communities (Mascarenhas, 2007). Stressors on water resources is becoming an increasingly prominent and relevant problem, particularly to Southern Ontario, as historic influxes in population continue and finite sources of water become increasingly susceptible to degradation (Coles, 2012).

ii. The Opportunity

If development continues as it has historically, this will result in the consumption of more land in Southern Ontario with significant ecological, agricultural, social and cultural pressures. However, different tools and processes have emerged in response to development pressure to limit impacts and ensure long-term success and strategic. Land-use planning is a process with tools used by local and regional municipalities under the authority of the Provincial Government to manage resources, such as water, as well as development.

The Ontario Planning Act is a land use planning policy that is composed of official plans, secondary plans, plans of subdivision and by-laws. A key policy document prepared and periodically reviewed by the Provincial government is the Provincial Policy Statement (PPS), found in Section 3 of the Planning Act (Ministry of Municipal Affairs, 2010). The Provincial Policy Statement is a province-wide statement of the government’s policies on land use planning, providing clear directions to ensure community development, economic growth and a healthy environment. It addresses policy issues such as the efficient use and management of land and
infrastructure, protection of the environment and opportunities for employment (Ministry of Municipal Affairs, 2014).

There are several key land use planning policies implemented to carefully manage development in Southern Ontario, especially within regions considered to be ecologically sensitive and economically significant. In 1973, the provincial government passed the Niagara Escarpment Planning and Development Act following by the Niagara Escarpment Plan in 1985. In 2001, the Oak Ridges Moraine Conservation Act was passed, followed by the Greenbelt Act and Greenbelt Plan in 2005. These plans provide strategic direction to guide development. In response to increasing urbanization and need to update policies, these provincial land use plans undergo periodic review (Ministry of Municipal Affairs and Housing, 2015). Currently, these plans are undergoing a Coordinated Land Use Plans Review, which commenced in 2015 (Lura Consulting, 2015). These stand-alone pieces of legislation and associated environmental land-use plans are critical to addressing development in these peri-urban areas. With this review, current policymakers and stakeholders are given the opportunity to critically assess various aspects of these land use plans. With respect to water resource management, it is evident that current management strategies require a systemic paradigm shift in order to adapt to unprecedented periods of growth and increasing stressors (Whitelaw and Hamilton, 2008; Davidson and de Loe, 2014). Recommendations based on current best management strategies can be made to implement policy changes that reflect more adaptive, resilient and integrated land use plans that can effectively address the interconnected and multifaceted issues surrounding water resources.
iii. The Objective:

The purpose of this paper will be to identify select strengths and weaknesses of the water resource management strategies outlined in the Niagara Escarpment, Oak Ridges Moraine and Greenbelt land use plans based on current, innovative water resource management practices derived from scientific research. Strengths and weaknesses of the various land use plans will be discussed and potential recommendations and opportunities for further improvement will also be proposed to ensure water resources are regulated in a robust and strategic manner in the increasingly urbanized region of the Greater Golden Horseshoe. This paper serves as a tool to stimulate further discussions and implement approaches towards more adaptive, resilient and integrated policies, capable of addressing the interconnected and multifaceted issues surrounding water resources.

This paper is structured as follows: Section 2 will present the methods of analysis used in the paper to identify current best management practices and examine the specific land use. Section 3 will focus on the specific ecologically significant areas of study, namely the Niagara Escarpment, Oak Ridges Moraine and Greenbelt regions of Southern Ontario. Next, Section 4 will provide a summary of the literature review and detailed water policy criteria for the purpose of evaluating the Niagara Escarpment Plan, the Oak Ridges Conservation Plan and the Greenbelt Plan. Each plan will be evaluated based on the current best management practices for water resources. The results and discussion portion, Section 5, will elaborate on the strengths and weaknesses of the plans as well as provide recommendations. Section 6 will serve as final portion of the paper, reflecting on the findings as well as including the Summary of Main Points.
2. Methods

This report aims to present scholarly and grey literature on improving land use planning within the context of the 2015 Co-Ordinated Land Use Planning Review. Scholarly research was considered papers found in peer-review academic journals. Grey literature was considered to be materials and research produced by government officials, non-government officials, academic centres and consultant companies such as annual reports, technical reports, evaluations and plans. Both resources were reviewed to develop a concrete understanding of the issue at hand as well as current research being conducted in the field of water planning policies to produce relevant and focused recommendations.

The main research methods include: 1) review of scholarly literature on current innovative water planning policies to create the criteria for robust water resource management; 2) review of government policy documents and use of secondary research to assess the Niagara Escarpment Plan (NEP), Oak Ridges Moraine Conservation Plan (ORMCP) and the Greenbelt Plan (GBP) based on the criteria developed in the first part (Plaunt, 1978; Parliamentary Commissioner for the Environment 2003; Hanna et al., 2007).

The policy recommendations and discussions extracted from this processes is derived from triangulation of both scholarly and grey literature review, utilizing qualitative research methods. Triangulation was used to establish convergent validation of the research results to improve accuracy and provide validation for the results (Bouchard, 1976; Jick, 1979). Using multiple research methods allowed for corroboration and more defendable comparisons between results from the literature review and document analysis. The outcome of this project will be a
document for the Partnership for the 2015 Land Use Planning Co-Ordinated Review, identifying strengths and weaknesses in addition to recommendations pertaining to adaptive water resource management.

3. Areas of Study

The Niagara Escarpment, Oak Ridges Moraine and Greenbelt region were the chosen sites of study as these regions are governed by stand-alone planning legislation to better protect green space, farmland, forests, wetlands, and watersheds (Figure 2). Located in Southern Ontario, they encompass a significant portion of the most populated and fastest-growing regions of Canada, while also recognized as ecologically significant areas and sources of income for many surrounding residents (Ministry of Municipal Affairs and Housing, 2008). In addition, the 10-year review of the land use plans involving stakeholder consultation coincides with the need to address water resource management in these regions facing accelerated urbanization (Ministry of Municipal Affairs and Housing, 2012).
Figure 2. Map of Southern Ontario highlighting the Oak Ridges Moraine, Greenbelt and Niagara Escarpment regions covered under their respective provincial land use plans (Ministry of Municipal Affairs and Housing, 2005; Ministry of Municipal Affairs and Housing, 2002; Ministry of Municipal Affairs and Housing, 2012) This figure was modified based on the one provided in Ministry of Municipal Affairs and Housing (2005).

i. Niagara Escarpment

The Niagara Escarpment in Southern Ontario is a linear geological formation extending from the Niagara River to Tobermory and the Manitoulin (Figure 2). The Escarpment extends south into the State of New York and northwest into Wisconsin. In Southern Ontario, it encompasses 194,555 hectares, containing forests, farms, cliffs, streams, wetlands, waterfalls, mineral resources and wildlife habitats (Ministry of Municipal Affairs and Housing, 2012). The
Escarption is home to almost 40% of Ontario’s rare flora with over 300 bird species, 53 mammals, 36 reptiles and amphibians, 90 fish and 100 varieties of special interest flora. It was designated as UNESCO World Biosphere Reserve in Canada in 1990 (UNESCO, 2007). Ongoing land use planning issues include mineral resource and aggregate extraction, continued demand for new permanent and vacation residential development and significant pressure to expand urban boundaries into the rural portions of the Niagara Escarpment region (Ministry of Municipal Affairs and Housing, 2012).

ii. Case Study: Oak Ridges Moraine

The Oak Ridges Moraine (ORM) is located north of the City of Toronto extending from the Niagara Escarpment in the west to the Trent River in the east (Figure 2). The moraine is approximately 190,000 hectares in size, 160 km in length and between 3 and 24 km wide. The landscape is a glacial feature created by multiple advances and retreats of glaciers during the Pleistocene (Barnett, 1998). The moraine was extensively deforested during the mid-1800s, leading to soil erosion and water quality and quantity impairment of rivers that originate on the moraine. Following significant reforestation efforts, the ORM today is mainly a combination of agricultural areas and natural cores that contain an abundance of native plants and animal species. It also serves as a groundwater recharge and discharge area for 65 watercourses (Gerber and Howard, 2002). Due to heavy residential development pressure, substantial development of the region extended urban sprawl outwards from the Greater Toronto Area, threatening this important resource (Ministry of Municipal Affairs and Housing, 2005). As a result, surface and below groundwater resources within these important headwaters were threatened. The estimated current population on the moraine land itself is roughly 200,000 but continues to increase with
large urban developments occurring in Stouffville, Vaughan, Richmond Hill, Oak Ridges and Aurora regions (Ministry of Municipal Affairs and Housing, 2001).

iii. Case Study: Greenbelt

The Greenbelt was established in 2006 through the Greenbelt Alliance in response to intense development impacting agriculture in one of the fastest growing urban regions, known as the Golden Horseshoe. Population increase were placing urban development pressure on areas surrounding Toronto and Hamilton, Ontario resulting in farmland loss by decreasing by 7% in the Greater Toronto Area and by 6% in Hamilton between 1996 and 2001 (Ministry of Municipal Affairs and Housing, 2005). The Greenbelt Act required the creation of the Greenbelt Plan. The Greenbelt Plan Area’s outer boundary follows property boundaries, watercourses, major roads and rail lines. It also encompasses the Oak Ridges Moraine Conservation Plan and the Niagara Escarpment Plan areas (The Friends of the Greenbelt Foundation, 2009). The purpose of the Greenbelt Plan is to contain urban growth in the Greater Golden Horseshoe region. By 2031, it is projected that the region’s population will reach 11.5 million (Ministry of Municipal Affairs and Housing, 2008). The Greenbelt plan has policies to protect important natural features and agricultural lands from urban sprawl (Hemson Consulting, 2005).
4. Literature Review and Creation of Criteria for Evaluation of Niagara Escarpment Plan, Oak Ridges Moraine Conservation Plan and Greenbelt Plan

**Negative Impacts of Urbanization on Water Resources**

Increased human development, resource consumption and environmental degradation all have a multitude of effects on water resources. Selected literature was reviewed to gain a deeper understanding of the negative impacts on urbanization. Channel geomorphology, water quality, ecosystem processes and biological communities were four main categories of effects reviewed (Table 1). Urbanization of a catchment can result in irreversible consequences to channel morphology as it affects the stability, sediment distribution, sediment load and flow variability of different streams and rivers (Coles, 2012). Municipal roads are serviced by a network of surface drains and sewers, which deliver water to the local channel, reducing the lag time between initial rainfall and the onset of flooding. Over time, channel erosion degrades the ability of a channel to contain a flood (Booth and Henshaw, 2001). Additionally, the channel is often constricted by bridge supports or riverside structures, thus reducing the carrying capacity of the stream. This increases the frequency with which high flows top the riverbanks (Short, 2005). The creation of impermeable surfaces, such as parking lots and roads, inhibits infiltration so that storm rainfall appears as runoff. Runoff erodes sediment from construction sites, parking lots or roads where vegetation is cleared, increasing the sediment load in streams. The changes in hydrology increase the in-stream potential for erosion and the quantity suspended sediment available from the channel itself (Shepherd et al., 2010). These factors, in combination, create conditions that are conducive to accelerated degradation of channels in urbanized regions.
Urbanization also affects the water quality of catchments, sub-watersheds, streams and
rivers. Physical removal of riparian vegetation and decreased groundwater recharge affect stream
temperature as seasonal diurnal fluctuations are greater in urban streams. Stormwater also result
in increased temperature pulses 10–15°C warmer than forested areas (Paul and Meyer, 2001). In
addition, there is a consistent increase in almost all chemical constituents including ions,
nutrients, oxygen demand, suspended solids, ammonium, hydrocarbons, and metals in urban
streams (Khamer and et al., 2000). Higher phosphorus concentrations are also noted in urban
catchments, increasing the demand for oxygen and the potential for eutrophication of lakes (Paul
and Meyer, 2001). Ions, especially chloride, were also found in high amounts as over 100,000
tons of sodium chloride were applied in Toronto for de-icing roads. It is released slowly, raising
stream chloride concentrations throughout the year (Howard and Haynes, 1993). Metals such as
nickel, chromium, lead, and copper; tires contain zinc, lead, chromium, copper, and nickel alloys
have also been noted in small quantities in rivers, tracing back to automobile parts, electronic
devices and stormwater runoff (Khamer and et al., 2000).

The chemical and physical impacts associated with increasingly populated watersheds
also have effects on regional biodiversity. While coliform bacterial densities are usually higher in
urban streams (often associated with catchments containing wastewater treatment plants), other
biota tend to decline (Young and Thackston, 1999). The effects of urbanization tend to diminish
the diversity of invertebrates due to responses to contaminants, temperature change, siltation, and
organic nutrients fluxes (Wright, 1995). As urban land cover increases, the presence of sensitive
taxa also decreases. As a result, declines in population of Ephemeroptera, Plecoptera, and
Trichoptera orders are observed. Areas that are highly impacted by urbanization are instead
dominated by Oligochaete, gastropod and Chironomidae species. These are species generally
considered to be more tolerant of environmental changes (Wright, 1995). On a larger scale, along urban gradients within single catchments, fish and reptile abundance also tends to decline (Yoder et al., 1999). For instance, road construction results in an increase in the relative abundance of water-column feeders as opposed to benthic feeders. This is because benthic invertebrate populations are negatively affected by the sedimentation resulting from construction (Yoder et al., 1999). As a result, ecological biodiversity in catchments associated with urbanization is affected on multiple trophic levels.

In terms of overall ecosystem processes, gross primary production and community respiration tend to be higher in urban streams than forested streams. Urbanized waters have higher negative net ecosystem metabolism, indicating greater respiration and heterotrophy rates (Steedmann, 1988). Additionally, uptake lengths in these rivers are much longer than in non-urbanized rivers, suggesting that not only is nutrient loading elevated, but nutrient removal efficiency is greatly reduced in urban regions. The net result of these alterations in urban streams is increased nutrient loading to downstream lakes, reservoirs, and estuaries (Paul, 1999).
Table 1. Summary of the changes in channel geomorphology, water quality, biological communities and ecosystem processes due to human development in regions containing water resources.

<table>
<thead>
<tr>
<th>Effect of Urbanization on Water Resources</th>
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<tbody>
<tr>
<td>Channel Geomorphology</td>
<td>• Increased sediment load widens stream size (Shepherd <em>et al</em>., 2010)</td>
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<td></td>
<td>• Decreased headwater stream length and drainage density (Booth and Henshaw, 2001)</td>
</tr>
<tr>
<td></td>
<td>• Increase the in-stream potential for erosion and scour (Coles, 2012)</td>
</tr>
<tr>
<td>Water Quality</td>
<td>Increased water temperature and diurnal temperature variability (Paul and Meyer, 2001)</td>
</tr>
<tr>
<td></td>
<td>• Increased pollutant export from urban catchments (Khamer <em>et al</em>., 2000)</td>
</tr>
<tr>
<td></td>
<td>• Increased concentrations of fecal coliforms, hydrocarbons, and organic compounds in water ways (Booth and Reinelt, 1993)</td>
</tr>
<tr>
<td></td>
<td>• Increased oxygen demand, conductivity, total suspended sediments, and metals (Paul and Meyer, 2001)</td>
</tr>
<tr>
<td>Biological Communities</td>
<td>• Decreased abundance of intolerant macroinvertebrate taxa (Wright, 1995)</td>
</tr>
<tr>
<td></td>
<td>• Decreased diversity of invertebrates, fish, mollusks, and salamanders (Wright, 1995; Yoder <em>et al</em>., 1999)</td>
</tr>
<tr>
<td></td>
<td>• Increased bacterial communities (Young and Thackston, 1999)</td>
</tr>
<tr>
<td>Ecosystem Processes</td>
<td>• Decreased organic matter retention and processing (Steedmann, 1988)</td>
</tr>
<tr>
<td></td>
<td>• Changes in balance between production and respiration (Paul, 1999)</td>
</tr>
<tr>
<td></td>
<td>• Altered food web interactions with resultant impacts on energy flow (Paul, 1999).</td>
</tr>
</tbody>
</table>

Additional literature was reviewed to explore current thinking on how impacts on water resources should be managed. The management approaches selected for discussion and use as criteria for evaluation of the three plans included Integrated Water Resource Management and monitoring. Integrated Water Resource Management was selected as a key concept because it is an accepted and well-established approach to water governance (Parkes *et al*., 2010; Whitelaw and Hamilton, 2001; Wang, 2001). Monitoring was selected because it is a major component of
Integrated Water Resource Management that contributes to adaptive environmental management (Whitelaw et al., 2003). Upon examination of the various effects on water resources, several key themes were identified in order to prevent, minimize or mitigate further degradation of watersheds. These two criteria will be further explored below based on a review of scientific literature and will serve as the criteria for which the three land use plans of interest are evaluated.

Integrated Water Resource Management (IWRM)

Integrated Water Resource Management (IWRM) was created by the Global Water Partnership, an organization created in 1996 that contains government agencies, public institutions, private companies, professional organizations and multilateral development agencies committed to the Rio-Dublin principles of water management. These principles were created during the International Conference on Water and the Environment (ICWE) in 1992 and set out recommendations for appropriate actions at local, national and international levels to reduce water scarcity (Global Water Partnership, 2000). The concept of IWRM was developed in 2000 and is defined as, “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership, 2000). This process is often integrated at the provincial and municipal level to manage catchments, sub-watersheds, rivers and streams so that social, economic and environmental issues and community interests surrounding water resources are managed sustainably (Radif, 1999). It is an evolving and continuous process through which decisions are made for the sustainable use, development, restoration and protection of ecosystem features and functions in a complex environment (Parson, 1995). It requires the integration of scientific components and identification of agency and stakeholder responsibilities as part of the process,
leading to social learning (Medema et al., 2008). IWRM accounts for variable spatial and temporal scales from its implementation, meaning that results can therefore be applied at different scales.

Creation and maintenance of a robust and strategic IWRM plan required several key components, determined based on review of scientific literature. These components will form the basis of evaluating the three land use plans of interest. Scoping of water resources in a land use planning is required as information compiled allows for environmental, economic, social, heritage and health issues associated with water resource to be considered. Having a properly scoped land use plan will allow for more contextual and effective resource management (Parson, 1995; Medema et al., 2008). Definitive biophysical and temporal boundaries are set so that projects and goals are more clearly outlined. In addition, it is important to characterize hydrologic systems, sensitive features, species and ecosystems that will help characterize the system and provide valuable baseline data on the current and historic conditions of various water bodies (Vandierendonck and Mitchell, 1997; Noble and Harriman, 2008). For instance, a regional water budget is a key tool used by policymakers to determine the status of demand and supply within a watershed and involve the determination of quantities and rates of water movement throughout the watershed. Water budgets determine the rates of groundwater recharge, discharge, the rate of streamflow at both a temporal and spatial scale (Armitage et al., 2015). These criteria will help ensure that water governance policies are based on sound scientific research.

Additionally, future stressors and negative impacts of urbanization on water should be considered. Cumulative effects in assessing land use impacts are seen as an essential addition
to the process and interpreted as the culmination of multiple project stresses played out at the regional scale. This allows the extent of impacts such as channel erosion, decreased biodiversity and increased flooding, to be properly addressed through strategic, regional planning and assessment processes (Noble and Harriman, 2008). This approach also encourages modelling and consideration of future conditions and delineation of desirable outcomes through alternatives assessment and scenario analysis. This is closely linked to monitoring (Parson, 1995). Periodic review of scientific research and gathering of new data will allow for new uncertainties to be managed, information gaps to be bridged and continuous improvement of management plans (Mitchell, 2004). This is key to maintaining adaptive water governance policies as the negative effects of climate change and urbanization continue to increase.

Lastly, a nested approach to governance and stakeholder consultation are two key components that should be incorporated into all steps of IWRM to ensure efficient and effective delivery of management plans. A nested approach to watershed governance incorporates the knowledge and expertise of managers at all levels into watershed decision-making. This improves the inter-agency coordination and provides an opportunity for different resource managers to connect land-use planning initiatives with aquatic systems (Hill et al., 2013; Mitchell, 2004). Consultation of provincial, municipal, non-government organization, First Nations and citizens should also be included whenever possible in resource management to ensure that planning is carried out in a fair and just manner that seeks out all societal groups (Brisbois and de Loe, 2015).
Table 2. Criteria developed under Integrated Water Resource Management, based on literature review of the following ten scientific journals and published sources.

<table>
<thead>
<tr>
<th>Literature Review No.</th>
<th>Scientific Journal</th>
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Table 3. Cross-referencing of the specific Integrated Water Resource Management criteria against the ten scientific papers reviewed (as listed above). All criteria listed below were found in multiple journals, demonstrating their importance to IWRM.

<table>
<thead>
<tr>
<th>IWRM Criteria</th>
<th>Literature Review</th>
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<tbody>
<tr>
<td>Define spatial and temporal scope</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>Characterization of hydrological systems, sensitive features and ecosystems</td>
<td>X X X</td>
</tr>
<tr>
<td>Cumulative effects in land use impact assessments</td>
<td>X X X X</td>
</tr>
<tr>
<td>Monitoring to manage emerging uncertainties and info gaps</td>
<td>X X X</td>
</tr>
<tr>
<td>Nested approach for all governance organizations</td>
<td>X X X X</td>
</tr>
<tr>
<td>Stakeholder consultation</td>
<td>X X X X</td>
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</table>

Monitoring

From the IWRM criteria, monitoring was selected as it is central to adaptive environmental management. Structured decision-making embodies a number of tools for making informed decisions, including monitoring (Mitchell, 2004). Monitoring provides the feedback loop to complete the cycle of planning, implementation, and evaluation (Lyons et al., 2001). Observations and results derived from monitoring programs are periodically compared with predictions of each model and subsequent decisions can be adjusted accordingly and creates a feedback loop for learning. With respect to IWRM, monitoring policies focus on a variety of issues, including the protection of drinking water sources and maintenance of ecosystem function from land use activities (Vos et al., 2000). This is particularly important as large-scale shifts in
land-use associated with urbanization leads to changing demands and information required for water resource management. Performance evaluation can be conducted to determine if actions implemented in the previous management cycles are achieving fundamental objectives and goals. (Stokes et al., 1990; Williams, 2001). Thus, land use plans themselves should be flexible and adaptive as to allow for changes in structural changes, targets and methods of evaluating its own effectiveness periodically.

In order to implement effective and efficient changes to the water resource management regime, monitoring of physical and chemical channel conditions are required over different spatial and temporal boundaries (Table 3). Conventional water quality sampling occurs at specific points in time but do not provide continuous data that more accurately represents dynamic hydrologic patterns (Cullen, 1990). Advances in communication and sensor technology have led to increased remote and continuous water monitoring capabilities. Dynamic hydrologic properties can be more easily characterized at different temporal and spatial scales has greatly improved. This guides statistical and mechanistic modeling in monitoring of water quality trends at local, watershed level and regional scales (Cullen, 1990; Slocombe, 1998). This is crucial in real-time and rapid detection of hydrologic variability, fulfilling the critical need for an early warning system and rapid response to harmful events such as algal blooms and point-source pollution (Slocombe, 1998). Another aspect of adaptive water management is ecosystem monitoring through ecological indicators and specialist species sensitive to disruptors. For instance, benthic macroinvertebrates can be used to determine development impacts on stream health, extent of degradation and sensitivity of different ecosystems (Vaughn et al., 2001). This will help guide the selection of appropriate stewardship and restoration activities.
Throughout the implementation of monitoring programs, collaboration with different stakeholders and periodic evaluations of the Plans are also required. Collaboration with non-government sectors such as non-governmental environmental organization, First Nations and local communities encourages holistic approaches to watershed management that extend beyond traditional methods and participants are able to bring forth concerns otherwise overlooked. Collaboration-based monitoring programs includes multiple sources of knowledge, promoting the use of multiple methods of discovery and extends dissemination of the knowledge. This ultimately leads to social action and effective change (Imperial, 2005; Stokes et al., 1990).
Table 4. Criteria developed for key components of monitoring programs were based on literature review of the following ten scientific journals and published sources.

<table>
<thead>
<tr>
<th>Literature Review No.</th>
<th>Scientific Journal</th>
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</table>
Table 5. Cross-referencing monitoring criteria against the ten scientific papers reviewed. All criteria listed below were found in multiple journals, demonstrating their importance to effective monitoring.

<table>
<thead>
<tr>
<th>Monitoring Criteria</th>
<th>Literature Review</th>
</tr>
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<tbody>
<tr>
<td>Continuous monitoring of chemical and physical properties of water bodies</td>
<td>X  X</td>
</tr>
<tr>
<td>Using ecological indicators to monitor ecosystem integrity</td>
<td>X  X  X</td>
</tr>
<tr>
<td>Collaboration and integration of stakeholders in monitoring programs</td>
<td>X  X  X  X</td>
</tr>
<tr>
<td>Periodic evaluation and assessment of monitoring programs</td>
<td>X    X</td>
</tr>
</tbody>
</table>

All criteria listed below were found in multiple journals, demonstrating their importance to effective monitoring.
5. Results and Discussion

Table 6. Strengths and weaknesses of the Oak Ridges Moraine, Niagara Escarpment and Greenbelt Land Use Plans based on water resource management criteria identified in literature review conducted in Section 4.

<table>
<thead>
<tr>
<th>IWRM Criteria 1: Does the plan have a defined spatial and temporal scope?</th>
<th>Niagara Escarpment Plan</th>
<th>Oak Ridges Moraine Conservation Plan</th>
<th>Greenbelt Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Section 1.1 defines strict physical boundaries</td>
<td>• Physical (geographical, geological and morphological) boundaries are clearly outlined in introduction, referencing topographical maps and UTM coordinates</td>
<td>• Section 5.5 addresses the physical boundaries of the plan as well as boundaries for agriculture, village, natural heritage sites and hydrologic features</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IWRM Criteria 2: Does the plan characterize hydrological systems, sensitive features and ecosystems?</th>
<th>Niagara Escarpment Plan</th>
<th>Oak Ridges Moraine Conservation Plan</th>
<th>Greenbelt Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Section 24.3 requires water budget and conservation plan</td>
<td>• Section 24.8 requires major development proposals identify hydrologically sensitive features and their protection</td>
<td>• Section 3.24-3.29 focuses on hydrological features including watershed plans, water budgets, hydrologically sensitive features, wellhead protection and areas of high aquifer vulnerability</td>
<td>• Section 1.2 outlines protection, improvement and restoration of ground/surface water and watersheds as a goal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IWRM Criteria 3: Are the cumulative effects considered in land use assessments?</th>
<th>Niagara Escarpment Plan</th>
<th>Oak Ridges Moraine Conservation Plan</th>
<th>Greenbelt Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Section 2.2 restricts permitted uses if serious cumulative impacts are noted</td>
<td>• Section 1.18 uses specific settlement areas to minimize impact of development</td>
<td>• Section 1.37 permits low-intensity recreational uses that has minimal impact on environment and requires few modifications</td>
<td>• Section 3.2.3 includes cross-jurisdictional and cross-watershed impacts but does not state cumulative effects</td>
</tr>
<tr>
<td>• Section 2.6 minimizes cumulative effects of new development on water quality and quantity, especially flood plains and ponds</td>
<td>• Section 2.6 minimizes cumulative effects of new development on water quality and quantity, especially flood plains and ponds</td>
<td></td>
<td>• Focuses on avoiding negative impacts on natural heritage sites, biodiversity and connectivity of systems</td>
</tr>
<tr>
<td>IWRM Criteria 4: Is monitoring used to manage emerging uncertainties and information gaps?</td>
<td>Purpose and objective clearly state that monitoring will be developed and implemented</td>
<td>Section 3.24 states that watershed plans should have a monitoring plan</td>
<td>Section 5.6 states that a monitoring program will be used to assess policy effectiveness</td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
<td>---</td>
</tr>
<tr>
<td>IWRM Criteria 5: Are all governance organizations encouraged to work towards harmonizing plans and reducing unnecessary overlap?</td>
<td>In Purpose and Objectives, plan states availability of resources to other groups but does not explicitly mention collaborative methods of conducting research</td>
<td>Section 3.2 states cross-jurisdictional and cross-watershed impacts and planning should be integrated</td>
<td>Section 3.2.3 emphasizes approaches in Protected Countryside area should be integrated with NEP, ORMCP and other regions beyond</td>
</tr>
<tr>
<td>IWRM Criteria 6: Are stakeholders such as communities, First Nations, non-governmental organizations consulted throughout planning?</td>
<td>Coalition on the Niagara Escarpment (consisting of environmental groups, conservation organizations, citizens and academics) monitor land use, advocate controlled development and lead research (CONE, 2016).</td>
<td>Non-governmental environmental organizations integrate local communities, schools and citizens in restoration projects and meetings (EcoSpark, 2012)</td>
<td>Section 5.1 states that the Ontario government will consult with Aboriginal peoples about decisions affecting use of Crown land and resources Section 5.9 states that other municipalities, other government sectors and public proceeds will be carried out by the Greenbelt Council, particularly for periodic reviews</td>
</tr>
</tbody>
</table>
Table 7. Strengths and weaknesses of the Oak Ridges Moraine, Niagara Escarpment and Greenbelt Land Use Plans based on monitoring criteria identified in literature review conducted in Section 4.

<table>
<thead>
<tr>
<th>Monitoring Criteria 1: Is continuous monitoring of chemical and physical properties of water bodies being conducted?</th>
<th>Niagara Escarpment Plan</th>
<th>Oak Ridges Moraine Conservation Plan</th>
<th>Greenbelt Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fluvial geomorphology, streamflow, groundwater quality/levels, surface water quality (sediment and temperature) were all indicators (Credit Valley Conservation, 2012)</td>
<td>• Phosphorous and chloride concentrations and E. Coli coliform counts were used to measure water quality (Enviroscape Consulting, 2011) • Monitoring stations record data on base flow, groundwater and aquatic habitats (Enviroscape Consulting, 2011)</td>
<td>• Section 5.8 identifies used of performance indicators for monitoring • Specific indicators not mentioned</td>
<td></td>
</tr>
<tr>
<td>• A comprehensive report on each indicator was provided specifically for the Credit River Watershed within the NE region (Credit Valley Conservation, 2012).</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monitoring Criteria 2: Are ecological indicators required to monitor ecosystem integrity?</th>
<th>Niagara Escarpment Plan</th>
<th>Oak Ridges Moraine Conservation Plan</th>
<th>Greenbelt Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ecological health indicators such as endemic fish, benthic macroinvertebrate communities and vegetated streams (Credit Valley Conservation, 2013). • 57 environmental real-time monitoring stations for water quality (Credit Valley Conservation, 2012) • A comprehensive report on each indicator was provided</td>
<td>• Ecological health indicators such as endemic fish, benthic macroinvertebrate communities and vegetated stream corridors were evaluated to determine watershed health (Enviroscape Consulting, 2011)</td>
<td>• Section 5.8 identifies used of performance indicators for monitoring • Specific indicators not mentioned</td>
<td></td>
</tr>
<tr>
<td><strong>Monitoring Criteria 3:</strong> Is collaboration encouraged through integration of stakeholders in monitoring programs?</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>---</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| • Collaboration mainly includes other government agencies such as Niagara Escarpment Commission (NEC), Bruce Peninsula National Park and Ontario Ministry of Natural Resources (Carruthers et al., 2012)  
  • In 1978, Coalition on the Niagara Escarpment formed, mainly consisting of environmental groups and conservation organizations (CONE, 2016) |
| • EcoSpark and Save the Oak Ridges Moraine Collaboration formed Monitoring the Moraine (Ecospark, 2012)  
  • In 2000, nine conservation authorities across the ORM joined together as the Conservation Authorities Moraine Coalition (CAMC) with goals of groundwater, surface water and ecological preservation (CAMC, 2011) |
| • Section 5.8 identifies role of different partners in the collection and monitoring of ecological indicators |

<table>
<thead>
<tr>
<th><strong>Monitoring Criteria 4:</strong> Are the monitoring programs periodically evaluating and assessing effectiveness of plans?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ONE monitoring program was developed to evaluate whether the goals and objectives described in NEP were being achieved</td>
</tr>
<tr>
<td>• Implementation section states that Plan will be reviewed to assess its effectiveness based on pre-determined performance indicators</td>
</tr>
<tr>
<td>• Section 5.8 encourages collation, publication and discussion of monitoring results to evaluate effectiveness</td>
</tr>
</tbody>
</table>
After cross-examining the Oak Ridges Moraine, Niagara Escarpment and Greenbelt Land Use plans against innovative water resource management criteria, strengths and weaknesses were identified for each land use plan (Table 6). In this section, each Plan will be addressed individually in terms of its strengths, weaknesses and recommendations.

i. Niagara Escarpment Plan

Strengths

The Ontario Niagara Escarpment (ONE) Monitoring Program operates as a long term monitoring strategy based on the Niagara Escarpment Cumulative Effects Framework. It examines change over time using both landscape level and site level analysis (Table 6). Both remote and on-site monitoring projects are conducted that focus on corridor linkages, disturbances due to human activities, cold water streams and sources and biodiversity integrity (ONE, 2016). The program emphasizes the importance of evaluating land use changes on natural landscapes over longer periods of time, recognizing the significance of cumulative impacts (Damman et al., 1995). Additionally, the monitoring program covers a large geographic region and includes partnerships with Parks Canada, Conservation Authorities, University of Waterloo, Ministry of Environment and Canadian Wildlife Services (ONE, 2016). These strong collaborative partnerships integrate ecosystem planning and conservation across multiple jurisdictional boundaries and scales.

The Credit River Valley, spanning a significant portion of the Niagara Escarpment region, is a central focus that incorporates IWRM practices. A comprehensive array of environmental assessments and monitoring programs are conducted for ecological indicators (such as
benthic macroinvertebrate studies), water quality, stream flows and water chemistry (Credit Valley Conservation, 2013). Additionally, in-depth fisheries and ecosystem management plans exist for economic and biodiversity protection. Natural heritage systems were also identified through integration of stakeholders are present within its management plans (Credit Valley Conservation, 2012).

Weaknesses and Recommendations

While the inter-jurisdictional partnerships of government agencies are beneficial to the water resource management, there is weaker involvement of citizen science and local communities. A community-based monitoring program would also be beneficial as it can be tied to current NEP monitoring provisions, such as the Monitoring the Moraine program for the ORMCP (Monitoring the Moraine Partners, 2012). Monitoring resources should be made available for the NEC to share with the environmental NGO community and areas of high vulnerability identified as having significant cultural and local importance should be mapped and restrictions placed on activities in that zone, such as those outlined in the ORMCP (Whitelaw et al., 2009). Citizen scientists can contribute to background and analysis of real-time monitoring data, contributing to ongoing source water and biodiversity protection work by Conservation Authorities and municipalities. This would help to address urbanization issues related to Escarpment water resources, but also contribute to collaborative planning approaches (Whitelaw and Hamilton, 2008).
ii. Oak Ridges Moraine Conservation Plan

Strengths

A number of public groups affiliated with local grass-root organizations were noted as major stakeholders actively involved in the ORMCP. Save the Oak Ridges Moraine (STORM), Citizens Environment Watch (CEW) and the Centre created the Monitoring the Moraine Project in 2005 for community monitoring (Table 7; Whitelaw et al., 2009). The STORM Coalition is another environmental organization formed due to concerns about urbanization and resource extraction. CEW was founded in 1997 to protect and monitor the ORM. These community-based monitoring groups protect and enhance effectiveness of the ORMCP by assisting in the establishment of connections between science, policy and action by improving environmental conditions and integrating both school and community groups in environmental monitoring initiatives (Oak Ridges Moraine Foundation, 2011). Since the inception of these groups, multiple ecological parameters of local water systems have been monitored, such as water quality and reporting of native and invasive species. These groups are an integral part of communicating scientifically-relevant data to government agencies and providing information relevant for policy changes (Whitelaw et al., 2003). In addition, a report card was published by the Oak Ridges Conservation Coalition evaluating the effectiveness of the land use plan using information gathered from monitoring programs, based on performance indicators (Oak Ridges Moraine Foundation, 2015).
Weaknesses and Recommendations

Additionally, there are deficiencies in the integration of other water management legislation and regulations that could limit practitioners of the Plan’s ability to maintain or improve water quality, preserve water storage and hydrological features on the moraine. For instance, water-taking permits on or adjacent to the moraine are not required to meet the Plan’s objectives or consider cumulative impacts. As a solution, Ontario Regulation 387/04 (Water Taking) under the Ontario Water Resources Act, can be amended to require that all water-taking permit applications consider cumulative impacts and the ORMCP requirements (Environmental Commissioner of Ontario, 2012). Thus, more tiered integration of policies and the Oak Ridges Moraine Conservation land use plans are required to address any gaps, conflicts and areas of overlap.

iii. Greenbelt Plan

Strengths

The GBP serves as a significant land use plan that clearly outlines the physical boundaries of the region that take into consideration the variety of human uses, such as preservation of agricultural and natural heritage sites, and also serves as a corridor between environmental significant areas such the Niagara Escarpment and the ORM (Fung and Conway, 2007). The three land use plans interact with several other acts such as the Places to Grow Act (PGA; 2005), which aimed to ensure growth occurred in a coordinated and strategic fashion. Under the authority of the PGA, the Ministry of Public Infrastructure and Renewal created the Growth Plan for the Greater Golden Horseshoe to establish density targets and planning priorities for managing growth (Ministry of Municipal Affairs and Housing, 2005). The
PGA is complementary to the GBP in protecting ecosystem services and using more holistic methods of addressing the effects of urbanization on watersheds. However, it is important to note that its effectiveness largely depends on its integration with existing plans and legislation, such as the ORMCP, the NEP and the Clean Water Act (2006) over time as the Plans are all implemented (Molnar et al., 2012).

Weaknesses and Recommendations

The Greenbelt Plan requires more substantial monitoring of the region as well as performance indicators to assess the effectiveness of the Plan. Although indicators were mentioned as a part of the watershed management strategy in the plan, the first set of hydrological indicators was proposed in 2014, nine years after the Plan was created. This only included certain aspects of ecosystems such as natural cover and wetland features. Little consideration was paid to biodiversity, water quality (nutrients, ions, pollutants, etc.) and hydrological flow throughout catchments (Ministry of Municipal Affairs and Housing, 2015). Additionally, these indicators were evaluated used Southern Ontario Land Resource Information System (SOLRIS), providing data solely from satellite imagery, topographic maps and aerial photos (Ministry of Municipal Affairs and Housing, 2015). More in-field site inspections and implementation of real-time monitoring programs should be created to gain a more comprehensive understanding of the region.

Additionally, the goals of the GBP focus on the “enhancement of natural heritage features” and the “restoration of the hydrological integrity of watersheds” (Ministry of Municipal Affairs and Housing, 2005). However, the plan neither supports nor requires an increase in the
extent or health/function of wetlands. The existing legal and policy framework can be extended to promote increased protection and restoration watersheds to achieve a net gain in hydrological services in preparation for increasing development and future generations. Additionally, all three Land Use Plans require extended sources of funding in order to continue monitoring programs and implementation of various projects (Ministry of Municipal Affairs and Housing, 2012).

6. Conclusion

Urbanization and human development brings a multitude of environmental consequences. This paper focused on water resources management in the Oak Ridges Moraine, Greenbelt and Niagara Escarpment regions. Through review of scientific literature and grey literature, the three land use plans were evaluated based on criteria associated with Integrated Water Resource Management and monitoring. Strengths, weaknesses and recommendations were addressed accordingly. More adaptive, resilient and integrated policies are required to resolve the complex and multifaceted nature of water resources management in the face of development stressors. The Niagara Escarpment, Oak Ridges Moraine and Greenbelt Plans have provided a strong outline addressing land use issues but each requires more work to be done. Moving forward, the 2015 Coordinated Land Use Plan is an important opportunity to incorporate Integrated Water Resource Management and monitoring strategies into the Plans. This could help to foster policy changes to reflect more adaptive, resilient and integrated the Land Use Plans that can more effectively address the interconnected and multifaceted issues surrounding water resources.
Summary of Main Points

- Urbanization is a complex environmental and socioeconomic issue that is intrinsically tied to water resources management.
- Integrated water resource management is an effective framework that encourages comprehensive monitoring programs and collaboration among invested stakeholders.
- The Niagara Escarpment Plan addresses cumulative effects through its government-led initiatives but should also strive to integrate community-based monitoring programs.
- The Oak Ridges Moraine Conservation Plan is supported by a multitude of research and monitoring initiatives led by non-governmental environmental organizations but still depend on the horizontal integration of other related policies.
- The Greenbelt Land Use Plans is significant policy that focuses on preservation of agricultural and natural heritage sites and maintaining linkages between environmental significant areas but should work towards implementation of more comprehensive monitoring methods.
- Policy changes should be based on holistic, adaptive and resilient principles in order to address the ecological effects of urbanization to ensure sustainability of water resource.
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Literature Cited


