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Barriers and Policy Alternatives for Successful Aquatic Habitat Restoration in Urban Streams

An Inquiry into Engineering and Public Policy

by

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for

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1.0 Introduction

Urban populations have expanded tremendously during the twentieth century, a growth that is not expected to slow in the future with a projected 4.8 million more people in Ontario over the next 26 years (Ministry of Finance, 2010). Urbanization has been associated with adverse impacts to streams which drain urban watersheds, creating a cause and effect chain of disrupted hydrology, stream morphology and dynamics, sediment transport, water quality and riparian corridors leading ultimately to the destruction of aquatic habitat within the stream (Allan, 2004; Gregory, 2006; Paul, 2001; Bernhardt, 2007, Walsh, 2005a). Initiatives to restore urban streams to their previous state are not always successful, and encounter many implementation barriers. This paper examines some of the barriers to successful aquatic habitat restoration in the urban streams of Ontario, and recommends several policy alternatives to overcome them.

2.0 The Impacts of Urbanization on Streams

Natural streams support a variety of functions related to the physical, chemical and biological character of the waterways and their riparian areas. These functions can be thought of as belonging to five different categories (Fischenich, 2003):

- Stream dynamics;
- Hydrologic balance;
- Sediment processes and character;
- Biological support; and
- Chemical processes and landscape pathways.

Within each of these categories, Fischenich identifies three components or processes that characterize the functional nature of streams and waterways, each with their own suite of indicators and metrics for quantification. The interrelated nature of these functions is one of the key points of understanding developed through Fischenich's analysis, and is critical for understanding the effects of stressors or perturbations on a stream and how the stressors can both directly and indirectly impact various components of stream function. The fifteen stream processes are evaluated according to which of the other stream processes they directly and indirectly affect, and are ranked based on this hierarchy, i.e. on how many other processes are dependent on that one. The top three ranked processes, and the function category to which they belong, are:

1. Hydrodynamic character (hydrologic balance);
2. Stream evolution processes (stream dynamics); and
3. Surface water storage processes (hydrologic balance).

Two of the three key processes in the hydrologic balance function category are in the top three stream processes, based on their level of influence on other processes, emphasizing the importance of a natural hydrologic balance for the sustainable natural function of a stream. This emphasis is echoed in several other studies (Paul, 2001; Bunn, 2002; Walsh, 2005a). Any impact to the natural hydrologic balance will unavoidably impact the stream processes that are dependent on it. When considering the impacts to aquatic habitat, key component processes of the biological support and chemical processes categories do not make the list until ranks 9 and 11, respectively, reliant as they are on the hydrologic balance, stream dynamics and sediment character of the stream. Indeed, the component that describes the necessary habitats for all life cycles is ranked last on the list. Without the cornerstone of a natural hydrologic balance, and all other key stream functions that are derived from it, a thriving ecological community will be difficult to sustain.

When considering the functional categories and hierarchy of stream functions with respect to the stressor of human development, it can be seen that the urbanization of a watershed has significant and far-reaching consequences for streams. The act of making a watershed impervious through construction of buildings and pavement, the increased efficiency of drainage, and the compaction of the ground has been shown to be one of the primary causes of stream degradation (Allan, 2004; Paul, 2001; Bledsoe, 2001; Walsh, 2005b, Poff, 2006). This is due to the alteration of the hydrologic regime of the watershed (Figure 1), with a larger volume of water entering the streams as runoff during precipitation events, and a smaller volume infiltrating into the groundwater and entering the stream as baseflow. The alteration of the hydrologic regime in turn alters the dynamics of the system, adversely impacting the stream geomorphology (e.g., sediment transport, erosion and deposition patterns, rate of migration) and water quality. Together, the hydrology, geomorphology and water quality of a stream create aquatic habitat for vegetation, benthic macro invertebrates, fish, amphibians and others that depend on streams for part or all of their life cycles. These impacts have been shown to be proportional to the level of imperviousness in a watershed (Walsh, 2005a; Chin, 2006; Bledsoe, 2001), which thus can be considered an accurate predictor of urban impacts on streams (Allan, 2004; Paul, 2001).

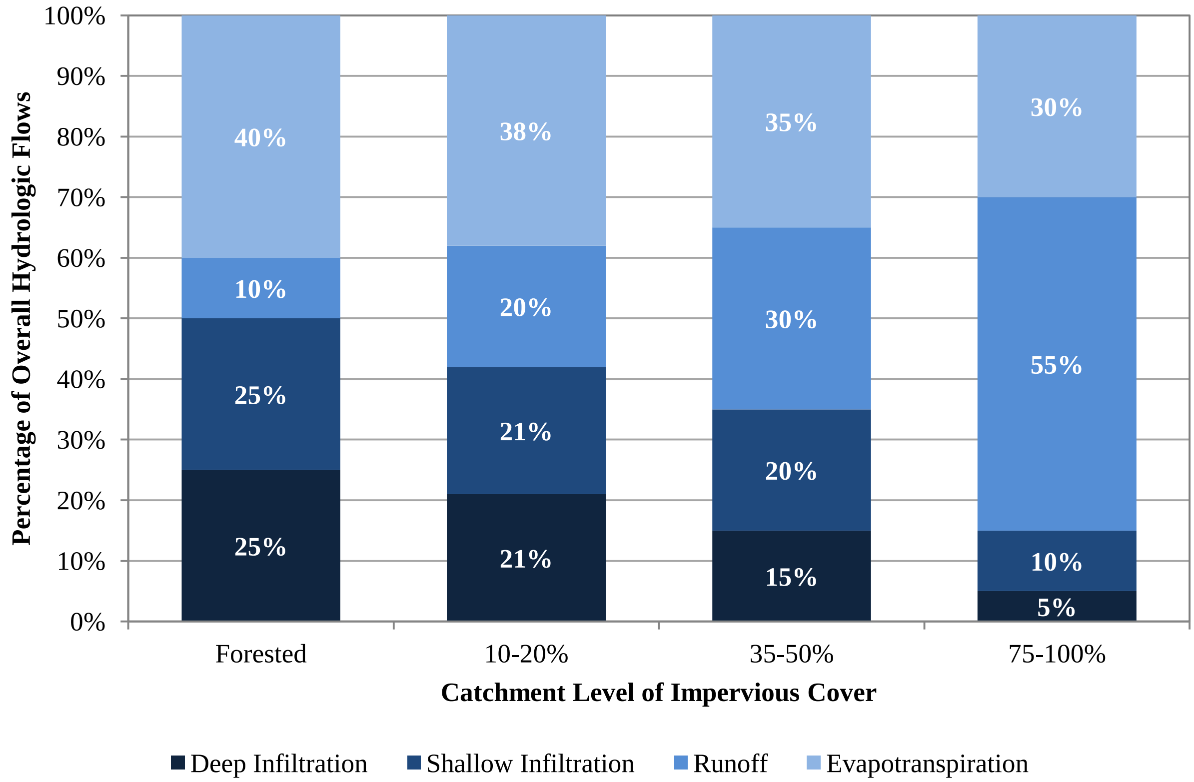

Figure 1 - Changes in catchment water balance due to impervious cover (adapted from Environmental Protection Agency, 1993)

Several studies have observed the impact of urbanization on specific characteristics, processes and functions of urban streams. Chin (2006) found that the impact on the intensity of runoff flows was approximately a two to four times increase in peak discharge, and a one-half to one-fifth decrease in flow lag times, resulting in larger flows reaching the stream more quickly during precipitation events. The magnification and intensification of high-frequency flow events and the imbalance between increasing sediment transport capacity and dwindling sediment source in urban areas, both due to the increase of impervious cover in urban watersheds, alters the hydraulic characteristics of the stream channel, increasing the size of the stream cross-section in most catchments (Chin, 2006; Paul, 2001; Booth, 2000; Henshaw, 2000). Such changes have been observed to be up to a 7 to 8 times increase in width and a 2 to 3 times increase in depth

(Chin, 2006) compared to pre-development conditions. The changes in physical form also affect the planform of a stream, with urban streams commonly exhibiting a decrease in sinuosity, and thus an overall increase in slope (Chin, 2006; Paul, 2001). Changes in channel cross-section are further complicated by the tendency for urban streams to incise deeply into their valleys, due to the decreased sinuosity of their planform (and thus increased slope), resulting in a higher energy hydraulic regime due to the loss of connection to the floodplain (Booth, 1997), exacerbating erosion, incision and migration of the channel.

Evaluation of the ecological impacts in urban streams indicate that there is an overall decrease in species diversity in both fish and invertebrates, with a decrease in sensitive species and an increase in tolerant species (Walsh, 2005a; Bernhardt, 2007; Paul, 2001; Blanton, 2009; Kennen, 2009, Morgan, 2005). These impacts are observed at impervious cover levels of only 10-15% in many cases (Paul, 2000; Walsh, 2005a; Roy, 2003), emphasizing the vulnerability of sensitive ecological communities to watershed change. One study indicated that the habitat degradation may be related to the simplification of geomorphologic conditions in a stream and resultant destruction of the wide variety of physical conditions that comprise aquatic habitat as a result of urbanization (Sullivan, 2006). This finding corroborates Fischenich's work on the hierarchy of stream functions, illustrating the cause and effect chain of hydrologic alteration leading to geomorphic disruption and habitat destruction.

An additional significant impact of urbanization is the destruction or degradation of the stream riparian corridor, as demonstrated by the ranking of "stream evolution processes" in Fishenich's evaluation. Vegetation within the riparian corridor serves several important functions in the overall stream dynamic, including the stabilization of stream banks, the cycling of nutrients, and the provision of habitat and transportation corridors for wildlife. A potentially equal amount of stream degradation can be attributed to the localized destruction of the riparian zone as to the hardening of the upland drainage areas (McBride, 2005). Other studies have found that streams in forested areas are shown to be wider and shallower and have slower migration and accretion rates than those in grassed areas, which in turn are shown to be similar in form and response to urbanized streams (Hession, 2003). This is also shown to hold true when a stream has a forested riparian zone in an urbanized catchment, indicating that riparian vegetation can provide some stability to streams under flow regimes. These findings imply that a significant benefit could be realized in the goal of urban stream restoration if the riparian corridors of urban streams could be protected, enhanced or restored, and has contirbuted to the practice of incorporating buffers around streams for new urban developments. There are many other social and recreational benefits to maintaining vegetated riparian corridors around streams, as they can be integrated with pathways, forested parks and other social infrastructure.

3.0 Barriers to the Restoration of Urban Streams

Recognition of the causes of aquatic habitat degradation in urban streams creates an impetus for restoration to reverse the damage caused by human development, yet often does not present a clear path for implementation. As demonstrated in the literature and described in Section 2.0, a stream’s natural hydrologic regime and riparian zones are the foundations for a sustainable stream ecosystem; the restoration of these functions should similarly be the foundation for a successful restoration project. However, these functions can be challenging to restore in established urban areas, due to the extent and potentially irreversible nature of the urban impact to hydrology and riparian zones (Findlay, 2006).

If the hydrology and riparian zones of an urban stream could be readily restored, however, there is an additional challenge associated with an understanding of the processes themselves: what level of function the processes need to provide in order to create sustainable aquatic habitat, what level of function is existing, and what level of function can be provided through restoration efforts. Without this understanding, practitioners and proponents cannot know if the restoration is successful or not. This understanding in urban streams requires monitoring of stream processes before and after urbanization, establishment of quantitative relationships between the different processes, and the development of goals, objectives, targets and metrics by which to guide and measure restoration efforts. Practitioners in Ontario have made progress in the definition of these metrics in recent years, as defined through stormwater management criteria for erosion and habitat flows as well as for flood mitigation, and establishing groundwater recharge targets for areas of new development, requiring that a certain portion of the stormwater runoff be infiltrated to function closer to a natural hydrologic regime.

A contributing factor of these challenges is the ability of restoration proponents to obtain the resources required to plan, design and implement restoration projects. In order to maximize the resources that are available, many aquatic habitat restoration projects are incorporated into erosion and flood control projects as requirements for agency permits and approvals, or are included as mitigation measures to attempt to limit the impact of new urban development. Although these are important components of a restoration strategy, they often result in an unfocused, piecemeal approach, without consideration for which areas may require restoration of aquatic habitat the most, or for areas outside of the immediate area of project concern. In addition, these strategies do not recognize the transient nature of many fish species, which may inhabit different parts of the stream during different life stages or during different times of the year, requiring a comprehensive watershed approach to habitat management.

A comprehensive restoration strategy that is integrated with watershed monitoring and municipal requirements for erosion and flood control, and is conscious of the aquatic habitat system as a whole rather than in segments or individual habitat units could provide a greater net benefit for the resources made available to proponents. However, one of the greatest struggles faced by agencies and municipalities with regards to aquatic habitat restoration is obtaining the resources to develop and implement such a comprehensive strategy. More so, it is likely that a successful restoration strategy would remain difficult to implement, since the management of watershed resources related to aquatic habitat is the purview of several jurisdictions in Ontario, including bodies at the municipal, Provincial and Federal levels of government. This creates an environment of fragmented legislation and policies around watershed management, stormwater management and methods of pursuing aquatic habitat restoration, providing few tools to agencies with which to function. The jurisdictional isolation of the various components of watershed management results in limited power for any of the agencies to bring about comprehensive restoration.

The challenges of hydrologic and riparian restoration, stream function monitoring and measuring, effective restoration planning and implementation, and the fragmented legislation and policies supporting watershed management are described in the following sections.

3.1 The Challenge of Hydrologic and Riparian Restoration

The altered hydrologic regime of a watershed due to urbanization, along with the destruction of the riparian corridor, are the primary causes of the degradation of urban streams (Paul, 2001; Booth, 2005; Chin, 2006; Walsh, 2005a). This implies that if the hydrologic regime of an urban area were to be similar to that of a natural area in volume distribution, flow timing and duration and other hydrologic factors, then much of the impacts to urban streams could be avoided. Coupled with the protection of the riparian corridor, it is likely that urban streams would function similarly to counterparts in more natural watersheds.

To restore a natural hydrologic regime to an urbanized watershed is a monumental undertaking, due to the sheer extent and potential irreversibility of urbanization, our poor understanding of how to accomplish hydrologic restoration and the cost of implementing such a restoration in established urban areas. Although it is beginning to be understood that pre-urban water balance must be maintained to minimize impact to streams and other natural areas, it is only in the newest urban areas that water balance considerations are realized in the form of recharge targets for infiltration and erosion threshold analyses of the watercourses that are to receive flows from stormwater management facilities.

Hydrologic restoration in established urban areas is extremely difficult, requiring extensive land purchases to install stormwater management facilities or the creation of storage through buried chambers or on rooftops. To replace the hydrologic attenuation features of a natural watershed would likely require a vast amount of storage, equal to approximately 45% of the entire water budget (established through comparison of the runoff proportions shown in Figure 1). 35% of this would need to be infiltrated or mimic the function of infiltration to match a natural water budget, which requires infrastructure distributed over the entire watershed to avoid mounding of the groundwater table and premature failure of infiltration features due to sedimentation.

Many innovative stormwater management techniques for use in urban areas have been developed, that when taken collectively are referred to as Low Impact Development (LID) in the United States and Canada, Sustainable Urban Drainage Systems (SUDS) in the United Kingdom, or Water Sensitive Urban Drainage (WSUD) in Australia. Whichever label is used to refer to these techniques, they share a similar objective: to design and implement stormwater controls in urban development so that there is as little an impact as possible on the pre-development hydrologic and water quality regime. This is accomplished through storage, infiltration, detention, filtration and/or evaporation of stormwater as close to the source of the runoff as possible, using measures such as bioretention basins, pervious pavement, green roofs, rain barrels, cisterns and grassed swales. Although LID techniques are much easier to implement in a new development, their decentralized and scalable nature allows them to be retrofit into established urban areas in a variety of ways when the space and opportunity becomes available. Despite the availability of such measures, their application remains relatively limited.

3.2 Goals, Objectives, Targets and Metrics

Establishing clear goals, objectives, targets and metrics for restoration projects will help to focus projects on repairing key elements that drive healthy stream function, as well as to monitor the success of such projects. Goals provide guidance for the overall project direction, and represent the ideal that is being strived for. For example, the goal of a practitioner may be a healthy, natural stream that supports a thriving, productive and sustainable trout-based fishery. Objectives establish the key operational components of the restoration plan to achieve the goal and are typically action- or results-based. The objectives to obtain the example goal of a thriving trout-based fishery may include to restore a natural hydrologic regime, to create a varied geomorphic environment, to restore the stream riparian corridor or to eliminate sources of water quality contamination in the watershed, all of which are key elements of creating sustainable aquatic habitat. Each objective should then include one or more targets, which quantify the objective and make it measurable. For the objective of establishing a natural flow regime, to continue the example, several potential targets could be to infiltrate a specific volume of stormwater in the watershed, reduce peak storm flows below critical geomorphic and ecological flows, or to detain small storms completely in upland areas to simulate the natural detention features of a natural watershed. Each target is comprised of one or several metrics that can be monitored in the watershed or stream and allows the target to be measured.

Without an understanding of the processes and functions of a stream, as monitored through the metrics established to achieve the targets, objectives and goals of restoration, practitioners cannot effectively guide restoration efforts since there will be only a limited ability to predict the interactions between the different functions. This is particularly relevant to the restoration of aquatic habitat, since the availability of habitat is dependent on many other stream functions that combine in an intricate balance. Developing an understanding within a specific watershed involves monitoring of stream function metrics to an extent sufficient to characterize those functions and identifying the key thresholds of degradation where stream functions become impaired (e.g., imperviousness level). These thresholds can serve as restoration targets, to be attained through targeted restoration projects.

Clearly establishing the goals, objectives, targets and metrics for aquatic habitat restoration allows the development of an effective restoration strategy. Too often restoration practitioners focus on the goals and objectives level, without establishing clear actionable tasks that can be undertaken, resulting in unclear direction for implementation and confused or unfocused stakeholders. Breaking down the overall goals of restoration into quantifiable, actionable targets facilitates the definition of a potentially wide range of projects that will contribute to the goal, with costs and benefits that can be weighed against the targets to gauge which projects are the most effective. These projects can then be implemented in a manner that provides the greatest benefit to the goals of restoration established by the proponents and stakeholders. This clarity also promotes buy in and engagement from the different restoration stakeholders, including the municipality, environmental agencies and the public. The specific purpose or method of a project should be agreed on by all stakeholders, in order to establish clear objectives for success. Understanding of these objectives will focus efforts on the desired metrics for improvement rather than trying to "do it all" (unless that is the projectgoal), increasing the chance of a successful project.

A clear strategy that can be measured will also promote the concept that streams and aquatic habitat in urban areas are assets to be managed, albeit natural assets, alongside manmade infrastructure such as roads and sewers. Restoration targets and metrics can be used to denote a "level of service" similar to the ratings often applied to infrastructure, identifying key areas that require attention. Several Conservation Authorities in Ontario currently produce scores for the subwatersheds under their jurisdiction, referred to as "report cards", detailing key elements of watershed health or impairment such as water quality, land use and biological metrics, which can be expanded as needed to drive restoration.

3.3 Planning, Economic and Implementation Challenges

There are large annual expenditures on erosion control, flood mitigation, and other projects to repair damage associated with the impacts of urbanization on the natural hydrologic balance. For example, the Toronto Wet Weather Flow Master Plan (Toronto, 2008) planned for approximately one billion dollars in 2003 to repair the impacts of urban hydrology through basement flooding mitigation, stream restoration, and stormwater management; recent City of Toronto capital budgets (Toronto, 2011) contain expenditures of approximately 1.8 billion dollars for the Wet Weather Flow Master Plan for the period of 2011 to 2020 alone, with at least one billion more in the period following. Billions of dollars more are spent on stream and river restoration in the United States (Palmer, 2005). If this money was instead spent on eliminating the causes of the degradation, the net benefit to aquatic habitat would likely be greater and more sustainable in the long term. Effective stream restoration through hydrologic restoration will likely require significant expenditures to implement, money which may be difficult to obtain particularly since aquatic habitat is not a highly visible feature of the urban landscape. Putting aquatic habitat on the vocal public agenda should be one of the primary goals of practitioners, encouraging the allocation of funds towards restoration efforts.

There are similar implementation barriers facing the restoration of urban riparian corridors. In many established urban areas, property and infrastructure encroach onto streams, to the point where many streams have been hardened with retaining structures and rock to prevent migration through erosion and have been straightened to mitigate flooding impacts. To restore the riparian corridor would require significant alterations to property and expansive naturalization programs.

Although riparian corridors have many social benefits as well as environmental benefits, there is little political will to incur the necessary disbursements to restore riparian corridors in urban areas. Indeed, the acquisition of sufficient property to restore riparian corridors along many urban streams may be impossible, which may require alternative approaches such as landowner incentives for naturalization.

Given these barriers, most restoration in urban areas encompasses an ad-hoc implementation of bank stabilization and channel improvements to mitigate flooding and erosion issues, such as the enlargement of channel crossings to increase hydraulic capacity and the creation of auxiliary floodways. These projects are not often initiated with the intention of restoring the stream, but rather to protect infrastructure and property adjacent to the stream with a secondary goal to enhance geomorphic character, water quality, or aquatic habitat.

3.4 Legislation and Policy Challenges

There are a diverse collection of regulations and policies that govern the management of water resources in Ontario, regarding a wide range of topics from stormwater management, the discharge of contaminants, drinking water treatment, source water protection, and many others. Three topics in particular are evaluated in this section due to their importance to the function of urban streams:

- Aquatic habitat, as administered through the federal Department of Fisheries and Oceans (DFO);
- Stormwater management (SWM), as administered through the Ontario Ministry of the Environment (MOE); and,

- Watershed management, as administered through Ontario's Conservation Authorities

Some of the barriers to aquatic habitat restoration that are presented by the regulations and policies governing these topics are discussed in the sections below.

3.4.1 Aquatic Habitat

The Fisheries Act (R.S.C., 1985, c. F-14) in Canada, administered by the DFO, stipulates that:

> *"No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat." (S.35, Fisheries Act)*

The DFO can require under the Fisheries Act that any undertakings that are deemed to cause a harmful alteration, disruption or destruction (HADD) of fish habitat be modified so that the HADD is eliminated, or be stopped altogether. The policy document that provides guidance to DFO staff in managing a potential HADD, the Policy for the Management of Fish Habitat (DFO, 1986), outlines a "no net loss" principle with respect to the productive capacity of fish habitat. This principle is employed in those situations where a HADD is unavoidable, and seeks to replace any fish habitat capacity lost as a result of the HADD with a "like-for-like" compensation policy, restoring habitat at or near the site where the HADD occurred, though the policy states that avoidance of the HADD is preferable to permitting compensation.

In many situations, this policy is an effective method to ensure that no net loss of fish habitat occurs, such as in natural, undeveloped watersheds where a localized disruption takes place, such as at a culvert or bridge, that creates a direct impact on the physical habitat in an otherwise healthy and sustainable stream. In other cases, particularly that of urban development, the

HADD may not be a direct alteration of the physical habitat. As has been discussed in Section 2.0, the most pervasive and destructive element of urbanization is the alteration of the natural hydrologic regime. The Policy for the Management of Fish Habitat explicitly accounts for altered flow as being destructive to aquatic habitat. In practice, however, no compensation is required for an altered hydrologic regime, and there is no requirement for innovative stormwater management controls, such as LID, that simulate a natural hydrologic regime and avoid or mitigate the HADD.

In addition to increased recognition of altered hydrology as a HADD of fish habitat, a greater flexibility in employing the "like-for-like" compensation policy would allow practitioners to pursue more effective restoration methods in degraded watersheds, such as hydrologic and riparian restoration, rather than being limited to replacing only the physical habitat that was disturbed. When a HADD occurs, the DFO could instead require that a proponent provide a specified amount of hydrologic storage in the contributing watershed, equivalent or greater to the extent of damage caused in the HADD. This approach may be effective in implementing hydrologic restoration in established urban areas where there may be few other means to do so.

As a clarification to the compensation of an unavoidable HADD, the policy requires that any impact to the water quality cannot be compensated; rather, proper treatment must be provided. This requirement is recognized in the stormwater management guidelines developed by the MOE (see Section 3.4.2); however, the effectiveness of conventional SWM controls in mitigating urban impacts to water quality have been found lacking, or to have highly variable performance. This requirement under the Fisheries Act and associated policy document provides additional legal mandate for the use of innovative SWM controls for water quality mitigation, since similar to water quality impacts, altered flow cannot be compensated for.

3.4.2 Stormwater Management

The Ontario Water Resources Act (OWRA, R.S.O. 1990, CHAPTER O.40), administered by the MOE, stipulates that:

> *"no person shall establish, alter, extend or replace new or existing sewage works except under and in accordance with an approval granted by a Director." (S.53, OWRA)*

In the context of the OWRA, the definition of sewage includes drainage and stormwater, and therefore stormwater management controls are required to be approved by the MOE prior to construction or rehabilitation. The MOE guidance document on SWM, the Stormwater Management Planning and Design Manual (MOE, 2003), outlines design criteria and considerations for a wide range of SWM controls, including lot-level controls (rooftop storage, lot grading, soakaway pits), conveyance controls (grassed swales, pervious pipes) and end-of-pipe controls (wet ponds, wetlands).

Although there is an extensive array of controls to consider when developing a SWM plan, the guidance document inherently favours the use of end-of-pipe controls, such as conventional wet ponds. This is due to the environmental sizing criteria for these facilities: the requirement for water quality control (to avoid or mitigate the potential for a HADD) considers only the imperviousness of the contributing drainage area, and does not account for the presence of lot-level or conveyance controls despite their potentially significant impact on the hydrology of the watershed. This is likely due to the conservative nature of many government policies, so that in the event the lot-level or conveyance controls fail, the end-of-pipe control will still provide the required level of water quality treatment and flood control. However, this policy provides little incentive for a proponent to incorporate innovative SWM controls into their developments, and therefore limits the amount of hydrologic restoration or mitigation that will typically be provided.

In addition, these stormwater management policies do not adequately consider the significant shift of the water balance due to urbanization. Although controlling peak flows provides flood protection, this method of SWM allows the runoff of much greater volumes of water than pre-development conditions. This results in a storm hydrograph that may match the pre-development peak flow, but maintains that peak flow over a significantly longer duration as the greater volume of runoff is gradually drained, increasing the amount of energy in the stream and impacting the geomorphic regime and overall dynamic of the stream. Effective mitigation of the hydrologic impacts of urbanization requires that the natural water balance be simulated as much as possible, maintaining the proportionate volumes of infiltration and runoff.

3.4.3 Watershed Management

Watershed management in many places of Ontario, particularly the more populated south, is the mandate of the Conservation Authorities, established under the provincial Conservation Authorities Act in 1946. Conservation Authorities have responsibility over the management of resources within an entire watershed, which is the ideal unit for environmental management. Although originally established to provide a comprehensive and integrated approach to flood control, the mandate of Conservation Authorities has grown significantly since their foundation, reflective of their purpose as stated in their founding legislation:

> *"establish and undertake, in the area over which it has jurisdiction, a program designed to further the conservation, restoration, development, and management of natural resources other than gas, oil, coal and minerals." (S.20, C. A. Act)*

With such a wide-ranging mandate, CA's have been shouldered with increasingly more responsibilities, and in many cases serve as extensions of Provincial and Federal agencies such as the Ministry of Natural Resources, Ministry of Environment and Department of Fisheries and Oceans. Funding levels to CAs for these additional responsibilities have not similarly increased.

In fact, despite being Provincially-founded agencies, funding from the Province to CAs accounts for less than 17% of an average CA budget (Conservation Ontario, 2008). The majority of the remainder is sourced from the population base within their watersheds of responsibility through self generated revenues (42%) and municipal levies (33%). This proportion of funding is even more skewed in some of the most urbanized CAs, such as the Credit Valley Conservation, where 76% of revenues are sourced from municipal levies, and a further 17% from user fees, leaving less than 7% of funding originating from Provincial and Federal sources (CVC, 2011). Similarly, the Toronto Region Conservation Authority receives just 8% of its funding from the Province (TRCA, 2009). Provincial funding to the CAs was significantly reduced during the government budget cuts of the mid 1990's (CVC, pers. comm.), and have since not been restored.

Although it is admirable that the municipalities within a CA borders have identified the value of their services and helped to mitigate the funding gap, this funding can present conflicts of interest when approval must be granted for municipal planning initiatives. The requirement for potentially unpopular or expensive environmental programs, such as effective stormwater management to mitigate impact on aquatic habitat, has the potential to be compromised in the face of pressure from municipal or political figures who supply their funding, creating a desire to not "bite the hand that feeds them". To effectively implement their Provincial mandate, a CA should operate primarily from Provincial funding.

Despite the expansive mandate of the CAs stated in their legislation, the same document codifies the specific management responsibilities of the agencies into five distinct categories or tests that must be evaluated when reviewing planning applications: flooding, erosion, conservation of land, pollution and dynamic beaches. These boundaries are reflected in the CA's own Environmental Assessment guidelines, stipulated as being for "remedial flood and erosion control projects". Of these categories, the test for conservation of land is perhaps the closest to the need to protect and enhance aquatic habitat, but leaves room for varying interpretations as to the scope of activities that can be performed under this mandate. Explicit accounting for a wider range of environmental management goals would better reflect the mandate of CAs and increase the ability to implement aquatic habitat restoration programs.

In addition, clarifying the jurisdictional overlap between the CAs and other environmental agencies would result in more focused and consistent watershed management; for example, SWM legally falls under the jurisdiction of the MOE (see Section 3.4.2) yet is a critical component of watershed management and the restoration of aquatic habitat. As a reflection of this importance, several CAs have developed their own SWM guidelines to attempt to guide development within their watersheds; however, there is no legislative backing for these guidelines, since a proponent need only obtain approval from the MOE for the SWM controls. An additional example is the relationship that many CAs have developed with the DFO, providing a front-line screening service of development proposals for the potential to create a HADD. After evaluation by CA staff, if a proposal is determined to be likely to cause a HADD it is referred to the DFO for evaluation and mitigation or compensation. However, the DFO may not have as intimate a knowledge of the watershed or stream functions as does the CA, and may not effectively integrate the compensation or mitigation into the context of the larger watershed to provide a greater net benefit to aquatic habitat.

The CA legislation also provides only a limited ability for the agencies to enforce environmental management failures, with a maximum fine of only $10,000. This fine can also be contested, requiring lengthy legal trials at costs that many CAs cannot support. When considering the scale of urban development projects, this fine is easily incorporated into the costs of business. Although it is in the best interest of a municipality or developer to meet CA requirements, for example to facilitate approvals, maintain relationships and maintain public approval, increased enforcement capabilities would allow more effective and consistent fulfillment of the CA legislation.

4.0 Policy Alternatives to Enhance Aquatic Habitat Restoration

Several policy alternatives have been developed to address and overcome the barriers to aquatic habitat restoration described in Section 3.0, including:

- Focus restoration efforts on hydrology and riparian zones, as well as the preservation of existing high-quality habitat areas;
- Establish targets and objectives for restoration;

- Prioritize restoration efforts to implement high-impact, cost-effective projects in a proactive manner;
- Empower and engage citizen groups on aquatic habitat;
- Strengthen the legislation and enforcement capabilities of conservation authorities;
- Effectively monitor ecological and hydrologic conditions in watersheds of growth areas;
- Rejuvenate DFO habitat compensation policies; and
- Enhance stormwater management policies.

These alternatives are described in detail in the following sections.

4.1 Focus Restoration Efforts on Hydrology and Riparian Zones, as well as the Preservation of Existing High-Quality Habitat Areas

An overwhelming amount of literature on urban streams identifies an altered hydrologic regime as the primary culprit of the degradation of aquatic habitat. In addition, there is a growing recognition on the role of the riparian zone in a stream's stability and healthy functioning, with some studies attributing the impact due to the local riparian conditions as proportional to the larger subwatershed impact. Given the prevailing knowledge of the causative factors of degraded aquatic habitat, restoration efforts should be focused on restoring these key functions.

There are many challenges associated with the restoration of pre-development hydrology and of riparian zones in urbanized areas, including cost, appropriate restoration targets, and conflicts with the social environment. Many studies that recommend hydrologic restoration as an effective method to restore pre-development function to urban streams also acknowledge that further evaluation is required to better understand the extents to which altered hydrology impacts stream function, and what level of restoration is sufficient.

Therefore, in keeping with the precautionary principle, new urban development should be designed so that the impact to the pre-development hydrology is mitigated to the fullest extent possible. This will arrest the spread of degraded watercourses, and allow restoration and rehabilitation efforts to focus on those streams in established urban areas. Opportunities should be identified in these mature urbanized areas to provide storage and attenuation features to simulate a more natural hydrologic balance.

Furthermore, opportunities to expand the riparian corridor adjacent to urban streams should be identified and pursued. Existing healthy riparian areas should be preserved against future development as part of a city's natural heritage system or other equivalent green space network.

4.2 Establish Targets and Objectives for Restoration

Measurable targets should be established for restoration objectives to provide focus for proponents and stakeholders in developing a restoration strategy. Targets and metrics will allow key stream functions to be monitored, deficiencies noted, and restoration efforts targeted to provide the most effective approach to aquatic habitat restoration. An understanding of the targets also provides an understanding of the limitations of restoration, and leads to the development of an achievable restoration strategy. Without clear targets and metrics, restoration can be based only on analogy and best practice.

The ability to measure key stream functions will also allow successful restoration projects to be identified, contributing to the field's best practices and allowing resources to be used for those methods that are proven to be most successful.

Quantification and measurement of stream functions will promote the concept that streams and aquatic habitat are assets to be managed, similar to municipal roads and linear infrastructure. Metrics will allow the establishment of performance indicators, similar to the concept of "level of service" for other infrastructure, naturally leading to an effective and targeted restoration approach.

4.3 Effectively Monitor Ecological and Hydrologic Conditions in Watersheds of Urban and Growth Areas

It is critical that a sufficient quantity and quality of data for hydrology and ecological functions (metrics) be collected in areas that are to be developed. Without an understanding of watershed performance, the extent of potential impact to aquatic habitat cannot be quantified, and mitigation and restoration efforts cannot be appropriately scaled or targeted. Similarly, without an understanding of these functions in established urban areas, the focus for restoration efforts cannot be established and the success of restoration efforts cannot be determined. Determining whether or not restoration is successful is particularly important: first, it contributes to restoration knowledge, identifying successful and effective methods and eliminating those methods which do not perform; second, it provides accountability for the expenditures of resources which can increase transparency and trust among stakeholders and the public.

To engage in an effective asset management program, an asset manager must understand the asset to be managed. This is as true for streams and aquatic habitat as it is for any other infrastructure, natural or otherwise.

4.4 Prioritize Restoration Efforts to Implement High-Impact, Cost-Effective Projects in a Proactive Manner

To ensure that each dollar allocated to the restoration of aquatic habitat is used as efficiently as possible, providing the greatest overall net benefit, a comprehensive inventory of potential restoration projects should be developed. The restoration projects should be evaluated in terms of their implementation and maintenance costs, as well as their benefit to aquatic habitat, whether in expanded habitat area, anticipated species richness or diversity improvement, or other such measure of biological integrity established by the proponents and approval agencies. Additional benefits may include water quality improvements, reductions in required erosion control expenditures, and the social benefits of improved recreational areas.

The objective of such an inventory is to develop a database of restoration projects, with cost-effectiveness data, to create a restoration “credit trading program” wherein whatever restoration monies available in a watershed are applied to the project that has the greatest benefit to cost ratio. In this way, the overall biological integrity of a watershed can be restored in an efficient and orchestrated process, rather than in an ad-hoc manner in response to external stressors or motivators (e.g., new development, erosion impacts to property and infrastructure). This inventory can be made possible through the use of effective targets and metrics (Section 4.2) and monitoring efforts (Section 4.3).

4.5 Empower and Engage Citizen Groups on Aquatic Habitat

The restoration of aquatic habitat will not become a priority for political decision makers until it becomes a priority for the constituency whom they represent. Public opinion is a powerful political motivator, and if aquatic habitat restoration is seen to be a public priority, much in the same way as recycling, composting, water conservation, gas-efficient vehicles and other environmentally-minded initiatives have become, increased resources will be allocated to it.

Public interest and involvement in restoration can be developed by integrating restoration efforts into the public sphere to a greater extent, education initiatives, stewardship programs, public campaigns celebrating restoration successes and other outreach programs. Many Conservation Authorities in Ontario have developed strong stewardship, outreach and education programs, and these initiatives should be supported and expanded with increased funding and regulatory mandate.

Of critical importance for proponents and practitioners is to demonstrate to the public why the restoration of aquatic habitat is worthwhile, and why it should receive the attention of policy-makers alongside public infrastructure, health care, education and all other government and municipal obligations of modern life.

4.6 Strengthen the Legislation and Enforcement Capabilities of Conservation Authorities

The *Conservation Authority Act* or policies that are founded upon the *Act* need to be strengthened to ensure that the CAs have the regulatory tools to enforce the expansive mandate contained in the *Act*. With regards to the restoration of aquatic habitat, specific wording regarding biological or ecological integrity of the watershed under their jurisdiction, perhaps as a sixth category of responsibility (in addition to erosion, flooding, conservation of lands, pollution and dynamic beaches), may provide the CAs with increased ability to drive restoration efforts.

The current Provincial funding levels for Conservation Authorities, agencies founded under Provincial legislation, stand at an average of 17% of total revenues, funding that has historically been significantly reduced through Provincial budget cuts. Increasing the amount of Provincial funding to the CAs, particularly considering the level of service provided by the CAs to other Provincial and Federal agencies, will provide more resources for the CAs to pursue regulatory enforcement, stewardship and education programs, and specific restoration projects.

4.7 Rejuvenate DFO Habitat Compensation Policies

The current practice of aquatic habitat compensation required by the DFO in the event of an unavoidable HADD can be limited by the restrictions of the “like-for-like” compensation policy, and by insufficient recognition of an altered hydrologic regime as a HADD. The policy that guides the habitat compensation procedure explicitly recognizes altered flow as a destructor of aquatic habitat; however, in practice an urban development that does not directly impact the watercourses that contain aquatic habitat (e.g., through construction of a bridge or realignment of a creek) does not require a permit under the *Fisheries Act*. This requirement could greatly increase the effectiveness of stormwater management controls and policies (Section 4.8), and direct restoration efforts towards that of hydrologic restoration.

The current practice of restoring “like-for-like” habitat is potentially ineffective since it does not address the underlying causes of habitat degradation. Increasing the flexibility of the “like-for-like” policy would allow more effective compensation to be undertaken in the event of a HADD, such as hydrologic or riparian restoration, or other such project that has been identified and included in a potential restoration credit trading database (Section 4.4).

4.8 Enhance Stormwater Management Policies

Increased adoption of LID or other innovative SWM controls, in both new and established urban areas, would help to reduce the impact of urbanization on the hydrology of a watershed and therefore on the aquatic habitat in its watercourses. In many cases the knowledge and guidelines for LID exist, such as with the MOE's Stormwater Planning and Design Manual and the SWM guidelines of some CAs; however, policy shortfalls do not provide incentive for proponents to implement LID, either in the form of some benefit to the permitting process or simply of avoiding enforcement procedures. Providing increased incentive to adopt LID as standard SWM practice will allow development to proceed in a manner that does not impact aquatic habitat as significantly, potentially to a level that can be accommodated by the natural resiliency of the streams themselves.

5.0 Conclusions

The impacts of urbanization on streams were evaluated from a process-based viewpoint, finding that the alteration of the natural watershed hydrology and riparian corridors are the most significantly felt impacts, with far-reaching consequences to the function of urban streams and ultimately the availability and quality of aquatic habitat. Barriers encountered by stream restoration projects were discussed, including the difficulty of hydrologic restoration, unclear targets and metrics, planning and implementation challenges, and legislation and policy challenges. An evaluation of the underlying causes of these barriers suggested eight potential policy alternatives to improve the restoration of urban streams, which are recommended to be considered by the agencies, practitioners and proponents involved in the restoration of aquatic habitat.

6.0 References

Allan, J.D. 2004. Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems. Annu. Rev. Ecol. Evol. Syst. 35: 257-84.

Bernhardt, E. S., Palmer, M. A. 2007. Restoring streams in an urbanizing world. Freshwater Biology. 52:738-751.

Blanton, P., Marcus, W. A. 2009. Railroads, roads and lateral disconnection in the river landscapes of the continental United States. Geomorphology. 112:212-227.

Bledsoe, B.P., Watson, C.C. 2001. Effects of Urbanization on Channel Instability. JAWRA. 37(2).

Booth, D.B., Jackson, C.R. 1997. Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detection, and the Limits of Mitigation. JAWRA. 33(5).

Booth, D. B. 2000. Stream-Channel Incision Following Drainage-Basin Urbanization. Water Resources Bulletin of the American Water Resources Association. 26(3):407-417.

Booth, D.B. 2005. Challenges and prospects for restoring urban streams: a perspective from the Pacific Northwest of North America. J. N. Am. Benthol. Soc., 24(3): 724-737.

Bunn, S.E., Arthington, A.H. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management 30 (4).

City of Toronto. 2008. Wet Weather Flow Master Plan – The Plan in Action – 5-Year Summary Report.

City of Toronto. 2011. Wet Weather Flow Master Plan and Basement Flooding Protection Program Update. Public Works and Infrastructure Committee consideration on September 7, 2011.

Conservation Authorities Act. R.S.O. 1990, Chapter C.27.

Conservation Ontario. Fact Sheet. October 2008.

Chin, A. 2006. Urban transformation of river landscapes in a global context. Geomorphology. 79:460-487.

Credit Valley Conservation. Funding. Accessed from: http://www.creditvalleyca.ca/about-cvc/about-the-organization/funding/. Recent as of Sept. 17, 2011.

Department of Fisheries and Oceans. 1986. Policy for the Management of Fish Habitat. Cat. No. Fs23-98/1986E.

Environmental Protection Agency. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Source Pollution in Coastal Waters. United States Environmental Protection Agency #EPA-506/9-90. Washington, DC: USEPA Office of Water.

Findlay, S. J., Taylor, M. P. 2006. Why rehabilitate urban river systems? Area. 38(3):312-325.

Fischenich, J.C. 2003. Technical Considerations for Evaluating Riverine/Riparian Restoration Projects. Environmental Laboratory, USACE. ERDC/EL TR-WRAP-03-XX. April 2003.

Fisheries Act. R.S.C., 1985, c. F-14.

Gregory, K. J. 2006. The human role in changing river channels. Geomorphology. 79:172-191.

Henshaw, P.C., Booth, D. B. 2000. Natural Restabilization of Stream Channels in Urban Watersheds. JAWRA. 36(6):1219-1236.

Hession, W. C., Pizzuto, J. E., Johnson, T. E., Horwitz, R. J. 2003. Influence of bank vegetation on channel morphology in rural and urban watersheds. Geology. 31:147-150.

Kennen, J. G, et al. 2009. Determining hydrologic factors that influence stream macroinvertebrate assemblages in the northeastern US. Ecohydrology. 3:88-106.

McBride, M., Booth, D. B. 2005. Urban Impacts on Physical Stream Condition: Effects of Spatial Scale, Connectivity, and Longitudinal Trends. JAWRA. 41(3):565-580.

Ministry of Environment of Ontario. 2003.Stormwater Management Planning and Design Manual. Queen's Printer for Ontario.

Ministry of Finance of Ontario. 2010. Ontario Population Projections Update. Queens Park Printer for Ontario.

Morgan, R.P., Cushman, S.F. 2005. Urbanization effects on stream fish assemblages in Maryland, USA. J. N. Am. Benthol. Soc., 24(3): 643-655.

Ontario Water Resources Act. R.S.O. 1990, Chapter O.40.

Palmer, M.A., et al. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology, 42: 208-217.

Paul, M. J., Meyer, J. L. 2001. Streams in the Urban Landscape. Annu. Rev. Ecol. Syst. 32:333-365.

Poff, N. L., Bledsoe, B. P., Cuhaciyan, C. O. 2006. Hydrologic variation with land use across the contiguous United States: Geomorphic and ecological consequences for stream ecosystems. Geomorphology. 79:264-285.

Roy, A. H., et al. 2003. Stream macroinvertebrate response to catchment urbanisation (Georgia, U.S.A.). Freshwater Biology. 48:329-346.

Sullivan, S. M. P, et al. 2006. Influence of stream geomorphic condition on fish communities in Vermont, U.S.A. Freshwater Biology. 51:1811-1826.

Toronto and Region Conservation Authority. 2009 Annual Report. www.trca.on.ca.

Walsh, C. J., et al. 2005a. The urban stream syndrome: current knowledge and the search for a cure. J. N. Am. Benthol. Soc. 24(3):706-723.

Walsh, C. J., et al. 2005b. Stream restoration in urban catchments through redesigning stormwater systems: looking to the catchment to save the stream. J. N. Am. Benthol. Soc. 24(3):690-705.