

*'Towards a Framework for Determining Ecological Flows
and Water Levels in the Lake Simcoe Watershed –
A Guidance Document'*



Prepared for: Ontario Ministry of the Environment
January, 2011

Lake Simcoe Region Conservation Authority
And
Dr. A Bradford, School of Engineering
University of Guelph

With support provided by



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1.0 Introduction

The Lake Simcoe watershed is stressed due to excessive nutrient (primarily phosphorus) loading. On average, phosphorus discharge to Lake Simcoe from all sources is about 72 Tonnes per year. The Lake Simcoe Protection Act, 2008 (LSPA) was passed by the province for the purpose of protecting and restoring the ecological health of Lake Simcoe and its watershed. The Act also called for the development and implementation of the Lake Simcoe Protection Plan (LSPP), which came into effect in June 2009. The LSPP contains a broad range of policies and recommendations which are necessary to support the purpose of the Act. Some of those policies and recommendations directly affect the Ministry of the Environment (MOE), Ministry of Natural Resources (MNR), Ministry of Agriculture, Food and Rural Affairs (OMAFRA), the Lake Simcoe Region Conservation Authority (LSRCA), and its municipal partners.

The LSPP has several guiding principles that are essential to the protection and restoration of the ecological health of the Lake Simcoe watershed (LSPP, 2009). They include:

- Ecosystem Approach
- Subwatershed Approach
- Precautionary Approach
- Adaptive Management Approach
- Sustainable Development Approach
- Shared Responsibility
- Cost-effectiveness

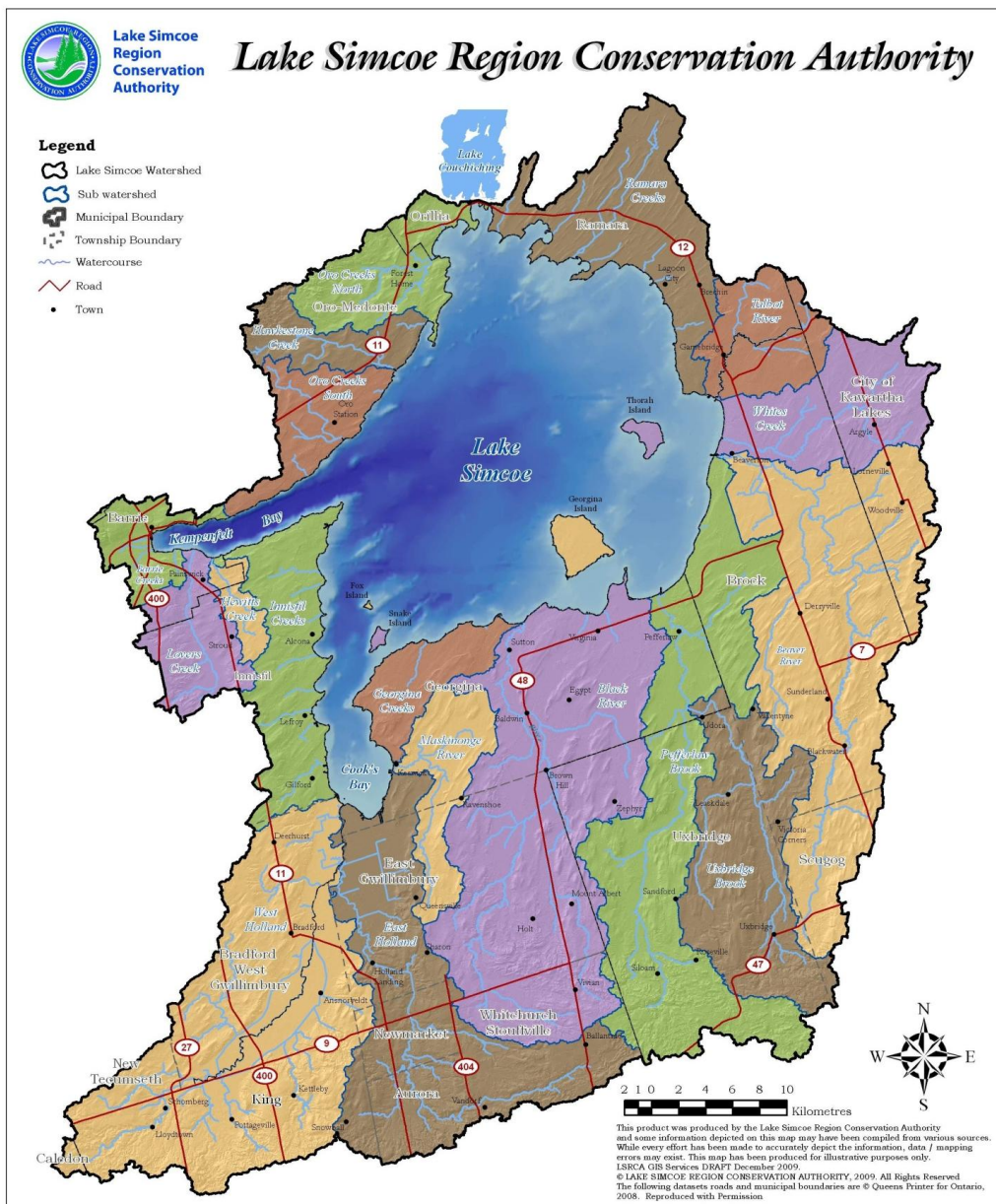
One of the primary focuses of the LSPP is the priority for “*maintaining water quantity*”, where it is recognized that initial strategies will need to evolve over time based on science and experience in implementing the plan (LSPP, 2009).

Chapter 5 (LSPP, 2009), states that in order to ‘*protect aquatic ecosystems in the Lake Simcoe watershed, an adequate portion of the available water supply must be reserved for the ecosystem and restricted from human consumption*’. In addition, it states that ‘*this Plan would support research to estimate the reserve flows required to maintain healthy aquatic ecosystems*’ in the watershed. According to the LSPP (2009), specific targets for protecting water quantity will eventually be developed, once the research has been completed. It is our expectation that research will be part of a continued effort to provide improved information to help refine the approach to maintain healthy aquatic ecosystems into the future.

As described specifically in Policy 5.1-SA, the MOE and MNR ‘*will develop in-stream flow targets for quantity-stressed subwatersheds in collaboration with LSRCA*’. This includes the ‘*development of targets for in-stream flow regimes and water extraction limits for the Maskinonge River subwatershed*’ (LSPP, 2009).

In March 2010, the MOE contracted LSRCOA to work with various watershed partners to develop a 'Guidance Document' for 'in-stream flow targets for water quantity-stressed subwatersheds'.

This Guidance Document provides the rationale and science that supports the proposed direction and its framework. The framework, involving several processes, is intended as a guide rather than a prescriptive approach, which will make it applicable to the many subwatersheds of the Lake Simcoe watershed. It will allow the application of professional judgement and the consideration of specific conditions in various subwatersheds.



1.1 The Need for Ecological Flows and Water Levels Assessment

It is essential that we work towards meeting human needs and at the same time maintain the integrity of aquatic ecosystems. Aquatic ecosystems provide numerous values to society such as: water supply, natural water treatment, sediment transport, moderation of floods and droughts, habitats that support biodiversity, healthy populations of commercially important native species, recreational opportunities, and aesthetic values (Bradford, 2008).

Environmental (or ecological) flow assessment involves the determination of the flow regime required (or the acceptable departure from the original flow regime) to maintain specified, valued features of the ecosystem (Tharme, 2003).

Natural variations in flows (both within and between years) are needed to maintain and restore the natural form and function of streams (Holling and Meffe, 1996; Poff et al., 1997; Stanford et al., 1996). Consideration of a single, minimum threshold flow, to the exclusion of other ecologically relevant flows, is no longer an acceptable approach to instream flow management. It is also necessary to go beyond maintaining “means” or a subdued replica of the natural hydrograph because of the important functions of extreme flows (IFC, 2002; Petts and Maddock, 1994; Stalnaker, 1994; Hill et al., 1991). Poff et al, (1997) reminded the science community that “half of the peak discharge will not move half of the sediment, half of the migration motivational flow will not move half of the fish and half of an overbank flow will not inundate half of the floodplain”.

In addition to stream flow magnitudes, characteristics of the hydrologic regime including frequency, timing and duration, rate of change and sequences of flows also play important roles in regulating ecological processes. The ecological response to changes in a hydrologic regime will depend upon the degree to which critical characteristics deviate from natural ranges. For example, if changes are too great, the life-cycle needs of native species may not be met. They may be displaced by non-native species, and energy flow through the ecosystem may be modified (Stanford et al., 1996).

Water levels or flows within certain ranges may be needed to maintain:

- Habitat conditions (e.g. water depth which influences “living space”)
- Channel and floodplain morphology
- Substrate characteristics (e.g. particle size distribution and looseness)
- Water quality characteristics (e.g. water temperature and dissolved oxygen levels)

A range of flows provides various hydraulic connections that support various ecological functions and processes such as:

- Maintaining *longitudinal connections* in streams, which are important for fish migration to spawning or overwintering habitat, provision of access to refuge areas at times of stress (summer temperature extremes and/or winter ice conditions) and to prevent disruptions to the food web such as insect emergence or drift.
- *Lateral connections*, which are essential to provide water to floodplains, riparian wetlands and side channels and to allow sediment and nutrient exchange and recruitment of woody material for streams. The rate of increase or recession of floodwaters influences cues for fish spawning, access to floodplains and success of the spawning activity. Certain riparian species of vegetation require a seasonal connection with the water table to stimulate growth. (IFC, 2002; Poff et al., 1997)
- *Connection to the groundwater* flow system, which may be critical for baseflow and thermal regimes in streams, and for spawning areas that are reliant on flow/discharge through substrates. (Imhof et al., 1996)

Appendix I provide further details further regarding ecological processes and functions. Poff et al. 1997 also provides good background on the importance of stream flow to ecological processes.

1.2 The Need for an Ecological Flows and Water Levels Framework

A framework is needed to support the implementation of an ecological flow assessment process that can address multiple functions of aquatic ecosystems and consider a range of ecologically significant flows. The framework will set out a process for ecological flow assessment in the various subwatersheds in the Lake Simcoe watershed. It is a starting point from which the responsible partners can engage experts and initiate technical studies to move towards land and water management that can better meet ecological needs.

The framework is intended to provide some consistency in approach, particularly in helping to match the level of analysis to the degree of sensitivity or vulnerability of the aquatic system. This hierarchical approach or tiered system essentially implies that there will be an increase in time and effort for assessment as the spatial scale (of the question) decreases, resulting in more focused and quantitative assessments being required (Arthington et al., 1998; Dunbar et al., 1998). (Refer to Appendix II).

The framework will provide the basis for a structured process to involve a multi-disciplinary group of experts to consider potential ecological responses to change in the flow regime at three scales of management (watershed/subwatershed, reach and site). For some subwatersheds, the process may lead to development of ecological flow targets (or more correctly, target regimes). However, in most cases it will lead to the

identification of critical ecological functions and appropriate methods to determine ecological responses to hydrologic changes. This would allow the anticipated effects of alternative scenarios (e.g. for land and water management / restoration) to be evaluated and communicated to decision-makers.

It will also provide a platform for agencies/stakeholders to move forward in fulfilling their regulatory responsibilities under the Lake Simcoe Protection Act.

In addition, the framework should also be used as an opportunity to raise awareness regarding the importance of an ecological flows and water levels process in protecting the aquatic resources of the Lake Simcoe watershed.

1.3 Principles of an Ecological Flows and Water Levels Framework

1. *Holistic* - the intent (unless other objectives have been identified for a particular catchment) is to protect the ecosystem and community of organisms rather than focus on a single species. A holistic approach recognizes that the assessment of the requirements of a single species or a few indicator species, may neglect the needs of other species and ecosystem processes and functions in general (Noss, 1996).
2. *Consensus-based* – goals, objectives and priorities should be informed by a consultative watershed planning process.
3. *Integrated* – where the management and/or development of water resources is considered in an integrated way (through a watershed planning process) rather than in isolation (e.g. the PTTW program).
4. *Pragmatic* – need to move forward (in preferred direction) despite the fact that all of the scientific answers may not be available, or the design technologies are not fully developed ie. a half full tool-box. There is a need to avoid ‘paralysis by analysis’ and the ‘not having enough data’ syndrome. Nevertheless, a precautionary approach is necessary.
5. *Process-based* – process-based understanding allows for identification of priorities in terms of functions, in cases of conflicts regarding water needs. Process is also required for linking across scales (e.g. scales at which management is happening vs. scales at which ecological response is happening. Particularly relevant to the *Science/Expert Group*).
6. *Establish a decision-making process* – a way of evaluating tradeoffs and alternatives among various disciplines and/or stakeholders; endorsement of the catchment-specific ‘what are we managing for’ goals and objectives (particularly relevant to the *Decision-making Group*).

7. *Hierarchical* - more detailed analysis is required in cases of more sensitive systems and/or more extreme pressures (risk analysis-based).
8. *Adaptive* – continuous process of evaluation and adjustment.

1.4 Who's Involved

There is a significant need to develop 'teams' of people to deal with the myriad of approaches and conflicts that exist in developing an ecological flow regime. Capacity building is critical to the success of this process. It is recommended that the formation of two groups be considered - a *Decision-making Group* and a *Science/Expert Group*.

Decision-making Group

The *Decision-making Group* would be made up of multiple stakeholders that represent a variety of interests in the Lake Simcoe watershed. Those interests would include watershed, municipal, agricultural, ecological, social and public. This group would be required to deal with the priorities and trade-offs, inherent conflicts and competing interests that are expressed by members of the *Decision-making Group* or identified by the science experts. They would have to evaluate the acceptable risk as a balance between the perceived value of the ecological goals, the economic costs involved, and the scientific uncertainties. They will deal with 'values' and choices, rather than just the environmental gain / protection parameters. They must take a precautionary approach to those choices, be they economic, social or environmental. The group will confirm and endorse the values, goals and objectives, and the 'what are we managing for' directive.

This group will ultimately make the decisions. They will possess the authority to enable decisions regarding the implementation of a target ecological flow and water level regime.

Science/Expert Group

The *Science/Expert Group* would be made up of interdisciplinary experts. These may include specialists in ecological flow assessment, GIS, hydrology, hydrogeology, fluvial geomorphology, water quality, fisheries, benthic invertebrates, and riparian vegetation.

They will use the best available science and practice, including the recognition of knowledge gaps at that time, to initiate the process for developing ecological flow assessment in the subwatersheds of Lake Simcoe.

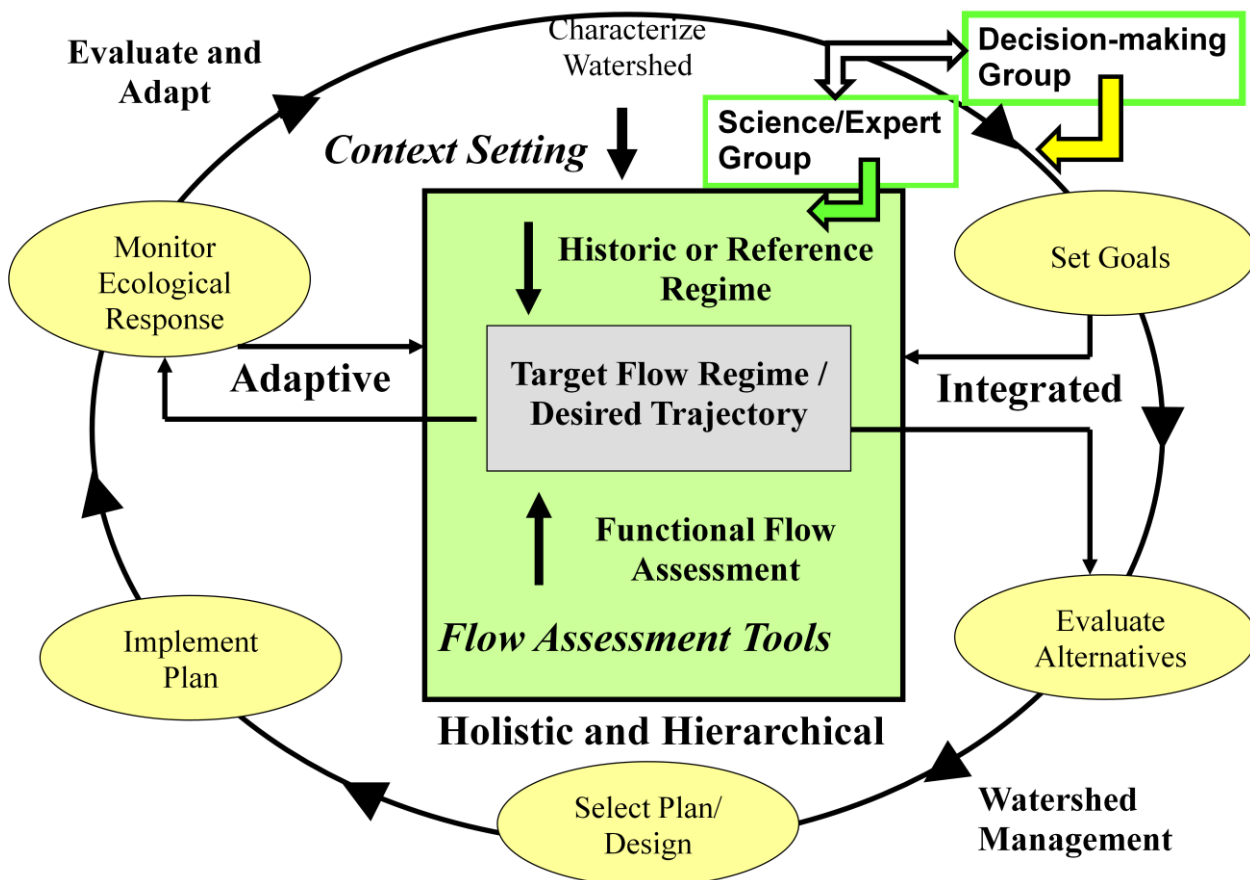


Figure 1 Components of an Ecological Flows and Water Levels Framework (adapted from Bradford, 2008).

2.0 Components of a Framework

2.1 Context Setting – objectives and needs

The Ecological Flows and Water Levels Framework must be linked with current watershed planning processes (or other available information) to determine the management objectives (water quality, recreational uses; riparian vegetation or stream bank stability, wildlife, fisheries, invertebrates) and management issues (water supplies (quantity and quality), sewage assimilation, land use or land development, opportunities for improvement/innovative restoration, opportunities for improved knowledge base, watershed characterization and ground and surface water interaction). In the case of the Lake Simcoe watershed, the LSPP encourages this integrated connection as well.

Quantification of the hydrologic regime (surface water and groundwater interaction) is necessary to establish goals which are achievable, given the physical constraints of climate, geology etc. This is the kind of knowledge which is being gained through the water budget and risk assessments which are part of Source Protection initiatives in the Province. The water budget tools e.g. integrated groundwater and surface water models which have been developed through these initiatives are fundamentally required to predict hydrologic changes in response to alternative management scenarios.

Ecological responses cannot be effectively considered, without a sound understanding of expected hydrologic changes. That is not to say that information flow is unidirectional. It may be important for interdisciplinary experts to provide information on the types of hydrological information, and the temporal and spatial scales which are of ecological relevance.

The water budget tools may also be used to gain an understanding of the hydrologic regime that existed under a reference (or more natural) watershed condition, and the degree of alteration that the system has experienced. In addition to providing some bounds on what is achievable, a reference regime may serve as the desired trajectory in the absence of more detailed information. The inherent assumption is that the less deviation from the ‘natural’, the better.

It is also essential to translate the goals and objectives for each subwatershed into a ‘list’ of specific functions which have water needs (e.g. if sewage assimilation is an objective, ecological flows and water levels that will sustain this function need to be assessed; if there are habitat specialists with specific water needs at specific times of year then these need to be assessed).

Based on this context-setting exercise, the process can then be directed to the appropriate hierarchical level of analysis and tools. (Refer to Appendix II).



2.2 Functional Ecological Flows and Water Levels Assessment

The Ecological Flows and Water Levels Framework goes as far as to provide a table (Table 1. *Functional Approach to Ecological Flows and Water Levels Assessment*) to help implementers make connections between the functions / species needs, the variables that limit functions in time and/or space, and the processes that control the variables.

However, it does not go as far as identifying specific tools to quantify parameters of interest. It is necessary to leave some flexibility for the disciplinary experts to identify innovative tools or methods and to introduce the most recent research. Part of the rationale for this is that field is evolving quickly and typically, by the time it is documented in guidance, it is out of date.

The following table (Table 1) summarizes an approach to focus an ecological flows and water levels assessment on the process(es) governing the values of variables, which must have values within acceptable ranges to meet biotic and human needs.

Biotic and Human Needs (Required Functions)	Variable(s) that Limits Function	Flow-related Process(es) Governing Variable	Non-flow Related Processes Affecting Variable	Flow Regime (Temporal Aspects)
Step 1	Step 2	Step 3	Step 4	Step 5

Table 1 Functional Approach to Ecological Flows and Water Levels Assessment

Step 1

The *biotic and human needs* may be related to living space (physical, chemical, hydraulic habitat), reproduction, feeding, and/or recreation as examples. A broad range of needs should be considered, but may be grouped if they require similar conditions (with similar timing and frequency). Begin with those needs that are known; the assessment can be expanded if additional needs are later recognized.

Step 2

For each of the needs, identify the variable(s) that has an acceptable range in order to meet the need, or perhaps a threshold at which conditions become unacceptable. A complicating, but important, consideration is the relevant spatial scale for the particular variable. It may be appropriate to consider needs at the macro-, meso-, and microhabitat scales.

Steps 3

A critical step is the identification of the *flow-related processes* which govern each variable identified in Step 2. This knowledge will determine the tools that are appropriate to assess potential effects of flow changes.

Step 4

There may be *non-flow related processes* that also influence variables which limit functions and these should also be identified. This is important because it may be possible to meet the needs (biotic and/or human) by managing these processes (rather than or in combination with flow management). In some cases, it may be impossible to meet the needs without management of these non-flow related processes.

Step 5

The final step is intended to assess the temporal dimension of water flow and level needs – at what time during the year do the flows and levels need to meet certain requirements; with what frequency may the variable take on a value outside the acceptable range. While timing of flows and levels should be dealt with at this stage, frequency may need to be addressed later in process. The occurrence of flows and levels must be considered in relation to the timing of the needs.

Next Steps

Table 1 assists in the identification of flow-related processes that control variables, which must have values within certain ranges to meet biotic and human needs. It is subsequently necessary to quantify the flows required to sustain processes and maintain values of variables within acceptable ranges, or to assess the effects of modifications in flow (alternative development and/or management scenarios) on the processes and variables that limit important functions.

The proposed approach is helpful in identifying appropriate tools for the ecological flow assessment (Table 2. provides some examples) and in focussing data collection efforts on relevant parameters.

Table 2. Examples of Tools for Analyzing Ecological Functions

Geomorphic Functions	
Substrate Maintenance	Hydraulic model and sediment transport equations
Channel Maintenance	
Connectivity Functions	
Longitudinal	Low flow hydraulic model including barriers
Lateral	Hydraulic model
Water Quality Functions	
Temperature	Hydraulic model plus stream temperature or full water quality model
Dissolved Oxygen	
Other	

(Further information can be obtained for example about hydrological/habitat functions of fish in Grand River Conservation Authority, 2005.)

2.3 Adaptive

In recognition of ecosystem complexities, most frameworks highlight the need for adaptive management (e.g. Richter *et al.*, 2003; Arthington *et al.*, 1998; Castleberry *et al.*, 1995). King *et al.* (2003) state, “A commitment to sustainable use requires a commitment to implement the selected flow regime, monitor the outcome in a way that will unambiguously indicate if it is achieving its goals, and have the capacity in management structures to adapt either the goals or the flow regime if the monitoring results indicate this is necessary.”

Rogers and Biggs (1999) describe the use of Thresholds of Probable Concern (TPC) for strategic (as opposed to reactive) management of the rivers of Kruger National Park, South Africa. TPC are specific ecological end-points, which represent hypotheses of the limits of acceptable change in ecosystem structure (form), function and composition. As scientific descriptions of management objectives, they are consistent with higher level watershed goals that reflect societal values. The end-points (TPC's) are described by quantified predictions of the system's response bounded in space and time. They form the basis of the monitoring program and the link between management targets and a hypothesis setting approach to gaining knowledge.

In addition to flow characteristics, monitoring may include measures related to channel and floodplain morphology, water quality, vegetation, invertebrates and fish. A suite of ecosystem indicators can address multiple scales and multiple levels of biological organization (Noss, 1990). Measures of biotic responses are important to confirm assumed flow – habitat – biota relationships but are less effective for management purposes. They are more distant from the cause of change and Rogers and Biggs (1999) suggest this may lead to more reactive management.

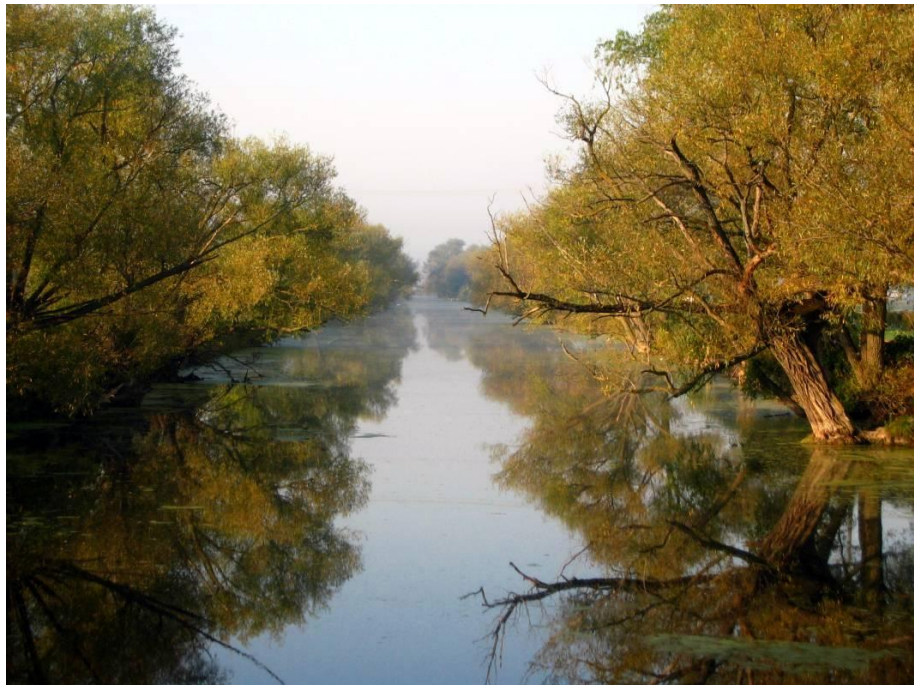
Ultimately post-implementation monitoring needs to assess three essential elements of the desired trajectory:

- River Flow – is the prescribed design flow regime close to the actual
- Ecosystem Response – have the ecological objectives been achieved/maintained
- Social Response – have the social expectations been met/maintained

Future improvements in our understanding (as a result of monitoring and/or new research) may reveal the need to restate assumptions with respect to flow – habitat – biota relationships, adapt/adjust the tools used within the framework to set design flow regimes and/or to modify the desired trajectory. Assessment may determine that the flow – habitat – biota relationships are dependent on or are controlled by a non-flow related process (e.g. land development, or sediment regime which may be influenced by land use). That process may need to be dealt with/accounted for prior to being able to move toward the desired trajectory.

As the process moves forward, there may be multiple ways (eg. managing land use or water takings) to advance along the desired trajectory. Enhancing resilience in the ecosystem through restoration could become a significant option in coping with human impacts. Strategies such as in-river rehabilitation, riparian and wetland restoration, floodplain enhancement, innovative stormwater design, dam removal, maintaining and enhancing groundwater recharge and water allocation and conservation programs should all be considered as part of the proposed management scenario.

Although it is obvious that there should be an adaptive component to the proposed Ecological Flows and Water Levels framework, of equal importance is that an actively adaptive component should be included in the broader watershed management framework, within which the Ecological Flows and Water Levels framework is nested.



2.4 *Integration*

If the goal is to ultimately arrive at a design flow regime for management purposes, the magnitude and timing of flows required for each function must be integrated. It will be one of the key roles of the *Science/Expert Group* to address conflicts between flows needed for various ecological functions. It may be possible to resolve such conflicts by considering the frequency with which particular conditions are needed and building inter-annual (between year) variability in the design flow regime, such that the needs for different ecological functions are met in different years. The ‘natural flow regime’ may also be referred to in the case of conflicts. Interaction with the *Decision-making Group* may be needed early in the process, to “weigh” the importance of ecological functions that have conflicting water needs.

To encourage integration and moving the process forward, both the *Decision-making Group* and the *Science/Expert Group* will require time and an opportunity to learn about each others' disciplines and expertise. Trust among the individual members and between the two groups is essential.

The *Decision-making Group* will need to have training in water budgeting (surface and groundwater modelling) and environmental flow assessment ie. reasons for and approaches to this technology. The team members will need certain personal attributes beyond their representative interest/expertise such as respect for the needs of other stakeholders and a willingness to work together to address potentially conflicting needs. There is a strong need to try to maintain continuity of the team members and a succession plan would be required to replace them.

The *Science/Expert Group* will need to bring together several individuals that have significant science expertise in their own discipline and a willingness to build relationships that allow for constructive, interdisciplinary and technical discussion. There will be a need to take the time required to foster a respect for each others' disciplines and to develop some common understanding related to different terminology, approaches and scales used within those different disciplines. The group may also require training in processes used by experts in environmental flows assessment that are tailored to the Ontario context. In addition, it is important to try to maintain continuity of the group members and to develop a succession plan to replace them.

3.0 Conclusions

The objective of this report is to offer guidance that provides direction towards the assessment of ecological flows and water levels in a holistic way. By placing ecological flows and water levels in the context of the natural flow regime, we have recognized that flow variability is essential in maintaining ecological function. It is also acknowledged that non-flow related processes play important roles and therefore it is critical to integrate the development of an ecological flows and water levels process into the broader watershed management efforts within the Lake Simcoe watershed. As we work towards a desired trajectory in each subwatershed or reach of a river or stream, much more effort is going to be required. This document provides a framework for moving forward.

More detailed guidance is needed in a number of areas. For example, what processes would facilitate the work of the *Decision-making Group* and *Science/Expert Group* and the exchange of information between them? There is a tremendous need for strong leadership and commitment to whatever process is developed.

The framework and principles used must be applied consistently. However, each watershed is unique and it may be necessary to use different tools, depending on the system. A 'recipe' or template at this high level may not be possible and would not likely be useful. Nevertheless, it is recognized that a practical approach will be necessary in order to see the benefits of the overall framework. It will be a matter of at which scale that this can be accomplished.

Appendix I

Flow Need	Rationale
Connectivity (Vannote et al., 1980; Junk et al., 1989; Ward and Stanford, 1995; Jungwirth et al., 2000)	
Longitudinal connectivity	Prevent disruption of food web and allow for migration and access to refugia
Lateral connectivity	Sustain floodplains and riparian wetlands Access to complex biophysical floodplain habitats Maintain nutrient dynamics
Vertical connectivity	Recruit woody debris Maintain hyporheic interactions
Water Quality	
Stream temperature	Maintain preferred ranges for community of aquatic organisms Prevent negative influence on dissolved oxygen
Meet water quality objectives	Maintain dissolved oxygen concentrations Flush away by-products of metabolism Achieve nutrient transformation, biodegradation and dilution associated with wastewater effluent discharges
Sediment Motion (Church, 2006; Kondolf and Wilcock, 1996; Carling, 1995)	
Maintain sediment transport capacity	Maintain balance between deposition and erosion/sustain natural evolution of channel and floodplain morphology Replenish substrates for habitat and spawning areas for fish and benthic organisms
Flushing flows	Maintain quality and character of substrate materials (e.g. prevent suffocation of biota and allow removal of metabolic wastes) Scour encroaching vegetation
Channel and Floodplain Morphology (Whiting, 2002; Hill et al., 1991; Rosgen et al., 1986)	
Maintain planform (natural meander amplitude and wavelength, sinuosity and braiding)	Maintain sediment transport capacity Maintain aquatic habitat
Maintain profile, spacing and sequences of features	Hydraulic biotypes (e.g. riffles, runs, pools, cascades, backwards and side channels) are integral habitats
Maintain cross-sectional shape of channel	Maintain capacity of channel Maintain thalweg structure for longitudinal connectivity Maintain wetted perimeter for food production
Maintain floodplain morphology	Maintain bank structure for channel stability and habitat provision Maintain diversity of floodplain habitats
Biological Requirements (Gregory et al., 1991; Imhof et al., 1996)	
Maintain stream hydraulics and unique features	Maintain conditions for habitat specialists (e.g. groundwater discharge zones for Brook Trout)
Moisture levels for riparian vegetation	Riparian vegetation controls bank morphology; controls light and water temperature; provided some organic matter

Taken from Bradford (2008). *Table 1. Ecological Processes and Functions Important to Society and Natural System*

Appendix II

Hierarchical Levels of Analysis		
Level 1	Level 2	Level 3
<ul style="list-style-type: none"> • Validated hydrologic methods (spatially and temporally variable better) • “Single transect” hydraulic geometry methods (multiple transects better) • Add some larger flows (e.g. biological trigger, flushing, floodplain connectivity) 	<ul style="list-style-type: none"> • Hydraulic models (especially 1 D) / hydraulic geometry • Sediment transport equations / models • Water quality models 	<ul style="list-style-type: none"> • Hydraulic models (2D if necessary) • Sediment transport equations /models • Water quality models • Habitat simulation (Bioenergetic or habitat preference) models
<ul style="list-style-type: none"> • Compare to ranges of hydrologic characteristics for a reference regime (e.g. RVA) • Structures, multi-disciplinary expert input 		

Adapted from Bradford (2008). *Fig 2. Context and Design Flow Setting Tools.*

****Note:**

1. Validation of hydrologic methods (see Level 1) involves observations of flow and stream health in numerous streams of similar type, along with statistical analysis. **The use of arbitrary percentages or probabilities as flow targets is not encouraged.** Values used in other jurisdictions should not be adopted without assessing the data upon which they are based and validating for Ontario streams.

2. Groundwater and surface water models are critical tools to provide predictions of hydrologic changes. They can provide a time series of flow or water level data that may be used in conjunction

with an approach such as the Range of Variability Approach (RVA). Such hydrologic approaches can provide initial target ranges for hydrologic parameters but ecological response must be monitored and targets refined by means of a long-term adaptive management approach. Groundwater and surface water models may provide some information on ecological responses, such as connectivity along a watercourse under various flow conditions, but in most cases would need to be combined with other tools to evaluate the ecological response to hydrologic changes.

Appendix III

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