THE CASE FOR INTEGRATED WATERSHED MANAGEMENT IN MUSKOKA

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Muskoka WATERSHED COUNCIL

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Acronym List

DMM	The District Municipality of Muskoka
IWM	Integrated watershed management
MNRF	Ministry of Natural Resources Forestry, Ontario
MECP	Ministry of Environment, Conservation and Parks, Ontario
MRWMP	Muskoka River Water Management Plan
MWC	Muskoka Watershed Council
NGO	Non-governmental organization

Synopsis

The Muskoka River Watershed is rich in natural capital in the form of extensive areas under natural vegetation and numerous lakes and waterways. Because of the ecosystem services it provides, this natural capital is vital to our economy and the quality of our lives. Effective management will sustain that capital to the maximum extent possible while permitting the development required to house our population and sustain our economy.

One important ecosystem service is the regulation of water flow through the watershed. Major portions of our natural capital – the soils, forests, grasslands, wetlands – play roles in determining the flow of water into the surface streams, rivers and lakes. However, because soils in the watershed are mostly shallow, their capacity to retain water and release it slowly to surface waterbodies may be quite limited relative to regions of southern Ontario with greater average soil depths. Capacity to impede water flow is also likely to vary substantially from place to place across the watershed, depending on the distribution of well-forested land, wetlands, and so on.

Climate change is already having many significant impacts on our watershed communities and ecosystems, including on fauna, flora, soils and waterbodies. One consequence is that over future decades, climate change will exacerbate the seasonality and extent of water flow by directly altering patterns of precipitation, evaporation and transpiration, as well as by radically altering soil moisture, and water-holding capacity of wetlands. We should seek ways to maximize our use of available natural capital in managing the flow of water through the watershed.

These issues reveal an immediate problem. We lack a sufficiently detailed understanding of how natural capital affects flow from place to place across this watershed, and how climate change may modify these regulating processes.

For other reasons as well, protecting natural capital will be one of the most effective ways we have of adapting to climate change, but climate change impacts will be varied. They will differ in severity from place to place, and from year to year, and they will make managing for a sustainable environment and sustainable economy more challenging than it has been in the past. We will be operating on a rapidly changing stage. Environmental management and land-use planning have become much more difficult than they were in the past, when climate and environment varied only modestly through time.

The Muskoka River Water Management Plan (MRWMP) is a product of management approaches used in an earlier, more dependable, time. It is too narrowly focused on flow, and it assumes the environment is static. It was never intended as a flood-control plan, and its capacity to mitigate flooding has always been very limited (we estimate that under optimal conditions the various storage bodies behind dams and reservoirs could have retained only slightly over half the flow occurring between 15 April and 10 May 2019). Nor are there feasible ways to modify the MRWMP to provide more effectiveness for flood control. Yet, climate change will lead to more extreme seasonal flooding, and greater variability in water flow from year to year.

For all these reasons, we recommend that an advanced form of Integrated Watershed Management (IWM) be implemented in this region, ultimately to drive all aspects of environmental management and land-use planning. Recognizing the strong dependence of the economy and community on a high quality environment, IWM can be designed to meet the needs and goals of every business owner, wage earner, property owner and visitor in the watershed. By integrating socio-economic criteria with environmental management, IWM is intended to create more sustainable communities.

To achieve this will require establishment of a Roundtable or Steering Committee, incorporating all regulatory entities, business and community interests, to plan for and build integrated IWM. That group will evolve into the senior management group or Board of the agency that will ultimately manage IWM in Muskoka.

Such a change in environmental and land-use management conforms to the recommendations in the Provincial Policy Statement, but we recommend going beyond the form of IWM advocated in Provincial policy, and practiced, to varying effectiveness, elsewhere in Ontario. We see the new, more dynamic world of the 21st century – a world of rapid environmental change as well as rapid changes in demography, economic activity, and lifestyles – as incompatible with the relatively static form of IWM that has been practiced until now. Muskoka Watershed Council is interested in facilitating the formation of the Roundtable, and development of the operating policies needed for an effective IWM.

There are significant challenges in implementing IWM, particularly in the advanced, model-driven form we propose. IWM is necessarily collaborative while governance in places like Ontario is mostly siloed, top-down and regulatory. It will take real vision and informed leadership to implement advanced IWM here, but this is the right thing to do, and the most appropriate way to move environmental management and land-use planning forward in Muskoka. There are important lessons to be learned from efforts to implement IWM elsewhere in Ontario, and in jurisdictions beyond, and a valuable literature of critical analysis of such efforts is now available. The need is present, the time is ripe, and the opportunity to begin the process of building a modern IWM program for this region is here.

Therefore, Muskoka Watershed Council recommends the following:

1) That iterative, watershed-scale Integrated Watershed Management be planned and implemented on the Muskoka River Watershed ultimately to drive **all forms of environmental management and land-use planning**;
2) That, as a crucial early step, a multi-stakeholder Roundtable or Steering Committee be formed with representation from key community NGOs, the business community, municipalities and relevant provincial ministries (at minimum Natural Resources and Forestry and Environment, Conservation and Parks). This Roundtable will evolve into/be replaced by the senior leadership group, or Board, of the eventual agency responsible for IWM, and will continue to be a representative, collaborative group linking the agencies, ministries, municipalities, and community sectors in Integrated Watershed Management;
3) That, as a second early step, the stakeholders at the Roundtable develop and sign onto a multi-disciplinary Charter containing a vision and goal for the future of the watershed, against which future land-use decisions and management actions can be assessed and tracked;
4) That IWM be applied initially to water flow management, but with the clear understanding that IWM will be progressively expanded to include all aspects of environmental management and land-use planning within eight years;
5) That this IWM program be built upon the ***continuing use*** of a living, interactive, spatially explicit hydrological model of the entire watershed covering both the landscape and the rivers and lakes, and available to be interrogated regularly to answer questions concerning likely trends in environmental conditions and environmental effects of proposed management actions undertaken for land-use planning and/or for climate mitigation;

6) That the hydrological model be constructed using latest understanding of watershed hydrology, with collaborative input from the signatories to the Muskoka River Water Management Plan, the MNRF, DMM (and specialists working on floodplain mapping), and other specialists from watershed NGOs and agencies;
7) That Muskoka Watershed Council support the introduction of this IWM program by convening stakeholders in a Roundtable, and starting the process of developing the rules and building the collaboration necessary for successful Integrated Watershed Management.

Background

The Muskoka River Watershed (Figure 1) is located on the eastern side of Georgian Bay. The headwaters arise on the western slopes of Algonquin Park, and river flow is southwesterly for a distance of approximately 210 km to discharge into the southeast corner of Georgian Bay. The watershed measures over 62 km at its widest point and is approximately 120 km long north-east to south-west, encompassing an area of approximately 5,100 km^2. Every raindrop or snowflake landing on this watershed has one of two paths forward, either a rather quick return to the atmosphere, via evaporation from land or water surfaces or transpiration by the vegetation, or a more variably timed, lazy trip to Georgian Bay. About half of them take the lazy path to Georgian Bay.

With their tributaries originating in the Algonquin Highlands, both the North Branch and the South Branch of the Muskoka River flow southwesterly until converging in Bracebridge before flowing into Lake Muskoka. Drainage out of Lake Muskoka is by way of the Moon and Musquash Rivers which both discharge into Georgian Bay. The watershed can be divided into three main sections: the North Branch, the South Branch, and the Lower Muskoka drained by the Muskoka, the Moon and the Musquash Rivers. The North and South Branches together comprise approximately the eastern two-thirds of the watershed. The Lower Muskoka portion covers the western one-third of the watershed. Over 2,000 lakes have been carved out of the Precambrian Shield and cover about 17% of the watershed. The three largest lakes in the watershed are Lake Muskoka (115.79 km^2), Lake of Bays (67.63 km^2) and Lake Rosseau (62.58 km^2). The Muskoka River Watershed descends approximately 345 m in elevation along its 210 km journey from its headwaters to its mouths at Georgian Bay.

Based on an analysis of data collected over the 20th century and compiled for the development of the Muskoka River Water Management Plan (MRWMP), the average annual flow through the Musquash and Moon Rivers to Georgian Bay is 85 m^3 per second, or 2.7 km^3 per year. (That's over a million Olympic swimming pools' worth.) This sizeable quantity of water is about 51% of the precipitation received within the watershed each year. The other 49% is returned to the atmosphere via evaporation from surfaces and transpiration by trees and other plants. Rates of precipitation, flow, and evapotranspiration all vary significantly across the watershed and through the year, as do the total precipitation, evapotranspiration and flow among years. The Muskoka River Watershed is a complex, dynamic, natural system with a significant and variable flow of water.

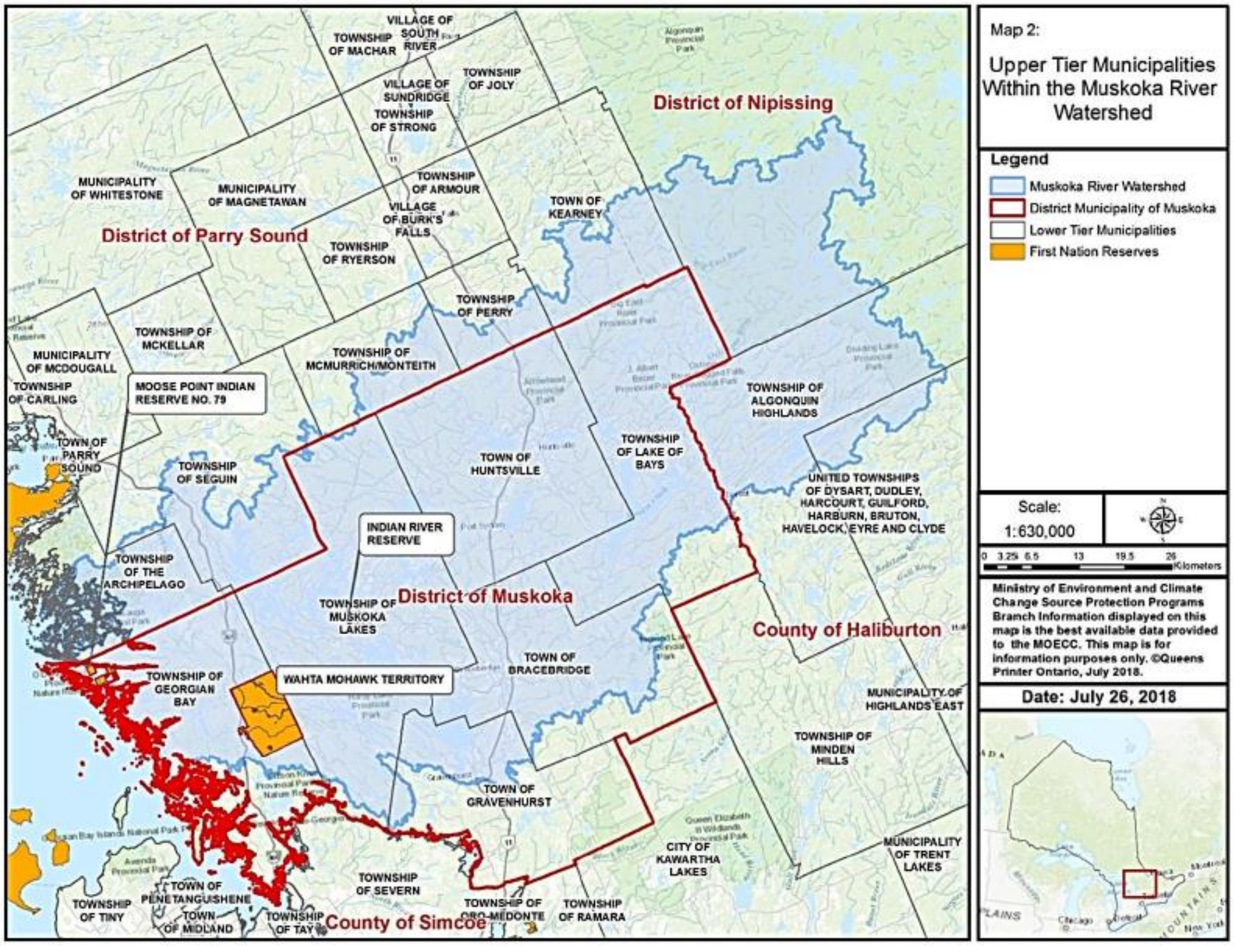

Figure 1. *The Muskoka River Watershed (blue outline) includes most of The District Municipality of Muskoka, plus portions of seven lower tier municipalities in Parry Sound and Nipissing Districts and Haliburton County. It is an appropriately sized region for environmental management, and coordinated, collaborative management of all aspects of environmental management makes sense. This will require collaboration of all municipalities, of appropriate provincial and federal ministries and agencies, of business sectors and community groups. Image ©Queen's Printer Ontario, 2018.*

Water Quantity – Control of Water Flow

Water movement and flow within the Muskoka River Watershed are driven by spatially and temporally variable patterns of precipitation, spatially variable but mostly shallow soils, the topographically complex, mainly granitic bedrock that has been sculpted by Pleistocene ice flow, the distribution of vegetation, the extent and location of wetlands, and the nature, extent and distribution of human modifications to the landscape through a variety of land uses.

Beginning not long after first European settlement, the watershed has been modified to suit the needs of the human economy. Dam construction began in the 1880s initially to facilitate transportation and logging. Hydroelectric power generation began in 1894. Dams originally built of timber and stone were replaced with appropriately engineered concrete beginning in the 1940s. Today, the levels of the seven largest lakes (and therefore river flows) are managed by dams under the control of the Ontario Ministry of Natural Resources and Forestry. A 1940 agreement between the Province and the Hydroelectric Power Commission of Ontario (now Ontario Power Generation), the Hackner-Holden Agreement, established rules governing desired lake levels and flow rates, intended to ensure flows for power generation and the ecological and recreational requirements of the watershed. This first agreement was strengthened in 1969 and formed the basis for water management today. The 1969 amendment recognized the growing importance of recreational uses and ecological needs within the watershed and revised the drawdown limits on some of the lakes. It also established fall and winter drawdown limits in most of the Lake trout lakes to encourage trout propagation. A numerical simulation model of the watershed was developed in the early 1980s and used to improve operational decision making for the various flow control structures.

In 2006 the Muskoka River Water Management Plan (MRWMP) was implemented and replaced the Hackner-Holder Agreement governing management of water flows through the system. Based on improved modelling of flows and volumes and driven by data on June lake levels and November to May patterns of precipitation, the MRWMP allowed a somewhat more refined operation of existing flow control structures to provide flow for power generation, to ensure adequate flow and lake levels for fish populations, and to minimize, to the extent possible, fluctuations in lake levels particularly during the summer tourism season.

It's important to note what the MRWMP cannot do. There are currently 42 different control dams and spill structures throughout the watershed that provide some control over water levels. Of these structures, 11 are associated with power facilities, while 29 are owned and operated by the MNRF. The District of Muskoka owns and operates one while the remaining one is privately owned/operated. All are manually operated – i.e. adjustment is by raising or lowering stop-logs in dams, opening or closing gates of valves – and coordination among control structures relies on operators talking to each other. This loosely coordinated, manual system of controls has quite limited ability to store water at times of ample flow so its ability to ‘manage flooding’ is similarly limited.

To illustrate that statement, we used data in the MRWMP to estimate the total “controllable” volume available in all lakes or reservoirs behind control structures as approximately 0.6 km^3 of water. While this is a considerable quantity – about 240,000 Olympic pools worth – the total flow of water in the system during 15 April to 10 May 2019 was about 1.0 km^3. If all controllable volume had been available on 15 April (all lakes drawn down to the maximum) the spring thaw would have filled all storage capacity and still pushed 0.4 km^3 water through as a flood.

The system of control structures was not planned as a flood control system and the infrastructure can only mitigate flooding to a limited degree even when operated as efficiently as possible. The management of floods is not an explicit goal of the Water Management Plan process (McNeil, 2019).

Over time, the intensity of development of private lakefront land in most parts of Muskoka has increased substantially, with elaborate docks, boathouses and other amenities built at the water’s edge. This infrastructure is subject to damage due to seasonal flooding and ice movement during the spring. In addition, expansion of development for commercial and residential use in the urban centres of the watershed has sometimes intruded into lands that should rightfully have been retained in their natural state as floodplains. Flooding damage to such commercial and residential premises causes significant hardship, particularly for those individuals who own or rent permanent homes in flood-prone areas. Flooding may not yet be substantially more severe or less predictable than it was in the past, but the economic cost, and potential human cost of seasonal flooding has certainly increased, and there is growing public interest in revisiting how water is managed in this region. Furthermore, development pressure is likely growing, rather than peaking, and the new development needs to be managed in ways that do not exacerbate flooding risks. Even without climate change, the time is ripe for a reevaluation of how best to manage water flow across this landscape.

Major Impacts on Watershed Hydrology

Climate change impacts are altering precipitation, evapotranspiration, and flows both directly and indirectly through their effects on vegetation. Continuing development also has the capacity to alter flow dynamics and evaporation though its modification of the absorptive capacity of land surfaces and the profiles and rugosity of river, stream and drainage channels. Between them, climate change and continuing development create a moving target for anyone attempting to manage water quality, quantity and flow through the watershed.

We already have sufficient information concerning the trend in climate change over the next 30 years to project our likely future. Numerous studies project a warmer and slightly wetter climate for this region (Bush et al., 2014; McDermid et al., 2015; Bush and Lemmens, 2019), and our own evaluation of the likely climate at 2050 (Sale et al., 2016) confirms that Muskoka is destined for hotter, drier summers and falls, and warmer but wetter winters and springs. The increased dryness in summers and falls is not due to reduced rainfall at those times; models show rainfall largely unchanged from present conditions in those seasons. Instead, the increased warmth will enhance both evaporation and transpiration making the soils and the air drier. The wetter winters and springs that are anticipated would arise as a direct consequence of increased precipitation caused primarily because larger lakes are expected to remain open well into winter because of the warmer climate. Open lakes, especially Georgian Bay, provide supplies of water available for evaporation to fuel precipitation further to the east – so-called lake-effect snow. The 'mismatch' in seasonality of the expected increases in precipitation and in evapotranspiration have an important consequence for river flow; flows in winter and spring are expected to be substantially larger than at present while flows in summer and fall will be less than now. This shifting of the seasonality in patterns of flow is very likely to exacerbate the risk of winter/spring flooding and the risk of summer/fall drought and wildfire.

While we can be confident that over the next several decades the extent of winter/spring flow and flood will be substantially enhanced, the interannual variability that already exists will also be exacerbated. With our climate warming, average winter temperatures will be closer to 0 °C than in the past, with more frequent and extensive periods of thaw mid-winter. Some winters, colder than usual for the future climate, will see substantial snow-packs develop, setting in place conditions for significant spring flooding; other winters, milder than usual, will see most winter precipitation flowing downstream during the winter months, with negligible accumulation to fuel a spring flood. Similarly, there will be summers, warmer than usual for the future climate that will lead to severe seasonal drought through the fall, and others, cooler than average, that give rise to falls much like at present. The overall result of climate change in Muskoka, over the next several decades, is a substantially more variable hydrologic regime, with consequently increased risks for residents.

There also seems little likelihood that development pressures are going to be reduced in Muskoka in coming decades. Development pressure is already strong and growing stronger. For example, a single Township in Muskoka issued building permits for 267 new boathouses valued at over $46M between 2013 and 2016 alone (McNeil 2019). In the aftermath of the massive 2013 floods in Alberta, it became clear that there had been a hands-off approach with respect to flood risk management in local land-use planning (Bryant and Davies, 2017), and that may also be the case in Muskoka. To the extent that new development increases impervious surfaces and reduces the capacity of the watershed to slow the passage of water towards Georgian Bay, that development could have wide-ranging effects on water flow, and will tend to exacerbate the risks already being increased by climate change. The management of development must be done in ways that mitigate these impacts on water flow. Ideally, the management of development can be used in a proactive way to reduce some of the risks surrounding water flow caused by climate change. How do we achieve this ideal management?

The Need for Integrated Watershed Management

Muskoka's economic vitality and community health are intrinsically tied to the quality of its environment and the nature and extent of its natural capital. A framework is needed to manage and sustain the watershed functions that provide the goods, services and community conditions we need in the long term (Wang et al., 2016).

In order to sustain environmental quality, it will likely become necessary to undertake management actions of various types to mitigate certain impacts of climate change on the environment. These actions will be additional to actions required to manage development (including effects of development on environmental health). Where possible, of course, management actions that simultaneously address climate and development pressures will be favored. Regardless, it is important to recognize that the world is moving into a new, more dynamic phase in which the challenges of land-use and environmental management have become substantially more complex. We need to implement Integrated Watershed Management (IWM) for the Muskoka River Watershed, and to rely on IWM to drive a coherent, cost-effective management of this dynamic environment over future years.

In this paper, we have stressed the anticipated effects of climate change on patterns of water flow, both in amount and in timing, through its direct effects on precipitation and evapotranspiration and its indirect effects via its alterations to the capacity of forests, soils and wetlands to manage flows of water towards our rivers and lakes. We have done so because of evident community concern about flooding.

But environmental management in the watershed is not just flood management. It extends to all aspects of the environment both on land and in the water, including forest health, biodiversity, control of invasive species and pathogens, recreational and potable water quality, and ecosystem resilience. All such aspects of the environment interconnect and management of one often affects others. As well, development and management of same have impacts on the environment that may reinforce, or counter efforts to manage the environment directly.

In other words, it is now time to recognize both that ***it will be unwise to continue seeking to manage flooding as a separate activity, and that an integrated approach to all aspects of land-use planning and environmental management is now necessary***. We need to adopt a land-use and environmental management approach that recognizes the Muskoka River Watershed for what it is – a complex and dynamic ecological system within which we are attempting to live our lives. A comprehensive literature review by Wang et al. (2016) indicates there is a strong global consensus that watersheds are the most appropriate units for the management of water resources and ecosystems in a land use framework. While this may represent a substantial change in perspective for Muskoka, the provincial government has been encouraging coordinated and integrated land-use planning at a watershed scale for at least the last 20 years. To quote Veale and Cooke (2016), "*Addressing natural resource problems at a watershed scale, rather than a single location or portion within it allows all relevant factors contributing to the problem to be included in the planning process, increasing the number of potential solutions to the problem or threat.*"

What is Integrated Watershed Management?

Integrated Watershed Management is an inclusive, collaborative, and continuing process for managing landscapes, fundamentally distinct from the approach formerly used in most western democracies (Veale and Cooke, 2016; Wang et al., 2016). Typical environmental management proceeds as a set of separate, siloed tasks undertaken by different tiers of, and departments within government, and different sectors of society. IWM is organizationally more complex; introducing IWM requires significant commitment from participating levels of government, ministries, agencies, and all community sectors, if it is to be successful.

At its simplest, IWM brings a science-based, ecological perspective to environmental and land-use management, recognizing that the broad range of ecological processes operates across landscapes, and that management is best done on the same scales and using natural boundaries without regard to municipal boundaries. Human management of land and water which conforms to natural boundaries and pathways is likely to be more successful than management that is constrained to follow municipal and other political borders. IWM is integrated spatially, temporally and across disciplines in recognition of the fact that every management action will have ramifying effects on the ecological system.

While the watershed was originally selected as the appropriate management unit for planning related to water, there has, over the years, been a growing recognition that 1) water transports many nutrients and pollutants through natural systems, and 2) the pattern of surface waters across a landscape imposes a structure on the movements of fauna and other aspects of connectivity that are vital to the sustainability of ecological systems. Watersheds naturally subdivide ecologically into a series of levels of sub-watersheds, thereby offering a range of spatial scales on which to base planning decisions. For these reasons, management at a watershed scale and using watershed boundaries is being adopted as appropriate for most aspects of land-use planning when that land is in a natural, rural or agricultural state, and for many aspects even in urban settings.

Management decisions applied to the same piece of land are inherently interconnected even when directed to different management objectives or applied by different branches or levels of government. For example, regulation of water flow to facilitate hydroelectric generation must be compatible with water levels and flow needed for fishery management. And management of runoff from hardened surfaces created by urban development impacts both fishery management and hydro-generation. This interconnection and the developing concept of 'cumulative impacts' with respect to impacts of human activities on ecological systems, have led to the recognition that land-use planning should always be integrated spatially and temporally.

There is also a strong socio-economic argument for integrated management of the watershed. The local economy, property values and recreational enjoyment are just a few examples of how the economy is dependent on the environment. IWM targets socio-economic health just as much as ecosystem health. By accounting for the socio-economic impacts of flooding and other aspects of climate change, a number of watershed plans, such as in the Rhine and Fraser River Watersheds, have demonstrably improved local economic conditions (Wang et al., 2016). This socio-economic value was a factor in establishing the first watershed agency in Canada in the early 1930s. Lobbying by local business leaders impacted by drought and pollution in the river led to the formation of the Grand River Conservation Authority (Veale and Cooke, 2016). Wang et al. (2016) reviewed many cases in which the separation of social and environmental goals from narrowly focused economic growth created problems that required the interests of all stakeholders to be reconciled. IWM can build the needed collaborative solutions.

IWM is thus a modern approach to management of the environment which integrates decisions made to achieve different goals whether these are water quality, flood control, climate change adaptation, forest management, urban planning, or economic development. IWM applies management decisions to sites at a spatial scale which is ecologically meaningful, and which makes use of the natural scales and boundaries provided by watersheds.

The concept of integrated watershed management has been around for a long time and has been applied in some parts of Ontario since the mid-1980s. It has also been employed across North America, Europe and developing countries, but it has never been utilized in Muskoka. There has been a gradual evolution in the extent and formalization of IWM used in Ontario as seen in the text of the Provincial Policy Statement, which governs all land-use planning in this province (MMAH, 2014). The current (2014) version still does not require IWM, nor require a coordinated approach (Nelson, 2017), but states:

1.2.1 A coordinated, integrated and comprehensive approach should be used when dealing with planning matters within municipalities, across lower, single and/or upper-tier municipal boundaries, and with other orders of government, agencies and boards including:

This is followed by eight specific examples including management of natural heritage, water, agricultural land, transportation and waste-management systems, ecosystem, shoreline and watershed issues.

The 2014 Provincial Policy Statement does direct municipalities to use the watershed scale when managing water:

2.2.1 Planning authorities shall protect, improve or restore the quality and quantity of water by:

a) using the watershed as the ecologically meaningful scale for integrated and long-term planning, which can be a foundation for considering cumulative impacts of development;

The first version of the Provincial Policy Statement (1996) said merely,

1.1.1e A coordinated approach should be achieved when dealing with issues which cross municipal boundaries, including:

Followed by a list of four issues including '*ecosystem and watershed related issues*' and '*shoreline and riverine hazards*'.

The Process of Integrated Watershed Management

IWM is an iterative process of adaptive management of a watershed (Figure 2). It begins with **Characterization** of existing conditions across the watershed. This characterization may detect issues that require correcting. Such corrections become included in the **Objectives** of management. **Planning for Action** is the process of selecting discrete management actions to achieve the **Objectives**. The Action Plan is **Implemented**, and the watershed is **Monitored** to observe changes and detect any apparent responses to the management actions taken. Results of monitoring lead to a refined and/or altered **Characterization.** This completes one circuit around the management cycle.

In the dynamic world we now occupy, an effective IWM program will require integral use of a spatially explicit hydrological model capable of visualizing the watershed decades into the future, and assessing the effectiveness of proposed management actions before they are implemented. We discuss this modelling need below (Developing a Water Budget). Effective IWM will also require re-characterization at regular intervals (every four years, every decade) so that management planning and action proceed iteratively into the future, in response to changed conditions, improved management techniques and revised objectives. This regular cycle conforms well to current policies concerning development and revision of municipal Official Plans; however, as noted below, application of IWM elsewhere in Ontario has had variable success and seldom met its full potential. In Muskoka, we should learn from others' mistakes rather than simply repeating them.

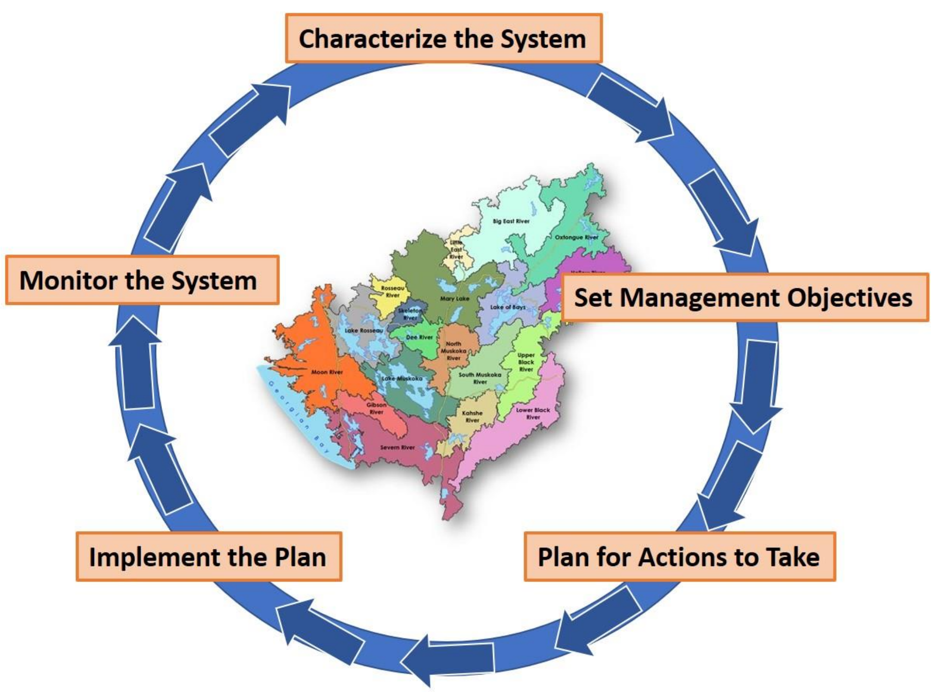

***Figure 2**: Adaptive management of a watershed as an iterative process. Management commences with the first Characterization and proceeds through the other elements of IWM. Modelling of the system, and of likely effects of proposed management actions, occurs during the Characterization, Objective setting, and Action planning phases. On completion of the first cycle, the system is recharacterized, which may lead to modified management objectives. IWM is a continuous adaptive management process.*

Preparation for IWM – The First Steps to Take

There is a common misconception that the initial development and implementation of IWM is long, expensive and onerous, but this is not true. If an iterative approach is used, progressive planning and active management at the watershed scale can begin in short order. A critical element of buy-in for the Grand River Watershed Charter was that IWM planning was scoped according to available time and resources (Veale and Cooke, 2016). Instead of beginning with new research, data collection or modelling, the process was initiated with existing information and the "*collective knowledge of the partners*".

However, before IWM can commence, several preparatory steps are required. These steps become part of the first characterization of the system. Integrated Watershed Management is necessarily a collaborative activity among neighboring municipalities, provincial and federal agencies with responsibilities for land, water or natural resources, major economic sectors, conservation NGOs, and members of the community, including members of First Nations and other traditional owners. The first preparatory step is to build the forum at which these entities will interact in IWM.

This is intended to be a forum that will exist long-term, so it needs to be carefully designed to ensure that participant groups recognize its continuing importance. While existing IWM programs around North America have their flaws, strong collaboration among all stakeholders has been critical to the successful ones. The Grand River IWM program involved a collective Charter that stakeholders committed to (Veale and Cooke, 2016). Understanding the strong linkage between environmental issues and socio-economic interests has led to more successful institutional and private sector collaboration in IWM in places such as Lake Tahoe (Imperial and Hennessey, 2000).

A second early step is to develop clear principles for adjudicating the responsibilities of each participant, and the priorities to be used in deciding among policies or actions. One important task is to decide which among the various entities will take the leadership role in driving the IWM process. Such preparatory steps could be daunting if there was no history of collaborative activity. Fortunately, in the Muskoka region there is already a long history of collaboration among upper and lower tier municipalities, adjacent municipalities, and municipalities and provincial ministries. However, for IWM to be fully effective, there is a need to formalize these relationships and think through the ways in which the management task is to be handled.

One complexity we foresee in successfully completing these first two tasks is that there is no existing oversight body and no municipality with boundaries totally covering the entire Muskoka River Watershed. The District Municipality of Muskoka (DMM), which might be a logical entity to lead these first steps of the process, includes most, but not all of the Muskoka River Watershed, and includes some lands in the Black/Severn River Watershed to the south. Ideally, an IWM plan should be developed for the Muskoka River Watershed, perhaps led by DMM but with all lower tier municipalities including the seven lying outside DMM included among the partners (see Figure 1). A separate IWM plan for the Black/Severn River Watershed would include DMM among its partners. Implementing IWM will require some significant changes to municipal Official Plans simply in order to reflect the need for effective cross-border cooperation in management, while retaining management responsibilities, in so far as possible, with current agencies.

There are many different examples of regulatory oversight bodies across North America (Unger, 2009; Imperial and Hennessey, 2000). In many parts of Ontario, conservation authorities, with their own borders defined by watershed boundaries, have been the entities charged with leading on

IWM. A conservation authority does not exist in the Muskoka region, and the establishment of one seems unlikely at present, so other solutions should be explored. Regardless of the solution that is adopted for Muskoka, it is vital that a specific entity have responsibility for leading on IWM, have the capacity and be adequately resourced to lead, and have the full support of the other entities that will be partners in the project. The success of IWM for this region will depend upon the effectiveness with which the management structure is established and maintained.

Existing IWM programs also offer a range of approaches for achieving desired management action. These range from ones with more voluntary oversight to more strictly regulatory models. While regulations can enforce action, models with at least some voluntary accountability are more collaborative and potentially more progressive. They allow participants to set the bar higher with less fear of penalty; regulations to be met do not encourage any partner to go further than the minimum. Regardless of whether goals are set collaboratively or through a regulatory framework, the core idea of adaptive management remains that goals will be modified as new information dictates (Veale and Cooke, 2016; Unger, 2009).

Watershed management and planning, as it has evolved in much of the United States and Canada, is focused on "collaborative watershed partnerships" and has been described as having the following institutional characteristics according to a broad review for the Alberta government by Unger (2009):

(1) the use of hydrographic watersheds as the principal jurisdictional boundary;

(2) the involvement of a wide variety of stakeholders (including interest groups, experts, and agency officials from multiple levels of government);

(3) a reliance on face-to-face negotiations with agreed-on procedural rules (and often a professional facilitator) designed to ensure civility and engender trust;

(4) a goal of seeking win-win solutions to a variety of interrelated environmental and socioeconomic problems; and

(5) a fairly extensive fact-finding phase designed to develop a common understanding of the seriousness and causes of relevant problems.

There has recently been some critical evaluation of the success of IWM as practiced in Ontario and elsewhere in Canada, resulting, among other things, in a single-topic issue of the International Journal of Water Resources Development published in 2017. Many of the papers in this journal issue identify common problems in the implementation of IWM. This list of problems provides a valuable guide for those attempting to implement IWM in Muskoka. Scott et al. (2017), writing with reference to the IWRM (integrated water resources management) process in the North Bay-Mattawa Conservation Authority, described the transition towards IWRM as "*not a linear path; it is an evolving and turbulent process influenced by resources, institutional arrangements, commitment and social capital. The financial, human, technical and information resources are ongoing concerns that inhibit the successful implementation of any programme.*" They also referred to ongoing problems with limited resources, a too narrow mandate, and failure to adequately engage First Nations communities. Nelson (2017, also for North Bay-Mattawa) echoed Scott et al., listing lack of agency capacity, lack of baseline information, and lack of capacity for informed decision making as key shortcomings. Veale and Cooke (2017), writing with reference primarily to the Grand River experience, stated, "*Water management is* *fragmented in Ontario. Roles and responsibilities are mandated by federal and provincial legislation and are shared among many government agencies and departments, municipalities and the GRCA (Veale, 2004). Water is also central to the culture of First Nations peoples. Coordination and collaboration among and within agencies is needed to achieve an integrated approach. One of the biggest hurdles in successful watershed management is building processes that are collaborative, yet streamlined, to match stakeholder capacity and sustain interest and enthusiasm over the long term."*

Worte (2017) attempted a more synthetic treatment of IWM across Ontario's conservation authorities. He noted five features important to the current state of IWM in Ontario. First, the existence in many parts of Ontario of conservation authorities with explicit, watershed-scale jurisdictions, has provided legal acceptance of the appropriateness of watershed-scale management. Second, conservation authorities, by their existence, also endorse the principle of integration of land and water processes and management. Third, but less positively, the integration of water management and other environmental management has unfortunately been disrupted several times by emergencies (Hurricane Hazel, Walkerton water crisis) which have resulted in a biased focus on one or two specific 'problems' in place of the holistic management of environment initially intended. Fourth, effectively embracing the relationships among environmental, economic, and social aspects of the IWM task has proved very difficult, partly because initial planning in many conservation authorities focused on water management and was done by water experts with inadequate attention to engage other partners and include other expertise. Fifth, recognition of the need to fully engage all stakeholders has also been difficult to achieve, partly because the process of IWM in Ontario has always been collaborative rather than regulatory. It is difficult to bring partners to the table and keep them there indefinitely. Indeed, Worte views the contrast between a holistic, cross-disciplinary environmental management, which is the hallmark of IWM, and the top-down, siloed and regulatory form of management common to all Canadian governments as a major problem in effectively implementing IWM. He argues, however, that the collaborative and voluntary approach to IWM is the only one likely to be successful, and that there is a need in Ontario to continue to resist the temptation to narrow the mandate or weaken efforts. In his final section, Worte (2017) writes, "*Despite considerable progress in developing and implementing IWM concepts, significant challenges remain. Ontario still has a fragmented legislative structure and lacks the comprehensive provincial water management strategy endorsed by Justice O'Connor (2002b) in the Walkerton report, Part 2. In the absence of the broad guidance of a provincial water strategy, integrated management still depends on the various agencies and stakeholders acting collectively on a voluntary basis."*

We see identification of appropriate partners and establishment of the collaboration as fundamentally important to success and are confident there is much Muskoka can learn from the past mistakes of others. Decisions regarding leadership and decision-making procedures, clear policies on how priorities are set, and clear and agreed understanding of overall goals and of the fact that IWM is essentially iterative and long-term are also fundamental to success. There needs to be care and commitment in completing these early tasks if IWM is to be implemented successfully; likelihood of success could also be enhanced if there is strong endorsement by relevant provincial and federal ministries of the effort to implement IWM.

The First Characterization for IWM

There is a substantial amount of environmental, economic and social information already compiled concerning the Muskoka River Watershed. Characterization should commence by identifying available datasets and ensuring access by all partners. Gaps in data can then be identified and plans to fill these gaps formulated. Meanwhile, the technical task of building a spatially explicit hydrological model of the watershed should commence; this also will help identify gaps in the data.

Ontario has produced several documents outlining the types of data to be compiled when developing an IWM plan and the general approach to be followed in implementing the program. Particularly valuable are a set of four documents produced in 2010 by Conservation Ontario (representing Ontario's 36 Conservation Authorities), the Ontario Ministries of Natural Resources (now MNRF) and Environment (now MECP) and Fisheries and Oceans Canada. These are listed in the Bibliography as Conservation Ontario 2010 a, b, c, and d. More recently, Ontario's Ministry of Environment, Conservation and Parks has released a draft document for public comment (MECP, 2018) titled, *Watershed Planning in Ontario. Guidance for Land-use Planning Authorities*. As emphasized above, the initial stages in establishing an IWM program are critical to success. While these MECP documents are a useful guide, it will be important to look carefully to experience in other parts of the Province to avoid pitfalls. In particular, as we emphasize in the following section, we are advocating an advanced form of IWM that has not yet been successfully implemented in Ontario. To do what we recommend requires not only succeeding where others have failed, but also going beyond the steps described in the MECP documents to achieve a truly iterative and integrated adaptive management program for this watershed.

Developing a Water Budget: The Need for a Hydrological Model of the Watershed

The Muskoka River Watershed is rich in natural capital in the form of extensive areas of natural vegetation and numerous lakes and waterways; that natural capital is vital to the ecosystem services on which our economy and the quality of our lives depend. Effective management will sustain that capital to the maximum extent possible while permitting the development required to house our population and sustain our economy. Major portions of that natural capital – the soils, forests, grasslands, wetlands – play roles in determining the flow of water into the surface streams, rivers and lakes. As such, these natural capital elements become important in defining the water budget.

Because soils in the watershed are mostly shallow, their capacity to retain water and release it slowly to surface waterbodies may be quite limited relative to regions of southern Ontario with greater average soil depths. Capacity to impede water flow is likely also to vary substantially from place to place across the watershed depending on the distribution of well-forested land, wetlands, and so on. Wherever such capacity exists, we would be wise to ensure we act in ways that maximize its effectiveness, and even consider ways to enhance that effectiveness.

Climate change is likely to have significant direct impacts over future decades that will exacerbate the seasonality of water flow. We would be wise to maximize our use of available natural capital in regulating the flow of water through the watershed. But climate-induced changes likely over the next three or four decades will also radically alter soil moisture, seasonality of stream flow, and water-holding capacity of wetlands. Each of these could materially impact the effectiveness with which natural capital slows water flow. These issues reveal an immediate problem. We lack a sufficiently detailed understanding of how natural capital affects flow from place to place across this watershed, and how climate change may modify these regulating processes.

Protecting natural capital will be one of the most effective ways we have of adapting to climate change, but climate change impacts will be varied. They will differ in severity from place to place, and from year to year, and they will make managing for a sustainable environment more challenging than it has been in the past. We will be operating on a rapidly changing stage.

Not only does this region need IWM; that IWM needs to be grounded in a detailed hydrological understanding capable of visualizing where, when, how, and how quickly climate change is altering the movement of water through the system. Management decisions are not going to be effective in sustaining natural capital and maintaining current economies and lifestyles without that knowledge. Continuing development pressure also adds environmental challenges demanding knowledge of available natural capital and changes to that. The only way to build such knowledge and have it available in real time to guide management decisions is by using a modern hydrological model appropriate to this watershed.

For these reasons, we recommend that Integrated Watershed Management undertaken in Muskoka needs to be based on a living, interactive, spatially explicit hydrological model of the entire watershed covering both the landscape and the rivers and lakes. This model is living and interactive in the sense that it will not just be used in the initial planning phase to develop static policies but will be interrogated regularly to answer questions concerning likely trends in conditions and effects of proposed management actions. Far better to have a detailed picture of the likely future than to manage assuming conditions will not change or will change in limited ways. Far better to test the effectiveness of management actions before they are applied, than to incur the cost of implementation, only to discover that they do not have the anticipated effect, or have unexpected, undesired consequences.

Decisions on the type of model to use, the level of detail to build into it, and the degree, if at all, to which it will interface with an appropriate regional climate model need to be made carefully, during the process of planning actions to take (in the first iteration of the IWM cycle).

With the kinds of computer systems routinely available at environmental agencies, including municipal planning offices, and with the understanding of hydrologic system modelling now available, the kind of living, interactive watershed model we recommend is both fully feasible and appropriate, although implementing such a model will require resourcing including added staff resources. In moving to an IWM program based on a living watershed model, we would be making a substantial leap forward, putting this region in the forefront of environmental, land, and water management in Ontario.

Examples of How a Living, Interactive, Spatially Explicit Hydrological Watershed Model Will Aid Land-Use Planning and Water Management

Present-day municipal land-use management makes extensive use of georeferenced data on natural capital such as forests, open grasslands, wetlands, lakes, rivers and streams. These are static data, updated from time to time. Such an approach to compiling information on the existing character of the landscape has been sufficient in the past, when change in the nature of that landscape was relatively slow on human time scales. That is no longer the case. Not only is there now a need for a robust process of regular updating of georeferenced information, but management actions expected to have long-term consequences (more than 10 years) need also to be based on knowledge of how the landscape is changing, and how quickly.

The inadequacy of present-day management approaches can be seen, for example, in current calls to use the MRWMP more effectively to manage flooding. The MRWMP could be updated modestly. Timing and coordination of control decisions at different water flow structures could be automated and made more responsive to current conditions. There may even be worthwhile modifications to flow control structures that will enhance their capacity to control flow. But taken together these amendments to the MRWMP will yield only modest improvements in the capacity to control flooding. The system lacks the physical capacity to hold large quantities of water back, or to wash large quantities of water down to Georgian Bay to avoid flooding, and future climates are likely to result in floods much larger than those experienced recently. We need a nimbler approach to flood management, one that can adapt as climate changes.

An interactive hydrological model would be able to use current, spatially georeferenced data on the state of the environment, knowledge of past states, and of rates and directions of change in state to produce a visualization of how water is currently flowing through this landscape (not just within the rivers), and how that flow will change as the state of the environment changes. Such detailed data provides far richer information than is available now. Such data also provide a visualization of flood risk in future years, and where and how flood risk is growing. It will not solve our flooding problem, but it will enable us to see flooding in context and adapt appropriately to this changing environment. Similarly, an interactive hydrological model will reveal the long-term trends in extent of late summer/fall droughts and their consequences for forests, for soil moisture, for river flow and for lake levels.

An interactive hydrological model should also be able to inform decisions on land-use management, in particular by making it possible to explore the future effects of specific land-use scenarios before the decisions are made. As climate change alters the forests, how will the retention of water in the soils be impacted, and how will this modify the nature of flooding? What ground surfaces should be used in this extensive recreational/retail hub? In the course of this resort development, will it be possible to do some landscaping that will enhance the natural water retention capacity of the site, and how significant of an improvement can be achieved? At present, none of these questions can be answered except by taking the planned management action and watching for future environmental responses.

Above all, the routine interrogation of a hydrological model in the course of making decisions on environmental management will encourage investigation of the interactions among development decisions and between these and an environment being rapidly altered by climate change. The 'cumulative effects' of development decisions will be measurable, and important, but difficult, questions will be investigated. Questions such as: "What are the effects on watershed hydrology of increasing the area of impervious surfaces in an urban region?" "Will actions to increase the extent of wetlands have measurable impacts on the water storage capacity in the watershed?" "Will changes in hydrology brought about by climate change have impacts on lake water quality?" and "How sensitive is river and lake hydrology to changes in land use?" A hydrological model will allow us to improve our understanding of the interrelated processes affecting water over the entire watershed and therefore position us to make better decisions for the challenges we face into the future.

Development of Management Objectives; Implementing Actions; Making IWM Routine

While decisions on a modeling approach are a core need, there are a number of others that form part of an integrated plan. The simple, circular, adaptive environmental management plan shown in Figure 2 is in reality a suite of parallel, iterative paths addressing different management objectives. Some of these will relate directly to land use and will lead to actions to amend existing zoning by-laws or building regulations. Others will relate to management of natural heritage, to conservation of water quality, to protection of species at risk. These activities are all ones that take place at present. With the introduction of IWM, they will become more tightly integrated than in the past. According to Unger (2009), who undertook an extensive review for Alberta, IWM programs will likely require multi-faceted watershed objectives to be integrated into land use decision-making.

The process of setting objectives must also include consideration of the main impetus for the watershed plan, and the key issues to be resolved. In the U.S., so many watershed plans were initiated to solve non-point source pollution problems that the EPA's guidance document focusses almost exclusively on that issue (EPA, 2013). In British Columbia, a number of watershed plans were driven by socio-economic and ecological impacts of changes in salmon fisheries. In southern Ontario, large scale land development gave rise to most watershed plans, but climate change, flood management and waterfront development provide a potential impetus for IWM in the Muskoka River Watershed.

One of the most recently completed IWM plans in Ontario is for the Nottawasaga River Watershed (NVCA, 2019). That plan includes sets of goals specific to each of five central issues. However, there is a greater opportunity in the Muskoka River Watershed to more fully integrate issue-specific goals and create an over-arching goal or vision for the future watershed.

With the establishment of a functioning, iterative IWM program for the Muskoka River Watershed, we enter a world in which the many interacting impacts of land use decisions, of climate change, and of other factors or processes (such as the use of salt on winter roads) are not just considered. They are central to the management process. In such a world the likelihood of unintended consequences of management decisions should be reduced, despite the new complexities being created by climate change (Figure 3).

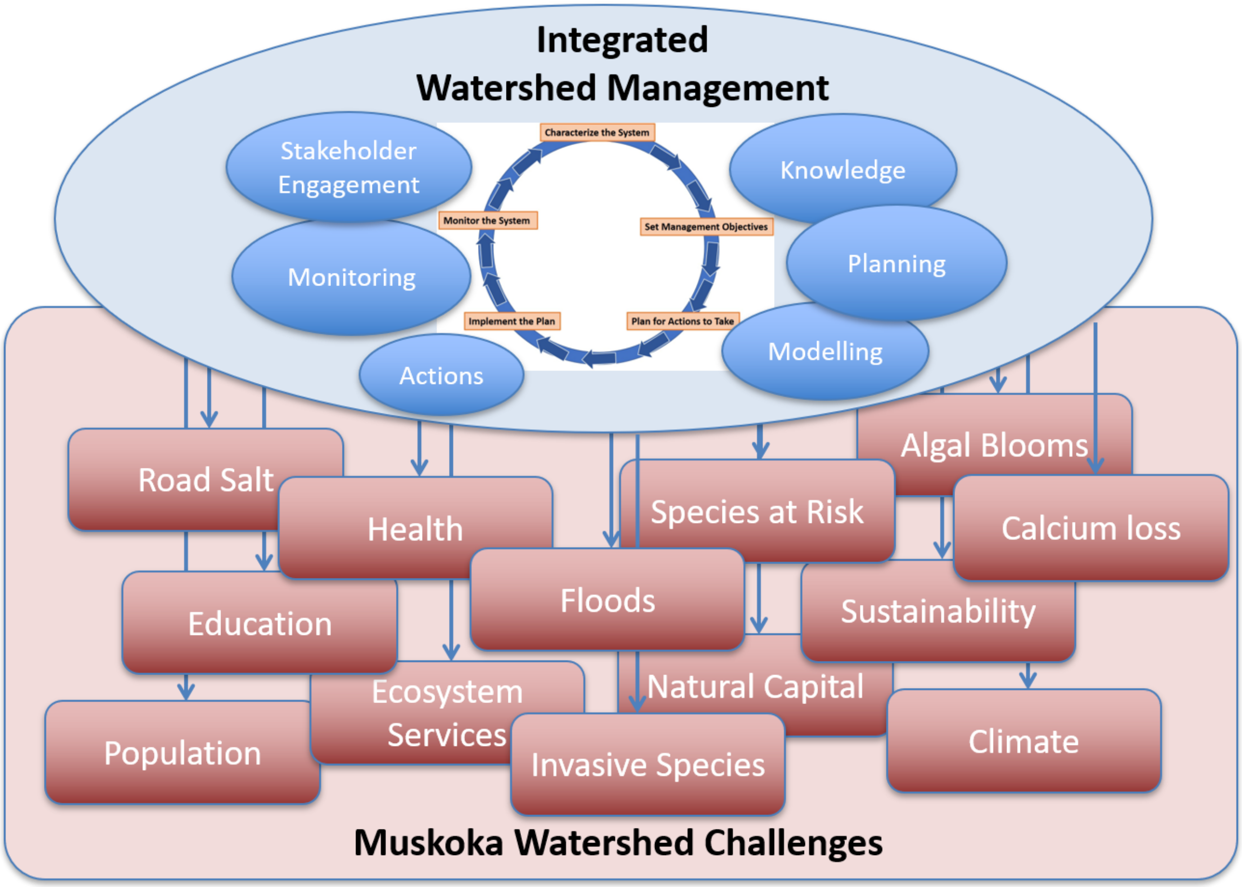

***Figure 3**: Addressing the numerous individual challenges in the Muskoka River Watershed (the red rectangles) will be aided by an Integrated Watershed Management approach that engages stakeholders and uses available knowledge, modelling and other cross-disciplinary synthetic approaches (the blue ovals). The deeply interconnected and interdependent watershed system means no single challenge can be adequately addressed or resolved without understanding and accounting for the impacts on the rest of the watershed.*

Conclusions

We live in an increasingly dynamic world that is challenging the abilities of environmental managers and land-use planners. The Muskoka region faces particular challenges because of its predominantly natural environment, and the enormous importance of the quality of that environment for economic prosperity and quality of life of its residents. Muskoka's location on the Canadian Shield precludes straightforward application of management actions appropriate to southern Ontario, and the established ways of managing environmental quality, water flow, and economic development are no longer adequate. In this changing world, planners will be best able to make wise decisions if they have the opportunity, in an on-going way, to test proposed actions against a future environment – that means an interactive, hydrological model of the watershed available to them to answer the 'what if' questions.

Integrated Watershed Management is an approach to environmental and land-use planning that can serve the Muskoka River Watershed well, particularly if it is underpinned by a robust, living, interactive, spatially explicit hydrological model against which proposed management actions can be tested. Municipalities within the watershed have not yet formally embraced IWM, although many of the components of watershed management have been done. Summers et al. (2004) found that successful implementation of watershed plans throughout Ontario was dependent on the extent to which they are integrated into Official Plans. They also suggested that watershed planning has found applications other than direct land-use planning, such as guidance for environmental impact assessment, prioritizing funding, stormwater management planning and large scale environmental management planning. MWC sees a full embrace of IWM, based in a sound hydrological understanding, as very desirable in this region.

Such active IWM requires effective collaboration among all municipalities within or partially within the watershed, MECP, MNRF and the community. Such a collaboration, long-term, with multiple partners, requires leadership and a clear administrative structure. DMM, as the municipality with the largest 'footprint' in the watershed, might provide that leadership, although it may be more effective politically for a clearly autonomous, watershed-based entity to be established, comparable to a conservation authority or Severn Sound Environmental Association, to hold that leadership responsibility.

As development increases in the coming years, it will be vital that land-use planning take full account of natural capital if we wish to sustain our environment, quality of life, and vibrant tourist and recreational economy. It has long been recognized that Muskoka's rich natural environment is a major driver of our economy, providing opportunities for healthful outdoor recreation and tourism throughout the year, so wishing to retain that is the obvious correct way forward. Our challenge over the next several decades will be to provide for needed development and enable population growth, while retaining this amazing natural environment and the quality of life we all enjoy. It's a stiff challenge because of climate change. Muskoka Watershed Council is interested in seeing IWM become a core part of planning and management in Muskoka and is prepared to facilitate a workshop to iron out the details of IWM goals, priorities, and organizational structure for the region.

Recommendations

Therefore, Muskoka Watershed Council recommends the following:

1) That iterative, watershed-scale Integrated Watershed Management be planned and implemented on the Muskoka River Watershed ultimately to drive **all forms of environmental management and land-use planning**;
2) That, as a crucial early step, a multi-stakeholder Roundtable or Steering Committee be formed with representation from key community NGOs, the business community, municipalities and relevant provincial ministries (at minimum Natural Resources and Forestry and Environment, Conservation and Parks). This Roundtable will evolve into/be replaced by the senior leadership group, or Board, of the eventual agency responsible for IWM, and will continue to be a representative, collaborative group linking the agencies, ministries, municipalities, and community sectors in Integrated Watershed Management;
3) That, as a second early step, the stakeholders at the Roundtable develop and sign onto a multi-disciplinary Charter containing a vision and goal for the future of the watershed, against which future land-use decisions and management actions can be assessed and tracked;

4) That IWM be applied initially to water flow management, but with the clear understanding that IWM will be progressively expanded to include all aspects of environmental management and land-use planning within eight years;

5) That this IWM program be built upon the ***continuing use*** of a living, interactive, spatially explicit hydrological model of the entire watershed covering both the landscape and the rivers and lakes, and available to be interrogated regularly to answer questions concerning likely trends in environmental conditions and environmental effects of proposed management actions undertaken for land use planning and/or for climate mitigation;

6) That the hydrological model be constructed using latest understanding of watershed hydrology, with collaborative input from the signatories to the Muskoka River Water Management Plan, the MNRF, DMM (and specialists working on floodplain mapping), and other specialists from watershed NGOs and agencies;

7) That Muskoka Watershed Council support the introduction of this IWM program by convening stakeholders in a Roundtable, and starting the process of developing the rules and building the collaboration necessary for successful Integrated Watershed Management.

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